Normally Pressured Lance Natural Gas Development Project

Draft Environmental Impact Statement

Appendix J

AGWA Technical Report

NORMALLY PRESSURED LANCE (NPL)
NATURAL GAS DEVELOPMENT PROJECT

Modeling the Effects of Surface Disturbance using the Automated Geospatial Watershed Assessment (AGWA) Tool
TECHNICAL REPORT

U.S. Department of the Interior
Bureau of Land Management

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The BLM manages more land – 253 million acres – than any other Federal agency. This land, known as the National System of Public Lands, is primarily located in 12 Western States, including Alaska. The Bureau, with a budget of about $1 billion, also administers 700 million acres of sub-surface mineral estate throughout the nation. The BLM's multiple-use mission is to sustain the health and productivity of the public lands for the use and enjoyment of present and future generations. The Bureau accomplishes this by managing such activities as outdoor recreation, livestock grazing, mineral development, and energy production, and by conserving natural, historical, cultural, and other resources on public lands.

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ACRONYMS AND ABBREVIATIONS

AGWA	Automated Geospatial Watershed Assessment (Tool)
APD	Application for Permit to Drill
BLM	Bureau of Land Management
CN	Curve Number
CSA	Channel Source Area
DA	Development Area
DayMet	Daily Meteorological Data
DEM	Digital Elevation Model
EIS	Environmental Impact Statement
EPA	U.S. Environmental Protection Agency
ET	Evapotranspiration
ETM	(Landsat) Enhanced Thematic Mapper
GIS	Geographic Information System
JIDPA	Jonah Infill Drilling Project Area
KINEROS2	Kinematic Runoff and EROSion Model
MRLC	Multi-Resolution Land Characteristics Consortium
NAD	North American Datum
NAIP	National Agriculture Imagery Program
NED	National Elevation Dataset
NLCD	National Land Cover Database
NPL	Normally Pressured Lance
NRCS	Natural Resources Conservation Service
PAPA	Pinedale Anticline Project Area
PFO	Pinedale Field Office (BLM)
PETT	Parameter Modification System
RGF	Regional Gathering Facility
SGCA	(Wyoming Governor's Greater) Sage-grouse Core (Populations) Area
SSURGO	Soil Survey Geographic (Database)
STATSGO	U.S. General Soil (Map)
SWAT	Soil and Water Assessment Tool
UA	University of Arizona
UGRB	Upper Green River Basin
USDA-ARS	U.S. Department of Agriculture-Agricultural Research Service
USGS	U.S. Geologic Survey
UTM	Universal Transverse Mercator (coordinate system)
UW	University of Wyoming
WOGCC	Wyoming Oil and Gas Conservation Commission
WSO	Wyoming State Office (BLM)
WyGISC	(University of) Wyoming Geographic Information Science Center

DEFINITIONS

<u>Jenks Natural Breaks Classification</u>: is a data classification method designed to determine the best arrangement of values into different classes. This is done by seeking to minimize each class' average deviation from the class mean, while maximizing each class' deviation from the means of the other groups. The method seeks to reduce the variance within classes and maximize the variance between classes.

<u>Manning's equation</u>: is a standard hydrologic method for estimating channel velocity and runoff. Velocity is estimated as a function of surface roughness and channel morphology, and discharge is estimated as the product of velocity and channel cross-section area"

<u>Muskingum's routing method</u>: estimates channel storage volume as a factor of the channel length and prism dimensions assuming the channel changes in morphology as a wedge in the downstream direction. Inflow and outflow from the stream is represented as a wedge with a positive wedge produced on the rising limb of a hydrograph and a negative wedge on the falling limb.

1.0 INTRODUCTION

Jonah Energy proposes to continue oil and gas development operations on its leases in the Normally Pressured Lance Natural Gas Development (NPL) Project Area in Sublette County, Wyoming (Figure 1.1). They submitted a Plan of Development to the Bureau of Land Management (BLM) in June 2011, to drill up to an additional 3,500 natural gas wells in the NPL Project Area over a ten-year period. Jonah Energy proposes to directionally these wells from centrally located multi-well pads to minimize surface disturbance and impacts to wildlife. Approximately 4.5 percent (6,340, revised from 6,854 acres (5-24-2013)) of the approximately 140,859-acre project area would be disturbed during the well-drilling phase of the project. After interim reclamation, approximately 1.3 percent (1,890 revised from 2,405 acres (5-24-2013)) would remain disturbed for the 40-year life of the project.

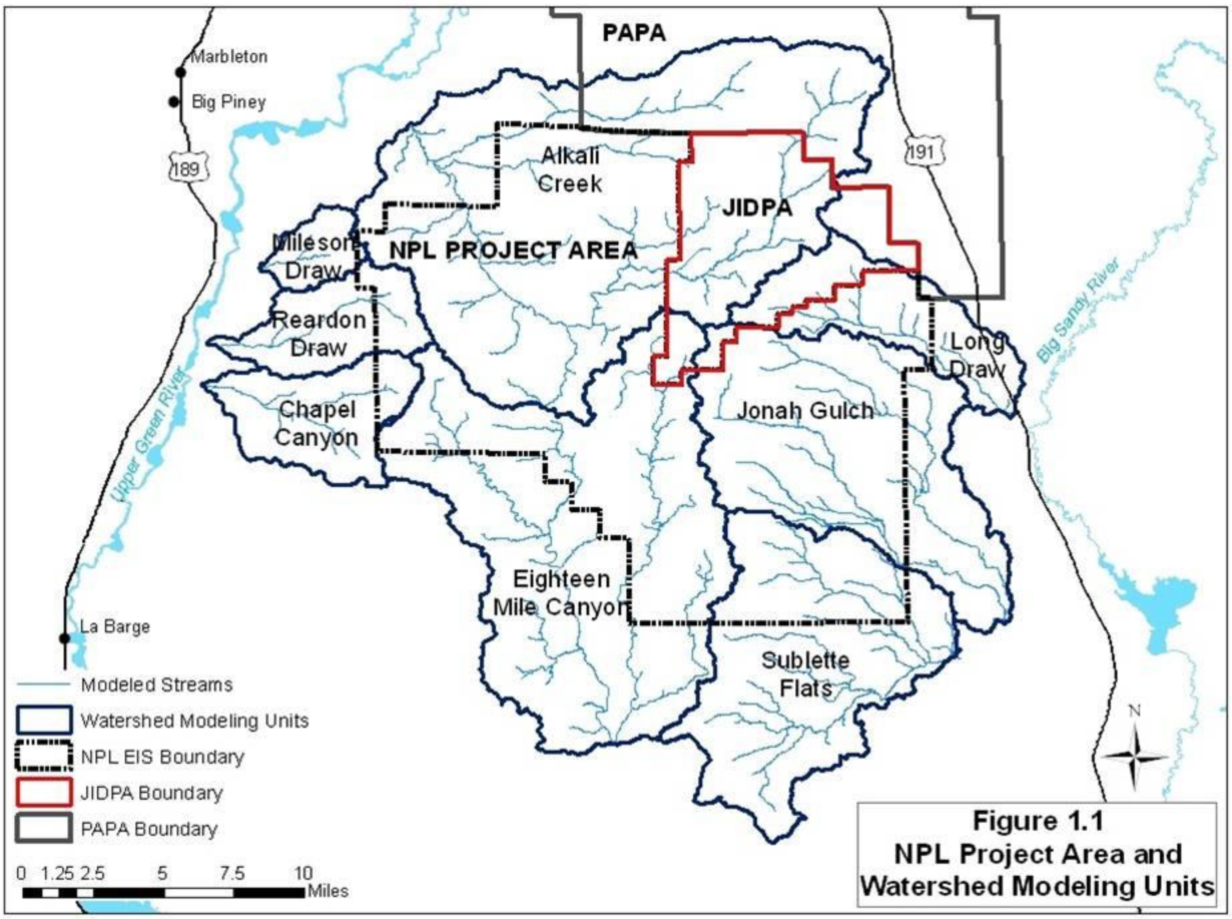


Figure 1.1 NPL Project Area and Watershed Modeling Units

The NPL Project Area is located in western Wyoming, east of the towns of Marbleton, Big Piney, and La Barge (Figure 1.1), adjacent to the west, south, and east borders of the Jonah Infill Drilling Project Area (JIDPA); and adjacent to portions of the southern border of the Pinedale Anticline Project Area (PAPA); both intensely developed natural gas fields. The NPL Project Area is located on a topographic mound that acts as a drainage divide between the Upper Green River, approximately five to ten miles to the west, and the Big Sandy River (a tributary of the Upper Green River), approximately five miles to the east, in the Upper Green River Basin (UGRB).

Potential environmental impacts from project development could occur to the Upper Green and Big Sandy rivers and their tributaries, both within the NPL Project Area, and potentially outside of the NPL Project Area boundary in the form of increased surface runoff, sediment transport, erosion, and salinity from areas disturbed within the NPL Project Area during the development of the project.

The Automated Geospatial Watershed Assessment modeling tool (AGWA) was used to identify areas within the NPL Project Area most susceptible to land-use change from the proposed oil and gas drilling activities. Results of the model simulations would be used to assist BLM in the preparation of the Environmental Impact Statement (EIS) for the NPL project and to aid in the determination of best management practices and future monitoring and mitigations of water resources.

AGWA is a Geographic Information System (GIS) based toolkit designed to set up, run, and analyze the following hydrologic model results:

- The Soil and Water Assessment Tool (SWAT; http://swat.tamu.edu/software/swat-model; Arnold, et al., 2008); and,
- The Kinematic Runoff and EROSion model (KINEROS2; http://tucson.ars.ag.gov/kineros; Goodrich, et al., 2002; Semmens, et al., 2008).

This technical report presents an overview of the models used, details the watershed analysis modeling methods and outcomes used in the estimation of hydrologic parameters for the pre-development model, presents modeling results, quantifies potential impacts associated with the NPL project, and provides recommendations for mitigations, best management practices, and future monitoring.

1.1 Modeling Objectives

The goal of the hydrologic modeling using AGWA was to compare and predict surface runoff, water yield, and sediment yield within the NPL Project Area by executing SWAT and KINEROS2 under the following scenarios, which were selected for analysis because they encompass the range of potential surface disturbance of the proposed alternatives for the NPL Project Area.

- Pre-development: a representation of the landscape prior to significant natural gas development in the NPL Project Area and vicinity, particularly the JIDPA;
- Present: a representation of existing conditions within the NPL Project Area and the JIDPA, including wells pads, access roads, and pipelines;
- 2-Mile Buffer (Proposed Action): a reasonable representation of Jonah Energy's Proposed Action using Jonah Energy's placement of proposed power lines and Regional Gathering Facilities (RGF); and,
- Worst Case: represented by locating proposed natural gas wells in areas identified in the pre-development scenario as having the highest potential for increased surface runoff.

1.2 Modeling Approach

AGWA is a GIS interface that automates the running of the SWAT and KINEROS2 watershed runoff and erosion simulation models and enables users to model and assess watersheds at multiple temporal (time) and spatial scales (small or large complex watersheds). AGWA was chosen for the analysis of the NPL Project Area because both SWAT and KINEROS2 are widely used, scientifically defensible, and it allows for the integration of the output of both models.

AGWA was developed by the southwest branch of the U.S. Department of Agriculture (USDA) Agricultural Research Service (ARS), U.S. Environmental Protection Agency (EPA), University of Arizona (UA) and University of Wyoming (UW). The UW Geographic Information Science Center (WyGISC) modified the AGWA Toolkit for the NPL Project Area in conjunction with the BLM State Office (WSO), High Desert District (HDD), and Pinedale Field Office (PFO). In the NPL Project Area, AGWA was used to:

- Determine estimates of surface runoff within eight defined Watershed Modeling Units during pre-development conditions;
- Predict surface runoff and channel discharge within the same Watershed Modeling Units by adding estimates of new surface disturbance from well pads, access roads, and pipelines identified for the various scenarios described in Section 1.1;
- Predict surface runoff, sediment transport, and erosion potential for increased surface runoff and erosion areas during an extensive storm event; and,
- Identify areas where monitoring and/or more extensive mitigation activities should be focused or areas that should be avoided.

1.3 Impact Analysis

The scenarios described in Section 1.1 were modeled using AGWA. SWAT was used to model surface runoff and stream channel discharge on a regional scale to strategically identify areas where more understanding was necessary. KINEROS2 was used in those areas identified in SWAT to have increased potential for surface runoff and erosion by evaluating the area during a heavy rainfall event.

Alternatives A and B were not modeled. Because Alternatives A and B were being developed at the same time as the model simulations were developed and run, it was determined that the alternatives would fall within the range of scenarios described in Section 1.1.

Mitigation measures were not modeled, nor were individual alternatives to the Proposed Action. Quantitative impacts from alternatives that were not explicitly modeled were interpolated from the conditions that were modeled.

The NPL Project Area is located in a region where limited to no runoff or climate data are available, which presents several challenges to the development of robust, accurate hydrologic models. The output and analysis of the AGWA modeling results are initial estimates of conditions and predictions based upon the best available data. While they may provide an initial focus for development and reclamation, it is not a substitute for inventory and monitoring of physical features.

2.0 PROJECT DESCRIPTION

An EIS is being prepared to evaluate the proposal, as well as, a 'No Action' and two alternatives (A and B), which are briefly summarized below. Refer to the EIS for detailed descriptions of the proposed action and Alternatives A and B.

2.1 Proposed Action

Under their Plan of Development, or the Proposed Action, Jonah Energy would drill up to 3,500 additional natural gas wells within the NPL Project Area. Wells, along with associated infrastructure, access roads, pipelines, RGFs, etc., would be constructed over a 10-year period at a rate of up to 350 wells per year until the resource base is fully developed. Wells would be drilled directionally from multi-well pads with well placement averaging: one multi-well pad per 640-acre area in Sage-Grouse Priority Habitat Management Areas (PHMA)(core only); and, four multi-well pads per 640-acre area in non-SGCAs. Each multi-well pad would range from between 5.5 to 19 surface acres and would support between 1 and 64 wells each. Approximately 6,340 acres (revised from 6,854 acres (5-24-2013)) would be disturbed in the short term during the 10-year drilling phase of the project (Draft EIS Table 2-12). Long-term surface disturbance after interim reclamation would be approximately 1,890 acres (revised from 2,405 acres (5-24-2013)) over the 40-year life of the project (Figure 2.1).

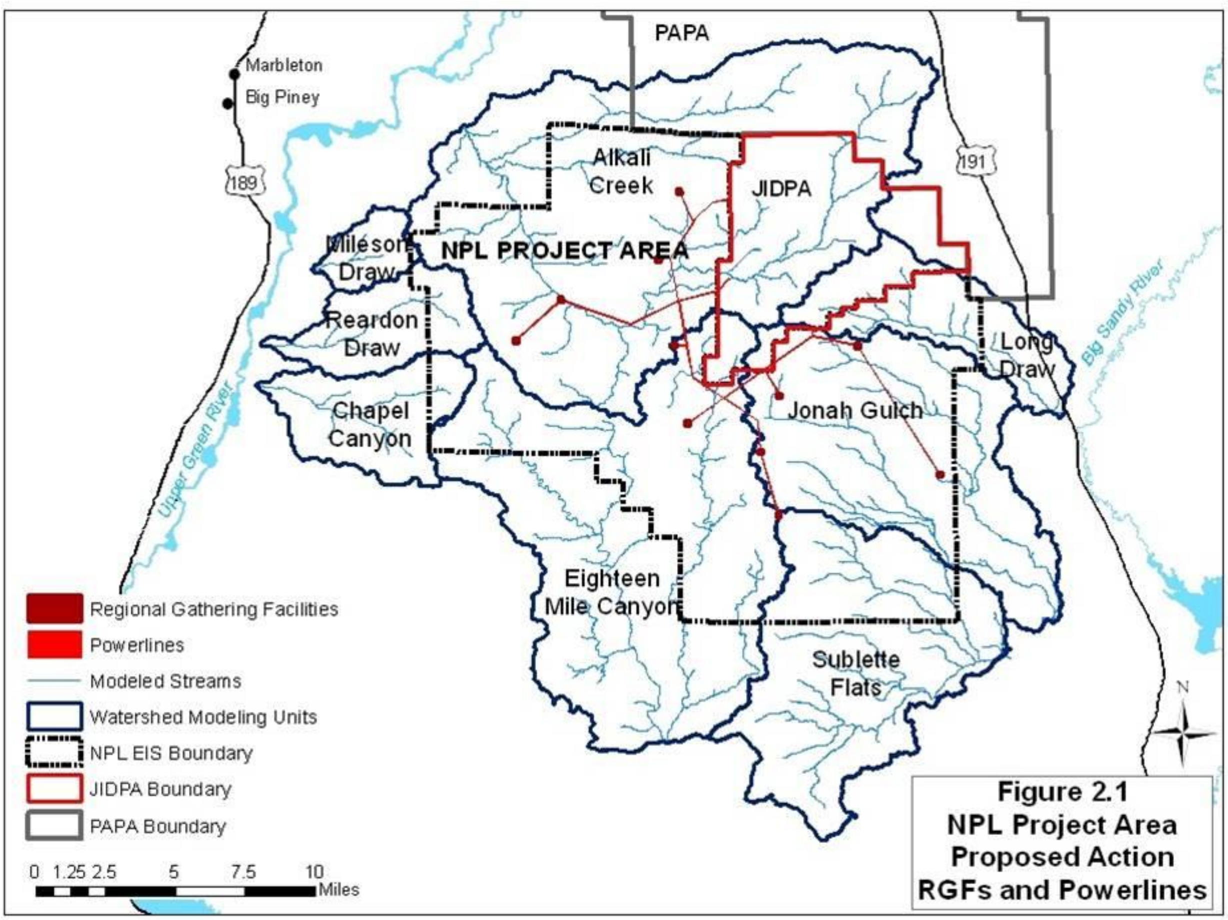


Figure 2.1 NPL Project Area Proposed Action RGFs and Powerlines

Hydrocarbons and associated liquids would be transported from wells via approximately 227 miles of pipeline to 11 RGFs for gas and liquid separation, electric compression, liquid storage, gas dehydration, water disposal at injection wells, and truck loading for hauling produced water for processing and condensate to sales locations. RGFs would cause approximately 20 acres of surface disturbance each.

The proposed project also includes construction of associated facilities and infrastructure including approximately 227 miles of access roads, approximately 38.6 miles of power lines, and separation, dehydration, metering, and fluid storage facilities to the extent such facilities are not already constructed.

Placement of future well pad locations is currently unknown. Jonah Energy will develop criteria for selecting well locations to delineate the extent of the natural gas resource and will be able to refine those criteria as more information on subsurface conditions and hydrocarbon resources becomes available from delineation drilling. Placement of final surface locations would be contingent on any environmental constraints identified during the Application for Permit to Drill (APD) process and the on-site inspection reviews conducted by BLM.

2.2 EIS Described Alternatives

In accordance with 40 CFR 1502.14(a), BLM is required to define issues and evaluate all reasonable alternatives to the Proposed Action. The following alternatives were identified.

2.2.1 No-Action Alternative

Under the No Action alternative, federal oil and gas resources could continue to be developed and produced on an individual-lease or unit-area basis. For the purpose of this analysis, BLM assumed that development and production would continue at the same rate seen in the NPL Project Area since 1997. This would include drilling and completions for approximately 30 new wells over the same 10-year period as the Proposed Action. Wells would be vertically drilled from approximately 30, 3.7-acre, single-well pads. Ancillary infrastructure would include water disposal wells, gas pipelines, and access roads. It was assumed that existing power lines and compressor stations would be sufficient for the anticipated development under the No Action Alternative.

Under this alternative, approximately 213 acres of new surface disturbance would result from drilling, well completion, access roads, and pipelines (Draft EIS, Table 2-5). Disturbance would consist of 111 acres for well pads, 45 acres for pipelines, and 57 acres for access roads. Approximately 213 acres would be disturbed over the 10-year development period. After interim reclamation, an estimated 79 acres would remain disturbed over the 40-year life of the wells.

2.2.2 Alternative A

Alternative A was developed primarily to address sensitive wildlife resources. Under this alternative, the maximum number of wells and the life of the project would be the same as the Proposed Action but development would be phased, the maximum allowable density of development would be based on delineated important wildlife habitats within seven identified Development Areas (DA), and year-round drilling would be prohibited. Approximately 6,748 total acres (revised from 6,193 acres (5-24-2013)) of surface disturbance would occur under Alternative A in the short term. It is anticipated that the development period of the project would be slightly longer than the proposed action. After interim reclamation, approximately 1,811 acres (revised from 2,240 acres (5-24-2013)) of surface disturbance would remain for the 40-year life of the project (Draft EIS, Table 2-18).

The DAs would be based on the spatial distribution of important wildlife habitats found throughout the NPL Project Area, which would be incorporated into three phases (Figure 2.2). Development of the three phases would occur sequentially starting with development of Phase 1 adjacent to the JIDPA. BLM would implement resource protection and conservation measures unique to each DA.

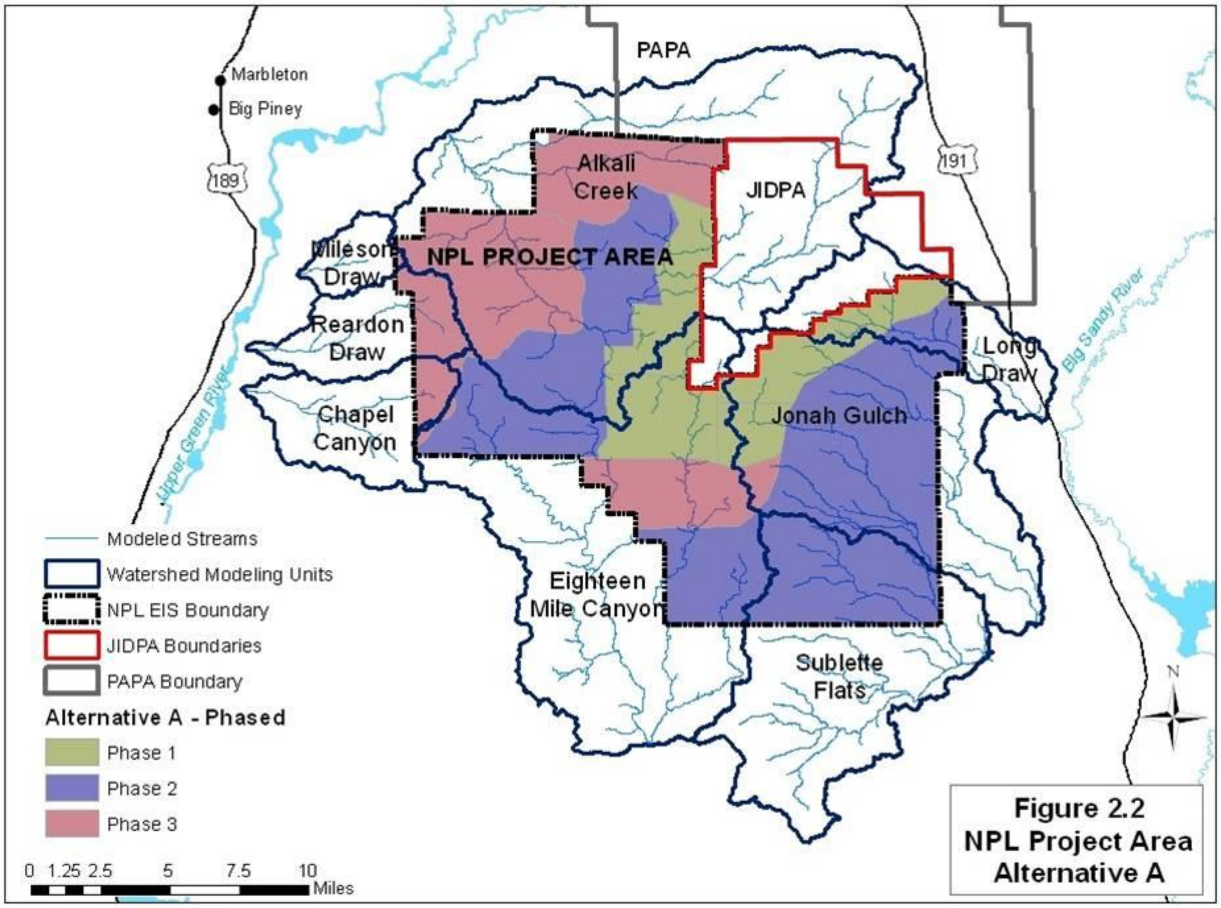


Figure 2.2 NPL Project Area Alternative A

2.2.3 Alternative B

Alternative B was developed to address concerns expressed during scoping associated with conserving a broad range of resource values and focusing development in the least environmentally sensitive areas. In contrast to Alternative A, where the density of development and development limitations would be based primarily on wildlife habitat for focus species, development for Alternative B would be based on a broader range of resources including visual resources, paleontological resources, surface water features, identified lands with wilderness characteristics, and other resources (including wildlife habitat). Under Alternative B, the maximum number of wells would be the same as for the Proposed Action, but the DA 1 area (Figure 2.3) would have a reduced density of development, reduced surface disturbance, and more clustering of disturbance locations to reduce impacts to a range of sensitive resources in this area. Sage-

Grouse Winter Concentration Areas would have additional resource protection measures including a disturbance threshold, phasing development from east to west in Winter Concentration Areas, and centralizing above-ground facilities. Buried pipelines would be constructed to transport produced water and condensate from RGFs within Sage-Grouse Winter Concentration Areas and PHMA to RGFs outside of these areas. The development period would be slightly longer than that of the Proposed Action resulting in slightly fewer new wells drilled per year (on average). In contrast to Alternative A, development could occur in all DAs simultaneously.

The estimated total short-term surface disturbance resulting from natural gas drilling and completions activities would be approximately 5,874 acres (revised from 10,677 acres (5-24-2013)) (Draft EIS, Table 2-24). After interim reclamation, an estimated 1,741 acres (revised from 3,360 acres (5-24-2013) would remain disturbed for the 40-year life of the project.

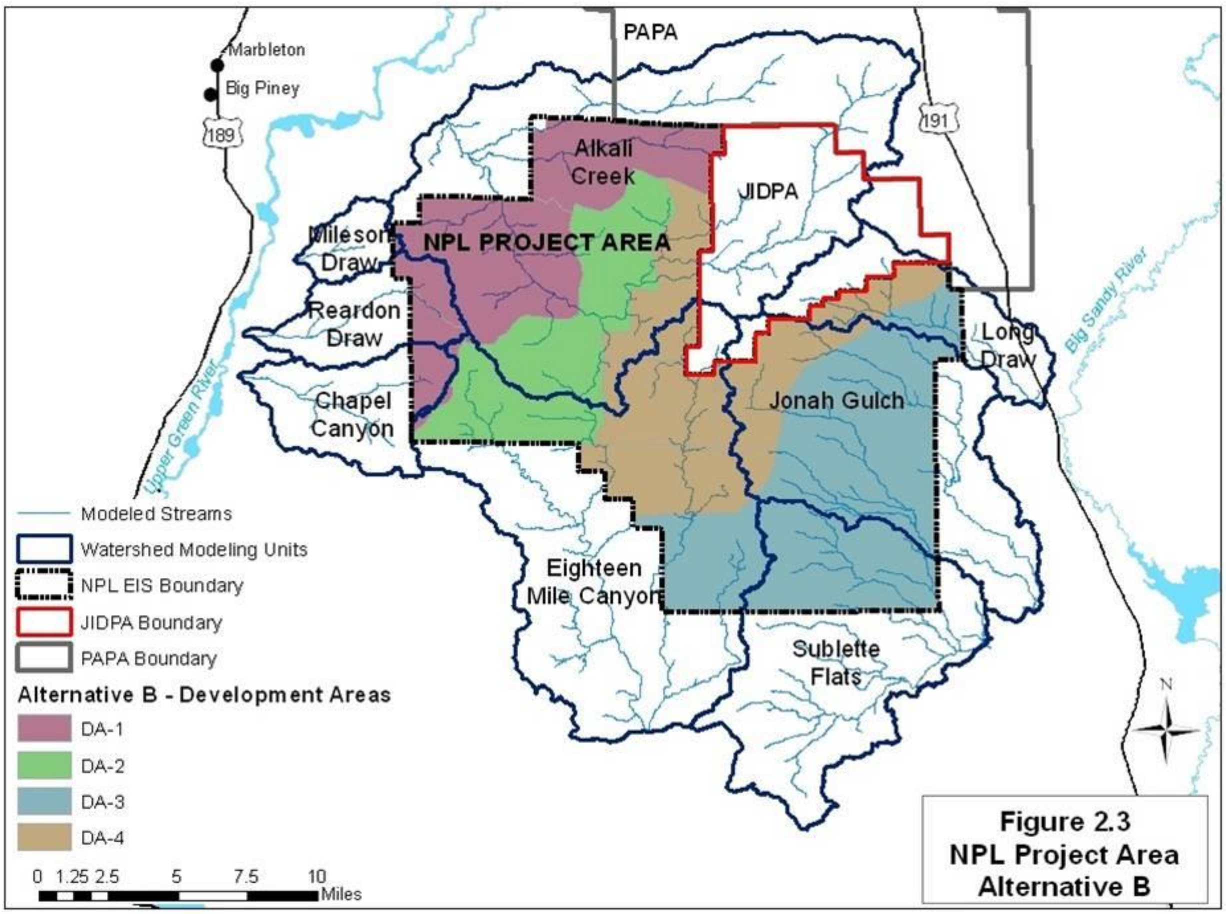


Figure 2.3
NPL Project Area
Alternative B

3.0 SITE DESCRIPTION

The NPL Project Area encompasses primarily BLM-administered lands in the BLM Pinedale and Rock Springs Field Offices within Townships 27 through 29 North, Ranges 107 through 110 West, 6th Principal Meridian in Sublette County, Wyoming. Topography is characterized by low rolling hills interspersed with buttes, rock outcrops, large draws, and deep canyons. Vegetation consists primarily of Wyoming big sagebrush and other species of sagebrush, rabbit brush, saltbrush, and forbs and grasses abundant in the area. The NPL Project Area experiences a semi-arid, cold desert climate and is dotted with ephemeral washes, playas, and range improvement water sources.

The NPL Project Area has slopes ranging from near horizontal to greater than 25 percent, soils are frequently shallow, alkaline- and/or or salt-affected, and range from clay to sandy creating conditions that are subject to wind and water erosion and can be difficult to reclaim.

All drainages in the NPL Project Area are ephemeral, flowing only in response to snowmelt and rain storm events. There are surface expressions of groundwater but none that produce perennial surface flows that reach other surface waters. The watersheds that are either wholly or partially located within the NPL Project Area are shown in Figure 3.1.

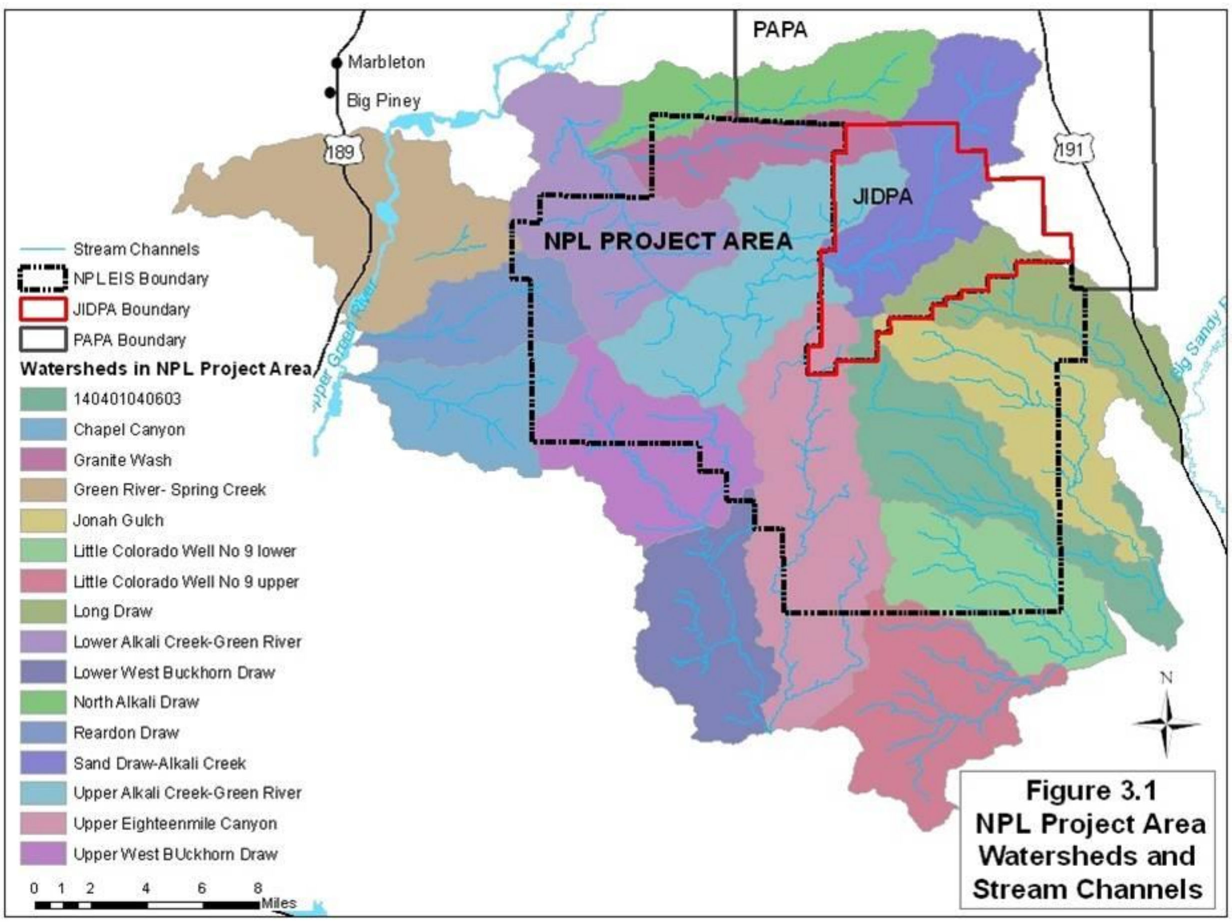


Figure 3.1
NPL Project Area Watersheds and Stream Channels

4.0 MODEL SETUP

AGWA was chosen for the hydrologic analysis of the NPL Project Area because it was designed to assess the trends and magnitudes of hydrologic changes associated with surface disturbance activities, such as oil and gas, especially in regions where limited to no runoff or climate data are available. Additionally, AGWA can identify areas that are susceptible to changes in land cover, surface-disturbing activities, and/or climate.

For this analysis, AGWA was used to determine whether affected areas in the NPL Project Area were likely to experience substantial changes in surface runoff, channel discharge, and erosion due to changes in surface disturbance as a result of natural gas drilling and completions activities.

Hydrologic response within the NPL Project Area was modeled within eight Watershed Modeling Units are shown in Figure 4.1. The Watershed Modeling Units were named according to their primary channel names for convenience in this report. The Watershed Modeling Unit outlets are each located well outside the NPL Project Area to ensure that the entire NPL Project Area was modeled.

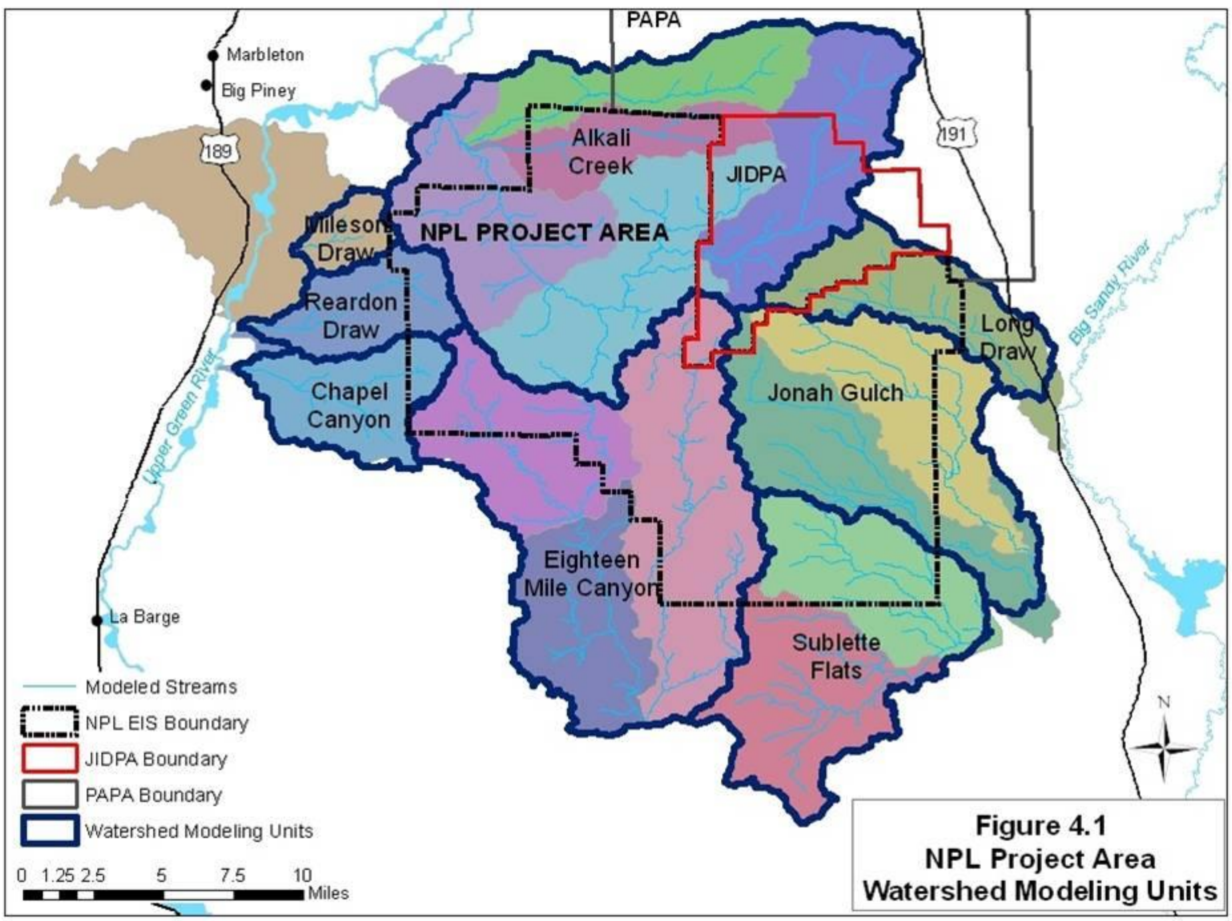


Figure 4.1
NPL Project Area
Watershed Modeling Units

The areas of each Watershed Modeling Unit and the lengths of stream channels within them were determined for both the entire Watershed Modeling Unit and the portion of the Watershed Modeling Unit within the NPL Project Area (Table 4.1).

TABLE 4.1
AREAS OF WATERSHED MODELING UNITS AND STREAM CHANNELS WITHIN EACH

	Watershed Modeling Units		Stream Channels	
Watershed Unit	**Total Acres**	**Acres in NPL**	**Total Miles**	**Miles in NPL**
Alkali	101,201	48,932	132.02	66.27
Chapel	14,380	2,000	16.12	1.13
Eighteen Mile	76,340	35,014	99.89	42.69
Jonah Gulch	46,096	31,480	74.51	50.54
Long Draw	17,213	6,365	22.40	12.88
Mileson	4,673	123	4.69	0
Reardon	12,255	3,489	13.16	2.33
Sublette Flats	43,285	13,665	72.28	20.83

SWAT was run on each on each Watershed Modeling Unit for four land cover change scenarios (described below) to simulate long-term (decadal) surface runoff and determine in what manner annual runoff volumes would be potentially affected by development.

- Pre-development: a representation of the landscape prior to natural gas development in the project area and in the JIDPA;
- Present: a representation of existing conditions within the NPL Project Area and the JIDPA, including wells pads, access roads, pipelines, and other ancillary facilities;
- 2-Mile Buffer: a reasonable representation of Jonah Energy's Proposed Action created by buffering the proposed power lines and RGFs; and,
- Worst Case: represented by locating proposed natural gas wells in areas identified in the pre-development scenario as having the highest potential for surface runoff.

KINEROS2 was then used to simulate the hydrological response to a single large rainfall event on selected areas identified in the SWAT modeling simulations in the NPL Project Area based on the SWAT model outcomes.

Based on the results of the SWAT and KINEROS2 modeling runs, mitigations and best management practices are suggested for consideration in the Record of Decision (ROD) to the EIS.

4.1 Models Used

BLM, in cooperation with research scientists at the WyGISC and Department of Ecosystem Science and Management), used AGWA to assess potential surface runoff and channel discharge in the Watershed Modeling Units that are intersected by the NPL Project Area. A description of the basic structure of each model is provided, as well as, their simplifying assumptions, strengths, and weaknesses in this section.

4.1.1 Automated Geospatial Watershed Analysis Toolkit (AGWA)

AGWA is a GIS interface that automates the running of SWAT and KINEROS2 watershed runoff and erosion simulation models and enables users to model and assess watersheds at multiple temporal (time) and spatial scales (small or large complex watersheds). AGWA is an add-in for the Environmental Systems Research Institute, Inc. (ESRI) suite of desktop GIS software packages from ArcView 3.1 to ArcGIS 10.1. It requires that the user provide spatially accurate GIS maps of terrain, soils, and land cover. From these basic data sets the tool can be used to build hydrologic models of a project area. The quality of the data are paramount to modeling success, but the AGWA framework is capable of ingesting very crude data if necessary, such as the county-level Soil Survey Geographic Database (STATSGO) soils, or high resolution data, such as the U.S. General Soil (SSURGO) soils.

Terrain data consists of a Digital Elevation Model (DEM), which can vary in spatial resolution, although most commonly, 10-meter or 30-meter resolution data. AGWA is highly flexible and can automatically utilize a wide range of land-cover mapping, such as the National Land Cover Database (NLCD) and Multi-Resolution Land Characteristics Consortium (MRLC).

AGWA guides the user through a series of steps in the modeling process:

- Data processing. Slope, flow direction, flow accumulation, and locations of streams are derived from standard DEM data.
- Watershed delineation. Watersheds are defined in the area of interest.
- Watershed discretization. Each watershed is subdivided into modeling elements (planes and channels) set by the user. These modeling elements represent overland flow and channel planes and are the minimum unit of analysis in the modeling environment.
- Parameter estimation. Model elements are assigned environmental variables, such as slope, soil type, or elevation, to be used by the SWAT and KINEROS2 in the quantification of hydrologic processes.
- Climate generation: Necessary climatological inputs are either provided by the user or generated by a climate generator.
- Model execution. Hydrologic model parameter files are created and the hydrologic models are executed.
- Model visualization. Results produced by the hydrologic models are read back into the GIS environment for visual display and comparison.
- Change analysis. Spatial and temporal impacts of change in the hydrologic system can be determined and portrayed.

4.1.2 Soil and Water Assessment Tool (SWAT)

AGWA provides an interface to the SWAT 2000 and SWAT 2005 models (SWAT). SWAT is a strategic model that can be applied at a range of watershed scales over a long period of record (months to years) and is well suited for larger-scale operations. It uses a modified Curve Number (CN) approach to simulate overland flow and is run on a daily time step, with daily estimates of precipitation and other climate forcing agents. It is capable of running multi-decadal simulations of runoff and is often used in strategic planning where long-term impacts are being assessed. SWAT is highly dependent on distributed rainfall and climate data, and the interpretation of results is limited by the spatial distribution of these data. It simulates all major aspects of the hydrologic cycle, including overland flow, evapotranspiration, interflow, groundwater recharge, groundwater exfiltration, and channel transmission losses.

SWAT has been used extensively in hydrologic research worldwide and its appropriate uses are well documented in the hydrologic modeling literature. Elements of the hydrologic cycle are simulated on a daily basis within SWAT, solving for soil moisture as:

$$SW_i = SW_o + \sum_{i=1}^{j}\left(R - Q_s - ET - w - Q_g\right)$$

Where: *SW_t is soil water content (mm) at time t, SW_o is initial soil water content on day i (mm), t is time (days), R is daily precipitation (mm), Q_s is surface runoff (mm), ET is evapotranspiration (mm), w is seepage water from the soil profile (mm), and Q_g is the amount of groundwater return flow (mm), each of which are calculated for each day (i).*

The core runoff prediction mechanism within SWAT is a modified CN approach, which is one of the most widely applied methods for predicting runoff worldwide. The CN equation is most often written as:

$$Q_s = \frac{(R - I_a)^2}{R - I_a - S}, \ \ I_a = 0.2S \ and \ S = \frac{1000}{CN} - 10$$

Where: *Qs is total surface runoff (mm), R is daily rainfall (mm), I_a is the initial abstraction such as infiltration and interception prior to runoff (mm), S is a retention parameter based on the combination of soil, land use and land-cover. Initial estimates of CN, I_a and S are commonly derived from look-up tables, which are provided by AGWA.*

For the NPL Project Area analysis, the SWAT model produced hydrologic simulations on a daily basis for the duration of the model simulation. In this effort, the model was run for a 10-year period on all affected Watershed Modeling Units. Results were available for each day of the simulation and also as long-term average monthly and average annual values. AGWA was then used to spatially represent long-term average annual values for surface runoff and water yield, as well as stream channel discharge, the three primary metrics for assessing impacts across the NPL Project Area.

- Surface Runoff. Surface Runoff is defined as excess rainfall that does not infiltrate into the soil and is available to flow across the surface. Surface runoff from upland elements, or planes, (sometimes referred to as subwatersheds) is defined by SWAT as the contribution to stream flow during the modeling period. For example, if the model simulation is 10 years long, surface runoff will be the 10-year average total runoff from each plane that contributes to stream flow in the stream channel immediately adjacent to the plane . The fate of this water is determined by the model in the estimation of other losses (e.g., evapotranspiration (ET), transmission losses, and change in soil moisture). The surface runoff generated on a plane is always higher than the water yield, which is the total surface runoff delivered to the stream channel after losses are accounted for. Surface runoff is highly correlated to soil, vegetation, and management characteristics.

- Water Yield: Water yield for upland areas is defined by SWAT as the net amount of water that leaves a sub-basin and contributes to stream flow in the downstream reach during the time step. The equation that governs the estimation of water yield (in millimeters (mm) of water) is:

$$WY = SURF_Q + LAT_Q + GW_Q - T_{loss} - P_{loss}$$

Where: *WY = water yield,* $SURF_Q$ *= surface runoff,* LAT_Q *= lateral runoff through the soil matrix,* GW_Q *= runoff contribution from groundwater,* T_{loss} *= transmission losses, and* P_{loss} *= losses from ponds. Units are output from the model in mm (converted to inches), which is the equivalent depth of water spread out over the entire contributing area.*

- Stream channel discharge. Stream channel discharge is modeled in SWAT as a free surface flowing down an open trapezoidal channel and is routed using the Muskingum method. Channels may be depicted as impervious, losing water to the subsurface via transmission flows, or gaining water from the subsurface. Water is routed as a volume, and velocity is estimated using Manning's equation for velocity. For each time step, water in a given channel reach is estimated using a water balance model where flow in from upland subwatersheds and channel elements is reduced (or increased) by transmission losses or gains from groundwater, changes in bank storage, evaporation losses from the reach, and losses due to diversions. The volume of water output from a stream channel can be expressed as the summation of incoming water from contributing stream channels and planes, evaporative losses, changes in bank storage, and either gains or losses to the regional aquifer. In the NPL Project Area, channels were modeled assuming a low rate of transmission loss to the regional aquifer of 20 mm per hour.

4.1.3 Kinematic Runoff and EROSion Model (KINEROS2)

KINEROS2 is a process-based runoff model that simulates the production of excess rainfall and its conversion to surface runoff under conditions of infiltration-excess. KINEROS2 is most successful when applied to individual rainfall-runoff events, although it can also be run over a long-time period with short intervals between rainfall events. It is most effective when applied to areas where runoff is driven primarily by saturation excess; such as a semi-arid landscape where convective storms occasionally produce overland flow. It should be used only for overland flow and smaller streams, as it is not suitable for larger streams or rivers.

A watershed modeled in KINEROS2 is represented as a series of overland flow planes and channels in cascade, on which the processes of infiltration, interception, retention, erosion, sediment detachment, transport and deposition are all explicitly treated. KINEROS2 uses the kinematic simplification method of surface runoff for overland and channel flow where the slope of the channel is assumed to equal the slope of the runoff surface and pressure and backwater forces are negligible. Partial differential equations are used to describe these processes and are solved by finite difference techniques. Runoff is routed using kinematic wave equations for overland and channel flow:

$$\frac{\partial h}{\partial t} + \frac{\partial h^m}{\partial x} = r_i(t) - f_i(x,t) \;\; and \;\; \frac{\partial A}{\partial t} + \frac{\partial Q(A)}{\partial x} = q_i(t) - f_{ci}(x,t)$$

Where: *h is mean overland flow depth, t is time, x is distance along the element, A is solved using the Manning equation, ,* $r_i(t)$ *is rainfall rate at time t,* $f_i(x,t)$ *is infiltration rate, A is channel cross-sectional area of flow, Q(A) is channel discharge as a function of area,* $q_i(t)$ *is net lateral inflow per unit length of channel and* $f_{ci}(x,t)$ *is net channel infiltration per unit length of channel. These equations, and those for erosion and sediment transport, are solved using a four-point implicit finite difference method (Smith et al., 1995).*

For the NPL Project Area, AGWA was used to parameterize, run, and visualize results from the KINEROS2 model on selected portions of watersheds in the NPL Project Area. The target KINEROS2 watersheds were selected based on outcomes from the SWAT modeling exercise, where it was determined that additional intensive hydrologic modeling would be of benefit to the assessment of impacts. The basic process by which AGWA was used to drive the KINEROS2 model was as follows:

- Identify the target watershed outlet through investigation of the SWAT results.
- Create a watershed based on the outlet.
- Subdivide the watershed into upland planes and channels. A channel source area threshold of 50,000 square meters was used to determine the locations of stream channels and plane edges. This threshold was chosen by comparing the results from various source areas to the high resolution aerial photographs, with the goal of matching the synthetic stream locations created by AGWA with the significant channels present on the landscape as identified through aerial photo interpretation.
- The resultant planes and channels were parameterized by AGWA by intersecting the elements with terrain, soil, and vegetation map layers in GIS. Adjustments were made to the standard AGWA parameters to account for the local conditions in the NPL Project Area. A thorough calibration was not possible due to the lack of historical observational runoff data, but a combination of expert opinion and observational analyses were made for the following parameters:
    - Channel width: set to 3.5 meters based on intensive interpretation of aerial photographs.
    - Channel depth: set to one meter based on intensive interpretation of aerial photographs.
    - Channel infiltration rate: set to 50 mm per hour based on local knowledge and results from the SWAT model.
- A 25-year, 24-hour rainfall event was generated from standard Western U.S. Precipitation Frequency Maps provided by the Western Regional Climate Center at http://www.wrcc.dri.edu/pcpnfreq. In the NPL Project Area, this storm depth is approximately two inches.
- The same land-cover maps used to provide input to the SWAT model were used for KINEROS2. These maps represent possible future conditions based on the proposed plan of action and development in the study area.
- Soils data used in the KINEROS2 simulations were restricted to STATSGO as the more detailed SSURGO data sets are incomplete. SSURGO data contain adequate surface soil characteristics to develop parameters for the SWAT model, but the more stringent data requirements of the KINEROS2 model made it impossible to use the incomplete SSURGO data. This is a source of uncertainty in the modeling exercise since the spatial variability in soils is not fully represented in the STATSGO data.

- Simulations were run to compare the Worst Case to the Present condition by subtracting model results for all upland planes and channels for the present land cover map from the proposed worst case land cover map.
- Similarly, a simulation was run to compare the 2-Mile Buffer to the Present condition by subtracting model results for all upland planes and channels for the present land-cover map from the proposed 2-Mile Buffer.

4.2 Data Sources

The following data sources were used in the AGWA for both the SWAT and KINEROS2 modeling efforts.

4.2.1 Elevation

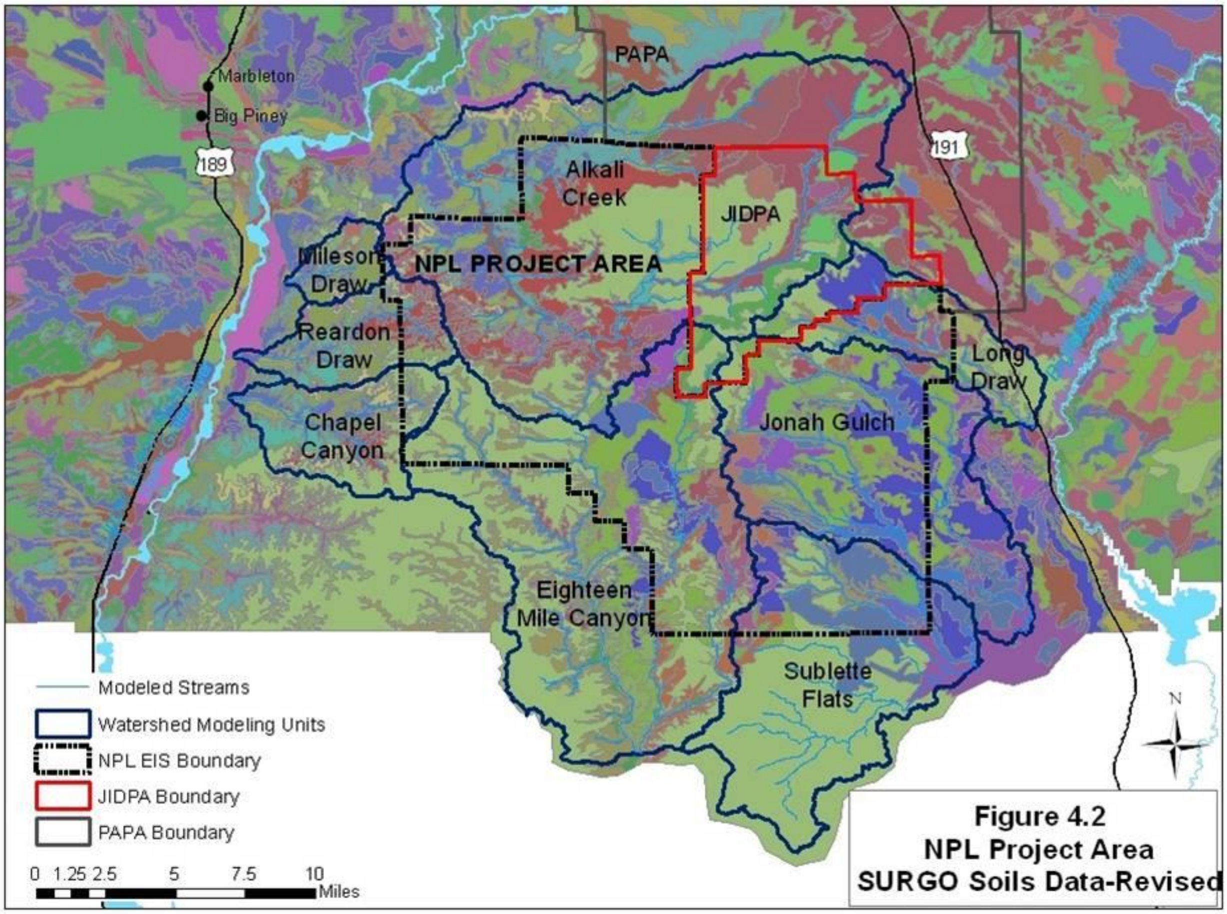
The topography of the NPL Project Area is controlled by a ridgeline that runs approximately east-west across the middle of the project area with additional divides that partition runoff into receiving waterways to the east, south, and west.

The AGWA/SWAT system simulates surface runoff at the plane level, which necessitates that the landscape be subdivided into Watershed Modeling Units for the purposes of modeling. AGWA/KINEROS2 calculates flow and erosion in a plane by assuming each element is a connected series of planes and channels, which are defined from the DEM.

The NPL Project Area was subdivided into eight Watershed Units using the following DEM data: National Elevation Dataset (NED) 1/3 Arc Second, downloaded in November 2011 in ArcGRID NAD 83 Geographic format (vertical datum is GRS 80) and was converted to NAD 1983, Universal Transverse Mercator (UTM) Zone 12, in meters. The cell size is 0.00009 degrees or 10 meter resolution (http://nationalmap.gov/viewer.html).

4.2.2 Soils

The Sublette County soil survey (WY635) was downloaded as a shapefile from the Natural Resources Conversation Service NRCS) Soil Data Mart (http://soildatamart.nrcs.usda.gov). It was converted to NAD 1983 UTM Zone 12 North in meters. Four of the southern-most watersheds in the NPL Project Area extended from Sublette County, south into Sweetwater County, into an area without any soil survey data. Twenty seven polygons from the Sublette County soil survey were digitally extended and eight polygons from the Sublette County soil survey were digitally added using ArcGIS, to cover approximately 60,000 acres in Sweetwater County. Aerial photo interpretation of the U.S. Geological Survey (USGS) Sublette County Digital Orthophoto Quarter Quadrangle imagery 2009, one-meter resolution, and field work were used to facilitate the digitizing process. Field work included driving to the interpolated (digitized) areas and visually matching landforms and vegetation with the interpolated polygons and by digging soil pits within some of the larger interpolated polygons and comparing them to the existing soils data for each map unit description from the Sublette County soil survey. ArcGIS topology rules were used to correct any slivers and overlaps between soil polygons with the default snapping tolerance of 10 pixels (Figure 4.2). Soil keys in all added features are consistent and were compared to the soil database WY635 for soil descriptions.



4.2.3 Land Cover

The goal of the hydrologic modeling using AGWA was to compare and predict surface runoff, water yield, and sediment yield within the NPL Project Area by executing SWAT and KINEROS2 under the defined four scenarios: Pre-Development, Present, 2-Mile Buffer, and Worst Case, which were selected for analysis because they encompass the range of potential surface disturbance of the proposed alternatives for the NPL Project Area EIS.

Pre-Development Disturbance

The NLCD from 2001 was used for Pre-Development conditions. Land cover classes in the NLCD 2001 overlap with the Watershed Modeling Units in the NPL Project Area and are shown in Figure 4.3.

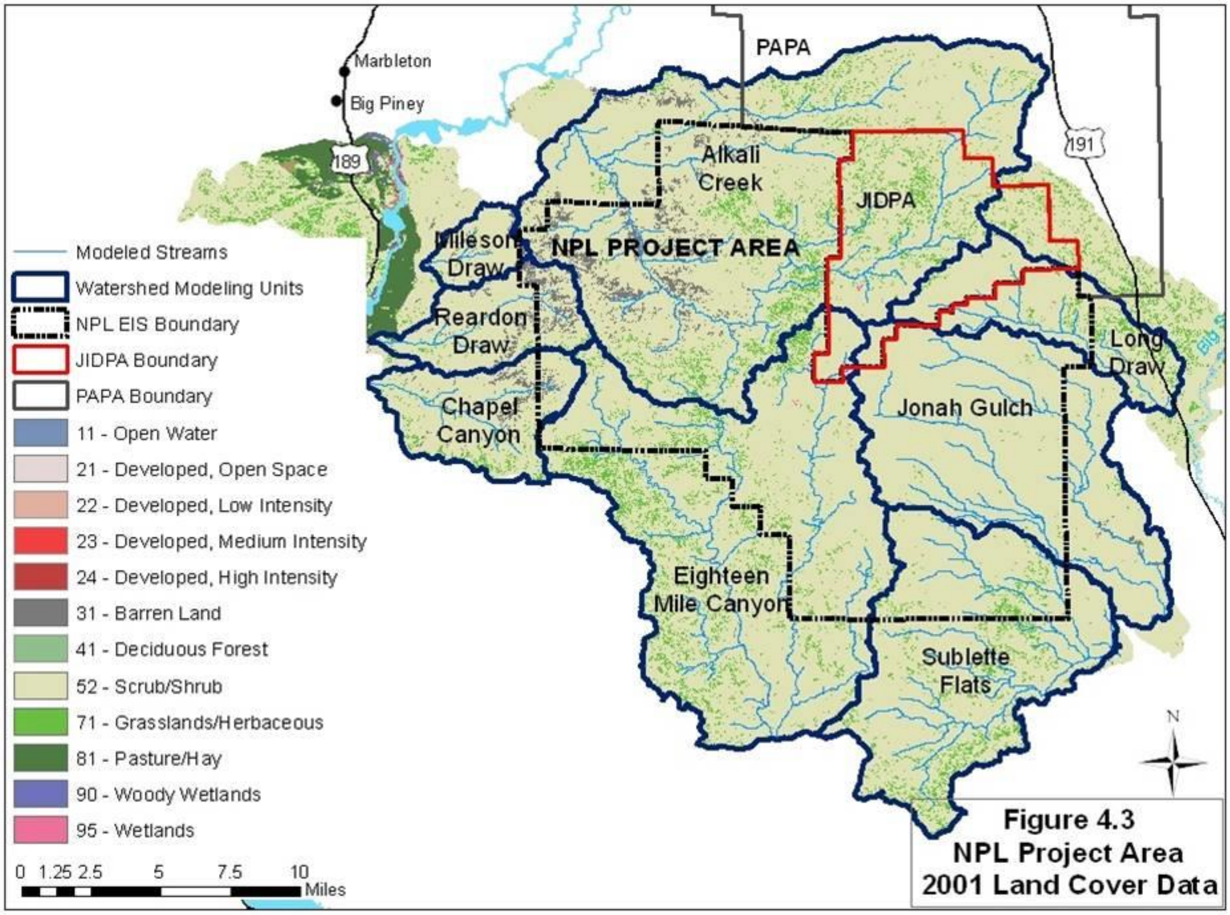


Figure 4.3
NPL Project Area
2001 Land Cover Data

Because significant development had already occurred in the JIDPA (adjacent to the NPL Project Area and within shared Watershed Modeling Units) prior to 2001, cells attributed with the four developed categories were removed and replaced with surrounding natural land cover categories in order to simulate the Pre-Development land cover (using the ArcGIS focal statistics tool with a majority statistic).

Table 4.2 shows the cell counts and percentages of each land cover type, before and after the removal of developed categories for modeling purposes.

TABLE 4.2
DEVELOPMENT CATEGORIES REMOVED FROM NLCD 2001

		NLCD 2001		Development removed from NLCD 2001	
LAND COVER	**CODE**	**COUNT**	**PERCENT**	**COUNT**	**PERCENT**
Developed, Open Space	21	70,946	0.558	0	0.000
Developed, Low Intensity	22	11,632	0.091	0	0.000
Developed, Medium Intensity	23	90	0.001	0	0.000
Developed, High Intensity	24	0	0.000	0	0.000

TABLE 4.2 DEVELOPMENT CATEGORIES REMOVED FROM NLCD 2001					
		NLCD 2001		Development removed from NLCD 2001	
LAND COVER	**CODE**	**COUNT**	**PERCENT**	**COUNT**	**PERCENT**
Barren Land	31	276,430	2.173	276430	2.173
Deciduous Forest	41	288	0.002	288	0.002
Scrub/Shrub	52	11,491,465	90.324	11,574,133	90.974
Grasslands/Herbaceous	71	859,215	6.754	859,215	6.754
Pasture/Hay	81	3,607	0.028	3,607	0.028
Woody Wetlands	90	1,811	0.014	1,811	0.014
Emergent Herbaceous Wetlands	95	6,944	0.055	6,944	0.055
Sum		12,722,428		12,722,428	

Although, an earlier NLCD was available from data compiled in 1992, differences in land cover classifications made it difficult to do a comparison between years with subsequent land cover datasets from 2001; therefore requiring the above cell removal.

The Pre-Development scenario included a total of 447 planes, with 285 planes within or overlapping the NPL Project Area boundary. The planes were classified by surface runoff using the Jenks natural breaks classification of five different categories. Table 4.3 shows the number modeling units per surface runoff categories.

TABLE 4.3 MODELING PLANES FOR LAND COVER WITHIN NPL PROJECT AREA		
Surface Runoff Category	Planes Outside SGCA	Planes inside SGCA
1 (0 - 2.96)	114	29
2 (2.961 - 8.8)	42	30
3 (8.81 - 15.52)	23	13
4 (15.521 - 34.25)	9	23
5 (34.251 - 60.14)	2	0
Total Planes	190	95

Present Disturbance

The Present disturbance layer was compiled from the following four data sources:

- National Land Cover Dataset, 2006 (NLCD 2006).
- Disturbance digitized off of aerial photos for existing oil and gas fields, including the JIDPA and the southern portion of the PAPA, portions of which, drain into the NPL Project Area.
- Additional disturbance digitized using 2009 NAIP imagery; only disturbance associated with well locations downloaded from the Wyoming Oil and Gas Commission in November 2012. The

disturbance associated with the footprint for each well was digitized off of 2009 NAIP imagery, including connecting roads.

- Existing roads, from the Wyoming roads and trails dataset, which was captured from 2001 NAIP imagery (1:12,000), downloaded in November 2012 from http://www.blm.gov/wy/st/en/resources/public_room/gis/datagis/office/transportation/statewide-roads-trails.html

The existing roads (represented by arcs) from 2001 were buffered by various widths in order to simulate width of disturbance. These widths were determined by creating 20 random samples along roads of each category (20 x 5 random samples), then measuring the width of disturbance from 2009 NAIP aerial photography for each random point. Mean widths in meters that were used as buffers for the roads are listed as follows for each road category:

- Two track mean: 3.61/2 = 1.805 m (6 feet)
- Light duty mean: 22.73/2 = 11.365 m (37.3 feet)
- Highway mean: 35.5/2 = 17.75 m (58.25 feet)
- BLM road mean: 15.52/2 = 7.76 m (25.5 feet)
- County road mean: 25.77/2 = 12.885 m (42.27 feet)

The buffered roads were then merged with the existing disturbance layers into a single polygon layer, and converted to a two-meter resolution raster (a resolution sufficient to capture narrow roads). This disturbance raster was used to replace existing land cover in the NLCD 2006, changing the land cover to high intensity development (class 24). This raster was resampled to 10 meters because of AGWA's limitations in handling small cells sizes. The Present disturbance is shown on Figure 4.4.

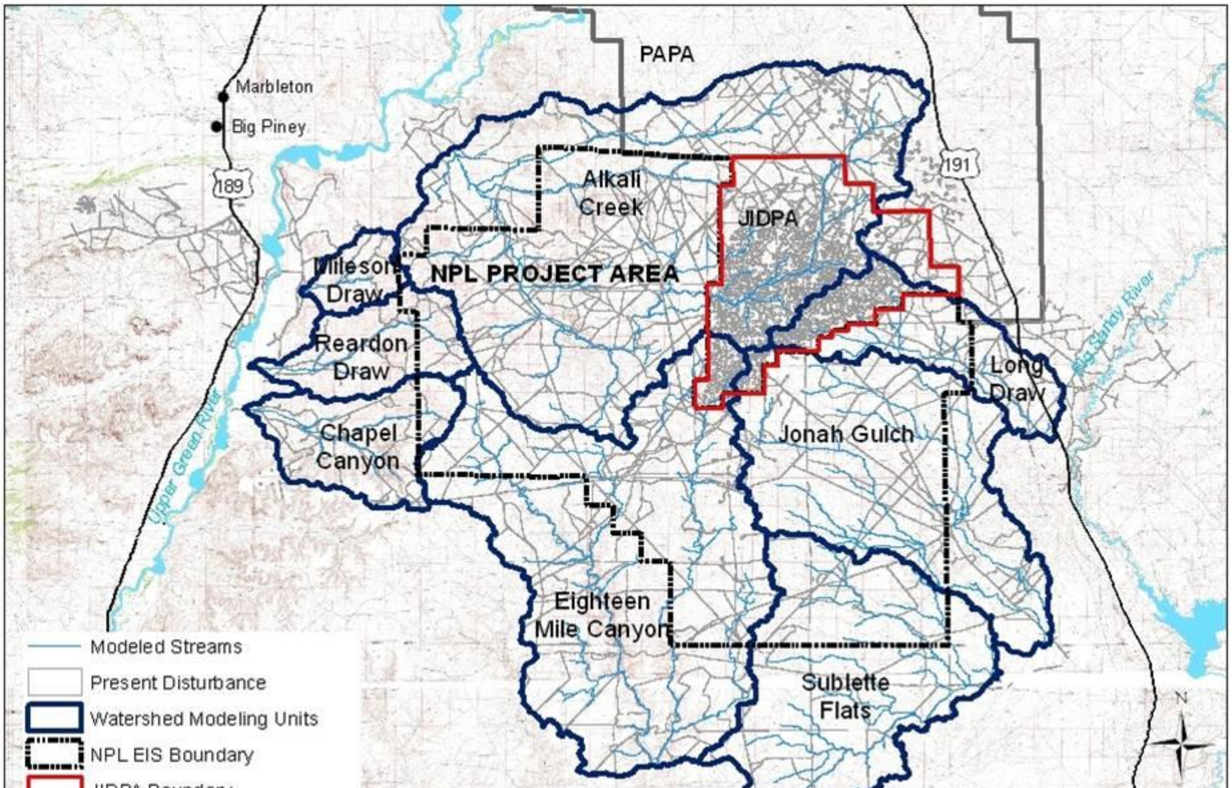


Figure 4.4 NPL Project Area Present Disturbance

Table 4.4 shows the decrease in cell counts and percentages of other land cover types as they were replaced by high intensity developed land.

TABLE 4.4 PRESENT DISTURBANCE - DEVELOPMENT CATEGORIES ADDED TO NLCD 2001				
	NLCD 2001		Added to NLCD 2001	
LAND COVER	COUNT	PERCENT	COUNT	PERCENT
Developed, Open Space	108,702	0.854	47,132	0.370
Developed, Low Intensity	14,152	0.111	4,803	0.038
Developed, Medium Intensity	477	0.004	107	0.001
Developed, High Intensity	63	0.000	399,724	3.142
Barren Land	275,537	2.166	273,863	2.153
Deciduous Forest	288	0.002	288	0.002
Scrub/Shrub	11,454,226	90.031	11,147,404	87.624
Grasslands/Herbaceous	856,600	6.733	836,441	6.575
Pasture/Hay	3,607	0.028	3,448	0.027
Woody Wetlands	1,820	0.014	1,810	0.014

TABLE 4.4 PRESENT DISTURBANCE - DEVELOPMENT CATEGORIES ADDED TO NLCD 2001				
	NLCD 2001		Added to NLCD 2001	
LAND COVER	COUNT	PERCENT	COUNT	PERCENT
Emergent Herbaceous Wetlands	7,007	0.055	6,888	0.054
Sum	12,722,479		12,721,908	

Disturbance Scenarios –2-Mile Buffer and Worst Case

Under the 2-Mile Buffer and Worst Case scenarios, Jonah Energy would directionally drill up to 3,500 natural gas wells within the NPL Project Area from multi-well pads. The Proposed Action stats that multi-well placement would average:

- One multi-well pad per 640-acre area in SGCA; and,
- Four multi-well pads per 640-acre section of land in non-SGCA.

Because the actual placement of future well pad locations, access or connecting roads, or pipelines is currently unknown for the Proposed Action; two additional spatial scenarios were developed for disturbance: a reasonable representation of the Proposed Action called the 2-Mile Buffer Scenario, and a Worst Case Scenario.

- The 2-Mile Buffer scenario was created assuming that Jonah Energy would place the proposed wells within a reasonable distance from the proposed power line and RGFs as depicted in the shapefile submitted for the EIS analysis (submitted on February 4, 2013). In addition, Jonah Energy submitted their NPL disturbance matrix to BLM (November 9, 2012), which listed the number of multi-well pads to be placed in sections using the 80/20 Rule (Appendix A). The locations of the multi-well pads was not provided, however, Jonah Energy indicated that multi-well pads would be located in 26 sections in the SGCA and multi-well pads would be located in 109 sections in non-SGCA. By using a two-mile buffer around the proposed powerlines and RGFs, BLM was able to duplicate then sections in each SGCA and non-SGCA category. It was assumed that this would be a reasonable representation of the Proposed Action. The matrix also listed approximate road, well pad, and pipeline disturbances (Appendix A).

- The Worst Case scenario was created by assuming that the proposed 3,500 wells would be located in non-SGCA and SGCA as described in the Proposed Action, but located in areas shown to have the highest surface runoff by the SWAT model for the Present Case Scenario.

Tables 4.5 and 4.6 show the proposed well density for areas in non-SGCA and SGCA sections, respectively, as discussed in the Proposed Action and in the NPL Disturbance Matrix:

TABLE 4.5 WELL PLACEMENT AND DENSITY OUTSIDE SGCA					
Well Density per Section	Number of Sections	Pads per Section	Disturbance per Pad (acres)	Roads per Section (acres)	Pipelines per Section (acres)
64	35	4	11.7	6.27	18.81
16	28	4	5.5	6.66	19.97
4	22.4	4	5.5	6.66	19.97
1	22.4	1	5.5	2.76	8.29

TABLE 4.6 WELL PLACEMENT AND DENSITY INSIDE SGCA					
Well Density per Section	Number of Sections	Pads per Section	Disturbance per Pad (acres)	Roads per Section (acres)	Pipelines per Section (acres)
64	8.75	1	18	2.52	7.57
16	7	1	11.7	2.63	7.90
4	5.6	1	5.5	2.76	8.29
1	5.6	1	5.5	2.76	8.29

Multi-well pads were distributed across these categorized modeling planes as close as possible to the center of the quarter sections in non-SGCA, or full section in SGCA; avoiding a one-mile radius around Greater sage grouse leks, a 100-foot radius around stream channels, and areas with slope greater than 15 percent.

For the 2-Mile Buffer, all multi-well pads were placed in quarter sections within a two-mile radius of power lines and RGFs; and for the Worst Case scenario, all multi-well pads were placed first in the highest runoff category modeling planes. After the highest category quarter sections were placed, pads were then placed in the next lowest runoff category, and so forth. Table 4.7 shows the breakdown of multi-well pads within each category.

TABLE 4.7 NUMBER OF WELL PADS PER SURFACE RUNOFF CATEGORIES							
Surface Runoff Category	SGCA	1 (low)	2	3	4	5 (high)	Total
2-Mile Buffer	Inside	11	8	6	2	0	27
	Outside	220	86	54	2	2	364
Worst Case	Inside	0	0	4	23	0	27
	Outside	35	166	134	19	10	364

After distributing well pads, the well locations were buffered by the following various radii to approximate pad disturbance:

- Well pads with 19 acres of disturbance were buffered by a radius of 513 feet.
- Wells pads with 11.7 acres of disturbance were buffered by a radius of 403 feet.
- Well pads with 5.5 acres of disturbance were buffered by a radius of 276 feet.

To model road disturbance, connector roads (road connecting new wells with existing roads) were modeled using a least cost method, or the shortest path given weighted factors on the landscape. Five categories of slope were used for weighting using the Jenks natural breaks classification, a data classification method designed to determine the best arrangement of values into different classes.

- degrees slope: 0-2.14 (lowest cost category 1)
- degrees slope: 2.141 – 5.95 (category 2)
- degrees slope: 5.951 – 11.66 (category 3)
- degrees slope: 11.661 – 19.76 (category 4)
- degrees slope : 19.761 – 60.69 (highest cost category 5)

Least cost and existing roads were buffered in order to represent road and pipeline disturbance, with roads being used as a proxy for pipeline disturbance. Average road and pipeline disturbance were calculated by section as described in Table 4.8. An iterative procedure was used to determine buffer widths. Roads were clipped to sections of a particular category of well density, then buffered and average acres of buffer per section were calculated. Buffer widths were adjusted until the average acreage of buffer per section equaled the combined acreage of road and pipeline disturbance for the matching category in Tables 4.8.

TABLE 4.8
BUFFER WIDTHS TO SIMULATE ROAD AND PIPELINE DISTURBANCE (feet)

Development scenario	Sage grouse core area	64 wells per section	16 wells per section	4 wells per section	1 well per section
2-Mile Buffer	Inside	20	24	24	24
	Outside	36	31	31	18
Worst Case	Inside	22	25	28	28
	Outside	35	33	33	22

The amount of disturbance due to roads and pipelines vary because of density of well placement. After buffer widths were determined, new least cost roads were buffered for each category. For existing roads, the first buffer was determined based on average width measured from aerial photos (to model present day disturbance). This buffer was buffered again by the widths determined in Table 4.8 to model each development scenario.

All buffered layers (wells, new least cost roads, existing roads) were combined with existing disturbance layers to create a disturbance layer for each of the three scenarios. These combined layers were then converted to two- meters rasters, which were then used to replace 2006 land cover types with high density development land resampled to 10 meters to be used as input to AGWA. Surface Disturbance for the 2-Mile Buffer scenario is shown in Figure 4.5.

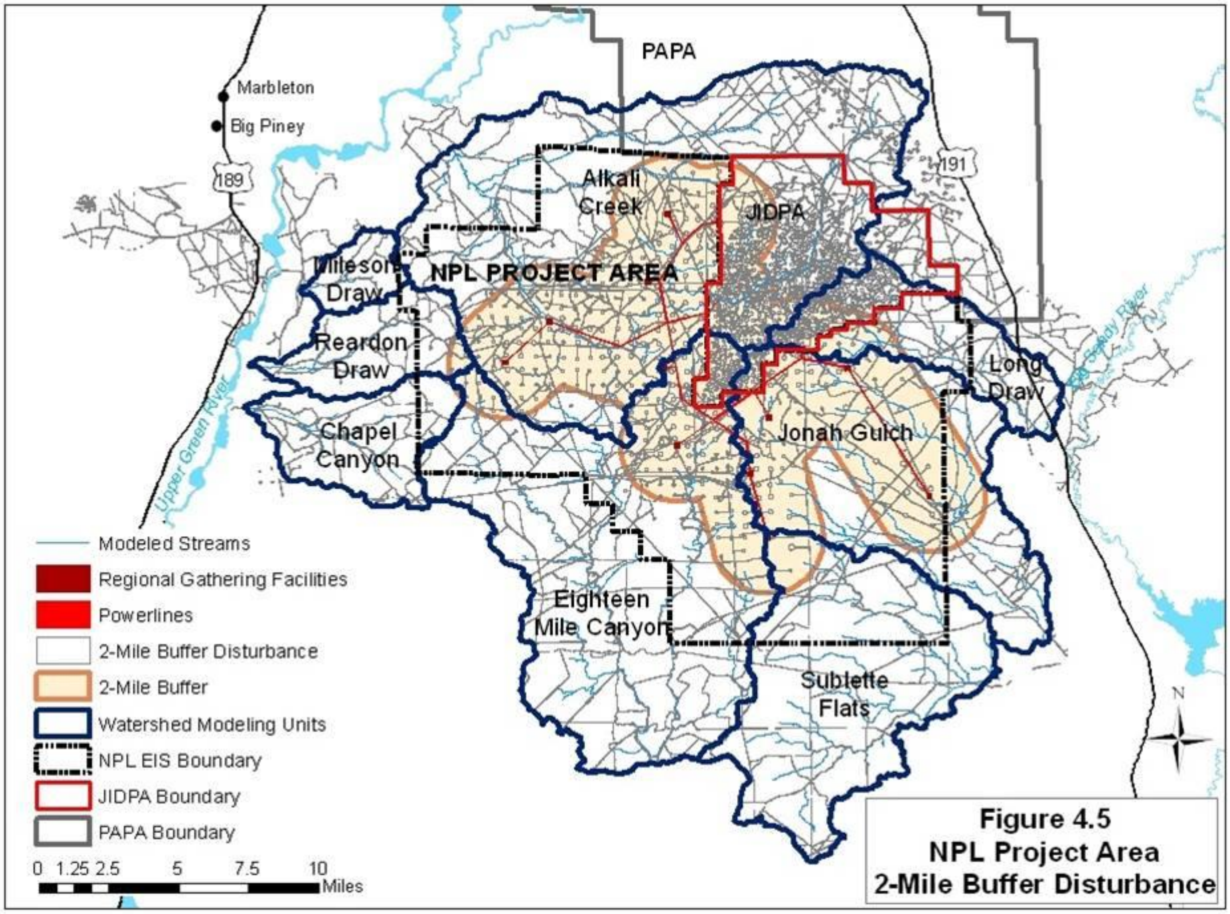


Figure 4.5
NPL Project Area
2-Mile Buffer Disturbance

Surface Disturbance for the Worst Case Scenario is shown in Figure 4.6.

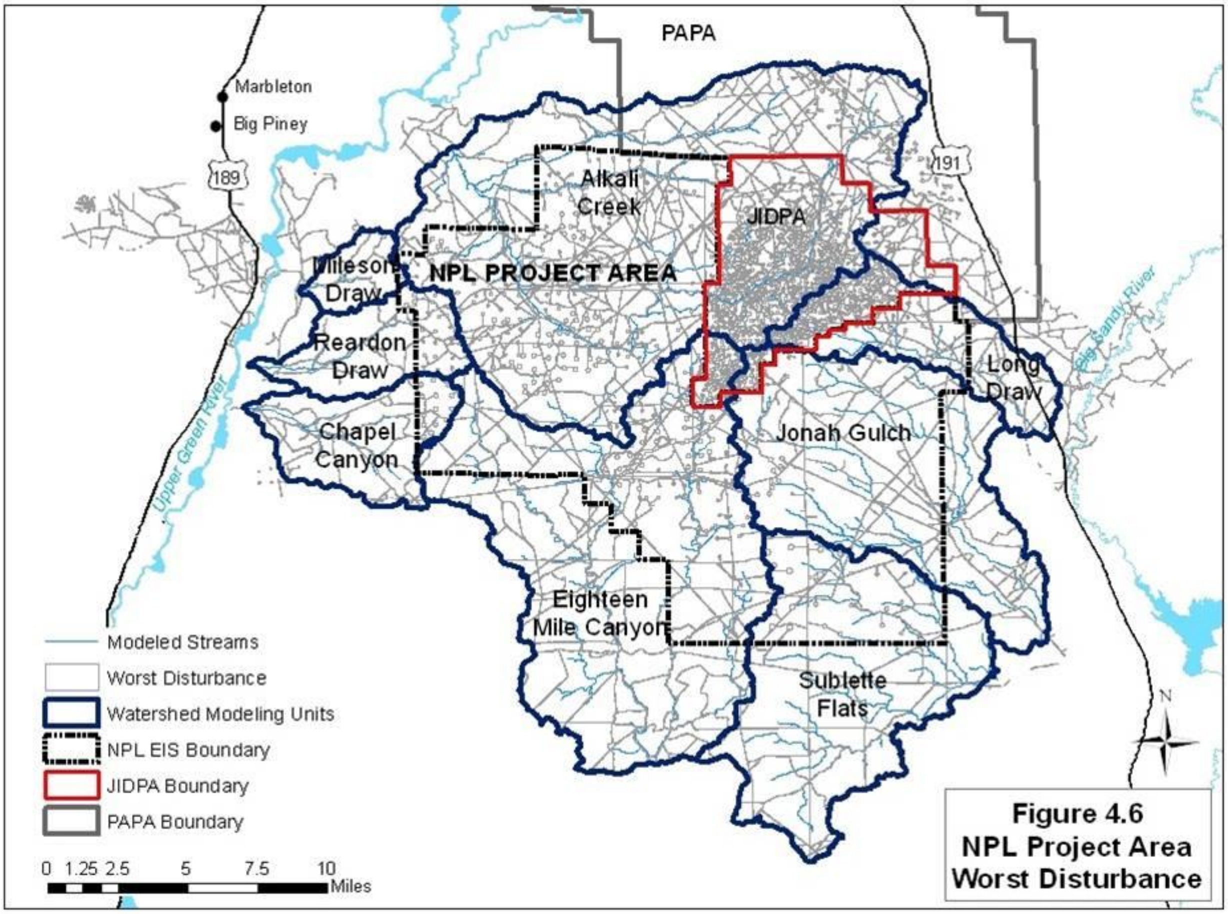


Figure 4.6 NPL Project Area Worst Disturbance

4.2.4 Climate

Three years of hourly precipitation have been collected at Department of Environmental Quality AQD monitor locations at two locations; one within the JIDPA and the other at Juel Springs. The SWAT model requires at least 10 years of daily precipitation data. Since there are no long-term observation sets in this area, a climate simulator (weather generator) was used to create a synthetic climate model, based on weather generator station at Kemmerer, Wyoming. Kemmerer was selected as a representative location since it is the closest weather station in the region with similar landscape and vegetation, indicating that the overall climate is similar to the NPL. There are undoubtedly differences in climate patterns between Kemmerer and the NPL, but for the purposes of the modeling exercise it is important that the seasonal climate patterns are well matched. The SWAT climate simulator uses average and standard deviation monthly values for key weather parameters to develop daily weather data (wind, temperature, relative humidity, etc.) that drives the model.

4.3 Model Steps and Parameter Estimation

The following steps were followed to set up the initial parameterization and model runs for SWAT using AGWA.

4.3.1 Watershed Delineation

AGWA used the following data sources: 10-meter resolution DEM, flow direction, flow accumulation maps and identifiable stream outlet locations. The outlets for each of the watersheds were chosen to accommodate the entire study area with a minimum of watersheds and to make them large enough to break into similar hydrologic elements.

4.3.2 Watershed Modeling Unit Discretization

Discretization refers to the process of creating distinct modeling elements within the Watershed Modeling Units of the NPL Project Area. Each of the Watershed Modeling Units was broken into modeling elements using the standard AGWA practice of setting a threshold for 0-order stream channels. In this exercise the channel source area (CSA) was set to 618 acres (250 hectares) meaning that the uppermost modeling elements on the landscape are approximately 618 acres in size (Figure 4.7). This approach is important because it unitizes the surface runoff modeling calculations and reduces biases in results that can occur when landscapes are subdivided into modeling elements at different scales.

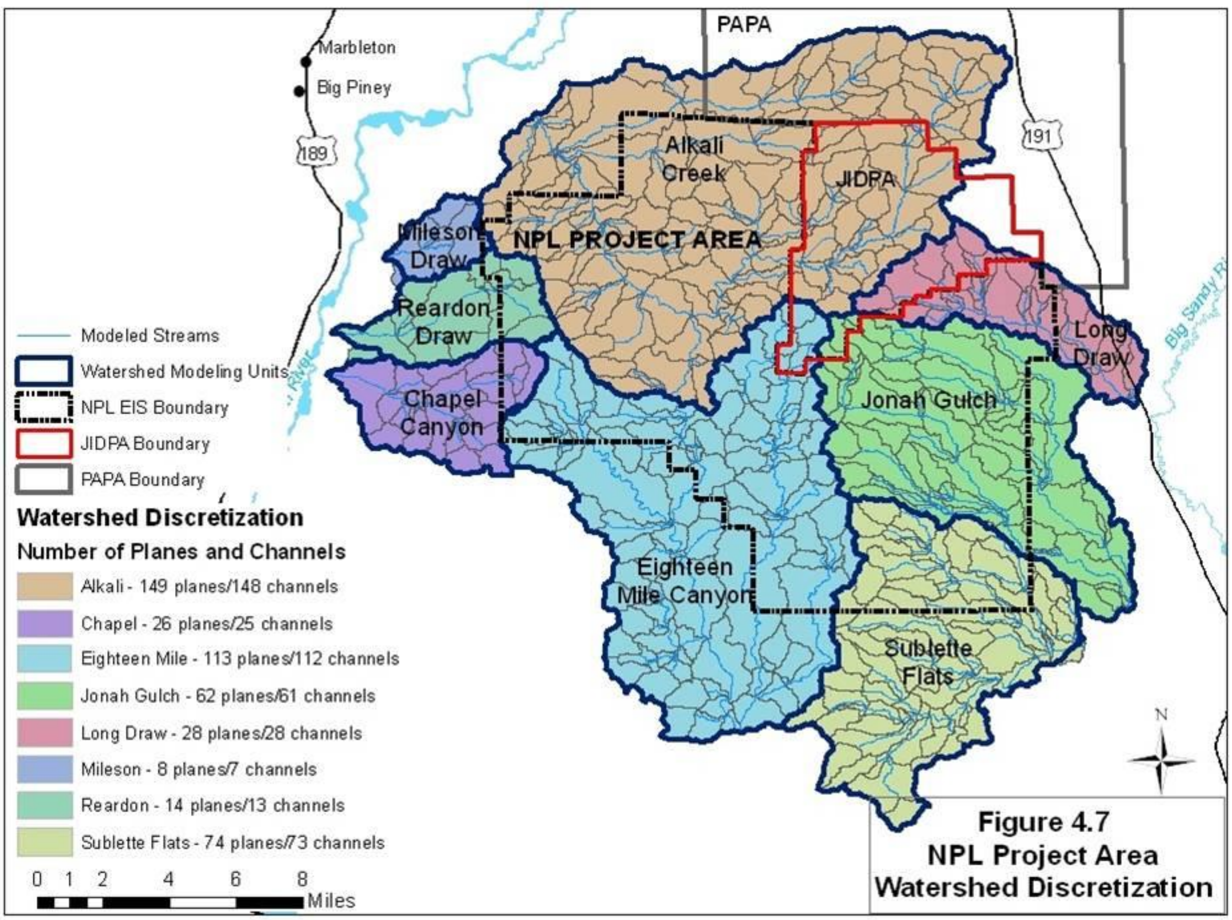


Figure 4.7
NPL Project Area
Watershed Discretization

Discretization yielded the following number of planes and channels for each of the Watershed Modeling Unit are shown in Table 4.9.

TABLE 4.9 NUMBER OF PLANES AND CHANNELS IN EACH WATERSHED MODELING UNIT		
Watershed Modeling Unit	Number of Planes	Number of Channels
Alkali	149	148
Chapel	26	25
Eighteen Mile	113	112
Jonah Gulch	62	61
Long Draw	28	28
Mileson	8	7
Reardon	14	13
Sublette Flats	74	73

4.3.3 Element Parameterization

This is the first step in identifying suitable parameters for hydrologic modeling of the NPL Project Area. AGWA determines basic geometric features for the elements listed above such as slope, size, morphology and aspect. The default settings were accepted in this step with one important change: channel transmission losses were simulated based on channel morphology relationships that estimate width and depth as a function of the Watershed Modeling Unit area. Intensive aerial photo interpretation indicated that statistically significant relationships among these variables do not exist in the NPL Project Area. Stream channels appear very uniform in the downstream direction. Channel width was mapped throughout the EIS Project Area and it was determined that assigning an average channel width was more appropriate than using a statistical relationship. The following relationships were used:

- Channel width = 3.5 m
- Channel depth = 1 m

4.3.4 Land Cover and Soils Parameterization

The AGWA Toolkit assigned initial parameter values for landscape and soil attributes by intersecting each model element with the SSURGO and NLCD 2001 land cover data sets and used a combination of look up tables and mathematical relationships. The mrlc2001_lut.dbf table (provided with the AGWA 2.0 installation, also in Appendix B.1) was used for look up values for land cover, interception, Manning's N, percent impervious and curve number values for soil hydrogroups (A, B, C, and D). Interception value for land cover type "developed, high intensity" was changed from 0.05 to 0 to ensure that the model simulated the pad with disturbance having no vegetation and therefore, no interception.

SWAT also used a table used by SWAT called crop.dat (Appendix B.2) containing information to simulate plant growth. For rangeland land cover types, the values in this file were changed from perennial (6) to warm seasonal annual (4) to better represent rangeland plant growth in the NPL Project Area. The rest of the default values associated with SWAT were accepted without change and the Parameter Modification System for SWAT 2005 Files (PETT) software was used to adjust parameters to fit a calibrated model (Section 4.4) outside of AGWA.

SSURGO component table, lookup table and horizon tables are presented in (Appendices C.1, C.2, and C.3).

4.3.5 Climate Data

There is a lack of climatological data recorded within the NPL Project Area. No long-term data sets for rainfall, wind, solar radiation, temperature or relative humidity could be identified that would provide the necessary inputs to the model. Therefore, the AGWA/SWAT option was used to generate synthetic climate data for a 10-year period of record using the climate characteristics from Kemmerer, WY weather station. Since there is an approximately 95 km (59 miles) distance between the Kemmerer station and the center of the study area this approach has a distinct risk in misrepresenting climate.

A regional assessment of climate variability was performed using data downloaded from the Daily Meteorological (DayMet) site (http://daymet.org/, and it was determined that the differences between Kemmerer and NPL were relatively small and justified the use of this gage for creating initial climate data. The climate data were adjusted in the parameter estimation process outlined below to create a more realistic annual hydrograph, with details discussed later in this document. Rainfall data for the KINEROS2 simulations is in Appendix D.1

4.4 Parameter Estimation

A complete model calibration in the NPL Project Area was not possible because there is an absence of any historical climate or runoff data. However, it is important in hydrologic modeling to establish reasonable parameters to ensure that the model is providing reasonable and proper estimations of surface runoff, including such metrics as annual water yield, proportion of runoff contributed by overland flow or groundwater, and the amount of loss due to evapotranspiration.

4.4.1 Hydrologic Data Availability and Analysis

Surface Runoff in this region is heavily dominated by spring melt, making it important to approximate the annual hydrograph and partition surface runoff into monthly or seasonal flows to better match the model outcome with actual hydrologic response. This attempt to match model outcomes with real-world hydrology falls under the general heading of “model calibration”, which usually entails two steps:

- Parameter Estimation, in which a set of adjustments are made to the model to better match observational data; and,
- Parameter Determination, in which the parameters are verified against a second set of data to ensure that they are appropriate. The approach for the NPL Project Area is strictly in the area of indirect parameter estimation and is detailed below.

Parameter estimation was performed using two fundamental objective functions:

- Total annual water yield; and,
- Long-term monthly average flow.

Because there were no data available in the immediate proximity of the NPL Project Area, a suitable nearby watershed was identified that would respond in a similar hydrologic fashion to the NPL Project Area. This nearby watershed was the USGS 09215000 PACIFIC CREEK NEAR FARSON, WY gage station, (http://waterdata.usgs.gov/nwis/nwisman/?site_no=09215000) as a suitable candidate for establishing baseline flow conditions. A second DayMet analysis of climate was performed and it was found that the climatological system in the watershed is similar to both Kemmerer and the NPL Project Area. The watershed is 500 square miles in area and lies approximately 43 miles to the southeast of the NPL Project Area and drains a similar terrain.

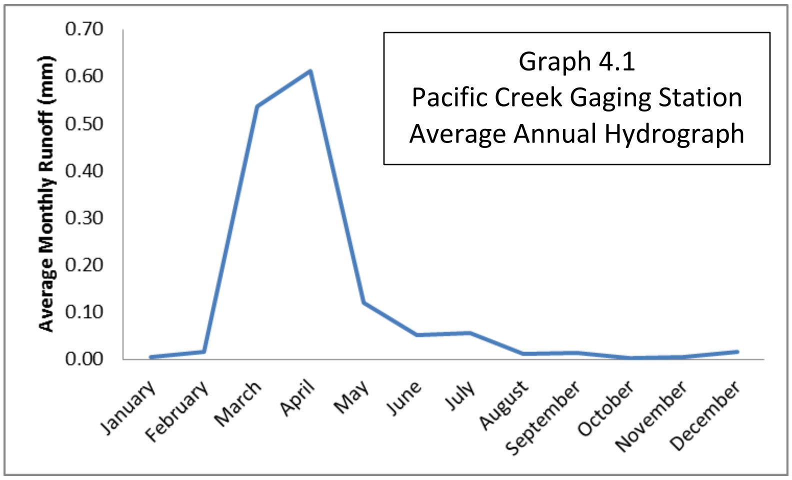
Differences in soil and land cover present a clear concern in that the hydrologic response in the Pacific Creek drainage is likely not exactly the same as the NPL Project Area. However, in light of the need to better adjust the parameters in the study area, this area was deemed suitable as a comparator given the relative strengths of proximity, climate, and similarity in topography.

The Pacific Creek gage station was in operation from 1954 through 1973. A standard hydrograph analysis was performed using daily runoff data and yielded the stream runoff data shown in Table 4.10. These data indicate a highly seasonal system with snowmelt dominating annual surface runoff. Average peak runoff occurs in April, with limited to no flow in the late summer season. After evapotranspiration shuts down in the late fall/early winter, some winter seasonal flows occur. Diversions are present in the Pacific Creek watershed to supply irrigation water, and it is likely that the gage under-reports surface runoff compared to a natural setting.

TABLE 4.10
PACIFIC CREEK GAGING STATION – SURFACE RUNOFF (1954-1973)

MONTH	SURFACE RUNOFF (cubic feet per second)	SURFACE RUNOFF (millimeters)
January	0.23	0.006
February	0.75	0.017
March	21.76	0.537
April	25.63	0.612
May	4.89	0.121
June	2.11	0.050
July	2.27	0.056
August	0.45	0.011
September	0.61	0.015
October	0.15	0.004
November	0.16	0.004
December	0.68	0.017
TOTAL		1.45

The average annual hydrograph for the Pacific Creek gaging station is shown in Graph 4.1:



4.4.2 Goals of Parameter Estimation

The PETT Parameter Modification System for SWAT 2005 Files (PETT) software was used to adjust parameters outside of AGWA. PETT is a software built by UW in support of this effort and it allows the operator to adjust model parameters and test the output against previous model runs or observational data. The PETT tool was used in an iterative fashion to systematically adjust parameters within the range established by the SWAT/2005 developers in order to approximate surface runoff from a selected watershed draining the NPL Project Area to match the average annual hydrograph data from the Pacific Creek gaging station. Because of the absence of rigorous observational data against which a calibration could be performed, the multiplier calibration method was chosen for the NPL Project Area. In this method, all parameters across the watershed were manipulated with the same rules (e.g. if the CN was increased by 10 percent, all Curve Numbers (CN) on all model elements were increased by the same rate).

4.4.3 Parameters Used in Estimation

The following parameters were adjusted to test sensitivity and improve model performance:

- Channel hydraulic conductivity in both main and small channels;
- Snow parameters coupling the rate of melt to atmospheric temperature and time of year;
- Monthly temperature and precipitation;
- Evaporation model choice;
- Groundwater parameters controlling the rate on influx and efflux between channels and groundwater;
- Connectivity of subsurface pores to control ET losses from soils; and
- NRCS Curve Number to adjust overland flow production.

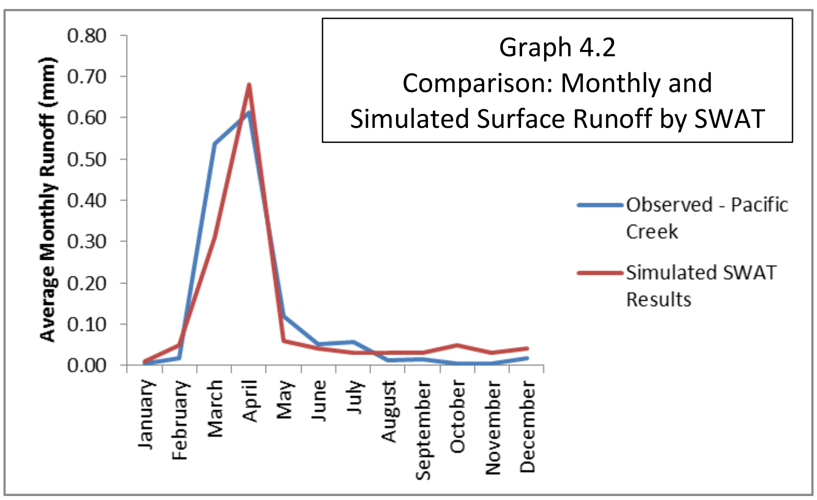
Climate data were adjusted to better match daily DayMet data for the center of the basin for precipitation. Average monthly rainfall depths and corresponding standard deviations for the NPL Project Area were determined, and the Kemmerer weather data were updated. Monthly temperature and standard deviation data for November and December were manually adjusted to reduce runoff in those months.

The Nash-Sutcliffe error statistic was used to determine the optimal parameter estimation set. This statistic determines whether simulation results improve the quality of prediction over using a long-term mean. The value of the statistic ranges from highly negative (a very poor fit) to 1 (perfect correlation). Results from the calibration are shown in Table 4.11.

TABLE 4.11
OBSERVED AVERAGE MONTHLY RUNOFF VALUES FOR PACIFIC CREEK AND AVERAGE MONTHLY RUNOFF VALUES SIMULATED ON EIGHTEEN-MILE CREEK

	PACIFIC CREEK	EIGHTEEN MILE
Month	Average Monthly Runoff (millimeters)	Simulated Average Monthly Runoff (millimeters)
January	0.01	0.01
February	0.02	0.05
March	0.54	0.31
April	0.61	0.68
May	0.12	0.06
June	0.05	0.04
July	0.06	0.03
August	0.01	0.03
September	0.01	0.03
October	0.00	0.05
November	0.00	0.03
December	0.02	0.04
TOTAL	**1.45**	**1.36**
Nash-Sutcliffe Statistic: 0.99		

Graph 4.2 shows the comparison between monthly and simulated runoff produced by AGWA/SWAT.



4.4.4 Adjustments to AGWA Parameters

Results from this parameter estimation process yielded the following adjustments to the AGWA parameters:

Table 4.12
PARAMETER ESTIMATION ADJUSTMENTS FOR PETT TOOL

Parameter	File	Value	Explanation
CH_K(1): Effective hydraulic conductivity in tributary channel (default)	.SUB	20	Reduces the rate of infiltration losses to more closely balance the amount of groundwater flow
!Line4 SFTMP **!Line5 SMTMP** **!Line6 SMFMX** **!Line7 SMFMN** **!Line8 TIMP**	.BSN	1.0 2.0 2.0 1.0 0.01	Delays the onset of melt of the snowpack and de-couples the rate of melt from the ambient air temperature. Effectively pushes the melt later into the season.
WGN File Changes	.WGN	-1	Nov TMPMX
		-1	Dec TMPMX
		1	Nov TMPSTDMX
		2	Dec TMPSTDMX
		13.59	Jan PCPMM
		17.1	Feb PCPMM
		18.38	Mar PCPMM
		26.55	Apr PCPMM
		39.88	May PCPMM
		21.71	Jun PCPMM
		16.68	July PCPMM
		16.11	Aug PCPMM
		25.36	Sep PCPMM
		21.18	Oct PCPMM
		17.64	Nov PCPMM
		14.46	Dec PCPMM
		0.59	Jan PCPSTD
		0.32	Feb PCPSTD
		0.29	Mar PCPSTD
		0.51	Apr PCPSTD
		0.58	May PCPSTD
		0.52	Jun PCPSTD
		0.47	July PCPSTD
		0.34	Aug PCPSTD
		0.34	Sep PCPSTD
		0.28	Oct PCPSTD
		0.30	Nov PCPSTD
		0.28	Dec PCPSTD

Table 4.12 PARAMETER ESTIMATION ADJUSTMENTS FOR PETT TOOL			
Parameter	**File**	**Value**	**Explanation**
TMPSIM: temperature simulation code: 1 = measured, 2 = simulated **IPET: PET method: 0=priest-t, 1=pen m, 2=har, 3=read into model**	.CIO	2 0	Forces the model to accept the observed temperature from the weather station. Better mimics ET rates in the basin.
!SHALLST **!DEEPST** **!GW_DELAY** **!ALPHA_BF** **!GWQMN** **!GW_REVAP** **!REVAPMN**	.GW	2000 5000 1 0.5 2000 0.2 1500	These are set to limit stream flow from receiving groundwater or lateral flow support during most of the year.
EPCO	.HRU	0.01	Shuts down ET model from pulling water from deeper in the soil.
CH_K(2) : Effective hydraulic conductivity of main channel alluvium (default)	.RTE	20	Reduces the rate of infiltration losses to more closely balance the amount of groundwater flow.

5.0 MODEL RESULTS

Results of the AWGA Tool modeling runs for both SWAT and KINEROS2 are presented in the following section.

5.1 SWAT Model Results

Because the NPL Project Area is located in a region where limited to no surface runoff and climate data are available, a fully detailed calibration exercise on the project area was not feasible, which is why the model was calibrated using monthly and seasonal averages from a nearby gaging station. Simulation results for surface runoff and channel discharge output from the model are internally consistent and represent trends and the magnitude of those trends, rather than predictive values of surface runoff or channel discharge that would result from a fully calibrated model. To best represent the trend and magnitude of change AGWA simulations were categorized, using the Jenks natural breaks method, into five impact categories for comparative purposes. These are initial estimates of impact categories and future monitoring and observation will be necessary to validate these estimates.

Results of the AGWA/SWAT simulations indicate that for all Watershed Modeling Units in all four scenarios simulated (Pre-Development, Present, 2-Mile Buffer, and Worst), the values for average annual surface runoff ranged from 0 to 2.48 inches per year (in/yr) over the 10-year simulation period. Impact categories for surface runoff are shown in Table 5.1.

TABLE 5.1
SURFACE RUNOFF ANALYSIS IMPACT CATEGORIES

Category	Runoff (inches/year)	Impact Category
1	0.00 – 0.14	Very Low
2	0.14 – 0.46	Low
3	0.46 – 0.81	Minimal
4	0.81 – 1.40	Moderate
5	1.40 – 2.48	High

For all stream channels in all Watershed Modeling Units, the average annual channel discharge ranged from 0 to 0.61 cubic feet per second (cfs) over the 10-year simulation period. The following five impact categories were derived from the AGWA results of channel discharge are shown in Table 5.2.

TABLE 5.2
CHANNEL DISCHARGE ANALYSIS CATEGORIES

Category	Water Yield (cubic feet/second)	Impact Category
1	0.00 – 0.03	Very Low
2	0.03 – 0.07	Low
3	0.07 – 0.13	Minimal
4	0.13 – 0.27	Moderate
5	0.27 – 0.61	High

The acreage that falls within each Watershed Modeling Unit and within each Watershed Modeling Unit within the NPL Project Area is presented in Table 5.3.

TABLE 5.3
ACRES WITHIN EACH WATERSHED MODELING UNIT

Alkali	Chapel	Eighteen Mile	Jonah Gulch	Long Draw	Mileson	Reardon	Sublette Flats	Totals
101,201	14,380	76,340	46,096	17,213	4,673	12,255	43,285	315,443
ACRES WITHIN THE NPL PROJECT AREA								
48,932	2,000	35,014	31,480	6,365	123	3,489	13,665	136,068

The miles of stream channels within each Watershed Modeling Unit and within each Watershed Modeling Unit within the NPL Project Area are presented in Table 5.4:

TABLE 5.4
MILES OF STREAM CHANNEL WITHIN EACH WATERSHED MODELING UNIT

Alkali	Chapel	Eighteen Mile	Jonah Gulch	Long Draw	Mileson	Reardon	Sublette Flats	Totals
132.02	16.12	99.90	74.52	22.40	4.70	13.15	72.28	435.09
MILES OF STREAM CHANNEL WITHIN EACH NPL WATERSHED UNIT								
66.27	1.13	42.69	50.54	12.88	0.00	2.33	20.83	196.67

5.1.1 Modeling Scenarios

Simulations were performed for the four scenarios described in Section 1.1.

<u>Pre-Development Conditions</u>

Pre-Development conditions are those conditions in existence prior to surface disturbance. Under pre-development conditions, no natural gas associated disturbance was considered.

The results of this simulation describe existing conditions and indicate areas of vulnerability of the landscape to erosion and surface runoff under undisturbed conditions. These conditions reflect the natural background vulnerability to erosion based on soil, vegetation, aspect, slope, precipitation, and other non-disturbance related model inputs. Figure 5.1 shows the areas of greatest native surface runoff and sediment production that would be the most vulnerable to increased surface runoff and channel discharge as a result of additional surface disturbance.

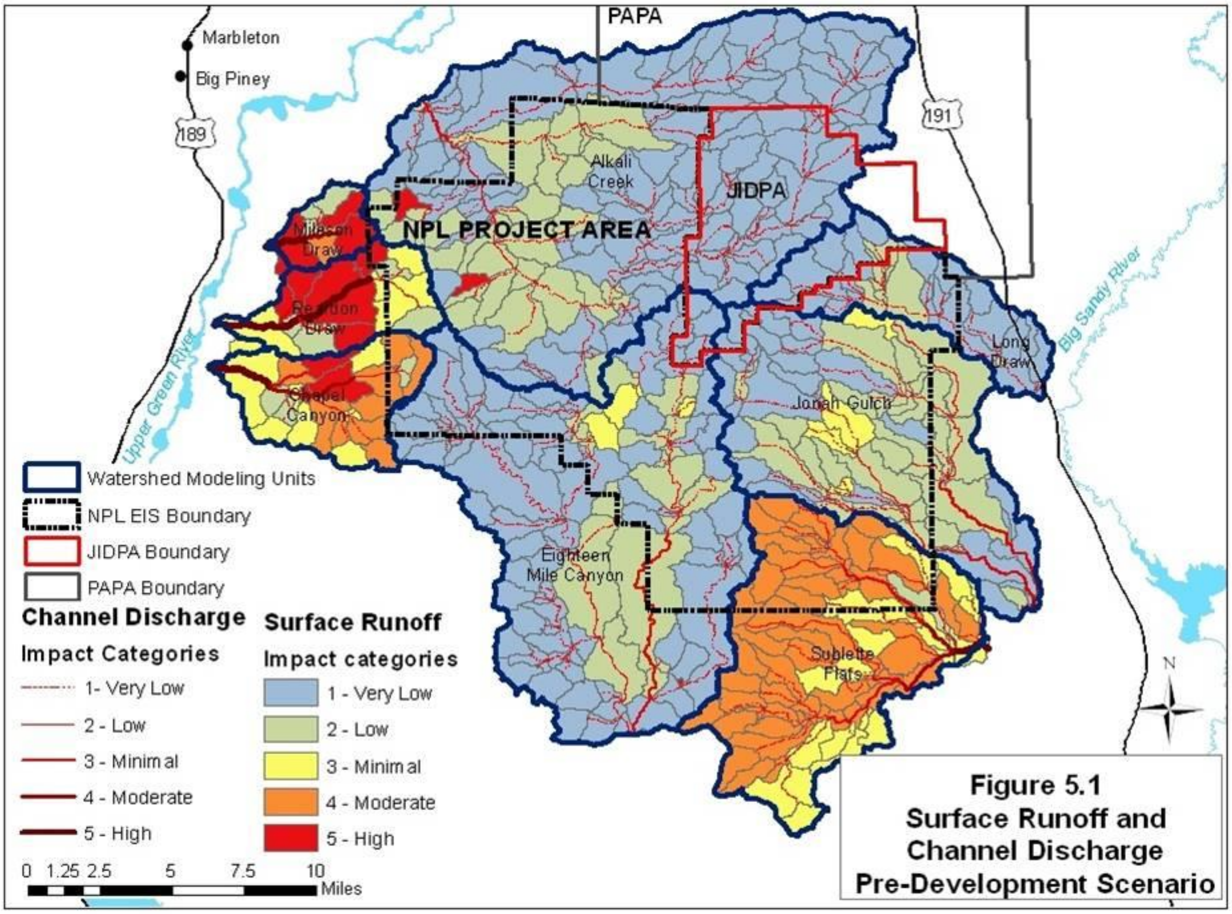
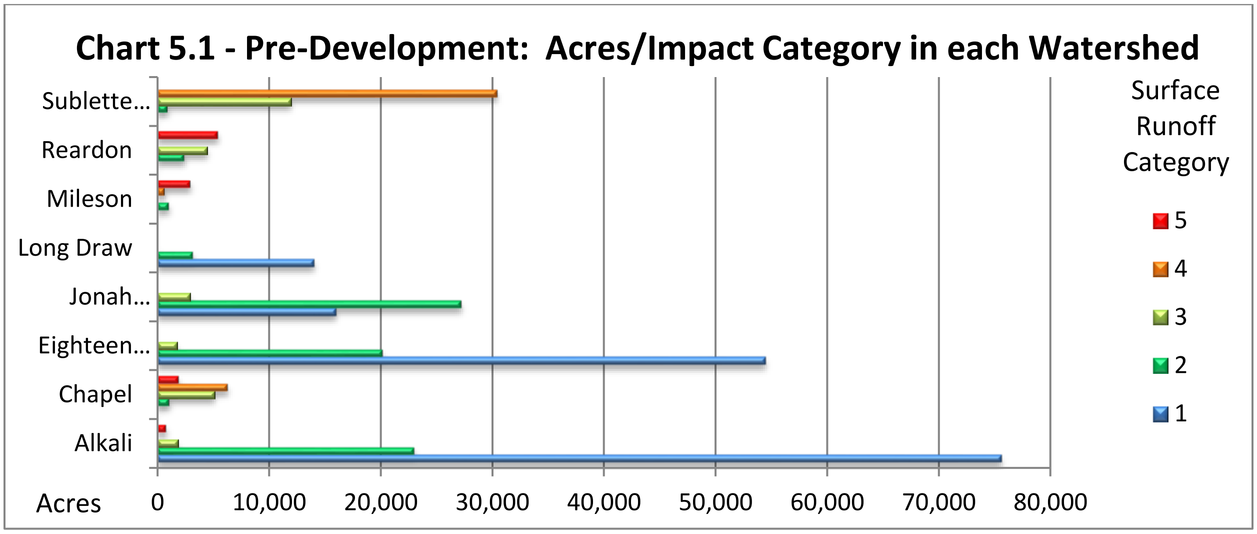


Figure 5.1
Surface Runoff and Channel Discharge
Pre-Development Scenario

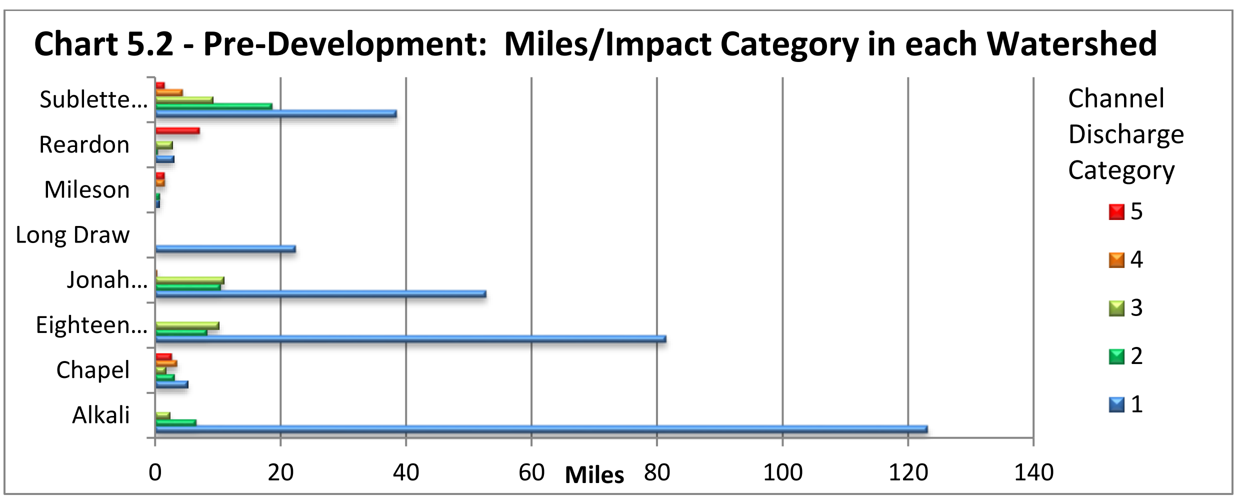
Acreage in each impact category for each Watershed Modeling Unit is presented in Table 5.5 and displayed in Chart 5.1. Slight rounding errors occur in totals of all tables.

TABLE 5.5 PRE-DEVELOPMENT SCENARIO – SURFACE RUNOFF									
	ACRES PER IMPACT CATEGORY IN EACH WATERSHED MODELING UNIT								
IMPACT CATEGORY	Alkali	Chapel	Eighteen Mile	Jonah Gulch	Long Draw	Mileson	Reardon	Sublette Flats	Totals
1 - Very Low	75,610	0	54,445	15,991	14,023	0	0	0	160,069
2 - Low	22,986	1,092	20,138	27,192	3,190	1,045	2,438	936	79,017
3 - Minimal	1,801	5,093	1,728	2,913	0	0	4,422	11,922	27,879
4 - Moderate	0	6,285	0	0	0	674	5	30,426	37,390
5 - High	804	1,909	30	0	0	2,955	5,390	0	11,088
Total Acreage	101,201	14,380	76,341	46,096	17,213	4,674	12,255	43,284	315,444



Miles of stream channel that fall within each impact category for each channel discharge in each Watershed Modeling Unit are presented in Table 5.6 and shown in Chart 5.2

TABLE 5.6 PRE-DEVELOPMENT CONDITIONS – CHANNEL DISCHARGE									
IMPACT CATEGORY	MILES PER IMPACT CATEGORY IN EACH WATERSHED MODELING UNIT								
	Alkali	Chapel	Eighteen Mile	Jonah Gulch	Long Draw	Mileson	Reardon	Sublette Flats	Totals
1 - Very Low	123.12	5.12	81.42	52.72	22.40	0.59	2.91	38.49	326.77
2 - Low	6.63	3.23	8.36	10.52	0.00	0.88	0.54	18.69	48.85
3 - Minimal	2.27	1.60	10.11	10.86	0.00	0.00	2.67	9.16	36.67
4 - Moderate	0.00	3.46	0.00	0.41	0.00	1.60	0.00	4.35	9.82
5 - High	0.00	2.71	0.00	0.00	0.00	1.62	7.04	1.59	12.96
Total Miles	132.02	16.12	99.89	74.51	22.40	4.69	13.16	72.28	435.09

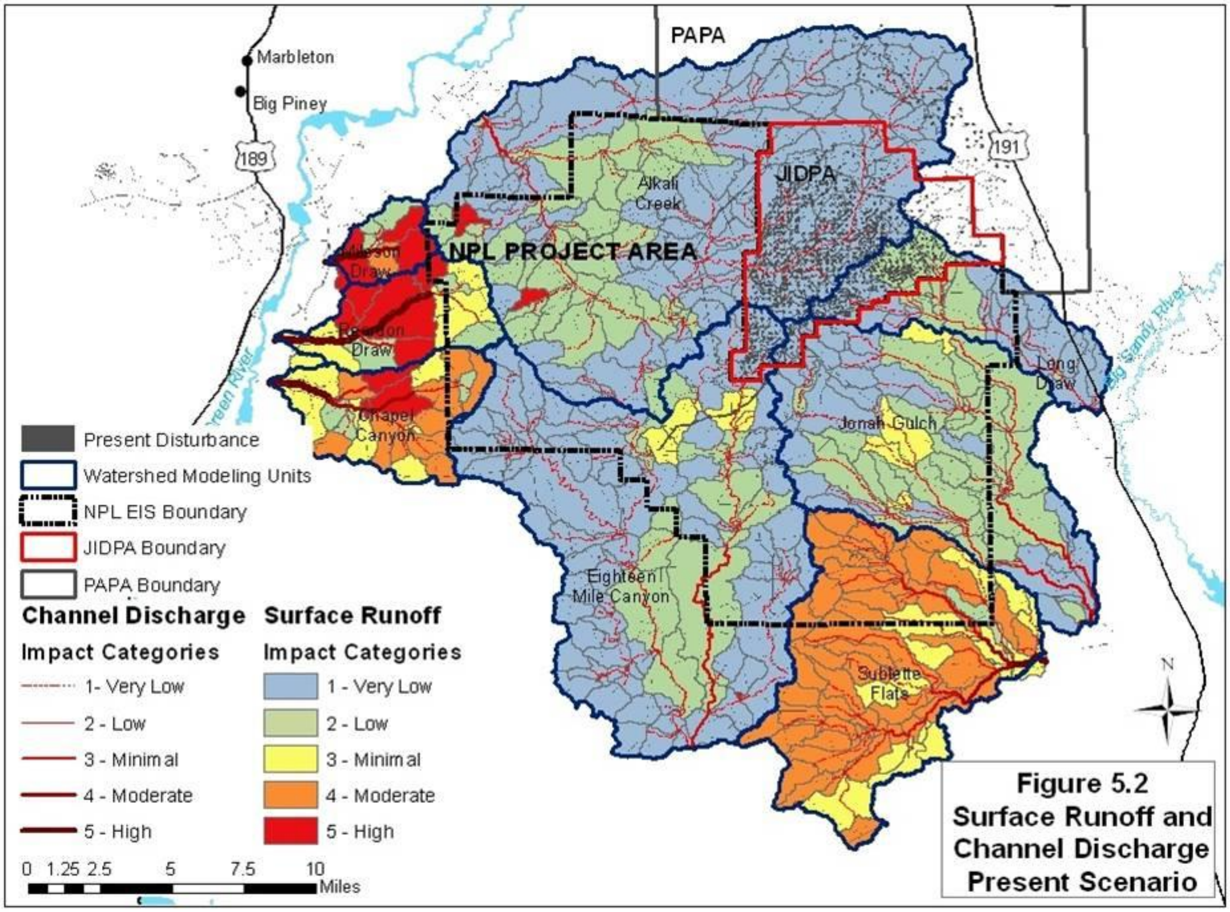


Most of the NPL Project Area is generally flat and surface runoff is very low to low (impact categories 1 and 2). Areas that show minimal (impact category 3) effects of surface runoff and channel discharge in a pre-development setting, occur in Eighteen Mile Canyon, Jonah Gulch, and Long Draw. Areas that indicate moderate to high effects to surface runoff and channel discharge under pre-development conditions, occur in two small areas in Alkali Creek, Chapel Canyon, Mileson Canyon, and Reardon Draw, Jonah Gulch, Long Draw, and Sublette Flats.

- Alkali Creek: The two areas that have moderate to high impact category ratings for surface runoff and channel discharge in Alkali Creek consist of badlands and weathered shale escarpments with slopes greater than or equal to 25 percent.
- Chapel Canyon/Reardon Draw/Mileson Draw: The areas within these drainages that occur in the moderate to high surface runoff/channel discharge impact categories consist of weathered shale escarpments with slopes of 20 to 100 percent along the stream channels.
- Eighteen Mile Canyon: Areas that are located in the minimal to high surface runoff and channel discharge impact categories consist primarily of eolian deposits and slope alluvium from escarpments of weathered sandstone and shale. The hydrologic rating for soils in these areas is moderately poor. Slopes are generally less than 15 percent.
- Jonah Gulch: Areas that are located within the minimal surface runoff and channel discharge impact categories in this Watershed Modeling Unit consist of eolian deposits and slope alluvium from weathered sandstone and shale escarpments. The hydrologic group rating for soils in these areas is moderately poor. Slopes are greater than or equal to 15 percent in areas along the stream channels.
- Long Draw: Areas that are located within the minimal surface runoff and channel discharge impact categories consist of eolian deposits and slope alluvium from weathered sandstone and shale escarpments. The hydrologic rating for soils in these areas is moderate to moderately poor. Slopes are greater than or equal to 15 percent along stream channels.
- Sublette Flats: Areas that are located within the minimal to moderate surface runoff and channel discharge consist primarily of slope alluvium with a hydrologic soils rating of moderately poor to poor and slopes greater than or equal to 15 percent.

Present (existing) Conditions

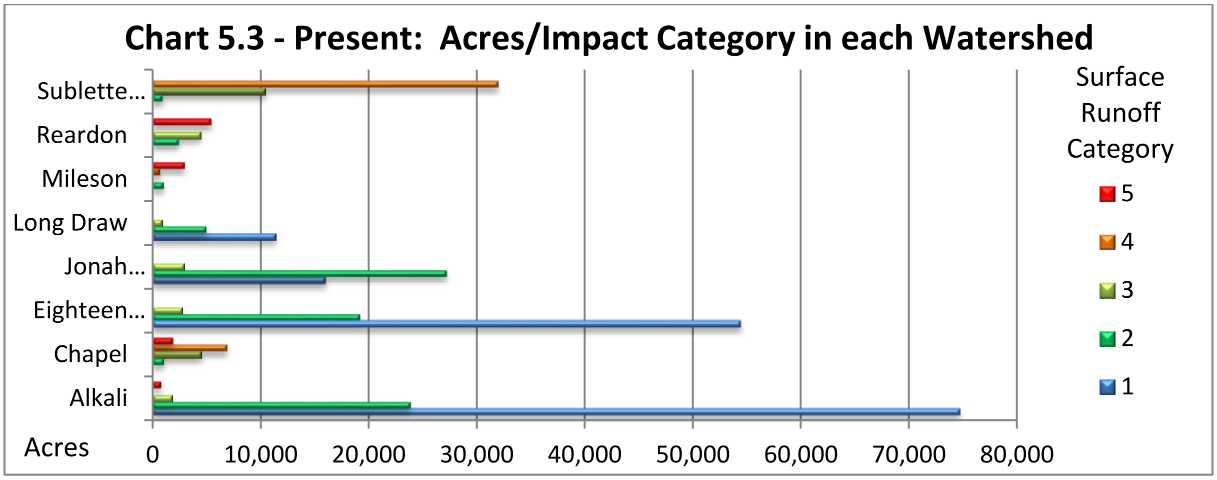
Present, or existing conditions, include the JIDPA and all natural gas wells drilled and developed by Jonah Energy in the NPL Project Area. Present conditions represent the baseline or starting point from which all disturbance is measured for the proposed NPL Project Area proposal. The AGWA simulation of present conditions in the Watershed Modeling Units is shown in Figure 5.2.



Acreages within each impact category area for present conditions in all Watershed Modeling Units are presented in Table 5.7 and shown in Chart 5.3.

TABLE 5.7
PRESENT CONDITIONS – SURFACE RUNOFF

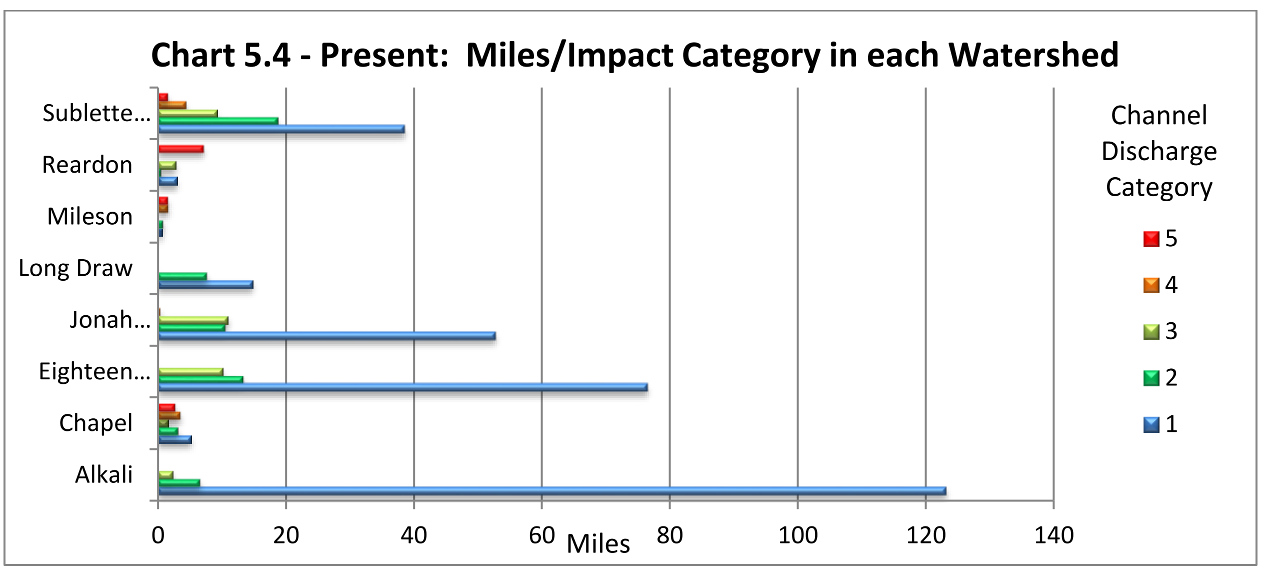
IMPACT CATEGORY	ACRES PER IMPACT CATEGORY IN EACH WATERSHED MODELING UNIT								
	Alkali	Chapel	Eighteen Mile	Jonah Gulch	Long Draw	Mileson	Reardon	Sublette Flats	Totals
1 - Very Low	74,738	0	54,445	15,991	11,368	0	0	0	156,542
2 - Low	23,858	1,066	19,168	27,192	4,969	1,045	2,438	920	80,656
3 - Minimal	1,801	4,500	2,698	2,913	875	0	4,422	10,417	27,626
4 - Moderate	0	6,904	0	0	0	674	5	31,948	39,531
5 - High	804	1,909	30	0	0	2,956	5,390	0	11,089
Total Acreage	101,201	14,379	76,341	46,096	17,212	4,675	12,255	43,285	315,444



Miles of stream channel within each impact category are presented in Table 5.8 and shown in Chart 5.4

TABLE 5.8
PRESENT CONDITIONS – CHANNEL DISCHARGE

IMPACT CATEGORY	MILES PER IMPACT CATEGORY IN EACH WATERSHED MODELING UNIT								
	Alkali	Chapel	Eighteen Mile	Jonah Gulch	Long Draw	Mileson	Reardon	Sublette Flats	Totals
1 - Very Low	123.12	5.12	76.48	52.72	14.72	0.59	2.91	38.49	314.15
2 - Low	6.63	3.23	13.31	10.52	7.68	0.88	0.54	18.69	61.48
3 - Minimal	2.27	1.60	10.03	10.86	0.00	0.00	2.67	9.16	36.59
4 - Moderate	0.00	3.46	0.08	0.41	0.00	1.60	0.00	4.35	9.9
5 - High	0.00	2.71	0.00	0.00	0.00	1.62	7.04	1.59	12.96
Total Miles	132.02	16.12	99.90	74.51	22.40	4.69	13.16	72.28	435.08



2-Mile Buffer

The results of the AGWA simulation for the 2-Mile Buffer scenario are presented in Figure 5.3.

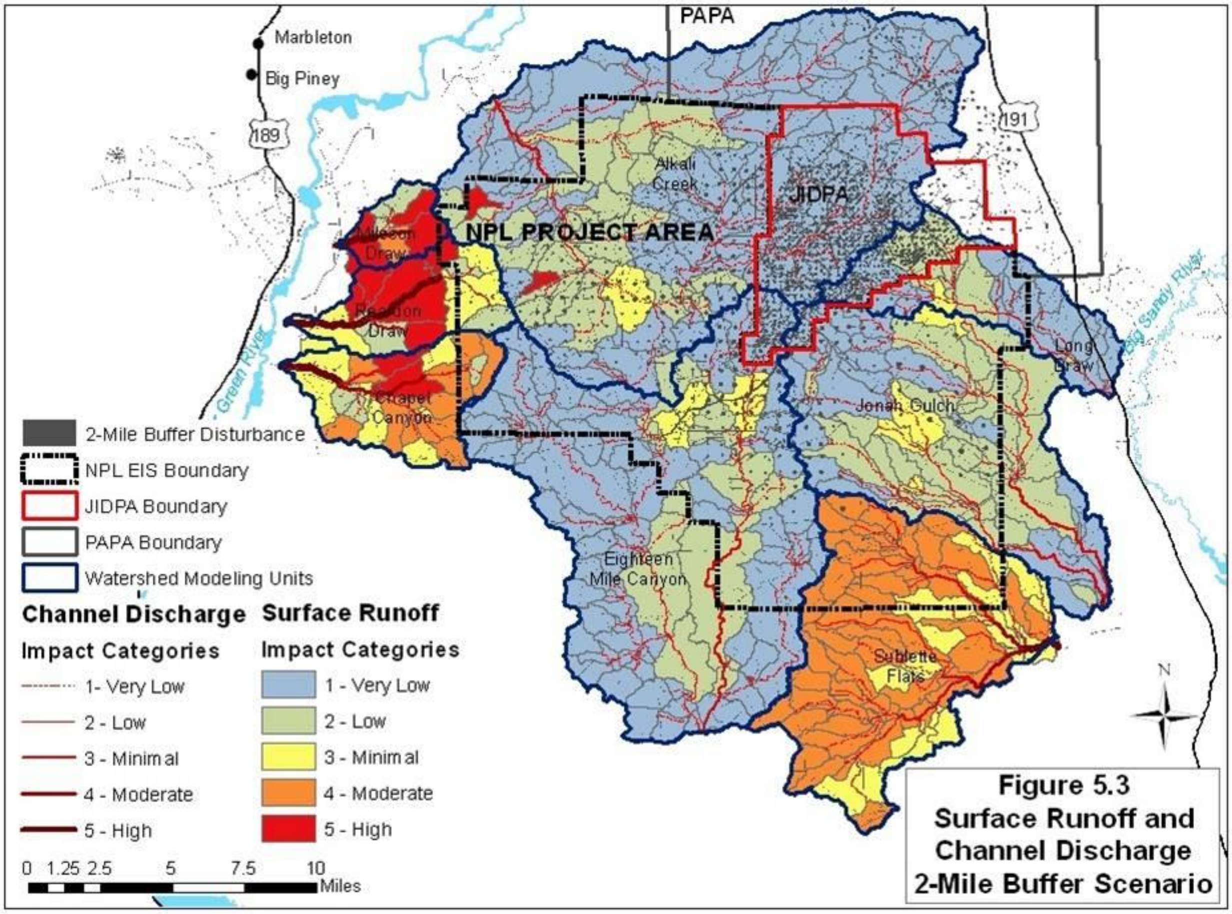
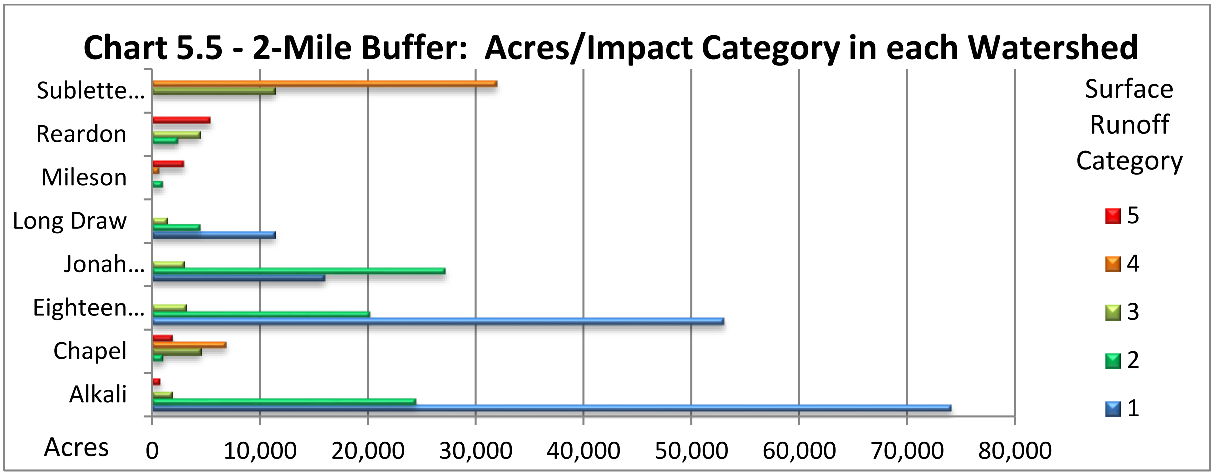


Figure 5.3
Surface Runoff and
Channel Discharge
2-Mile Buffer Scenario

Acreages within each impact category by Watershed Modeling Unit are shown in Table 5.9 and on Chart 5.5.

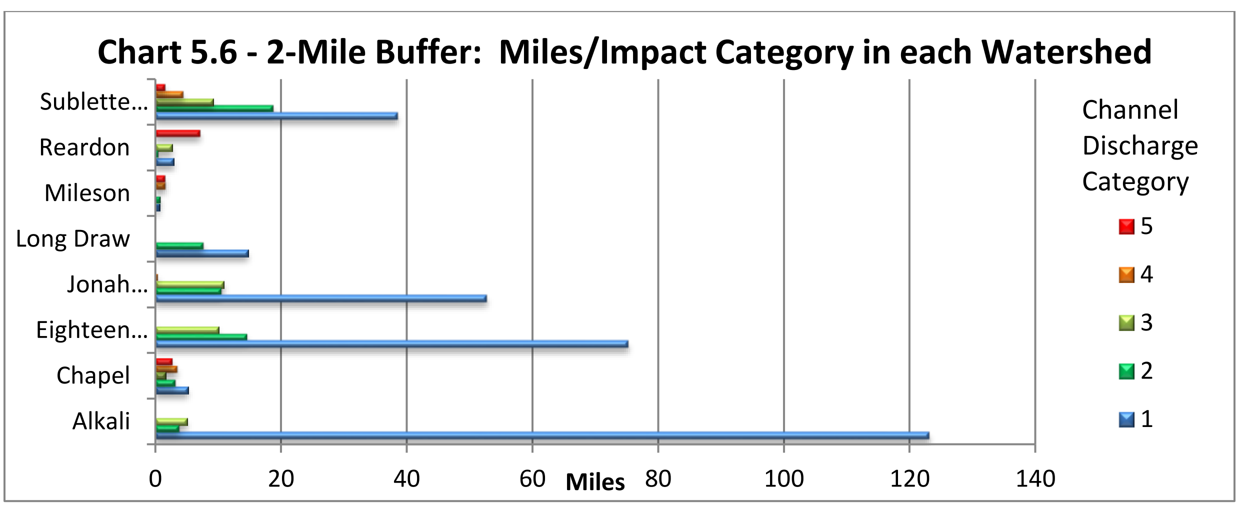
TABLE 5.9
2-MILE BUFFER – SURFACE RUNOFF

IMPACT CATEGORY	ACRES PER IMPACT CATEGORY IN EACH WATERSHED MODELING UNIT								
	Alkali	Chapel	Eighteen Mile	Jonah Gulch	Long Draw	Mileson	Reardon	Sublette Flats	Totals
1 - Very Low	74,112	0	53,016	15,991	11,368	0	0	0	154,487
2 - Low	24,484	1,066	20,191	27,192	4,509	1,045	2,438	0	80,925
3 - Minimal	1,801	4,500	3,103	2,913	1,335	0	4,422	11,337	29,411
4 - Moderate	0	6,904	0	0	0	674	5	31,948	39,531
5 - High	804	1,909	30	0	0	2,955	5,390	0	11,088
Total Acreage	101,201	14,379	76,340	46,096	17,212	4,674	12,255	43,285	315,442



The miles of stream channels within each impact category for all Watershed Modeling Units are shown in Table 5.10 and shown in Chart 5.6.

TABLE 5.10 2-MILE BUFFER – CHANNEL DISCHARGE									
IMPACT CATEGORY	MILES PER IMPACT CATEGORY IN EACH WATERSHED MODELING UNIT								
	Alkali	Chapel	Eighteen Mile	Jonah Gulch	Long Draw	Mileson	Reardon	Sublette Flats	Totals
1 - Very Low	123.12	5.12	75.21	52.72	14.72	0.59	2.91	38.49	312.88
2 - Low	3.87	3.23	14.57	10.52	7.68	0.88	0.54	18.69	59.98
3 - Minimal	5.03	1.60	10.03	10.86	0.00	0.00	2.67	9.16	36.35
4 - Moderate	0.00	3.46	0.08	0.41	0.00	1.60	0.00	4.35	9.9
5 - High	0.00	2.71	0.00	0.00	0.00	1.62	7.04	1.59	12.96
Total Miles	132.02	16.12	99.89	74.51	22.40	4.69	13.16	72.28	435.07



Within the NPL Project Area, the acres that fall within each impact category for just that portion of the Watershed Modeling Units that are located within the NPL Project Area are presented in Table 5.11 and shown in Figure 5.3.

TABLE 5.11
2-MILE BUFFER – SURFACE RUNOFF – NPL PROJECT AREA ONLY

IMPACT CATEGORY	ACRES PER IMPACT CATEGORY IN EACH WATERSHED MODELING UNIT								
	Alkali	Chapel	Eighteen Mile	Jonah Gulch	Long Draw	Mileson	Reardon	Sublette Flats	Totals
1 - Very Low	24,023	0	22,945	12,014	3,397	0	0	0	62,379
2 - Low	22,357	288	8,966	16,553	2,511	0	1,131	0	51,806
3 - Minimal	1,801	1	3,103	2,913	457	0	2,026	2,231	12,532
4 - Moderate	0	1,711	0	0	0	0	0	11,434	13,145
5 - High	752	0	0	0	0	123	333	0	1,208
Total Acreage	48,933	2,000	35,014	31,480	6,365	123	3,490	13,665	141,070

Within the NPL Project Area, the miles of stream channel that fall within each impact category for just that portion of the Watershed Modeling Units within the NPL Project Area is shown in Table 5.12 and shown in Figure 5.3.

TABLE 5.12
2-MILE BUFFER – CHANNEL DISCHARGE – NPL PROJECT AREA ONLY

IMPACT CATEGORY	MILES PER IMPACT CATEGORY IN EACH WATERSHED MODELING UNIT								
	Alkali	Chapel	Eighteen Mile	Jonah Gulch	Long Draw	Mileson	Reardon	Sublette Flats	Totals
1 - Very Low	62.42	0.84	34.60	44.83	9.62	0.00	2.33	12.77	167.41
2 - Low	3.85	0.29	5.90	5.70	3.26	0.00	0.00	4.58	23.58
3 - Minimal	0.00	0.00	2.19	0.00	0.00	0.00	0.00	3.48	5.67
4 - Moderate	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0
5 - High	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0
Total Miles	66.27	1.13	42.69	50.53	12.88	0.00	2.33	20.83	196.66

Worst Case Scenario

The worst case scenario would place the 3,500 proposed natural gas wells in the highest runoff areas as determined by the pre-development AGWA simulation and shown in Figure 5.4.

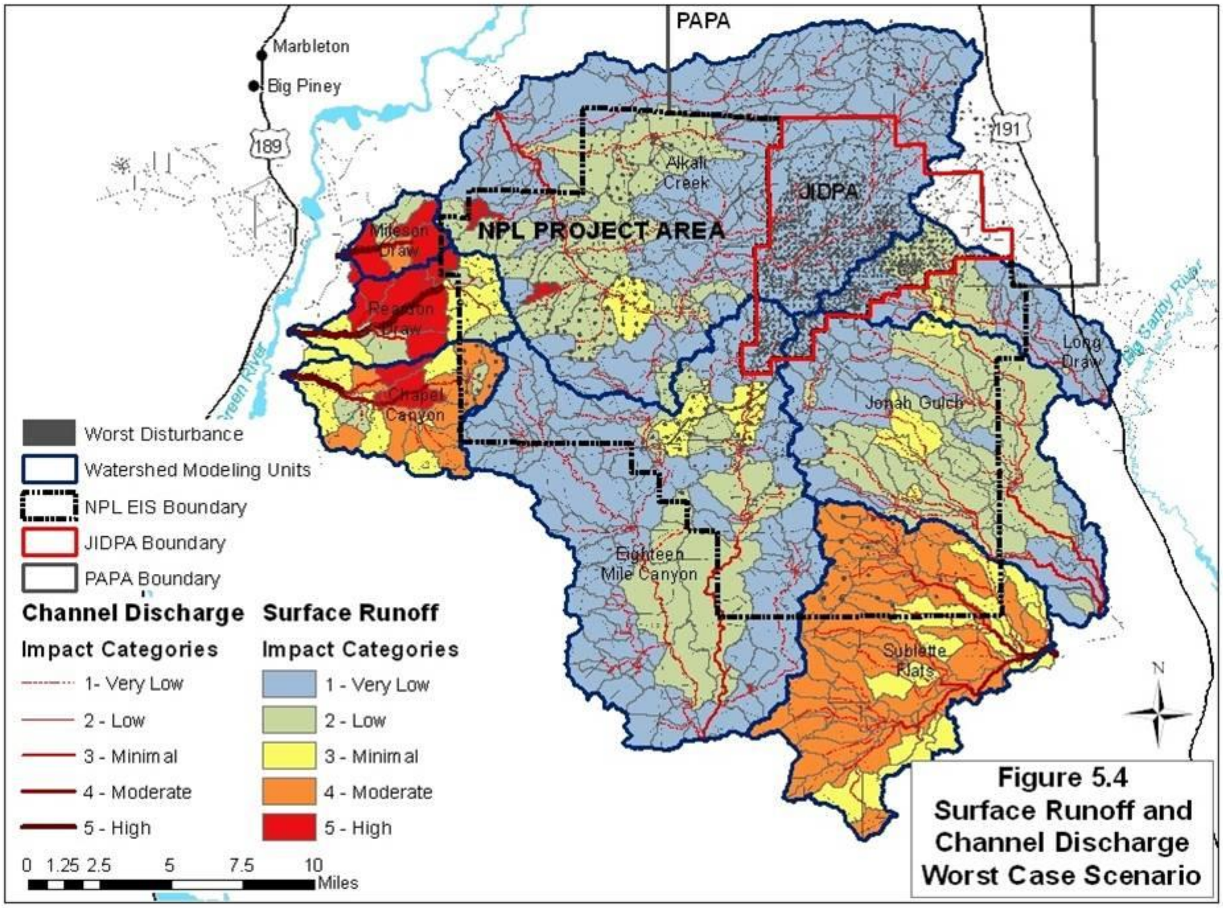
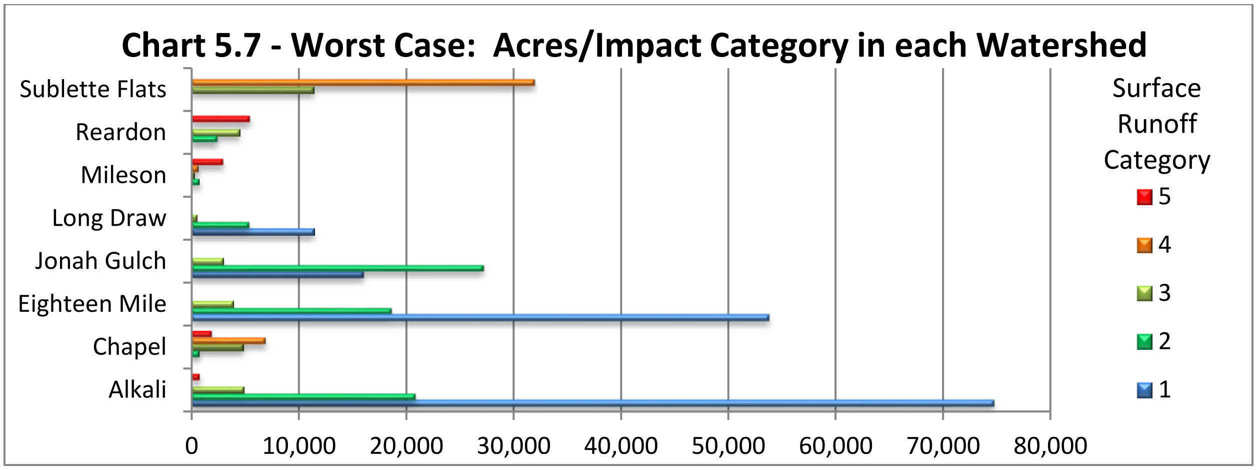


Figure 5.4
Surface Runoff and Channel Discharge Worst Case Scenario

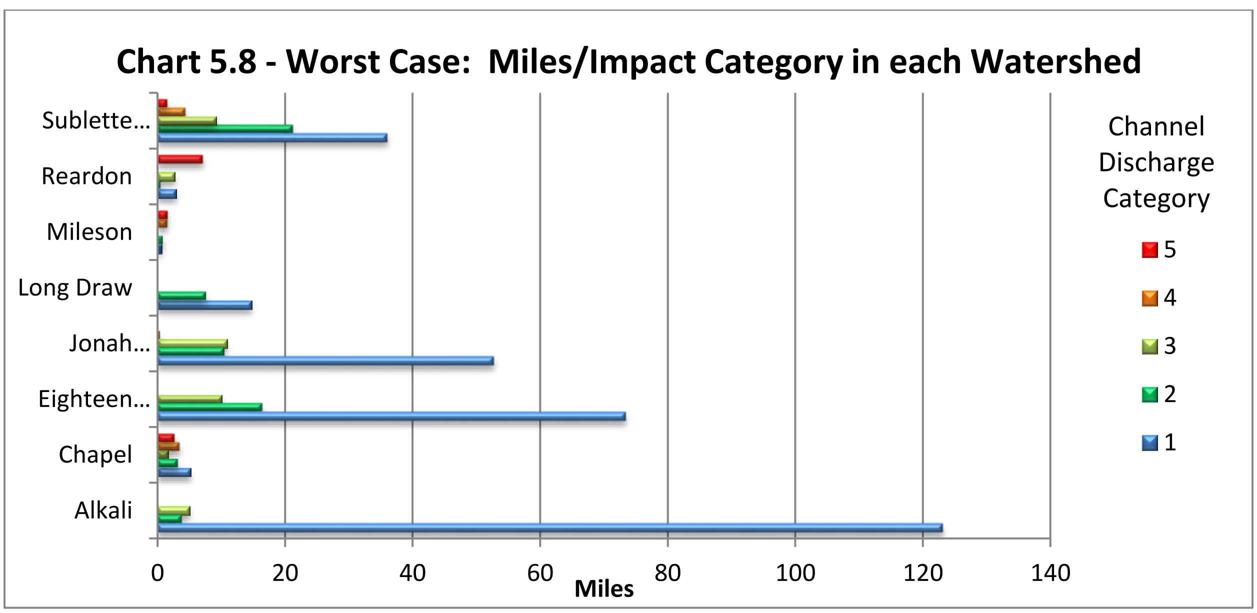
The acreages that fall within each impact category within all Watershed Modeling Units are presented in Table 5.13 and shown in Chart 5.7.

TABLE 5.13 WORST CASE – SURFACE RUNOFF									
IMPACT CATEGORY	ACRES PER IMPACT CATEGORY IN EACH WATERSHED MODELING UNIT								
	Alkali	Chapel	Eighteen Mile	Jonah Gulch	Long Draw	Mileson	Reardon	Sublette Flats	Totals
1 – Very Low	74,738	0	53,798	15,991	11,368	0	0	0	155,895
2 - Low	20,834	778	18,598	27,193	5,384	815	2,438	0	76,040
3 - Minimal	4,825	4,788	3,854	2,913	460	229	4,422	11,337	32,828
4 - Moderate	0	6,904	61	0	0	674	5	31,948	39,592
5 - High	804	1,909	30	0	0	2,955	5,390	0	11,088
Total Acreage	101,201	14,379	76,341	46,097	17,212	4,673	12,255	43,285	315,443



The miles of stream channel within each impact category in all Watershed Modeling Units are presented in Table 5.14 and shown in Chart 5.8.

TABLE 5.14 WORST CASE – CHANNEL DISCHARGE									
IMPACT CATEGORY	MILES PER IMPACT CATEGORY IN EACH WATERSHED MODELING UNIT								
	Alkali	Chapel	Eighteen Mile	Jonah Gulch	Long Draw	Mileson	Reardon	Sublette Flats	Totals
1 - Very Low	123.12	5.12	73.36	52.72	14.72	0.59	2.91	35.99	308.53
2 - Low	3.87	3.23	16.43	10.52	7.68	0.88	0.54	21.19	64.34
3 - Minimal	5.03	1.60	10.03	10.86	0.00	0.00	2.67	9.16	39.35
4 - Moderate	0.00	3.46	0.08	0.41	0.00	1.60	0.00	4.35	9.9
5 - High	0.00	2.71	0.00	0.00	0.00	1.62	7.04	1.59	12.96
Total Miles	132.02	16.12	99.90	74.51	22.40	4.69	13.16	72.28	435.08



Within the NPL Project Area only, the acres that fall within each impact category for that portion of the Watershed Modeling Units that are located within the NPL Project Area are presented in Table 5.15 and shown in Figure 5.4.

TABLE 5.15
WORST CASE – SURFACE RUNOFF – NPL PROJECT AREA ONLY

IMPACT CATEGORY	ACRES PER IMPACT CATEGORY BY WATERSHED MODELING UNIT								
	Alkali	Chapel	Eighteen Mile	Jonah Gulch	Long Draw	Mileson	Reardon	Sublette Flats	Totals
1 - Very Low	24,649	0	23,726	12,014	3,397	0	0	0	63,786
2 - Low	18,707	0	7,770	16,553	2,511	0	1,131	0	46,672
3 - Minimal	4,825	289	3,456	2,913	457	0	2,026	2,231	16,197
4 - Moderate	0	1,711	61	0	0	0	0	11,434	13,206
5 - High	752	0	0	0	0	123	333	0	1,208
Total Acreage	48,933	2,000	35,014	31,480	6,365	123	3,490	13,665	141,070

For the NPL Project Area, the miles of stream channels within each impact category for that portion of the Watershed Modeling Units that fall within the NPL Project Area are presented in Table 5.16 and shown in Figure 5.4.

TABLE 5.16
WORST CASE – CHANNEL DISCHARGE – NPL PROJECT AREA ONLY

IMPACT CATEGORY	MILES PER IMPACT CATEGORY IN EACH WATERSHED MODELING UNIT								
	Alkali	Chapel	Eighteen Mile	Jonah Gulch	Long Draw	Mileson	Reardon	Sublette Flats	Totals
1 - Very Low	62.42	0.84	32.75	44.83	9.62	0.00	2.33	10.27	163.06
2 - Low	3.85	0.29	7.75	5.70	3.26	0.00	0.00	7.08	27.93
3 - Minimal	0.00	0.00	2.19	0.00	0.00	0.00	0.00	3.48	5.67
4 - Moderate	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0
5 - High	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0
Total Miles	66.27	1.13	42.69	50.53	12.88	0.00	2.33	20.83	196.66

5.1.2 Comparison of Scenarios

Differences between the following scenarios were derived to quantify the changes and analyze the impacts to the NPL Project Area under the Present Conditions scenario, the 2-Mile Buffer scenario, which is the likely pattern of development for the Proposed Action, and the Worst Case scenario. As discussed in Section 1.2, the objective of this hydrologic modeling was to predict impacts to surface runoff and channel discharge as a result of natural gas development proposed for the NPL Project Area.

For purposes of the AGWA modeling, it was assumed that the present level of surface disturbance is the starting point from which the effects of the scenarios are considered.

For all watershed units in all four scenarios, the values for average annual surface runoff ranged from 0 to 0.41 inches per year (in/yr) over the 10-year simulation period. Impact categories for the differences between all the scenarios are listed in Table 5.17.

TABLE 5.17 SURFACE RUNOFF IMPACT CATEGORIES FOR DIFFERENCE ANALYSIS		
Category	Runoff (inches/year)	Impact Category
1	0.00 – 0.03	Very Low
2	0.03 – 0.08	Low
3	0.08 – 0.14	Minimal
4	0.14 – 0.27	Moderate
5	0.27 – 0.41	High

For all stream channels in all watershed units; the channel discharge ranged from 0 to 0.034 cubic feet per second (cfs) over the 10-year simulation period. The following five categories were derived from the AGWA results of discharge in the channel (Table 5.18).

TABLE 5.18 CHANNEL DISCHARGE IMPACT CATEGORIES FOR DIFFERENCE ANALYSIS		
Category	Water Yield (feet3/second)	Impact Category
1	0.000 – 0.001	Very Low
2	0.001 – 0.004	Low
3	0.004 – 0.010	Minimal
4	0.010 – 0.016	Moderate
5	0.016 – 0.034	High

Comparison of Present Conditions and Pre-Development Conditions

The comparison between present conditions and pre-development conditions represent the changes that have occurred on the landscape due to surface disturbance from the JIDPA and the current natural gas drilling and development within the NPL Project Area are shown in Figure 5.5.

A comparison between the Present and Pre-Development scenarios indicates that the areas of highest surface runoff and channel discharge change occurred at the headwaters of Long Draw as a result of surface disturbance in the JIDPA. Impact categories of moderate and high for surface runoff occur within the JIDPA and a resulting impact category of high occurs for the channel discharge downstream of the JIDPA in the NPL Project Area and extending beyond the NPL Project Area boundary (refer to Figure 5.1, Pre-Development scenario for comparison).

A moderate rating for channel discharge at the headwaters of Eighteen Mile Canyon occurs within the NPL Project Area, potentially as a result of drilling and development in the JIDPA. Minimal impacts also occur in Chapel Canyon and Sublette Flats.

The Present conditions are the starting point from which future change will be measured.

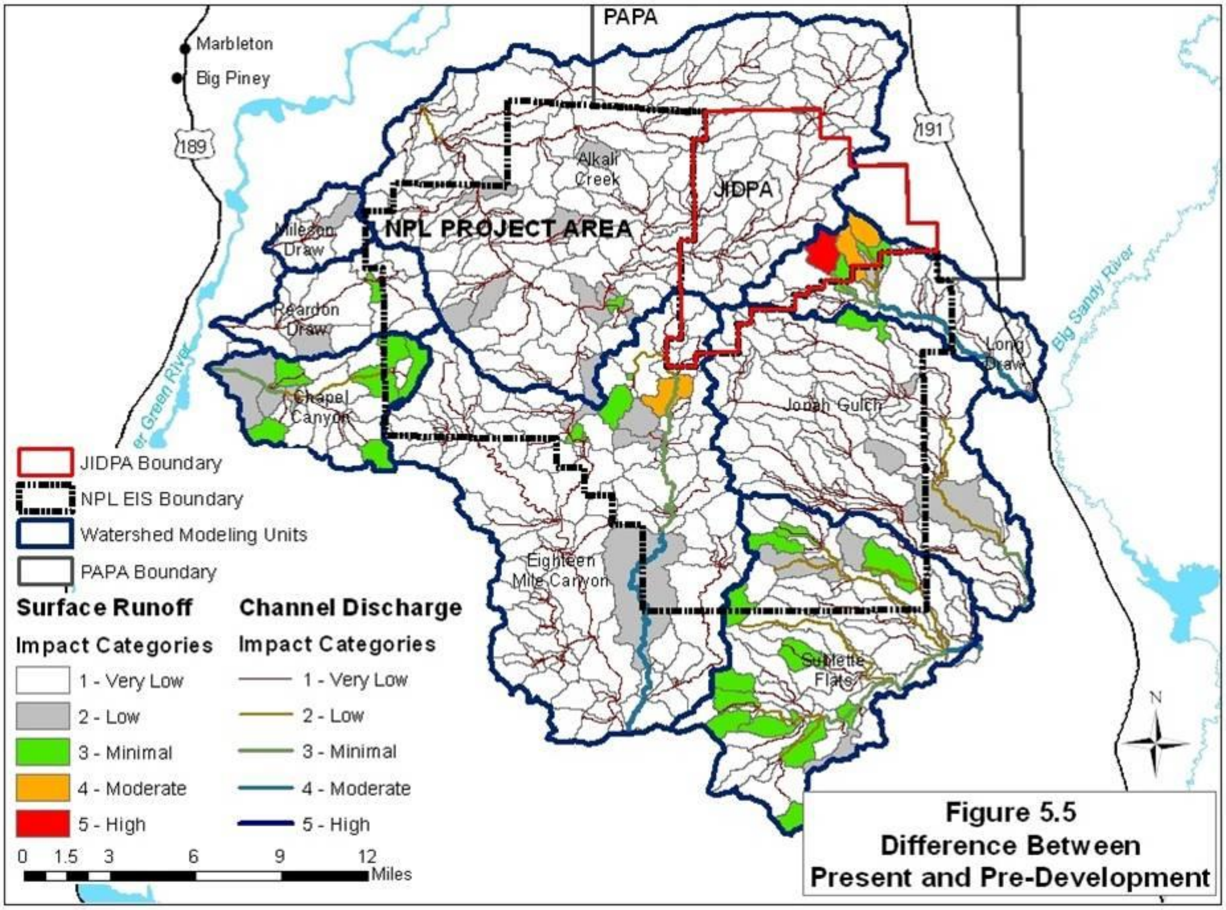


Figure 5.5
Difference Between
Present and Pre-Development

<u>Comparison of 2-Mile Buffer and Present Conditions</u>

Differences between the 2-Mile Buffer, and the present condition is presented in Figure 5.6. This is an estimate of potential changes that would result from a development pattern that would likely represent the Proposed Action, based on the placement of powerlines and RGFs as submitted by Jonah Energy (Appendix A).

Minimal impact category rating increases greater than the Present conditions occur at the headwaters of Eighteen Mile Canyon and near the headwaters of Alkali Creek. Low to minimal impact category changes would occur in channel discharge along Alkali Creek, downstream on Jonah Gulch and in a tributary of Sublette Flats.

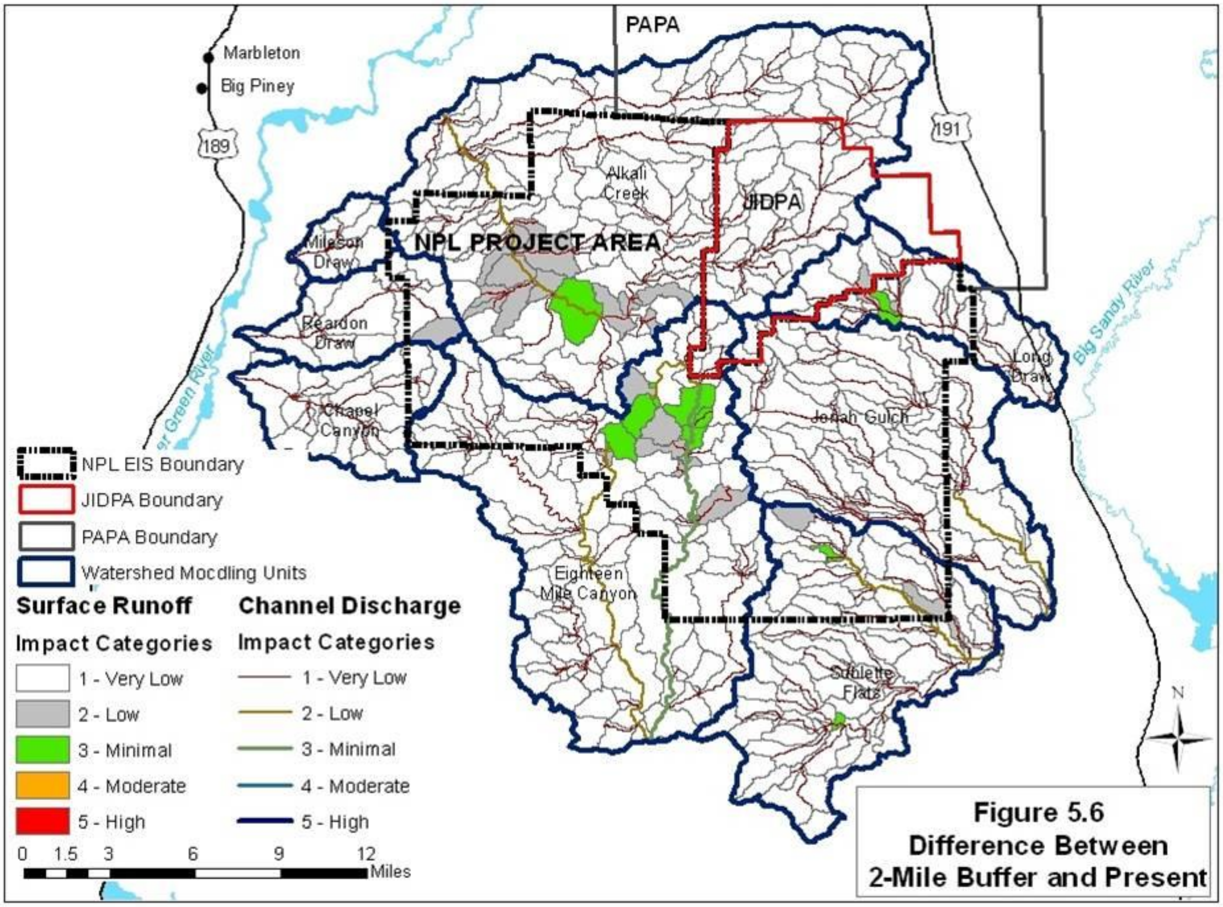


Figure 5.6
Difference Between
2-Mile Buffer and Present

Comparison of Worst Case and Present Conditions

Differences between the Worst Case scenario and the Present conditions are presented in Figure 5.7. This is a scenario which would be considered as having the most change from present conditions. Multi-well pads and access roads would be located in the areas showing the most change in impact category rating in surface runoff and channel discharge as shown in the Pre-Development scenario (See Figure 5.1 for comparison).

Areas showing the greatest change in impact category are in the Alkali Creek area, along the upper reaches of Eighteen Mile Canyon and along the upper reaches of Sublette Flats. Impact category ratings along Alkali Creek show an increase of from minimal to high for surface runoff but minimal impacts in channel discharge. Additionally, increases in surface runoff and channel discharge affect Reardon Draw and Chapel Canyon, which are both deeply incised canyons with highly erodible soils and steep slopes. Impact ratings for channel discharge are low to minimal in both Reardon Draw and Chapel Canyon.

An increase in surface runoff impact category ratings for Eighteen mile Canyon range from minimal to high in the upper reaches of Eighteen Mile Canyon south of the JIDPA and in reaction to increased surface disturbance for the worst case scenario; and from minimal impact ratings along the upper reaches of Eighteen Mile Canyon increasing to moderate on the south reaches of Eighteen Mile Canyon extending south of the Project Area boundary.

The upper reaches of tributaries in the Sublette Flats Watershed Modeling Unit show minimal impact category ratings due to surface disturbance within in the NPL Project Area. Channel discharge increases to minimal within the NPL Project Area but moderate outside of the NPL Project boundary.

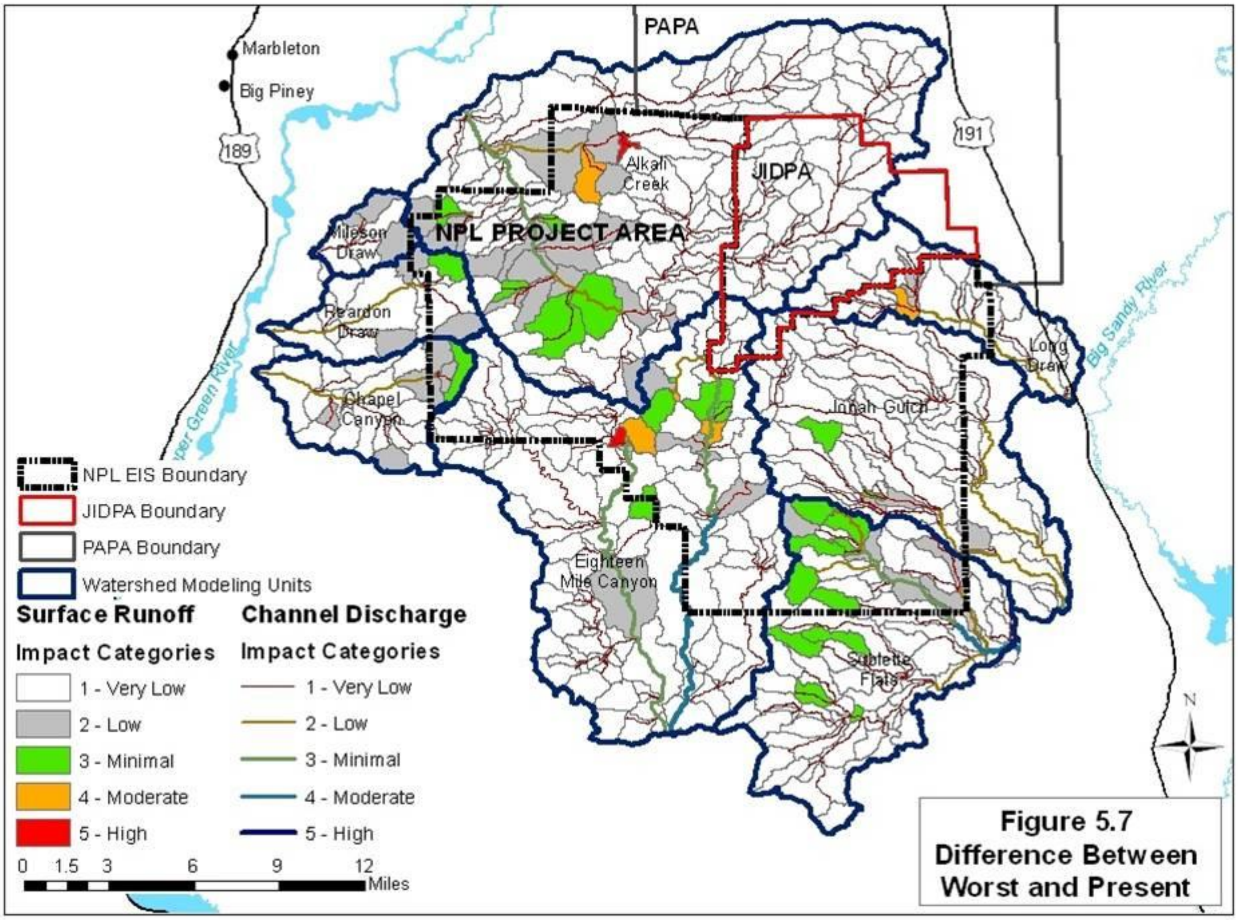
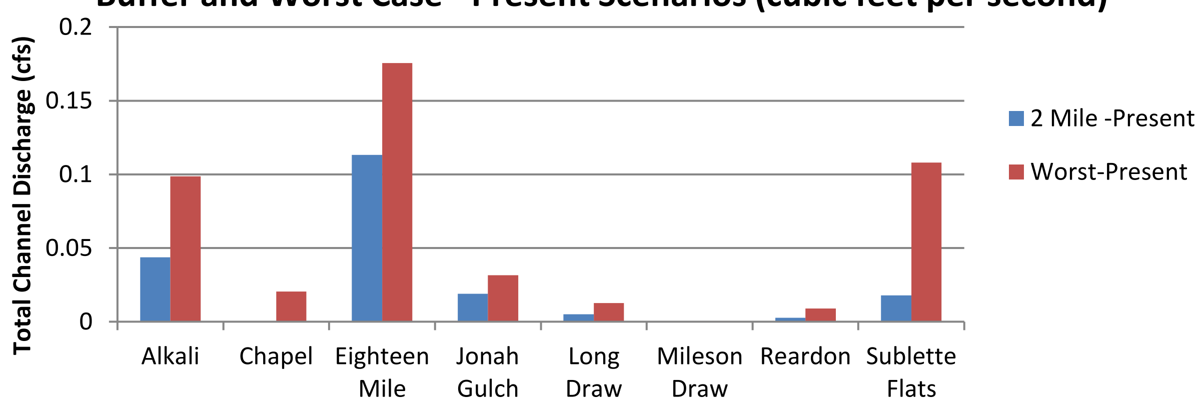


Figure 5.7
Difference Between Worst and Present

A comparison between the total channel discharge between the 2-Mile Buffer and Worst Case scenarios and the Present Conditions is shown in Chart 5.9.

Chart 5.9 - Differences in Total Channel Discharge Between the 2-Mile Buffer and Worst Case - Present Scenarios (cubic feet per second)



Comparison of Worst Case and Pre-Development Conditions

The difference between the Worst Case and Pre-Development Conditions would indicate the level of impact category change from Pre-Development contitions with natural gas development occuring in the JIDPA and the NPL Project Area by placing multi-well pads and access roads in the most vulnerable areas of the NPL Project Area. As shown in Figure 5.8, the impacts to the landscape from development in both areas would be in the moderate to high range of impact categories for both the surface runoff and channel discharge.

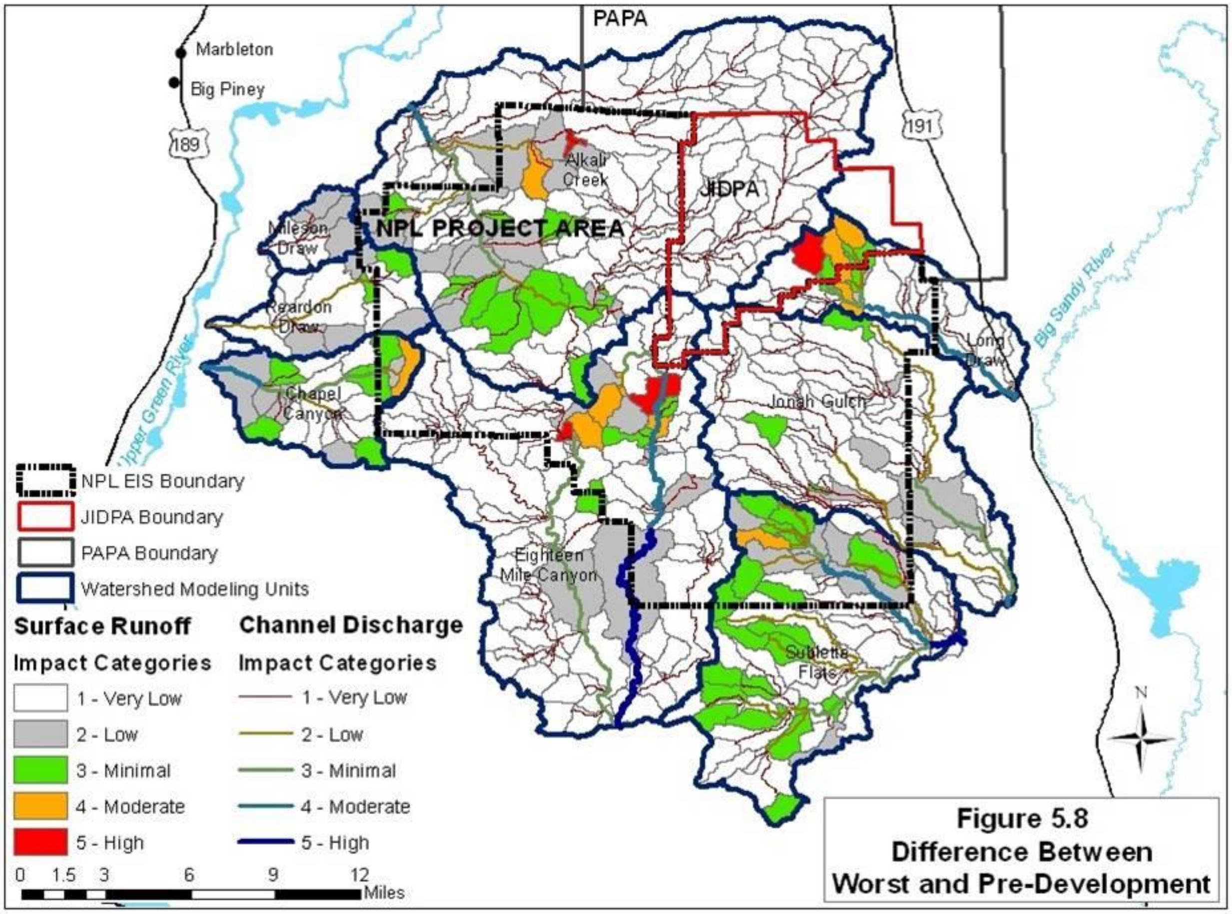


Figure 5.8
Difference Between Worst and Pre-Development

Comparison of results between the Worst and Pre-Development indicates that the areas of highest surface runoff and channel discharge impacts from a Worst Case scenario, which would include the cumulative impacts of the JIDPA, current drilling and production in the NPL Project Area, and the addition of 3,500 natural gas wells placed in the most vulnerable areas of the Watershed Modeling Units as determined by SWAT modeling of the Pre-Development scenario, would occur on Long Draw and Eighteen Mile Canyon, Reardon Draw and Chapel Canyon, and to a lesser extent on Alkali Draw and Sublette Flats.

Changes to Long Draw would range from minimal to high surface runoff impact category ratings in the upper reaches of the watershed. Impacts to channel discharge would increase to moderate, especially along the lower reaches of the drainage. Eighteen Mile Canyon would show the greatest increase in impacts, with surface runoff with moderate to high ratings throughout the upper reaches of the canyon.

The most substantial impacts would be in channel discharge in the lower reaches of the channel which show a high impact category rating. Surface disturbance southwest of Alkali Creek would affect Chapel Canyon with impacts to channel discharge of moderate downstream outside the NPL Project Area boundaries. Impacts to channel discharge would affect channel discharge in the lower reaches of Alkali Creek with an increase to a moderate rating. Similarly, Sublette Flats would show an increase in impacts in surface runoff ranging from minimal to moderate, but an increase to moderate impacts in the lower reaches of the tributaries in Sublette Flats.

The most substantial changes from Pre-Development conditions by the cumulative development of the JIDPA and the NPL Project Area under this scenario, would be in the impacts to the lower reaches of the stream channels outside the NPL Project Area boundaries, which show increases in channel discharge, and likely increases in erosion and sediment transport.

It is important to note that although the actual values within each impact category are very small, the impacts to the channels can be relatively large, which necessitates that a robust and dynamic monitoring system for the life of the NPL project.

5.2 KINEROS2 Results

The KINEROS2 model is appropriate for modeling local hydrologic and erosion impacts associated with land cover change; or surface disturbance, for a single storm event. Results presented in this report show the spatial heterogeneity in hydrologic response under a given scenario of projected land cover change in the NPL Project Area after initiation of natural gas development. Results show that, as expected, the primary driver of change to the hydrologic cycle is the presence of well pads, access roads, and other infrastructure that contributes to bare ground. However, inspection of the results shows that there are competing controls that mitigate or enhance changes to runoff and erosion, namely terrain characteristics and soil/vegetation complexes.

Because the KINEROS2 model could not be appropriately calibrated due to the lack of historical observational data, results from the KINEROS2 modeling should be interpreted as an indicator of the relative trend and magnitude of change exhibited across the NPL Project Area. The model results are internally consistent, meaning that channel and upland plane elements across the watershed respond in a predictable and deterministic fashion. Furthermore, rainfall was applied uniformly across the watershed assuming a two-inch, 24-hour, 25-year, storm event, so variability in model outcomes are independent of rainfall intensity or depth, allowing for the variability to be directly associated with changes in land cover since terrain and soil characteristics were also unchanged.

As an engineering-scale model, KINEROS2 results can be used to guide the design and development of mitigation structures such as detention basins, sediment control structures such as check dams, and the identification of appropriate monitoring locations. Because the land cover development scenarios are not specific to the exact locations of the well pads and roads, these results cannot be used for this purpose but rather serve to identify the relative influence of development spatially throughout the NPL Project Area. However, given the exact locations of roads, multi-well pads, and other infrastructure, this modeling approach could be used to further the management and mitigation of local and downstream effects and to guide the development of a monitoring program.

In all cases the model shows that increasing levels of disturbance result in changes to hydrology and sediment. Results are highly variable depending on the level of disturbance within the modeling element. In general, increasing bare ground by adding well pads and roads results in the following changes for a standard two-inch, 24-hour, 25-year storm:

- Increased total runoff ;
- Decreased infiltration and soil moisture;
- Increased peak flow; and,
- Increased erosion and off-site sediment transport.

These results indicate that monitoring and mitigation will likely be important in areas where changes in hydrology and erosion are predicted to be relatively high. Downstream receiving channels will likely be affected by higher volumes and rates of flow and may become unstable due to increases in flow.

Precipitation in the NPL Project Area is low, averaging between 8 to12 inches per year, with much of that coming in the form of snow during the winter. Summer rainfall data are lacking in the region, but regional data from national sources indicate that the depth and intensity of summer storms are relatively low. Thus, model results show that total runoff volumes are relatively low and it is unlikely that small-scale summer storms will propagate flows very far downstream due to transmission losses in ephemeral channels. This is, however, primarily conjecture since rigorous field studies in infiltration rates and transmission losses do not exist in this area. Presumably, sediment and associated constituents transported by water will move downstream from the NPL Project Area to the Green River in pulses, where surface or channel erosion occurs during a rainfall event, is moved into a channel where it is deposited during the receding limb of the surface runoff event, and then is remobilized in future events. Model predictions show that effects of development in the NPL Project Area will likely be delayed, as pulses of rainfall, surface runoff and erosion will transport material over years to decades.

An additional area of concern relates to potential increases in delivery of sediment and associated salts to the Green River, which is a significant contributor to the Colorado River and falls under the Salinity Control Forum. Increased erosion and sediment transport from the NPL Project Area will carry additional salts because of their presence in the upper layers of soil within the NPL Project Area.

5.2.1 Comparison of KINEROS2 Simulations

Simulations were run using the KINEROS2 model for highly vulnerable areas within the eight representative Watershed Modeling Units in the NPL Project Area. These were chosen based on SWAT modeling results and are considered representative of the potential levels of disturbance and changes in single-storm runoff response. The following scenarios were run using their corresponding disturbance layer for: Present Conditions, 2-Mile Buffer, and, Worst Case. A two inch storm representing the 25-year, 24-hour return period event was applied across the Watershed Modeling Units that were parameterized for KINEROS2 for estimation of runoff and erosion (Appendix D.1, KINEROS2 Rainfall file). The focus of the modeling effort was on upland runoff and erosion processes since surface disturbance most significantly affects hillslope and overland flow processes.

Present Conditions

Figure 5.9 shows the results of surface runoff for the Present Conditions scenario. KINEROS2 results show that this is an infiltration-dominated landscape, with relatively little surface runoff. On average, the surface runoff efficiency was less than four percent, with average runoff for all upland planes of 0.035 inches (Table 5.19). The wide range in response across the modeled landscape is due to several factors, notably that many of the planes contained no or very little change in land cover and that a wide range in soil and slope characteristics occur within the study area. The watersheds with the greatest change in hydrologic and erosion response occur in areas with steep slopes, fragile soils, and relatively sparse land cover. In these watersheds, disturbance results in significant alterations to hydrologic processes.

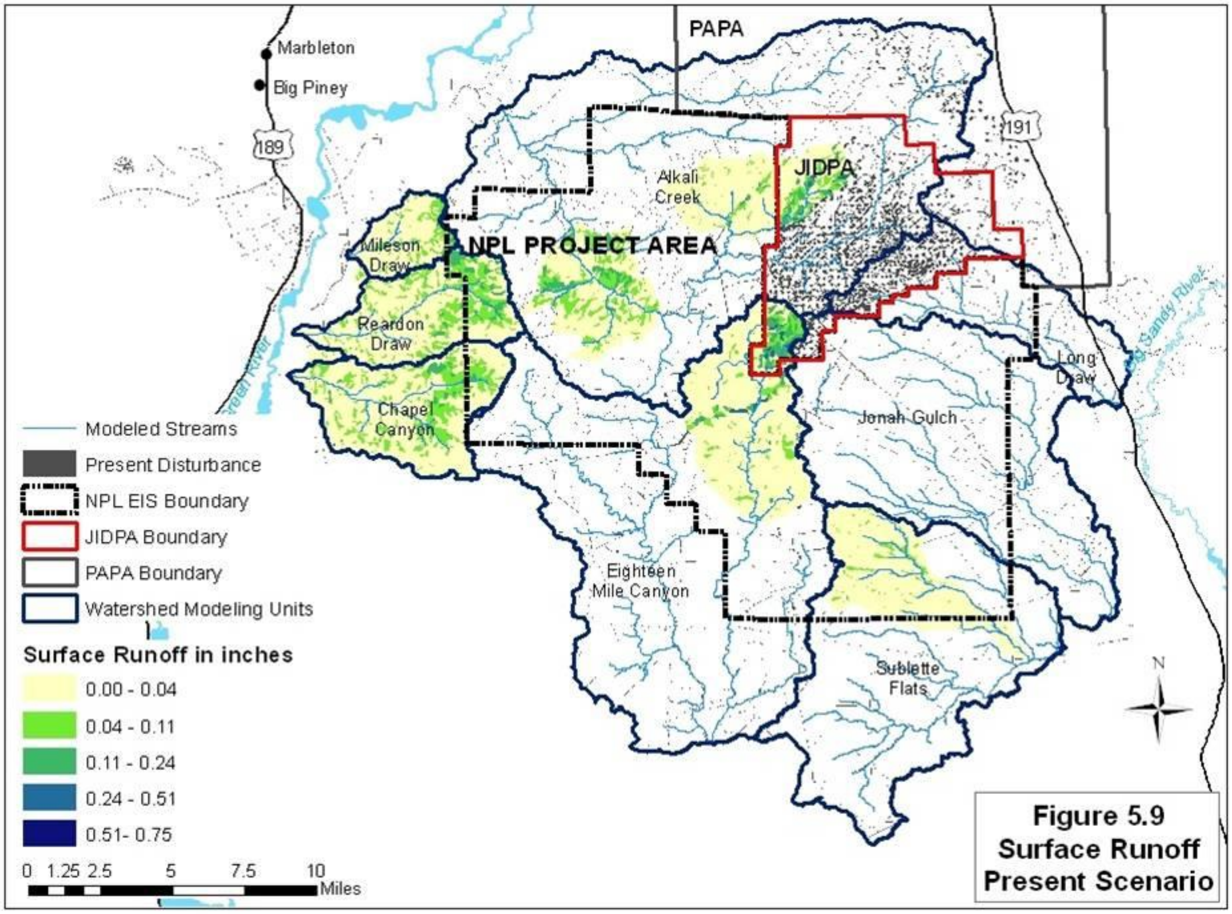


Figure 5.9
Surface Runoff
Present Scenario

TABLE 5.19
COMPARISON OF KINEROS2 SIMULATIONS

Scenario	Avg Q	StdDev Q	Max Q	Avg F	StdDev F	Avg E	Std Dev E	Max E
Present	0.035	0.045	0.736	1.93	0.04	0.035	0.137	2.499
2Mile - Present	0.018	0.066	0.732	-0.016	0.063	0.009	0.053	1.748
Worst – Present	0.023	0.065	0.732	-0.021	0.063	0.021	0.094	1.824

Where: *Surface runoff depth (Q, in.), infiltration depth (F, in.), and erosion (E, ton/acre). In this table Avg = average change, StdDev = standard deviation of change, and Max = maximum change. Scenario results represent the difference between different simulations achieved by subtracting one simulation result from another. Total number of planes in this table is 7,171.*

Erosion was highly variable across the landscape, with some planes simulated as having almost no erosion, while others were simulated as producing approximately 2.5 tons of sediment per acre (Figure 5.10). This high variability across the landscape is typical of western rangelands and is indicative of the need to place well pads, access roads, and other forms of surface disturbance appropriately so as to minimize impacts on hydrology and erosion.

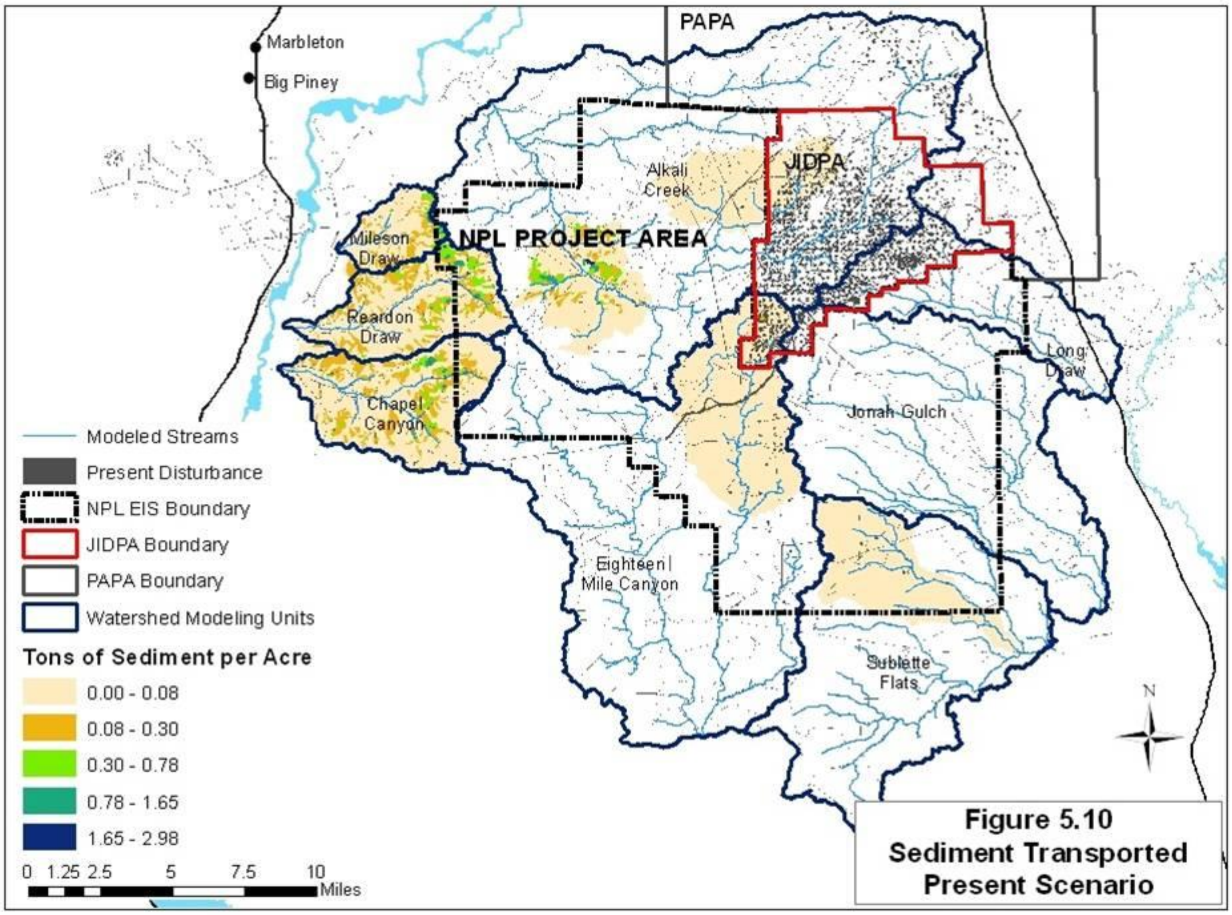


Figure 5.10
Sediment Transported
Present Scenario

Comparison of 2-Mile Buffer and Present Conditions

These modeling results are limited in application in that they represent potential outcomes, which are likely not to be implemented exactly as modeled. The comparison of modeling results for surface runoff as a result of a two-inch, 24-hour, 25-year storm for the 2-Mile Buffer and the Present Condition is shown in Figure 5.11. These results indicate that the 2-Mile Buffer option is likely to have less impact on increased surface runoff and erosion.

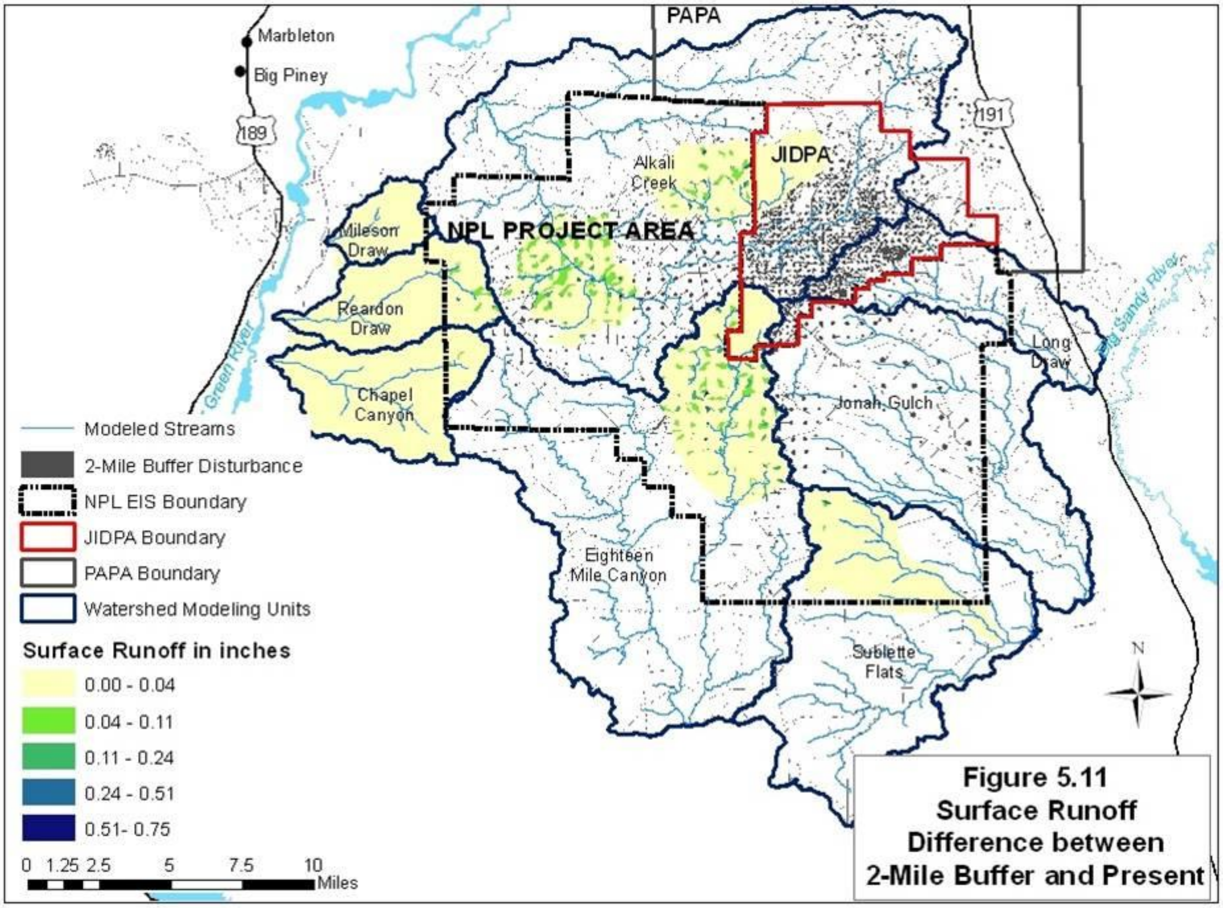


Figure 5.11
Surface Runoff
Difference between
2-Mile Buffer and Present

Watersheds showing an increase in surface runoff after a two-inch, 24-hour, 25-year storm event are the upper reaches of Alkali Creek, the central reach of Alkali, a small portion of the upper watershed of Reardon Draw and the upper reaches of Eighteen Mile Canyon.

Figure 5.12 shows the difference between the changes in the sediment transported between the 2-Mile Buffer and the Present conditions. All surface runoff and sediment transported, as modeled stays within the boundaries of the NPL Project Area and may have minimal impacts on those portions of the Watershed Modeling Units or stream channels outside of the NPL Project Area boundary.

As management plans are developed with respect to multi-well pad and road placement, the potential disturbance locations can be modeled using the KINEROS2 model to determine the relative impacts of the potential disturbance scenarios.

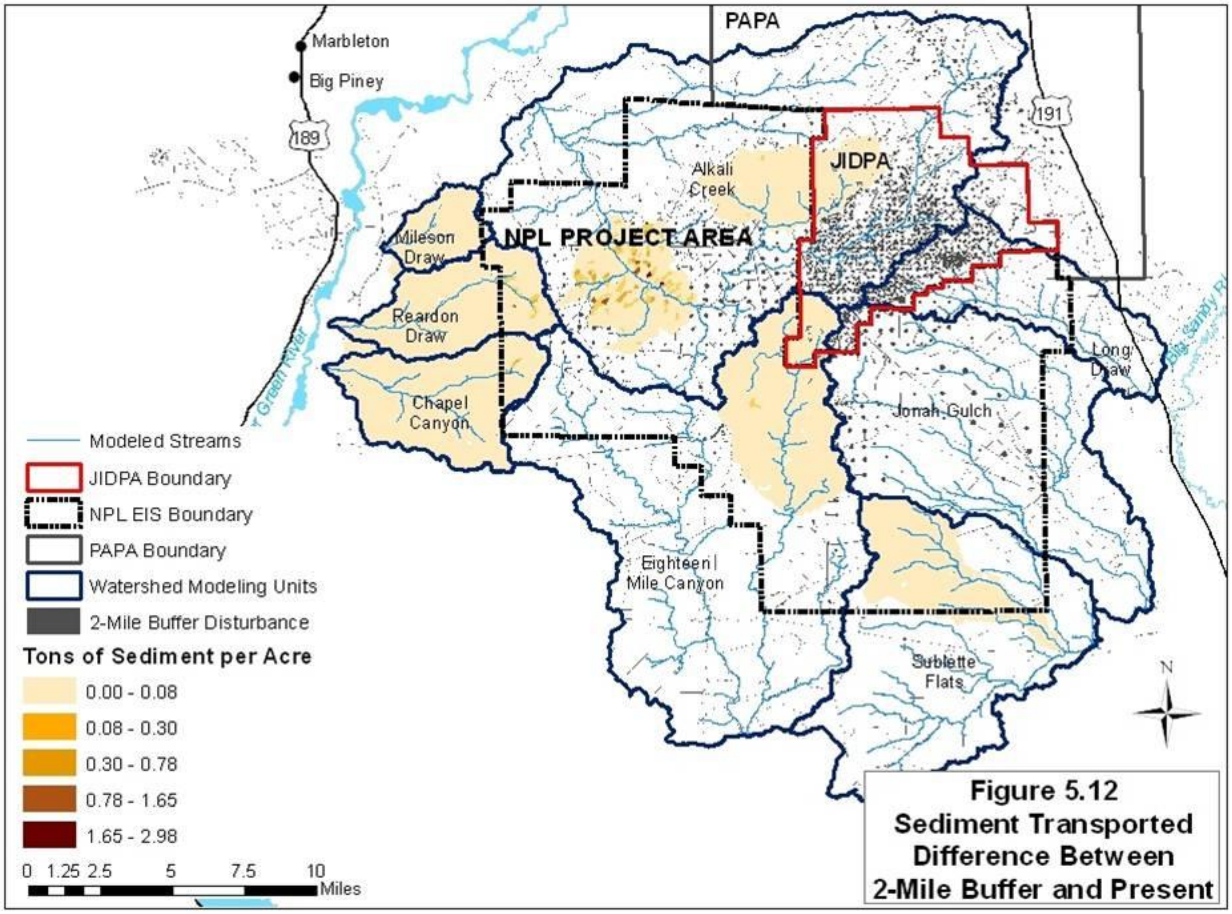


Figure 5.12
Sediment Transported Difference Between 2-Mile Buffer and Present

AGWA can be used to support land cover development planning to minimize hydrologic and erosion impacts.

Comparison of Worst Case and Present Scenarios

Table 5.20 shows the comparison of surface runoff between the Worse Case and Present Conditions as a result of a two-inch, 24-hour, 25-year storm event. These results show that the greatest proportion of the NPL Project Area produces little to no runoff (identified as 0 – 0.03 inches of runoff in Table 5.20). A very small proportion of the project area produces large amounts of runoff (greater than 0.37 inches).

TABLE 5.20
SURFACE RUNOFF BY RUNOFF CATEGORY DIFFERENCE BETWEEN THE WORST AND PRESENT SCENARIOS

Runoff category (inches)	Present Land Cover (square miles)	Worst Case Land Cover (square miles)	Difference (Square miles)
0.0 - 0.03	53.2 (79%)	43.5 (64.7%)	-9.7
0.03 – 0.08	9.4 (14%)	11.2 (16.7%)	1.8
0.08 – 0.14	3.6 (5%)	7.4 (11%)	3.8
0.14 – 0.37	1.1 (1.6%)	4.8 (7.2%)	3.8
0.37 – 0.74	0.03 (0.04%)	0.3 (0.48%)	0.3

Simulation results show that almost 10 square miles of the area within the lowest impact category shows enough increased surface runoff to move it from the lowest category to a higher category. This pattern is true across all categories, with more surface runoff being simulated to occur across the landscape. The greatest percent increase in category occurred in the highest runoff category, with a total area of the watershed increasing from 0.03 to 0.3 inches. Figure 5.13 shows the difference in the results of the simulation for surface runoff between the Worst Case and Present conditions.

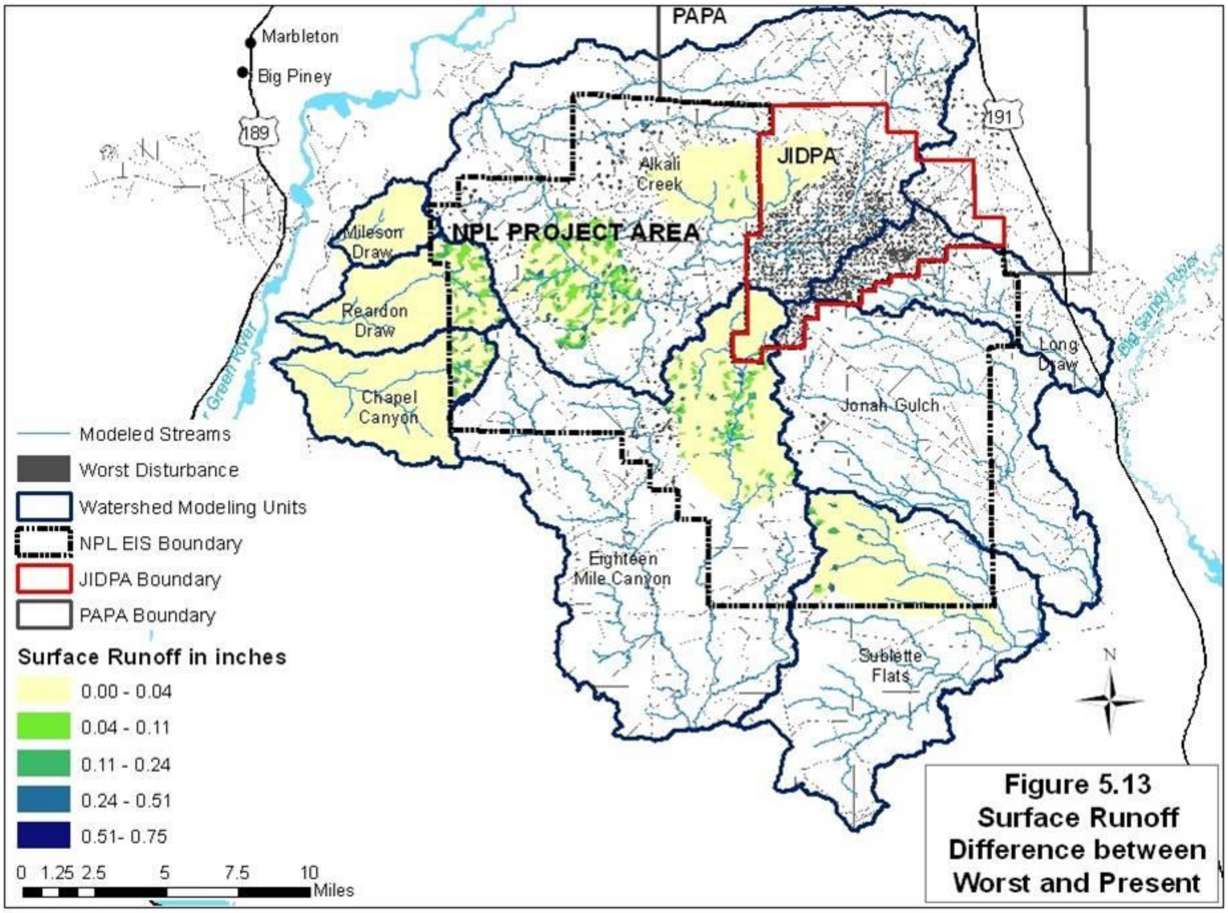


Figure 5.13 Surface Runoff Difference between Worst and Present

Table 5.21 shows the change in surface runoff summarized by runoff category.

TABLE 5.21
PERCENT OF SURFACE RUNOFF IN EACH RUNOFF CATEGORY – DIFFERENCE BETWEEN WORST AND PRESENT SCENARIOS

Runoff Category – Increase in Runoff depth (inches)	Area (square miles)	Percent of Project Area
0.00 - 0.03	55.75	82.80
0.03 - 0.11	7.78	11.60
0.11 - 0.23	2.92	4.30
0.23 - 0.47	0.86	1.28
0.47 - 0.74	0.04	0.06

The values represent the total increase in runoff resulting from the same two-inch storm. Given that nearly 80 percent of the entire project produces less than 0.03 inches of runoff from a two-inch storm, any increase in runoff greater than 0.03 inches is identified as having a "substantial change" in runoff response.

Many planes in the simulation did not change surface runoff at all, due to the fact that no surface disturbance was placed inside the plane. The largest change in runoff was simulated to be 0.73 inches. The majority of the area was simulated to change less than 0.03 inches (82.8 percent), which means that 17.2 percent of the area was simulated to have a "substantial change in runoff" as a result of the Worst Case scenario.

The primary mechanism by which changes in hydrologic response occurs is via reduced infiltration. Surface roughness is also reduced, which furthers the rate of water flow across the landscape and off the simulation planes. These changes generally result in greater surface runoff and erosion or sediment transport.

The most significant changes in surface runoff, infiltration, and erosion were simulated to occur when land cover was changed from Present to the Worst case scenario. Sediment Yield in response to a two-inch, 25-year, 24-hour storm event are shown in Figures 5.14.

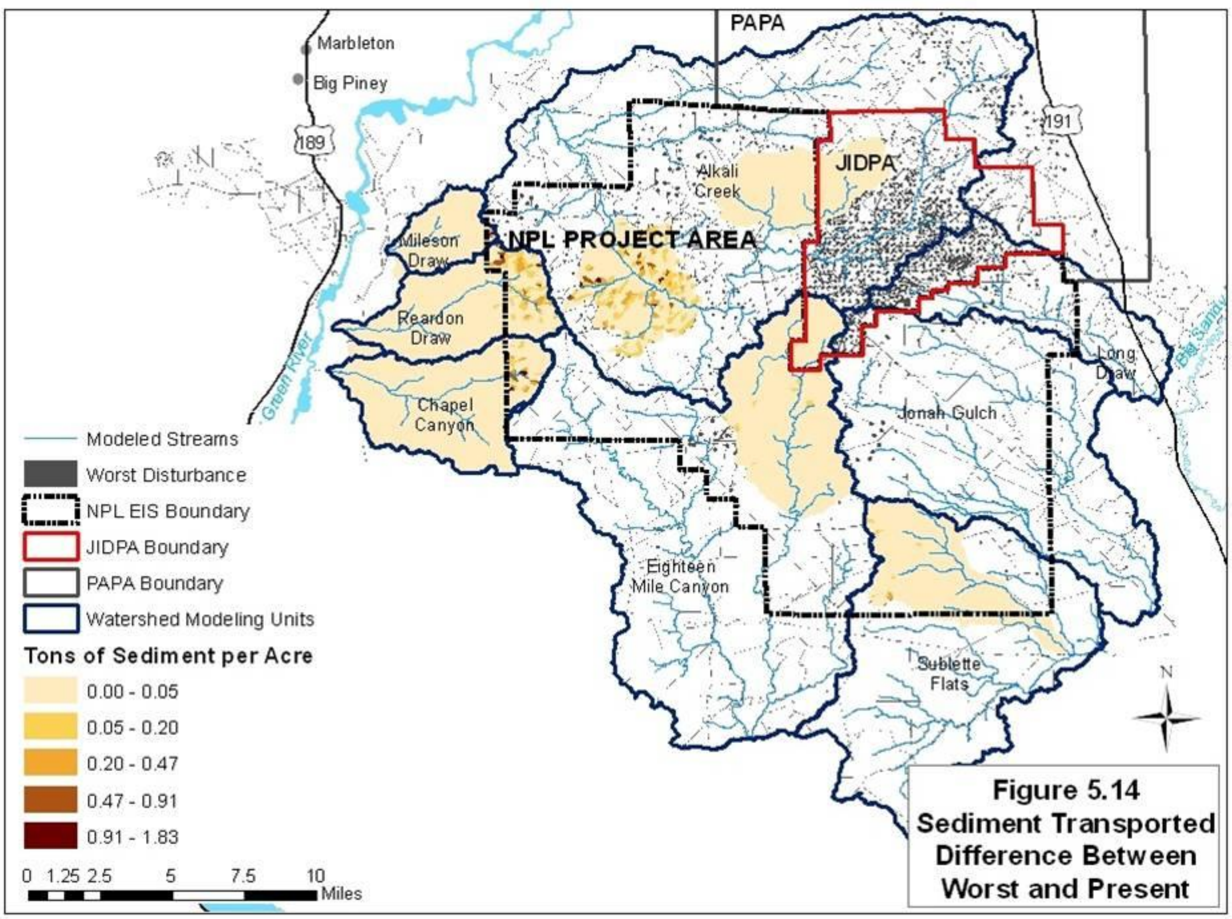


Figure 5.14 Sediment Transported Difference Between Worst and Present

6.0 CONCLUSIONS AND RECOMMENDATIONS

This section summarizes the observations, conclusions, and recommendations from results of the AGWA modeling. In addition, a brief discussion of EIS alternatives, and recommended mitigations.

6.1 General

Numerous chemical and physical variables exist in the soils, surface water, and related resource values at the local, as well as, regional levels. These variables influence or control the nature and extent of changes in surface runoff and channel discharge and changes in watershed conditions and channel stability among the Watershed Modeling Units in the modeling analysis and predictive outcomes for each of the scenarios. These factors include:

- The types of plant communities across the landscape (e.g., species mix, productivity, aerial or basal cover, life form distribution).
- The physical characteristics of the landscape (e.g., slopes (percent and length), drainage patterns/density and distribution).
- Channel types and characteristics (e.g., ephemeral (other), stability or lack thereof, known headcuts or structures due to previous development/improvements (road and pipelines crossings, impoundments, reservoirs, etc.)).
- Soil characteristics (e.g., chemical and physical properties (e.g., salinity, sodicity, alkalinity, depth, restrictive layers, sand/clay fractions, engineering limitations, etc.))
- Surficial geology.
- Precipitation and temperature affecting the plant communities and reclamation potential.

Actual surface runoff and erosion monitoring data are extremely limited within the NPL Project Area. Sufficient supporting data (e.g., landscape cover, digital elevation data, soils data) were available to allow the use of AGWA to complete a relative, comparative analysis of the current surface runoff and channel discharge for the NPL Project Area. With these factors in mind, it is possible to make only the following general observations, from model results for Pre-Development Conditions, regarding the existing surface runoff and channel discharge for the Watershed Modeling Units:

- The amount of surface runoff and channel discharge modeled for each of the eight Watershed Modeling Units in all the scenarios does not indicate a large increase in surface runoff and channel discharge at the-Watershed Modeling Unit level. Some model elements (planes and channels) within the larger watersheds show large changes to various development scenarios but the overall effect is often suppressed on the larger regional scale. However, although actual values appear very small, the impacts can be relatively large. **These areas of greater modeled change provide an initial focus for monitoring efforts.**

- The cumulative effects, or expression, of all the resource variables in the Long Draw, Jonah Gulch, Eighteen Mile Canyon, and Alkali Creek Watershed Modeling Units result in their having comparatively lower surface runoff and channel discharges, from the portions of the channels within the NPL Project Area. This difference is apparent under the modeled Pre-Development conditions and is most likely the result of initial inputs related to native soil and vegetation conditions. The ephemeral nature of many of the streams in these watersheds suggests that this difference is related more towards initial resistance rather than resilience to disturbance. **As a result, prevention, rather than recovery should be emphasized.**

- Of the Watershed Modeling Units that intersect the NPL Project Area, Sublette Flats, Reardon Draw, Mileson Draw, and Chapel Canyon have overall higher initial per-acre surface runoff and sediment production, lower resistance and greater vulnerability to increased surface and channel erosion associated with the effects of surface disturbance.
  - These conditions even appear under undisturbed Pre-Development conditions and are most likely the result of initial inputs related to percent slope and length of slope and soil and vegetation conditions. Under the modeled scenarios, Sublette Flats, Reardon Draw, Mileson Draw, and Chapel Canyon Watersheds Modeling Units received comparatively low levels of disturbance. Therefore, as modeled, the watersheds that exhibited the greatest potential vulnerability to disturbance, received less overall disturbance on the larger watershed scale.

Examination of the modeling results for surface runoff and discharge in the stream channels support the following observations:

- The increase in surface runoff and channel discharge is most notable in the Worst Case scenario, but are not that dissimilar to the increases predicted in the other three scenarios (Figure 5.1 through Figure 5.4).

- Other Factors not considered in the modeling process may also result in local increases in surface runoff, channel discharge and sediment production. **As a result, the model output may provide an initial focus for monitoring but should not be the sole source of monitoring design input.**

- The amount of surface runoff and channel discharge modeled for each of the eight Watershed Modeling Units in all the scenarios does not indicate a dramatic increase in surface runoff and channel discharge at the major watershed level.
  - However, some individual planes within the Watershed Modeling Units do exhibit a much greater, on the order of several changes in magnitude, increases in runoff from the planes and channel discharge within the channels than nearby or adjacent planes within the same watersheds under the same modeled conditions. **Therefore, it will be necessary to consider these conditions in the prescription of monitoring and mitigation measures in the smaller catchments to avoid undue degradation of soil and water resources.**

- The Sublette Flats, Reardon Draw, Mileson Draw, and Chapel Canyon Watersheds Modeling Units appear to have lower resistance and greater vulnerability to the effects of surface and channel erosion associated with the effects of surface disturbance. **This will necessitate the implementation of the more rigorous monitoring and mitigation measures on those areas of these Watershed Modeling Units showing the greatest increases in surface runoff and channel discharge.**

- The comparatively large size of the area combined with low amounts of precipitation and surface runoff indicates that an individual storm event of reasonable size has a low probability of transporting sediment and associated salt and sediment from large or distant areas of contributing watersheds to major stream channels, such as the Upper Green River and The Big Sandy River. However, sediment and salt transport are not limited to single events but are the result of multiple sequential flows that incrementally transport produced materials downstream towards major channels. SWAT is designed to highlight areas of high and increased erosion potential. The size of the areas being modeled also tends to buffer changes. A dramatic local event may be minor when viewed at a large watershed scale. **Even though the changes in modeled surface runoff may first appear to be minor, the shift towards more eroded conditions may have a cumulative effect over time and should be considered.**

- Predictive models, by their very nature, do not provide absolute, quantitative data, rather, they provide qualitative model results that are representations of changes in the natural hydrologic system resulting from project-related surface disturbances. Although the initial model results have not been validated or verified by actual site specific monitoring data, they do have immediate value in providing an idea of the relative magnitude and trend of changes in surface runoff and channel discharge across a landscape over time. These data will enable BLM and the Jonah Energy to focus the most rigorous monitoring activity and mitigation measures in those areas that will likely be most impacted by the surface disturbance. **It is critical that a project specific <u>Monitoring and Mitigation Plan</u> be developed promptly for the selected preferred alternative and should be continued over the life of the project. The intensity and distribution of the prescribed monitoring and mitigation should be determined by the initial model designations of plane or channel impact and intensity of landscape disturbance. New monitoring data should be used to re-parameterize the model and re-run it as necessary (e.g., KINEROS), to aid in identifying significance thresholds, or action levels, for channel erosion and runoff/salinity increases.**

- The determination of the type and intensity of monitoring and mitigation, and identification of resource conditions or impacts that would trigger protective/corrective actions (action levels or thresholds), will follow the analysis of resource conditions and the assessment of surface disturbing impacts.

- These measures should be determined and documented in a monitoring and mitigation plan prepared by Jonah Energy consistent with the Regional Framework and accompanying Technical Support Document, and upon approval of the plan by BLM, appropriate resource condition/trend monitoring and mitigation should be applied by the project proponent to protect soil and water resources from unnecessary and undue degradation. **Such measures should include: sensitive indicators that have both short-term aspects to trigger actions and long-term aspects to determine if the short-term triggers are effective; and a list of potential actions related to specific erosional sources and indicators.**

- Because some individual planes in the Watersheds Modeling Units exhibited a relatively substantial increase in surface runoff and discharge within the channels, **Jonah Energy should**

implement monitoring and mitigation measures/or other approved measures that are as rigorous and protective, recommended in the Monitoring and Mitigation tables, Section 6.3.

- **Jonah Energy should engineer all surface runoff control structures and treatments for higher levels of storm intensity and duration as indicated by the KINEROS2 modeling analysis (e.g., 25 year 24 hour event).**

- **Jonah Energy should be required to be extremely diligent in compliance monitoring of the condition of runoff control structures (e.g., after every precipitation event that resulted in <u>any</u> water movement off pads into detention ponds, off roads and into wing ditches and catchments, etc.), and promptly repair any damages before the next precipitation event.**

6.2 EIS Alternatives

The alternatives as presented in the EIS and summarized in Section 2.0 – Project Description, were not simulated as such. The following conclusions can be made for the alternatives in the EIS:

6.2.1 No Action Alternative

Under the No Action Alternative, approximately 30 vertical natural gas wells would be drilled over a 10-year period from 30 single, 3.7-acre well pads. Ancillary infrastructure would include water disposal wells, gas pipelines, and access roads, but it was assumed that existing power lines and compressor stations would be sufficient for the anticipated development under the No Action Alternative. Under this alternative, approximately 213 acres would be disturbed per year over the 10-year development period.

The No Action Alternative would be most similar to the Present Condition modeled scenario. As a result, even though not specifically modeled, the No-Action Alternative would be within the range of scenarios simulated by both SWAT and KINEROS2.

6.2.2 Alternative A

Under Alternative A, which was developed primarily to address sensitive wildlife resources, the maximum number of wells and the life of the project would be the same as the Proposed Action, but development would be subdivided into DAs based on the spatial distribution of important wildlife habitats which would be incorporated into three phases. The short-term disturbance would be 6,748 acres (408 acres more than the Proposed Action of 6,340 acres).

Alternative A, would be most similar to the Proposed Action, which was simulated as the 2-Mile Buffer by both SWAT and KINEROS2. Similarly, even though this alternative was not specifically modeled, Alternative A would be within the range of scenarios simulated.

6.2.3 Alternative B

Under Alternative B, the number of wells would be the same as the Proposed Action but development would be focused in areas most suitable for development with respect to environmental resources while limiting development in areas with sensitive resources. The NPL Project Area would be subdivided into three DAs with varying densities of development.

The amount of short-term surface difference would be 466 acres less than for the Proposed Action. Within the scale and focus of the AGWA modeling, the positioning of the surface disturbance within less sensitive areas of the landscape, as described in the 2-Mile Buffer modeled scenario, places Alternative B within the range of analysis between that of the 2-Mile Buffer scenario and the Worst Case scenario, which places all surface disturbance within the most vulnerable areas of the NPL Project Area. As a result, even though this alternative was not specifically modeled, Alternative B would fall within the range of scenarios simulated.

6.3 Recommended Monitoring And Mitigation

As an engineering-scale model, KINEROS2 results can be used to guide the design and development of mitigation structures such as detention basins, sediment control structures such as check dams, and the identification of appropriate monitoring locations. Because the land-cover development scenarios are not specific to the exact locations of the well pads and roads, these results cannot be used for this purpose but rather serve to identify the relative influence of development spatially throughout the NPL. However, given the exact locations of roads, pads, and other infrastructure, this modeling approach could be used to further the management and mitigation of local and downstream effects and to guide the development of a monitoring program.

Jonah Energy should develop Monitoring and Mitigation Plans and Storm Water Pollution Protection Plans (SWPPP) considering the following summarized criteria and the Technical Support Document for the Application of the Regional Framework for Water-Resources Monitoring Related to Energy Exploration and Development.

TABLE 6.1
SUGGESTED MEASURES FOR MONITORING AND MITIGATION FOR EACH IMPACT CATEGORY

Impact* Category – in relative % increase in sediment and runoff	Selection Of Monitoring Appropriate To The Level Of Impact	Selection Of Mitigation Appropriate To The Level Of Impact
Very Low and Low impact Impact Categories 1 and 2	A variety of the following (more qualitative measures) to document non-impacted conditions for comparison purposes (i.e., *relict or comparison sites*): A *limited* number of the following comparison sites generally on a (3) year cycle (unless significant erosion is noted from a major storm): • photo plots of channel cross-sections and segment lengths;	• Prompt reclamation as required to protect other resource values, e.g., sage grouse; vegetation health and diversity; • Minimize disturbance duration and footprint; • also all measures as described in the SWPPP prepared to satisfy the State of Wyoming Non-Point Source Program requirements;

	• erosion photo plots • GPS location and document conditions of existing headcuts • green-line PFC transects; • flumes and water quality analysis at selected perennial stream locations (3 times annually); • channel cross-sections at major confluences; • longitudinal profiles on selected channel reaches; • erosion-pin plots/transects on/and adjacent to disturbed areas.	• Air photo analysis of existing headcuts field wide. More intense monitoring of headcut position for headcuts in vicinity to or downstream of areas of high sensitivity and/or increased disturbance and after significant overland flow events. Monitoring could include GPS location and/or distance from known locations (posts). Headcuts with the potential to affect riparian resources would be considered high priority. Also, designed structures to control most increases (above natural levels) in sediment discharge and runoff, including • Erosion control fencing • Hydro-mulching and wood mats at drill pad; • Wing ditches and similar runoff control measures on roads.
Minimal Impact Category 3	In addition to the above, a representative number of: • photo plots of channel cross-sections and segment lengths every (5) years (unless erosion is evident follow major storms); • erosion photo plots every (3) years.	• as above
Moderate Impact Category 4	In addition to the above, a representative number of the following generally on a (2) year cycle (unless significant erosion is noted from a major storm): • as above • flumes and water quality analysis at selected perennial stream locations (3 times annually); • channel cross-sections at major confluences;	• as above

<table>
<tr><td></td><td>longitudinal profiles on the most sensitive channel reaches repeated as appropriate;
measuring sediment accumulation in detention ponds on a (5) year basis and following major (erosion is evident) storm events;
erosion pin plots/transects on/and adjacent to disturbed areas.</td><td></td></tr>
<tr><td>High Impact Category 5</td><td>Extensive use of the following, generally on an annual basis (unless significant erosion is noted from a major storm):
flumes and water quality analysis on the most impacted/vulnerable perennial stream locations(3 times annually);
channel cross-sections at major confluences;
longitudinal profiles on the most sensitive channel reaches;
measuring sediment accumulation in detention ponds on a semi-annual basis and following major (erosion is evident) storm events;
erosion pin plots/transects on/and adjacent to disturbed areas;
GPS location and document condition of existing headcuts</td><td>as above
Also, designed structures to control nearly all increases (above natural levels) in sediment discharge and runoff, including:
detention ponds;
erosion control fencing;
wing ditches and similar runoff control measures on roads, etc.
fabric drop structures on head-cuts;
hydro-mulching and wood mats at drill pads, other?
Management and practices to include:
reduced pace of development in balance with pace of rehabilitation;
using the AGWA models (e.g., re-run AGWA models with Kineros) to aid in locating pads and roads in most stable areas;</td></tr>
</table>

REFERENCES

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ATTACHMENTS

ATTACHMENT A: NPL Disturbance Matrix (Encana, 11-09-2012)

A.1 Disturbance Matrix

80/20 Rule									
SAGR		Bottom Hole Spacing	Wells/Sec	Locs/Sec	Wells/Loc	Acres/Loc	# wells	# Sections	Initial Wellpad Dist/sec
N	64.00%	10	64	4	16	11	2240	35.00	46.80
N	12.80%	40	16	4	4	5	448	28.00	22.00
N	2.56%	160	4	4	1	5	89.6	22.40	22.00
N	0.64%	640	1	1	1	5	22.4	22.40	5.50
Y	16.00%	10	64	1	64	18	560	8.75	19.00
Y	3.20%	40	16	1	16	11	112	7.00	11.70
Y	0.64%	160	4	1	4	5	22.4	5.60	5.50
Y	0.16%	640	1	1	1	5	5.6	5.60	5.50
	100.00%						3500	134.75	138.00

Final Wellpad Dist/sec	Total Initial Wellpad Dist	Total Final Wellpad Dist	Initial Road Dist/sec	Final Road Dist/sec	Total Initial Road Dist	Total Final Road Dist	Initial Pipeline Dist/sec	Final Pipeline Dist/sec	Total Initial Pipeline Dist
11.00	1638.00	385.00	6.27	6.27	219.43	219.43	18.81	0.00	658.30
5.00	616.00	140.00	6.66	6.66	186.35	186.35	19.97	0.00	559.04
5.00	492.80	112.00	6.66	6.66	149.08	149.08	19.97	0.00	447.23
1.25	123.20	28.00	2.76	2.76	61.86	61.86	8.29	0.00	185.59
4.50	166.25	39.38	2.52	2.52	22.07	22.07	7.57	0.00	66.21
2.75	81.90	19.25	2.63	2.63	18.43	18.43	7.90	0.00	55.30
1.25	30.80	7.00	2.76	2.76	15.47	15.47	8.29	0.00	46.40
1.25	30.80	7.00	2.76	2.76	15.47	15.47	8.29	0.00	46.40
32.00	3179.75	737.63	33.02	33.02	688.15	688.15	99.06	0.00	2064.45

Total Final Pipeline Dist	RGFs	Powerlines	Grand Total Initial	Post Recl
0.00				
0.00				
0.00				
0.00				
0.00				
0.00				
0.00				
0.00				
0.00	220	702	6854.35	2347.78

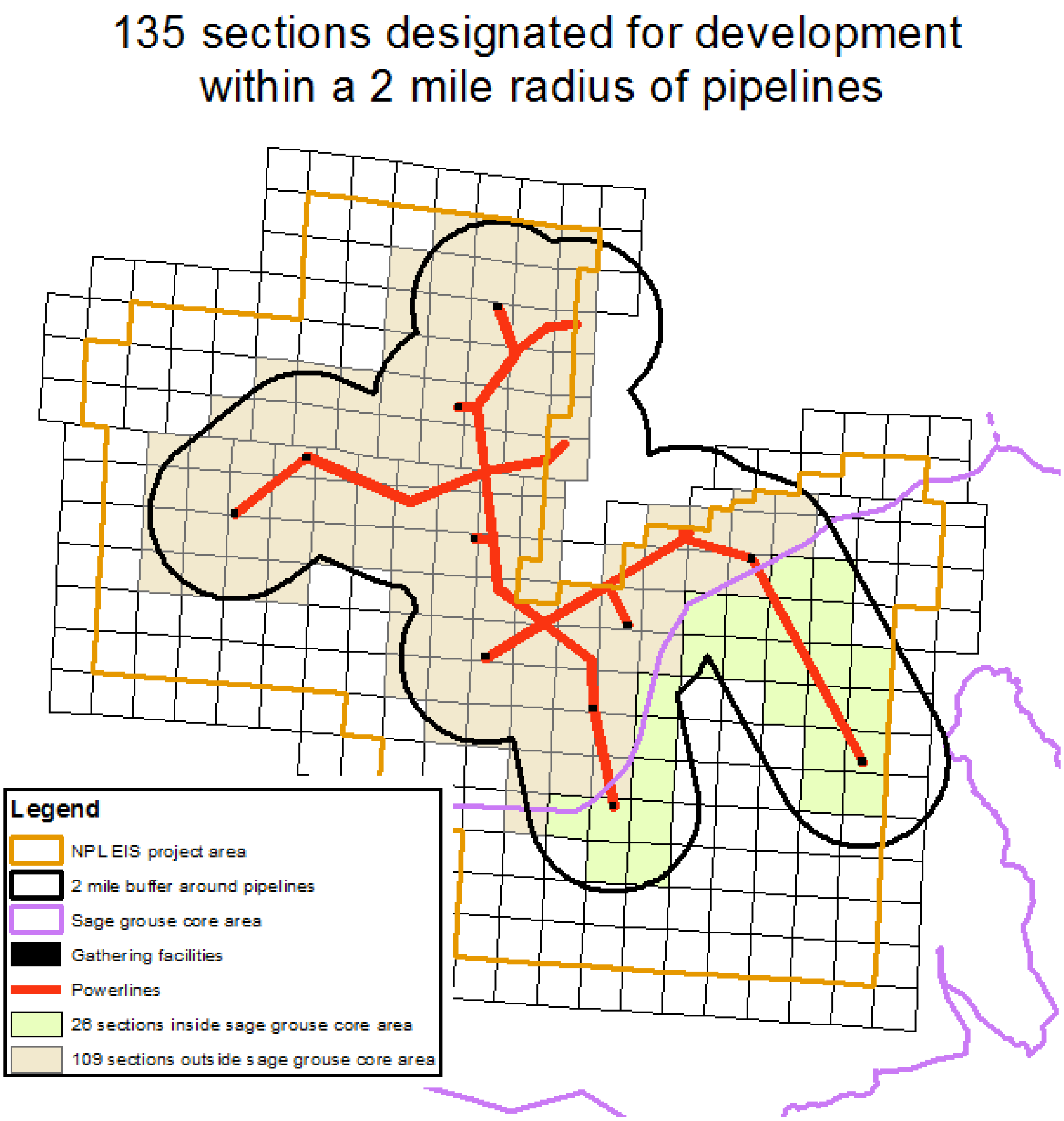
A.2 2-Mile Buffer Determination

E-Mail and determination of 2-Mile Buffer and comparison with NPL Disturbance Matrix

From: Margo Elizabeth Berendsen <mberends@uwyo.edu>
Date: Mon, Feb 4, 2013 at 4:15 PM
Subject: data from Encana CORRECTION
To: "Bellis, Janet" <jbellis@blm.gov>
Cc: Paul Alan Caffrey <Caffrey@uwyo.edu>, "Scott N. Miller" <SNMiller@uwyo.edu>

Corrected: number of section inside core is 26, outside is 109 = 135

Janet, Yes I see what you mean, there is almost perfect overlap of 109 sections outside the core but within a 2 mile buffer of powerlines, and 26 sections within the core and within 2 mile buffer of powerlines. This totals 135 sections, the same amount provided by Encana in their 80/20 table of disturbance.



ATTACHMENT B: LAND COVER FILES

B.1 Land Cover Look Up Table (mrlc2001_lut)

Contains parameter values for each land cover class in the 2001 and 2006 National Land Cover Datasets. Each record is identified by a unique key, identical to the values contained in the VALUE field of the land cover grid. Additional parameters include cover, interception, Manning's N, percent impervious and curve number values for soil hydrogroups A, B, C, and D.

NAME	A	B	C	D	COVER	INTRCEPT	N	IMPERV
Open Water	100	100	100	100	0	0.00	0.00	0.00
Perenial Ice/Snow	98	98	98	98	0	0.00	0.00	0.00
Developed, Open Space	68	79	86	89	90	2.50	0.41	0.01
Developed, Low Intensity	77	85	90	92	15	0.10	0.15	0.55
Developed, Medium Intensity	81	88	91	93	10	0.08	0.12	0.90
Developed, High Intensity	89	92	94	95	2	0.05	0.01	0.90
Barren Land	82	88	91	93	8	0.00	0.01	0.24
Unconsolidated Shore	82	88	91	93	0	0.00	0.01	0.00
Deciduous Forest	55	55	75	80	50	1.15	0.40	0.00
Evergreen Forest	55	55	70	77	50	1.15	0.80	0.00
Mixed Forest	55	55	75	80	50	1.15	0.60	0.00
Dwarf Shrub	63	77	85	88	25	3.00	0.06	0.00
Scrub/Shrub	63	77	85	88	25	3.00	0.06	0.00
Grasslands/Herbaceous	49	69	79	84	25	2.00	0.13	0.00
Sedge Herbaceous	49	69	79	84	25	2.00	0.13	0.00
Lichens	63	77	85	88	25	3.00	0.06	0.00
Moss	63	77	85	88	25	3.00	0.06	0.00
Pasture/Hay	68	79	86	89	70	2.80	0.40	0.00
Cultivated Crops	71	81	87	91	57	1.75	0.13	0.00
Woody Wetlands	85	85	90	92	70	1.15	0.60	0.00

NAME	A	B	C	D	COVER	INTRCEPT	N	IMPERV
Palustrine Forested Wetland	85	85	90	92	70	1.15	0.60	0.00
Palustrine Scrub/Shrub	85	85	90	92	70	1.15	0.60	0.00
Estuarine Forested Wetland	85	85	90	92	70	1.15	0.60	0.00
Estuarine Scrub/Shrub	85	85	90	92	70	1.15	0.60	0.00
Emergent Herbaceous Wetlands	77	77	84	90	70	1.15	0.60	0.00
Palustrine Emergent Wetland (Persistent)	77	77	84	90	70	1.15	0.60	0.00
Estuarine Emergent Wetland	77	77	84	90	70	1.15	0.60	0.00
Palustrine Aquatic Bed	77	77	84	90	70	1.15	0.60	0.00
Estuarine Aquatic Bed	77	77	84	90	70	1.15	0.60	0.00

B.2 CROP.DAT

This file contains information used to simulate plant growth in the SWAT model. For rangeland land cover types (RNGE and RNGB), the values in this file were changed from perennial (6) to warm seasonal annual (4) to better represent rangeland plant growth in the NPL region. The entire crop.dat file is not included, only the portion that was altered.

```
15  RNGE   4
34.00   0.90   2.50   0.05   0.10   0.25   0.70   0.35   1.00   2.00
25.00   12.00   0.0160   0.0022   0.0200   0.0120   0.0050   0.0014   0.0010   0.0007
0.900   0.0030   0.0050   4.00   0.750   10.00   660.00   39.00   0.0500   0.000
0.000    0    0.00   0.330
16  RNGB   4
34.00   0.90   2.00   0.05   0.10   0.25   0.70   0.35   1.00   2.00
25.00   12.00   0.0160   0.0022   0.0200   0.0120   0.0050   0.0014   0.0010   0.0007
0.900   0.0030   0.0050   4.00   0.750   10.00   660.00   39.00   0.0500   0.000
0.000    0    0.00   0.330
```

ATTACHMENT C: SOIL DATABASE TABLES

The SSURGO data encompassing the NPL area, as of 2012-2013, is considered "provisional" in status and subject to change. Therefore the map unit numbers and corresponding values in associated tables (component, horizon and texture group) are provided here for record. Only the fields used by SWAT are included. STATSGO soils were used for the KINEROS2 analysis with corresponding component and layer tables that are considered final, not provisional, and therefore are not included in these appendices.

C.1 Component Table From Sublette County, Wyoming SSURGO Database

(corresponding to map units in the NPL and the following field descriptions):

Comppct_l, comppct_r and comppct_h: The percentage of the component of the mapunit (low, RV and high)

Compname: Name assigned to a component based on its range of properties

Hydgrp: A group of soils having similar runoff potential under similar storm and cover conditions

Cokey: A string of characters used to uniquely identify a record in the Component table and associate the records with the mukey (map unit key).

comppct_l	comppct_r	comppct_h	compname	hydgrp	cokey
0	20	0	Sandbranch	B	1473758:1389201
0	15	0	Giarch	C	1473758:1389202
0	30	0	Havermom	D	1473758:1389203
0	25	0	Forelle	B	1473769:1548286
0	35	0	Obadia	C	1473769:1548287
0	40	0	Sandbranch	C	1473769:1548288
0	40	0	Diamondville	C	1473770:1539042
0	20	0	Edlin	A	1473770:1539043
0	20	0	Cushool	C	1473770:1539044
0	15	0	Comer	A	1473772:1384355
0	35	0	Ryark	A	1473772:1384356
0	40	0	Maysprings	B	1473772:1384381
0	40	0	McFadden	B	1473778:1386722
0	23	0	Anchutz	B	1473778:1386723

comppct_l	comppct_r	comppct_h	compname	hydgrp	cokey
0	25	0	Pahlow	B	1473778:1386724
0	20	0	Burmaloaf	B	1474220:1383799
0	55	0	Jonah	B	1474220:1383801
0	35	0	Fluetsch	B	1474228:1413127
0	50	0	Diamondville	C	1474228:1413128
0	15	0	Forelle	C	1474238:1393073
0	25	0	Diamondville	C	1474238:1393074
0	40	0	Abston	D	1474238:1393075
25	30	35	Boettcher	D	1475556:1385003
20	25	30	Sandbranch	C	1475556:1386116
15	20	25	Cushool	C	1475556:1386406
0	40	0	Bluerim	C	1475559:1384936
0	20	0	Zagpeed	C	1475559:1693168
0	15	0	Tigon	D	1475559:1700893
0	30	0	Bluerim	C	1475561:1384374
0	15	0	Forelle	B	1475561:1700119
0	20	0	Figuore	A	1475561:1700122
0	25	0	Forelle	B	1475565:1384882
0	30	0	Yoda	C	1475565:1384890
0	15	0	Tigon	D	1475565:1384898
0	15	0	Luhon	A	1475571:1413306
0	20	0	Chaperton	C	1475571:1413307
55	60	65	Diamondville	C	1475571:1413308
5	15	15	Blackhall	D	1475575:1391561

comppct_l	comppct_r	comppct_h	compname	hydgrp	cokey
0	15	0	Worfman	D	1475575:1391562
0	25	0	Bluerim	C	1475575:1391563
30	33	35	Forelle	B	1475575:1391564
0	65	0	Diamondville	C	1475577:1363182
0	15	0	Cotha	B	1475577:1388534
10	15	15	Badland	A	1475585:1389134
0	15	0	Zagpeed	B	1475585:1389135
0	15	0	Bluerim	C	1475585:1389136
0	25	0	Worfman	D	1475585:1389137
10	15	20	Delphill	C	1475588:1388529
15	20	25	Blazon	D	1475588:1388531
45	50	50	Forelle	B	1475588:1388532
10	15	20	Cushool	B	1475588:1530416
0	30	0	Simanni	B	1486742:1382059
0	25	0	Bluerim	C	1486742:1382657
0	20	0	Cotha	B	1486742:1382685
0	15	0	Milren	C	1486742:1382713
0	20	0	Boettcher	C	1672277:1525383
0	40	0	Pilotpeak	D	1672277:1525384
0	20	0	Squaretop	C	1672277:1525385
0	30	0	Badland	A	1672338:1534346
0	15	0	Diamondville	C	1672338:1534642
0	85	0	Mayssprings	B	1673045:1550097
0	15	0	Rawlins	A	1673045:1550113

comppct_l	comppct_r	comppct_h	compname	hydgrp	cokey
0	25	0	Rock Outcrop	A	1673046:1529840
0	50	0	Badland	A	1673046:1529841
0	90	0	Fonce	B	1898035:1721801
0	45	0	Golphco	B	1898037:1716146
0	20	0	Chinatown	C	1898037:1716335
0	30	0	Soapy	B/D	1903412:1716408
0	50	0	Soapole	D	1903412:1716409
0	20	0	Taffom	B	1906355:1721723
0	15	0	Twocabin	B	1906355:1721802
0	50	0	Fonce	B	1906355:1777123
0	25	0	Sandbranch	C	2233653:1759878
0	55	0	Debone	D	2233653:1759879
0	20	0	Bruja	C	2233700:1760938
0	70	0	Grubrob	C	2233700:1813848
0	50	0	Figuore	A	2233706:1766927
0	25	0	Bodorumpe	A	2233706:1837403
0	15	0	Twocabin	A	2233708:1762676
0	25	0	Twocabin	A	2233708:1762677
0	45	0	Fonce	B	2233708:1762678
0	40	0	Figuore	A	2370699:1761085
0	50	0	Bodorumpe	A	2370699:1761086
0	15	0	Sandbranch	C	2378529:1775766
0	70	0	Scooby	C	2378529:1775773
0	75	0	Bruja	C	2424399:1811698

comppct_l	comppct_r	comppct_h	compname	hydgrp	cokey
0	20	0	Zagpeed	B	2424399:1813138
0	65	0	Scooby	C	2424645:1812580
0	20	0	Fola	B	2424645:1812629
0	55	0	Langspring	B	2425124:1813454
0	30	0	Rosseau	A	2425124:1813639
0	60	0	Diamondville	C	2426357:1816739
0	15	0	Forelle	C	2426357:1816746
0	25	0	Oasiswell	D	2426357:1816747
0	70	0	Twocabin	C	2426395:1817129
0	20	0	Rock outcrop	A	2426413:1817248
0	75	0	Badland	A	2426413:1817249
0	45	0	Rock outcrop	A	2426474:1817367
0	55	0	Spool	D	2426474:1817368
0	40	0	Rock outcrop	A	2426558:1817451
0	60	0	Cragosen	D	2426558:1817452
0	75	0	Reardon	B	2427888:1820877
0	90	0	Sandbranch	C	2427892:1822759
0	30	0	Kandaly	A	2427932:1820887
0	70	0	Sandbranch	C	2427932:1820888
0	70	0	Cragosen	D	2427933:1820717
0	20	0	lithic haplocambids	D	2427933:1820719
0	50	0	Subwater	B	2514542:1958303
0	35	0	Forelle	B	2514542:1958304

comppct_l	comppct_r	comppct_h	compname	hydgrp	cokey
0	50	0	Zagpeed	B	2514543:1958308
0	25	0	Zagpeed	B	2514543:1958309
0	15	0	Figuore	B	2514543:1958310
0	35	0	Jonah	C	2514544:1958312
0	35	0	Figuore	B	2514544:1958313
0	20	0	Burmaloaf	C	2514544:1958314
0	80	0	Zagpeed	B	2514545:1958317
0	75	0	Subwater	C	2514547:1958323
0	15	0	Tismid	C	2514547:1958324

C.2 Horizon Table From Sublette County, Wyoming SSURGO Database

(corresponding to map units in the NPL). There were four components listed in the previous table that are missing in this table (due to the provisional status of this data). The missing components (cokeys) are: 2426474:1817367, 2426558:1817451, 2514547:1958323, and 2514547:1958324.

Field descriptions:

Hzdept (shortened from hzdept_r): The distance from the top of the soil to the upper boundary of the soil horizon.

Hzdepb (hzdepb_r): The distance from the top of the soil to the base of the soil horizon.

Sieveno10 (sieveno10_r): Soil fraction passing a number 10 sieve (2.00mm square opening) as a weight percentage of the less than 3 inch (76.4mm) fraction

Sandtotal (sandtotal_r): Mineral particles 0.05mm to 2.0mm in equivalent diameter as a weight percentage of the less than 2 mm fraction

Silttotal (silttotal_r): Mineral particles 0.002 to 0.05mm in equivalent diameter as a weight percentage of the less than 2.0mm fraction.

Claytotal (claytotal_r): Mineral particles less than 0.002mm in equivalent diameter as a weight percentage of the less than 2.0mm fraction.

Om (om_r): The amount by weight of decomposed plant and animal residue expressed as a weight percentage of the less than 2 mm soil material.

Dbthirdb (dbthirdbar_r): The oven dry weight of the less than 2 mm soil material per unit volume of soil at a water tension of 1/3 bar.

Awc (awc_r): The amount of water that an increment of soil depth, inclusive of fragments, can store that is available to plants. AWC is expressed as a volume fraction, and is commonly estimated as the difference between the water contents at 1/10 or 1/3 bar (field capacity) and 15 bars (permanent wilting point) tension and adjusted for salinity, and fragments.

Kffact: An erodibility factor which quantifies the susceptibility of soil particles to detachment by water

Cokey: A string of characters used to uniquely identify a record in the Component table and associate the records with the mukey (map unit key).

hzdept	hzdepb	sieveno10	sandtotal	silttotal	claytotal	om	dbthirdb	awc	kffact	cokey
78	152	85.0	85.0	7.0	8.0	0.2	1.7	0.1	0.0	1473758:1389203
52	78	95.0	60.0	9.0	31.0	0.5	1.5	0.1	0.2	1473758:1389203
41	52	100.0	35.0	33.0	32.0	0.3	1.4	0.0	0.3	1473758:1389203
22	41	100.0	60.0	14.0	26.0	0.8	1.5	0.0	0.2	1473758:1389203
5	22	100.0	30.0	29.0	41.0	0.8	1.3	0.0	0.3	1473758:1389203
0	5	100.0	35.0	31.0	34.0	1.3	1.1	0.1	0.3	1473758:1389203
90	152	100.0	85.0	5.0	10.0	0.2	1.7	0.1	0.1	1473758:1389201
40	90	100.0	60.0	10.0	30.0	0.3	1.5	0.1	0.2	1473758:1389201
30	40	91.0	85.0	4.0	11.0	0.3	1.5	0.0	0.1	1473758:1389201
15	30	100.0	40.0	30.0	30.0	0.8	1.4	0.1	0.3	1473758:1389201
10	15	100.0	60.0	14.0	26.0	0.8	1.4	0.1	0.2	1473758:1389201
0	10	82.0	70.0	15.0	15.0	1.3	1.3	0.1	0.2	1473758:1389201
85	95	48.0	85.0	7.0	8.0	0.2	1.7	0.0	0.1	1473758:1389202

hzdept	hzdepb	sieveno10	sandtotal	silttotal	claytotal	om	dbthirdb	awc	kffact	cokey
65	85	100.0	60.0	14.0	26.0	0.2	1.5	0.1	0.2	1473758:1389202
21	65	100.0	35.0	29.0	36.0	0.3	1.4	0.1	0.3	1473758:1389202
15	21	100.0	55.0	17.0	28.0	0.3	1.4	0.1	0.2	1473758:1389202
4	15	100.0	35.0	29.0	36.0	0.8	1.3	0.1	0.3	1473758:1389202
0	4	100.0	55.0	11.0	34.0	1.3	1.2	0.1	0.2	1473758:1389202
95	152	84.0	65.0	15.0	20.0	0.2	1.6	0.1	0.2	1473758:1389202
97	152	100.0	40.0	39.0	21.0	0.2	1.4	0.1	0.4	1473769:1548286
47	97	100.0	40.0	38.0	22.0	0.3	1.4	0.1	0.4	1473769:1548286
12	47	100.0	55.0	23.0	22.0	0.3	1.3	0.2	0.3	1473769:1548286
2	12	100.0	45.0	35.0	20.0	0.8	1.3	0.2	0.4	1473769:1548286
0	2	82.0	60.0	26.0	14.0	1.3	1.3	0.1	0.3	1473769:1548286
108	152	100.0	35.0	37.0	28.0	0.2	1.4	0.2	0.3	1473769:1548288
84	108	100.0	15.0	49.0	36.0	0.3	1.3	0.2	0.4	1473769:1548288
32	84	100.0	35.0	37.0	28.0	0.3	1.4	0.2	0.4	1473769:1548288
24	32	100.0	23.0	51.0	26.0	0.3	1.2	0.2	0.4	1473769:1548288

hzdept	hzdepb	sieveno10	sandtotal	silttotal	claytotal	om	dbthirdb	awc	kffact	cokey
7	24	100.0	55.0	20.0	25.0	0.8	1.3	0.2	0.2	1473769:1548288
3	7	98.0	55.0	30.0	15.0	1.3	1.3	0.1	0.4	1473769:1548288
0	3	98.0	60.0	28.0	12.0	1.3	1.3	0.1	0.3	1473769:1548288
80	152	96.0	50.0	15.0	35.0	0.2	1.3	0.2	0.2	1473769:1548287
20	80	96.0	40.0	26.0	34.0	0.3	1.3	0.2	0.3	1473769:1548287
4	20	100.0	15.0	47.0	38.0	0.8	1.2	0.2	0.3	1473769:1548287
0	4	95.0	30.0	54.0	16.0	1.3	1.1	0.2	0.5	1473769:1548287
0	2	94.0	85.0	7.0	8.0	1.5	1.4	0.1	0.1	1473770:1539042
2	9	98.0	70.0	18.0	12.0	1.5	1.3	0.1	0.2	1473770:1539042
9	20	100.0	60.0	13.0	27.0	0.8	1.3	0.2	0.2	1473770:1539042
20	47	100.0	70.0	6.0	24.0	0.8	1.3	0.2	0.2	1473770:1539042
47	86	100.0	70.0	11.0	19.0	0.3	1.6	0.1	0.3	1473770:1539042
86	200	0.0	0.0	0.0	0.0	0.0	1.7	0.0	0.0	1473770:1539042
0	5	90.0	75.0	17.0	8.0	1.5	1.3	0.1	0.2	1473770:1539044
5	34	100.0	60.0	11.0	29.0	0.8	1.3	0.1	0.2	1473770:1539044

hzdept	hzdepb	sieveno10	sandtotal	silttotal	claytotal	om	dbthirdb	awc	kffact	cokey
49	60	74.0	70.0	6.0	24.0	0.8	1.3	0.1	0.2	1473770:1539044
60	120	100.0	50.0	33.0	17.0	0.3	1.6	0.1	0.4	1473770:1539044
120	135	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1473770:1539044
34	49	66.0	65.0	9.0	26.0	0.8	1.3	0.1	0.2	1473770:1539044
0	2	91.0	85.0	7.0	8.0	1.5	1.4	0.1	0.0	1473770:1539043
2	8	100.0	75.0	13.0	12.0	1.5	1.3	0.1	0.2	1473770:1539043
8	43	100.0	65.0	20.0	15.0	0.8	1.4	0.1	0.2	1473770:1539043
43	76	100.0	70.0	17.0	13.0	0.8	1.6	0.1	0.2	1473770:1539043
76	101	100.0	70.0	18.0	12.0	0.5	1.6	0.1	0.2	1473770:1539043
101	152	100.0	75.0	12.0	13.0	0.5	1.6	0.1	0.2	1473770:1539043
102	152	44.0	85.0	7.0	8.0	0.2	1.7	0.0	0.0	1473772:1384381
64	102	52.0	70.0	12.0	18.0	0.2	1.6	0.1	0.2	1473772:1384381
43	64	96.0	60.0	10.0	30.0	0.3	1.4	0.2	0.2	1473772:1384381
20	43	96.0	60.0	12.0	28.0	0.3	1.4	0.2	0.2	1473772:1384381
5	8	94.0	65.0	17.0	18.0	1.3	1.3	0.1	0.2	1473772:1384381

hzdept	hzdepb	sieveno10	sandtotal	silttotal	claytotal	om	dbthirdb	awc	kffact	cokey
0	5	90.0	75.0	9.0	16.0	1.3	1.3	0.1	0.2	1473772:1384381
75	152	60.0	85.0	12.0	3.0	0.2	1.7	0.0	0.1	1473772:1384356
40	75	65.0	85.0	10.0	5.0	0.2	1.7	0.1	0.2	1473772:1384356
15	40	96.0	65.0	20.0	15.0	0.8	1.4	0.1	0.2	1473772:1384356
4	15	100.0	77.0	11.0	12.0	1.3	1.3	0.1	0.2	1473772:1384356
0	4	83.0	85.0	7.0	8.0	1.3	1.4	0.1	0.1	1473772:1384356
0	3	91.0	75.0	15.0	10.0	1.3	1.3	0.1	0.1	1473772:1384355
3	8	96.0	72.0	16.0	12.0	1.3	1.3	0.1	0.2	1473772:1384355
8	23	100.0	70.0	16.0	14.0	0.3	1.3	0.1	0.2	1473772:1384355
23	63	100.0	72.0	16.0	12.0	0.3	1.3	0.1	0.2	1473772:1384355
63	88	92.0	70.0	16.0	14.0	0.2	1.6	0.1	0.2	1473772:1384355
88	152	42.0	85.0	7.0	8.0	0.2	1.6	0.0	0.0	1473772:1384355
8	20	96.0	60.0	14.0	26.0	0.8	1.4	0.2	0.2	1473772:1384381
152	200	44.0	85.0	12.0	3.0	0.2	1.7	0.0	0.1	1473772:1384356
25	65	39.0	83.0	11.0	6.0	0.2	1.6	0.0	0.1	1473778:1386724

hzdept	hzdepb	sieveno10	sandtotal	silttotal	claytotal	om	dbthirdb	awc	kffact	cokey
5	25	74.0	70.0	14.0	16.0	0.5	1.3	0.1	0.2	1473778:1386724
0	5	68.0	70.0	14.0	16.0	1.0	1.3	0.1	0.2	1473778:1386724
95	152	97.0	65.0	21.0	14.0	0.2	1.6	0.1	0.3	1473778:1386723
38	95	95.0	42.0	40.0	18.0	0.2	1.5	0.2	0.4	1473778:1386723
6	38	94.0	37.0	37.0	26.0	0.5	1.3	0.2	0.4	1473778:1386723
0	6	94.0	40.0	38.0	22.0	1.0	1.2	0.2	0.4	1473778:1386723
0	6	96.0	65.0	21.0	14.0	0.5	1.3	0.1	0.3	1473778:1386722
6	20	100.0	45.0	41.0	14.0	0.5	1.4	0.1	0.4	1473778:1386722
20	130	100.0	45.0	40.0	15.0	0.2	1.5	0.1	0.4	1473778:1386722
130	150	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1473778:1386722
65	100	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1473778:1386724
143	200	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1474220:1383801
60	104	91.0	55.0	25.0	20.0	0.2	1.5	0.1	0.3	1474220:1383801
14	25	91.0	55.0	21.0	24.0	0.3	1.4	0.2	0.2	1474220:1383801
2	14	96.0	55.0	21.0	24.0	0.8	1.4	0.2	0.2	1474220:1383801

hzdept	hzdepb	sieveno10	sandtotal	silttotal	claytotal	om	dbthirdb	awc	kffact	cokey
0	2	90.0	60.0	24.0	16.0	1.3	1.3	0.1	0.3	1474220:1383801
0	3	87.0	65.0	20.0	15.0	1.3	1.3	0.1	0.3	1474220:1383799
3	30	82.0	45.0	35.0	20.0	0.8	1.4	0.2	0.4	1474220:1383799
30	48	91.0	45.0	31.0	24.0	0.2	1.4	0.2	0.3	1474220:1383799
48	88	36.0	55.0	17.0	28.0	0.2	1.5	0.1	0.2	1474220:1383799
165	200	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1474220:1383799
110	150	35.0	55.0	17.0	28.0	0.2	1.5	0.1	0.2	1474220:1383799
88	110	95.0	55.0	19.0	26.0	0.2	1.5	0.1	0.2	1474220:1383799
44	60	91.0	45.0	29.0	26.0	0.3	1.5	0.2	0.3	1474220:1383801
25	44	91.0	45.0	30.0	25.0	0.3	1.4	0.2	0.3	1474220:1383801
104	143	100.0	55.0	23.0	22.0	0.2	1.5	0.2	0.3	1474220:1383801
150	165	100.0	40.0	26.0	34.0	0.2	1.5	0.1	0.3	1474220:1383799
70	200	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1474228:1413128
31	42	100.0	40.0	36.0	24.0	0.5	1.4	0.2	0.4	1474228:1413128
14	31	100.0	60.0	14.0	26.0	0.5	1.4	0.2	0.2	1474228:1413128

hzdept	hzdepb	sieveno10	sandtotal	silttotal	claytotal	om	dbthirdb	awc	kffact	cokey
6	14	95.0	65.0	19.0	16.0	1.0	1.4	0.1	0.2	1474228:1413128
0	6	91.0	70.0	15.0	15.0	1.0	1.4	0.1	0.2	1474228:1413128
42	70	100.0	40.0	38.0	22.0	0.3	1.4	0.1	0.4	1474228:1413128
105	155	100.0	30.0	42.0	28.0	0.2	1.5	0.2	0.4	1474228:1413127
90	105	100.0	40.0	43.0	17.0	0.2	1.4	0.2	0.4	1474228:1413127
58	90	91.0	40.0	44.0	16.0	0.2	1.4	0.2	0.4	1474228:1413127
21	58	91.0	55.0	19.0	26.0	0.3	1.4	0.2	0.2	1474228:1413127
5	21	91.0	60.0	19.0	21.0	0.8	1.4	0.2	0.2	1474228:1413127
0	5	74.0	70.0	20.0	10.0	1.3	1.3	0.1	0.2	1474228:1413127
75	100	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1474238:1393075
65	75	100.0	40.5	22.7	36.8	0.2	1.4	0.2	0.3	1474238:1393075
35	65	100.0	51.0	17.2	31.8	0.3	1.4	0.1	0.2	1474238:1393075
20	35	94.0	41.6	14.5	43.9	0.3	1.2	0.2	0.2	1474238:1393075
5	20	100.0	39.9	23.8	36.3	0.8	1.3	0.2	0.3	1474238:1393075
0	5	73.0	60.6	32.0	7.4	1.3	1.3	0.1	0.4	1474238:1393075

hzdept	hzdepb	sieveno10	sandtotal	silttotal	claytotal	om	dbthirdb	awc	kffact	cokey
84	200	100.0	40.0	32.0	28.0	0.2	1.4	0.2	0.3	1474238:1393073
69	84	100.0	40.0	22.0	38.0	0.2	1.4	0.2	0.2	1474238:1393073
42	69	91.0	50.0	16.0	34.0	0.3	1.4	0.2	0.2	1474238:1393073
19	42	94.0	50.0	16.0	34.0	0.3	1.3	0.2	0.2	1474238:1393073
7	19	94.0	55.0	19.0	26.0	0.8	1.3	0.2	0.2	1474238:1393073
3	7	91.0	65.0	19.0	16.0	0.8	1.4	0.1	0.2	1474238:1393073
0	3	73.0	70.0	18.0	12.0	1.3	1.3	0.1	0.2	1474238:1393073
57	65	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1474238:1393074
34	57	100.0	35.0	29.0	36.0	0.2	1.4	0.2	0.3	1474238:1393074
11	34	100.0	40.0	26.0	34.0	0.8	1.3	0.2	0.3	1474238:1393074
0	11	82.0	65.0	21.0	14.0	1.3	1.3	0.1	0.3	1474238:1393074
60	80	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1475556:1385003
43	60	100.0	15.0	45.0	40.0	0.3	1.4	0.2	0.4	1475556:1385003
25	43	100.0	30.0	33.0	37.0	0.8	1.4	0.2	0.3	1475556:1385003
0	4	100.0	18.0	50.0	32.0	1.5	1.1	0.2	0.4	1475556:1385003

hzdept	hzdepb	sieveno10	sandtotal	silttotal	claytotal	om	dbthirdb	awc	kffact	cokey
9	25	100.0	30.0	30.0	40.0	0.8	1.2	0.2	0.3	1475556:1385003
4	9	100.0	30.0	33.0	37.0	0.8	1.3	0.2	0.3	1475556:1385003
88	152	100.0	45.0	35.0	20.0	0.2	1.5	0.2	0.4	1475556:1386116
44	88	100.0	45.0	35.0	20.0	0.2	1.4	0.2	0.4	1475556:1386116
30	44	100.0	40.0	33.0	27.0	0.3	1.3	0.2	0.3	1475556:1386116
4	30	100.0	35.0	32.0	33.0	0.8	1.3	0.1	0.3	1475556:1386116
0	4	66.0	40.0	40.0	20.0	1.3	1.2	0.1	0.4	1475556:1386116
63	80	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1475556:1386406
20	63	100.0	40.0	38.0	22.0	0.8	1.4	0.1	0.4	1475556:1386406
3	20	100.0	35.0	37.0	28.0	0.8	1.3	0.2	0.3	1475556:1386406
0	3	100.0	40.0	41.0	19.0	1.5	1.2	0.2	0.4	1475556:1386406
72	200	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1475559:1384936
59	72	92.0	70.0	12.0	18.0	0.2	1.6	0.1	0.2	1475559:1384936
8	24	96.0	55.0	21.0	24.0	0.8	1.4	0.2	0.2	1475559:1384936
4	8	91.0	65.0	21.0	14.0	0.8	1.5	0.1	0.2	1475559:1384936

hzdept	hzdepb	sieveno10	sandtotal	silttotal	claytotal	om	dbthirdb	awc	kffact	cokey
0	4	90.0	70.0	18.0	12.0	1.3	1.3	0.1	0.2	1475559:1384936
24	59	91.0	55.0	23.0	22.0	0.3	1.4	0.2	0.3	1475559:1384936
0	3	80.0	50.0	35.0	15.0	1.3	1.2	0.2	0.3	1475559:1693168
3	11	96.0	55.0	28.0	17.0	1.3	1.3	0.1	0.3	1475559:1693168
11	26	96.0	55.0	18.0	27.0	0.8	1.5	0.2	0.2	1475559:1693168
26	34	83.0	48.0	23.0	29.0	0.3	1.5	0.2	0.2	1475559:1693168
34	50	83.0	35.0	34.0	31.0	0.3	1.5	0.2	0.3	1475559:1693168
50	85	89.0	25.0	42.0	33.0	0.3	1.4	0.2	0.3	1475559:1693168
85	127	88.0	18.0	47.0	35.0	0.3	1.3	0.2	0.4	1475559:1693168
127	140	100.0	40.0	34.0	26.0	0.2	1.3	0.1	0.4	1475559:1693168
140	200	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1475559:1693168
46	200	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1475559:1700893
35	46	95.0	65.0	18.0	17.0	0.2	1.5	0.1	0.3	1475559:1700893
16	35	100.0	60.0	14.0	26.0	0.3	1.4	0.2	0.2	1475559:1700893
4	16	95.0	65.0	18.0	17.0	0.8	1.4	0.1	0.2	1475559:1700893

hzdept	hzdepb	sieveno10	sandtotal	silttotal	claytotal	om	dbthirdb	awc	kffact	cokey
0	4	90.0	70.0	16.0	14.0	1.3	1.3	0.1	0.2	1475559:1700893
83	95	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1475561:1384374
71	83	100.0	60.0	16.0	24.0	0.2	1.5	0.2	0.3	1475561:1384374
57	71	100.0	65.0	17.0	18.0	0.3	1.5	0.1	0.3	1475561:1384374
24	57	100.0	60.0	16.0	24.0	0.3	1.4	0.2	0.2	1475561:1384374
5	24	100.0	60.0	20.0	20.0	0.8	1.3	0.2	0.2	1475561:1384374
0	5	94.0	70.0	18.0	12.0	1.3	1.3	0.1	0.2	1475561:1384374
130	140	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1475561:1700122
118	130	100.0	75.0	13.0	12.0	0.2	1.6	0.1	0.2	1475561:1700122
77	118	91.0	70.0	14.0	16.0	0.2	1.4	0.1	0.2	1475561:1700122
63	77	91.0	70.0	12.0	18.0	0.2	1.4	0.1	0.2	1475561:1700122
44	63	97.0	85.0	5.0	10.0	0.3	1.5	0.1	0.2	1475561:1700122
20	44	98.0	75.0	6.0	19.0	0.8	1.4	0.1	0.2	1475561:1700122
9	20	100.0	70.0	15.0	15.0	0.8	1.4	0.1	0.2	1475561:1700122
2	9	100.0	75.0	13.0	12.0	1.3	1.3	0.1	0.2	1475561:1700122

hzdept	hzdepb	sieveno10	sandtotal	silttotal	claytotal	om	dbthirdb	awc	kffact	cokey
0	2	96.0	85.0	5.0	10.0	1.3	1.4	0.1	0.1	1475561:1700122
76	152	100.0	50.0	34.0	16.0	0.2	1.5	0.2	0.4	1475561:1700119
50	76	98.0	42.0	26.0	32.0	0.3	1.3	0.2	0.2	1475561:1700119
15	50	94.0	42.0	25.0	33.0	0.3	1.3	0.2	0.2	1475561:1700119
5	15	94.0	40.0	32.0	28.0	0.8	1.3	0.2	0.3	1475561:1700119
0	5	84.0	45.0	33.0	22.0	1.3	1.2	0.2	0.2	1475561:1700119
60	160	100.0	55.0	17.0	28.0	0.5	1.5	0.2	0.2	1475565:1384882
31	60	100.0	55.0	13.0	32.0	0.5	1.5	0.2	0.2	1475565:1384882
13	31	100.0	60.0	16.0	24.0	0.5	1.3	0.2	0.2	1475565:1384882
2	13	94.0	60.0	19.0	21.0	1.0	1.4	0.2	0.2	1475565:1384882
0	2	94.0	70.0	12.0	18.0	1.0	1.3	0.1	0.1	1475565:1384882
70	200	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1475565:1384890
50	70	100.0	60.0	10.0	30.0	0.3	1.3	0.2	0.2	1475565:1384890
42	50	100.0	65.0	1.0	34.0	0.5	1.3	0.2	0.2	1475565:1384890
16	42	100.0	60.0	8.0	32.0	0.5	1.3	0.2	0.2	1475565:1384890

hzdept	hzdepb	sieveno10	sandtotal	silttotal	claytotal	om	dbthirdb	awc	kffact	cokey
5	16	96.0	70.0	15.0	15.0	1.0	1.3	0.1	0.2	1475565:1384890
0	5	82.0	70.0	16.0	14.0	1.0	1.3	0.1	0.2	1475565:1384890
0	3	82.0	70.0	15.0	15.0	1.0	1.3	0.1	0.2	1475565:1384898
3	8	94.0	68.0	17.0	15.0	1.0	1.3	0.1	0.3	1475565:1384898
8	24	94.0	65.0	9.0	26.0	0.5	1.3	0.2	0.2	1475565:1384898
24	40	84.0	65.0	11.0	24.0	0.5	1.3	0.2	0.2	1475565:1384898
40	48	80.0	80.0	13.0	7.0	0.3	1.6	0.1	0.2	1475565:1384898
48	200	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1475565:1384898
81	95	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1475571:1413308
67	81	100.0	35.0	35.0	30.0	0.3	1.4	0.1	0.4	1475571:1413308
39	67	100.0	40.0	32.0	28.0	0.3	1.3	0.1	0.4	1475571:1413308
18	39	92.0	40.0	33.0	27.0	0.5	1.3	0.2	0.3	1475571:1413308
5	18	90.0	40.0	32.0	28.0	0.5	1.2	0.2	0.3	1475571:1413308
0	5	87.0	60.0	22.0	18.0	1.0	1.3	0.1	0.3	1475571:1413308
68	80	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1475571:1413307

hzdept	hzdepb	sieveno10	sandtotal	silttotal	claytotal	om	dbthirdb	awc	kffact	cokey
56	68	100.0	35.0	35.0	30.0	0.3	1.4	0.1	0.3	1475571:1413307
42	56	100.0	35.0	36.0	29.0	0.3	1.4	0.1	0.3	1475571:1413307
33	42	100.0	40.0	34.0	26.0	0.3	1.3	0.1	0.4	1475571:1413307
21	33	100.0	40.0	34.0	26.0	0.3	1.3	0.1	0.4	1475571:1413307
3	21	90.0	65.0	15.0	20.0	0.5	1.3	0.2	0.2	1475571:1413307
0	3	87.0	70.0	13.0	17.0	1.0	1.3	0.1	0.2	1475571:1413307
105	120	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1475571:1413306
65	105	75.0	65.0	17.0	18.0	0.3	1.5	0.1	0.2	1475571:1413306
20	65	59.0	65.0	16.0	19.0	0.3	1.4	0.1	0.2	1475571:1413306
0	20	52.0	70.0	13.0	17.0	1.0	1.3	0.1	0.2	1475571:1413306
96	152	100.0	65.0	13.0	22.0	0.2	1.4	0.2	0.2	1475575:1391564
62	96	100.0	60.0	15.0	25.0	0.3	1.3	0.2	0.2	1475575:1391564
7	21	98.0	55.0	17.0	28.0	0.8	1.3	0.2	0.2	1475575:1391564
3	7	94.0	65.0	21.0	14.0	1.3	1.3	0.1	0.2	1475575:1391564
0	3	82.0	70.0	20.0	10.0	1.3	1.3	0.1	0.2	1475575:1391564

hzdept	hzdepb	sieveno10	sandtotal	silttotal	claytotal	om	dbthirdb	awc	kffact	cokey
64	110	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1475575:1391563
38	44	100.0	70.0	14.0	16.0	0.3	1.4	0.1	0.2	1475575:1391563
24	38	100.0	65.0	11.0	24.0	0.3	1.4	0.2	0.2	1475575:1391563
0	6	72.0	75.0	9.0	16.0	1.3	1.4	0.1	0.2	1475575:1391563
46	46	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1475575:1391562
38	46	95.0	65.0	19.0	16.0	0.2	1.6	0.1	0.3	1475575:1391562
16	28	100.0	55.0	17.0	28.0	0.3	1.3	0.2	0.2	1475575:1391562
7	16	100.0	40.0	25.0	35.0	0.8	1.3	0.2	0.2	1475575:1391562
3	7	94.0	45.0	31.0	24.0	0.8	1.2	0.2	0.3	1475575:1391562
0	3	85.0	45.0	31.0	24.0	1.3	1.2	0.2	0.2	1475575:1391562
31	45	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1475575:1391561
15	31	97.0	85.0	9.0	6.0	0.2	1.6	0.1	0.2	1475575:1391561
6	15	74.0	70.0	20.0	10.0	1.3	1.4	0.1	0.2	1475575:1391561
0	6	82.0	85.0	7.0	8.0	1.3	1.4	0.1	0.1	1475575:1391561
21	62	100.0	60.0	15.0	25.0	0.3	1.3	0.2	0.2	1475575:1391564

hzdept	hzdepb	sieveno10	sandtotal	silttotal	claytotal	om	dbthirdb	awc	kffact	cokey
12	24	90.0	65.0	11.0	24.0	0.3	1.3	0.2	0.2	1475575:1391563
6	12	90.0	65.0	13.0	22.0	0.8	1.3	0.2	0.2	1475575:1391563
28	38	100.0	60.0	16.0	24.0	0.3	1.4	0.2	0.2	1475575:1391562
44	64	100.0	70.0	14.0	16.0	0.2	1.5	0.1	0.2	1475575:1391563
89	105	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1475577:1363182
34	66	100.0	40.0	25.0	35.0	0.3	1.3	0.2	0.2	1475577:1363182
17	34	96.0	40.0	28.0	32.0	0.5	1.3	0.2	0.3	1475577:1363182
8	17	90.0	40.0	30.0	30.0	0.5	1.3	0.2	0.3	1475577:1363182
0	8	80.0	45.0	30.0	25.0	1.3	1.2	0.2	0.2	1475577:1363182
66	89	100.0	40.0	34.0	26.0	0.2	1.3	0.2	0.4	1475577:1363182
44	74	52.0	81.2	9.2	9.6	0.5	1.6	0.0	0.2	1475577:1388534
34	44	75.0	74.2	10.6	15.2	0.5	1.4	0.1	0.2	1475577:1388534
13	34	83.0	71.6	16.6	11.8	0.5	1.4	0.1	0.2	1475577:1388534
5	13	74.0	74.2	17.7	8.1	1.0	1.3	0.1	0.1	1475577:1388534
0	5	60.0	87.4	9.3	3.3	1.0	1.3	0.0	0.1	1475577:1388534

hzdept	hzdepb	sieveno10	sandtotal	silttotal	claytotal	om	dbthirdb	awc	kffact	cokey
74	200	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1475577:1388534
50	200	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1475585:1389137
16	50	94.0	65.0	9.0	26.0	0.3	1.4	0.1	0.2	1475585:1389137
11	16	91.0	85.0	1.0	14.0	0.3	1.5	0.1	0.2	1475585:1389137
3	11	94.0	70.0	11.0	19.0	0.8	1.4	0.1	0.2	1475585:1389137
0	3	60.0	85.0	5.0	10.0	1.3	1.4	0.1	0.0	1475585:1389137
62	200	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1475585:1389136
28	62	69.0	65.0	10.0	25.0	0.3	1.5	0.1	0.2	1475585:1389136
20	28	98.0	75.0	13.0	12.0	0.3	1.5	0.1	0.2	1475585:1389136
7	20	98.0	75.0	14.0	11.0	0.8	1.4	0.1	0.2	1475585:1389136
0	7	94.0	80.0	13.0	7.0	1.1	1.4	0.1	0.1	1475585:1389136
105	200	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1475585:1389135
29	105	100.0	65.0	13.0	22.0	0.3	1.5	0.2	0.2	1475585:1389135
15	29	96.0	60.0	6.0	34.0	0.3	1.4	0.2	0.2	1475585:1389135
9	15	96.0	65.0	14.0	21.0	0.3	1.3	0.2	0.2	1475585:1389135

hzdept	hzdepb	sieveno10	sandtotal	silttotal	claytotal	om	dbthirdb	awc	kffact	cokey
2	9	96.0	65.0	13.0	22.0	0.8	1.3	0.2	0.2	1475585:1389135
0	2	82.0	70.0	13.0	17.0	1.3	1.3	0.1	0.1	1475585:1389135
50	152	100.0	45.0	37.0	18.0	0.3	1.5	0.2	0.4	1475588:1388532
18	50	100.0	45.0	37.0	18.0	0.3	1.4	0.2	0.4	1475588:1388532
2	18	100.0	45.0	37.0	18.0	0.8	1.3	0.2	0.4	1475588:1388532
0	2	89.0	50.0	35.0	15.0	1.3	1.2	0.2	0.4	1475588:1388532
10	70	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1475588:1388531
3	10	82.0	45.0	37.0	18.0	0.2	1.3	0.2	0.4	1475588:1388531
0	3	54.0	45.0	37.0	18.0	1.3	1.2	0.1	0.4	1475588:1388531
90	120	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1475588:1388529
60	90	100.0	60.0	28.0	12.0	0.2	1.5	0.1	0.4	1475588:1388529
40	60	100.0	45.0	35.0	20.0	0.2	1.4	0.1	0.4	1475588:1388529
10	40	100.0	40.0	34.0	26.0	0.8	1.3	0.1	0.3	1475588:1388529
0	10	82.0	35.0	37.0	28.0	1.3	1.2	0.2	0.3	1475588:1388529
104	120	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1475588:1530416

hzdept	hzdepb	sieveno10	sandtotal	silttotal	claytotal	om	dbthirdb	awc	kffact	cokey
74	104	100.0	55.0	25.0	20.0	0.2	1.5	0.1	0.3	1475588:1530416
49	74	100.0	52.0	16.0	32.0	0.3	1.5	0.2	0.2	1475588:1530416
28	49	100.0	55.0	19.0	26.0	0.3	1.3	0.2	0.2	1475588:1530416
4	28	100.0	60.0	20.0	20.0	0.8	1.3	0.2	0.2	1475588:1530416
0	4	80.0	65.0	19.0	16.0	1.3	1.2	0.1	0.3	1475588:1530416
60	165	100.0	65.0	19.0	16.0	0.2	1.5	0.1	0.2	1486742:1382059
34	60	100.0	60.0	22.0	18.0	0.3	1.4	0.1	0.2	1486742:1382059
6	34	100.0	55.0	19.0	26.0	0.8	1.3	0.2	0.2	1486742:1382059
0	6	100.0	65.0	21.0	14.0	1.3	1.3	0.1	0.2	1486742:1382059
88	100	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1486742:1382657
65	88	100.0	70.0	16.0	14.0	0.2	1.6	0.1	0.2	1486742:1382657
48	65	100.0	65.0	16.0	19.0	0.3	1.4	0.1	0.2	1486742:1382657
24	48	100.0	55.0	17.0	28.0	0.8	1.4	0.2	0.2	1486742:1382657
6	24	100.0	60.0	16.0	24.0	0.8	1.3	0.2	0.2	1486742:1382657
0	6	90.0	65.0	18.0	17.0	1.3	1.3	0.1	0.1	1486742:1382657

hzdept	hzdepb	sieveno10	sandtotal	silttotal	claytotal	om	dbthirdb	awc	kffact	cokey
88	100	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1486742:1382685
65	88	100.0	75.0	13.0	12.0	0.2	1.6	0.1	0.1	1486742:1382685
48	65	100.0	70.0	16.0	14.0	0.3	1.5	0.1	0.2	1486742:1382685
24	48	100.0	65.0	18.0	17.0	0.3	1.4	0.1	0.2	1486742:1382685
6	24	100.0	65.0	18.0	17.0	0.8	1.4	0.1	0.2	1486742:1382685
0	6	94.0	70.0	18.0	12.0	1.3	1.3	0.1	0.1	1486742:1382685
0	6	90.0	60.0	23.0	17.0	1.3	1.3	0.1	0.3	1486742:1382713
6	24	100.0	55.0	21.0	24.0	0.8	1.3	0.2	0.3	1486742:1382713
24	60	100.0	40.0	18.0	42.0	0.3	1.3	0.2	0.2	1486742:1382713
60	100	100.0	35.0	20.0	45.0	0.3	1.4	0.2	0.2	1486742:1382713
100	120	100.0	55.0	19.0	26.0	0.2	1.5	0.2	0.2	1486742:1382713
120	150	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1486742:1382713
44	200	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1672277:1525384
30	44	26.0	60.0	16.0	24.0	0.3	1.4	0.1	0.3	1672277:1525384
20	30	60.0	50.0	18.0	32.0	0.3	1.3	0.1	0.2	1672277:1525384

hzdept	hzdepb	sieveno10	sandtotal	silttotal	claytotal	om	dbthirdb	awc	kffact	cokey
10	20	66.0	55.0	17.0	28.0	0.3	1.3	0.1	0.2	1672277:1525384
5	10	52.0	60.0	18.0	22.0	0.3	1.3	0.1	0.3	1672277:1525384
1	5	46.0	60.0	20.0	20.0	0.3	1.2	0.1	0.3	1672277:1525384
0	1	28.0	65.0	19.0	16.0	1.5	1.3	0.1	0.3	1672277:1525384
55	200	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1672277:1525383
42	55	60.0	47.0	11.0	42.0	0.3	1.4	0.1	0.2	1672277:1525383
10	42	53.0	48.0	12.0	40.0	0.8	1.3	0.1	0.2	1672277:1525383
7	10	52.0	50.0	16.0	34.0	0.3	1.3	0.1	0.2	1672277:1525383
1	7	22.0	55.0	19.0	26.0	1.5	1.2	0.1	0.2	1672277:1525383
0	1	15.0	58.0	20.0	22.0	1.5	1.1	0.1	0.3	1672277:1525383
104	200	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1672277:1525385
60	104	35.0	35.0	31.0	34.0	0.3	1.4	0.1	0.4	1672277:1525385
35	60	96.0	32.0	26.0	42.0	0.8	1.3	0.2	0.2	1672277:1525385
5	35	93.0	30.0	30.0	40.0	0.8	1.2	0.2	0.3	1672277:1525385
2	5	70.0	32.0	26.0	42.0	1.5	1.1	0.2	0.2	1672277:1525385

hzdept	hzdepb	sieveno10	sandtotal	silttotal	claytotal	om	dbthirdb	awc	kffact	cokey
0	2	37.0	32.0	26.0	42.0	1.5	1.1	0.1	0.2	1672277:1525385
55	200	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1672338:1534642
42	55	100.0	71.0	11.0	18.0	0.2	1.4	0.1	0.3	1672338:1534642
13	19	100.0	65.0	9.0	26.0	0.3	1.4	0.2	0.2	1672338:1534642
5	13	100.0	40.0	31.0	29.0	0.8	1.5	0.2	0.3	1672338:1534642
2	5	100.0	72.0	14.0	14.0	1.3	1.3	0.1	0.2	1672338:1534642
0	2	100.0	70.0	18.0	12.0	1.3	1.3	0.1	0.2	1672338:1534642
19	42	100.0	72.0	12.0	16.0	0.3	1.4	0.1	0.3	1672338:1534642
0	2	82.0	60.0	26.0	14.0	1.3	1.3	0.1	0.3	1673045:1550097
2	12	100.0	45.0	35.0	20.0	0.8	1.3	0.2	0.4	1673045:1550097
12	47	100.0	55.0	23.0	22.0	0.3	1.3	0.2	0.3	1673045:1550097
47	97	100.0	40.0	38.0	22.0	0.3	1.4	0.2	0.4	1673045:1550097
97	152	100.0	40.0	39.0	21.0	0.2	1.4	0.2	0.4	1673045:1550097
56	90	96.0	65.0	21.0	14.0	0.3	1.4	0.1	0.3	1673045:1550113
14	56	96.0	65.0	18.0	17.0	0.8	1.4	0.1	0.2	1673045:1550113

hzdept	hzdepb	sieveno10	sandtotal	silttotal	claytotal	om	dbthirdb	awc	kffact	cokey
4	14	96.0	60.0	28.0	12.0	1.3	1.3	0.1	0.3	1673045:1550113
0	4	96.0	55.0	35.0	10.0	1.3	1.3	0.1	0.4	1673045:1550113
90	152	97.0	80.0	13.0	7.0	0.2	1.7	0.1	0.2	1673045:1550113
90	152	97.0	40.0	37.0	23.0	0.2	1.7	0.1	0.2	1673046:1529840
90	152	97.0	40.0	37.0	23.0	0.2	1.7	0.1	0.2	1673046:1529841
41	170	62.0	55.0	17.0	28.0	0.3	1.5	0.1	0.2	1898035:1721801
26	41	82.0	60.0	16.0	24.0	0.3	1.4	0.2	0.2	1898035:1721801
14	26	96.0	52.0	18.0	30.0	0.5	1.3	0.2	0.2	1898035:1721801
5	14	96.0	55.0	19.0	26.0	0.8	1.3	0.2	0.2	1898035:1721801
2	5	92.0	60.0	24.0	16.0	1.0	1.3	0.1	0.3	1898035:1721801
0	2	96.0	65.0	23.0	12.0	1.0	1.3	0.1	0.3	1898035:1721801
170	200	37.0	75.0	10.0	15.0	0.3	1.6	0.1	0.2	1898035:1721801
60	152	40.0	65.0	15.0	20.0	0.3	1.5	0.1	0.2	1898037:1716146
30	60	74.0	65.0	11.0	24.0	0.8	1.4	0.1	0.2	1898037:1716146
13	30	74.0	65.0	9.0	26.0	0.8	1.4	0.1	0.2	1898037:1716146

hzdept	hzdepb	sieveno10	sandtotal	silttotal	claytotal	om	dbthirdb	awc	kffact	cokey
3	13	74.0	65.0	19.0	16.0	1.5	1.3	0.1	0.2	1898037:1716146
0	3	42.0	65.0	22.0	13.0	1.5	1.3	0.1	0.2	1898037:1716146
155	170	100.0	70.0	18.0	12.0	0.2	1.6	0.1	0.3	1898037:1716335
32	155	100.0	65.0	15.0	20.0	0.2	1.5	0.1	0.2	1898037:1716335
16	32	100.0	65.0	7.0	28.0	0.3	1.3	0.2	0.2	1898037:1716335
4	16	44.0	55.0	3.0	42.0	0.8	1.3	0.1	0.2	1898037:1716335
2	4	63.0	60.0	4.0	36.0	1.3	1.3	0.1	0.2	1898037:1716335
0	2	15.0	65.0	13.0	22.0	1.3	1.2	0.0	0.2	1898037:1716335
130	200	76.0	35.0	39.0	26.0	0.2	1.5	0.1	0.4	1903412:1716409
90	130	100.0	35.0	39.0	26.0	0.2	1.5	0.1	0.4	1903412:1716409
57	90	100.0	25.0	37.0	38.0	0.2	1.4	0.1	0.3	1903412:1716409
4	57	100.0	25.0	35.0	40.0	0.8	1.2	0.1	0.3	1903412:1716409
0	4	100.0	30.0	42.0	28.0	1.3	1.2	0.1	0.4	1903412:1716409
98	170	92.0	70.0	18.0	12.0	0.2	1.6	0.1	0.2	1903412:1716408
35	98	100.0	65.0	15.0	20.0	0.2	1.4	0.1	0.2	1903412:1716408

hzdept	hzdepb	sieveno10	sandtotal	silttotal	claytotal	om	dbthirdb	awc	kffact	cokey
5	35	100.0	55.0	21.0	24.0	0.8	1.3	0.1	0.2	1903412:1716408
1	5	100.0	40.0	34.0	26.0	1.3	1.2	0.1	0.3	1903412:1716408
0	1	100.0	35.0	37.0	28.0	1.3	1.2	0.1	0.2	1903412:1716408
104	140	100.0	60.0	32.0	8.0	0.2	1.6	0.1	0.4	1906355:1721723
48	78	96.0	60.0	16.0	24.0	0.2	1.4	0.2	0.2	1906355:1721723
27	48	96.0	60.0	18.0	22.0	0.3	1.4	0.2	0.2	1906355:1721723
5	27	96.0	50.0	23.0	27.0	0.8	1.4	0.2	0.2	1906355:1721723
0	5	98.0	70.0	23.0	7.0	1.3	1.3	0.1	0.3	1906355:1721723
0	4	72.0	70.0	20.0	10.0	1.3	1.3	0.1	0.2	1906355:1777123
4	11	45.0	70.0	20.0	10.0	1.3	1.3	0.1	0.3	1906355:1777123
11	21	73.0	60.0	14.0	26.0	0.8	1.4	0.1	0.2	1906355:1777123
21	40	67.0	60.0	15.0	25.0	0.3	1.4	0.1	0.2	1906355:1777123
40	78	73.0	45.0	30.0	25.0	0.2	1.4	0.1	0.3	1906355:1777123
140	200	100.0	80.0	15.0	5.0	0.2	1.7	0.1	0.3	1906355:1721723
110	200	97.0	45.0	34.0	21.0	0.2	1.6	0.2	0.4	1906355:1721802

hzdept	hzdepb	sieveno10	sandtotal	silttotal	claytotal	om	dbthirdb	awc	kffact	cokey
87	110	84.0	55.0	21.0	24.0	0.2	1.6	0.2	0.2	1906355:1721802
5	24	54.0	45.0	29.0	26.0	0.8	1.4	0.1	0.3	1906355:1721802
0	5	58.0	70.0	20.0	10.0	1.3	1.3	0.1	0.3	1906355:1721802
78	104	100.0	45.0	31.0	24.0	0.2	1.5	0.2	0.3	1906355:1721723
117	200	25.0	50.0	26.0	24.0	0.2	1.5	0.1	0.3	1906355:1777123
78	117	48.0	50.0	22.0	28.0	0.2	1.5	0.1	0.2	1906355:1777123
66	87	49.0	55.0	19.0	26.0	0.2	1.5	0.1	0.2	1906355:1721802
33	66	36.0	45.0	31.0	24.0	0.3	1.4	0.1	0.3	1906355:1721802
24	33	67.0	55.0	19.0	26.0	0.3	1.4	0.1	0.2	1906355:1721802
120	200	100.0	25.0	20.0	55.0	0.2	1.4	0.1	0.2	2233653:1759879
48	70	100.0	8.0	42.0	50.0	0.3	1.3	0.0	0.3	2233653:1759879
12	48	100.0	15.0	47.0	38.0	0.8	1.2	0.0	0.4	2233653:1759879
0	12	100.0	15.0	51.0	34.0	1.3	1.1	0.2	0.4	2233653:1759879
95	150	100.0	40.0	28.0	32.0	0.2	1.5	0.1	0.3	2233653:1759878
27	95	100.0	40.0	30.0	30.0	0.2	1.4	0.2	0.3	2233653:1759878

hzdept	hzdepb	sieveno10	sandtotal	silttotal	claytotal	om	dbthirdb	awc	kffact	cokey
10	27	100.0	40.0	30.0	30.0	0.8	1.4	0.2	0.3	2233653:1759878
0	10	100.0	40.0	36.0	24.0	1.3	1.2	0.2	0.4	2233653:1759878
150	200	100.0	40.0	31.0	29.0	0.2	1.5	0.1	0.3	2233653:1759878
70	120	100.0	25.0	20.0	55.0	0.2	1.4	0.1	0.2	2233653:1759879
70	200	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2233700:1760938
40	70	68.0	40.0	36.0	24.0	0.3	1.4	0.1	0.4	2233700:1760938
23	40	57.0	40.0	36.0	24.0	0.3	1.4	0.1	0.4	2233700:1760938
8	23	74.0	40.0	36.0	24.0	0.3	1.4	0.1	0.4	2233700:1760938
0	8	90.0	70.0	20.0	10.0	1.5	1.3	0.1	0.3	2233700:1760938
80	200	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2233700:1813848
50	80	50.0	35.0	42.0	23.0	0.3	1.4	0.1	0.4	2233700:1813848
34	50	56.0	35.0	37.0	28.0	0.3	1.4	0.1	0.4	2233700:1813848
21	34	73.0	40.0	30.0	30.0	0.8	1.4	0.2	0.3	2233700:1813848
5	21	81.0	40.0	30.0	30.0	0.8	1.4	0.2	0.3	2233700:1813848
0	5	79.0	40.0	41.0	19.0	1.5	1.2	0.2	0.4	2233700:1813848

hzdept	hzdepb	sieveno10	sandtotal	silttotal	claytotal	om	dbthirdb	awc	kffact	cokey
100	120	58.0	75.0	10.0	15.0	0.2	1.6	0.1	0.3	2233706:1766927
60	100	85.0	75.0	10.0	15.0	0.2	1.6	0.1	0.2	2233706:1766927
43	60	84.0	75.0	9.0	16.0	0.3	1.5	0.1	0.2	2233706:1766927
8	43	96.0	75.0	9.0	16.0	0.8	1.5	0.1	0.2	2233706:1766927
0	8	100.0	75.0	17.0	8.0	1.3	1.3	0.1	0.2	2233706:1766927
120	200	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2233706:1837403
100	120	76.0	85.0	11.0	4.0	0.2	1.7	0.1	0.3	2233706:1837403
70	100	99.0	85.0	9.0	6.0	0.2	1.7	0.1	0.2	2233706:1837403
48	70	93.0	85.0	9.0	6.0	0.2	1.6	0.1	0.2	2233706:1837403
0	6	97.0	85.0	9.0	6.0	1.3	1.4	0.1	0.2	2233706:1837403
6	48	93.0	85.0	9.0	6.0	0.8	1.6	0.1	0.2	2233706:1837403
120	200	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2233706:1766927
81	152	95.0	35.0	36.0	29.0	0.2	1.5	0.2	0.3	2233708:1762678
30	81	95.0	60.0	14.0	26.0	0.2	1.5	0.2	0.2	2233708:1762678
20	30	94.0	60.0	16.0	24.0	0.3	1.3	0.2	0.2	2233708:1762678

hzdept	hzdepb	sieveno10	sandtotal	silttotal	claytotal	om	dbthirdb	awc	kffact	cokey
7	20	87.0	60.0	19.0	21.0	0.8	1.3	0.2	0.2	2233708:1762678
0	7	90.0	65.0	27.0	8.0	1.3	1.2	0.1	0.3	2233708:1762678
86	152	100.0	70.0	24.0	6.0	0.2	1.6	0.1	0.4	2233708:1762677
60	86	34.0	70.0	15.0	15.0	0.2	1.6	0.1	0.2	2233708:1762677
22	60	45.0	70.0	13.0	17.0	0.2	1.6	0.1	0.2	2233708:1762677
9	22	64.0	70.0	14.0	16.0	0.8	1.6	0.1	0.2	2233708:1762677
0	9	66.0	70.0	16.0	14.0	1.3	1.3	0.1	0.2	2233708:1762677
132	200	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2233708:1762676
90	132	85.0	80.0	15.0	5.0	0.2	1.7	0.1	0.3	2233708:1762676
74	90	76.0	80.0	14.0	6.0	0.2	1.7	0.1	0.2	2233708:1762676
28	74	48.0	75.0	15.0	10.0	0.2	1.6	0.1	0.3	2233708:1762676
8	28	40.0	75.0	10.0	15.0	0.8	1.4	0.1	0.2	2233708:1762676
0	8	40.0	80.0	12.0	8.0	1.3	1.4	0.1	0.2	2233708:1762676
165	200	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2370699:1761086
60	140	100.0	90.0	8.0	2.0	0.3	1.7	0.1	0.1	2370699:1761086

hzdept	hzdepb	sieveno10	sandtotal	silttotal	claytotal	om	dbthirdb	awc	kffact	cokey
10	60	100.0	80.0	15.0	5.0	0.8	1.6	0.1	0.2	2370699:1761086
0	10	100.0	80.0	15.0	5.0	1.3	1.4	0.1	0.2	2370699:1761086
130	200	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2370699:1761085
90	130	100.0	80.0	15.0	5.0	0.2	1.7	0.1	0.3	2370699:1761085
53	90	100.0	80.0	13.0	7.0	0.2	1.7	0.1	0.2	2370699:1761085
20	53	100.0	70.0	18.0	12.0	0.2	1.5	0.1	0.2	2370699:1761085
7	20	100.0	70.0	18.0	12.0	0.3	1.5	0.1	0.2	2370699:1761085
0	7	100.0	80.0	15.0	5.0	1.3	1.4	0.1	0.2	2370699:1761085
140	165	100.0	80.0	14.0	6.0	0.2	1.7	0.1	0.4	2370699:1761086
0	5	96.0	45.0	30.0	25.0	1.3	1.2	0.2	0.2	2378529:1775773
5	27	97.0	40.0	26.0	34.0	0.8	1.3	0.2	0.3	2378529:1775773
27	60	97.0	55.0	17.0	28.0	0.3	1.3	0.2	0.2	2378529:1775773
60	112	97.0	40.0	28.0	32.0	0.2	1.5	0.2	0.3	2378529:1775773
112	200	97.0	55.0	21.0	24.0	0.2	1.5	0.2	0.2	2378529:1775773
145	200	100.0	55.0	35.0	10.0	0.2	1.6	0.1	0.4	2378529:1775766

hzdept	hzdepb	sieveno10	sandtotal	silttotal	claytotal	om	dbthirdb	awc	kffact	cokey
70	145	100.0	40.0	38.0	22.0	0.2	1.5	0.2	0.4	2378529:1775766
36	70	100.0	45.0	30.0	25.0	0.3	1.4	0.2	0.3	2378529:1775766
24	36	100.0	55.0	30.0	15.0	0.8	1.5	0.1	0.4	2378529:1775766
8	24	100.0	50.0	32.0	18.0	1.3	1.2	0.2	0.4	2378529:1775766
0	8	100.0	60.0	25.0	15.0	1.3	1.4	0.1	0.3	2378529:1775766
95	200	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2424399:1811698
65	95	100.0	60.0	24.0	16.0	0.2	1.5	0.1	0.3	2424399:1811698
34	65	100.0	43.0	31.0	26.0	0.2	1.3	0.1	0.3	2424399:1811698
6	34	73.0	45.0	32.0	23.0	0.8	1.3	0.1	0.3	2424399:1811698
0	6	68.0	45.0	34.0	21.0	1.3	1.1	0.1	0.3	2424399:1811698
115	200	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2424399:1813138
95	115	45.0	35.0	35.0	30.0	0.2	1.5	0.1	0.3	2424399:1813138
65	95	67.0	40.0	26.0	34.0	0.2	1.5	0.1	0.2	2424399:1813138
22	65	70.0	40.0	33.0	27.0	0.3	1.4	0.1	0.3	2424399:1813138
8	22	80.0	45.0	30.0	25.0	0.8	1.4	0.1	0.3	2424399:1813138

hzdept	hzdepb	sieveno10	sandtotal	silttotal	claytotal	om	dbthirdb	awc	kffact	cokey
0	8	74.0	45.0	40.0	15.0	1.3	1.3	0.1	0.4	2424399:1813138
100	200	77.0	55.0	22.0	23.0	0.2	1.5	0.1	0.3	2424645:1812580
60	100	90.0	40.0	34.0	26.0	0.2	1.3	0.2	0.4	2424645:1812580
8	60	90.0	40.0	32.0	28.0	0.8	1.3	0.2	0.3	2424645:1812580
0	8	88.0	40.0	39.0	21.0	1.3	1.1	0.2	0.4	2424645:1812580
120	200	83.0	55.0	24.0	21.0	0.2	1.4	0.1	0.3	2424645:1812629
46	120	71.0	55.0	27.0	18.0	0.2	1.4	0.1	0.3	2424645:1812629
10	46	68.0	55.0	24.0	21.0	0.3	1.2	0.1	0.3	2424645:1812629
0	10	78.0	65.0	20.0	15.0	1.3	1.2	0.1	0.2	2424645:1812629
0	12	88.0	65.0	19.0	16.0	1.3	1.3	0.1	0.2	2425124:1813454
12	20	67.0	40.0	37.0	23.0	0.8	1.4	0.1	0.4	2425124:1813454
20	66	82.0	40.0	36.0	24.0	0.2	1.4	0.2	0.4	2425124:1813454
66	106	100.0	40.0	36.0	24.0	0.2	1.5	0.2	0.4	2425124:1813454
106	150	100.0	55.0	23.0	22.0	0.2	1.5	0.2	0.3	2425124:1813454
150	182	100.0	55.0	23.0	22.0	0.2	1.5	0.2	0.3	2425124:1813454

hzdept	hzdepb	sieveno10	sandtotal	silttotal	claytotal	om	dbthirdb	awc	kffact	cokey
182	200	100.0	55.0	19.0	26.0	0.2	1.5	0.2	0.2	2425124:1813454
0	8	74.0	65.0	17.0	18.0	1.3	1.3	0.1	0.2	2425124:1813639
8	22	61.0	60.0	22.0	18.0	0.8	1.5	0.1	0.2	2425124:1813639
22	33	52.0	60.0	29.0	11.0	0.2	1.5	0.1	0.3	2425124:1813639
33	80	54.0	60.0	30.0	10.0	0.2	1.6	0.1	0.3	2425124:1813639
80	200	55.0	80.0	15.0	5.0	0.2	1.7	0.0	0.2	2425124:1813639
0	6	98.0	65.0	20.0	15.0	1.3	1.3	0.1	0.3	2426357:1816739
6	24	95.0	40.0	36.0	24.0	0.8	1.4	0.2	0.3	2426357:1816739
24	34	92.0	60.0	14.0	26.0	0.3	1.4	0.2	0.2	2426357:1816739
34	60	71.0	60.0	13.0	27.0	0.2	1.4	0.1	0.2	2426357:1816739
60	200	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2426357:1816739
39	200	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2426357:1816747
22	39	60.0	45.0	31.0	24.0	0.2	1.4	0.1	0.4	2426357:1816747
8	22	80.0	45.0	29.0	26.0	0.3	1.4	0.1	0.4	2426357:1816747
0	8	95.0	40.0	37.0	23.0	1.3	1.2	0.2	0.4	2426357:1816747

hzdept	hzdepb	sieveno10	sandtotal	silttotal	claytotal	om	dbthirdb	awc	kffact	cokey
146	200	100.0	40.0	30.0	30.0	0.2	1.5	0.2	0.3	2426357:1816746
83	146	100.0	40.0	29.0	31.0	0.2	1.5	0.2	0.3	2426357:1816746
43	83	100.0	40.0	29.0	31.0	0.3	1.5	0.2	0.3	2426357:1816746
8	43	99.0	40.0	30.0	30.0	0.8	1.4	0.2	0.3	2426357:1816746
0	8	99.0	40.0	36.0	24.0	1.3	1.2	0.2	0.3	2426357:1816746
180	200	100.0	40.0	26.0	34.0	0.2	1.5	0.1	0.2	2426395:1817129
150	180	100.0	15.0	40.0	45.0	0.2	1.4	0.1	0.3	2426395:1817129
94	150	100.0	30.0	34.0	36.0	0.2	1.4	0.1	0.3	2426395:1817129
60	94	46.0	40.0	30.0	30.0	0.2	1.4	0.1	0.3	2426395:1817129
28	60	46.0	40.0	33.0	27.0	0.3	1.4	0.1	0.3	2426395:1817129
8	28	46.0	45.0	33.0	22.0	0.8	1.4	0.1	0.3	2426395:1817129
0	8	45.0	65.0	23.0	12.0	1.3	1.3	0.1	0.3	2426395:1817129
90	200	100.0	40.0	37.0	23.0	0.2	1.6	0.0	0.0	2426413:1817248
30	90	100.0	40.0	37.0	23.0	0.2	1.4	0.1	0.4	2426413:1817249
0	6	100.0	80.0	14.0	6.0	1.5	1.4	0.1	0.3	2426474:1817368

hzdept	hzdepb	sieveno10	sandtotal	silttotal	claytotal	om	dbthirdb	awc	kffact	cokey
6	22	100.0	80.0	14.0	6.0	0.3	1.6	0.1	0.3	2426474:1817368
22	38	100.0	80.0	12.0	8.0	0.3	1.6	0.1	0.2	2426474:1817368
38	200	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2426474:1817368
27	200	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2426558:1817452
6	27	100.0	40.0	37.0	23.0	0.2	1.4	0.0	0.4	2426558:1817452
0	6	100.0	40.0	37.0	23.0	1.3	1.2	0.1	0.4	2426558:1817452
85	200	100.0	70.0	13.0	17.0	0.2	1.6	0.1	0.2	2427888:1820877
25	65	100.0	60.0	16.0	24.0	0.2	1.5	0.2	0.2	2427888:1820877
18	25	100.0	60.0	16.0	24.0	0.8	1.4	0.2	0.2	2427888:1820877
4	18	100.0	60.0	13.0	27.0	1.3	1.4	0.2	0.2	2427888:1820877
0	4	100.0	60.0	13.0	27.0	70.0	0.2	0.3	0.0	2427888:1820877
65	85	100.0	70.0	15.0	15.0	0.2	1.6	0.1	0.2	2427888:1820877
120	200	64.0	70.0	12.0	18.0	0.2	1.6	0.1	0.2	2427892:1822759
70	120	84.0	70.0	13.0	17.0	0.2	1.6	0.1	0.2	2427892:1822759
37	70	82.0	65.0	11.0	24.0	0.3	1.4	0.1	0.2	2427892:1822759

hzdept	hzdepb	sieveno10	sandtotal	silttotal	claytotal	om	dbthirdb	awc	kffact	cokey
20	37	82.0	65.0	12.0	23.0	0.8	1.4	0.1	0.2	2427892:1822759
8	20	82.0	70.0	16.0	14.0	1.3	1.3	0.1	0.2	2427892:1822759
0	8	82.0	70.0	18.0	12.0	1.3	1.3	0.1	0.3	2427892:1822759
64	200	95.0	65.0	19.0	16.0	0.2	1.6	0.1	0.3	2427932:1820888
31	64	94.0	65.0	14.0	21.0	0.2	1.4	0.2	0.2	2427932:1820888
5	31	94.0	65.0	12.0	23.0	0.8	1.4	0.2	0.2	2427932:1820888
0	5	94.0	65.0	19.0	16.0	1.3	1.3	0.1	0.3	2427932:1820888
120	200	100.0	65.0	18.0	17.0	0.2	1.6	0.1	0.2	2427932:1820887
10	120	100.0	90.0	7.0	3.0	0.2	1.7	0.1	0.1	2427932:1820887
0	10	100.0	90.0	9.0	1.0	1.3	1.4	0.1	0.1	2427932:1820887
26	200	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2427933:1820717
11	26	100.0	35.0	35.0	30.0	0.2	1.4	0.1	0.4	2427933:1820717
0	11	100.0	35.0	33.0	32.0	1.3	1.2	0.1	0.3	2427933:1820717
0	7	100.0	85.0	7.0	8.0	1.3	1.4	0.0	0.2	2427933:1820719
7	28	100.0	85.0	5.0	10.0	0.8	1.6	0.0	0.2	2427933:1820719

hzdept	hzdepb	sieveno10	sandtotal	silttotal	claytotal	om	dbthirdb	awc	kffact	cokey
28	48	100.0	85.0	7.0	8.0	0.2	1.7	0.0	0.1	2427933:1820719
48	200	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2427933:1820719
0	7	96.0	75.0	13.0	12.0	1.3	1.4	0.1	0.2	2514542:1958303
7	46	96.0	65.0	15.0	20.0	0.8	1.4	0.2	0.2	2514542:1958303
46	65	96.0	65.0	17.0	18.0	0.3	1.5	0.1	0.2	2514542:1958303
65	120	97.0	75.0	7.0	18.0	0.2	1.6	0.1	0.2	2514542:1958303
120	200	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2514542:1958303
0	6	82.0	70.0	14.0	16.0	1.3	1.3	0.1	0.2	2514542:1958304
6	30	96.0	60.0	18.0	22.0	0.8	1.4	0.2	0.2	2514542:1958304
30	48	67.0	45.0	34.0	21.0	0.2	1.4	0.1	0.4	2514542:1958304
48	69	66.0	45.0	35.0	20.0	0.2	1.5	0.1	0.4	2514542:1958304
69	115	95.0	45.0	35.0	20.0	0.2	1.5	0.2	0.4	2514542:1958304
115	205	98.0	45.0	36.0	19.0	0.2	1.5	0.2	0.4	2514542:1958304
0	10	100.0	35.0	40.0	25.0	1.3	1.2	0.2	0.2	2514543:1958308
10	25	100.0	35.0	36.0	29.0	0.8	1.4	0.2	0.3	2514543:1958308

hzdept	hzdepb	sieveno10	sandtotal	silttotal	claytotal	om	dbthirdb	awc	kffact	cokey
25	110	100.0	35.0	41.0	24.0	0.2	1.5	0.1	0.4	2514543:1958308
110	200	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2514543:1958308
0	6	90.0	65.0	18.0	17.0	1.3	1.3	0.1	0.2	2514543:1958309
6	22	100.0	35.0	39.0	26.0	0.8	1.4	0.2	0.3	2514543:1958309
22	31	100.0	35.0	41.0	24.0	0.3	1.4	0.2	0.4	2514543:1958309
31	51	100.0	45.0	32.0	23.0	0.2	1.5	0.1	0.3	2514543:1958309
51	130	100.0	45.0	32.0	23.0	0.2	1.5	0.1	0.3	2514543:1958309
130	200	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2514543:1958309
0	12	100.0	50.0	35.0	15.0	1.3	1.2	0.2	0.4	2514543:1958310
12	35	100.0	50.0	37.0	13.0	0.8	1.4	0.2	0.4	2514543:1958310
35	75	100.0	50.0	34.0	16.0	0.3	1.4	0.2	0.4	2514543:1958310
75	120	100.0	50.0	31.0	19.0	0.2	1.5	0.2	0.4	2514543:1958310
120	200	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2514543:1958310
0	9	91.0	35.0	44.0	21.0	1.3	1.2	0.2	0.4	2514544:1958312
9	36	92.0	40.0	34.0	26.0	0.8	1.4	0.2	0.3	2514544:1958312

hzdept	hzdepb	sieveno10	sandtotal	silttotal	claytotal	om	dbthirdb	awc	kffact	cokey
36	58	92.0	40.0	40.0	20.0	0.2	1.4	0.2	0.4	2514544:1958312
58	108	39.0	45.0	39.0	16.0	0.2	1.5	0.1	0.4	2514544:1958312
108	200	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2514544:1958312
0	10	100.0	70.0	17.0	13.0	1.3	1.3	0.1	0.1	2514544:1958313
10	24	100.0	70.0	14.0	16.0	0.8	1.5	0.1	0.2	2514544:1958313
24	40	100.0	80.0	13.0	7.0	0.3	1.6	0.1	0.2	2514544:1958313
40	75	100.0	70.0	19.0	11.0	0.2	1.5	0.1	0.2	2514544:1958313
75	85	100.0	80.0	12.0	8.0	0.2	1.7	0.1	0.3	2514544:1958313
85	100	100.0	80.0	15.0	5.0	0.2	1.7	0.1	0.3	2514544:1958313
100	200	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2514544:1958313
0	7	81.0	35.0	40.0	25.0	1.3	1.2	0.1	0.2	2514544:1958314
7	50	54.0	35.0	44.0	21.0	0.3	1.4	0.1	0.4	2514544:1958314
50	90	35.0	35.0	48.0	17.0	0.2	1.5	0.1	0.4	2514544:1958314
90	110	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2514544:1958314
0	4	94.0	70.0	17.0	13.0	1.3	1.3	0.1	0.2	2514545:1958317

hzdept	hzdepb	sieveno10	sandtotal	silttotal	claytotal	om	dbthirdb	awc	kffact	cokey
4	13	91.0	45.0	35.0	20.0	0.8	1.4	0.2	0.4	2514545:1958317
13	74	44.0	45.0	37.0	18.0	0.3	1.4	0.1	0.4	2514545:1958317
74	120	96.0	15.0	57.0	28.0	0.2	1.4	0.2	0.5	2514545:1958317
120	200	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2514545:1958317
0	15	100.0	85.0	7.0	8.0	1.3	1.4	0.1	0.1	2514547:1958323
15	45	100.0	85.0	11.0	4.0	1.3	1.6	0.1	0.3	2514547:1958323
45	90	100.0	55.0	19.0	26.0	0.8	1.5	0.2	0.2	2514547:1958323
90	145	100.0	55.0	22.0	23.0	0.2	1.5	0.2	0.3	2514547:1958323
145	200	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2514547:1958323
0	7	96.0	65.0	16.0	19.0	1.3	1.3	0.1	0.2	2514547:1958324
7	40	96.0	55.0	13.0	32.0	0.8	1.4	0.2	0.2	2514547:1958324
40	75	100.0	55.0	27.0	18.0	0.3	1.5	0.1	0.3	2514547:1958324
40	85	100.0	70.0	4.0	26.0	0.2	1.5	0.2	0.2	2514547:1958324
85	200	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2514547:1958324

C.3 Soil Look Up Table

From the averaged layers and percentage composition of soils for each map unit, a texture is determined from the chtexturegrp table (SSURGO data) and from the layer table (STATSGO data). From this texture, the other SWAT and KINEROS parameters are estimated in AGWA using these look up values (kin-lut.dbf) provided in the AGWA 2.0 data files. The table is used to obtain the necessary soil parameters not found in the soils databases. Several soil parameters are modified by AGWA2 to avoid errors or improve estimates.

Field descriptions:

KS: Saturated hydraulic conductivity (mm/hr)

G: Net capillary drive (mm)

Por: porosity (cm3/cm3)

Smax: Maximum relative soil saturation (0-1)

Cv: Coefficient of variation of KS

Sand: Fractional sand content (0-1)

Silt: Fractional silt content (0-1)

Clay: Fractional clay content (0-1)

Dist: Pore size distribution index

Kff: soil erodibility factor (0-1)

TEXTURE	KS	G	POR	SR	SMAX	WILTING	CV	SAND	SILT	CLAY	DIST	KFF
C	0.6	407.0	0.5	0.2	0.8	0.6	0.5	27.0	23.0	50.0	0.2	0.3
CBV	210.0	46.0	0.4	0.0	1.0	0.1	0.7	91.0	1.0	8.0	0.7	0.1
CEM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3
CIND	210.0	46.0	0.4	0.0	1.0	0.1	0.7	91.0	1.0	8.0	0.7	0.0
CL	2.3	259.0	0.5	0.2	0.8	0.4	0.9	32.0	34.0	34.0	0.2	0.4
COS	210.0	46.0	0.4	0.0	1.0	0.1	0.7	91.0	1.0	8.0	0.7	0.2
COSL	26.0	127.0	0.5	0.1	0.9	0.2	1.9	65.0	23.0	12.0	0.4	0.2
FB	0.6	407.0	0.5	0.2	0.8	0.6	0.5	27.0	23.0	50.0	0.2	0.1
FRAG	210.0	46.0	0.4	0.0	1.0	0.1	0.7	91.0	1.0	8.0	0.7	0.1
FS	210.0	46.0	0.4	0.0	1.0	0.1	0.7	91.0	1.0	8.0	0.7	0.2

TEXTURE	KS	G	POR	SR	SMAX	WILTING	CV	SAND	SILT	CLAY	DIST	KFF
FSL	26.0	127.0	0.5	0.1	0.9	0.2	1.9	65.0	23.0	12.0	0.4	0.4
G	210.0	46.0	0.4	0.0	1.0	0.1	0.7	27.0	23.0	50.0	0.2	0.2
GYP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
HM	0.6	407.0	0.5	0.2	0.8	0.6	0.5	27.0	23.0	50.0	0.2	0.0
ICE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
IND	0.3	100.0	0.2	0.0	0.3	0.0	0.2	0.0	0.0	0.0	0.0	0.3
L	13.0	108.0	0.5	0.1	0.9	0.3	0.4	42.0	39.0	19.0	0.3	0.4
LCOS	61.0	63.0	0.4	0.1	0.9	0.1	0.9	83.0	7.0	10.0	0.6	0.2
LFS	61.0	63.0	0.4	0.1	0.9	0.1	0.9	83.0	7.0	10.0	0.6	0.3
LS	61.0	63.0	0.4	0.1	0.9	0.1	0.9	83.0	7.0	10.0	0.6	0.2
LVFS	61.0	63.0	0.4	0.1	0.9	0.1	0.9	83.0	7.0	10.0	0.6	0.4
MUCK	0.6	407.0	0.5	0.2	0.8	0.6	0.5	27.0	23.0	50.0	0.2	0.0
PC	26.0	127.0	0.5	0.1	0.9	0.2	1.9	65.0	23.0	12.0	0.4	0.3
PEAT	0.6	407.0	0.5	0.2	0.8	0.6	0.5	27.0	23.0	50.0	0.2	0.0
S	210.0	46.0	0.4	0.0	1.0	0.1	0.7	91.0	1.0	8.0	0.7	0.2
SC	1.2	302.0	0.4	0.3	0.8	0.6	1.0	50.0	4.0	46.0	0.3	0.4
SCL	4.3	263.0	0.4	0.2	0.8	0.4	0.6	59.0	11.0	30.0	0.4	0.4
SI	3.0	260.0	0.5	0.2	0.9	0.5	0.6	8.0	81.0	11.0	0.1	0.4
SIC	0.9	375.0	0.5	0.1	0.9	0.5	0.9	9.0	45.0	46.0	0.2	0.3
SICL	1.5	345.0	0.5	0.1	0.9	0.4	0.5	12.0	54.0	34.0	0.2	0.4
SIL	6.8	203.0	0.5	0.0	1.0	0.3	0.5	23.0	61.0	16.0	0.2	0.5
SL	26.0	127.0	0.5	0.1	0.9	0.2	1.9	65.0	23.0	12.0	0.4	0.3
SPM	0.6	407.0	0.5	0.2	0.8	0.6	0.5	27.0	23.0	50.0	0.2	0.0
SR	26.0	127.0	0.5	0.1	0.9	0.2	1.9	65.0	23.0	12.0	0.4	0.3

TEXTURE	KS	G	POR	SR	SMAX	WILTING	CV	SAND	SILT	CLAY	DIST	KFF
UWB	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
VAR	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6
VFS	210.0	46.0	0.4	0.0	1.0	0.1	0.7	91.0	1.0	8.0	0.7	0.5
VFSL	26.0	127.0	0.5	0.1	0.9	0.2	1.9	65.0	23.0	12.0	0.4	0.5
WB	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MPT	0.6	407.0	0.5	0.2	0.8	0.6	0.5	27.0	23.0	50.0	0.2	0.0
COARSE	67.1	92.7	0.4	0.0	0.9	0.1	1.4	75.2	14.2	10.7	0.5	0.3
MEDIUM	9.1	205.7	0.5	0.1	0.9	0.1	0.7	36.6	43.0	20.5	0.3	0.4
FINE	0.8	382.8	0.5	0.0	0.8	0.0	0.6	27.0	25.4	47.6	0.2	0.3
D/SS	210.0	46.0	0.4	0.0	1.0	0.1	0.7	91.0	1.0	8.0	0.7	0.2
SALT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
ROCK	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GLACIER	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
WATER	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NO DATA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

ATTACHMENT D: MODEL INPUT FILES

Both SWAT and KINEROS2 require multiple input files which are generated by AGWA after land cover and soils parameterization and selection of climate inputs. SWAT input files were modified using parameters described in section 4.4; all other inputs, including climate, came with the AGWA 2.0 datafiles and were not modified. KINEROS2 also uses datafiles provided by AGWA 2.0 (see AGWA 2.0 user manual) with the exception of the 25 yr, 24 hour design storm created specifically for Jonah (discussed in section 4.1.3).

D.1 KINEROS2 Design Storm for NPL

```
! Design storm depth acquired from the design storm database dsgnstrm.
! Design storm hyetograph computed using the SCS Methodology with a type II distribution.
! Storm generated for the chap500 watershed.
! Return Period (frequency) = 25 years
! Duration = 24 hours

BEGIN RG1
  SAT = 0.2
  N = 145
  TIME      DEPTH
! (min)     (mm)
  0.00      0.00
 10.00      0.09
 20.00      0.18
 30.00      0.27
 40.00      0.36
 50.00      0.46
 60.00      0.55
 70.00      0.64
 80.00      0.74
 90.00      0.84
100.00      0.94
110.00      1.04
120.00      1.14
130.00      1.24
140.00      1.34
```

150.00	1.45
160.00	1.56
170.00	1.66
180.00	1.77
190.00	1.88
200.00	2.00
210.00	2.11
220.00	2.23
230.00	2.34
240.00	2.46
250.00	2.58
260.00	2.71
270.00	2.83
280.00	2.96
290.00	3.09
300.00	3.22
310.00	3.36
320.00	3.49
330.00	3.63
340.00	3.77
350.00	3.92
360.00	4.07
370.00	4.22
380.00	4.37
390.00	4.53
400.00	4.69
410.00	4.86
420.00	5.03
430.00	5.20
440.00	5.38
450.00	5.56
460.00	5.75
470.00	5.95
480.00	6.15

490.00	6.36
500.00	6.57
510.00	6.79
520.00	7.02
530.00	7.26
540.00	7.51
550.00	7.77
560.00	8.04
570.00	8.32
580.00	8.62
590.00	8.94
600.00	9.27
610.00	9.63
620.00	10.01
630.00	10.43
640.00	10.88
650.00	11.38
660.00	11.94
670.00	12.57
680.00	13.32
690.00	14.24
700.00	15.46
710.00	17.38
720.00	25.40
730.00	33.42
740.00	35.34
750.00	36.56
760.00	37.48
770.00	38.23
780.00	38.86
790.00	39.42
800.00	39.92
810.00	40.37
820.00	40.79

830.00	41.17
840.00	41.53
850.00	41.86
860.00	42.18
870.00	42.48
880.00	42.76
890.00	43.03
900.00	43.29
910.00	43.54
920.00	43.78
930.00	44.01
940.00	44.23
950.00	44.44
960.00	44.65
970.00	44.85
980.00	45.05
990.00	45.24
1000.00	45.42
1010.00	45.60
1020.00	45.77
1030.00	45.94
1040.00	46.11
1050.00	46.27
1060.00	46.43
1070.00	46.58
1080.00	46.73
1090.00	46.88
1100.00	47.03
1110.00	47.17
1120.00	47.31
1130.00	47.44
1140.00	47.58
1150.00	47.71
1160.00	47.84

1170.00	47.97
1180.00	48.09
1190.00	48.22
1200.00	48.34
1210.00	48.46
1220.00	48.57
1230.00	48.69
1240.00	48.80
1250.00	48.92
1260.00	49.03
1270.00	49.14
1280.00	49.24
1290.00	49.35
1300.00	49.46
1310.00	49.56
1320.00	49.66
1330.00	49.76
1340.00	49.86
1350.00	49.96
1360.00	50.06
1370.00	50.16
1380.00	50.25
1390.00	50.34
1400.00	50.44
1410.00	50.53
1420.00	50.62
1430.00	50.71
1440.00	50.80

END

Normally Pressured Lance Natural Gas Development Project

Draft Environmental Impact Statement

Appendix K

Water Resource Support Appendix

NORMALLY PRESSURED LANCE (NPL)

NATURAL GAS DEVELOPMENT PROJECT

WATER RESOURCE SUPPORT APPENDIX

U.S. Department of the Interior
Bureau of Land Management

BLM Pinedale Field Office
P.O. Box 768
1625 West Pine Street
Pinedale, Wyoming 82941

The BLM manages more land – 253 million acres – than any other Federal agency. This land, known as the National System of Public Lands, is primarily located in 12 Western States, including Alaska. The Bureau, with a budget of about $1 billion, also administers 700 million acres of sub-surface mineral estate throughout the nation. The BLM's multiple-use mission is to sustain the health and productivity of the public lands for the use and enjoyment of present and future generations. The Bureau accomplishes this by managing such activities as outdoor recreation, livestock grazing, mineral development, and energy production, and by conserving natural, historical, cultural, and other resources on public lands.

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ACRONYMS AND ABBREVIATIONS

°C	degrees Celsius
µS/cm	micro Siemens per centimeter
AGWA	Automated Geospatial Watershed Assessment
bgs	below ground surface
BLM	Bureau of Land Management
BTEX	Benzene, toluene, ethylbenzene, xylenes
EIS	Environmental Impact Statement
Encana	Oil & Gas (USA) Inc.
EPA	U.S. Environmental Protection Agency
ft. bgs	feet below ground surface
GC/MS	Gas Chromatography/Mass Spectrometry
GGRB	Greater Green River Basin
GPM	Gallons per minute
GRB	Green River Basin
HSU	hydrostratigraphic units
HUC	Hydrologic Unit Code
JIDPA	Jonah Infill Drilling Project Area
MCL	maximum contaminant level
mg/L	milligrams per liter
MSL	mean sea level
NPL	Normally Pressured Lance
PAPA	Pinedale Anticline Project Area
PFC	Proper Functioning Condition
PFO	Pinedale Field Office
RGF	Regional Gathering Facility
ROD	Record of Decision
RSFO	Rock Springs Field Office
SU	standard unit
SVOC	semi-volatile organic compound
TDS	total dissolved solids
TPH-DRO	Total petroleum hydrocarbons – diesel range organics
TPH-GRO	Total petroleum hydrocarbons – gasoline range organics
USDW	Underground source of drinking water
USGS	United States Geological Survey
VOC	volatile organic compound
WDEQ	Wyoming Department of Environmental Quality
WOGCC	Wyoming Oil and Gas Conservation Commission
WSGS	Wyoming State Geological Survey

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1.0 INTRODUCTION

The purpose of this document is to present a targeted analysis of key technical issues associated with water resources to support the description of the affected environment (Chapter 3) and environmental consequences (Chapter 4) for water resources in the Normally Pressured Lance (NPL) Natural Gas Development Project Environmental Impact Statement (EIS). This targeted technical analysis specifically addresses the following NPL Project activities that could result in impacts to water resources:

- Disturbance of surface conditions from construction activities and infrastructure that could affect surface water runoff, infiltration rates, sedimentation, and surface and groundwater quality;
- Removal of groundwater from the top 1,000 feet of the Wasatch Formation, and the potential for depletion of groundwater resources; intrusion of lower quality water; and lowering of the potentiometric surface;
- Injection of formation fluids into the Fort Union Aquifer (4,000 to 8,000 feet below ground surface [bgs]), and the potential for impacts to water quality in shallower aquifers; and
- Loss of drilling fluids and completion fluids into water zones during drilling and well completion operations.

The analysis area for water resources described in this appendix and in the NPL Project EIS includes the following:

- The entire extent of the 15 Hydrologic Unit Code (HUC)-12-digit watersheds that intersect the Project Area, including the surface runoff and channel discharge points identified in Appendix J (*AGWA Technical Report*);
- Aquifers underlying the Project Area and potential migration/transport pathways outside the Project Area; and
- Groundwater at the supply wells that will be used for the NPL Project that are located outside of and within the Project Area, including the area of influence of these wells.

2.0 INFORMATION SOURCES

The Project Area is located in the northern portion of the Green River Basin (GRB), within the Upper Green River and Big Sandy River subbasins in Wyoming. Because of the limited extent of development in the NPL Project Area, limited data have been collected from within the NPL Project Area on geology, water resources, water quality, and hydrogeology.

To support timely completion of the NPL Project EIS, the water resources analysis utilizes readily available existing information from the adjacent Jonah Infill Drilling Project Area (JIDPA) and the Pinedale Anticline Project Area (PAPA), as well as NPL Project Area-specific studies conducted to date, as described below. The project proponent has initiated a voluntary water quality sampling and analysis program to document current water quality in selected wells and springs in the NPL and adjacent areas. The sampling program is ongoing, and data from the program have been provided to the BLM for use in developing the NPL Project EIS. Due to relatively similar geological conditions, it is assumed that conditions in the NPL Project Area would be similar to those in the JIDPA. An NPL Groundwater Monitoring Program will be implemented by the project proponent prior to development to provide additional information on groundwater conditions and to monitor potential impacts resulting from the project. The NPL Groundwater Monitoring Program will be consistent with WOGCC regulations and is different than operator's sampling and analysis program described and referenced in this appendix. The primary information sources used for the NPL Project EIS are described below. Because there has been limited project-area specific data collection, the sources used represent the best available information to evaluate water resources. Limitations of these readily available existing data are described below.

The Groundwater Flow Model and Hydrogeologic Impact Assessment, Jonah Infill Drilling Project (HydroGeo 2004) report summarizes results of a numerical model designed to simulate the regional effect on water resources from pumping groundwater from the Green River/Wasatch aquifer system. The model was based on simulating pumping water supply wells that would also be used to supply groundwater for the NPL Project. The results of this model describe the drawdown of groundwater that would result from removing water for drilling wells for the Jonah Project and approximates the time it would take for groundwater levels to return to normal conditions. The report describing the methods and model results is included as Attachment A (*Groundwater Flow Model and Hydrogeologic Impact Assessment)*. The model domain includes all of the NPL Project Area, with all pumping wells located within the JIDPA. The time frame for the most intense development systems for the JIDPA is 10 years, and intensive water use for the JIDPA is expected to decrease as development for the NPL Project increases.

Groundwater Well Inventory and Assessment in the Area of the Proposed Normally Pressured Lance Natural Gas Development Project, Green River Basin, Wyoming, 2012 (USGS 2013). The United States Geological Survey (USGS), in cooperation with the Bureau of Land Management (BLM), inventoried and assessed existing water wells in and around the NPL Project Area for inclusion in a possible groundwater monitoring network for the NPL Project. The study area encompassed all of the NPL Project Area and extended beyond the analysis area boundary. No water level or water quality samples were collected as part of this investigation. A total of 376 wells were identified in the study area based on available records. Of these, 141 well records contained sufficient information to evaluate the wells. Efforts were made to locate these 141 wells, but only 121 wells were found. Of the 121 wells, 92 met established monitoring well criteria and could potentially be used for the groundwater monitoring program; however, water level measurements could be made in only 79 of these wells. In this report, USGS summarizes the results of its record search and field inspection of these 79 wells. Wells are typically screened across a discrete water-bearing zone or aquifer. USGS reports that four of the 79 wells are screened in the shallow alluvial aquifer, 14 are screened in the Laney Member of the Green River Formation, 49 are screened in the Farson Sandstone Member of the Green River Formation, and 12 spanned three different units of the Wasatch Formation.

Normally Pressured Lance (NPL) Natural Gas Development Project: Modeling the Effects of Surface Disturbance Using the Automated Geospatial Watershed Assessment (AGWA) Tool – Technical Report (BLM 2013a). Results of the AGWA modeling identify areas within the NPL Project Area that would be most susceptible to increased erosion, surface runoff, and sediment transport under the Proposed Project. The model was also used to estimate changes in surface runoff and channel discharge that would result from surface disturbance and infrastructure associated with the NPL Project. Based on this analysis, areas were identified where runoff/erosion monitoring and/or more extensive mitigation activities should be focused, or areas where development should be minimized or avoided. The AGWA model domain includes the full extent of watersheds that intersect the NPL Project Area. The AGWA Technical Report is included in the NPL Project EIS as Appendix J (*AGWA Technical Report*).

Final Hydrogeologic Conceptual Model for the Pinedale Anticline Project Area (PAPA), Sublette County, Wyoming (Geomatrix 2008). Final Technical Report: Hydrogeologic Data Gaps Investigation Interim Plan, PAPA (AMEC 2012), and Numerical Groundwater Modeling Report (AMEC 2013a). These documents present the conceptual model at the PAPA including an overview of water resources; recharge, discharge, and flows; and a description of discrete hydrostratigraphic units within the 308-square-mile PAPA, which lies outside of the NPL Project analysis area. The PAPA differs from the NPL Project Area because it has been in production for many years; it contains surface water resources that interact with the upper aquifer system; and in general, the PAPA is different because it contains a higher percent of sand layers than the NPL due to its proximity to the source area. Hydraulic measurements reflect the best information available at this time, and due to similar geologic conditions, some of the information from this conceptual model, such as general hydrologic characteristics, is relevant to the NPL Project Area. The PAPA is formed by a structural anticline formed by a thrust fault with the northeastern side thrusting upward, whereas the NPL Project Area is a broader basin-centered gas accumulation with little confirmed faulting/fracturing. Surface waters, including the New Fork River, are present within the PAPA. The NPL Project Area has no permanent surface waters. The main hydrostratigraphic units (HSUs) described for the PAPA, as summarized below, are based on the site-specific stratigraphy within the PAPA assessment area. Over time the studies have led to an improved understanding of the hydrostratigraphy, and the delineation of HSUs has changed since 2008. The most recent understanding of the hydrostratigraphic units are described below. There has been no attempt to formally correlate or evaluate these as distinct units in the NPL Project Area.

- **Alluvial HSU**: Groundwater contained in sand and gravel deposits adjacent to the streams and rivers are classified as the Alluvial HSU. The deposits are generally no more than approximately 30 feet thick and are partially saturated. This HSU is hydraulically connected to the underlying Wasatch Formation, as well as to subjacent streams and rivers. Six domestic wells draw from this aquifer in the PAPA. A similar unit is present in the NPL Project Area, but due to the limited areal extent and distance between the NPL and PAPA, the units are unlikely to have a hydraulic connection.
- **Wasatch HSU**: Permeable sandstone units or lenses within the thick shale/siltstone units containing groundwater are described as the Wasatch HSU. Continuous water-bearing sandstone beds have not been documented over large areas because of the fluvial channel architecture of the Wasatch Formation. Groundwater in the Wasatch HSU in the PAPA is found under confined (artesian), semi-confined, and unconfined conditions. Sandstone lenses are not

continuously saturated, and in some areas perched groundwater may discharge locally to springs. The PAPA model does not provide a total depth or thickness of the HSU, but notes that the maximum depth of industrial wells within the Wasatch HSU is 1,210 feet. The stratigraphy and groundwater conditions of the Wasatch HSU at the PAPA are similar to those at the NPL Project Area. The Wasatch HSU is equivalent to the Wasatch Aquifer, as used in the NPL Project EIS and in this appendix. Within the PAPA, the Wasatch HSU has a greater net thickness of sand layers (Bartos and Hallberg 2010) and occurs at ground surface. In the southern part of the NPL Project Area, the Wasatch Aquifer underlies the Laney Aquifer.

- **Fort Union HSU:** Found in both the PAPA and the NPL Project Area; the Fort Union HSU is the target zone for formation fluids injection in both fields. The Fort Union Aquifer was not part of the PAPA numerical model.

The PAPA reports cited above do not include analysis or information relating to faulting or fracturing that could result in vertical migration pathways.

Evaluation of Potential Sources of Low Level Petroleum Hydrocarbon Compounds Detected in Groundwater, Interim Plan, Pinedale Anticline Project Area Record of Decision (ROD), Sublette County, Wyoming (AMEC 2013b). This report evaluates potential sources of low level hydrocarbon contamination identified in several water supply wells within the PAPA. This report builds upon previously completed aquifer characterization and numerical modeling studies in the PAPA and includes extensive sampling and analysis of water supply wells and potential source materials including flowback fluid, oil-based drilling mud, condensate, produced water, light nonaqueous-phase liquid, water supply well pump materials, and carbonaceous shale.

The investigation identified no evidence of widespread impacts to groundwater in the PAPA due to natural gas exploration and production activities. It identified the following known or potential sources of low levels of petroleum hydrocarbons in water wells:

- Upward seepage by natural processes of natural gas from deep, underlying gas reservoirs over time into overlying geologic layers where groundwater occurs;
- Organic constituents introduced into water wells during drilling, installation, and operation of natural gas wells; and
- Naturally occurring organic matter in groundwater or associated with particles suspended in water wells during sample collection.

Water supply wells to be used for the NPL Project may have been constructed or operated under similar conditions as those at the PAPA, and the potential for petroleum hydrocarbon contamination is possible by the same mechanisms.

NPL Project Sampling and Analysis Annual Reports (Trihydro 2011, 2013, 2014a, 2014b).[1] The operator for the NPL Project retained Trihydro Corporation (Trihydro) to conduct annual, project-specific water sampling and laboratory analysis from existing wells and springs within and adjacent to the NPL Project Area in 2011, 2012, 2013, and 2014 with on-going additional sampling and analysis. The purpose of the sampling and analysis is to document the water quality in the existing wells and springs prior to development of natural gas resources in the NPL Project Area and subsequently to provide indication of any changes to the quality of the water after development has begun. Although these are tests of water

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[1] Note that the dates referenced are the publication dates of the sampling and analysis reports. The actual sampling and analysis was conducted annually in 2011, 2012, 2013 and 2014.

quality in existing wells and springs, it is important to note that these are not monitoring wells and results may not reflect actual groundwater conditions. These annual sampling and analysis activities will be on-going throughout the project, with potential changes to locations of sampled wells in response to the NPL Project Record of Decision (ROD), pending groundwater monitoring plans for the NPL Project and other factors. The operator, in coordination with the BLM and other entities will develop and implement a groundwater monitoring program prior to initiating development to provide additional information on groundwater conditions.

Water samples were analyzed for general water quality parameters, total metals, and organic contaminants including volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), dissolved gases, alcohols, glycols, radiochemicals, total petroleum hydrocarbons, and aldehydes. Results indicate overall good groundwater quality and are further discussed within this report.

When available, information on well installation and boring logs was collected and reviewed to help understand the stratigraphy and the aquifer in which the wells were screened. An initial groundwater characterization was performed by Trihydro (2013) and determined that of the 26 wells that were located, four were determined to be screened in the alluvial aquifer based primarily on their shallow depths and unconfined conditions. Consistent with the very limited occurrence of the alluvial aquifer in the NPL Project Area, only one of the alluvial wells is located within the NPL Project Area and the remaining three shallow wells are located outside the Project Area. Measured depths of the remaining 22 wells were 210 to 1,573 feet bgs, indicating that they draw water from the shallow zones of the Wasatch Formation, which is the primary source of groundwater in the GRB. In 2014 Trihydro conducted a second analysis of available wells in the NPL area to incorporate the requirements of the new WOGCC rule for baseline water sampling (Trihydro 2014c). Within one mile of the NPL Project Area Boundary, 52 wells with SEO permits were recognized as complete or have been field verified. Additionally, three water sources were field verified by Trihydro and/or the USGS that do not have SEO permits, for a total of 55 identified water sources. Twelve of these water wells have not been field verified by Trihydro.

Annual Water Quality and Well Depletion Reports for JIDPA (AECOM 2008, 2009, 2011, 2014; AMEC 2010, 2013, 2014; BLM 2006a; BP 2004a, 2004b, 2009, 2010, 2011, 2012; Encana 2009, 2010, 2014; Linn Energy 2013, 2014). Under the 2006 ROD for the JIDPA, operators are required to submit annual reports to the BLM of the amount of water used for each water supply well at the JIDPA. Additionally, the operators are required to sample the active water wells annually and provide water quality information to the BLM. Water quality data also include the analysis of one well (Corona 2-14) currently not in use due to detection of petroleum hydrocarbons. Since 2006 several different operators have provided this information to the BLM as letter reports, and the BLM has made those data available for the NPL Project EIS and this analysis. Because the same water supply wells currently used for the JIDPA are anticipated to be used for the NPL Project, the data provided from these wells are directly applicable to the water quality and depletion analysis for the NPL Project presented in the NPL Project EIS and this appendix.

3.0 PHYSICAL SETTING

The NPL Project Area is located primarily on BLM-administered lands managed by the BLM Pinedale Field Office (PFO) and Rock Springs Field Office (RSFO) within Townships 27 through 29 North, Ranges 107 through 110 West, 6th Principal Meridian, in Sublette County, Wyoming (Figure K-1). The JIDPA is directly adjacent to the northeastern portion of the NPL Project Area. The PAPA is north of the JIDPA, in the northern portion of the GRB. The locations of the water supply wells within the JIDPA, which would supply water for NPL Project development, are depicted in Figure K-2.

The analysis area is characterized by low rolling hills interspersed with buttes, rock outcrops, large draws, and deep canyons (Clarey and Thompson 2010). The NPL Project Area consists primarily of shrub-steppe habitat dominated by Wyoming big sagebrush and grasses. There is a surface water drainage divide within the NPL Project Area between the Green River, approximately five to ten miles to the west, and the Big Sandy River (a tributary of the Green River), approximately five miles to the east (BLM 2013a).

Primary land uses in the general vicinity of the Project Area include livestock grazing, recreation, wildlife habitat, agriculture, and, increasingly, oil and gas development. Since 1992, development of the extensive oil and gas fields adjacent to the Project Area—including the PAPA to the north; the Riley Ridge and Big Piney/LaBarge Coordinated Activity Plan to the west; and the JIDPA to the immediate northeast—has greatly increased the level of human activity in the area and decreased the amount of land available for other uses. Prior to this surge in mineral exploration, the lands were primarily used for livestock grazing, with some areas frequented by recreationists searching for petrified wood or hunting for antelope and Sage-Grouse.

Thus far, the development of oil and gas resources within the Project Area has proceeded at a far slower pace than in surrounding fields. As of 2015, 116 wells have been drilled in the Project Area (WOGCC 2015), including:

- 55 producing natural gas wells;
- 19 dry/junked/abandoned wells;
- 1 Class II underground injection well (deep disposal of formation fluids);
- 10 water supply wells for oil and gas operations (drilling and completion operations, road construction, maintenance, dust control and reclamation) including 4 water supply wells for drilling in the JIDPA, and 1 water supply well for the Jonah workforce facility; and
- 31 existing stock water wells.

Figure K-2 in the NPL Project EIS identifies the location of the water supply wells and stock wells in the NPL Project Area. Attachment B (*Water Supply Wells in and around the NPL Project* Area) provides a description of the water supply wells in and around the NPL Project Area.

3.1 Climate

The NPL Project Area lies in a semi-arid, cold desert climate and is dotted with ephemeral washes and playas (Trihydro 2011). Precipitation is representative of a high desert region, and the area generally receives between approximately 7 and 11 inches of precipitation annually (Table K-1). Monthly precipitation ranges from around 0.2 to 1.7 inches. The highest precipitation rates occur in May through September, although average amounts of rainfall are generally very low and consistent throughout the year. Between 1999 and 2007, the GRB experienced an overall decrease in average annual precipitation (Wyoming State Geological Survey (WSGS) 2010).

Precipitation throughout the GRB is greatly influenced by topography, with higher amounts of rain and snowfall in mountainous areas surrounding the basin. The majority of water in the Project Area comes from precipitation and snowmelt from the mountains. The highest rates of runoff are anticipated in the spring, with little to no flow in the late summer season, and some flow beginning during the winter when evaporation rates are reduced with the cooler weather (BLM 2013a). Due to the arid climate, evaporation potential is approximately four times higher than annual precipitation (Geomatrix 2008). Given the low precipitation and high evaporation rates, little water is available for surface water runoff or infiltration through soils for groundwater recharge. Most groundwater recharge occurs through surface infiltration at the base of mountains along the perimeter of the basin.

Table K-1. Average Monthly Precipitation for Towns near the NPL Project Area

	Average Monthly Precipitation (inches)												Average Annual Precipitation (inches)
	January	February	March	April	May	June	July	August	September	October	November	December	
Big Piney, WY	0.31	0.35	0.43	0.51	0.83	0.79	0.71	0.71	0.79	0.51	0.20	0.31	6.45
Pinedale, WY	0.59	0.59	0.75	0.94	1.69	1.22	1.02	1.02	1.30	0.83	0.71	0.71	11.37
Farson, WY	0.35	0.31	0.51	0.75	1.42	0.87	1.02	0.67	0.94	0.67	0.39	0.35	8.25

Sources: US Climate Data 2015a, 2015b, 2015c.

Figure K-1. Surface Water Features in the Analysis Area

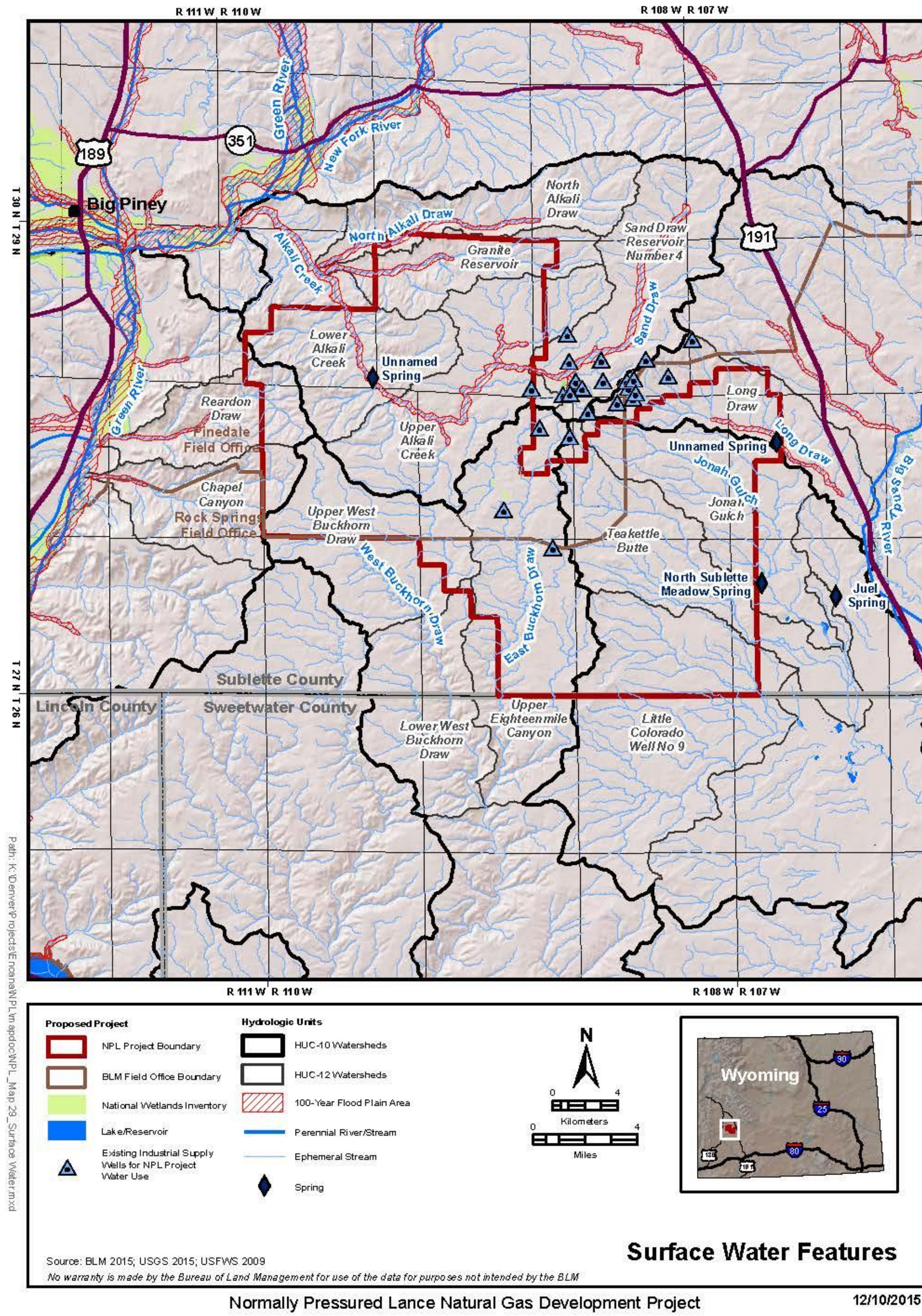
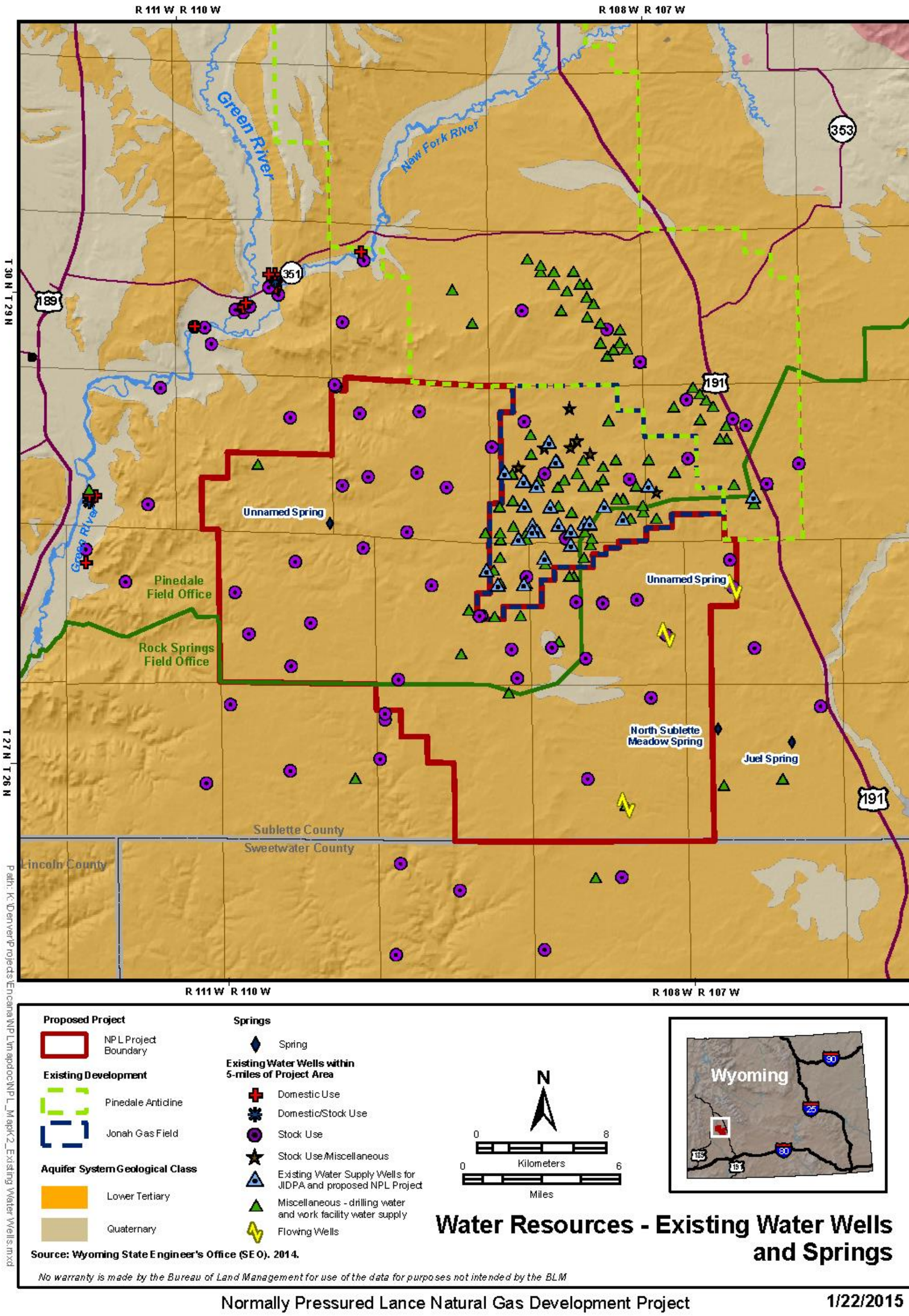


Figure K-2. Water Resources – Existing Water Wells and Springs



3.2 Geologic History and Structural Setting

The NPL Project Area is in the northwestern part of the geologic Greater Green River Basin (GGRB), in the Green River subbasin (referred to as the GRB or structural GRB). The geologic structural features that created the basins were formed beginning in the Jurassic period, approximately 140 million years ago and continued forming through the early Tertiary period, approximately 50 million years ago (Montgomery and Robinson 1997). The GGRB is bounded by deep thrust faults that uplifted the Uinta Mountains to the south, the Wind River Mountains to the north/northeast, and the Wyoming Thrust Belt to the west of the NPL Project Area. The Rock Springs Uplift to the southeast of the NPL Project Area was also created during this period. Figure K-3 illustrates the location of the NPL Project Area in relation to the major structural features of the GGRB. Downwarping and erosion associated with these uplifts created the structural GRB, which filled with up to 32,000 feet of sediments (Law 1996). Within the NPL Project Area, the entire sequence of Tertiary- and Cretaceous-age rocks represent non-marine sediments primarily formed in lacustrine and fluvial depositional environments (Warner 2000).

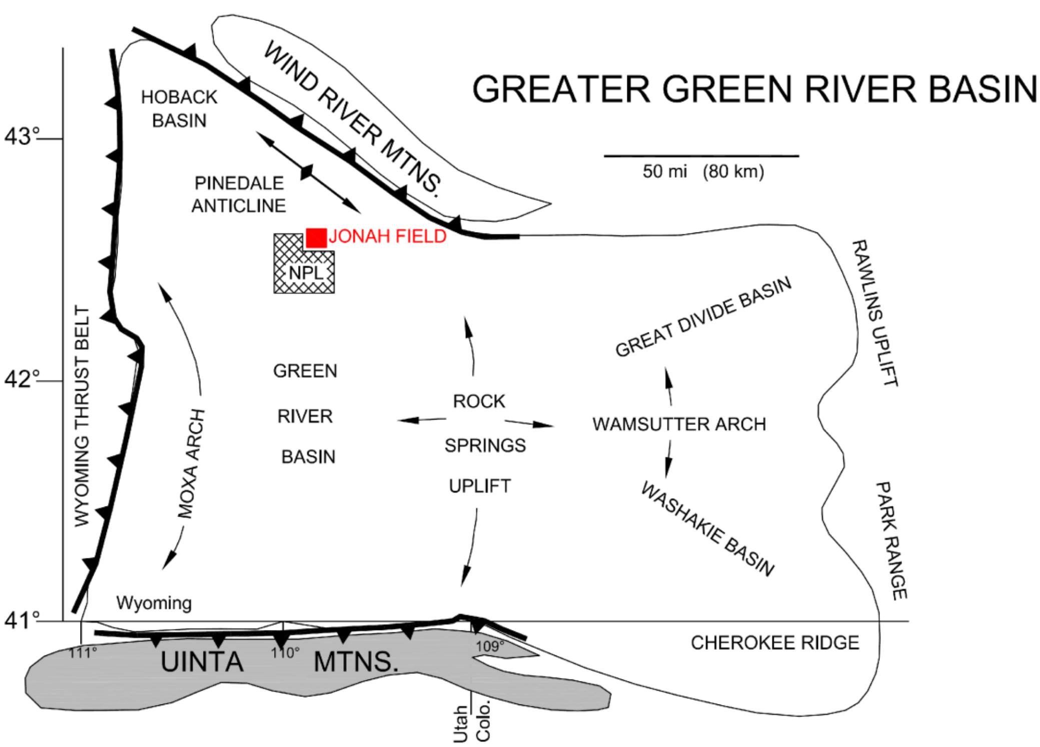
Smaller, regional structural features were formed with the major tectonic activities. These include the Pinedale Thrust and Anticline, the Moxa Arch-LaBarge Platform, and the bounding faults on the west and south of the JIDPA shown on Figure K-3. The Pinedale-Jonah area in the northern part of the GRB is structurally complex and contains a number of faults, folds, and associated fracture systems that created natural gas reservoirs. The Pinedale Anticline is 35 miles long and 6 miles wide and was formed as a result of uplift on the Wind River Thrust Fault (Law and Johnson 1989). It is oriented roughly parallel to the Wind River Thrust Fault. The southern end of the Pinedale Anticline is less than 10 miles to the northeast of the NPL Project Area. The PAPA lies within the Pinedale Anticline and produces gas from the Lance and other formations.

The Jonah Field, just northeast of the NPL Project Area and encompassing the JIDPA, is an over-pressured, fault-bounded, structurally trapped, basin-centered gas accumulation zone (Siguaw and Friend 2004). The faults that bound the Jonah Field are dominated by lateral movement (wrench faults) with little to no vertical movement. The faults have complex geometries with numerous splays and result in faulted blocks that create compartments of gas production in the Jonah Field (Warner 2000). Some of the faults within the Jonah Field have been interpreted to extend from the Precambrian basement upward into the Fort Union Formation (Warner 2000) and possibly to the surface; however, surface expression of such faults has not been verified or mapped. Seismic surveys acquired by Cabot Oil and Gas in December 2001 revealed that the faults extend one to two miles south and west of the currently productive area of the Jonah Field (Siguaw and Friend 2004), and that a northwest/southeast-trending thrust fault may be present within the NPL Project Area in the central part of T28N R109W. Camp (2008) and Grid Petroleum (2010) reference a seismic survey conducted southeast of the Jonah Field that appears to include part of the NPL Project Area. The authors interpret the results to include several northeast/southwest-trending faults in the area. These authors and Shanley (2004, as cited in Grid Petroleum 2010) describe the bounding faults at the Jonah Field as "sealing faults," indicating they are not transmissive and do not allow upward fluid migration. Other than the seismic survey conducted by Cabot, which focused on the southern tip of the Jonah Field within the NPL Project Area, no publicly available structural data is available for the NPL Project Area.

Based on readily available existing information from nearby similar, well-studied geological features, it appears that the NPL Project Area may have similar structural features, including faults and fractures, but at a smaller scale than the features that created the Pinedale Anticline or Jonah Field. If present, the faults and fractures would likely have a low possibility for transmitting fluids from producing zones to the shallow aquifer due to the limited vertical extent and the sealing nature of the faults as demonstrated in the nearby Jonah field; however, the NPL Project Area has not been fully investigated.

Based on currently available information it is difficult to definitively determine whether these faults could provide for communication between gas or liquids between producing zones and shallower aquifers. Additional information on communication between faults will be added as new studies become available and the NPL Project groundwater monitoring program will consider and apply new studies and information regarding fluid migration along faults and fractures as it becomes available. The groundwater monitoring program to be implemented to monitor water quality conditions prior to and during oil and gas development for the NPL Project would be used to evaluate the potential for fluid migration along existing and newly identified faults and fractures.

Figure K-3. Major Structural Features of the Greater Green River Basin



Source: Figure adapted from Montgomery and Robinson 1997.

3.3 Geology and Stratigraphy

Geologic data from exploration and production wells were used to develop a cross section through the NPL Project Area and the JIDPA (Figure K-4). The cross-section shows the geologic layers and primary zones of interest for the NPL Project Area and extends from south of and outside of the NPL Project Area to just north of the JIDPA. The interpreted depth and thickness of the geologic units and anticipated formation fluids injection zones were provided by the operator and based on analyses of geophysical logs, driller's logs, and local knowledge (Phillips 2013b). Sufficient data were not available to construct an east-west cross-section through the NPL Project Area. The zones depicted on the cross-section are described below from the oldest (deepest) to the youngest (shallowest).

The cross-section (Figure K-4) illustrates the relationship between the three primary zones of interest, which are, from oldest to youngest (deepest to shallowest), the Lance, Fort Union, and Wasatch

Formations. The Laney Member of the Green River Formation is present at the surface in the southern part of the cross section within the NPL Project Area. It is approximately 200 feet thick at the southern end of the cross section (Bartos and Hallberg 2010) and pinches out approximately at the NPL – Jonah boundary. This is not shown on the cross-section because the well logs used to select the tops of the formations do not extend to the surface where the Laney Member is present, and the Laney is too thin to be depicted at the scale shown. The Laney Member is known to contain oil shales, which contain solid organic matter but no free oil.

The Lance Formation would be the targeted gas-producing zone for the NPL Project and is the lowermost geologic unit shown on Figure K-4. The top of the Lance Formation becomes deeper to the north, and the target gas-producing interval also thickens to the north. Within the NPL Project Area, the Lance Formation is approximately 2,500 feet thick (Warner 2000) and thins to the southwest, where it pinches out at approximately eight miles to the southwest of the NPL Project Area. In the JIDPA, the lowermost sandstone beds of the overlying Fort Union Formation are included in the Wyoming Oil and Gas Conservation Commission (WOGCC) definition of the Lance Pool (Warner 2000, WOGCC 2003), and several wells in the JIDPA have producing intervals in the basal Fort Union Formation.

The top of the Lance Formation is marked by an erosional surface and a change in the composition of sediments. The Fort Union Formation lies above the Lance Formation and is approximately 4,000 feet thick in the NPL Project Area. It is informally subdivided into the basal, lower, and upper zones based on the presence of widespread geologic markers. The lower two-thirds of the upper Fort Union Formation is dominated by mudstones (Encana 2011a), but contains highly permeable, abundant porous sandstones, which are currently used in the JIDPA for disposal of formation fluids (as shown by Encana well SOL 119-7 WDW on the right side of the cross-section). This same zone is proposed as the injection and disposal zone in the NPL Project Area. The well logs in the NPL Project Area show that the upper Fort Union Formation consists of a series of shales, silts, and sands with a composite thickness of approximately 1,000 feet. Individual sands are generally less than 30 feet thick and are separated by up to several hundred feet of fine-grained materials. Regionally, the Fort Union Formation thins to between 2,000 and 3,000 feet thick to the northeast and southwest (Martin 1996) and is exposed at the surface near the Rock Springs Uplift, approximately 50 miles to the southeast.

The uppermost zone shown on the cross-section in Figure K-4 is the Wasatch Formation, which is similar in composition to the underlying Fort Union Formation. The Wasatch and Fort Union Formations have been designated as a single aquifer unit by the USGS (Martin 1996) and Wyoming Water Development Commission (Clarey 2010) but are hydrologically described as separate zones within the aquifer. In this report and the associated Environmental Impact Assessment, the broader terminology of the Wasatch Aquifer and Fort Union Aquifers are used and reflect the Wasatch Aquifer and Fort Union Zone of the Wasatch-Fort Union Aquifer. No regional confining unit separates the formations, and Martin (1996) describes groundwater flow across the boundary of the two formations. However, the chemical and hydrologic properties of the two formations are quite different. The Wasatch Formation is exposed at the surface in the northern part of the NPL Project Area and is approximately 3,300 feet thick at the southern end of the cross-section, thickening to approximately 4,200 feet in the JIDPA. Further north, the Wasatch Formation thickens to more than 7,000 feet and contains more thick, permeable, and extensive sandstones (Martin 1996). In the PAPA, the Wasatch ranges from approximately 3,000 to 7,000 feet (AMEC 2013a; as cited in Chafin and Kimball 1992; Glover et al. 1998; Martin 1996; Roehler 1992; Welder 1968). The sandstone layers in the JIDPA at depths of less than 1,000 feet are the source of freshwater for drilling and completion operations, and these same zones are also proposed as freshwater source zones for the NPL Project.

Although there is no clear contact between the Wasatch and Fort Union, they are not one continuous formation. Instead, there is a gradational change in lithology from approximately 1,200 feet in the Wasatch through the base of the Fort Union. The chemical composition of the formation water in the two formations are also different. Groundwater in the upper 1,200 feet of the Wasatch is generally of sodium-carbonate-bicarbonate type with TDS concentrations ranging from approximately 200 to 1,800 mg/L in the PAPA (SCCD 2013) and 373 to 4,330 mg/L in the NPL (Trihydro, 2014b). Groundwater in the Wasatch transitions from fresh water in the upper 1,200 feet to high salinity (greater than 40,000 mg/L) in the upper Fort Union at approximately 3,500 to 4,000 feet. This transition also includes a gradual increase in calcium levels downward. Groundwater in the lower Fort Union has lower salinity than does the upper portion of the formation with TDS concentrations of approximately 4,000 mg/L versus than 40,000 mg/L in the upper Fort Union; and is a sodium chloride/sodium bicarbonate type water versus a calcium chloride type (throughout the upper Fort Union).

As shown on the cross-section (Figure K-4), the surface casing for most of the wells is set at approximately 2,500 feet bgs, as required by the BLM (Rieman 2006). Some of the wells (Encana Hacienda 11-30 and 6-19, and Encana Holmes State 13-36) have shallower surface casings set at approximately 1,000 feet bgs. Geophysical well logs are generally not obtained within the surface casing in the upper part of the Wasatch Formation, but four wells in the JIDPA have well log data in the surface casing that were reviewed for shallow lithology. These logs show that the thickest sandstone beds in the JIDPA are found at depths of less than 800 feet, below which are thick sequences of layered shales and silts with a few thin sandstone beds. The high resistivity in these high-porosity sands indicates they contain water with low TDS.

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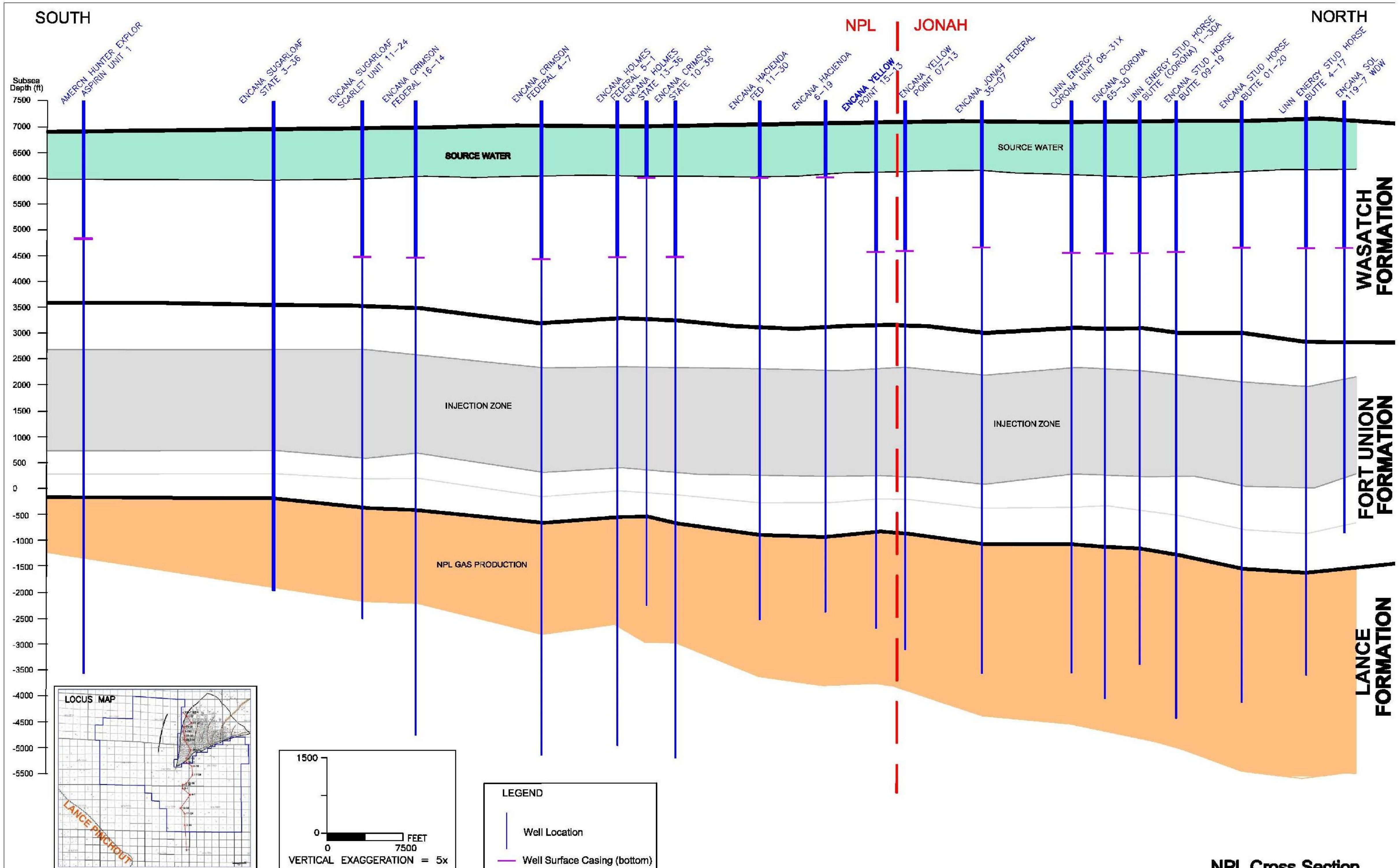
Figure K-4. South-North Geologic Cross Section through the NPL Project Area



Source: Modified from "Encana S-N Cross Section by DP DuBois", 2013

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4.0 EXISTING CONDITIONS OF WATER RESOURCES

This section provides a summary of water resources in the analysis area. Refer to Chapter 3 (*Affected Environment*) of the NPL Project EIS for more information on existing conditions for water resources.

4.1 Surface Water

Because it receives little runoff or precipitation, there are no permanent surface water features in the NPL Project Area, and drainage is mainly through ephemeral streams that receive runoff during spring snowmelt and rare storms events. Snowmelt from highlands surrounding the GRB watershed is the primary source of water to the basin. The meltwater drains off the mountain bases around the edges of the basin; however, the NPL Project Area is in the interior of the basin and does not receive much meltwater.

Fifteen 12-digit HUC watersheds intersect the NPL Project Area and contribute to five 10-digit HUC watersheds in the analysis area. All fifteen HUC-12 watersheds intersecting the NPL Project Area are drained by ephemeral streams and to a lesser extent by intermittent streams where there is a surficial alluvial aquifer. The major surface water bodies in the analysis area are the Green River, which runs north to south approximately six miles to the west of the NPL Project Area, and the Big Sandy River, which drains the area to the east of the NPL Project Area (Figure K-1). Table K-2 presents the total acreage of the watersheds in the analysis area as well as the acreages and percentages of the watersheds that occur within the NPL Project Area.

All drainages in the NPL Project Area are ephemeral and intermittent, which do not provide reliable water resources, and most intermittent streams only flow following snowmelt and precipitation events (WWDC 2014). There are surface expressions of groundwater, but none that produce perennial surface flows that reach other surface waters (BLM 2013a). Reservoirs and impoundment structures are present throughout the analysis area, but none contain permanent water. These impoundments accumulate water in response to precipitation events. Most of the water is lost to evaporation and a minor amount to recharge. These structures are range improvements used for livestock and sedimentation/flood control. WWDC (2014) stated in its analysis the Upper Green Watershed, in which part of the Project Area is located, produces excess water that could be beneficially utilized with additional storage capability.

Two unnamed groundwater springs within the NPL Project Area, along with the North Sublette Meadow Spring and Juel Spring outside the NPL Project Area boundary, discharge to ground surface. Locations of the springs are shown on Figure K-1. The two unnamed springs are in the Lower Alkali Creek and Long Draw watersheds. North Sublette Meadow Spring and Juel Spring are just east of the NPL Project Area boundary in the Jonah Gulch watershed. Field observation has indicated the presence of several shallow seeps and springs in the Teakettle Dune Field Area (Drucker 2016); however, these areas have not been mapped. The characteristics and water quality of springs in the analysis area is discussed in Section 4.2.2 (*Water Quality*) below, where data are available.

Although limited available data on ephemeral stream water quality are available for southwestern Wyoming, surface water quality can be both spatially and temporally variable in the arid high plains. No surface water quality data from within the Project Area were identified; however, general surface water quality can be inferred from the receiving perennial waters of the drainage area, which are the Green and Big Sandy Rivers. There were no reportable spills to the BLM found during a record search. If a spill does occur, it will be cleaned to WDEQ standards. The quality of runoff is largely dependent upon the amount of salts, sediments, and organic materials that accumulate in dry stream channels during periods of runoff. The degree to which these materials buildup between runoff events is influenced seasonally by physical characteristics of the soils (described in Section 3.15 (*Soil Resources)* of the NPL Project EIS) and land uses occurring within the watershed. The Green and Big Sandy Rivers experience the highest flows during spring snowmelt, and in the summer following thunderstorm events.

The Green and Big Sandy Rivers are classified by the WDEQ WQD as Class 2AB waterbodies (WDEQ 2014), which are known to support game fish populations or spawning and nursery areas at least seasonally and are protected for nongame fisheries, fish consumption, aquatic life other than fish, recreation, wildlife, industry, agriculture, and scenic value uses (WDEQ 2007). Neither the Big Sandy River nor the Green River appears on the State 303(d) list of impaired waters, and neither have existing TMDLs (WDEQ 2014).

In general, TDS is a water quality concern in the GRB and in the larger context of the Colorado River drainage area. However, TDS measurements for the Green River are relatively low (500 mg/L), although high TDS values (up to 3,000 mg/L) have been reported in downstream reaches of the Big Sandy River (Wyoming Water Development Office 2012). Surface water quality is generally better near the mountain ranges than in the lowlands. As runoff flows downstream from mountain ranges and over alkali soils in the basin flatlands, dissolved solids are accumulated and are transported downstream. Additional sources of dissolved solids may include agricultural runoff and other human activities.

The BLM has performed proper functioning condition (PFC) assessments for portions of two waterbodies in the analysis area: Alkali Creek and the Big Sandy River. The PFC assessment is a method for assessing hydrology, vegetation, and erosion/deposition attributes to determine the condition of riparian and /or wetland areas along a stream or river segment at a given point in time (Prichard et al. 1998). The PFC assessment is qualitative and is based on a checklist to make a relatively quick determination of condition. Following completion of the assessment, the stream segment is placed in one of the following categories: proper functioning condition; functional – at-risk; or, nonfunctional.

In 1998 and 2001, a total of approximately 5.5 miles of Alkali Creek were assessed in Sections 32 and 33 of T30N, R110W. All 5.5 miles of Alkali Creek assessed were determined to be functional – at-risk due to poor riparian vegetation cover, excessive erosion, and headcutting. Between 1994 and 2010, approximately 51 miles of the Big Sandy River were assessed using the PFC methodology; some of the assessed segments were located adjacent to the NPL Project Area. The majority (approximately 28.5 miles) of the segments assessed for the Big Sandy River were determined to be PFC, with approximately 18.8 miles functional – at-risk and another 3.8 miles unrated. Portions of the Big Sandy River adjacent to the NPL Project Area rated functional – at-risk exhibited high width to depth ratios, narrowing riparian vegetation cover, bank instability, and high sedimentation rates at the time of the assessments.

The *AGWA Technical Report* (Appendix J) identified 435 miles of stream channels within eight Watershed Modeling Units, encompassing all of the NPL Project Area and portions of all 15 HUC-12 watersheds comprising the water resources analysis area. Approximately 197 miles of these stream channels are represented by ephemeral drainages within the NPL Project Area.

Table K-2. Acreage of Watersheds in the NPL Project Area

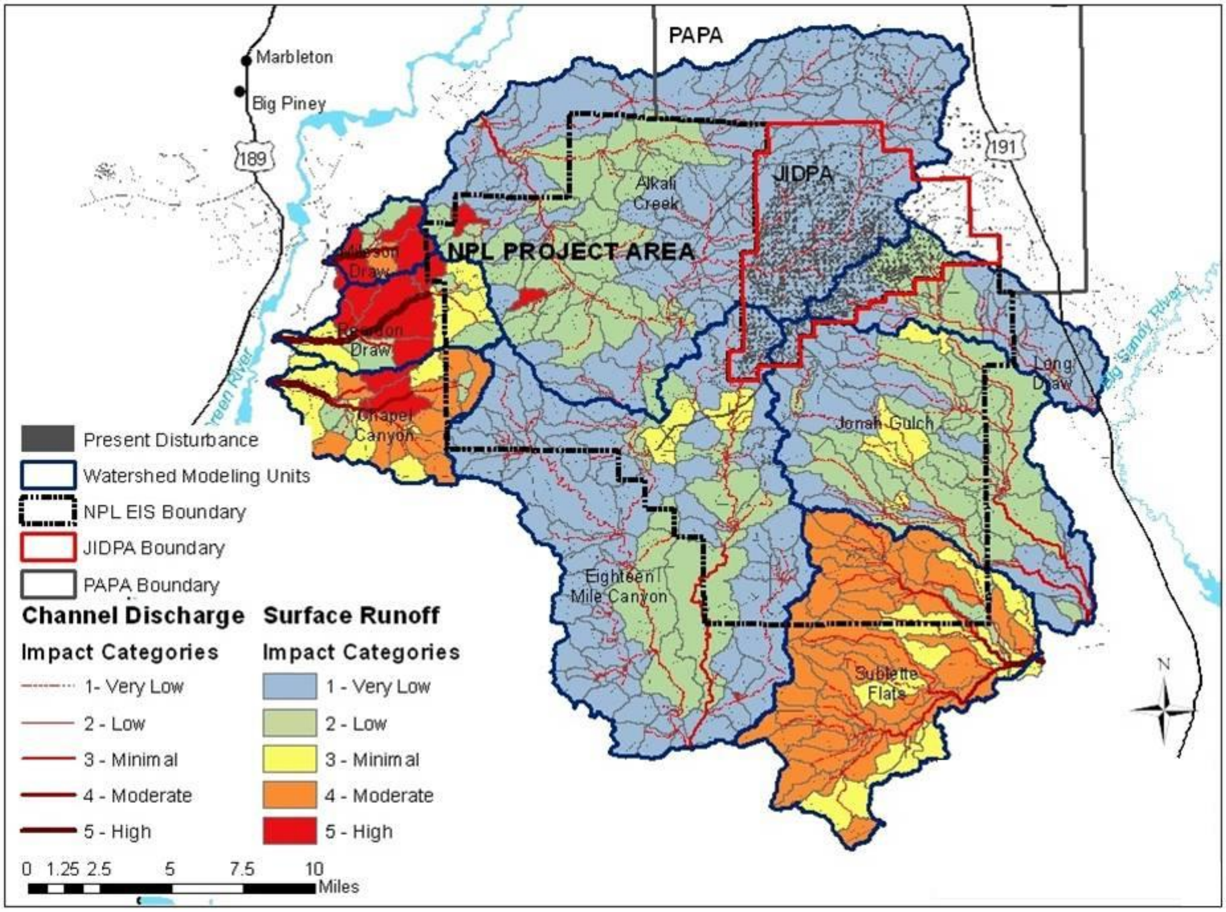
Watershed Unit	Total Watershed Acreage	Acres in the NPL Project Area	Percent of Watershed in the NPL Project Area
Alkali Creek (HUC 1404010106)	103,985	48,739	46.87%
Granite Reservoir (HUC 140401010603)	12,212	8,626	70.64%
Lower Alkali Creek (HUC 140401010605)	26,132	16,269	62.26%
North Alkali Draw (HUC 140401010604)	15,911	652	4.10%
Sand Draw Reservoir Number 4 (HUC 140401010601)	22,932	190	0.83%
Upper Alkali Creek (HUC 140401010602)	26,798	23,002	85.84%
Eighteenmile Canyon (HUC 1404010303)	211,311	35,025	16.57%
Lower West Buckhorn Draw (HUC 140401030303)	19,292	249	1.29%
Upper Eighteenmile Canyon (HUC 140401030301)	35,213	23,170	65.80%
Upper West Buckhorn Draw (HUC 140401030302)	21,746	11,605	53.37%
Birch Creek-Green River (HUC 1401040111)	233,326	5,601	2.40%
Chapel Canyon (HUC 140401011106)	14,357	2,036	14.18%
Reardon Draw (HUC 14041011105)	12,363	3,453	27.93%
Spring Creek-Green River (HUC 140401011104)	30,117	112	0.37%
Sublettes Flat (HUC 1404010404)	151,074	45,172	29.90%
Jonah Gulch (HUC 140401040401)	22,652	14,081	62.16%
Little Colorado Well No 9 (HUC 140401040403)	41,997	13,637	32.47%
Teakettle Butte (HUC 140401040402)	24,559	17,454	71.07%
Upper Big Sandy River (HUC 1404010401)	247,889	6,322	2.55%
Long Draw (HUC 140401040108)	18,522	6,273	33.87%
Bull Draw-Big Sandy River	19,761	49	0.25%

Source: USGS 2015b.

HUC Hydrologic Unit Code

The results of the AGWA modeling for the NPL Project indicate areas within the NPL Project Area that would be most susceptible to increased erosion, surface runoff, and sediment transport. As depicted in Figure K-5, there is generally very low runoff and channel discharge in the NPL Project Area. The comparatively large size of the area combined with low amounts of precipitation and surface runoff indicate that an individual storm event of reasonable size has a low probability of transporting sediment and associated salt from large or distant areas of contributing watersheds to major stream channels, such as the Green River and the Big Sandy River. However, areas with higher vulnerability to surface and channel erosion were identified at Sublette Flats, Reardon Draw, Mileson Draw, and Chapel Canyon. Refer to the NPL Project *AGWA Technical Report* (Appendix J) for more information resulting from the AGWA modeling for the NPL Project.

Figure K-5. Surface Runoff and Channel Discharge – Existing Conditions



Source: BLM 2013a.

4.2 Groundwater

4.2.1 Hydrogeology

The major structural features and resulting depositional patterns of the GRB influence the hydrologic characteristics of the NPL Project Area. Topography in the GRB follows undulations of the Precambrian basement. The thick sequences of Cretaceous- and Eocene-age shale, carbonate rock, and sandstone, which contain the primary aquifers for the area, thicken to the northeast and are exposed at the surface near the edges of the basin (Clarey 2010). In some areas, more recent unconsolidated sand and gravel alluvium with varying amounts of less permeable silts and clays form a surficial aquifer; however, these deposits are mainly limited to areas adjacent to the main riverbeds and washes. Similarly, groundwater conditions are highly variable in the Upper Green River Watershed due to variable geologic and hydrogeologic conditions. Refer to the Upper Green Level I Watershed Study (WWDC 2014) for more information on hydrogeologic conditions in the Upper Green Watershed. Refer to Section 3.6 (*Geology and Mineral Resources*) of the NPL Project EIS for more information on geology in the analysis area.

More recent alluvial deposits form localized saturated zones, mainly limited to areas in the bottomlands along the Green River west of, and the Big Sandy River east of, the NPL Project Area. Discontinuous alluvial aquifers exist to a limited extent in the floors of intermittent stream valleys in the Tea Kettle Butte watershed, located in the southeast portion of the Project Area (Figure K-1) (Bartos and Hallberg 2010).

Permeable water-bearing rocks of Lower Tertiary age make up the Lower Tertiary Aquifer and include the Laney Member of the Green River Formation, the Wasatch Formation, and the Fort Union Formation. Based on field observations by Winterfeld (2011) and other data, the Wasatch Formation occurs at ground surface in the northern portions of the NPL Project Area, and the Laney Member of the Green River Formation is exposed at the surface in the southern portion of the NPL Project Area. Water flowing south in the Wasatch Aquifer recharges the Laney Aquifer across a gradational formation contact. The Laney Member is only an important aquifer locally at the edge of the analysis area near the Big Sandy River, where it is fractured and/or contains solution-enhanced permeability. In the NPL Project Area, the Laney Aquifer is thin (less than 200 feet), the hydraulic conductivity is low, and well yields are small (Martin 1996).

The sections below describe the Wasatch Aquifer within the analysis area that could be affected by development of the NPL Project. Information presented in the sections below comes primarily from the Wyoming Water Development Commission and Wyoming State Geological Survey (Bartos and Hallberg 2010; Bartos et al. 2010; Clarey 2010; Clarey and Copeland 2010; Clarey and Thompson 2010; WSGS 2010) and are highly generalized in nature. These sources represent the best readily available existing information, which is often regional in nature and not specific to the NPL Project Area. As a result, all information may not reflect the site-specific conditions within the NPL Project Area. Additional information on NPL Project Area specific conditions will continue to be collected during development and implementation of the groundwater monitoring program for the NPL Project and other efforts prior to and during development.

The Mesaverde Aquifer is continuous with and considered part of the Lower Tertiary Aquifer system, although it is stratigraphically below the Lower Tertiary and is Mesozoic age (Cretaceous). The aquifer includes the Lance-Fox Hills Aquifer, the Lewis Confining Unit, and the Mesaverde Aquifer. It is underlain by the Baxer-Mowry Confining Unit, which is 5,000 to 12,000 feet thick in the GRB (Bartos and Hallberg 2010). The saturated thickness of the Mesaverde Aquifer is over 2,000 feet thick in the NPL Project Area. The Mesaverde aquifer is below the Lance Pool and is a potential source of produced formation fluids if identified as a targeted formation and if wells are completed below the Lance Pool.

4.2.1.1. Hydraulic Characteristics of the Wasatch Aquifer

The Wasatch Aquifer is the main source of groundwater in the analysis area. Water for livestock and potable uses is drawn from the shallower depths of the formation. Wasatch strata are present at ground surface (i.e., outcrops) in the northernmost, westernmost, and easternmost portions of the NPL Project Area (Winterfeld 2011) and are buried in the southern portions of the NPL Project Area, as shown on Figure K-6 (Bartos and Hallberg 2010). The Wasatch Formation is a sequence of a fluvial sandy shale and siltstone with few channel sands and coal deposits. The sandstone lenses are spatially limited and are generally not able to be correlated between two adjacent wells. The hydraulic characteristics of the Wasatch Aquifer reported by Bartos and Hallberg (2010) for a broad area of the GRB indicate large variations in groundwater flows and yields, representing the heterogeneity of the aquifer (Table K-3).

Table K-3. Hydraulic Characteristics of the Lower Tertiary Aquifers

Hydrogeologic Unit	Range of Hydraulic Conductivity (feet per day)			Well Yields (gpm)
	Simulated		Measured	Measured
	Vertical	*Horizontal*	*Horizontal*	
Laney Aquifer	0.00001 – 17.3	0.04 - 17.3	2 - 1,400	2 - 2,250 (median = 17)
Wasatch Aquifer	0.001 – 4	0.04 - 6.5	0.03 - 2,100	2 - 302 (median = 20)
Fort Union Aquifer	0.00001 - 0.01	0.00001 - 0.3	0.02 - 1,100	5 (only one measurement)

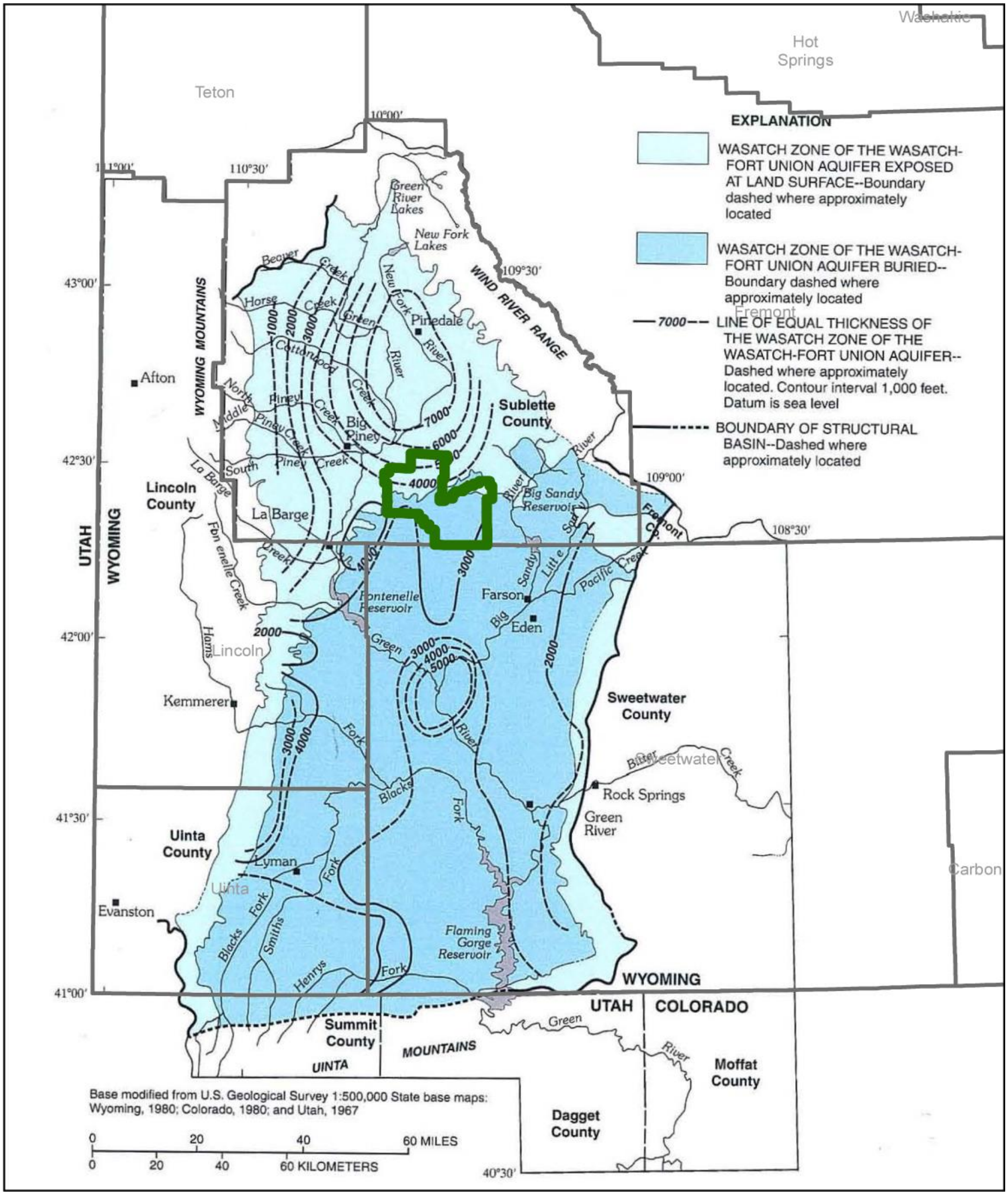
Source: Bartos and Hallberg 2010.

gpm gallons per minute

Aquifer tests were conducted in eleven industrial supply wells to support the PAPA Hydrologic Model (AMEC 2013a). The wells were completed within the Wasatch Aquifer and included screened intervals between 110 and 795 feet below surface. Hydraulic conductivity derived from the aquifer tests ranged from 0.02 to 9.5 ft/day (AMEC 2013a). The data also indicated that the hydraulic conductivity decreases in the lower Wasatch due to increased volumes of silt and clay. Industrial water supply wells producing from the Wasatch typically average around 150 gpm (AMEC 2013a). The JIDPA Hydrologic Model (HydroGeo 2004) uses a range of hydraulic conductivities similar to those measured at PAPA: 1.6 ft./day in the lower Wasatch and 9.5 ft./day in the upper Wasatch. No aquifer testing has been conducted within the NPL Project Area. The range of hydraulic conductivity values for the Wasatch Aquifer reported by Bartos and Hallberg (2010) is consistent with the results used for the PAPA and JIDPA numerical models, and is expected to be representative of the Wasatch Aquifer in the NPL Project Area.

Water quality in the Wasatch Formation is both spatially and vertically variable (Bartos et al. 2010). While the water quality in the shallow zones (less than 1,000 feet) generally meets the U.S. Environmental Protection Agency's (EPA 2009) Primary or Secondary MCL standards for domestic use and Wyoming Department of Environmental Quality's (WDEQ 2015) Class 2 and 3 standards for agriculture and livestock use, some naturally occurring constituents, such as fluoride, radon, arsenic, and boron are locally present at concentrations above these standards (Bartos et al. 2010; WWDC and University of Wyoming 1990). Refer to Section 4.2.2 (*Water Quality)* below for more information on groundwater quality in the Wasatch Aquifer.

Figure K-6. Wasatch Aquifer: Areal Extent and Thickness (including Project Area)



Source: Bartos and Hallberg 2010.

4.2.1.2. Hydraulic Characteristics of the Fort Union Aquifer

Throughout the analysis area, the Fort Union Formation underlies the Wasatch Formation and is mainly composed of fluvial sandstones, sandy shales, and siltstones interbedded with channel sands, lignite, and coal. The Fort Union Aquifer is approximately 4,000 feet thick and is not exposed at the surface in the analysis area. There are limited existing data or aquifer studies of the Fort Union Formation. Estimates of hydraulic characteristics of the Fort Union Aquifer were developed based on field data within the GRB and a basin scale groundwater model simulation (Martin 1996) and are not specific to the NPL Project Area. There is currently no readily available information on transmissivity specific to the NPL Project Area. Estimates of hydraulic conductivity in the Fort Union Aquifer vary widely due to the heterogeneity of the lithology (Table K-3), and the simulated hydraulic conductivities derived for the Fort Union Aquifer are orders of magnitude below those of the Wasatch Aquifer. In the 2011 WOGCC application for injection into the Lower Fort Union in the Jonah Hacienda 4-1, Encana stated that the porosity of the sands was approximately 17 percent and estimated the permeability to be between 1 and 5 millidarcies (Encana 2011a). The geologic description from logs in the Jonah and PAPA supporting the application stated the Fort Union was dominated by mudstones. There are very few wells that draw from the aquifer, and only one value of 5 gallons per minute (flowing) is reported for the Fort Union (Bartos and Hallberg 2010).

4.2.2 Water Quality

The sections below provide a summary of the best available existing information for water quality for wells in and around the NPL Project Area (Figure K-7). The water quality presented in this section focuses on the key analytes, parameters, and water quality characteristics for wells that target the alluvial aquifer, Laney Aquifer, and the Wasatch Aquifer and the Fort Union. Figure K-7 depicts the location of water wells that have been tested for certain water quality analytes by the operator's sampling and analysis program and water supply wells in the JIDPA that have been sampled as part of ongoing sampling in the JIDPA.

In addition, select water quality information from water wells for the most recent year sampled prior to 2014 is presented in Figure K-8 for representative wells (i.e., wells that covered the geographical range of the analysis area and had a detectable level of one or more analyte). Figure K-8 depicts the concentrations of methane, total dissolved solids (TDS), benzene, chlorides, total petroleum hydrocarbons - diesel range organics (TPH-DRO), and total petroleum hydrocarbons - gasoline range organics (TPH -GRO) in relation to established standards or limits. These standards and limits were chosen for comparison based on primary uses in the analysis area (e.g., there is high prevalence of livestock water use around the analysis area, therefore the WDEQ Class III – Livestock Use Suitability standard was chosen), safety standards (e.g., certain thresholds of methane are established due to risk of an explosion), and groundwater cleanup levels. Some of these standards overlap with EPA Primary or Secondary Drinking Water Standards, which are also described here as appropriate or where other standards do not exist. Data for wells sampled through 2014 by Trihydro (2011, 2013, 2014a, 2014b) as part of the NPL Groundwater Monitoring Program have been identified in the following sections. At the time of this report, there were no 2014 data available for wells in the Jonah Field. Refer to Attachment C (*Water Quality Results from Water Wells in and Around the Project Area*) for detailed information including measurements that have exceeded regulatory standards and limits.

Water quality information from wells presented in Attachment C (*Water Quality Results from Water Wells in and Around the Project Area)* was gathered from AECOM 2014; AMEC 2014; Trihydro 2011, 2013, 2014a, 2014b; and Wyoming SEO 2014. This information represents existing conditions and is depicted on Figure K-8. From these data, select wells, which are presented in Figure K-8, indicate several trends, including:

- Methane was detected in wells located in the central- to south-eastern portion of the analysis area, with four wells exceeding 5 mg/L (Figure K-8). Concentrations of methane above 5 mg/L warrant isotope analysis to help identify potential sources. There are no drinking water or groundwater standards established for methane.
- TDS was detected in wells throughout the analysis area but in larger concentrations throughout the western portion of the analysis area. Only one well exceeds the WDEQ Class III – Livestock Use Suitability standard of 5,000 mg/L (Map Reference #50 on Figure K-8). This standard was chosen for purposes of comparison because of the high prevalence of livestock water use in and around the Project Area. The primary component of TDS is sulfate.
- Benzene was detected in three wells in the central-north portion of the analysis area (Figure K-8). Only one well (Corona 2-14, Map Reference #61 on Figure K-8) exceeds the EPA Primary Drinking Water Standard and Wyoming Groundwater Cleanup Level of 5 µg/L. These are the only standards available for benzene, which is health concern in drinking water.
- Chlorides were detected in wells throughout the analysis area, with the largest concentrations found throughout the southeastern portion (Figure K-8). Two wells exceed the EPA Secondary Drinking Water Standard, Wyoming Groundwater Cleanup Level, and WDEQ Class I – Domestic Use Suitability standard of 250 mg/L (Map Reference #3 and 43 on Figure K-8). These standards are presented because WDEQ Class III – Livestock Use Suitability standard is 2,000 mg/L, and no wells exceeded this standard.
- TPH-DRO (hydrocarbon) was detected in six wells at very low concentrations, with the majority of wells with detected levels being in the western portion of the analysis area (Figure K-8). None of the wells exceed the Wyoming Groundwater Cleanup Level of 1.1 mg/L (if benzene is present) or 10 mg/L (if benzene is absent). There are no additional established drinking water standards for DRO.
- TPH-GRO (hydrocarbon) was detected in eight wells at very low concentrations, with the majority of wells with detected levels to the north-western portion of the analysis area (Figure K-8). None of the wells exceeded the Wyoming Groundwater Cleanup Level of 7.3 mg/L. There are no additional established drinking water standards for GRO.

Refer to Attachment C (Water Quality Results from Water Wells in and Around the Project Area) for more information on water quality for all wells where data are available and a summary of regulatory standards or limits for water quality parameters.

Figure K-7. Water Quality Sampling Locations

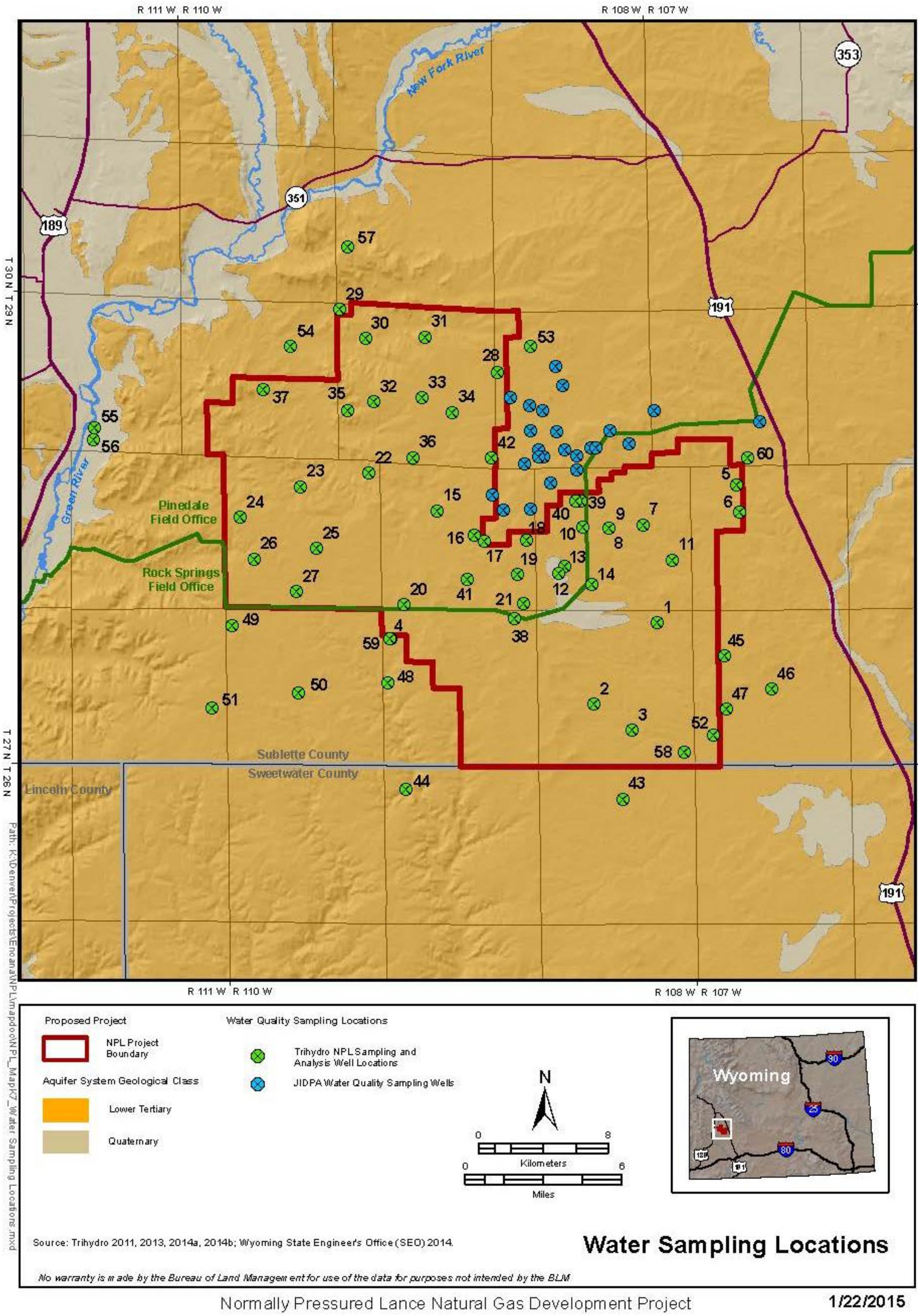
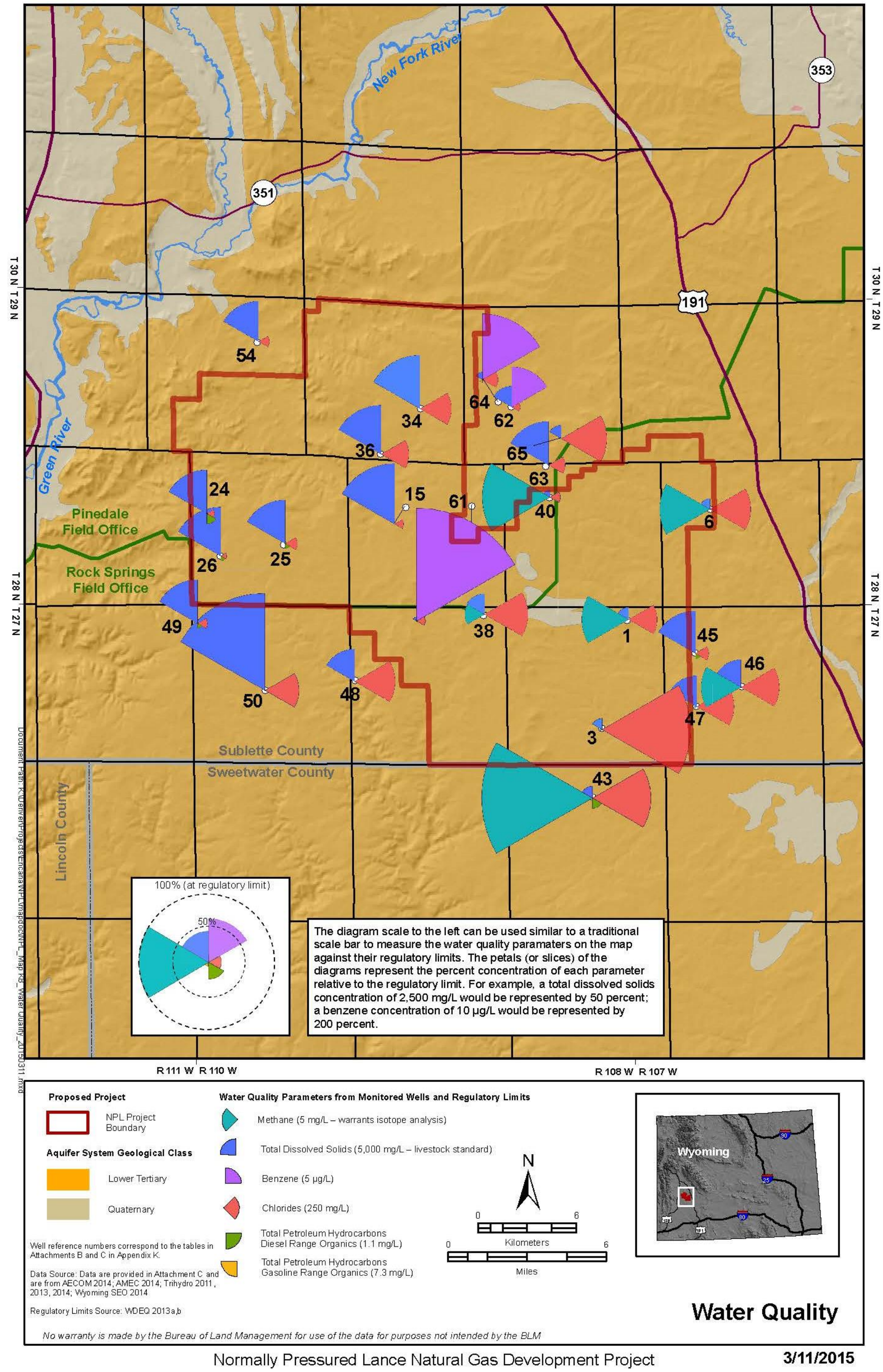


Figure K-8. Water Quality Summary of Representative NPL and JIDPA Wells



4.2.2.1. Alluvial Aquifer

Most wells in the NPL Project Area and JIDPA are completed in the upper 1,100 feet of the Wasatch Formation due to the favorable hydrologic properties in the upper strata; however, some wells and springs are interpreted to have source zones in the Alluvial Aquifer. Wells and springs are identified as alluvial sources if they were shallow (less than 150 feet) and adjacent to a river or stream (Trihydro 2011). No field or hydrological studies have been conducted to verify the water source relationships for the sampling points interpreted to be alluvial from the operator's sampling and analysis program. Sampling and analysis of existing wells and springs in the NPL Project Area (Figure K-7) (Trihydro 2011, 2013, 2014a, 2014b) provide the best available data for assessing water quality from the alluvium. Some alluvial aquifers may be recharged by underlying or adjacent zones including the Wasatch and Laney. Alluvial sources with water quality data include the following wells in or adjacent to the NPL Project Area: NA1, P9437, and McGinnis2 as identified in Attachment C (*Water Quality Results from Water Wells in and Around the Project Area*). North Sublette Meadow Spring, located immediately adjacent to the east boundary of NPL Project Area, is also likely sourced from the alluvium (Figure K-1). Attachment B (*Water Supply Wells in and around the NPL Project* Area) provides available water quality information for alluvial sources noted above, and Figure K-8 provides a summary of water quality.

Water quality in the Alluvial Aquifer is similar to the Wasatch, as described below. The water is a sodium sulfate to sodium bicarbonate composition. Elevated TDS, pH, sulfate, iron, and manganese are present in some wells and springs above U.S. EPA Primary Drinking Water Standards (EPA 2009). North Sublette Meadow Spring (Map Reference #45 on Figure K-8) contained detectable levels of TPH – DRO in 2011, 2013, and 2014 (Trihydro 2011, 2014a, 2014b), and well NA1 exhibited a low concentration of TPH – GRO in 2013 (Trihydro 2014a). Refer to Attachment C (*Water Quality Results from Water Wells in and Around the Project Area*) for more information on water quality, by well.

4.2.2.2. Wasatch Aquifer

The Wasatch Aquifer would provide water for the NPL Project from existing water supply wells in the JIDPA and NPL Project Area (Figure K-2) and potential new water supply wells in the NPL Project Area. Water quality data for the Wasatch Aquifer is described below for the upgradient area (JIDPA and PAPA), the NPL Project Area, and the areas adjacent to the NPL Project Area on the south, east, and west boundaries of the NPL Project Area. Water quality data for the Wasatch Aquifer were obtained from water supply wells in the JIDPA that draw from the Wasatch Aquifer and are summarized in Tables K-4 and K-5 and detailed in Attachment C (*Water Quality Results from Water Wells in and Around the Project Area*).

Water quality, represented by the TDS content, generally decreases in the deeper parts of the aquifer (Bartos et al. 2010). Analysis of well log data (Phillips 2013b) from the Wasatch in the JIDPA (well SHB 1-20, located in T29N, R108W, Section 20) shows high resistivity in the upper sands (0 to 1,000 feet below surface), corresponding to freshwater, and low resistivity in water bearing sands in the lower Wasatch (2,500 to 4,000 feet below surface) indicates higher TDS content. The BLM (Onshore Order No. 2) considers any groundwater from fresh (<1,000 mg/L) to moderately saline (<10,000 mg/L) as usable water, which is to be protected. Regulations from 40 CFR Section 144.3 indicate that all groundwater with TDS less than or equal to 10,000 mg/L are presumed to be an underground source of drinking water (USDW) and must be protected unless an aquifer exemption has been granted under the Safe Drinking Water Act (SDWA). Water samples from the underlying Fort Union at depths of 5,000 to 6,500 feet below surface have TDS concentrations of approximately 50,000 mg/L (Table K-6). The downward increase in TDS from fresh water to Class IV (B), or lower water quality, is demonstrated; however, the exact depth at which the water exceeds a TDS concentration of 10,000 mg/L (the BLM criteria for usable water) has not been established. For the purpose of the analysis of potential impacts, it is assumed that all of the water bearing zones of the Wasatch in the analysis area contain usable water (TDS concentration less than 10,000 mg/L) unless otherwise demonstrated, and is protected in accordance with Onshore Order No. 2. It is also considered an USDW and is protected under the SDWA.

The operator's sampling and analysis program in the NPL Project Area is conducted annually for a limited number of parameters including specific conductivity, pH, TDS, alkalinity, chloride, barium, calcium, iron, magnesium, sodium, benzene, toluene, ethylbenzene, and xylenes (BTEX), TPH - DRO and TPH – GRO (Trihydro 2011, 2013, 2014a, 2014b). The wells and springs included in the sampling program were not specifically designed for groundwater monitoring and therefore the sampling results may not represent ambient groundwater conditions. Drilling practices, well construction materials, and well construction may affect the representativeness for the samples. In addition, diesel or gasoline powered generators were used to power pumps at some of the well locations, and operation and maintenance of these generators could result in releases of petroleum hydrocarbons, and as a result, affect the water samples. Water quality results from the operator's sampling and analysis program is presented as the best available existing information for water quality in the NPL Project Area.

Four rounds of annual sampling and analysis of water wells and springs have been conducted in and adjacent to the NPL Project Area (Trihydro 2011, 2013, 2014a, 2014b). Between 2011 and 2013, 50 samples were collected from 30 wells and springs (Trihydro 2014a). Most of the sampled wells are used for livestock watering and a few are used for domestic water supply. There are no industrial, agricultural, monitoring, or observation wells in the NPL Project Area. A subset of all wells in the area was sampled each year: 26 wells were sampled in 2011, 11 wells were sampled in 2012, and 13 wells were sampled in 2013, with some wells being sampled in multiple years. Under the revised WOGCC Baseline Water Quality Sampling Plan, 21 wells were sampled in 2014. Water samples were initially analyzed for a wide range of analytes including general parameters, dissolved metals, general organics, dissolved gases, radiological, bacteria, alcohols, and glycols. Subsequent rounds of sampling events include a more limited list of indicator analytes with a provision to expand the analyte list if indicator compounds exceed established thresholds (Trihydro 2013). Fluoride was not sampled in 2011 (Trihydro 2011), but was added and included in the 2012 through 2014 analyte lists (Trihydro 2013, 2014a, 2014b). Arsenic was analyzed in 2011 and 2012 but was not analyzed subsequently. VOCs were analyzed using EPA Method 8260B, a gas chromatography/mass spectroscopy (GC/MS) method that is less likely to result in the misidentification of benzene, which may occur when using GC-only analytical methods such as EPA Method 8021B (AMEC 2013b). Results of the sampling and analysis program are summarized below, and results are presented by well in tabular format in Attachment C (*Water Quality Results from Water Wells in and Around the Project Area*). Refer to the TriHydro Sampling and Analysis Reports for piper diagrams of water chemistry for wells sampled in 2011-2014 (Trihydro 2011, 2013, 2014a, 2014b).

Select water quality parameters (based on the highest frequency of detected values and those parameters with established drinking water and groundwater standards from the EPA (2009) and WDEQ (2013)) for wells sampled in 2013 are presented in Figures K-10, A-L as boxplots by field to show the variation, median (i.e., typical value), minimum and maximum observations, and outliers. These boxplots are presented together at the end of this section to allow for side-by-side comparison of analytes.

Table K-4 Summary Statistics for Jonah Water Supply Wells, 2013

	Well Depths (ft. bgs)	Water Level (ft. bgs)	Temp °C	pH	Conductivity (µS/cm)	Total Dissolved Solids (mg/L)
Min	510	70	8.0	8.4	557	286
Max	2,310	360	16.3	10.5	5,660	4,370
Average	869	180	10.9	9.4	1,534	945

Source: AMEC 2014; AECOM 2014; Trihydro 2014a; USGS 2010; Wyoming SEO 2014.

Note: Data used to generate these statistics are found in Table K-5.

°C degrees Celsius
ft. bgs feet below ground surface
mg/L milligrams per liter
µS/cm micro Siemens per centimeter

Table K-5. Annual Groundwater Monitoring Results from Water Supply Wells in the Jonah Field, 2013

Well Identification	Total Depth (ft. bgs)	Water Level (ft. bgs)	Date	Field Temperature (Celsius)	Field pH (SU)	Field Conductivity (µS/cm)	Total Dissolved Solids (mg/L)
Cabrito 13-19W	900	360 [b]	11/8/2013	10.03	**10.0** [f]	570	**308** [d]
Jonah Fed 2-5W	920	167 [c]	11/6/2013	10.04	**8.6** [f]	2,500	**1,690** [d]
Jonah Fed 2-7W	745	220 [b]	11/6/2013	10.17	**9.2** [f]	1,640	**1,010** [d]
Jonah Fed (SHB) 32-34	1,000	300 [b]	11/6/2013	10.97	**9.6** [f]	1,090	**656** [d]
Stud Horse Butte 122-10	740	150 [b]	11/8/2013	8.89	**9.8** [f]	863	**514** [d]
Stud Horse Butte 11-20W	760	150 [b]	11/7/2013	9.63	**9.4** [f]	986	**565** [d]
Stud Horse Butte 11-26W	735	346 [c]	11/5/2013	11.04	**9.5** [f]	872	**466** [d]
Stud Horse Butte 10-28W	900	135 [b]	11/7/2013	9.47	**9.2** [f]	1,080	**591** [d]
Stud Horse Butte 11-29W	615	109 [c]	11/7/2013	8.03	**8.9** [f]	2,670	**1,870** [d]
Stud Horse Butte 7-32W	940	70 [b]	—	—	—	—	—
Stud Horse Butte 9-32W	700 [a]	100 [a]	11/8/2013	9.77	**8.4** [f]	2,480	**1,910** [d]
Stud Horse Butte 10-32W	940	140 [b]	11/8/2013	8.97	**9.0** [f]	2,250	**1,590** [d]
Stud Horse Butte 13-32W	740	320 [b]	11/8/2013	10.04	**8.5** [f]	3,430	**2,460** [d]
Stud Horse Butte 7-33W	1,100	120 [b]	11/7/2013	11.03	**9.4** [f]	949	**536** [d]
Stud Horse Butte 8-34W	900	280 [b]	11/6/2013	10.98	**9.8** [f]	854	**493** [d]
Stud Horse Butte 10-34W	1,000	160 [b]	11/6/2013	9.51	**9.6** [f]	1,060	**610** [d]
Stud Horse Butte 4-36W	960	189 [c]	11/9/2013	8.82	**9.7** [f]	660	**360** [d]
Yellow Point 10-11W	800	100 [b]	11/8/2013	10.78	**8.6** [f]	5,660	**4,370** [d]
Yellow Point 1-13W	575	150 [b]	11/7/2013	9.69	**9.3** [f]	1,700	**1,100** [d]
Wagon Road 1-26	800	90 [b]	—	—	**—**	—	**—**
Corona 2-14	973 [b]	250 [b]	9/12/2013	13	**10.5**	2,969	**453**
Jonah Field Office	640 [b]	130 [b]	9/12/2013	13	**9.29**	557	**286**

Table K-5. Annual Groundwater Monitoring Results from Water Supply Wells in the Jonah Field, 2013

Well Identification	Total Depth (ft. bgs)	Water Level (ft. bgs)	Date	Field Temperature (Celsius)	Field pH (SU)	Field Conductivity (µS/cm)	Total Dissolved Solids (mg/L)
Stud Horse Butte 15-16	680 [b]	145 [b]	9/12/2013	14	**9.91**	881	**439**
Stud Horse Butte 16-20	680 [b]	145 [b]	9/12/2013	12.7	**9.98**	1,022	**525**
Stud Horse Butte 23-16	1050 [b]	155	9/12/2013	16.3	**10.1**	562	**299**
Corona 7-19	900 [b]	265	9/12/2013	15.9	**10.3**	608	**320**
Holmes Federal 5-1W [e]	630	200	7/17/2013	—	**8.55**	1,130	**620**
Work Force Facility	1,100	—	7/16/2013	—	**9.05**	849	**540**
Plains WSW 2	510 [b]	150 [b]	—	—	—	—	—
Stud Horse Butte 14-32W	—	—	—	—	—	—	—
Stud Horse Butte 16-34W	2,310 [b]	200 [b]	—	—	—	—	—
SOL 9-36	920 [b]	175 [b]	—	—	—	—	—

Sources: AMEC 2014; AECOM 2014; Trihydro 2014a; USGS 2010; Wyoming SEO 2014.

[a]Assumed values were used because specific well information was not available.
[b]Information obtained from the State Engineers Office.
[c]Static water levels obtained using a sonic water level meter during 2009 annual groundwater monitoring event.
[d]Laboratory Analysis of total dissolved solids by Method A2540C.
[e]Water supply well for Jonah Field, but located in the NPL Project Area.
[f]pH measured in the laboratory.

ft. bgs feet below ground surface
mg/L milligrams per liter
SU Standard Units
µS/cm micro Siemens per centimeter

4.2.2.2.1. Petroleum Hydrocarbons

As part of the operator's sampling and analysis program in the NPL Project Area, wells were also sampled for general hydrocarbons (TPH-DRO and TPH-GRO using EPA Method 8015C). As indicated in Attachment C (Water Quality Results from Water Wells in and Around the Project Area), DRO was detected in four wells in 2013 in the NPL Project Area and two wells outside of the Jonah and NPL Project Area, with values ranging from 0.033 to 0.084 mg/L and 0.038 to 0.042 mg/L, respectively (Figure K-10G) (Trihydro 2014a). GRO was detected in one well in the NPL Project Area, and two wells outside of the JIDPA and NPL Project Area in 2013 (Figure K-10H). (Trihydro 2014a) These levels ranged from 0.011 to 0.326 mg/L. One of these sampling locations outside of the JIDPA and NPL Project Area is a spring – the North Sublette Meadow Spring. There are no EPA Primary or Secondary Drinking Water Standards for DRO or GRO. Wyoming has established Groundwater Cleanup Levels for DRO at 1.1 mg/L if benzene is present or 10 mg/L if benzene is not present, and for GRO at 7.3 mg/L (WDEQ 2013). None of the wells with detectable levels of DRO or GRO exceed these levels. It should be noted that the reporting levels for GRO and DRO were higher in 2011 and 2012 than in 2013; therefore DRO and GRO may have been present in the earlier sampling years, but in concentrations too low for detection or reporting (Trihydro 2011, 2013, 2014a). In 2014, 10 out of 16 wells in the NPL Project Area and four out of five wells outside of the NPL and Jonah Fields had detectable levels of DRO (Trihydro 2014b). No wells sampled in 2014 had detectable levels of GRO (Trihydro 2014b).

In 2013, low concentrations of petroleum hydrocarbons (including BTEX and TPH - GRO) were detected at JIDPA in five of the 24 wells sampled by Linn Energy and EnCana (Corona 2-14, Stud Horse Butte 16-20, Stud Horse Butte 11-20W [Map References 61, 62, and 64, respectively, on Figure K-8], Corona 7-19, and Stud Horse Butte 10-32W [not mapped]). These wells are located in the west central portion of the JIDPA and are hydrologically upgradient from the NPL Project Area (Figure K-8). Petroleum components have been detected in previous sampling rounds in other wells, but none were above U.S. EPA Primary Standards.

Petroleum hydrocarbons have been detected north of the JIDPA in the PAPA at concentrations above the U.S. EPA Primary Standards (AMEC 2013b). The water supply wells where organic constituents have been consistently detected at concentrations greater than applicable groundwater standards have been, or are currently, under regulatory oversight by the WDEQ through the Voluntary Remediation Program (AMEC 2013a). Extensive analysis of the presence of hydrocarbons at the PAPA concluded that there is no evidence that oil and gas operations have resulted in widespread impacts to groundwater in the PAPA. Hydrocarbons detected in the wells are the result of the following factors:

- Low level volatile organic compounds are largely attributable to upward seepage of natural gas from deep, underlying gas reservoirs over time into overlying geologic layers where groundwater occurs;
- The source of low level semivolatile organic constituents is not readily apparent but likely originates from substances introduced into water wells during drilling, installation, and operation of the well; or
- Naturally occurring organic matter in groundwater or associated with particles suspended in well water during sample collection (AMEC 2013a).

4.2.2.2.2. Total Dissolved Solids and Iron

As indicated in Attachment C (*Water Quality Results from Water Wells in and Around the Project Area),* TDS concentrations above the U.S. EPA secondary standards are present in many water supply wells in the JIDPA (Figure K-8) (Trihydro 2011, 2013, 2014a, 2014b). Elevated iron is also present in some wells. Elevated TDS and iron concentrations are a naturally occurring condition common within the Wasatch Formation (Bartos et al. 2010). As shown in Figure K-10, the ranges of TDS are similar between the Jonah and NPL Fields, with the typical (i.e., median) value for Jonah being the lowest among the group. In 2013, seven of the eight samples in the NPL Project Area indicate TDS levels above the EPA Secondary Drinking Water Standard and Wyoming Groundwater Cleanup Level of 500 mg/L for TDS (EPA 2009; Trihydro 2014a; WDEQ 2013), and in 2014, 14 out of the 16 samples exceeded these levels (Trihydro 2014b). Seventeen of the 27 samples for the JIDPA in 2013 indicated TDS levels above these standards, with an outlier at 4,370 mg/L and the next highest observation at 2,460 mg/L. All ten samples outside of the NPL and Jonah Fields (i.e., “other”) in 2013 and 2014 indicated TDS levels above the standards, with a range of 570-1,540 mg/L.

As indicated in Attachment C (*Water Quality Results from Water Wells in and Around the Project Area*), the typical ranges of total iron are similar among all the fields; however there are several significant outliers in the JIDPA, with the highest sample reaching 28.9 mg/L in 2013 (Figure K-10C) (Trihydro 2014a). This sample is well above the EPA Secondary Drinking Water Standard of 0.3 mg/L and above the Wyoming Groundwater Cleanup Level of 25.5 mg/L for iron (EPA 2009; WDEQ 2013). Nine of the 19 samples in the JIDPA in 2013 are above the EPA Secondary Drinking Water Standard and two are above the Wyoming Cleanup Level (Trihydro 2014a). In 2013, two of the six samples for the NPL Project Area and two of the five samples outside of the Jonah and NPL Fields are also above EPA standards; none of which are above Wyoming Groundwater Cleanup Levels. The minimum observations among the samples in the NPL Project Area and JIDPA are similar, with total iron values around 0.03-0.04 mg/L. Total iron was not part of the analyte list for wells tested in 2014 (Trihydro 2014b). Dissolved iron was only sampled in 12 wells in the JIDPA in 2013, with concentrations ranging from 0.03 to 3.8 mg/L (Figure K-10D) (Trihydro 2014a). Dissolved iron was sampled in all wells inside the NPL Project Area and all wells outside of the NPL and Jonah Fields in 2014; 11 out of 21 wells tested had detectable levels of dissolved iron, with concentrations ranging from 0.0105 to 1.15 mg/L (Trihydro 2014b). There are no drinking water or groundwater standards for dissolved iron.

4.2.2.2.3. Fluoride

As indicated in Attachment C (*Water Quality Results from Water Wells in and Around the Project Area)*, results of the of the water quality analyses show concentrations of fluoride above the EPA Primary Drinking Water Standard and Wyoming Groundwater Cleanup Level of 4.0 mg/L in three of the eight wells sampled in the NPL Project Area and two of the five wells sampled outside of the NPL Project Area and JIDPA (i.e., “other”) in 2013 (Figure K-10E) (EPA 2009; Trihydro 2014a; WDEQ 2013). However, it should be noted that fluoride is known to be high and natural occurring in this area (WSGS 2010). The ranges of detected fluoride in both sampling areas in 2013 are similar, with minimum observations of 0.69 and 0.8 mg/L and maximum observations of 9.8 and 8.8 mg/L for the NPL Project Area and other area, respectively (Trihydro 2014a). Fluoride was detected in eight out of 16 wells in the NPL Area and two out of five wells outside of the NPL and Jonah Fields at levels greater than the drinking water and groundwater cleanup level of 4.0 mg/L (Trihydro 2014b). No wells in the JIDPA were sampled for fluoride in these analyses.

4.2.2.2.4. Sulfate and PH

As indicated in Attachment C (*Water Quality Results from Water Wells in and Around the Project Area),* sulfate and pH exceeded U.S. EPA Secondary Drinking Water Standards in several wells over the four year period (Trihydro 2011, 2013, 2014a, 2014b). As indicated in Figure K-10A, each field has samples that exceed the upper range of the EPA Secondary Drinking Water and Wyoming Groundwater Cleanup Level of pH 6.5-8.5 (EPA 2009; WDEQ 2013) in 2013, with samples in the JIDPA having some of the highest observations of up to pH 10.5 (Trihydro 2014a). These high levels may be due to pH being measured in Jonah samples from AMEC (2014) in the laboratory, rather than the field; however, some of these samples with lower pH levels are similar to those in the other fields. Overall, 25 of the 27 wells in the JIDPA, five of the eight wells in the NPL Project Area, and three of the five wells in other areas exceed the upper limit (pH 8.5) of the EPA and Wyoming standards in 2013. In 2014, nine out of 16 wells in the NPL area and three out of four wells outside of the NPL and Jonah Fields exceeded the upper pH limit of 8.5 (Trihydro 2014b).

4.2.2.2.5. Metals

As indicated in Attachment C (*Water Quality Results from Water Wells in and Around the Project Area*), in 2011, 2012, and 2013, wells in the NPL Project Area were tested for a variety of metals, including arsenic, boron, manganese, and selenium (Trihydro 2011, 2013, 2014a). In 2014, wells were tested for boron, manganese, and selenium. One well had a detectable concentration of arsenic in 2011 at 0.0901 mg/L, which is above the EPA Primary Drinking Water Standard and Wyoming Groundwater Cleanup Level of 0.01 mg/L. Two wells in 2012, one well in 2013, and two wells in 2014 had boron concentrations above the Wyoming Groundwater Cleanup Level of 0.75 mg/L (Trihydro 2013, 2014a, 2014b). Eight wells in 2011 and four wells in 2014 had detectable levels of manganese above the EPA Secondary Drinking Water Standard and Wyoming Groundwater Cleanup Level of 0.05 mg/L (EPA 2009; WDEQ 2013). One well in 2011 had a detectable level of selenium at 0.157mg/L, which is above the EPA Primary Drinking Water Standard and Wyoming Groundwater Cleanup Level of 0.05 mg/L.

4.2.2.2.6. Benzene, Toluene, Ethylbenzene, Xylenes

As indicated in Attachment C (*Water Quality Results from Water Wells in and Around the Project Area*), benzene was detected in four wells in the JIDPA, with concentrations ranging from 1 to 11.8 µg/L in 2013 (Figure K-8). The EPA Primary Drinking Water Standard and Wyoming Groundwater Cleanup Level for benzene is 5 µg/L (EPA 2009; WDEQ 2013), and one of these four wells with detectable levels of benzene exceeded these standards in 2013 with a concentration of 11.8 µg/L (Figure K-10I) (Trihydro 2014a). Toluene was detected in seven wells in the JIDPA in 2013 ranging from 0.44 to 38 µg/L (Figure K-10J). One sample outside of the JIDPA and NPL Project Area had a detectable concentration of toluene at 7.4 µg/L in 2013 (Trihydro 2014a). No wells with detectable levels of toluene exceed the EPA Primary Drinking Water Standard and Wyoming Groundwater Cleanup Level of 1,000 µg/L (EPA 2009; WDEQ 2013). There were no wells in the NPL Project Area with detectable levels of toluene in 2013. Ethylbenzene was detected in two wells in the JIDPA in 2013 with values of 0.3 and 3.2 µg/L, both of which are well below the EPA Primary Drinking Water Standard and Wyoming Groundwater Cleanup Level of 700 µg/L (Figure K-10K) (EPA 2009; Trihydro 2014a; WDEQ 2013). Xylenes were detected in four wells in the JIDPA in 2013, with values ranging from 0.85 to 35 µg/L (Figure K-10L) (Trihydro 2014a). None of the wells with detectable levels of total xylenes exceed the EPA Primary Drinking Water Standard and Wyoming Groundwater Cleanup Level of 10,000 µg/L (EPA 2009; WDEQ 2013). Ethylbenzene and xylenes were not detected in any of the wells in the NPL Project Area or outside of the NPL Project Area and JIDPA (Trihydro 2011, 2013, 2014a). In 2014, there were no wells in the NPL Project Area or outside the NPL and Jonah Fields with detectable levels of benzene, toluene, ethylbenzene, or xylenes (Trihydro 2014b).

4.2.2.2.7. Methane

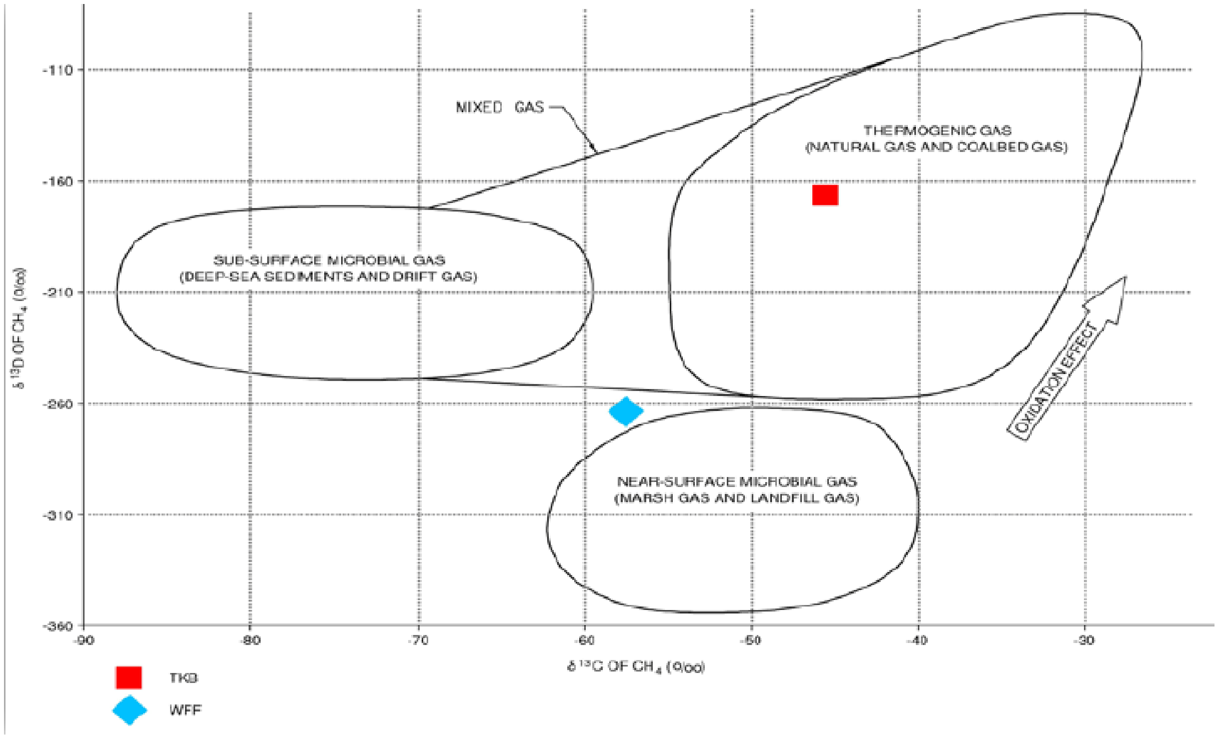
As indicated in Attachment C (*Water Quality Results from Water Wells in and Around the Project Area)*, dissolved methane levels were detected in water samples from five wells in the NPL Project Area and four wells in the area outside of the NPL Project Area and JIDPA in 2013. Methane was not analyzed in samples from JIDPA. The highest concentration detected in the NPL Project Area in 2013 was 5 mg/L (Figure K-8) (Trihydro 2014a). In 2014, 13 wells in the NPL Project Area and four wells outside of the NPL and Jonah Fields had detectable levels of methane (Trihydro 2014b). There are no drinking water or groundwater standards for methane; however, concentrations greater than 10 mg/L and less than 28 mg/L warrant investigation, and concentrations greater than 28 mg/L warrant immediate action due to risk of an explosion (Eltschlager et al. 2001). None of the detected concentrations of methane exceed these guidelines. Dissolved gas samples were collected from all wells and subjected to further isotopic analysis if the methane concentration exceeded 1.0 mg/L. Isotopic analysis of carbon and hydrogen in methane samples has been used to interpret the origin of methane gas to differentiate between biogenic gas, created by biological processes near or below the surface, and thermogenic gas, generally associated with thermal generation of oil and gas in the deep subsurface (Whiticar 1999). Over the four year sampling period (Trihydro 2011, 2013, 2014a, 2014b) methane was detected in 21 wells, and nine wells were at concentrations greater than 1.0 mg/L. All samples with concentrations greater than 0.1 mg/L are located in the eastern portion of the sampling area.

Eight methane samples from five wells (TKB, WFF, ETW, Err1, and Midland 2011-2) from the operator's sampling and analysis program were submitted for isotopic analysis between 2011 and 2014 to aid in determination of the source of the methane (Figures K-9, A-D) (Trihydro 2011, 2013, 2014a, 2014b). When plotted, samples from TKB and Err1 wells fell within the general range of thermogenic gas, and samples from Midland 2011-2, WFF, and ETW wells plotted near, but not within the biogenic near-surface region (Figures K-9, A-D). Trihydro (2011, 2014a, 2014b) interpreted the results of the methane analyses as potentially representative of methane from coal seams within the Wasatch; however, additional evidence has not been provided to support this interpretation. AMEC (2013b) found that the coal seams in the PAPA were not thermally mature enough to generate a hydrocarbon signature. In addition to Wasatch coal seams, the dissolved methane gas could be from a number of different sources including:

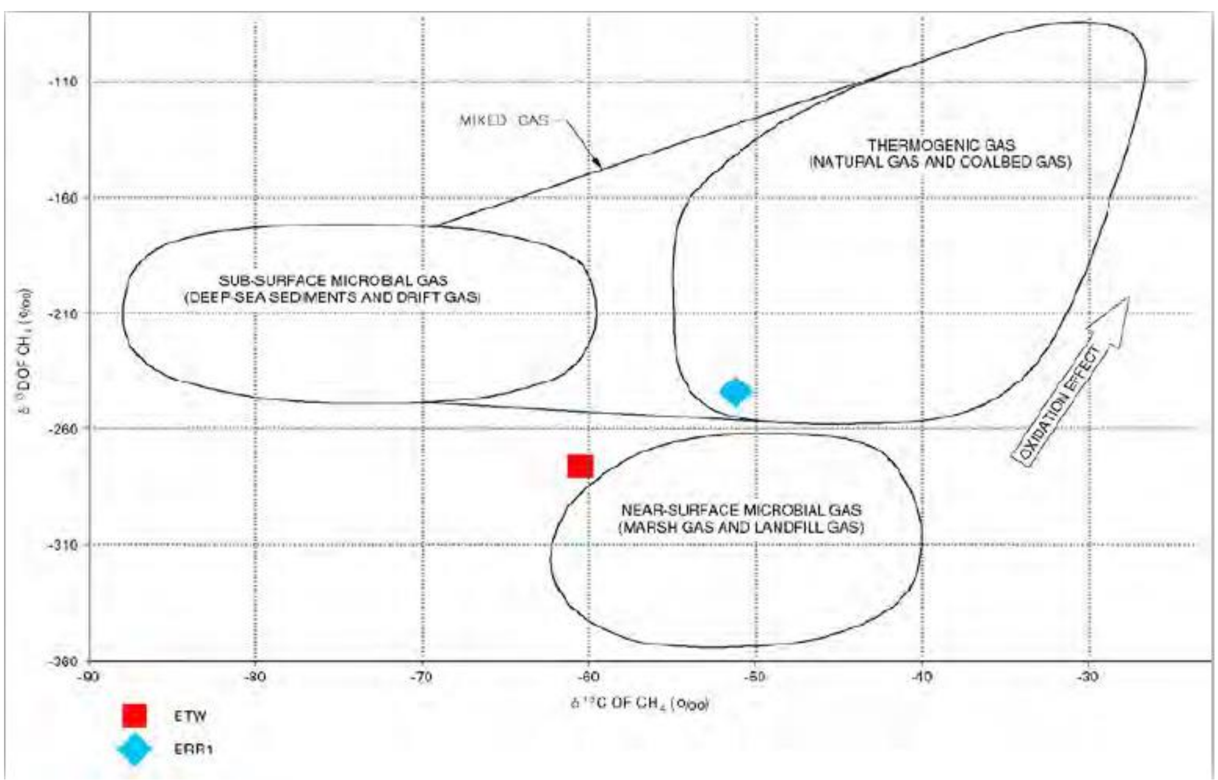
- Mixing of gases of different origins (e.g., microbial and thermogenic gas);
- Mixing of thermogenic gases with different maturities or complicated thermogenic histories; and,
- Microbial methane produced through biodegradation of hydrocarbon-containing compounds present in the Wasatch Formation, whether from natural or anthropogenic sources (AMEC 2013b).

Figure K-9. Isotopic Analysis of Methane for Wells in the NPL Area, 2011-2014

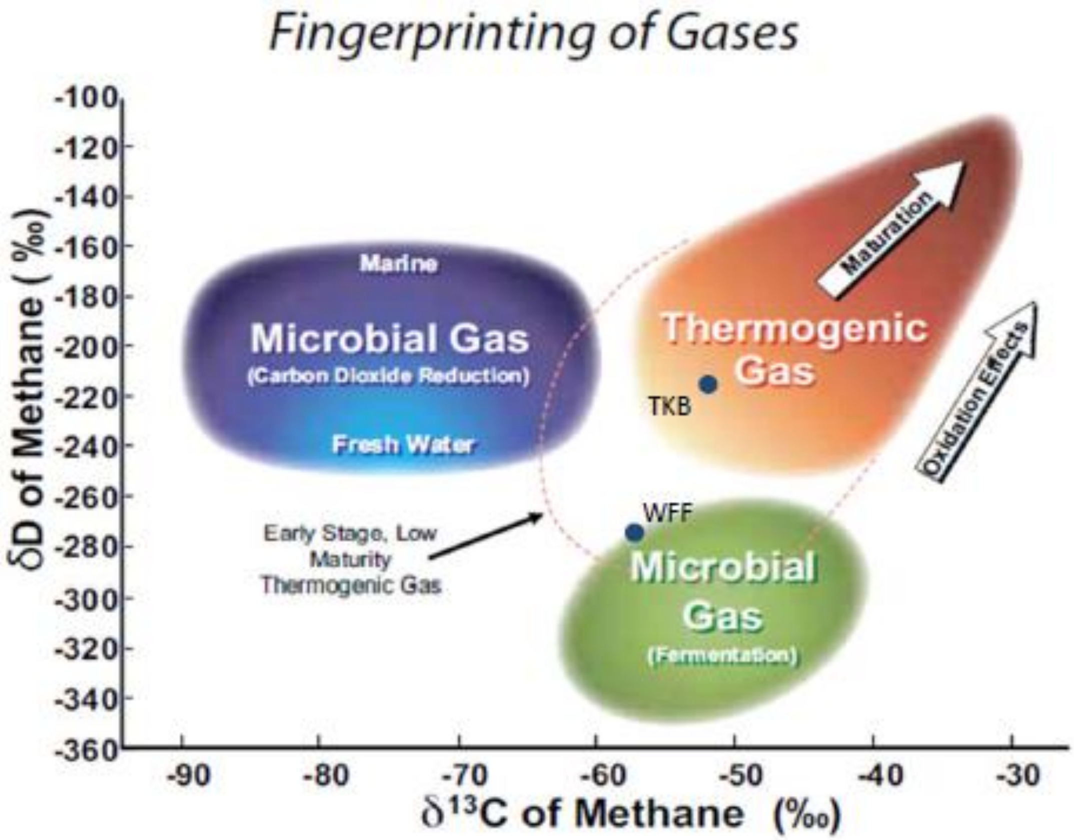
(A) Isotopic Analysis of Methane for TKB and WFF Wells, 2011



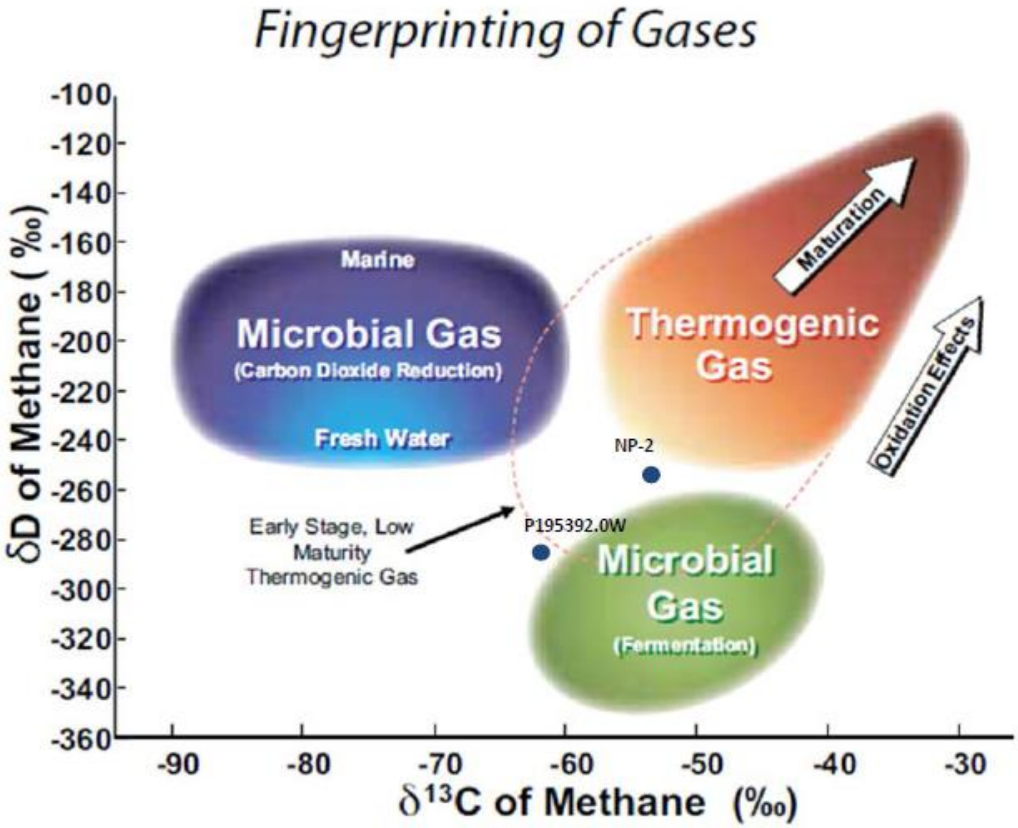
(B) Isotopic Analysis of ETW and ERR1 Wells, 2012



(C) Isotopic Analysis of TKB and WFF Wells, 2013



(D) Isotopic Analysis of Err1 and Midland 2011-2 Wells, 2014



Source: Trihydro 2011, 2013, 2014a, 2014b.

Notes for A and B: Chemical analysis based on standards accurate to within two percent. Analysis is of gas extracted from water by headspace equilibration. Analysis has been corrected for helium added to create headspace.

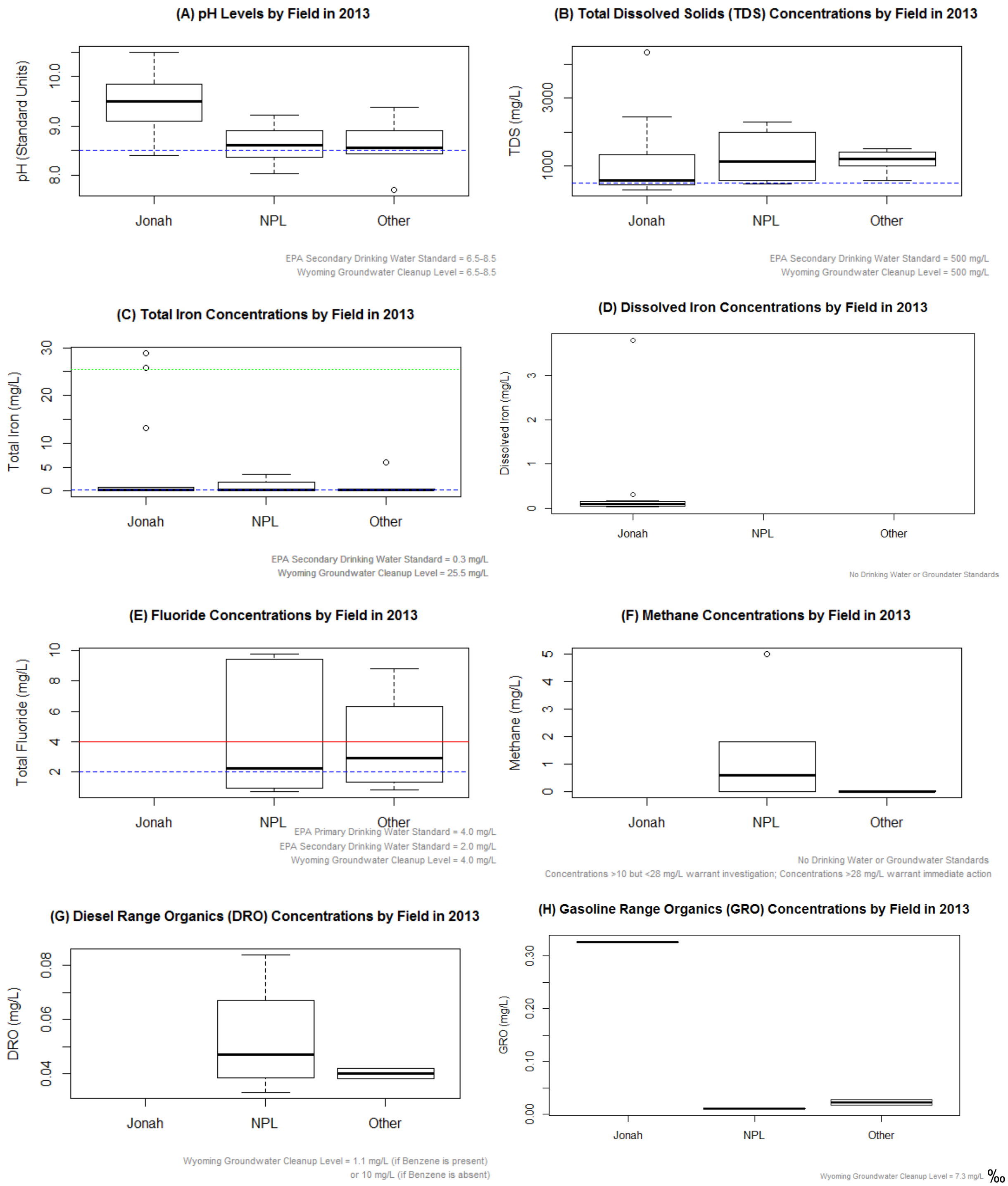
$\delta^{13}C_1$ = Carbon-13 isotope ratio, calculated from the following formula: $\delta C = [(^{13}C/^{12}C)_{SA}\text{-}(^{13}C\text{-}^{12}C)_{ST}/(^{13}C\text{-}^{12}C)_{ST}] \times 1000‰$
δDC_{SA} = Deuterium (H_2) isotope ratio, calculated from the following formula: $\delta S_{SA} = [(^{2}H/^{1}H)_{SA}\text{-}(^{2}H\text{-}^{1}H)_{ST}/(^{2}H/^{1}H)_{ST}] \times 1000‰$

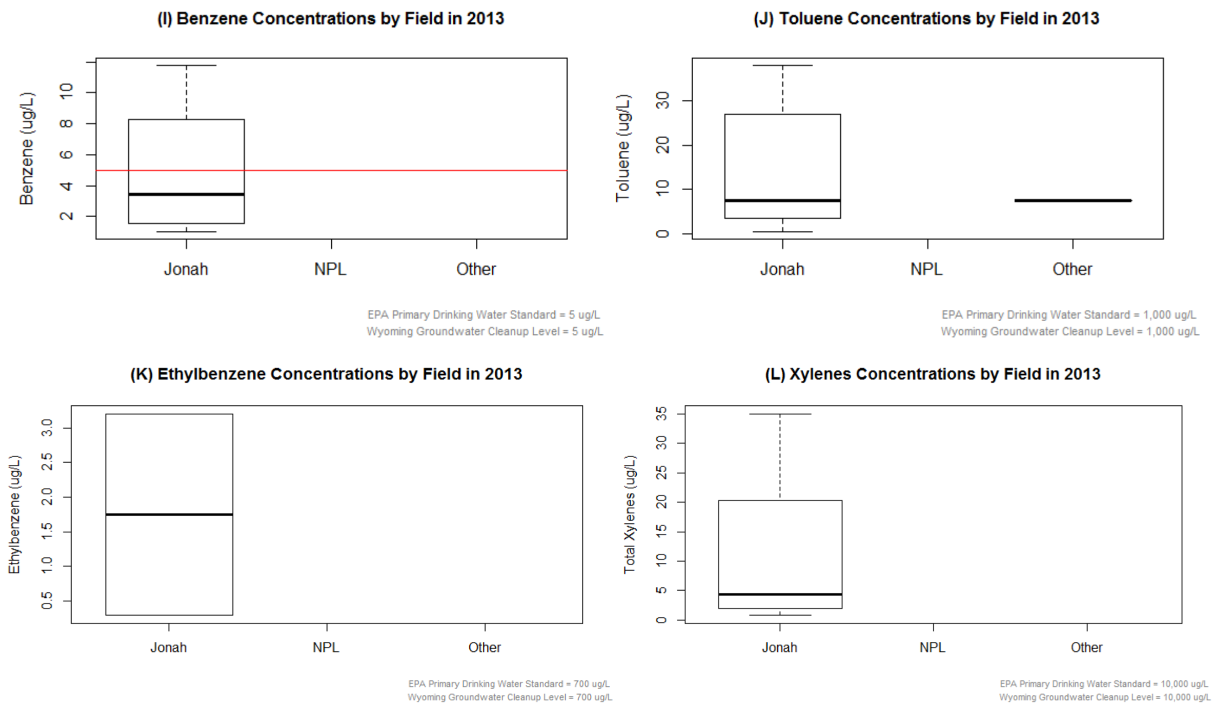
Notes for C: Dissolved Gas Identification $\delta^{13}C$ and δD from Isotech Laboratories, Inc. Chemical compositions are normalized to 100 percent. Mol. percentage is approximately equal to volume percentage. Analysis is of gas extracted from water by headspace equilibrium, corrected for helium to create headspace.

$\delta^{13}C$ = Carbon-13 isotope ratio; δD = Deuterium (H_2) isotope ratio
SA = Sample
ST = Internationally recognized standard

Gas groupings based on Coleman, 1995 (as cited in Trihydro 2011, 2013, 2014a, 2014b)

Figure K-10 (A-L). Boxplots of Water Quality Parameters for Water Supply Wells by Field in 2013





Sources: AMEC 2014; AECOM 2014; Eltschlager et al. 2001; EPA 2009; Trihydro 2014a; WDEQ 2013.

Red/solid line = EPA Primary Drinking Water Standard

Blue/dashed line = EPA Secondary Drinking Water Standard

Green/dotted line = Wyoming Groundwater Cleanup Level

mg/L milligrams per liter
µg/L micrograms per liter

Note: Some drinking water standards and cleanup levels are not show on the boxplots in cases where these limits are greater than the axis range of the plot. If two standards/limits are the same, the higher level is shown (e.g., if the EPA Primary Drinking Water Standard and the Wyoming Groundwater Cleanup Level are the same, the former is shown). Data were not available for parameters/fields missing boxplots. The methane concentration guidelines for action are established due to explosion risks, rather than health risks.

4.2.2.3. Fort Union Aquifer

In the GRB, water quality in the Fort Union Aquifer (the target zone for formation fluids injection) varies both laterally and vertically as a general function of transport distance from the recharge areas and subsurface depth (Bartos et al. 2010). Water quality data for the Fort Union Aquifer within the NPL Project Area are not available; however, data from several nearby JIDPA injection wells completed in the upper Fort Union were obtained from WOGCC (2014) and are summarized in Table K-6. Data from these wells represent the best available existing information for water quality in the Fort Union Aquifer. The chemical composition of the water is uniformly calcium chloride with some wells exhibiting high sodium concentrations. The sulfate and bicarbonate levels are very low compared to chloride. One well, on the southeastern side of the JIDPA, exhibited detectable concentrations of VOCs; however, no samples exceeded EPA (2009) MCLs for VOCs (Table K-6). Within the JIDPA, the porous sands in the upper Fort Union have consistently higher salinities than the underlying lower Fort Union, Lance, and overlying Wasatch Formations, as shown by a comparison of Tables K-4 and K-5, and in Attachment C (*Water Quality Results from Water Wells in and Around the Project Area)*. Jonah Energy has targeted these high salinity zones in the upper Fort Union as the proposed injection interval.

Table K-6. Water Quality Analysis from Selected Injection Wells in the JIDPA

Well Name	95-7 WDW SOL	3 WDW Jonah	14-21 WDW SHB	1 WDW Jonah	8-31 Cabrito*
Analysis Date	07/17/11	02/14/09	03/30/07	08/27/02	03/14/11
Injection Zone	Fort Union	Fort Union	Fort Union	Fort Union	Fort Union
Depth (ft. bgs)	4,898–7,160	5,705–6,400	5,200–6,515	6,004–6,513	5,944–7,720
Anions (mg/L)					
Chloride	**26,400**	**19,800**	**30,922**	**26,600**	**18,500**
Bicarbonate	60	18	0	39	254
Sulfate	**311**	**306**	15	116	106
Cations (mg/L)					
Sodium	3,970	3,190	3,650	2,516	3,270
Magnesium	80.0	15.0	59.0	33.0	30.3
Calcium	8700	8780	12700	12750	8020
Iron	7.47	15.00	7.00	0.20	0.35
Potassium	77.7	66.0	0.0	73.3	68.2
Lithium	0.29	NA	NA	ND	0.17
TDS (mg/L)	43,800	43,200	54,200	42,200	30,400
pH	6.51	6.57	7.57	7.27	7.71

Source: Data retrieved from WOGCC 2014.

Note: Exceedances of EPA (2009) Secondary Water Quality Criteria are indicated by bold numbers.

*Analysis from this well also noted Toluene (395 mg/L), Ethylbenzene (13.2 mg/L), and Xylenes (160 mg/L).

ft. bgs feet below ground surface
mg/L milligrams per liter

The EPA Secondary MCL for drinking water for TDS is 500 mg/L and chloride is 250 mg/L (EPA 2009) and WDEQ Class III water (suitable for livestock use) standard for TDS is 5,000 mg/L (WDEQ 2015). Data from JIDPA wells in the Fort Union Aquifer indicate TDS values from approximately 30,000 to 55,000 mg/L (Table K-6). Groundwater in the target injection zone has concentrations of TDS and chloride two orders of magnitude higher than drinking water standards for both parameters, and one order of magnitude higher than the Class III water standard, indicating that this is not a source of water for most applications. WDEQ groundwater regulations (2015) would likely classify the Fort Union minimally as either Class IV (B), which is water with TDS greater than 10,000 mg/L and suitable for industrial use, or more likely Class VI, which is unusable or unsuitable for use. The upper Fort Union proposed for injection does not contain usable water, as defined by the BLM, due to TDS content, and it does not meet the EPA definition of an USDW. Because of the high TDS content, injection into the upper Fort Union would not require an aquifer exemption from WOGCC (WOGCC 2014).

TDS concentration in the lower Fort Union is considerably lower than in the upper Fort Union. Water quality data from several injection wells in the Jonah Field completed in the lower Fort Union show less than 10,000 mg/L TDS. If the lower Fort Union is used for injection, it would require an aquifer exemption. Several injection wells in the Jonah Field use the lower Fort Union as the injection interval, and the EPA and WDEQ have determined that due to the combination of depth and water quality, this interval is not a source of drinking water and would qualify for an aquifer exemption (WOGCC 2014).

4.2.2.4. Mesaverde Aquifer

Water quality data for the Mesaverde aquifer was obtained from 74 produced water samples in the Green River Basin (Bartos et al. 2010). TDS concentrations range from 1,330 to 38,900 mg/L with a median concentration of 8,350 mg/L. In many samples TDS, chloride, sulfate and pH exceed aesthetic standards for domestic use. In the Project Area the Mesaverde aquifer is unlikely to be used as a source of drinking water due to its depth, quality, and availability of higher quality water at much shallower depths.

4.2.3 Groundwater Flow

The NPL Project Area is in the northwestern part of the GRB, and regional groundwater flows from the northern basin margins, where recharge occurs, southward to the center of the basin. Groundwater flow estimated from a potentiometric contour map of the lower Tertiary Aquifer (equivalent to the Wasatch Aquifer in the NPL Project Area) (USGS 2015a) indicates that groundwater flows mainly from the highlands of the Wind River Range, northeast of the analysis area, towards the west-southwest to the Green River (Figure K-11). Based on regional flow patterns, it is likely that a portion of groundwater flows through the PAPA and JIDPA before entering the NPL Project Area. There is also a component of flow directed towards the Big Sandy River to the southeast. Locally within the NPL Project Area, the direction of groundwater flow may differ from regional flow due to the heterogeneity of the rocks and the fluvial nature of the channel sand deposits within the Wasatch and Fort Union Aquifers. The potentiometric map (Figure K-11) and groundwater flow presented in this section represent the best available existing information as no NPL Project Area specific groundwater flow data have been collected at the time of this report.

Figure K-11. Potentiometric Surface of the Lower Tertiary Aquifer System (including the NPL Project Area)

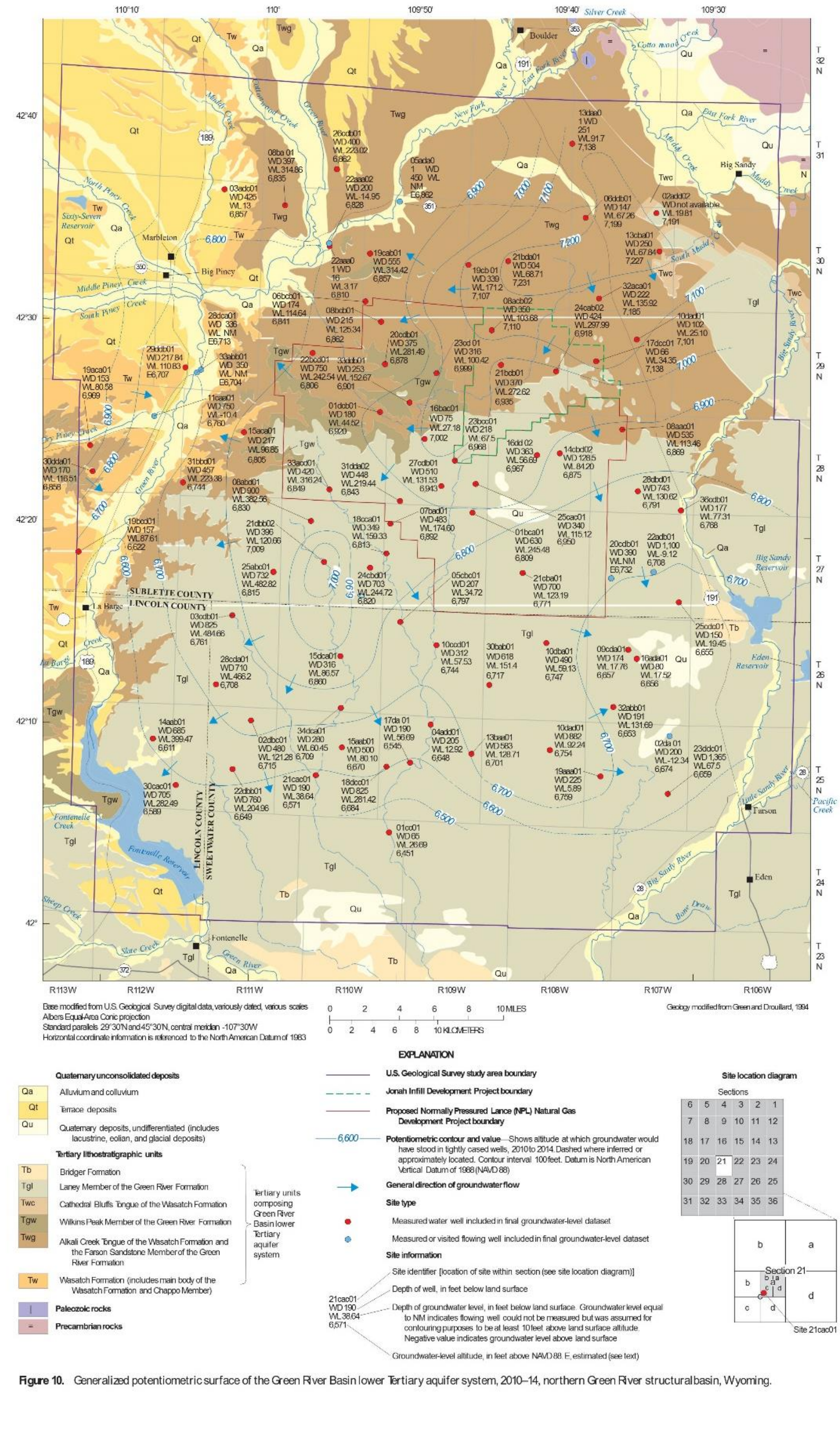


Figure 10. Generalized potentiometric surface of the Green River Basin lower Tertiary aquifer system, 2010–14, northern Green River structural basin, Wyoming.

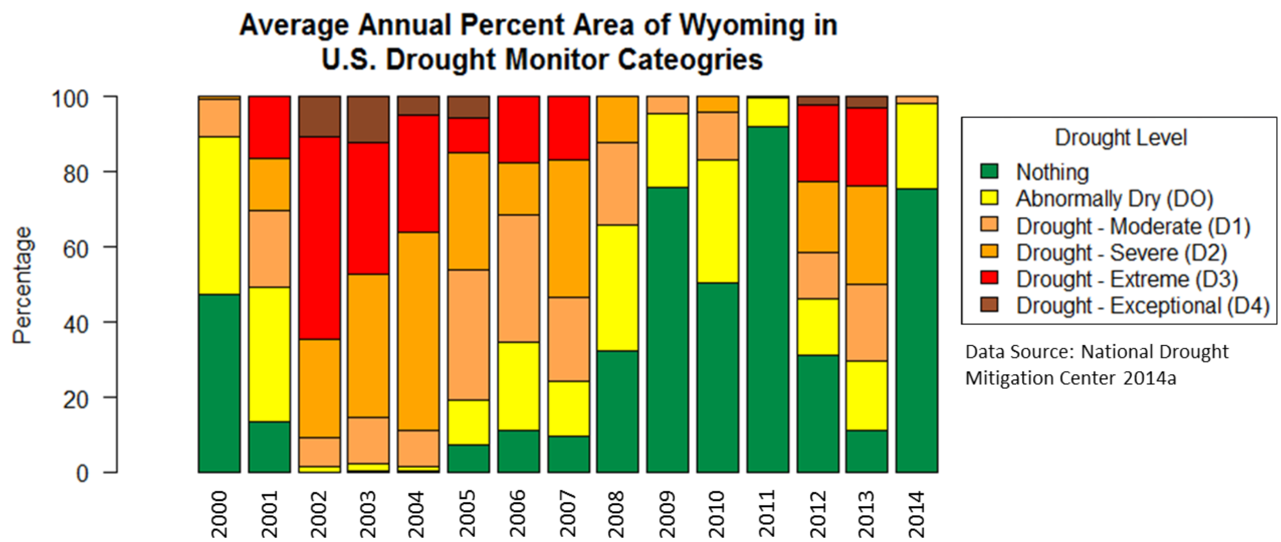
4.2.4 Depth to Groundwater

Groundwater is typically under confined (artesian) conditions in the GRB and, although groundwater may occur at great depth, the potentiometric surface of the water under pressure is often near ground surface. In the shallow aquifer and where the saturated Tertiary aquifer beds occur at shallow depth, groundwater may be unconfined (Bartos and Hallberg 2010). In general, the groundwater depths in both confined and unconfined wells in the GRB are within 200 feet of ground surface (Bartos and Hallberg 2010). Depth to groundwater maps prepared in support of the Wyoming Groundwater Vulnerability Mapping project (Hamerlinck and Arneson 1998) show that groundwater is typically between 50 and 100 feet below surface in the northwest part of the NPL Project Area and between 100 and 200 feet below surface in most of the remaining portions of the NPL Project Area. One significant deviation from the trend is the western Tea Kettle Butte area in the east-central portion of the NPL Project Area, where sandy surface soils are present and water levels are between 10 and 50 feet below surface (Figure K-1). Water level data were generally not collected from stock wells during the Trihydro (2011, 2013, 2014a, 2014b) annual sampling program because the sampling locations were not constructed to allow access. In cooperation with the BLM, the USGS collected water level measurements in the Project Area between 2010 and 2014 (USGS 2015a) from wells determined to be suitable for monitoring water level (USGS 2013). In the suitable wells, depth to water in the Laney Aquifer ranged from 26.29 feet e to 149.11 feet below land surface. For wells completed in the Wasatch (including the Green River equivalent strata), water levels ranged from 0 (seven flowing wells) to 484.66 feet below land surface. The 2013 USGS inventory of wells indicated that the shallowest depth to water in the Laney is in Townships 25N and 26N, Range 107W, southeast of the NPL Project Area, where the depth to water is less than 20 feet. Within the NPL Project Area where the Laney is targeted for water use, water levels range from 77.31 to 97.76 feet below ground surface. Flowing wells completed in the Wasatch are generally located in the eastern portion of the analysis area (Figure K-2), but several flowing wells were noted by USGS (2015) in the Green River floodplain in Townships 28N and 29N, Ranges 111W and 112W. North of the NPL Project Area flowing wells were identified in the New Fork River floodplain. The greatest depth to water in wells completed within the Wasatch Formation occurs south and west of the NPL Project Area where depth to water exceeds 450 feet below surface. USGS noted that some wells were pumping upon arrival or had recently been pumped, so the depths reported may be greater than static water level. In the far western part of the analysis area near Big Piney, groundwater discharges to the Green River and the depth to groundwater is very shallow, commonly less than 10 feet, and exhibits an upward gradient (Jorgensen 1994).

Water levels are not measured in the operating water supply wells at Jonah because the wells are not constructed to allow water level measurements (AMEC 2014). One JIDPA water supply well, Corona 2-14 (Map Reference #61 on Figure K-8), was shut down in 2006 as a result of contamination detected during regular sampling. Since 2009 water levels have been measured and observed to have increased from 290.78 feet below ground to 275.38 feet below surface; a recovery of 15.4 feet in five years.

Changes in groundwater levels are typically seasonal, although their effects can be exacerbated during drought conditions. During the drought of 1999-2007, groundwater levels across Wyoming decreased anywhere from a few feet to tens of feet (WSGS 2010). Figure K-12 shows the average annual percent of area for the state of Wyoming that falls within each of the drought monitoring categories in the U.S. Drought Monitor Classification Scheme (National Drought Mitigation Center 2014a). These categories are based on indicators and local reports from expert observers and range from "Nothing" (i.e., normal conditions) to "Drought – Exceptional" (i.e., exceptional and widespread drought conditions and impacts with shortages of water creating water emergencies) (National Drought Mitigation Center 2014b). The drought became more widespread and severe from 2000 (data were not available for 1999, which was the beginning of the drought) until 2008, when levels no longer reached "Extreme" conditions. In 2012 and 2013, significant areas of Wyoming again reached severe and exceptional drought conditions. The data for 2014 (currently available through May) shows no areas of Wyoming in drought conditions above "Moderate" (National Drought Mitigation Center 2014b).

Figure K-12. Average Annual Percent Area of Wyoming in U.S. Drought Monitor Categories



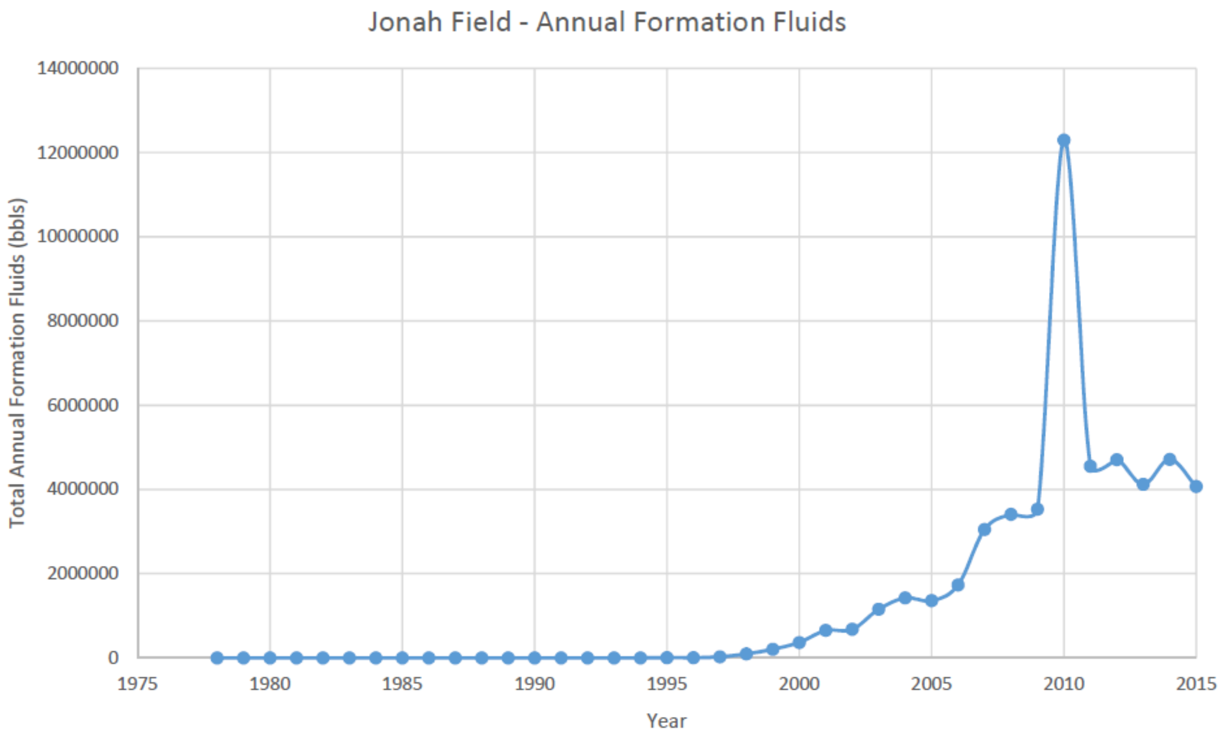
Groundwater levels can change over time in response to long-term weather patterns and water use. Historic depth to water measurements made in existing wells can be compared to recent water levels in the same wells to identify changes over time. USGS (2015) evaluated data from 27 wells in 2012-2014, mostly in the southern part of the study area, in which previous measurements had been taken in the 1960s and 1970s. The differences in water levels ranged from an increase of 5.5 feet to a decrease of 86.9 feet. Seventy-four percent of the wells showed a decrease in groundwater levels with declines ranging from 0.1 to 86.9 feet.

4.2.5 Formation Fluids

During operation, gas wells produce water along with natural gas and petroleum liquids. The water is brought to the surface, separated from the gas and other liquids and is either beneficially reused or disposed of in permitted surface locations or injected into subsurface locations. Formation fluids coming from the Lance Formation in the JIDPA are re-injected into the Fort Union, as described above, or piped or trucked to a central recycling facility to be reused for drilling and other field operations. Figure K-13 depicts annual formation fluids volumes for the JIDPA for 1978-November 2015. There were no formation fluids reported from 1978, the first year Jonah wells began producing gas, to 1984, and in 1985, 63 bbls of water were produced. An average of 1,372,373 bbls of water has been produced each year since 1978, and formation fluids spiked in 2010 at 12,298,414 bbls. Most recent data (through November 2015) indicate that the Jonah wells have cumulatively produced 52,150,184 barrels (approximately 6,722 acre-feet) of formation fluids (Table K-7) (WOGCC 2014).

Gas wells within the NPL Project Area (not designated as within the JIDPA) have cumulatively produced an estimated 217,186 barrels (28 acre-feet) of water from 1997 through April 2014; more current data were not available at the time of this report) (Table K-7) (WOGCC 2014). These values are estimates as some wells within the NPL Project Area are categorized by WOGCC as being within the JIDPA; therefore the field statistics for Jonah include some NPL Project Area wells, and as a result, formation fluids volumes for the JIDPA are likely lower than shown, and the NPL Project Area values are likely higher than shown (Figure K-8). In general, over time, gas wells tend to produce more water, and some wells are shut in or abandoned if water production is excessive. USGS found that gas-water ratios from the Jonah and Pinedale Fields do not change over time (Nelson et al. 2010). The reservoir characteristics in the NPL area have not been evaluated, and there is uncertainty as to whether the gas-water ratios will remain the same over time, like nearby structurally controlled fields, or if they will decrease over time.

Figure K-13. Total Annual Formation Fluids for the Jonah Field, 1978-2015



Source: WOGCC 2014.

bbl barrels

Note: 2015 data only include data for January through November. December data were not available at the time of this report.

Table K-7. Total Estimated Formation Fluids from Existing Oil and Gas Wells in the Jonah Field and NPL Project Area

Field/Area	Total Formation Fluids Volume (bbls)
Jonah Field[1]	52,150,184
NPL Project Area[2]	217,186

Source: WOGCC 2014.

[1]Total volume includes all formation fluids from 1978 through November 2015.
[2]Total volume includes all formation fluids from 1997 through April 2014.

bbls barrels

4.2.6 Groundwater Use

Wyoming State Engineers Office (SEO)[2] permits (Wyoming SEO 2014), USGS data (USGS 2013), and well sampling reports by Trihydro (2011, 2013, 2014a, 2014b) were used to develop a comprehensive list of water wells and groundwater uses within the NPL Project Area. Attachment B (*Water Supply Wells in and around the NPL Project Area*) identifies water supply wells and their uses, and Figure K-2 depicts the location of existing water supply wells. SEO data provides the most comprehensive information on well location and use, although several wells identified by USGS were not in the SEO database, and USGS data did not specify designated uses. The water rights search was conducted in July 2014 and included all groundwater permits categorized as complete, incomplete, blank, and fully adjudicated. Permits listed as abandoned, expired, or cancelled, were not included in the search. For wells where the use was not specified, it was assumed the well was used for livestock watering (stock use) as this is the primary permitted use for water supply wells in the analysis area. Based on available data, there are 32 stock water wells and no domestic water supply wells within the NPL Project Area. SEO records do not report any irrigation, industrial, or municipal wells within the NPL Project Area. Five wells were identified in the NPL Project Area as miscellaneous (MISC) use and are used for oil and gas operations by the JIDPA; however, only two wells, Holmes Federal 5-1 and Jonah Workforce Facility, operated in 2013. The volume of water used from the Holmes Federal 5-1 is not reported in the SEO database or by Jonah Energy (the operator) to the BLM. It is assumed that the well uses the average amount calculated for JIDPA supply wells, 235,591 barrels/year (30.4 acre-feet). In 2013 the Jonah Workforce Facility well withdrew 128,800 barrels (16.6 acre-feet) of water (Encana 2014).

The primary aquifer for many of the stock wells was identified by USGS, but for some wells and springs the aquifer was not identified. For wells without an identified aquifer, an aquifer was assigned based on the best available data from local geological features, well depths and descriptions, and comparisons to nearby wells. Most of the wells appear to produce water from the Wasatch Aquifer; however, at least four wells produce water from the Laney and one produces water from an alluvial aquifer.

Historic water withdrawal records were not available for stock wells in the NPL Project Area, therefore an estimate of water use was developed using the methods and default use values outlined in the PAPA Numerical Groundwater Model (AMEC 2013a). According to AMEC (2013a), who reported results from Clarey et al. (2010), the average annual groundwater volume used for each stock well in the GRB is 0.6 acre-feet/year. Multiplying this by the number of stock wells identified in the NPL Project Area (32) results in 19.2 acre-feet/year of groundwater use. No wells were identified as domestic supply wells in the NPL Project Area; however, if any are present, each would be assumed to supply one household, with an average of 2.47 persons per household (as cited in AMEC 2013a). Assuming an average use of 75 gallons per person per day (as cited in AMEC 2013a) and converting gallons to acre-feet/year, it is estimated that 0.21 acre-feet/year would be withdrawn for each domestic well. The PAPA analysis assumes that only 10 percent of the domestic water withdrawn is consumed and 90 percent is returned; therefore, the consumptive use of groundwater for domestic purposes is estimated at 0.021 acre-feet/year per well. Based on these estimates, total annual groundwater use within the NPL Project Area is estimated at 513,353 barrels (66.2 acre-feet) per year (Table K-8).

The nearest municipal water well is located in Big Piney, approximately eight miles northwest of the NPL Project Area. The municipal water well in Big Piney draws from alluvial sediments in the Green River

[2] *SEO records are updated regularly, and permitting information included at the time of this report is based on current information.*

floodplain and is not likely to be influenced by any activities in the NPL Project Area due to the distance from the NPL Project Area and the water source (alluvial sediments in Green River floodplain).

Table K-8. Annual Groundwater Use Estimates within the NPL Project Area

Water Use	Volume (barrels)	Volume (acre-feet)
Stock	148,962	19.2
Domestic	0	0
Miscellaneous (oil and gas operations)	364,391	47.0
Total	**513,353**	**66.2**

Source: AMEC 2013a and methods described in text above.

General consumptive water use in the Upper Green River Basin primarily includes irrigation and stock watering, with irrigation water being mostly obtained from surface water diversions (WWDC 2014). There are seven irrigation wells in the Green River Basin (WWDC 2014), although well data reveal no irrigation wells are within the Project Area (see Attachment B a full list of wells in the Project Area).

Groundwater use in the JIDPA is tracked and recorded in accordance with the requirements of the JIDPA ROD (BLM 2006c). In 2013, Jonah Energy and Linn Energy reported 20 wells in the JIDPA withdrew a total of 607.3 acre feet of water (Encana 2014; Linn Energy 2014). These wells range in depth from 575 to 1,100 feet below ground surface and obtain water from the Wasatch Aquifer. The amount of water used for drilling and completion in 2013 is likely less than average water use for the JIDPA drilling program. BLM records indicate that between 2008 and 2014, operators drilled and completed between 52 and 155 gas wells per year, with an average of 102 gas wells per year (BLM 2015b). In 2013, 69 gas wells were drilled and completed, approximately 30 percent less than the average number of gas wells drilled since 2008.

4.2.7 Sources of Groundwater Recharge and Discharge

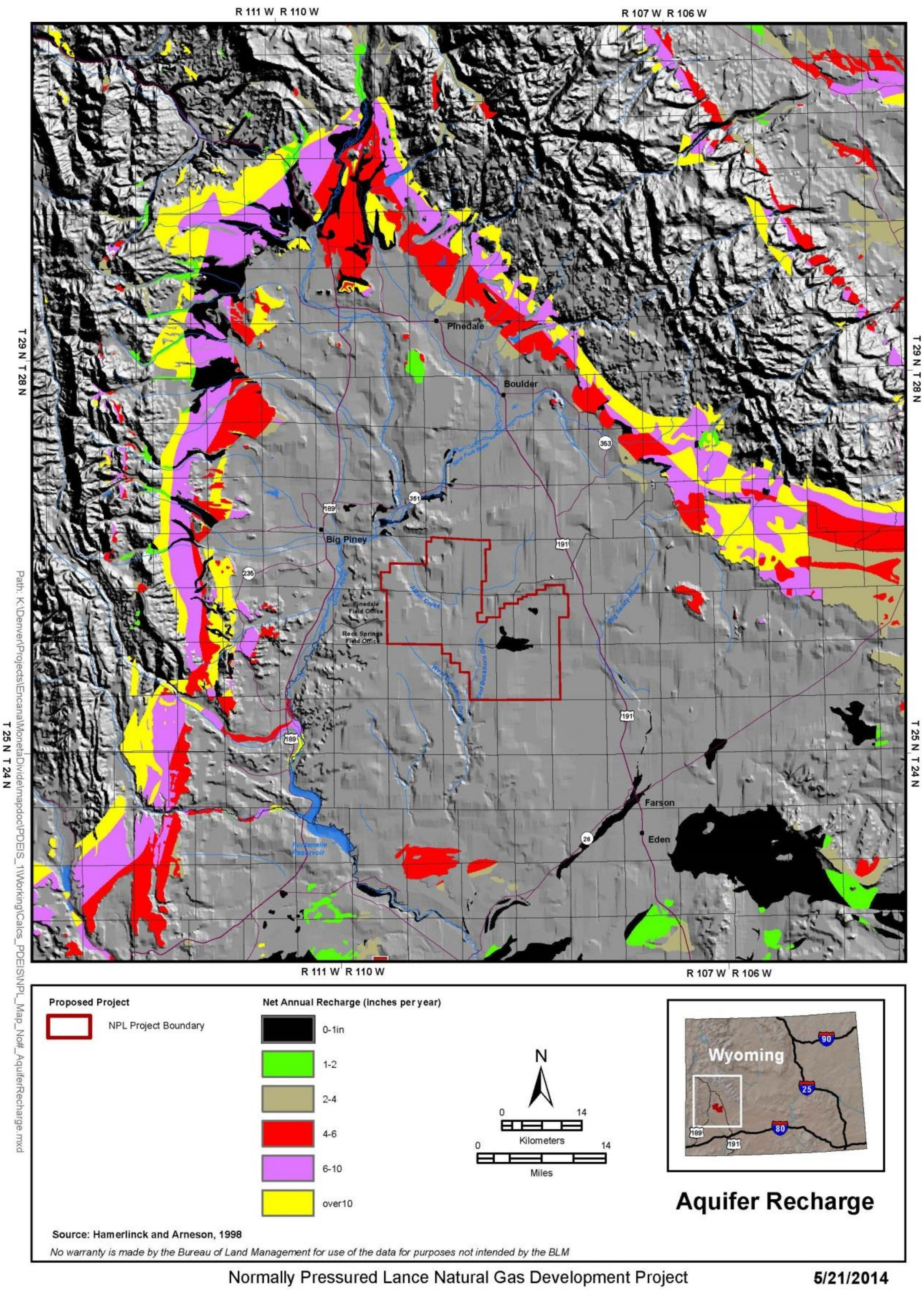
Groundwater recharge is the amount of water falling as precipitation that percolates into and through the soil and underlying rock to eventually migrate into and recharge water in the aquifer. Recharge is generally determined by the amount of precipitation, permeability of the surface and subsurface formations, the vertical hydraulic conductivity, the depth of the aquifer, and the access of the aquifer to surface infiltration (i.e., if there is a confining layer between the ground surface and the aquifer). Also, evaporation at the ground surface in dry climates and surface vegetation uptake (transpiration) can remove water from soils, resulting in low or negative recharge rates. In the analysis area, recharge rates range from five inches per year to negative values due to low precipitation and high evapotranspiration (Clarey and Copeland 2010; WWC Engineering et al. 2010). The Tea Kettle Butte area in the east-central portion of the NPL Project Area shows a positive recharge value of less than one inch per year. This is due to the permeable surface soils in the area (Hamerlinck and Arneson 1998)).

The Laney Member of the Green River Formation has a gradational contact within the upper part of the Wasatch Formation, and groundwater moving south in the Wasatch freely moves across the boundary and may be a source of recharge for the Laney Aquifer in the southern portion of the NPL Project Area (Martin 1996). A minor amount of discharge from the Laney may occur from wells and springs whose source is the Laney, but most discharge is to the Big Sandy and Green Rivers south of the NPL Project Area (Bartos and Hallberg 2010).

The primary source of recharge to the Wasatch Aquifer is from areas on the flanks of the aquifer, in particular the foothills of the Wind River Range to the northeast and the Wyoming Range to the northwest of the NPL Project Area, which receives snowmelt and precipitation from the mountains (HydroGeo 2004) (Figure K-14). The greatest amount of discharge from the lower Tertiary aquifer system, including the Wasatch and Fort Union Aquifers, is to the Green and New Fork Rivers upstream of Fontenelle Reservoir, which is west-southwest of the Project Area (Figure K-14) (Clarey and Copeland 2010). As indicated in Figure K-14, net recharge is near zero throughout most of the NPL Project Area and recharge is not expected to provide significant input to the aquifer. However, the permeable area near Tea Kettle Butte comprises approximately 5.7 square miles, and assuming one percent[3] of the recharge reaches the aquifer, the Wasatch receives approximately 27 acre-feet of recharge per year.

[3] The assumption of one percent infiltration comes from Wyoming State Geological Survey Green River Basin Water Plan II Groundwater Study Level 1 (2007–2009) (WSGS 2010).

Figure K-14. Net Annual Recharge in and around the NPL Project Area



4.2.8 Aquifer Sensitivity

The sensitivity of aquifers to contamination from surficial sources is influenced by precipitation, the permeability of surficial materials, and depth to groundwater. Aquifer sensitivity in the GRB was evaluated by Clarey and Copeland (2010) based on initial models for Wyoming developed by Hamerlinck and Arneson (1998) and is depicted on Figure K-15. The majority of the NPL Project Area is mapped as being not highly sensitive to contamination at the surface, primarily due to low precipitation and depth to groundwater. The surficial alluvial aquifer mapped in the Tea Kettle Butte watershed is relatively highly sensitive to contamination at the surface. The aquifer sensitivity is high west and northeast of the NPL Project Area near the Green and Big Sandy Rivers, where the aquifers are shallower and sand and gravel alluvium are at the surface.

WDEQ, in association with the USGS and the University of Wyoming, conducted aquifer monitoring prioritization to collect groundwater quality information in shallow aquifers and rank aquifers most susceptible to water quality degradation from human activities (Bedessem et al. 2005). The ranking of priority aquifers combined aquifer sensitivity mapping from a previous study on aquifer vulnerability to pesticides, groundwater well density data from SEO records, land use, and known and potential sources of contamination derived from land use and contaminated site data sources. WDEQ identified 33 priority areas for monitoring in six geologic basins including two areas within the GRB near Pinedale and Big Piney. Within the NPL Project Area and the JIDPA, no aquifers were delineated as high priority for groundwater monitoring (Figure K-16). The nearest high priority aquifers for monitoring are within the Green River Valley near Big Piney and the northern portion of the PAPA. Both areas are approximately six miles from the NPL Project Area.

To assist with the identification and mitigation of point source pollution related to activities from oil and gas development, the BLM Pinedale Field Office Approved Resource Management Plan and ROD (BLM 2008) includes a management action to establish a groundwater monitoring program in areas designated as high and moderately high priority by WDEQ.

Figure K-15. Aquifer Sensitivity Map

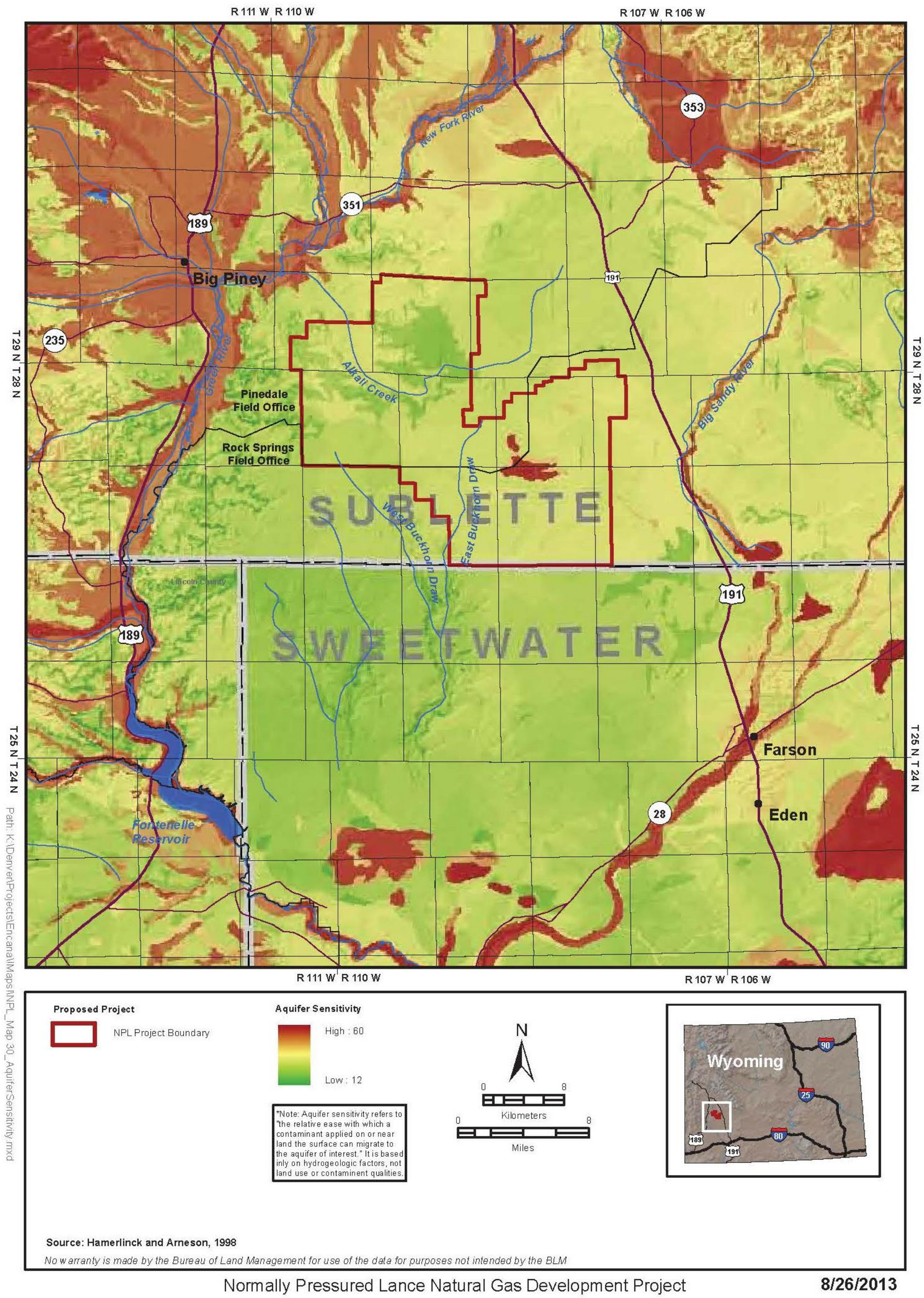
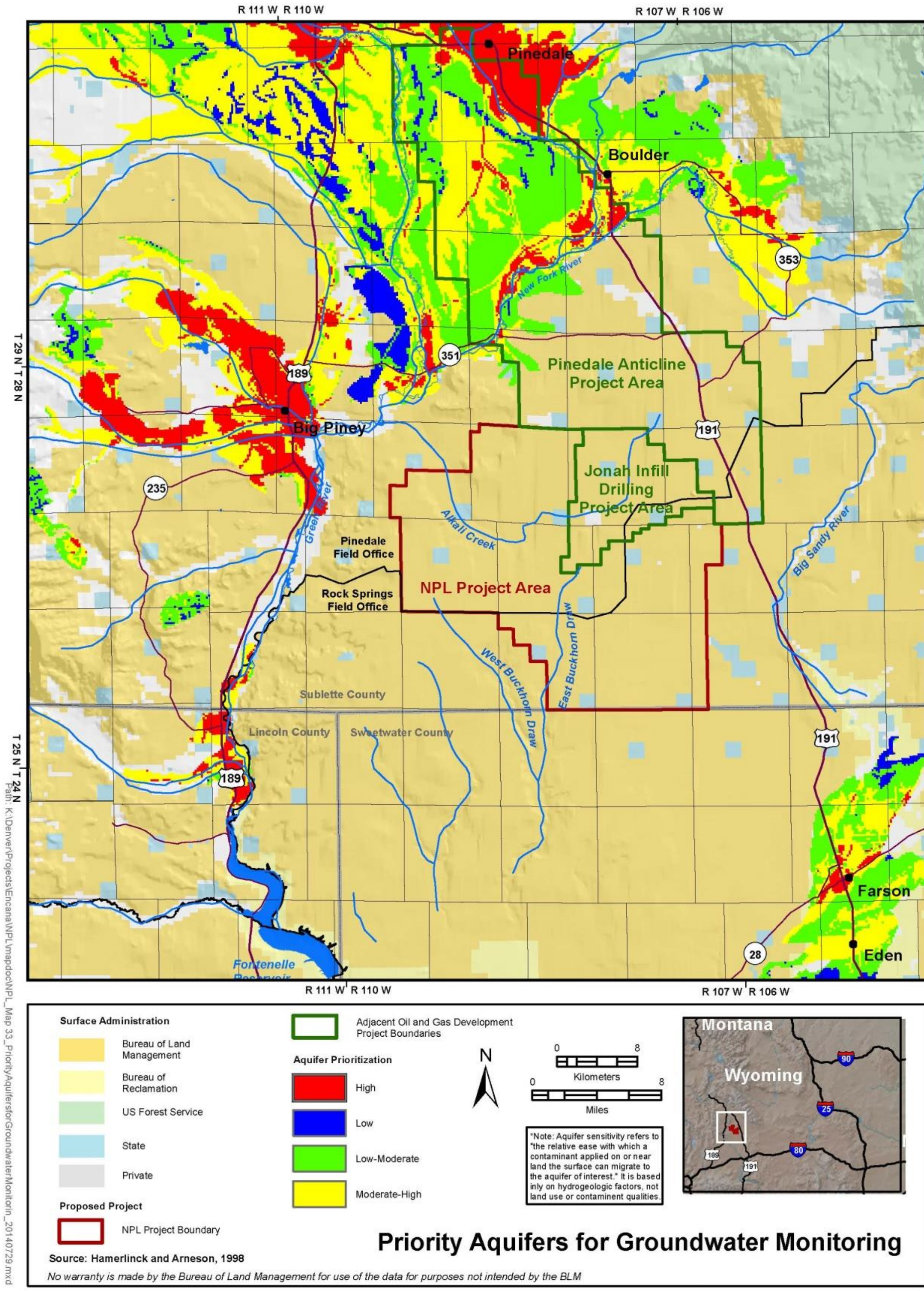


Figure K-16. Priority Aquifers for Groundwater Monitoring



Normally Pressured Lance Natural Gas Development Project 7/29/2014

5.0 POTENTIAL IMPACTS

5.1 Surface Water Impacts

The Proposed Action would result in surface disturbance in the NPL Project Area due to construction of well pads, regional gathering facilities, roads, and other infrastructure. The disturbance has the potential to decrease infiltration of precipitation, alter surface water runoff drainage, and increase erosion. Potential impacts to surface water quality resulting from the Proposed Action would include accidental discharge (spill) of completion fluids, drilling fluids, and formation fluids; and, on and off-site degradation of surface water quality from sedimentation, turbidity and salinity. The results of the AGWA modeling (BLM 2013a) for the NPL Project indicate there is a low probability of transporting sediment and salt from contributing watersheds to major stream channels.

All drainages in the NPL Project Area are ephemeral and intermittent, which do not hold surface water year-round, and most streams only flow following snowmelt and precipitation events (WWDC 2014). However, potential indirect impacts from project development could occur to the upper Green and Big Sandy Rivers and their tributaries, both within the NPL Project Area, and potentially outside of the NPL Project Area boundary in the form of increased surface runoff, sediment transport, erosion, and salinity from areas disturbed within the NPL Project Area. Four springs are known to exist in the area; two unnamed springs are within the NPL Project Area boundary, while North Sublette Meadow Spring and Juel Spring are immediately east of the NPL Project Area (Figure K-1). None of the springs are known to produce perennial surface flows that reach other surface waters, and none of the reservoirs contain permanent water (BLM 2013a).

AGWA was chosen for the hydrologic analysis of the NPL Project because it was designed to assess the trends and magnitudes of hydrologic changes associated with surface disturbance activities, such as oil and gas development, especially in regions with limited runoff and climate data. Additionally, AGWA can identify areas that are susceptible to changes in land cover, surface-disturbing activities, and/or climate. Areas within the analysis area susceptible to land-use changes from the Proposed Action and alternatives were identified using the AGWA tool with the goal of comparing and predicting surface runoff, water yield, and sediment yield for the following scenarios:

- Pre-development: a representation of the landscape prior to significant natural gas development in the NPL Project Area and vicinity, particularly the JIDPA;
- Present: a representation of existing conditions within the NPL Project Area and the JIDPA, including wells pads, access roads, and pipelines;
- Two-Mile Buffer (Proposed Action): a reasonable representation of Jonah Energy's Proposed Action using Jonah Energy's placement of proposed power lines and Regional Gathering Facilities (RGF); and
- Worst Case: represented by locating proposed natural gas wells in areas identified in the pre-development scenario as having the highest potential for increased surface runoff.

The results of the *AGWA Technical Report* (Appendix J) indicate there is a low probability of transporting sediment and salt from contributing watersheds to major stream channels for all scenarios modeled. However, heavy storms may increase the probability of impacts to tributaries of the Green and Big Sandy Rivers, as well as the rivers themselves, especially in watersheds where development may be concentrated and sediment transport more likely. The water quality of runoff from ephemeral streams and washes is largely dependent upon the amount of salts, sediments, and organic materials that accumulate in dry stream channels between runoff events. The degree to which these materials build up between runoff events is influenced seasonally by physical characteristics and land uses occurring within the watershed.

The Proposed Action would not directly impact the functioning condition of streams or rivers in the analysis area through the direct alteration of hydrologic, vegetative or depositional characteristics. However, indirect impacts on the functioning conditions of the Big Sandy River, Green River and Alkali Creek could result from increased surface runoff and erosion in the NPL Project Area if sediment is transported to these surface waters from the NPL Project Area. The potential for impacts to the functioning conditions of these surface waters would be greatest within segments evaluated as functioning at-risk for degradation, including segments of Alkali Creek downstream of the Project Area, and segments of the Big Sandy River, located adjacent to the Project Area.

Sediment would be transported incrementally downstream from the Project Area over time by a sequence of precipitation events and sequential flows. As a result, the likelihood for the Proposed Action to contribute to a downward trend in PFC for the Green River and Big Sandy River is low. However, the potential for the Proposed Action to contribute to the degradation of Alkali Creek is greater due to the presence of functioning at-risk for degradation segments near the NPL Project Area. The Proposed Action may increase channelization and discharge velocities along portions of Alkali Creek within the Project Area, which may also impact riparian and/or adjoining wetland habitats and increase the rate of sedimentation in downstream segments of Alkali Creek in the analysis area.

5.2 Groundwater Use Impacts

In 2013, Encana and Linn Energy reported using 4,711,821 barrels (607 acre-feet) of water for oil and gas operations within the JIDPA from 21 water supply wells, all but one of which are within the JIDPA (AECOM 2014; Encana 2014). As a result of fewer wells drilled in 2013, the amount of water used is likely lower than the average amount of water expected to be used in future years. The Proposed Action would require an estimated 35,000 bbls of water for drilling and completions of each well. Approximately 71 percent of water (25,000 bbls per well) for drilling and completion would be obtained from recycled sources (e.g., JIDPA Water Treatment Facility) with the remaining 29 percent of water (10,000 bbls per well) coming from shallow groundwater wells in the top 1,000 feet of the Wasatch Formation. No water would be removed from the Fort Union Aquifer due to its poor water quality and great depth. During the development phase, the Proposed Action would also require an estimated 13,620 bbls of groundwater per year for new road construction dust control, an average of 74,910 bbls of groundwater per year for road maintenance dust control, and 63,000 bbls of groundwater per year for well pad construction dust control. Total groundwater withdrawal for use development of the NPL Project Proposed Action is estimated at 474.0 acre-feet per year during the 10-year development phase (EnCana 2014). Total groundwater withdrawal during production for the NPL Project Proposed Action is estimated at 17.6 acre-feet per year during the approximate 30-year full production phase for road maintenance and dust control (years 10 to 40).

Fresh water would be obtained from existing shallow water wells in the JIDPA and NPL Project Area and would be used for drilling, cement production, and casing surface aquifers. If needed, new wells may be drilled at appropriate locations in the NPL Project Area to service new development activities. The primary factor driving the need for new water supply wells would be the distance from existing water supply wells to new development locations. As new development areas are located further from existing water supply wells, the need for new water supply wells closer to development areas would increase. The new water supply wells could be located at the RGF locations servicing well clusters. The increased potential for new water supply wells in the NPL Project Area would occur at a similar timeframe as the decline in water supply needs in the JIDPA. As a result, the total water withdrawal from the near-surface aquifers would remain relatively constant as NPL Project development and water use increases and JIDPA development and water use decreases.

To ensure that usable water is protected all water supply wells will be constructed and operated in accordance with SEO regulations (Wyoming SEO 2011). SEO requires that permits be obtained prior to drilling, and that wells be sited and constructed in accordance with published standards to protect the quality of the water and minimize potential for mechanical failure.

Potential impacts to groundwater from water use for the NPL Project could include the following:

1. The Wasatch Aquifer is the main source of groundwater in the region, and there is little recharge of the aquifer. As a result, removal of groundwater could result in a depletion of groundwater resources and impacts to stock wells and channel vegetation.
2. Groundwater removal could also potentially result in depression of the potentiometric surface or intrusion of lower quality water into fresh groundwater zones due to hydraulic changes.

These potential impacts are described in further detail below.

5.2.1 Depletion of Groundwater

Fresh groundwater is available primarily from the Wasatch Aquifer and to a lesser extent the Laney and Alluvial Aquifers. There are currently 31 stock water wells in the NPL Project Area that tap the permeable sandstone in the upper 1,100 feet of the Wasatch and shallow zones in the Alluvial and Laney Aquifers. One of the wells was drilled significantly deeper, 1,573 feet bgs, but is reported to produce from water-bearing zones above 860 feet (Wyoming SEO 2014). Five wells in the NPL Project Area are permitted to extract water for drilling, completion, dust suppression, and other oil and gas related activities at the JIDPA, and are completed in the upper 1,100 feet of the Wasatch Formation. Only two of these wells are currently operating. There are no industrial, agricultural, or domestic wells in the NPL Project Area. The stock wells use an estimated 19.2 acre-feet of water per year. The two Jonah water supply wells used approximately 47.0 acre feet of water in 2013. When combined, the water use in the NPL Project Area is estimated to be 66.2 acre-feet/year. Approximately one-third of the existing water use in NPL is not related to oil and gas activities and would be expected to continue regardless of oil and gas development. Summary statistics for existing JIDPA supply wells are provided in Table K-4, and well construction information and water quality data for these wells are summarized in Table K-5. Attachment B (*Water Supply Wells in and around the NPL Project Area*) provides a description of water supply wells, their location, permitted use, and other information for wells in and around the NPL Project Area. These data represent the best available existing information for water supply wells that could be used for the NPL Project. Implementation of the groundwater monitoring program prior to and during NPL Project development would provide additional information on groundwater conditions that inform development and monitoring.

Based on current use, depth, and water quality, the groundwater resources to be targeted for the NPL Project fall within the BLM definition of usable water, although the pH of the groundwater and the concentrations of TDS for some wells are outside the range of the EPA's Secondary Drinking Water Quality Criteria (EPA 2009). However, wells would not be used for potable water, and both pH and TDS within these concentration ranges can be effectively treated.

The amount of available water in the NPL Project Area is generally a function of the thickness and storage ability of the fresh water zones in the Wasatch. Well logs and well construction information demonstrate that the upper Wasatch, generally considered the upper 600 to 1,000 feet, contains the thickest and most permeable sandstone zones and is currently the only water source targeted in the Project Area (Phillips 2013b; Wyoming SEO 2014). Stock wells are variable in depth but generally produce from intervals shallower than the target zone for water for the project. Because of the nature of the water producing zones (isolated sands) the likelihood of well interference is low. Thinner permeable sands are present in the lower Wasatch, but it would be unnecessary to drill deeper into inferior aquifers with poor water quality when sufficient water of better quality is available at a shallower depth.

Based on an analysis of oil and gas well logs (Phillips 2013b) and completion information from existing water wells (Wyoming SEO 2014), the available water is contained in the upper 1,000 feet of the Wasatch and has over 500 feet of permeable sand aquifers for NPL Project water needs. This is consistent with the estimates used in the PAPA Hydrologic Model (Geomatrix 2008). Within the PAPA, the amount of available water in the Wasatch was roughly estimated using the lower end of the estimated storage coefficient for the Wasatch (S = 0.0001 (dimensionless)), the initial head of the aquifer (500 feet above the base of the aquifer), and the surface area of the project. When these parameters are applied to the NPL Project, the estimated aquifer storage is greater than 7,000 acre-feet. This estimate represents the low end estimate of the available water in the Wasatch, because there is likely fresh water below 1,000 feet and storage coefficient could be up to 0.001 (AMEC 2014). Based on the assumptions and estimates described above, current water use in the NPL Project Area represents approximately one percent of the available water storage.

Analyses of water level measurements from existing pumping wells have not been conducted in the JIDPA to evaluate the long-term trend of water levels in response to prolonged pumping or the recovery of aquifers after pumping. Most wells are not designed for access to measure water levels, or have pumps which restrict access (AECOM 2014), and observation wells are not available to monitor the long-term effects of prolonged pumping of the water supply wells and compare actual conditions to the predicted effects described in the JIDPA Groundwater Flow Model and Hydrologic Impact Assessment (HydroGeo 2004). Based on results from the JIDPA Model, drawdown of the potentiometric surface would occur up to four miles from the pumping wells and extend less than one mile outside the JIDPA boundary. Three stock wells within the JIDPA are within the predicted drawdown zone of greater than one meter (3.3 feet), and ten additional wells are within the 0.5 to 1 meter drawdown zone. Water levels naturally fluctuate by approximately 1.6 feet (0.5 meter), so recovery, or the no affect level, was determined to be 0.5 meters (HydroGeo 2004). Four wells outside the JIDPA and within the NPL Project Area are within the 0.5 to 1 meter drawdown zone. No stock or domestic wells outside the JIDPA or NPL Project Area would be affected by pumping. Recovery of the aquifer would likely occur within six years for rapid project development (250 wells per year for 12 years) (HydroGeo 2004). Groundwater would recover within half a year at a slower well construction rate (75 wells per year for 41 years). The JIDPA and PAPA hydrologic models, which are based on similar Wasatch Aquifer characteristics, both predict a limited area of drawdown influence and rapid recovery of wells following cessation of pumping. Additionally, the large spacing between the supply well locations and the lack of interconnectivity between the discrete sand lenses from which water is drawn suggests only localized and temporary impacts around the water supply well locations as a result of pumping for the NPL Project. Due to the extremely variable nature of the geologic conditions within the State of Wyoming, SEO has not established well spacing requirements; however SEO requires that wells be sited to protect from contaminant sources and interference between other wells and surface water resources. To reduce the likelihood of interference with stock wells or surface water/vegetation, water supply wells for drilling should maintain a safe setback distance based on the site-specifics characteristics of the water bearing zones.

In the JIDPA, the Corona 2-14 water supply well (Map Reference #61 on Figure K-8) was shut down due to contamination. Between 2009 and 2010, following cessation of pumping, the well showed significant recovery as indicated by a water level increase of over 12 feet (AECOM 2008; AECOM 2009; AECOM 2014; BP 2010; BP 2011; BP 2012; Linn Energy 2013). Since 2010, the well has shown more than three feet of recovery, indicating that recovery is ongoing. Data are not available to quantify the impacts from the continuation of pumping of JIDPA water supply wells at current levels to support NPL Project water use; however, no problems associated with water availability and well production have been reported in annual depletion reports to BLM. Additionally, withdrawal from the near-surface aquifers would remain relatively constant as NPL Project development and water use increases and JIDPA development and water use decreases. As a result, there would be no anticipated net change in groundwater levels or recovery compared to existing conditions.

Water level measurements have not been collected in the stock wells within the NPL Project Area during the operator's pre-development sampling and analysis program conducted by Trihydro. Most wells have pumps and have no access ports to conduct water level measurements. Additionally, the wells are designed for maximum water production, rather than for monitoring water level measurements. Stock wells produce water from different, unconnected, spatially limited sandstone lenses within the Wasatch Formation, and water level measurements would reflect a very localized condition. As a result, no analysis of the baseline conditions for water levels within the NPL Project can be made at this time; however, as indicated above there would be no anticipated net change in groundwater levels compared to existing conditions.

5.2.2 Hydraulic Effects from Groundwater Removal

The NPL Project Area is generally arid, receiving only 11 inches of precipitation annually, and with the high rates of evaporation, there is limited to no water available for recharge during most of the year. Recharge of the Wasatch Formation occurs close to the Wind River Range and Wyoming Range at the basin edges and to a limited extent within the Tea Kettle Butte area in the NPL Project Area (Figure K-14). Although the groundwater removed for the NPL Project would not be replaced, analysis of the time it would take to recover is evaluated below.

Attachment A (The *Groundwater Flow Model and Hydrogeologic Impact Assessment, Jonah Infill Drilling Project)* (HydroGeo 2004) summarizes results of a numerical model designed to simulate the regional effect on water resources from pumping groundwater from the Wasatch Aquifer. The model simulates withdrawal of groundwater from the upper 500 feet of the Wasatch Formation at the JIDPA and analyzes the effects of the withdrawals over a wide area that includes all of the NPL Project Area. Since the water supply wells for the JIDPA would also provide water for the NPL Project, the model provides the best available representation of the potential impacts of water withdrawal for the NPL Project. Results of this analysis are also discussed in the Final EIS for the Jonah Infill Drilling Project (BLM 2006b).

For the model, the pumping scenario was based on pumping from 25 water supply wells in the JIDPA over three scenarios as indicated below in Table K-9. These wells would also be pumped to supply water for development of the NPL Project. Pumping groundwater typically results in a localized lowering of the potentiometric surface (drawdown) during active pumping, and then after pumping is halted a recovery period occurs when water levels increase and eventually return to pre-pumping conditions. The amount of drawdown, the extent of the drawdown (known as the cone of depression), and the length of time for recovery are dependent on pumping rates and duration, and the hydraulic characteristics of the aquifer.

Three scenarios were modeled to simulate groundwater pumping to accommodate development of 3,100 natural gas wells in the JIDPA over varying time periods. The pumping rates and well installation rates in the model were adjusted to account for sufficient water for drilling the 3,100 JIDPA wells. The scenarios modeled and resulting years to recovery are presented in Table K-9. According to the report, seasonal variation of the potentiometric surface is typically 1.6 feet in the area. Thus, a drawdown of 1.6 feet was considered recovery for the model.

Table K-9. Results of Modeling Simulations of Water Supply Well Pumping for the JIDPA

Well Installation Rate (wells per year)	Duration of Drilling Operations (years)	Years to Recovery after Pumping Ends
75	41.3	0.5
150	20.7	4.0
250	12.4	6.0

Source: HydroGeo 2004.

The Jonah Infill Drilling Project Final EIS (BLM 2006b) indicates that the maximum drawdown under pumping conditions was estimated by the model to be approximately 10 feet. Under pumping conditions, the cone of depression extends approximately one mile beyond the JIDPA, where drawdown is between 3.3 and 1.6 feet, including to the south into the NPL Project Area. The area of depressed groundwater does not extend beyond the NPL Project Area.

Based on the depths of wells inventoried by USGS (USGS 2013) and the well information summarized in Attachment B (*Water Supply Wells in and around the NPL Project Area*), drawdown of 10 feet in this aquifer is not expected to impact current water users. Given the current light use of this groundwater resource within the groundwater drawdown area, recovery within six years would not likely affect current users. Also, a 10-foot drawdown in an aquifer that is thousands of feet thick is not expected to result in intrusion of lower quality groundwater to the fresh water zone. Groundwater elevations and water quality outside the NPL Project Area would not be affected by the withdrawal and use of water from the Wasatch Aquifer. The predicted model results could be verified by implementing a monitoring program as described in Section 6.2 (*Summary of Impacts*).

5.3 Water Quality Impacts from Injection of Formation Fluids

Formation fluids resulting from the NPL Project would be disposed in permitted Class II Underground Injection wells into the Fort Union Formation, similar to the injection wells used for the JIDPA. Construction of oil and gas wells would include cementing the intermediate casing from the Lance through the Fort Union which would protect groundwater zones in the Fort Union. Injection wells would be constructed in accordance with WOGCC requirements to isolate the injection zone and protect aquifers. To evaluate potential impacts of formation fluids injection, the quality of the groundwater resource in the injection zone and that of the formation fluids that would be injected are discussed below. The potential for vertical migration of formation fluids from the injection zone (generally deeper than 4,500 feet bgs) up to the shallower aquifers (less than 2,500 feet bgs) is also discussed.

5.3.1 Water Quality in the Injection Zone

As previously discussed in Section 4.2.2 (*Water Quality*), data from several JIDPA injection wells completed in the upper Fort Union (approximately 4,900 to 7,700 feet bgs) were obtained from WOGCC (2014) and are summarized in Table K-6. Water samples were collected after drilling the injection wells and prior to any injection of formation fluids. The data shows TDS concentrations from 30,000 to 55,000 mg/L. The chemical composition of the water is uniformly calcium chloride, with some wells exhibiting high sodium concentrations. The sulfate and bicarbonate levels are very low compared to chloride. The EPA Secondary Maximum Contaminant Level for drinking water is 500 mg/L for TDS and 250 mg/L for chloride (EPA 2009). Groundwater in the injection target zone has levels two orders of magnitude higher for both parameters, indicating that this is not a source of water supply for most applications.

WDEQ groundwater regulations (2015) would likely classify the Fort Union minimally as Class IV (B) industrial quality water because it has a TDS concentration in excess of 10,000 mg/L. Waters that meet quality criteria for higher use (i.e., domestic, agricultural, livestock, and fish/aquatic life) have lower TDS concentrations (from 500 to 5,000 mg/L) and require an aquifer exemption for injection into these aquifers. Because of the high TDS concentrations, the upper Fort Union would likely be considered a Class VI water source – unusable or unsuitable for use. WOGCC regulations for the injection of formation fluids under a Class II UIC permit only require an aquifer exemption if the water in the receiving zone is considered "fresh and potable water", which is defined as water currently being used as a drinking water source or having a TDS concentration less than 10,000 mg/L. Injection into the Upper Fort Union is unlikely to require an aquifer exemption because the TDS is well above the 10,000 mg/L threshold. Onshore Order 2 defines "usable water" as generally those waters containing up to 10,000 ppm (10,000 mg/L) of TDS and provides requirements for reporting their presence and protecting degradation of these waters through proper isolation.

5.3.2 Characteristics of Formation Fluids

The characteristics of the formation fluids samples from the upper Lance Formation in the JIDPA are assumed to be representative of formation fluids that would be generated by the NPL Project and represents the best available existing information. In both fields, gas and water are produced from permeable sandstones at depths between 6,500 and 13,500 feet (Encana 2011b). Table K-10 presents results of water quality analyses for several producing wells in the upper Lance Formation. Formation fluids exhibit TDS in the range of 3,000 to 4,500 mg/L, which is an order of magnitude lower than groundwater in the Fort Union Aquifer into which it would be injected for disposal. The water is typically a sodium bicarbonate to sodium chloride composition. Given that groundwater in the Fort Union Formation has much higher concentrations of dissolved solids than the formation fluids, little to no impact on groundwater quality would be expected from injection of formation fluids into the Fort Union Formation.

Table K-10. Formation Fluids Analysis from Selected Lance Wells in the JIDPA

Well Name	Jonah COR 6-9	Jonah HF 5-20	Jonah HF 5-29	Jonah HF 6-17A	Jonah HAC 6-19	Jonah HF 11-30	Jonah HF 12-21
Sampling Date	05/28/11	05/26/11	05/26/11	05/26/11	05/26/11	05/26/11	05/26/11
Anions (mg/L)							
Chloride	594	796	1,194	830	613	934	832
Bicarbonate	1,754	1,439	1,708	1,481	1,630	1,286	1,298
Sulfate	16.4	5.40	2.69	27.1	3.12	18.8	7.26
Silica	62.0	56.7	72.5	65.9	66.5	63.1	71.5
Cations (mg/L)							
Sodium	1,062	1,068	1,402	1,121	1,028	1,099	1,040
Magnesium	1.60	1.52	2.64	1.55	1.34	1.98	1.86
Calcium	9.98	12.4	21.1	12.5	10.3	18.9	15.5
Strontium	0.69	0.75	1.12	0.80	0.67	1.06	0.81
Barium	2.25	1.87	2.44	1.54	1.70	4.58	1.66
Iron	7.89	1.45	3.00	1.97	2.53	2.84	5.70
Potassium	12.4	13.1	47.0	13.4	13.2	15.2	13.4
Manganese	0.05	0.09	0.04	0.05	0.08	0.11	0.08
TDS (mg/L)	3,522	3,396	4,456	3,557	3,370	3,446	3,287
pH	7.55	7.22	7.17	7.36	7.14	7.34	7.18

Source: Phillips 2013c.

mg/L milligrams per liter
TDS total dissolved solids

5.3.3 Potential for Migration from the Injection Zone to Shallow Groundwater Resources

Potential water quality impacts to shallow groundwater in the upper 1,000 feet of the Wasatch Formation could occur if there were a hydraulic connection and upward flow between the injection zone and the shallow aquifer, and the fluid migration resulted in concentrations that adversely affect water quality. There is a low probability that both of these mechanisms would be present in the NPL Project Area, as described below.

Upward migration requires a hydraulic connection between the injection zone and the better quality groundwater in shallower aquifers. This connection can be through natural geologic structural features, such as faults or fractures, or via improperly abandoned or poorly constructed or damaged wells.

The available data on structural geologic features within the NPL Project Area are limited, but the best available existing information indicates that there are few geologic structural features outside of the bounding faults on the JIDPA that border the NPL Project Area. One study (Siguaw and Friend 2004) interpreted a thrust fault just southwest of the JIDPA and seismic data indicated that the fault terminates in the lower Eocene strata (Fort Union Formation) and does not extend to the upper aquifer. The structural styles presented in the publically available literature for the Jonah and Pinedale areas show fault patterns that affect only strata below the lower Eocene strata and do not extend upward into the Wasatch Formation (Montgomery and Robinson 1997). Warner (2000) refers to the northern Jonah bounding fault as extending from surface to basement, but provides no data to support the interpretation. As described in Section 3.2, bounding faults at Jonah are non-transmissive and do not allow upward migration of fluids. A similar situation is expected to be present in the NPL Project Area because of the proximity and similarity in geologic conditions within the region. Based on these publicly available data, there is no indication that a naturally occurring transmissive fracture zone, such as a fault, is present in the NPL Project Area that is capable of transmitting formation fluids to the shallow aquifer. Because there is currently limited data to support this assertion, a groundwater monitoring program would be implemented to monitor water quality conditions prior to and during oil and gas development to evaluate the potential for fluid migration along existing faults and fractures.

Upward migration could also occur through improperly constructed or abandoned injection or production wells. Wells with inadequate cement seals or seals and casings that have been damaged or deteriorated, could allow migration from the reservoir zone upward into the shallow water aquifer. Construction of oil and gas wells would include cementing the intermediate casing from the Lance through the Fort Union which would protect groundwater zones in the Fort Union and ensure gas or fluids cannot migrate into usable groundwater. As shown on the cross-section in Figure K-4, many wells in the NPL Project Area and the JIDPA are constructed with surface casings and cement seals to a depth of 2,500 feet, which ensures the shallow aquifer is isolated from upward migration of high salinity deeper water. Further, if all procedures required by the UIC Class II permits are followed, it is unlikely that injection wells would be improperly abandoned, poorly constructed, or damaged to result in a vertical migration conduit. The cross section (Figure K-4) shows several wells with surface casing set at 1,000 feet. Water sources in the vicinity of existing wells with shallow casing could increase the potential for water quality impacts to shallow water zones. There is currently no evidence of impacts in areas of shallow surface casing.

5.4 Water Quality Impacts from Drilling and Completion

The following information pertaining to drilling practices in the JIDPA were obtained from Jonah Energy (Dubois 2014). In the JIDPA, wells are drilled in a manner to prevent contamination of groundwater. Surface casing is set to 2,500 feet, and cement is circulated to the surface to ensure a full and complete seal across the water zone. The well is drilled with freshwater mud to the total depth. The well bore is underbalanced or balanced in the Wasatch Formation to limit infiltration of drilling mud and mud filtrate into the water zones, and is overbalanced with depth in the Lance Formation (pay zone). The freshwater mud creates a "filter cake" coating and seals off sides of the well bore across the open lower Wasatch and Fort Union Formations. This seal helps prevent loss of circulation and avoids loss of fluids into higher porosity sands as mud weight is increased for penetration of the over pressurized Lance gas productive zones. Biodiesel is sometimes used in difficult drilling spots within the borehole to increase lubricity of the mud and overcome differential sticking of the drill pipe to the borehole wall. Finally, a 4 ½-inch production casing is run to the total depth and cemented up to approximately 4,000 feet below ground surface, leaving the section from 2,500 to 4,000 feet open (without cement). The cemented zone thickness has varied through the years. Because of the high salinity of groundwater in the Upper

Fort Union Formation, corrosion of steel casing has occurred in this zone. All natural gas wells now have cathodic protection components to prevent corrosion.

The NPL Proposed Action includes directional drilling to reduce surface disturbance and centralize facilities. Directionally drilled wells for the NPL Project may utilize oil-based muds in rare cases and based on site-specific considerations and water quality testing (i.e., total dissolved solids greater than 10,000 ppm). The use of oil-based mud is expected to be infrequent and site-specific, but could increase the possibility of introducing undesirable petroleum-hydrocarbon components into water bearing zones. A recent BLM study from the Fox Hills Aquifer in the Powder River Basin (BLM 2015a) quantified the volume of hydrocarbons lost during oil-based mud drilling, and evaluated the dispersion of the hydrocarbon material away from the borehole. The report concluded that use of oil based drilling mud will result in estimated conservative fluid loss of three to as much as 14 gallons (0.06 to 0.34 barrels) of hydrocarbons per well, with toluene and ethylbenzene being the largest components. Dispersion of maximum estimated hydrocarbon volumes over one acre of the Fox Hills Sandstone would result in concentrations below EPA drinking water standards. The geologic and drilling conditions represented in the Fox Hills study are similar to those expected in the Project Area and similar results would be expected. Additional precautions are taken, including the installation of an intermediate casing string set to below water-bearing sands to avoid infiltration into the formation. Since there is no definitive depth at which the Wasatch Formation changes from TDS less than 10,000 mg/L to TDS greater than 10,000 mg/L) the entire Wasatch Formation is considered usable water until otherwise demonstrated. Water-bearing sands in the upper Fort Union injection zone have been demonstrated to contain TDS concentrations well in excess of 10,000 mg/L (Table K-6).

Operator's in the JIDPA typically use freshwater from their industrial water supply wells for drilling fluids. They have used recycled formation fluids in the past; however, there were issues with bacterial growth, which reduced the ability of the mud to carry solids. The NPL Project operator has not yet determined the specific drilling plan for future wells, including those in the NPL Project Area, but vertical and directional wells will likely be drilled with freshwater mud, and drilling practices will likely be similar to those described above. After the well has been drilled, several operations are conducted to prepare the well for gas production. Collectively, the operations after drilling and before production are called completion activities. Completion activities include cleaning the drilling fluids from the hole through circulation of low solids fluids (such as freshwater or brine), placing and cementing casing into the borehole, perforating the casing to allow gas to flow into the well, hydraulically fracturing the perforated zone to enhance communication with the formation, cleaning the hydraulic fracturing material from the borehole, and setting hardware and production tubing in the well for production. These operations use various fluids with a wide range of properties and components to accomplish these tasks without affecting the producing formation. The operator has provided general information on well completion methods and materials for the NPL Project, which are described below.

Hydraulic fracturing is a well stimulation method used to increase the permeability of the gas-bearing sandstones to allow trapped gas to flow more easily to the wellbore for recovery. The process involves pumping a large volume of water and sand, along with small volumes of treatment chemicals, into the producing zone and increasing the pressure until the reservoir rock breaks down and creates fractures. Hydraulic fracturing programs are designed to maximize the area of interconnected fractures within the gas-bearing reservoir rock and not allow the fractures to propagate outside the gas-bearing zone. Pumping is continued for a short time until the fracture length is sufficient to increase gas permeability, and sand is pumped into the fractures to prop them open. After the fractures are propped open, the pressure is reduced, causing reversal of flow from the reservoir into the wellbore. This allows the excess fracturing fluids and sand to be removed from the wellbore and reservoir. This period is called the flowback period and can last from a few days to a few weeks. Brine or freshwater is circulated in the well to aid in the removal of hydraulic fracturing fluids and other fluids used during well completion.

While it is desirable to remove all the excess fluids and sand, only a portion of the initial fluids is recovered during the flowback period. The exact amount of flowback is determined by many factors including drilling methods, hydraulic fracturing design and execution, and reservoir rock characteristics. The total volume of recovered hydraulic fracturing fluids can range from 15 to 80 percent (Groat and Grimshaw 2012), with most of the recovery occurring early in the flowback period. It is expected that flowback recoveries will be near the upper end of this range for the NPL Project (Phillips 2013a). Some water and chemical components in the hydraulic fracturing and other completion fluids may adsorb to the minerals in the reservoir and may never be recovered. Naturally-occurring water in the formation that is produced along with the gas after the well is completed is called formation fluids. During the production period, some of the water introduced into the reservoir during well completion procedures is mobilized and mixed with the formation fluids. It is often very difficult to determine what part of the flowback fluids is from drilling and completion activities. The Low Level Petroleum Hydrocarbon study at PAPA (AMEC 2013b) tested flowback fluids in several wells at various times during the flowback period. The analysis concluded that the concentration of BTEX compounds increased with flowback time, indicating the presence of naturally occurring formation fluids.

Water quality impacts from well completion, including hydraulic fracturing, could include the following five scenarios (BLM 2013b):

1. Upward movement of hydraulic fracturing fluids and naturally occurring formation fluids through the rock layers above the producing zone in response to the elevated pressure required to hydraulically fracture the target gas-producing zone.
2. Contamination of aquifers through the introduction of drilling and/or completion fluids through spills or drilling problems such as lost circulation zones.
3. Communication of the induced hydraulic fractures with existing fractures potentially allowing fluid migration into water-bearing zones.
4. Cross-contamination of aquifers that may result when fluids from a deeper aquifer/formation migrate into a shallower aquifer/formation due to improperly cemented well casings.
5. Progressive contamination of deep confined, shallow confined, and unconfined aquifers if the deep confined aquifers are not completely isolated from shallower aquifers. An example of this would be salt water intrusion resulting from sustained drawdown associated with the pumping of groundwater.

Potential water quality impacts to the groundwater in the upper 1,000 feet of the Wasatch Formation described above could occur if there were a hydraulic connection and flow between the deeper impacted zone and the shallow aquifer and if the fluid migration results in concentrations that adversely affect water quality. These scenarios are described in further detail below.

Scenario 1 – Hydraulic fracturing induces a pressure pulse into the gas-producing formation in order to create fractures in the formation. Some authors (Myers 2012; Rozell and Reaven 2012; Warner et al. 2012) have theorized that this pressure pulse could force naturally-occurring fluids and hydraulic fracturing fluids upward through the rock column into the shallow useable water aquifers. Recently, Flewelling and Sharma (2014) demonstrated that the conditions required for rapid upward migration of hydraulic fracturing fluid or brine via bedrock would require both high rock permeability and high upward head gradients to be present in the rock column. Flewelling and Sharma (2014) demonstrate that these two conditions are mutually exclusive, and rapid upward migration of hydraulic fracturing fluid and brine through the entire rock column is not plausible based on the following conditions:

- Reservoir zones with upward gradients are generally overlain by low permeability rocks (reservoir seals) that would have long travel times for fluids moving through them. The pressure pulse generated by the hydraulic fracturing event is typically short, and the impacted rock layer is thin relative to the total thickness of the column between the hydraulically fractured zone and the upper water-bearing zone. The resulting pressure pulse would not be great enough to drive fluids through the low permeability rock above the hydraulically fractured zone and into the shallow water zone in a short period of time. Timescales for transport are long, often on the order of 10^6 years.
- After fracturing is completed and wells are producing fluids, the flow gradient is towards the borehole and is not directed upward, so the upward driving pressure is no longer dominant.

Measurements of vertical and horizontal hydraulic gradients between the Wasatch Formation and the deeper, poor water quality zones in the Fort Union and Lance Formations in the NPL Project Area are not documented because there are no observation wells completed in these zones. In general, where these rocks (i.e., formations) are exposed at the edge of the GRB, the gradient is downward and towards the center of the basin because of the recharge areas (Bartos and Hallberg 2010). However, locally there may be upward vertical gradients (Bartos and Hallberg 2010). While there may be local upward gradients, the lack of hydraulic connections between the zones and the distance between them suggest there is a low likelihood of upward migration of completions fluids and naturally occurring formation fluids.

Scenario 2 – Contamination of aquifers could occur if drilling or completion fluids, or other hazardous or non-hazardous materials are accidentally spilled at the surface and percolate downward into the upper aquifer. Refer to Section 4.7 (*Hazardous and Non-Hazardous Materials*) in the NPL Project EIS for more information on the potential for accidental spills and leakages of hazardous and non-hazardous materials. Lost circulation can occur during drilling when mud and cuttings are not returned to the surface from downhole well location. These conditions exist when high permeable zones, such as fractures, conduits, and unconsolidated sands, are encountered and mud exits the borehole into the formation instead of continuing up the borehole to the surface. The drilling mud, including any additives and lost circulation control materials, can invade the permeable zone and could affect the water quality of the water bearing zones.

These potential impacts are minimized when the surface casing is set at the proper depth to isolate the water-bearing zones, and the cement quality ensures the complete isolation of the zones from upward flow in the well. For the NPL Project Proposed Action, surface casing would be set to a depth of 2,500 feet. Currently the deepest drilling water supply well is 1,573 feet. Refer to Attachment B (*Water Supply Wells in and around the NPL Project* Area) for a list of water supply wells, their depths, and other information. Well completion and casing procedures required by BLM, WOGCC, and other regulatory authorities are designed to ensure the surface casing protects aquifers. BLM requirements for completion and casing procedures are found in 43 CFR 3160 and Oil and Gas Onshore Order No. 2. The WOGCC requirements are located in Chapter 3 Section 22 of the operational and drilling rules (WOGCC 2008). The Resource Protection Measures in Appendix B of the NPL Project EIS and other best management practices during drilling and completions, including maintaining proper mud weight and properties, monitoring mud flow returns and drilling rates, and anticipation of known zones of high permeability, would reduce the potential impacts to groundwater resources associated with lost circulation zones.

Scenario 3 – The potential for impacts from communication with existing fractures is dependent on the presence, orientation, and density of natural fractures and the local hydraulic gradients that drive fluid flow. To date, the connection of hydraulic fractured zones with natural fractures that mobilize fluids to shallow water is an unproven theory (BLM 2013a). Recent studies by EPA indicate that the possibility of fault reactivation creating a pathway to shallow groundwater is remote (EPA 2012). The risk of induced fractures extending out of the target formation into an aquifer depends, in part, on the formation thickness separating the targeted fractured formation and the aquifer, as well as the physical properties, types, thicknesses, and depths of the targeted formation and surrounding geologic formations. Operators generally design hydraulic fracturing programs to contain the fractures within the target formation because fractures that extend outside the target zone do not benefit production and could intersect water-bearing strata or unproductive zones, thus incurring additional cost without increasing production. There is a limit to how much a fracture can grow vertically, even in the most advantageous conditions. Fisher (2010) plotted fracture depths (determined by microseismic monitoring) versus aquifer depths (from USGS) for thousands of wells in the Barnett, Woodford, and Marcellus Shales, similar in depth to the Lance Pool (the target zone for NPL Project drilling, completions, and production), to demonstrate the vertical separation between induced fractures and aquifers. Warpinski (2011) reviewed this data and determined that the microseismic data set includes induced fractures that intersect naturally occurring fractures. Warpinski (2011) concluded that while fractures do occasionally intersect faults and other fracture systems, the data shows that vertical growth is limited when this occurs because the stress regime favors more horizontal fracturing closer to the surface. Warpinski (2011) also noted that some of the largest fractures occur where a fault has been intersected, but growth is equally likely to be downward and upward.

In the NPL Project Area there is a relatively large distance between the producing zone in the Lance Formation and the shallower, Wasatch Formation. As described above in Section 3.3 (*Geology and Stratigraphy),* these zones are separated by low-permeability strata. As shown on the cross-section in Figure K-4, the distance is greater than 5,000 feet between the producing zone (Lance Formation) and the overlying currently used water (upper 1,000 feet of the Wasatch) and could exceed 9,000 feet. Well logs show the intervening layers include thick zones of shale and silt with extremely low permeability. Warner (2000) describes the shales in the Fort Union as a reservoir seal for the Lance Formation gas, indicating that the Fort Union is an effective and impermeable barrier to upward migration. Based on the thickness and geologic characteristics of the formations, there is a low likelihood of hydraulic fractures communicating with natural fractures between the producing and source water zones in the NPL Project Area.

Scenario 4 – Construction, drilling, maintenance, and operation of water source wells, gas production wells, and injection wells would be conducted in accordance with all permit requirements and in compliance with other plans, policies, regulations, procedures and resource protection measures in Appendix B (*Resource Protection Measures*) of the NPL Project EIS. Application of proper construction, drilling, operation, and maintenance activities in accordance with plans, policies, and regulations would limit the potential for contamination of aquifers, as discussed in Scenario 2. Additionally, as discussed above, the geologic characteristics of the Lance and Fort Union Formations provide an effective and impermeable barrier to upward migration of potential contamination (if it were to occur) from the Lance Formation to the shallower, Wasatch Formation.

Scenario 5 – Sustained pumping of groundwater may result in encroachment of lower quality water if the pumping creates a flow gradient of high TDS water toward the well intake point. This process, referred to as salt water intrusion, has been observed in coastal aquifers where seawater is adjacent to the freshwater lens and the wells area of influence extends outward into the seawater zone. Vertical intrusion can occur when water with higher TDS is pulled upward into the well (upconing) through aggressive or sustained pumping, where a relatively thin freshwater zone sits directly above a lower quality water zone. In both cases a hydraulic connection between the intake point of the well and the higher TDS water zone is necessary. Water supply wells at JIDPA are screened in the upper 600 to 1000 feet of the Wasatch Formation, and water with higher TDS is found in the lower portion of the Wasatch at depths greater than 2,500 feet. The freshwater and high TDS water are separated by over 1,500 feet of low permeability rocks; therefore, it is very unlikely that pumping in the isolated sands within the upper Wasatch Formation would induce upward flow from the lower Wasatch Formation through 1,500 feet of low permeability rocks.

Additionally, as discussed above, potential contamination would be minimized through proper construction, drilling, and operational procedures in accordance with applicable permits and regulations and because the surface casing would be set at a proper depth to isolate the fresh water zones, and the cement quality would ensure~~s~~ the complete isolation of water-bearing zones from upward flow in the well. Additionally, as discussed above, the geologic characteristics of the Lance Formation and Fort Union Formation provide an effective and impermeable barrier to upward migration of potential contamination in the production zone and injection zone (if it were to occur) to the shallower, Wasatch Formation. As a result, the potential for progressive contamination of deep confined, shallow confined, and unconfined aquifers, including the upper Wasatch Formation, is minimal.

Drilling and hydraulic fracturing activities have the potential to result in well bore collisions and frac hits if drilling of wells occur in close proximity to existing or additional new wells. Collisions and frac hits can result in loss of well control and potential release of drilling, completion and formation fluids to shallow aquifers and the surface. Well bore collisions occur when the drill bit deviates from the planned trajectory and accidentally intersects an existing wellbore. Directionally drilled well paths are planned prior to drilling and are designed to avoid adjacent wellbores by maintaining a minimum separation distance between wells. The distance between wells is maintained by monitoring the trajectory of the wellbore during drilling using directional sensors mounted near the drill bit, or by running a wireline directional survey tool. Frac hits, also called inter wellbore communication, occur when the pressure pulse from a well undergoing hydraulic fracture stimulation is transmitted to an adjacent well, either through interconnected fractures or improperly sealed casing. If the wells are weakly connected the effect of the pressure pulse is relatively small and may only register as a slight instantaneous increase in well pressure or a decrease in well production. For wells in close communication the sudden unexpected increase of pressure in the adjacent well can force fluids into the well at high pressure and result in loss of well control and release of completion and formation fluids to shallow aquifers and the surface. The EPA (2015) identified 10 incidents in the U.S. in which fluid spills were attributed to frac hits.

Wellbore collisions have potential to occur in the deviated part of the well when the measured trajectory of an existing well, or the new well is not accurately determined, or when the safety factor for the minimum separation distance between the wells is small. Wellbore collisions are most likely to occur at shallow depths, where the greatest well density exists (DeWardt et al. 2013). Successful collision avoidance management includes having an accurate description of the existing nearby well locations and trajectories, designing and maintaining a safe wellbore separation, and communicating the risks and avoidance procedures between those involved in the planning and drilling process (ISCWSA 2014). Hydraulic fracturing of wells drilled in close proximity to existing wells has a higher likelihood of affecting nearby wells, as do wells drilled from the same pad, and older wells with poor quality cement and casing (EPA 2015). A study of frac hits in the Woodford shale in Oklahoma showed that the likelihood of a communication event was less than 10 percent in wells more than 4,000 ft. apart, but rose to nearly 50 percent in wells less than 1,000 ft. apart (Montague and Pinder 2015). The results of this study are included to disclose the most recent literature on communication events. The outcome of this study may not be transferrable to the NPL Project or Project Area due to differences in hydrogeologic conditions, project-specific activities and procedures, and other factors.

A draft Industry Recommended Practice for the Canadian Oil and Gas Industry has been developed for minimizing Interwellbore Communication (Enform 2015) and states that the likelihood and potential impacts of frac hits can be reduced by designing and monitoring fracture treatments to control the length of fractures, and working with nearby well owners to temporarily shut in producing wells that may be potentially at risk during well stimulation activities. There are no known occurrences of fluid releases from frac hits in Wyoming or within the analysis area. Requirements for directional well planning and directional well surveys are provided in WOGCC Rules Chapter 3 Section 25. If all wells are designed and drilled in accordance with applicable WOGCC regulations it is assumed that these impacts would not occur. Additional analysis of potential for wellbore collisions and frac hits would occur during site-specific permitting at the APD level once specific drilling and well locations are known in relation to other existing and proposed new wells.

6.0 SUMMARY AND CONCLUSIONS

6.1 Conceptual Site Model for the NPL Project Area

This section summarizes current understanding of the hydrologic systems within and around the NPL Project Area. It is based on a synthesis of existing lithologic, hydrologic, climatological, and water quality data for both surface water and groundwater resources presented in the sections above. The NPL Project Area is in a semi-arid region with low precipitation and high evaporation rates that result in little to no recharge through surficial soils to groundwater. The NPL Project Area is drained by ephemeral streams that flow in response to spring snowmelt from the mountains to the north and east. A drainage divide runs through the NPL Project Area, with the western portion draining to the Green River, and the eastern portion draining to the Big Sandy River.

Fifteen HUC-12 level watersheds intersect the NPL Project Area. In general, watersheds overlapping the western portion of the NPL Project Area drain to tributaries of the Green River, while those overlapping the eastern portion of the Project Area drain toward the Big Sandy River, which ultimately discharges to the Green River, approximately 28 miles south of the NPL Project Area. No surface water quality data from within the NPL Project Area were identified; however, general surface water quality can be inferred from the receiving perennial waters of the drainage area, which are the Green River and the Big Sandy River. The quality of runoff is largely dependent upon the amount of salts, sediments, and organic materials that accumulate in dry stream channels during periods of runoff. TDS resulting from agricultural runoff and energy development are elevated and are a water quality concern in the Green River and Big Sandy River drainage areas.

The BLM used the AGWA model (BLM 2013a) to identify areas that are susceptible to changes in land cover, surface-disturbing activities, and/or climate. The present (existing conditions) show that more than 86 percent of the existing stream miles exhibit low to very low impacts. Areas of moderate to high impact account for approximately five percent of the analysis area and occur in portions of the Lower Alkali Creek, Chapel Canyon, Spring Creek – Green River, Reardon Draw, Jonah Gulch, Long Draw, and Little Colorado Watersheds. Much of the moderate and high impact area is outside the NPL Project Area, in the lower reaches of drainages near the Big Sandy and Green Rivers.

Recharge of groundwater from surface infiltration occurs mainly at the edges of the basin outside of the NPL Project Area, along the base of the mountains. A small area of permeable surface material exists in the NPL Project Area near Tea Kettle Butte (Figure K-14) and allows for some infiltration, but because of the low precipitation and high evaporation, recharge is generally insignificant. There is likely some groundwater exchange between the Laney and adjacent Wasatch beds, due to the lack of hydraulic barriers between the two zones and the gentle dip of the rocks to the southwest. Based on the best available existing information, the Wasatch Aquifer is not thought to discharge to surface water, although a complete analysis of vertical hydraulic gradients has not been completed.

Four important water-bearing zones are identified for the NPL Project Area, including the following:

- **Alluvial Aquifer –** Discontinuous alluvial deposits form isolated aquifers in a few areas of the NPL Project Area, but they are also not considered an important groundwater resource. Where the Alluvial aquifer is present, it is likely hydraulically connected to surface waters and would drain to and recharge the surface water. The Alluvial aquifer does not provide water for any of the wells in the NPL Project Area, but the springs may represent groundwater breakouts of water from the Alluvial aquifer.

- **Laney Aquifer –** This unit is thin (less than 200 feet thick) and made up of limestone, sandstone, marlstone, and thin shales. The Laney aquifer is found at ground surface in the central, southern, and eastern portions of the NPL Project Area. Four stock wells produce water from this zone in the NPL Project Area (Attachment B). The Laney aquifer is not identified as an important water resource or a target zone for NPL Project operations due to poor permeability and low yield.
- **Wasatch Aquifer–** The Wasatch Aquifer is the primary aquifer in the NPL Project Area and adjacent areas. The uppermost 600 to 1,000 feet of the Wasatch contains numerous thick sandstone layers that provide the source of water in stock wells and for oil and gas drilling operations at JIDPA and PAPA. West of the NPL Project Area, the Wasatch Aquifer may discharge to the Green River.
- **Fort Union Aquifer–** Permeable sandstone layers within the Fort Union Formation are classified by Bartos and Hallberg (2010) as the Fort Union Zone of the Wasatch-Fort Union Aquifer system (referred to here as the Fort Union Aquifer). The water quality is generally poor due to high TDS, and the aquifer is not used for domestic, agricultural, or livestock water uses in the analysis area. The Fort Union Aquifer is the target zone in the JIDPA for injection of formation fluids.

There have been few studies of the structural geology of the NPL Project Area. Compared to the JIDPA and PAPA to the north, which have been studied, the NPL Project Area has a less complex geologic history and fewer structural features, including faults and fractures. Minimal natural vertical conduits are expected that would provide hydraulic conductivity between the targeted formation fluids injection zone and the gas producing zone.

Water for the NPL Project would be removed from the top 1,000 feet of the Wasatch Formation from wells in the JIDPA and the NPL Project Area. Geochemical data indicate that the groundwater removed to date in the JIDPA contains elevated levels of TDS and pH greater than EPA (2009) Secondary MCLs for drinking water but is usable for livestock watering purposes and, if treated, other domestic uses. Groundwater quality in the Fort Union Aquifer is of low quality due to naturally occurring high TDS content.

6.2 Summary of Impacts

This section summarizes the potential impacts to surface water and groundwater resources resulting from the NPL Project. Additional information on these potential impacts can be found in the sections above. Refer to Chapter 4 (*Environmental Consequences*) of the NPL Project EIS for a comparative analysis of potential impacts to surface water and groundwater resources resulting from the NPL Project Proposed Action and alternatives.

The primary effect of oil and gas development on the surface water systems within the analysis area would be related to increased sedimentation and channel erosion. Results of the AGWA model (BLM 2013a) indicate there is a low probability of transporting sediment and salt from contributing watersheds to major stream channels for all of the modeled development scenarios. However, heavy storms may increase the probability of impacts to tributaries of the Green and Big Sandy Rivers, as well as the rivers themselves, especially in watersheds where development may be concentrated and sediment transport is more likely.

Groundwater to be used for the NPL Project would be permanently removed from the upper 1,000 feet of the Wasatch Formation for well drilling and cementing. Approximately 29 percent of the water used for the NPL Project Area would come from existing and potential new wells targeting the Wasatch and Fort Union Aquifers. Groundwater modeling results for the JIDPA and surrounding analysis area (including the NPL Project Area) described in Appendix A *(Groundwater Flow Model and Hydrogeologic Impact Assessment, Jonah Infill Drilling Project)* show that withdrawal of groundwater during active pumping would result in a localized lowering of the potentiometric surface within a few miles of the JIDPA of up to 10 feet. The lowered potentiometric surface would be greatest within a few miles of the JIDPA (proximate to the location of water supply wells) and would be expected to recover in less than six years. The area of depressed groundwater would not extend outside of the NPL Project Area. Groundwater elevations and water quality outside the NPL Project Area would not be affected by the withdrawal and use of water.

Drawdown associated with the JIDPA and transitioning to the NPL Project would not intersect or induce upward flow from the Fort Union Aquifer, located more than 3,500 feet below the water supply well intake zones. Adherence to BLM and WOGCC well construction and operation requirements would ensure the wells are not conduits for upward migration of fluids into the zones. Existing effects of water drawdown observed at the JIDPA would likely continue but not change in magnitude, because the total water withdrawal from the near-surface aquifers would remain reasonably constant as NPL Project drilling increases and JIDPA drilling decreases. Prolonged drought conditions could exacerbate the lowering of the potentiometric surface and lengthen the time for recovery.

Oil-based mud, which may be used to drill wells depending on site-specific conditions (i.e., total dissolved solids greater than 10,000 ppm), and biodiesel, an additive used to address problems and difficult drilling conditions, have the potential for loss into water-bearing zones during drilling. The risk of impact from loss of these fluids is minimal due to the small volume of hydrocarbons that would be lost to the formation and the limited distance of infiltration of the hydrocarbons. Impacts would be minimized through the use of proactive drilling mud management programs, which create and maintain an impermeable filter cake on the borehole wall, and casing and cement programs that ensure isolation of the water-bearing zones.

More than 71 percent of the total amount of water used for the NPL project would support well completion, and would come from recycled sources from the Jonah formation fluids treatment facility. The use of recycled water reduces the need for freshwater withdrawal and would reduce the potential impacts related to water withdrawal.

Formation fluids would be injected into the Fort Union Aquifer. Since formation fluids would have TDS levels significantly lower than the levels of the groundwater in this aquifer, no adverse impacts to groundwater quality in the Fort Union Aquifer are expected. Vertical migration of formation fluids into the shallow Wasatch Formation is unlikely through natural conduits, because there is insufficient head pressure to drive the dense brine through the 3,500-foot separation, which contains multiple low permeable layers. Additionally, adherence to BLM and WOGCC well construction and operation requirements would ensure the injection wells are not conduits for upward migration of fluids into shallow water-bearing zones.

The NPL Project target zone for gas production, that would include completion operations in the Lance Formation, is approximately 5,000 to 9,000 feet below the deepest currently used groundwater source, and 3,500 to 7,500 feet below the lowest potential source of low TDS water (the base of the Wasatch Formation). No existing hydrologic mechanisms or conditions have been identified that would allow completion fluids to be driven through the intervening rocks as a result of normal completion operations. Well construction and operation practices required by BLM and WOGCC ensure would ensure that the wellbores do not provide a pathway for transport of fluids from the producing zone to the shallow water-bearing zones.

Implementation of an NPL Project groundwater monitoring program prior to and during development would provide additional information on hydrogeological conditions, water quality, water levels and other information to inform proper drilling and operational activities and would provide a mechanism for early identification and remedy of impacts, if they were to occur. This effort would consist of a groundwater baseline study, groundwater and surface water monitoring, and installation of additional monitoring wells, as needed. The program would include routine sampling of existing water sources and new monitoring wells as NPL development progresses with implementation of appropriate safeguards and BMPs during all phases of development. Data would be used to validate the results of the predictive groundwater model.

7.0 REFERENCES

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ATTACHMENT A. Groundwater Flow Model and Hydrogeologic Impact Assessment - Jonah Infill Drilling Project

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HydroGeo, Inc.
Surface & Groundwater Hydrology (final version)

GROUNDWATER FLOW MODEL AND HYDROLOGIC IMPACT ASSESSMENT

JONAH INFILL DRILLING PROJECT

Prepared for
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February 2004

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GROUNDWATER FLOW MODEL AND HYDROLOGIC IMPACT ASSESSMENT, JONAH INFILL DRILLING PROJECT

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February 2004

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1.0 OVERVIEW

In conjunction with the Bureau of Land Management (BLM), TRC Mariah Associates Inc. (TRC Mariah) is preparing a third party environmental impact statement (EIS) for the proposed Jonah Infill Drilling Project (Project) located approximately 32 miles southeast of Pinedale, Wyoming (Map 1.1). TRC Mariah contracted HydroGeo, Inc. (HydroGeo) to complete a water depletion and hydrologic impact analysis to support the EIS. HydroGeo analyzed the potential direct hydrological impacts of the proposed Project by using a numerical groundwater flow model.

A numerical groundwater flow model was developed for the Project using the computer code MODFLOW. The model was designed to simulate the regional effect of combined groundwater pumping from the Green River/Wasatch aquifer system for the duration of project development (12.4 to 41.3 years). Model results were used to assess the potential direct impacts of proposed Project groundwater pumping to surface and groundwater resources.

MODFLOW is a block-centered, finite difference model that was developed by the U.S. Geologic Survey to model groundwater flow and the interaction between groundwater and surface water (McDonald and Harbaugh 1988). The MODFLOW model is widely accepted by federal and state regulatory agencies. Input and output from the groundwater flow was managed using Groundwater Vistas, a graphical interface for MODFLOW that facilitates the development of model files, contouring, and analysis of model results.

The Project groundwater flow model (Jonah Infill Model) was developed in two steps:

1. a steady-state model of the existing condition was prepared, and
2. a predictive model for the proposed Project was prepared.

The steady-state model was developed to simulate the hydrologic regime prior to oil and gas development. The steady-state model served as the basis for predictive model runs and was calibrated to simulate historic data. The calibrated steady-state model was used to predict potential future impacts from proposed Project-required freshwater pumping operations. The Jonah Infill Model was based on the conceptual hydrogeologic model developed for past

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Figures in this Attachment Are Unavailable

Map 1.1 Jonah Infill Drilling Project Location, Sublette County, Wyoming, 2004.

hydrogeologic studies (Dynamac Corporation [Dynamac] 2002) and recent data compiled by the BLM, TRC Mariah, and HydroGeo.

This report documents the Jonah Infill Model setup, hydrologic input parameters, and descriptions of the evaluated pumping scenarios, and includes a discussion of the modeling results and impact analysis.

2.0 DESCRIPTION OF MODEL DOMAIN AND INPUT PARAMETERS

2.1 INPUT FILES

The following MODFLOW packages (U.S. Geologic Survey 1996) were used in developing the Jonah Infill Model:

- BAS (basic package),
- BCF (block-centered flow package),
- OC (output control package),
- RCH (recharge package),
- PCG2 (solver package), and
- WEL (well package).

2.2 MODEL DOMAIN AND GRID

The Jonah Infill Model domain encompasses an area of approximately 1,400 square miles (3,626 square km) (Map 2.1). The model grid is oriented in a north/south direction. The southern model boundary extends from the Green River north of La Barge, Wyoming, east to the Big Sandy Reservoir. The western model boundary runs along the Green River north to the confluence with the New Fork River. The northern model boundary follows the New Fork River to its confluence with the East Fork River and then follows the East Fork River. The eastern model boundary follows the East Fork River and the Big Sandy River to Big Sandy Reservoir. The model grid is divided into 119 columns and 106 rows representing distances of approximately 41 miles (66 km) and 34 miles (55 km), respectively. Cell spacing is 250 m

(≈820 ft) inside the Project area, and 1,000 m (≈3,281 ft) everywhere else. Intermediate cell sizes are used between the small and large cells.

Two layers are used in the model. The thickness of the upper layer (Layer 1) was 500 ft (≈152 m), and the lower layer (Layer 2) was 3,600 ft (≈1,097 m). A total thickness of 4,100 ft (≈1,250 m) was used for the combined model layers. The combined layers are a simplified conceptualization of the Green River/Wasatch aquifer and also include the unconsolidated alluvial deposits along the river channels. The unconsolidated gravel deposits reach a thickness of up to 50 ft (≈15 m) in the New Fork Channel and generally pinch out as their elevation and distance from the river increases (Dynamac 2002). The Green River and Wasatch formations are comprised of sandstone, mudstone, shale, and limestone, and are approximately 4,100 ft (≈1,250 m) thick. The contact with the underlying Fort Union Formations is gradational and/or undifferentiated. The Fort Union Formation consists of interbedded conglomerate, sandstone, siltstone, and mudstone strata. The Fort Union Formation is approximately 2,300 ft (≈701 m) thick in the Project area (Dynamac 2002). The alluvial and tertiary (Green River and Wasatch Formations) aquifers are hydraulically interconnected (Dynamac 2002). Well data from the Project area indicate that freshwater occurs to a depth of about 2,300 ft (≈701 m) and that the groundwater is saline below 5,000 ft (1,524 m). The conservative hydrogeologic conceptual model used for this analysis considers the alluvium and Green River and Wasatch formations to be a single hydrostratigraphic unit. Two layers were created to simulate pumping only from the upper 500 ft (≈152 m) of this water-bearing unit.

2.3 BOUNDARY CONDITIONS

The model domain is underlain by the impermeable (as modeled) strata of the Lance Formation. The rivers that form the boundary of the model domain (Green River, New Fork River, East Fork River and Big Sandy River) were modeled as constant head cells. The elevations of the constant heads were set at the average river elevations within the domain. Along the eastern boundary of the model, constant head elevations were inferred between the East Fork River and the Big Sandy River. The southern boundary of the model is formed by no-flow cells, simulating the fact that the flow is predominately either west--towards the Green River--or east--towards the Big Sandy River. The location of the model's constant head boundary is shown on Map 2.1.

Map 2.1 Model Domain and Boundary, Jonah Infill Drilling Project, Sublette County, Wyoming, 2004.

2.4 MODEL PARAMETERS

2.4.1 Hydraulic Conductivity

The hydraulic conductivity used in the Jonah Infill Model ranges from 1.6 to 9.8 ft/day (≈0.5 to 3.0 m/day). The hydraulic conductivity of the upper model layer ranges from 5.0 to 9.8 ft/day (≈1.5 to 3.0 m/day) and is depicted on Map 2.2. The highest hydraulic conductivity is assigned to the constant head cells along the rivers to simulate the alluvial aquifer. Hydraulic conductivity decreases towards the center of the model domain.

The lowest hydraulic conductivity is applied to the lower layer of the model to represent the deeper part of the Wasatch aquifer. The hydraulic conductivity in the lower model layer was assumed to be uniform at 1.6 ft/day (≈0.5 m/day). This hydraulic conductivity is similar to the conductivity applied by Martin, as described in Chafin and Kimball (1992). Martin simulated a value of 6.5 ft/day (≈2.0 m/day) for the upper few hundred feet of the Wasatch Formation in most of the northern Green River Basin and a hydraulic conductivity of 0.9 ft/day (≈0.3 m/day) for the deeper part of the Wasatch Formation (Chafin and Kimball 1992). Hydraulic conductivity is isotropic in a horizontal direction throughout the model ($K_x = K_y$).

2.4.2 Specific Yield

A uniform specific yield (S_y) of 0.06 was used for the entire aquifer. This is a typical specific yield for an unconfined sandstone\siltstone type aquifer (Freeze and Cherry 1979).

2.4.3 Recharge

Typical recharge rates for semi-arid areas range from 5% to 10% of annual precipitation. The average precipitation in the Project area is about 10 inches (25.4 cm) per year (Lowham et al. 1985). A conservative uniform recharge rate of 5% (0.5 inch [≈1.3 cm]) per year was applied over the extent of the model domain.

Map 2.2 Assigned Hydraulic Conductivities, Upper Model Layer, Jonah Infill Drilling Project, Sublette County, Wyoming, 2004.

3.0 STARTING HEADS

A steady-state model, assuming no discharge from the pumping wells was used to develop starting heads for the pumping simulation. The steady-state potentiometric surface is displayed in Map 3.1.

4.0 CALIBRATION

A limited steady-state calibration based on data presented in the Dynamac report *Attachment E: Final PAPA Potentiometric Surface Map* (Dynamac 2002) was performed. The southern half of the PAPA study area overlaps the northern half of the model domain. Three wells on the PAPA map fall within the model boundaries. These wells were plotted and are shown on Map 2.1, and pertinent data are summarized in Table 4.1.

Four additional wells within the model domain (P131008W, P111928W, P9349P, P68609W) were inventoried (Dynamac 2002), but were not used in the creation of the potentiometric map, or for the calibration of the Jonah Infill Model. These four wells are in proximity to each other; however, they exhibit head differences of up to 64 m (≈210 ft). Since it could not be determined whether the head difference is due to a perched aquifer or other causes, these wells were not used in the calibration of the model.

Table 4.1 Calibration Target Heads, Jonah Infill Project, Sublette County, Wyoming, 2004.

Well Permit	Measured Head (m)	Model Head (m)	Residual (m)
P132627W	2,106	2,104.42	1.58
P107650W	2,112	2,114.40	-2.40
P113481W	2,114	2,116.14	-2.14

Map 3.1 Steady-state Potentiometric Surface Map (Contour Interval 10 m), Jonah Infill Drilling Project, Sublette County, Wyoming, 2004.

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Additional wells inventoried by the Wyoming State Engineer (2004) were also examined for use in the calibration of the steady-state potentiometric surface. However, information provided for those wells was not accurate enough to be useful for model calibration. Specifically, well location data were only provided to quarter-quarter section, so exact locations and elevations could not be mapped. No pumping data from area wells were available so a transient calibration could not be completed for this study.

5.0 PUMPING SIMULATION

A total of 25 pumping wells were simulated in the model scenarios (see Map 2.1). These 25 wells are existing wells inside the Project area that are currently used by oil and gas companies for project purposes (e.g., drilling, completion). A summary of the data for these wells is listed in Table 5.1. The northings and eastings have been estimated on the map, based on the quarter-quarter section of the well location. All wells were simulated as pumping from the upper model layer (i.e., all wells are assumed to pump from the upper 500 ft [≈152 m] of the aquifer). Well depth and depth to water are reported for some of the existing wells (Wyoming State Engineer 2004) and average well depth is about 500 ft (≈152 m) (Table 5.1).

An additional 16 water wells (estimated to be approximately 500 ft in depth) may be drilled within the Project area during development, but the locations of the new wells have not been determined. The addition of 16 new wells does not change the overall pumping requirements for the Project (as modeled) and would likely have little effect on the geometry and extent of the drawdown cone.

5.1 MODELED SCENARIOS

Three pumping scenarios were performed for this modeling effort. For all three scenarios it was assumed that all wells would produce at the same rate for the same time period.

Table 5.1 Pumping Wells, Jonah Infill Drilling Project, Sublette County, Wyoming, 2004.

		Location[2]								
Permit #	Status[1]	T	R	S	Qtr Qtr	Applicant	Facility Name	Northing	Easting	Wet Well Depth[3]
P136076W	GST	28N	108W	4	NESW	McMurry Oil Co., BLM	Jonah No. 1-4W	607004	4698258	450
P131932W	GST	28N	108W	7	NWNE	McMurry Oil Co., BLM	Jonah Federal 2-7W	604442	4697488	525
P136073W	GST	28N	109W	13	NENE	BLM, McMurry Oil Co.	Yellow Point 1-13W	603053	4695877	425
P112728W	GSE	28N	109W	14	NENE	BLM, BP America Production Co.	Corona #2-14 WSW	601460	4695884	723
P130677W	GSE	28N	109W	23	SWNE	Forest Oil Corporation	BLM Federal #23-22 Water Source Well	601274	4694078	
P126228W	GSE	29N	107W	18	SWSW	BLM, Amoco Production Co.	Cabrito Unit #13-18	610782	4703697	
P149405W	GST	29N	107W	19	SWSW	McMurry Oil Co. BLM	Cabrito #13-19 W	610803	4702102	540
P120843W	GST	29N	107W	20	SWNW	BLM, BP America Production Co.	Cabrito Unit #5-20 Water Well	612398	4702937	478
P112727W	GSE	29N	107W	31	NENW	BLM, BP America Production Co.	Cabrito #3-31 WSW	611062	4699893	585
P106042W	UNA	29N	108W	11	SWNE	BLM, Anshutz Exploration Corp.	Sand Draw #7-11 (W)	608319	4706042	455
P133368W	GSE	29N	108W	15	SWSE	Amoco Production	Stud Horse Butte #15-15	606742	4703665	
P120836W	GSE	29N	108W	16	SWSE	Wyoming State Board of Land Commissioners, Amoco Production Co.	Jonah Water Supply Well #1	605124	4703651	
P118352W	UNA	29N	108W	20	SESE	BLM, BP America Production Co.	Stud Horse Butte #1	603756	4702028	535
P105051W	UNA	29N	108W	21	SWSE	BLM, Western Gas Resources Inc.	Stud Horse Butte #15-21 W	605155	4702054	490
P104193W	UNA	29N	108W	23	SWSW	Western Gas Resources Inc.	Stud Horse Butte #1	607577	4702080	575
P106093W	UNA	29N	108W	24	SWSE	BLM, Ultra Petroleum	Stud Horse Butte #15-24 WW #1	609994	4702094	510
P134841W	GST	29N	108W	26	NESW	McMurry Oil Co., BLM	Stud Horse Butte #11-26 W	607803	4700675	520
P131350W	GSE	29N	108W	26	SENE	BLM, Amoco Production Co.	Jonah Warehouse Yard-Water Well	608607	4701279	
P103561W	UNA	29N	108W	27	SWSW	BLM, McMurry Oil Co.	Stud Horse Butte #13-27 W	606010	4700455	485
P136074W	GST	29N	108W	29	NESW	BLM, McMurry OIL CO.	Stud Horse Butte #11-29 W	602986	4700618	505
P127221W	GSE	29N	108W	30	SENE	Amoco Production Co., BLM	Corona Unit 1-30 Water Well	602223	4701188	
P149403W	GST	29N	108W	32	SWSW	McMurry Oil Co., BLM	Stud Horse Butte #13-32 W	602817	4698800	420
P130709W	GST	29N	108W	34	SENE	BLM, McMurry Oil Co.	Stud Horse Butte #8-34 W	607040	4699653	620
P148650W	GSI	29N	108W	34	SESE	EnCana Oil & Gas (USA) Inc., BLM	Stud Horse Butte #16-34 W	607040	4698849	--
P150264W	GSI	29N	108W	36	NENW	Frank S. Virden	Scutter Bun #1	609449	4699893	--

1 T = township; R = range; S = section.

2 Status:
- GSE = good standing permitted time limits have been extended
- GSI = good standing incomplete; required notices not received; not yet expired
- GST = good standing
- UNA = unadjudicated

3 Well depth below static water table.

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Modeled scenarios included the following.

Scenario 1: Simulate freshwater pumping to accommodate a development drilling rate of 75 wells per year for a period of 41.3 years (requirements for development of 3,100 natural gas wells).

Scenario 2: Simulate freshwater pumping to accommodate a development drilling rate of 150 wells per year for a period of 20.7 years (requirements for development of 3,100 natural gas wells).

Scenario 3: Simulated freshwater pumping to accommodate a development drilling rate of 250 wells per year for a period of 12.4 years (requirements for development of 3,100 natural gas wells).

A summary of the input data for each pumping scenario is presented in Table 5.2.

5.2 STRESS PERIODS

For each model scenario, two stress periods were used; the first one simulates pumping from the Green River/Wasatch aquifer for the duration of the drilling program (i.e., 41.3 years for Scenario 1; 20.7 years for Scenario 2; and 12.4 years for Scenario 3). The second stress period simulates recovery for 10 years after pumping has ended. The pumping stress period was divided into 120 time steps and the recovery period was divided into 100 time steps.

Table 5.2 Summary of Pumping Scenarios, Jonah Infill Drilling Project, Sublette County, Wyoming, 2004.

Scenario	No. of Gas Wells (per year)	Water Need per Gas Well (acre-feet)	Water Need for All Gas Wells (acre-feet/year)	Length of Drilling Program (years)	No. of Pumping Wells	Water Per Pumping Well (acre-feet/year)	Water Per Pumping Well (gpm)
1	75	4.9	367.5	41.3	25	14.7	9.1
2	150	4.9	735.0	20.7	25	29.4	18.2
3	250	4.9	1,225.0	12.4	25	49.0	30.4

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6.0 MODEL OUTPUT

6.1 RESULTS

Full recovery is defined as the point in time when no drawdown greater than or equal to 1.6 ft (≈0.5 m) exists. The approximate length of time in years to reach full recovery after the end of pumping is presented in Table 6.1. Contour maps of drawdown were prepared for each model scenario at the end of the pumping stress period and are presented in Maps 6.1, 6.2, and 6.3.

6.2 SENSITIVITY ANALYSIS

Hydraulic conductivity was decreased by one order of magnitude to a range from 0.16 to 0.98 ft/day (≈0.05 to 0.30 m/day) for the entire aquifer in order to test the sensitivity of the model to changes in hydraulic conductivity. Smaller hydraulic conductivity values create a lower transmissivity and lead to a larger drawdown from pumping wells. The sensitivity analysis model was run using the most aggressive pumping scenario (Scenario 3).

The drawdown cone resulting from the sensitivity analysis is shown in Map 6.4. The sensitivity analysis drawdown results at the Project boundary were very similar to modeled results in Scenario 3 (see Map 6.3). The drawdown closer to the pumping wells was larger in the sensitivity analysis than in Scenario 3. The results of this analysis indicate that the model is not very sensitive to variations in hydraulic conductivity, particularly in the area at the Project boundary. Sensitivity analyses for specific yield and recharge were not completed because the model values are conservative.

Table 6.1 Modeled Recovery Time, Jonah Infill Drilling Project, Sublette County, Wyoming, 2004.

Scenario	Years to Full Recovery After Pumping Ends	Years to Full Recovery from Start of Drilling Program
1	0.5	42
2	4.0	25
3	6.0	18

Map 6.1 Scenario 1 - Projected Drawdown after 41.3 Years of Pumping (Contour Interval 0.5 m), Jonah Infill Drilling Project, Sublette County, Wyoming, 2004.

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Map 6.2 Scenario 2 - Projected Drawdown after 20.7 Years of Pumping (Contour Interval 0.5 m), Jonah Infill Drilling Project, Sublette County, Wyoming, 2004.

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Map 6.3 Scenario 3 - Projected Drawdown after 12.4 Years of Pumping (Contour Interval 0.5 m), Jonah Infill Drilling Project, Sublette County, Wyoming, 2004.

Map 6.4 Sensitivity Analysis Drawdown using Lowered Hydraulic Conductivity (Contour Interval 0.5 m), Jonah Infill Drilling Project, Sublette County, Wyoming, 2004.

7.0 MODELING RESULTS AND IMPACT ANALYSIS

Based on the results of the modeling, a 0.5 m (≈1.6 ft) drawdown cone caused by the proposed freshwater pumping will extend only slightly beyond the Project area, even for the most aggressive development, (Scenario 3, 250 gas wells per year). Water levels in water wells within the modeled drawdown cone area may be lowered due to the proposed pumping, particularly in those wells located near the Project water supply wells. However, the groundwater level in the wells should recover rapidly after Project pumping ceases. The model results show that the recovery of the groundwater table will be rapid, ranging from 0.5 to 6 years (see Table 6.1), depending on the pumping scenario. Since seasonal fluctuations in groundwater levels are typically greater than 0.5 m (≈1.6 ft), it would be difficult to distinguish between seasonal effects and pumping effects. As a result, no measurable impacts to surface or groundwater resources outside the modeled drawdown cone are expected.

The 25 modeled pumping wells should be able to sustain the proposed pumping rates for the 250 gas wells per year development scenario. However, the possibility exists that some wells may not be completed in the Green River/Wasatch aquifer, but only in a perched water-bearing zone and, therefore, may not produce as expected. Groundwater quality will not likely be impacted as a result of freshwater pumping.

It should be noted, that the Jonah Infill Model is a large-scale model with limited data available for calibration. Possible variations in well productions due to small-scale variations in the vicinity of one or several water wells cannot be predicted. Well depths for all existing wells used in the model are not available. Local variations in hydraulic conductivity or specific yield may also influence and alter the modeled outcome, although the sensitivity analysis indicates that minor changes in hydraulic conductivity values will not have much effect.

8.0 RECOMMENDATIONS

Monitoring water levels in selected wells within and outside the Project area prior to and during Project operations is recommended to confirm the modeled results. The model could also be periodically recalibrated using the new monitoring data to enhance the model's predictive accuracy.

9.0 REFERENCES

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2.4 MODEL PARAMETERS

2.4.1 Hydraulic Conductivity

The hydraulic conductivity used in the Jonah Infill Model ranges from 1.6 to 9.8 ft/day (≈0.5 to 3.0 m/day). The hydraulic conductivity of the upper model layer ranges from 5.0 to 9.8 ft/day (≈1.5 to 3.0 m/day) and is depicted on Map 2.2. The highest hydraulic conductivity is assigned to the constant head cells along the rivers to simulate the alluvial aquifer. Hydraulic conductivity decreases towards the center of the model domain.

The lowest hydraulic conductivity is applied to the lower layer of the model to represent the deeper part of the Wasatch aquifer. The hydraulic conductivity in the lower model layer was assumed to be uniform at 1.6 ft/day (≈0.5 m/day). This hydraulic conductivity is similar to the conductivity applied by Martin, as described in Chafin and Kimball (1992). Martin simulated a value of 6.5 ft/day (≈2.0 m/day) for the upper few hundred feet of the Wasatch Formation in most of the northern Green River Basin and a hydraulic conductivity of 0.9 ft/day (≈0.3 m/day) for the deeper part of the Wasatch Formation (Chafin and Kimball 1992). Hydraulic conductivity is isotropic in a horizontal direction throughout the model ($K_x = K_y$).

2.4.2 Specific Yield

A uniform specific yield (S_y) of 0.06 was used for the entire aquifer. This is a typical specific yield for an unconfined sandstone\siltstone type aquifer (Freeze and Cherry 1979).

2.4.3 Recharge

Typical recharge rates for semi-arid areas range from 5% to 10% of annual precipitation. The average precipitation in the Project area is about 10 inches (25.4 cm) per year (Lowham et al. 1985). A conservative uniform recharge rate of 5% (0.5 inch [≈1.3 cm]) per year was applied over the extent of the model domain.

Map 2.2 Assigned Hydraulic Conductivities, Upper Model Layer, Jonah Infill Drilling Project, Sublette County, Wyoming, 2004.

3.0 STARTING HEADS

A steady-state model, assuming no discharge from the pumping wells was used to develop starting heads for the pumping simulation. The steady-state potentiometric surface is displayed in Map 3.1.

4.0 CALIBRATION

A limited steady-state calibration based on data presented in the Dynamac report *Attachment E: Final PAPA Potentiometric Surface Map* (Dynamac 2002) was performed. The southern half of the PAPA study area overlaps the northern half of the model domain. Three wells on the PAPA map fall within the model boundaries. These wells were plotted and are shown on Map 2.1, and pertinent data are summarized in Table 4.1.

Four additional wells within the model domain (P131008W, P111928W, P9349P, P68609W) were inventoried (Dynamac 2002), but were not used in the creation of the potentiometric map, or for the calibration of the Jonah Infill Model. These four wells are in proximity to each other; however, they exhibit head differences of up to 64 m (≈210 ft). Since it could not be determined whether the head difference is due to a perched aquifer or other causes, these wells were not used in the calibration of the model.

Table 4.1 Calibration Target Heads, Jonah Infill Project, Sublette County, Wyoming, 2004.

Well Permit	Measured Head (m)	Model Head (m)	Residual (m)
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P107650W	2,112	2,114.40	-2.40
P113481W	2,114	2,116.14	-2.14

Map 3.1 Steady-state Potentiometric Surface Map (Contour Interval 10 m), Jonah Infill Drilling Project, Sublette County, Wyoming, 2004.

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Additional wells inventoried by the Wyoming State Engineer (2004) were also examined for use in the calibration of the steady-state potentiometric surface. However, information provided for those wells was not accurate enough to be useful for model calibration. Specifically, well location data were only provided to quarter-quarter section, so exact locations and elevations could not be mapped. No pumping data from area wells were available so a transient calibration could not be completed for this study.

5.0 PUMPING SIMULATION

A total of 25 pumping wells were simulated in the model scenarios (see Map 2.1). These 25 wells are existing wells inside the Project area that are currently used by oil and gas companies for project purposes (e.g., drilling, completion). A summary of the data for these wells is listed in Table 5.1. The northings and eastings have been estimated on the map, based on the quarter-quarter section of the well location. All wells were simulated as pumping from the upper model layer (i.e., all wells are assumed to pump from the upper 500 ft [≈152 m] of the aquifer). Well depth and depth to water are reported for some of the existing wells (Wyoming State Engineer 2004) and average well depth is about 500 ft (≈152 m) (Table 5.1).

An additional 16 water wells (estimated to be approximately 500 ft in depth) may be drilled within the Project area during development, but the locations of the new wells have not been determined. The addition of 16 new wells does not change the overall pumping requirements for the Project (as modeled) and would likely have little effect on the geometry and extent of the drawdown cone.

5.1 MODELED SCENARIOS

Three pumping scenarios were performed for this modeling effort. For all three scenarios it was assumed that all wells would produce at the same rate for the same time period.

Table 5.1 Pumping Wells, Jonah Infill Drilling Project, Sublette County, Wyoming, 2004.

		Location[2]								
Permit #	Status[1]	T	R	S	Qtr Qtr	Applicant	Facility Name	Northing	Easting	Wet Well Depth[3]
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P136073W	GST	28N	109W	13	NENE	BLM, McMurry Oil Co.	Yellow Point 1-13W	603053	4695877	425
P112728W	GSE	28N	109W	14	NENE	BLM, BP America Production Co.	Corona #2-14 WSW	601460	4695884	723
P130677W	GSE	28N	109W	23	SWNE	Forest Oil Corporation	BLM Federal #23-22 Water Source Well	601274	4694078	
P126228W	GSE	29N	107W	18	SWSW	BLM, Amoco Production Co.	Cabrito Unit #13-18	610782	4703697	
P149405W	GST	29N	107W	19	SWSW	McMurry Oil Co. BLM	Cabrito #13-19 W	610803	4702102	540
P120843W	GST	29N	107W	20	SWNW	BLM, BP America Production Co.	Cabrito Unit #5-20 Water Well	612398	4702937	478
P112727W	GSE	29N	107W	31	NENW	BLM, BP America Production Co.	Cabrito #3-31 WSW	611062	4699893	585
P106042W	UNA	29N	108W	11	SWNE	BLM, Anshutz Exploration Corp.	Sand Draw #7-11 (W)	608319	4706042	455
P133368W	GSE	29N	108W	15	SWSE	Amoco Production	Stud Horse Butte #15-15	606742	4703665	
P120836W	GSE	29N	108W	16	SWSE	Wyoming State Board of Land Commissioners, Amoco Production Co.	Jonah Water Supply Well #1	605124	4703651	
P118352W	UNA	29N	108W	20	SESE	BLM, BP America Production Co.	Stud Horse Butte #1	603756	4702028	535
P105051W	UNA	29N	108W	21	SWSE	BLM, Western Gas Resources Inc.	Stud Horse Butte #15-21 W	605155	4702054	490
P104193W	UNA	29N	108W	23	SWSW	Western Gas Resources Inc.	Stud Horse Butte #1	607577	4702080	575
P106093W	UNA	29N	108W	24	SWSE	BLM, Ultra Petroleum	Stud Horse Butte #15-24 WW #1	609994	4702094	510
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P131350W	GSE	29N	108W	26	SENE	BLM, Amoco Production Co.	Jonah Warehouse Yard-Water Well	608607	4701279	
P103561W	UNA	29N	108W	27	SWSW	BLM, McMurry Oil Co.	Stud Horse Butte #13-27 W	606010	4700455	485
P136074W	GST	29N	108W	29	NESW	BLM, McMurry OIL CO.	Stud Horse Butte #11-29 W	602986	4700618	505
P127221W	GSE	29N	108W	30	SENE	Amoco Production Co., BLM	Corona Unit 1-30 Water Well	602223	4701188	
P149403W	GST	29N	108W	32	SWSW	McMurry Oil Co., BLM	Stud Horse Butte #13-32 W	602817	4698800	420
P130709W	GST	29N	108W	34	SENE	BLM, McMurry Oil Co.	Stud Horse Butte #8-34 W	607040	4699653	620
P148650W	GSI	29N	108W	34	SESE	EnCana Oil & Gas (USA) Inc., BLM	Stud Horse Butte #16-34 W	607040	4698849	--
P150264W	GSI	29N	108W	36	NENW	Frank S. Virden	Scutter Bun #1	609449	4699893	--

1 T = township; R = range; S = section.
2 Status:
GSE = good standing permitted time limits have been extended
GSI = good standing incomplete; required notices not received; not yet expired
GST = good standing
UNA = unadjudicated
3 Well depth below static water table.

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Modeled scenarios included the following.

Scenario 1: Simulate freshwater pumping to accommodate a development drilling rate of 75 wells per year for a period of 41.3 years (requirements for development of 3,100 natural gas wells).

Scenario 2: Simulate freshwater pumping to accommodate a development drilling rate of 150 wells per year for a period of 20.7 years (requirements for development of 3,100 natural gas wells).

Scenario 3: Simulated freshwater pumping to accommodate a development drilling rate of 250 wells per year for a period of 12.4 years (requirements for development of 3,100 natural gas wells).

A summary of the input data for each pumping scenario is presented in Table 5.2.

5.2 STRESS PERIODS

For each model scenario, two stress periods were used; the first one simulates pumping from the Green River/Wasatch aquifer for the duration of the drilling program (i.e., 41.3 years for Scenario 1; 20.7 years for Scenario 2; and 12.4 years for Scenario 3). The second stress period simulates recovery for 10 years after pumping has ended. The pumping stress period was divided into 120 time steps and the recovery period was divided into 100 time steps.

Table 5.2 Summary of Pumping Scenarios, Jonah Infill Drilling Project, Sublette County, Wyoming, 2004.

Scenario	No. of Gas Wells (per year)	Water Need per Gas Well (acre-feet)	Water Need for All Gas Wells (acre-feet/year)	Length of Drilling Program (years)	No. of Pumping Wells	Water Per Pumping Well (acre-feet/year)	Water Per Pumping Well (gpm)
1	75	4.9	367.5	41.3	25	14.7	9.1
2	150	4.9	735.0	20.7	25	29.4	18.2
3	250	4.9	1,225.0	12.4	25	49.0	30.4

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6.0 MODEL OUTPUT

6.1 RESULTS

Full recovery is defined as the point in time when no drawdown greater than or equal to 1.6 ft (≈0.5 m) exists. The approximate length of time in years to reach full recovery after the end of pumping is presented in Table 6.1. Contour maps of drawdown were prepared for each model scenario at the end of the pumping stress period and are presented in Maps 6.1, 6.2, and 6.3.

6.2 SENSITIVITY ANALYSIS

Hydraulic conductivity was decreased by one order of magnitude to a range from 0.16 to 0.98 ft/day (≈0.05 to 0.30 m/day) for the entire aquifer in order to test the sensitivity of the model to changes in hydraulic conductivity. Smaller hydraulic conductivity values create a lower transmissivity and lead to a larger drawdown from pumping wells. The sensitivity analysis model was run using the most aggressive pumping scenario (Scenario 3).

The drawdown cone resulting from the sensitivity analysis is shown in Map 6.4. The sensitivity analysis drawdown results at the Project boundary were very similar to modeled results in Scenario 3 (see Map 6.3). The drawdown closer to the pumping wells was larger in the sensitivity analysis than in Scenario 3. The results of this analysis indicate that the model is not very sensitive to variations in hydraulic conductivity, particularly in the area at the Project boundary. Sensitivity analyses for specific yield and recharge were not completed because the model values are conservative.

Table 6.1 Modeled Recovery Time, Jonah Infill Drilling Project, Sublette County, Wyoming, 2004.

Scenario	Years to Full Recovery After Pumping Ends	Years to Full Recovery from Start of Drilling Program
1	0.5	42
2	4.0	25
3	6.0	18

Map 6.1 Scenario 1 - Projected Drawdown after 41.3 Years of Pumping (Contour Interval 0.5 m), Jonah Infill Drilling Project, Sublette County, Wyoming, 2004.

07207

Map 6.2 Scenario 2 - Projected Drawdown after 20.7 Years of Pumping (Contour Interval 0.5 m), Jonah Infill Drilling Project, Sublette County, Wyoming, 2004.

Map 6.3 Scenario 3 - Projected Drawdown after 12.4 Years of Pumping (Contour Interval 0.5 m), Jonah Infill Drilling Project, Sublette County, Wyoming, 2004.

07209

Map 6.4 Sensitivity Analysis Drawdown using Lowered Hydraulic Conductivity (Contour Interval 0.5 m), Jonah Infill Drilling Project, Sublette County, Wyoming, 2004.

7.0 MODELING RESULTS AND IMPACT ANALYSIS

Based on the results of the modeling, a 0.5 m (≈1.6 ft) drawdown cone caused by the proposed freshwater pumping will extend only slightly beyond the Project area, even for the most aggressive development, (Scenario 3, 250 gas wells per year). Water levels in water wells within the modeled drawdown cone area may be lowered due to the proposed pumping, particularly in those wells located near the Project water supply wells. However, the groundwater level in the wells should recover rapidly after Project pumping ceases. The model results show that the recovery of the groundwater table will be rapid, ranging from 0.5 to 6 years (see Table 6.1), depending on the pumping scenario. Since seasonal fluctuations in groundwater levels are typically greater than 0.5 m (≈1.6 ft), it would be difficult to distinguish between seasonal effects and pumping effects. As a result, no measurable impacts to surface or groundwater resources outside the modeled drawdown cone are expected.

The 25 modeled pumping wells should be able to sustain the proposed pumping rates for the 250 gas wells per year development scenario. However, the possibility exists that some wells may not be completed in the Green River/Wasatch aquifer, but only in a perched water-bearing zone and, therefore, may not produce as expected. Groundwater quality will not likely be impacted as a result of freshwater pumping.

It should be noted, that the Jonah Infill Model is a large-scale model with limited data available for calibration. Possible variations in well productions due to small-scale variations in the vicinity of one or several water wells cannot be predicted. Well depths for all existing wells used in the model are not available. Local variations in hydraulic conductivity or specific yield may also influence and alter the modeled outcome, although the sensitivity analysis indicates that minor changes in hydraulic conductivity values will not have much effect.

8.0 RECOMMENDATIONS

Monitoring water levels in selected wells within and outside the Project area prior to and during Project operations is recommended to confirm the modeled results. The model could also be periodically recalibrated using the new monitoring data to enhance the model's predictive accuracy.

9.0 REFERENCES

Chafin, T. Daniel, and B.A., Kimball. 1992. Ground-Water Geochemistry of the near-surface Wasatch Formation, Northern Green River Basin, Sublette County, Wyoming. U.S. Geological Suvey Water-Resources Investigations Report 91-4069.

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8.0 RECOMMENDATIONS

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ATTACHMENT B. Water Supply Wells in and around the Project Area

Table B-1. Water Supply Wells in and Around the NPL Project Area

Map Reference #	Well name (SEO Facility)	SEO Permit No.	Township	Range	Section	Qtr Section	Qtr-Qtr	Trihydro Reference Name	USGS Reference Name/Site Number	Latitude	Longitude	Well Depth (ft bgs)	Static Water Level (ft)	Permitted Use	Primary Aquifer	Notes
Existing Water Supply Wells within the NPL Project Area																
1	Tea Kettle Butte Well	96392W	27	108	2	SE	NWSE	TKB	--	42.34194	109.652675	1573*	840	Stock	Wasatch	SEO indicates the bottom of the water producing zone is 860 feet.
2	Davis Luman Road Water	41168W	27	108	21	SW	NWSW	--	421800109420701	42.299861	109.701889	700*	70*	Stock	Wasatch	
3	Davis Old Road Unit #1 Water	54621W	27	108	27	SE	NWSE	STA	421706109402501	42.285028	109.673528	730*	Flowing	Misc.	Wasatch	Flowing artesian well. Former drilling water supply, no longer used.
58	Midland Well 2011-2	195392W	27	108	36	NE	SWNE	--	--	42.272683	109.63505	400*	Flowing	Stock	Wasatch	Artesian well.
4	12 Mile Road Well #4519	51217W	27	109	7	NW	SENW	--	422016109511001	42.337833	109.852889	483	215*	Stock	Wasatch	
59	Davis Sugar Loaf Unit #1 Water	41012W	27	109	7	NW	NENW	--	--	42.33795	109.85351	200*	80*	Misc.	Wasatch	
5	Radio Tower 1-8 WW	180214W	28	107	8	NE	NENE	--	422513109353401	42.420167	109.592694	587*	110	Misc.	Wasatch	
6	--	--	28	107	8	NW	NWNW	Err1/NP2	422408109350001	42.405056	109.590694	900	Flowing	Stock	Wasatch	Flowing artesian well.
7	14cbd02	--	28	108	14	SW	NWSW	NP4	422357109394801	42.399083	109.663194	128.5	--	Stock	Laney	
8	Jonah Well #1	147913W	28	108	16	SE	SESE	--	422351109411902	42.397472	109.688611	363	110*	Stock	Wasatch	
9	--	--	28	108	16	SE	SESE	--	422351109411901	42.397417	109.688611	299.13	--	Stock	Wasatch	Old well; abandoned.
10	Sagebrush Well	180487W	28	108	17	SE	SESE	--	--	--	--	--	--	Stock	Wasatch	
11	Boundary #4645	51229W	28	108	25	NW	NENW	--	422245109383001	42.379222	109.641722	1042*	Flowing	Stock	Wasatch	Flowing artesian well.
12	Hacienda Federal No. 5-29W	135634W	28	108	29	NW	SWNW	--	--	--	--	900*-	--	Misc.	Wasatch	Former drilling water supply, no longer used.
13	Wild Horse Reservoir Well	180486W	28	108	30	SE	NESE	--	--	--	--	--	--	Stock	Wasatch	
14	Erramouspe Well	10497P	28	108	33	NW	NWNW	--	28-108-33bb01	42.366667	109.702111	160	30*	Stock	Wasatch	
15	Bloom Well	9347P	28	109	16	NW	SWNW	P9347	422431109490001	42.408583	109.816528	75*	30*	Stock	Laney	Trihydro shows well as Alluvial
16	Stanley Energy #1 Water Well	107042W	28	109	22	NE	NWNE	--	--	--	--	673*	75*	Misc.	Wasatch	Former drilling water supply, no longer used.
17	Dry Lakes Well #353	9373P	28	109	23	NW	SWNW	--	28-109-23bcc01	42.391222	109.781556	218	100*	Stock	Wasatch	
18	Yellow Point No. 2-24W (Luman Compressor Station)	136075W	28	109	24	NE	SWNE	--	--	--	--	753*	250*	Misc.	Wasatch	Former drilling water supply, no longer used.
19	Horse Trap Well 4462	36203W	28	109	25	SW	NESW	--	422221109452701	42.3725	109.757444	339.61	119*	Stock	Wasatch	
20	Buckhorn #308	9361P	28	109	31	SE	SESE	BHW2	28-109-31dda01	42.356722	109.842694	268	90	Stock	Laney	
21	--	--	28	109	36	SE	SWSE	--	28-109-36dc01	42.3565	109.753556	68	--	Stock	Laney	

Table B-1. Water Supply Wells in and Around the NPL Project Area

Map Reference #	Well name (SEO Facility)	SEO Permit No.	Township	Range	Section	Qtr Section	Qtr-Qtr	Trihydro Reference Name	USGS Reference Name/Site Number	Latitude	Longitude	Well Depth (ft bgs)	Static Water Level (ft)	Permitted Use	Primary Aquifer	Notes
22	Buckhorn Well #313	9360P	28	110	1	SE	NWSE	--	28-110-01dc01	42.429806	109.867722	200*	-1	Stock	Wasatch	
23	Sugar Loaf #389	9619P	28	110	9	NE	SENE	Rees 2	28-110-09ad01	42.422861	109.918528	220	220*	Stock	Wasatch	
24	South Desert #1	8531W	28	110	18	NW	SWNW	BF	28-110-18bc01	42.40625	109.964083	472*	435*	Stock	Wasatch	
25	Antelope #4066	8527W	28	110	22	NW	SENW	PLW	28-110-22bd01	42.388667	109.9075	471*	370*	Stock	Wasatch	
26	CCC Road Well #4083	8522W	28	110	29	NW	NWNW	CCC	--	42.369585	109.968444	500*	300*	Stock	Wasatch	
27	Sugar Loaf Well #390	9620P	28	110	33	NE	SWNE	Rees 1	28-110-33ac01	42.364722	109.922889	420	320*	Stock	Wasatch	
28	Desert	71947W	29	108	18	NW	SWNW	--	--	--	--	225*	105*	Stock	Wasatch	
29	North Alkali Well #2	8434P	29	109	6	NW	SWNW	--	29-109-06bb01	42.520889	109.887528	174	117*	Stock	Wasatch	
30	Granite Wash Well 4461	36202W	29	109	7	SE	NWSE	BRD2	423016109520801	42.504583	109.868833	220*	86*	Stock	Wasatch	
31	Alkali Sun Well #1	176877	29	109	10	NW	NENW	--	--	--	--	23*	16*	Stock	Wasatch	
32	Burma Road Well #2	78016W	29	109	20	SW	SESW	P78016W	422811109514701	42.469444	109.863111	375	285	Stock	Wasatch	
33	Burma Road #1 (Deepened)	8431P	29	109	22	NW	SWNW	--	29-109-22cb01	42.471278	109.826583	480*	295*	Stock	Wasatch	
34	Burma Road Well #3	99087W	29	109	23	SW	SESW	BRD1	422747109481601	42.463028	109.804361	310*	80*	Stock	Wasatch	
35	Alkali Spring #4081	27163W	29	109	30	NW	NENW	--	--	--	--	Spring	0*	Stock	Alluvial	Spring. Source is likely alluvium in stream bed.
36	Alkali Fence Well #1	85836W	29	109	33	SE	SESE	WW1	422618109500401	42.438306	109.834472	254	146	Stock	Wasatch	Windmill.
37	Palomino #5-22W	148371W	29	110	22	NW	SWNW	--	422838109564501	42.477194	109.945833	749.6	220*	Misc.	Wasatch	Former drilling water supply, no longer used.
JIDPA Water Supply Wells within the NPL Project Area (Drilling and Facility Support)																
38	Holmes Federal #5-1W	196053W	27	109	1	NW	SWNW	HOL 5-1W	422054109453601	42.348417	109.760139	630*	200*	Misc.	Wasatch	Artesian Well. Water supply for Jonah drilling.
39	Jonah Federal 4-8WW	181396W	28	108	8	SE	SWSE	--	--	--	--	--	--	Misc.	Wasatch	Water supply for Jonah drilling.
40	Encana Workforce Facility	187090W	28	108	8	SE	SESE	WFF	422446109423501	42.412778	109.709806	1100	358*	Misc.	Wasatch	Jonah Workforce Facility water supply; also used for drilling and reclamation.
41	Plains WSW 32	196049W	28	109	27	SW	SESW	--	--	--	--	510*	150*	Misc.	Wasatch	Water supply for Jonah drilling.
42	SOL 9-36W	195830W	29	109	36	SE	NESE	--	--	--	--	920*	175*	Misc.	Wasatch	Water supply for Jonah drilling.
Wells outside the NPL Project Area used for the Operator's Sampling and Analysis Program (Trihydro 2011, 2013, 2014, 2015)																
43	Emigrant Trail Well 4518	51216W	26	108	10	NW	--	ETW	--	--	--	490	9	Stock	Wasatch	
44	Desert Well #1	10501P	26	109	6	SE	--	DW1	--	--	--	210	124	Stock	Wasatch	
45	North Sublette Meadow Spring	--	27	107	8	SW	SWSW	NSMS/NP3	--	42.326467	109.604021	Spring	--	Stock	Alluvial	Spring.
46	--	--	27	107	--	--	--	PA1	--	--	--	800	Flowing	Stock	Wasatch	Flowing artesian well.

Table B-1. Water Supply Wells in and Around the NPL Project Area

Map Reference #	Well name (SEO Facility)	SEO Permit No.	Township	Range	Section	Qtr Section	Qtr-Qtr	Trihydro Reference Name	USGS Reference Name/Site Number	Latitude	Longitude	Well Depth (ft bgs)	Static Water Level (ft)	Permitted Use	Primary Aquifer	Notes
47	Sagebrush 14-20WW	163911W	27	107	20	SW	SESW	SBW	--	42.297033	109.60159	390*	Flowing	Misc.	Wasatch	Flowing artesian well.
48	Desert Well #2	10502P	27	109	18	SW	SWSW	DW2	--	42.31329	109.856349	205*	28*	Stock	Wasatch	
49	Fear Well #1	6874W	27	110	6	SW	SESW	Fear1	--	42.342749	109.967724	725*	480*	Stock	Wasatch	
50	Oasis Well	10507P	27	110	21	NE	--	Oasis	--	--	--	493	173	Stock	Wasatch	
51	Green River #2	6877W	27	111	24	SW	--	GRW2	--	--	--	732	485	Stock	Wasatch	
52	Reservoir #4638	51222W	28	107	30	SE	--	FEWE	--	--	--	220	31	Stock	Wasatch	
60	JIO Boundary Well	191117W	29	107	34	SE	NWSE	--	--	42.435556	-109.584167	360*	200*	Stock	Wasatch	
53	--	--	29	108	--	--	--	GFW	--	--	--	354	112	Stock	Wasatch	
54	North Alkali Well #1	8432P	29	110	11	SW	--	NA1	--	--	--	91	42	Stock	Alluvial	
55	--	--	29	111	--	--	--	McGinnis 1	--	--	--	400	--	Domestic	Wasatch	Private well.
56	McGinnis #2	140G	29	111	33	--	--	McGinnis 2	--	--	--	155	--	Domestic	Alluvial	Private well.
57	Ross Ridge Well #4310	23979.0W	30	109	19	SW	--	BRD3	--	--	--	555	300	Stock	Wasatch	

Sources: AECOM 2014; AMEC 2014; Trihydro 2011, 2013, 2014a, 2014b; Wyoming SEO 2014.

* = Data obtained from the Wyoming State Engineer's Office (SEO).
"—" = not available

ft feet
ft bgs feet below ground surface

Note: Wyoming SEO records are updated regularly, and permitting information included at the time of this report is based on current information.

ATTACHMENT C. Water Quality Results from Water Wells in and around the NPL Project Area

Table C-1. Water Quality Results from Water Wells in and around the NPL Project Area

Field	Well Name (SEO Facility)	SEO Permit No.	Trihydro Reference Name [Well/Map Reference No.][c]	Data Year	pH (Standard Units)	Total Dissolved Solids (mg/L)	Iron - Total (mg/L)	Iron - Dissolved (mg/L)	Fluoride (mg/L)	Chloride (mg/L)	Methane (mg/L)	DRO (mg/L)	GRO (mg/L)	Benzene (µg/L)	Toluene (µg/L)	Ethylbenzene (µg/L)	Xylenes (µg/L)
NPL	Alkali Fence Well #1	85836W	WW1 [36]	2011	8.9[e,f,g,i]	2070[e,f,g,h]	0.13	--	--	61.8	ND(0.026)	ND(0.0971)	ND(0.1)	--	ND(1)	--	--
				2013	8.78[e,f,g,i]	2300[e,f,g,h]	0.043[a]	--	3.3[e]	65	0.0047[a]	ND(0.24)	ND(0.025)	ND(1)	ND(1)	ND(1)	ND(2)
	Antelope #4066	8527W	PLW [25]	2012	8.18	1600[e,f,g]	--	0.1[a]	1.4	26	0.0015	ND(0.25)	ND(0.025)	ND(1)	ND(1)	ND(1)	ND(2)
				2013	8.48	1700[a,e,f,g]	1.8[e,g]	--	1.1	24	ND(0.005)	0.044[a]	ND(0.025)	ND(1)	ND(1)	ND(1)	ND(2)
				2014	7.08	1640[e,f,g]	--	0.125[a]	1.12[a]	25.8	ND(0.005)	ND(0.0962)	ND(0.1)	ND(0.5)	ND(0.5)	ND(0.5)	ND(1.5)
	CCC Road Well #4083	8522W	CCC [26]	2012	7.99	2300[e,f,g,h]	--	0.052[a]	0.7[a]	16	0.0021	ND(0.24)	ND(0.025)	ND(1)	ND(1)	ND(1)	ND(2)
				2013	8.25	2300[e,f,g,h]	3.5[e,g]	--	0.69[a]	14	0.0041[a]	0.05[a]	ND(0.025)	ND(1)	ND(1)	ND(1)	ND(2)
				2014	7.96	2240[e,f,g,h]	--	1.15	0.667[a]	16	0.00413[a]	ND(0.098)	ND(0.1)	ND(0.5)	ND(0.5)	ND(0.5)	ND(1.5)
	Encana Workforce Facility	187090W	WFF [40]	2011	9.37[e,f,g,h,i]	542[e,f,g]	ND(0.05)	--	--	35.2	4.93[a]	ND(0.098)	ND(0.1)	--	ND(1)	--	--
				2013	9.05[e,f,g,h,i]	540[e,f,g]	ND(0.1)	--	9.4[d,e,f,g]	39	5[j]	ND(0.24)	ND(0.025)	ND(1)	ND(1)	ND(1)	ND(2)
	Granite Wash Well 4461	36202W	BRD2 [30]	2011	8.8[e,f,g,i]	678[e,f,g]	0.399[e,g]	--	--	5.52	ND(0.026)	ND(0.0962)	ND(0.1)	--	ND(1)	--	--
				2013	8.03	670[e,f,g]	0.11	--	1.2	6.8	ND(0.005)	0.033[a]	ND(0.025)	ND(1)	ND(1)	ND(1)	ND(2)
				2014	8.42	696[e,f,g]	--	0.022[a]	1.38[a]	7.43	ND(0.005)	0.0435[a]	ND(0.1)	ND(0.5)	ND(0.5)	ND(0.5)	ND(1.5)
	Holmes Federal #5-1W	196053W	HOL 5-1W [38]	2012	9.02[e,f,g,h,i]	800[e,f,g]	--	0.07[a]	8.9[d,e,f,g]	150[h]	0.11	ND(0.24)	ND(0.025)	ND(1)	ND(1)	ND(1)	ND(2)
				2013	8.55[e,f,g,i]	620[e,f,g]	0.081[a]	--	9.5[d,e,f,g]	65	0.59	ND(0.25)	ND(0.025)	ND(1)	ND(1)	ND(1)	ND(2)
				2014	8.86[e,f,g,i]	597[a,e,f,g]	--	ND(0.25)	9.79[a,d,e,f,g]	53.2[a]	ND(0.005)	0.0808[a]	ND(0.1)	ND(0.5)	ND(0.5)	ND(0.5)	ND(1.5)
	South Desert #1	8531W	BF [24]	2013	8.68[e,f,g,i]	1600[e,f,g]	0.26	--	0.76	14	ND(0.005)	0.084[a]	0.011[a]	ND(1)	ND(1)	ND(1)	ND(2)
				2014	7.56	1600[e,f,g]	--	0.107	0.849[a]	16	0.0165	ND(0.098)	ND(0.1)	ND(0.5)	ND(0.5)	ND(0.5)	ND(1.5)
	Tea Kettle Butte Well	96392W	TKB [1]	2011	9.2[e,f,g,h,i]	466	0.222	--	--	60.7	1.58	ND(0.0952)	ND(0.1)	--	ND(1)	--	--
				2013	9.22[e,f,g,h,i]	470	ND(0.1)	--	9.8[d,e,f,g]	55	1.8	ND(0.24)	ND(0.025)	ND(1)	ND(1)	ND(1)	ND(2)
				2014	8.79[e,f,g,i]	479	--	0.0217[a]	9.9[a,d,e,f,g]	60.4	1.66	ND(0.1)	ND(0.1)	ND(0.5)	ND(0.5)	ND(0.5)	ND(1.5)
	Buckhorn #308	9361P	BHW2 [20]	2011	10.05[e,f,g,h,i]	2490[e,f,g,h]	17.9[e,g,h]	--	--	145[h]	0.054	0.232	ND(0.1)	--	ND(1)	--	--
				2012	9.55[e,f,g,h,i]	2400[e,f,g,h]	--	0.082[a]	5.3[d,e,f,g]	61	0.03	ND(0.24)	ND(0.025)	ND(1)	ND(1)	ND(1)	ND(2)
	Burma Road Well #3	99087W	BRD1 [34]	2011	8.51[e,f,g,i]	2930[e,f,g,h]	3.65[e,g]	--	--	86.8	ND(0.026)	ND(0.0952)	ND(0.1)	--	ND(1)	--	--
				2012	--	2800[e,f,g,h]	--	0.043[a]	2.3[e]	82	0.003	ND(0.24)	ND(0.025)	ND(1)	ND(1)	ND(1)	ND(2)
				2014	8.20	2840[e,f,g,h]	--	ND(0.25)	2.03[a,e]	83.8	0.00385[a]	ND(0.0962)	ND(0.1)	ND(0.5)	ND(0.5)	ND(0.5)	ND(1.5)
	--	--	Err1/NP2 [6]	2011	9.45[e,f,g,h,i]	516[e,f,g]	ND(0.05)	--	--	93.8	11.1[j]	ND(0.0962)	ND(0.1)	--	ND(1)	--	--
				2012	9.82[e,f,g,h,i]	510[e,f,g]	--	ND(0.1)	11[d,e,f,g]	97	2.4[a]	ND(0.24)	ND(0.025)	ND(1)	ND(1)	ND(1)	ND(2)
				2014	9.32[e,f,g,h,i]	515[e,f,g]	--	ND(0.25)	11[a,d,e,f,g]	95.9	7.85[j]	0.0373[a]	ND(0.1)	ND(0.5)	ND(0.5)	ND(0.5)	ND(1.5)
	Bloom Well	9347P	P9347 [15]	2011	8.05	4010[e,f,g,h]	4.38[e,g]	--	--	31.1	ND(0.026)	ND(0.0952)	ND(0.1)	--	ND(1)	--	--
				2012	7.61	3900[e,f,g,h]	--	0.04[a]	1.4	29	0.0017	ND(0.24)	0.013[a]	ND(1)	ND(1)	ND(1)	ND(2)
				2014	8.06	3740[e,f,g,h]	--	ND(0.25)	1.39[a]	27.1	0.00965	0.0549[a]	ND(0.1)	ND(0.5)	ND(0.5)	ND(0.5)	ND(1.5)

Table C-1. Water Quality Results from Water Wells in and around the NPL Project Area

Field	Well Name (SEO Facility)	SEO Permit No.	Trihydro Reference Name [Well/Map Reference No.][c]	Data Year	pH (Standard Units)	Total Dissolved Solids (mg/L)	Iron - Total (mg/L)	Iron - Dissolved (mg/L)	Fluoride (mg/L)	Chloride (mg/L)	Methane (mg/L)	DRO (mg/L)	GRO (mg/L)	Benzene (µg/L)	Toluene (µg/L)	Ethylbenzene (µg/L)	Xylenes (µg/L)
	Davis Old Road Unit #1 Water	54621W	STA [3]	2011	8.56[e,f,g,i]	1040[e,f,g]	0.134	--	--	362[e,f,g,h]	0.17	ND(0.0962)	ND(0.1)	--	ND(1)	--	--
				2012	8.81[e,f,g,i]	990[e,f,g]	--	ND(0.1)	14[d,e,f,g]	390[e,f,g,h]	0.2	ND(0.24)	ND(0.025)	ND(1)	ND(1)	ND(1)	ND(2)
				2014	8.52[e,f,g,i]	857[e,f,g]	--	0.111	12.6[a,d,e,f,g]	294[e,f,g,h]	1.62	0.063[a]	ND(0.1)	ND(0.5)	ND(0.5)	ND(0.5)	ND(1.5)
	Sugar Loaf Well #390	9620P	Rees1 [27]	2011	7.97	2610[e,f,g,h]	0.289	--	--	21.2	ND(0.026)	ND(0.0943)	ND(0.1)	--	ND(1)	--	--
	Sugar Loaf #389	9619P	Rees2 [23]	2011	8.99[e,f,g,i]	1580[e,f,g]	0.72[e,g]	--	--	19.8	ND(0.026)	ND(0.111)	ND(0.1)	--	ND(1)	--	--
	14cbd02	--	NP4 [7]	2014	9.05[e,f,g,h,i]	809[e,f,g]	--	ND(0.25)	16.3[a,d,e,f,g]	135[h]	1.2	0.0918[a]	ND(0.1)	ND(0.5)	ND(0.5)	ND(0.5)	ND(1.5)
	Boundary #4645	51229W	-- [11]	2014	9.75[e,f,g,h,i]	373	--	0.0105[a]	6.72[a,d,e,f,g]	46.1	0.259	ND(0.0962)	ND(0.1)	ND(0.5)	ND(0.5)	ND(0.5)	ND(1.5)
	Midland Well 2011-2	195392W	-- [58]	2014	8.72[e,f,g,i]	1080[e,f,g]	--	ND(0.025)	17.8[a,d,e,f,g]	373[e,f,g,h]	8.5[j]	0.706	ND(0.1)	ND(0.5)	ND(0.5)	ND(0.5)	ND(1.5)
	Radio Tower 1-8 WW	180214W	-- [5]	2014	9.39[e,f,g,h,i]	641[e,f,g]	--	ND(0.25)	3.28[a,e]	8.1	0.00374[a]	0.0674[a]	ND(0.1)	ND(0.5)	ND(0.5)	ND(0.5)	ND(1.5)
	Davis Luman Road Water	41168W	-- [2]	2014	9.20[e,f,g,h,i]	638[e,f,g]	--	ND(0.25)	9.69[a,d,e,f,g]	111[a,h]	2.98	0.0492[a]	ND(0.1)	ND(0.5)	ND(0.5)	ND(0.5)	ND(1.5)
	Buckhorn Well #313	9360P	-- [22]	2014	7.04	4330[e,f,g,h]	--	0.0311	1.36[a]	37.1	0.00333[a]	0.0371[a]	ND(0.1)	ND(0.5)	ND(0.5)	ND(0.5)	ND(1.5)
Jonah	Cabrito 13-19W	193708W	--	2013	10.0[b,e,f,g,h,i]	308	ND(0.03)	ND(0.03)	--	44	--	ND(0.30)	ND(0.020)	ND(1.0)	ND(1.0)	ND(1.0)	ND(1.0)
	Corona 2-14	183409W	-- [61]	2013	10.5[e,f,g,h,i]	453	--	ND(0.050)	--	46.1	--	ND(0.50)	ND(500)	11.8[d,f]	2.6	ND(1.0)	ND(3.0)
	Corona 7-19	200462W	--	2013	10.3[e,f,g,h,i]	320	--	3.8	--	36.9	--	ND(0.50)	ND(500)	ND(1.0)	27.1	ND(1.0)	ND(3.0)
	Corona 7-19 Dup	200462W	--	2013	10.3[e,f,g,h,i]	315	--	0.137	--	36.9	--	ND(0.50)	ND(500)	ND(1.0)	26.7	ND(1.0)	ND(3.0)
	Jonah Fed (SHB) 32-34	195782W	--	2013	9.6[b,e,f,g,h,i]	656[e,f,g]	0.21	ND(0.03)	--	19	--	ND(0.30)	ND(0.020)	ND(1.0)	ND(1.0)	ND(1.0)	ND(1.0)
	Jonah Fed 2-5W	195992W	-- [63]	2013	8.6[b,e,f,g,i]	1690[e,f,g]	0.39[e,g]	0.13	--	32	--	ND(0.30)	ND(0.020)	ND(1.0)	ND(1.0)	ND(1.0)	ND(1.0)
	Jonah Fed 2-7W	193709W	--	2013	9.2[b,e,f,g,h,i]	1010[e,f,g]	0.8[e,g]	ND(0.03)	--	43	--	ND(0.30)	ND(0.020)	ND(1.0)	ND(1.0)	ND(1.0)	ND(1.0)
	Jonah Field Office	--	--	2013	9.29[e,f,g,h,i]	286	--	ND(0.050)	--	41.8	--	ND(0.50)	ND(500)	ND(1.0)	ND(1.0)	ND(1.0)	ND(1.0)
	Stud Horse Butte 10-28W	171643W	--	2013	9.2[b,e,f,g,h,i]	591[e,f,g]	0.06	ND(0.03)	--	121[h]	--	ND(0.30)	ND(0.020)	ND(1.0)	ND(1.0)	ND(1.0)	ND(1.0)
	Stud Horse Butte 10-32W	195826W	--	2013	9.0[b,e,f,g,h,i]	1590[e,f,g]	0.79[e,g]	0.06	--	16	--	ND(0.30)	ND(0.020)	ND(1.0)	0.44[a]	ND(1.0)	0.85[a]
	Stud Horse Butte 10-34W	195779W	--	2013	9.6[b,e,f,g,h,i]	610[e,f,g]	0.07	ND(0.03)	--	25	--	ND(0.30)	ND(0.020)	ND(1.0)	ND(1.0)	ND(1.0)	ND(1.0)
	Stud Horse Butte 10-34W (Duplicate)	195779W	--	2013	9.6[b,e,f,g,h,i]	633[e,f,g]	0.12	ND(0.03)	--	25	--	ND(0.30)	ND(0.020)	ND(1.0)	ND(1.0)	ND(1.0)	ND(1.0)
	Stud Horse Butte 11-20W	195829W	-- [64]	2013	9.4[b,e,f,g,h,i]	565[e,f,g]	0.05	ND(0.03)	--	56	--	ND(0.30)	0.326	4.8	38	3.2	35
	Stud Horse Butte 11-20W (Duplicate)	195829W	--	2013	--	--	--	--	--	--	--	ND(0.30)	ND(0.020)	2.1	7.5	0.30[a]	3.1
	Stud Horse Butte 11-26W	180553W	--	2013	9.5[b,e,f,g,h,i]	466	0.04	ND(0.03)	--	73	--	ND(0.30)	ND(0.020)	ND(1.0)	ND(1.0)	ND(1.0)	ND(1.0)
	Stud Horse Butte 11-29W	195997W	--	2013	8.9[b,e,f,g,i]	1870[e,f,g]	0.44[e,g]	0.04	--	20	--	ND(0.30)	ND(0.020)	ND(1.0)	ND(1.0)	ND(1.0)	ND(1.0)
	Stud Horse Butte 122-10	192164W	--	2013	9.8[b,e,f,g,h,i]	514[e,f,g]	0.85[e,g]	0.11	--	13	--	ND(0.30)	ND(0.020)	ND(1.0)	ND(1.0)	ND(1.0)	ND(1.0)
	Stud Horse Butte 13-32W	193916W	--	2013	8.5[b]	2460[e,f,g,h]	0.52[e,g]	0.03	--	21	--	ND(0.30)	ND(0.020)	ND(1.0)	ND(1.0)	ND(1.0)	ND(1.0)
	Stud Horse Butte 15-16	198795W	--	2013	9.91[e,f,g,h,i]	439	--	ND(0.050)	--	76.6	--	ND(0.50)	ND(500)	ND(1.0)	ND(1.0)	ND(1.0)	ND(3.0)
	Stud Horse Butte 16-20	198796W	-- [62]	2013	9.98[e,f,g,h,i]	525[e,f,g]	--	0.162	--	10.3	--	ND(0.50)	ND(500)	1.0	4.6	ND(1.0)	5.7
	Stud Horse Butte 23-16	199923W	--	2013	10.1[e,f,g,h,i]	299	--	ND(0.050)	--	38.1	--	ND(0.50)	ND5(500)	ND(1.0)	ND(1.0)	ND(1.0)	ND(3.0)
	Stud Horse Butte 4-36W	196598W	--	2013	9.7[b,e,f,g,h,i]	360	0.12	0.03	--	68	--	ND(0.30)	ND(0.020)	ND(1.0)	ND(1.0)	ND(1.0)	ND(1.0)
	Stud Horse Butte 7-33W	195827W	-- [65]	2013	9.4[b,e,f,g,h,i]	536[e,f,g]	0.04	ND(0.03)	--	91	--	ND(0.30)	ND(0.020)	ND(1.0)	ND(1.0)	ND(1.0)	ND(1.0)
	Stud Horse Butte 8-34W	195828W	--	2013	9.8[b,e,f,g,h,i]	493	0.07	ND(0.03)	--	9	--	ND(0.30)	ND(0.020)	ND(1.0)	ND(1.0)	ND(1.0)	ND(1.0)

Table C-1. Water Quality Results from Water Wells in and around the NPL Project Area

Field	Well Name (SEO Facility)	SEO Permit No.	Trihydro Reference Name [Well/Map Reference No.][c]	Data Year	pH (Standard Units)	Total Dissolved Solids (mg/L)	Iron - Total (mg/L)	Iron - Dissolved (mg/L)	Fluoride (mg/L)	Chloride (mg/L)	Methane (mg/L)	DRO (mg/L)	GRO (mg/L)	Benzene (µg/L)	Toluene (µg/L)	Ethylbenzene (µg/L)	Xylenes (µg/L)
	Stud Horse Butte 9-32W	168426W	--	2013	8.4[b]	1910[e,f,g]	25.7[e,f,g,h]	0.31	--	32	--	ND(0.30)	ND(0.020)	ND(1.0)	ND(1.0)	ND(1.0)	ND(1.0)
	Stud Horse Butte 9-32W (Duplicate)	168426W	--	2013	8.4[b]	1880[e,f,g]	28.9[e,f,g,h]	ND(0.03)	--	32	--	ND(0.30)	ND(0.020)	ND(1.0)	ND(1.0)	ND(1.0)	ND(1.0)
	Yellow Point 10-11W	196048W	--	2013	8.6[b,e,f,g,i]	4370[e,f,g,h]	13.2[e,g,h]	0.06	--	42	--	ND(0.30)	ND(0.020)	ND(1.0)	ND(1.0)	ND(1.0)	ND(1.0)
	Yellow Point 1-13W	184873W	--	2013	9.3[b,e,f,g,h,i]	1100[e,f,g]	0.21	0.05	--	34	--	ND(0.30)	ND(0.020)	ND(1.0)	ND(1.0)	ND(1.0)	ND(1.0)
Other	Desert Well #2	10502P	DW2 [48]	2011	9.25[e,f,g,h,i]	916[e,f,g]	0.614[e,g]	--	--	70.1	ND(0.026)	ND(0.0952)	ND(0.1)	--	ND(1)	--	--
				2013	8.44	1000[e,f,g]	0.21	--	6.3[d,e,f,g]	62	0.00099[a]	ND(0.24)	ND(0.025)	ND(1)	ND(1)	ND(1)	ND(2)
				2014	8.57[e,f,g,i]	1050[e,f,g]	--	0.457	7.1[a,d,e,f,g]	67.4	ND(0.005)	0.0612[a]	ND(0.1)	ND(0.5)	ND(0.5)	ND(0.5)	ND(1.5)
	North Sublette Meadow Spring	--	NSMS/NP3 [45]	2011	8.84[e,f,g,i]	1480[e,f,g]	0.407[e,g]	--	--	6.01	ND(0.026)	0.104	ND(0.1)	--	ND(1)	--	--
				2013	8.91[e,f,g,i]	1400[e,f,g]	0.2	--	2.9[e]	22	0.014	0.042[a]	ND(0.025)	ND(1)	ND(1)	ND(1)	ND(2)
				2014	--	1390[e,f,g]	--	ND(0.25)	3.1[a,e]	24.3	0.00536	0.0481[a]	ND(0.1)	ND(0.5)	ND(0.5)	ND(0.5)	ND(1.5)
	Sagebrush 14-20WW	163911W	SBW [47]	2011	9.05[e,f,g,h,i]	600[e,f,g]	0.0588	--	--	37.3	0.0668	ND(0.0962)	ND(0.1)	--	ND(1)	--	--
				2013	9.37[e,f,g,h,i]	580[e,f,g]	0.03[a]	--	8.8[d,e,f,g]	35	0.049	ND(0.26)	ND(0.025)	ND(1)	ND(1)	ND(1)	ND(2)
				2014	8.55[e,f,g,i]	588[e,f,g]	--	0.0168[a]	8.74[a,d,e,f,g]	34.9	0.0307	ND(0.098)	ND(0.1)	ND(0.5)	ND(0.5)	ND(0.5)	ND(1.5)
	Fear Well #1	6874W	FEAR1 [49]	2011	8.1	1420[e,f,g]	1.14[e,g]	--	--	19	ND(0.026)	ND(0.0943)	ND(0.1)	--	ND(1)	--	--
				2013	8.55[e,f,g,i]	1500[e,f,g]	0.36[e,g]	--	0.8	17	0.00091[a]	0.038[a]	0.028	ND(1)	7.4	ND(1)	ND(2)
				2014	8.08	1540[e,f,g]	--	0.0296	0.836[a]	19.3	0.00905	0.0962	ND(0.1)	ND(0.5)	ND(0.5)	ND(0.5)	ND(1.5)
	North Alkali #1	8432P	NA1 [54]	2011	8.01	1130[e,f,g]	2.18[e,g]	--	--	15	ND(0.026)	ND(0.0943)	ND(0.1)	--	ND(1)	--	--
				2013	7.7	1200[a,e,f,g]	6[e,g,h]	--	1.3	16	ND(0.005)	ND(0.24)	0.017[a]	ND(1)	ND(1)	ND(1)	ND(2)
	Emigrant Trail Well 4518	51216W	ETW [43]	2011	9.24[e,f,g,h,i]	1210[e,f,g]	0.572[e,g]	--	--	245[h]	23.7[j]	1.26[a,f]	ND(0.1)	--	22.8	--	--
				2012	9.16[e,f,g,h,i]	1200[e,f,g]	--	0.024[a]	21[d,e,f,g]	290[e,f,g,h]	11[j]	0.23[a]	0.01[a]	ND(4)	ND(4)	ND(4)	ND(8)
	Oasis Well	10507P	Oasis [50]	2011	7.78	5820[e,f,g,h,i]	9.31[e,g,h]	--	--	104[h]	ND(0.026)	ND(0.0943)	ND(0.1)	--	ND(1)	--	--
				2012	8.59[e,f,g,i]	6300[e,f,g,h,i]	--	0.041[a]	1.3[a]	110[h]	0.0069[a]	ND(0.24)	0.024[a]	ND(1)	ND(1)	ND(1)	ND(2)
	--	--	PA1 [46]	2011	9.45[e,f,g,h,i]	562[e,f,g]	ND(0.05)	--	--	37.2[a]	2.47	ND(0.0952)	ND(0.1)	--	ND(1)	--	--
				2012	9.86[e,f,g,h,i]	560[e,f,g]	--	ND(0.1)	8.2[d,e,f,g]	39	0.81[a]	ND(0.24)	0.012[a]	ND(1)	ND(1)	ND(1)	ND(2)
	McGinnis #2	--	McGinnis 2 [56]	2011	9.45[e,f,g,h,i]	670[e,f,g]	ND(0.05)	--	--	15.2[a]	ND(0.026)	ND(0.0952)	ND(0.1)	--	ND(1)	--	--
	Ross Ridge Well #4310	--	BRD3 [57]	2011	7.34	2530[e,f,g,h]	0.971[e,g]	--	--	80.2	ND(0.026)	ND(0.0971)	ND(0.1)	--	ND(1)	--	--
	Desert Well #1	10501P	DW1 [44]	2011	8.25	3340[e,f,g,h]	0.11	--	--	69.9	ND(0.026)	ND(0.098)	ND(0.1)	--	ND(1)	--	--
	Reservoir #4638	51222W	FEWE [52]	2011	8.77[e,f,g,i]	453	0.138	--	--	5.68	ND(0.026)	ND(0.0962)	ND(0.1)	--	ND(1)	--	--
	--	--	GFW [53]	2011	8.89[e,f,g,i]	1300[e,f,g]	0.6[e,g]	--	--	18.1	ND(0.026)	ND(0.0952)	ND(0.1)	--	ND(1)	--	--
	Green River #2	6877W	GRW2 [51]	2011	9.08[e,f,g,h,i]	1380[e,f,g]	0.452[e,g]	--	--	33.9	ND(0.026)	ND(0.0943)	ND(0.1)	--	ND(1)	--	--
	--	--	McGinnis 1 [55]	2011	9.27[e,f,g,h,i]	664[e,f,g]	ND(0.05)	--	--	19.4[a]	ND(0.026)	ND(0.0943)	ND(0.1)	--	ND(1)	--	--
	JIO Boundary Well	191117W	-- [60]	2014	9.17[e,f,g,h,i]	570[e,f,g]	--	ND(0.25)	3.35[a,e]	11.4	0.0209	0.091	ND(0.1)	ND(0.5)	ND(0.5)	ND(0.5)	ND(1.5)

Table C-1. Water Quality Results from Water Wells in and around the NPL Project Area

Field	Well Name (SEO Facility)	SEO Permit No.	Trihydro Reference Name [Well/Map Reference No.][c]	Data Year	pH (Standard Units)	Total Dissolved Solids (mg/L)	Iron - Total (mg/L)	Iron - Dissolved (mg/L)	Fluoride (mg/L)	Chloride (mg/L)	Methane (mg/L)	DRO (mg/L)	GRO (mg/L)	Benzene (µg/L)	Toluene (µg/L)	Ethylbenzene (µg/L)	Xylenes (µg/L)

Sources: AECOM 2014; AMEC 2014; Trihydro 2011, 2012, 2014a, 2014b; Wyoming SEO 2014

[a]Estimated quantified (i.e., detected) value
[b]pH measured in the laboratory
[c]Map reference number refers to the numbered wells presented in Figure K-7 and Figure K-8. Some wells are not depicted on these maps and therefore will not have a reference number.

"—" = not available; no measurement taken
ND(0.0) = Non-detect(reporting limit)
mg/L milligrams per liter
µg/L micrograms per liter

Note: Wyoming SEO records are updated regularly, and permitting information included at the time of this report is based on current information.

Note: Water quality standards or limits are provided in Table C-2 below. Observations that exceed any recommended standards or limits are highlighted orange and noted with the following:

[d]Exceeds the EPA Primary Drinking Water Standard
[e]Exceeds the EPA Secondary Drinking Water Standard
[f]Exceeds the Wyoming Groundwater Cleanup Level
[g]Exceeds the WDEQ Class I – Domestic Use Suitability
[h]Exceeds the WDEQ Class II – Agriculture Use Suitability
[i]Exceeds the WDEQ Class III – Livestock Use Suitability
[j]Exceeds another established standard or recommended safety level

Table C-2. Water Quality Regulatory Standards and Limits

Parameter/Constituent	EPA Primary Drinking Water Standard	EPA Secondary Drinking Water Standard	Wyoming Groundwater Cleanup Level	WDEQ Underground Water Class Use Suitability			Other
				Class I - Domestic	*Class II - Agriculture*	*Class III - Livestock*	
pH	--	6.5 - 8.5	6.5 - 8.5	6.5 - 8.5	4.5 - 9.0	6.5 - 8.5	--
Total Dissolved Solids (TDS)	--	500 mg/L	500 mg/L	500 mg/L	2,000 mg/L	5,000 mg/L	--
Iron - Total	--	0.3 mg/L	25.5 mg/L	0.3 mg/L	5.0 mg/L	--	--
Iron - Dissolved	--	--	--	--	--	--	--
Fluoride	4.0 mg/L	2.0 mg/L	4.0 mg/L	4.0 mg/L	--	--	--
Chloride	--	250 mg/L	250 mg/L	250 mg/L	100 mg/L	2,000 mg/L	--
Methane	--	--	--	--	--	--	5.0 mg/L warrants isotope analysis; >10 mg/L but <28 mg/L warrants investigation and > 28 mg/L warrants immediate action due to risk of an explosion
Diesel Range Organics (DRO)	--	--	1.1 mg/L (if benzene is present); 10 mg/L (if benzene is absent)	--	--	--	--
Gasoline Range Organics (GRO)	--	--	7.3 mg/L	--	--	--	--
Benzene	5 µg/L	--	5 µg/L	--	--	--	--
Toluene	1,000 µg/L	--	1,000 µg/L	--	--	--	--
Ethylbenzene	700 µg/L	--	700 µg/L	--	--	--	--
Xylenes - Total	10,000 µg/L	--	10,000 µg/L	--	--	--	--

Sources: Eltschlager et al. 2001; EPA 2009; WDEQ 2013, 2015.

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Normally Pressured Lance Natural Gas Development Project

Draft Environmental Impact Statement

Appendix L

Air Quality Assessment Technical Support Document

NORMALLY PRESSURED LANCE (NPL)

NATURAL GAS DEVELOPMENT PROJECT

AIR QUALITY ASSESSMENT TECHNICAL SUPPORT DOCUMENT

U.S. Department of the Interior
Bureau of Land Management

BLM Pinedale Field Office
P.O. Box 768
1625 West Pine Street
Pinedale, Wyoming 82941

The BLM manages more land – 253 million acres – than any other Federal agency. This land, known as the National System of Public Lands, is primarily located in 12 Western States, including Alaska. The Bureau, with a budget of about $1 billion, also administers 700 million acres of sub-surface mineral estate throughout the nation. The BLM's multiple-use mission is to sustain the health and productivity of the public lands for the use and enjoyment of present and future generations. The Bureau accomplishes this by managing such activities as outdoor recreation, livestock grazing, mineral development, and energy production, and by conserving natural, historical, cultural, and other resources on public lands.

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ACRONYMS AND ABBREVIATIONS

ANC	Acid Neutralizing Capacity
AQRV	Air Quality Related Value
AQS	Air Quality System
ASOS	Automated Surface Observation System
b_{ext}	Beta extinction (extinction coefficient)
BLM	Bureau of Land Management
CASTNet	Clean Air Status and Trends Network
CB	Carbon bond
CH_4	Methane
CMAQ	Community Multiscale Air Quality
CNG	Compressed natural gas
CO	Carbon monoxide
CO_2	Carbon dioxide
DA	Development area
DAT	Deposition Analysis Threshold
DEM	Digital Elevation Model
dv	Deciview
EGU	Electric generating unit
EIS	Environmental Impact Statement
EPA	U.S. Environmental Protection Agency
FDV	Future design value
FLAG	Federal Land Manager's Air Quality Related Values Work Group
GHG	Greenhouse gas
ha	Hectare
HAP	Hazardous Air Pollutant
HNO_3	Nitric acid
IC/BC	Initial conditions/boundary conditions
IDLH	Immediately Dangerous to Life or Health
IMPROVE	Interagency Monitoring of PROtected Visual Environments
IUR	Inhalation Unit Risk
kg	Kilogram
LCC	Lambert Conformal Conic
m	Meter(s)
µeq/L	Micro equivalents per liter
$\mu g/m^3$	Microgram per cubic meter
MATS	Modeled Attainment Test Software
MCIP	Meteorology-Chemistry Interface Processor
mg/m^3	Milligram per cubic meter
Mm^{-1}	Inverse megameters
MMIF	Meteorological Model Interface Program
MOVES	Motor Vehicle Emission Simulator
N	Nitrogen
N_2O	Nitrous oxide
NAAQS	National Ambient Air Quality Standards
NADP	National Acid Deposition Program
NCAR	National Center for Atmospheric Research
NEI	National Emission Inventory
NEPA	National Environmental Policy Act
NH_3	Ammonia
NO	Nitrogen oxide
NO_2	Nitrogen dioxide
NO_3	Nitrate
NO_x	Oxides of nitrogen
NP	National Park
NPL	Normally Pressured Lance
NPS	National Park Service
NWS	National Weather Service
O_3	Ozone
OLM	Ozone Limiting Method
PBL	Planetary boundary layer
PG	Pasquill-Gifford
PM	Particulate matter
$PM_{2.5}$	Fine particulate matter
PM_{10}	Coarse particulate matter
PMC	Coarse particulate matter
PMF	Fine particulate matter
ppb	Parts per billion
PSD	Prevention of Significant Deterioration
PVMRM	Plume Volume Molar Reaction Model

QA	Quality Assurance
RA	Roadless Area
REL	Reference Exposure Level
RfC	Reference Concentration
RFD	Reasonably Foreseeable Development
RFFA	Reasonably Foreseeable Future Actions
RGF	Regional Gathering Facility
rh	Relative humidity
RHR	Regional Haze Rule
RMP	Resource Management Plan
ROD	Record of Decision
RPO	Regional Planning Organization
RRF	Relative response factor
SMOKE	Sparse-Matrix Operator Kernel Emissions
S	Sulfur
SO_2	Sulfur dioxide
SO_4	Sulfate
TSP	Total suspended particulate
UGRB	Upper Green River Basin
U.S.	United States
USFS	U.S. Forest Service
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geologic Survey
VOC	Volatile organic compound
VRU	Vapor recovery unit
WA	Wilderness Area
WAAQS	Wyoming Ambient Air Quality Standards
WRAP	Western Regional Air Partnership
WRF	Weather Research and Forecasting
WY DEQ	Wyoming Department of Environmental Quality
yr	Year

1.0 INTRODUCTION

This technical support document (TSD) summarizes the application of air quality modeling tools to support the assessment of impacts from emissions associated with the development of the Normally Pressured Lance (NPL) natural gas field on local and regional air quality. The NPL natural gas field is located northwest of Rock Springs, Wyoming, south of Pinedale, Wyoming, and adjacent to the existing Jonah Field; the project area comprises 140,859 acres of land. A number of natural gas wells have already been drilled in the NPL. Jonah Energy proposes to drill an average of 350 wells per year over a 10-year period for a total of approximately 3,500 wells. Many outside factors, including economic, technological, and regulatory factors, may influence the rate of development as well as the total number of wells that will ultimately be drilled over the duration of the project.

The Bureau of Land Management (BLM) oversees and administers the public lands within the proposed NPL project from the BLM Pinedale and Rock Springs field offices. Oil and gas development activities in the area are governed by the Pinedale Resource Management Plan (RMP) (2008) and the Green River RMP (1997). An Environmental Impact Statement (EIS) for the proposed project will be prepared by BLM in accordance with National Environmental Policy Act (NEPA) guidelines. Other NEPA analyses have been conducted for the area and management plans have been previously prepared for sections of the project area. These include the Green River RMP and Final EIS and Record of Decision (ROD) (1997), and the Pinedale RMP and Final EIS and ROD (2008).

1.1 Project Description

The primary purpose of Jonah Energy's proposal to develop the NPL field is the recovery of natural gas and other hydrocarbon resources. Target formations for the development include the Lance Pool, and potentially the Unnamed Tertiary, Mesa Verde, and other possible productive formations evaluated during exploration and testing. Jonah Energy's planned development of the NPL field will include the building and/or installation of new access roads, well pads, pipelines, compressor stations, and other supporting facilities. At the present time, Jonah Energy proposes to use directional drilling from no more than four centralized surface locations per section. Drill pads are proposed to encompass up to approximately 19 acres per location for a total initial surface disturbance of approximately 6,340 acres of the NPL area. Upon completion of reclamation activities, approximately 1,890 acres would remain disturbed. Although the exact location of each well is not known at this time, the bottom-hole-location density is expected to be no less than a 10-acre spacing pattern to retrieve natural gas in the formations identified during exploration and testing.

To transport products (gas, condensate, and produced water), a three-phase pipeline gathering system is proposed to be installed from the well heads to designated Regional Gathering Facilities (RGF). For the development of the NPL, each RGF would be designed with facilities that support gas/liquid separation, gas compression and dehydration, liquid storage, and truck loading for condensate sales. Jonah Energy proposes to minimize emissions by employing natural-gas-powered drill rigs, and using electric compressors in place of diesel-powered compressors. Jonah Energy also proposes to undertake simultaneous completion operations whenever possible in an effort to minimize emissions associated with equipment use and movement. In addition, Jonah Energy proposes to limit emissions with the use of flare-less flow back technology for the completion operations.

1.2 Study Objectives

The objectives of this air quality assessment were to examine and quantify the potential air quality impacts from emissions associated with the development of the NPL natural gas field using the best available data and state-of-the-science data processing and modeling tools. This information is intended to support the development of an EIS for the NPL project area.

1.3 Overview of the Air Quality Assessment

The NPL air quality assessment was designed to examine and quantify the expected future impacts of emissions from equipment and activities associated with the development of the NPL field. It includes the assessment of both near-field and far-field (regional) impacts for criteria pollutants and air quality related values (AQRVs) using a variety of modeling tools. Near-field impacts were evaluated using the Environmental Protection Agency (EPA) guideline model AERMOD, and far-field (or regional) impacts were evaluated using Version 5.0 of EPA's Community Multiscale Air Quality (CMAQ) modeling system and Version 5.8.4 of the CALPUFF model.

The air quality modeling analysis included an assessment of "current" conditions for a recent historical period (2008). Potential future impacts were then evaluated for a selected future year by applying the modeling systems using the historical meteorological inputs and estimated emissions for sources associated with the development of the field, as well as other regional sources. The assessment considered both near-field and far-field air quality impacts and focused on:

- Criteria pollutants including ozone (O_3), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), carbon monoxide (CO), and particulate matter (PM), including both coarse (PM_{10}) and fine particulates ($PM_{2.5}$).
- Hazardous Air Pollutants (HAPs), including acetaldehyde; acrolein; benzene; ethyl benzene; formaldehyde; methanol; n-hexane; toluene; and xylene, and;
- AQRV's including visibility, atmospheric deposition to soils, and acid neutralizing capacity (ANC) of sensitive water bodies.

The HAPs assessment focused only on the NPL project area, and the ANC analysis was conducted for acid sensitive water bodies within nearby Class I and Class II areas identified in the analysis. The remaining air quality impacts were evaluated for the NPL project area, nearby Class I areas, nearby sensitive Class II areas, and throughout the regional-scale air quality modeling domain.

The current- and future-year regional modeling analyses were conducted using emissions data available from the BLM, the Wyoming Department of Environmental Quality (WY DEQ), the Western Regional Air Partnership (WRAP), and the EPA. The NPL impacts analysis modeling was conducted using emissions specifically developed by Jonah Energy for the NPL field development operations. Detailed information on the emissions is provided in Section 2 of this document.

Near-field ambient air quality impacts within the NPL project area resulting from project-related emissions were quantified using AERMOD (version 12060). AERMOD was applied for a five-year simulation period spanning 2006 to 2010. The modeling scenarios were designed to capture the reasonable maximum emissions year impacts for each pollutant for each of the major development phases of the project, namely, construction, drilling, and production. The modeling scenarios focused on the emissions within one section of the NPL field which is equivalent to one square mile. AERMOD was used to examine the impacts of emissions of the following criteria pollutants: PM_{10}, $PM_{2.5}$, NO_2, SO_2 and CO. For each criteria pollutant, the averaging period(s) was based on the relevant National Ambient

Air Quality Standards (NAAQS). AERMOD was also used to examine the impacts of emissions of the following HAPs: acetaldehyde; acrolein; benzene; ethyl benzene; formaldehyde; methanol; n-hexane; toluene; and xylene. For the HAPs, the modeled concentrations were used to establish inhalation unit risk (IUR) factors for carcinogens and reference concentrations (RfCs) or reference exposure levels (RELs) for non-carcinogens. Both short-term and long-term exposures were considered. The project-specific emissions are presented in Section 2 of this document, and the near-field modeling methods and results are discussed in detail in Section 3.

Far-field ambient air quality impacts from project-related emissions were examined and quantified using regional-scale modeling and both the CMAQ and CALPUFF models.

CMAQ modeling was used to support the analysis of impacts from the NPL emissions on ambient air concentrations and AQRVs throughout the region, including within any nearby Class I and Class II areas. The CMAQ modeling included a detailed model performance evaluation. The CMAQ modeling scenarios include:

- 2008 Base Case – The current air quality conditions were established using the base-year meteorological inputs and emissions data.
- No Action Alternative – This scenario includes future-year local and regional emissions from all source categories, including emissions from nearby oil and gas development projects, as available. This alternative utilizes reasonably foreseeable development (RFD) emissions for the selected future year, excluding emissions from NPL.
- Proposed Action – This scenario includes future-year local and regional emissions from all source categories, including emissions from nearby oil and gas development projects, as available. This alternative utilizes RFD emissions for the selected future year, including emissions from NPL. This scenario was used to evaluate and quantify project-specific air quality impacts.

It should be noted that the future year 2024 was originally selected based on available projections for the planned ten-year development of the NPL field provided by Jonah Energy, which, at the time of the analysis, was expected to commence in 2015. Given that development will now likely not begin until 2018 or later, the future year for the regional modeling analysis of NPL impacts was based on the availability of future-year modeling emissions from EPA (2020) and the maximum emissions year for the project. The emissions for the NPL project for the impact analysis were from Year 10 of the development, since NOx and VOC emissions are expected to be greatest during this year.

The CMAQ-based future-year air quality impact assessment included the projection and modification of the emission inputs to reflect the selected future year and the application of CMAQ to assess the impacts of the project emissions on future air quality and AQRVs throughout the region of interest. The future-year assessment examined air concentrations for ozone, PM_{10}, $PM_{2.5}$, NO_x, SO_2, CO, and NH_3; visibility; and sulfur and nitrogen deposition and included the following components:

- Assessment of the change in air concentrations and AQRVs resulting from the addition of the project emissions
- Assessment of the NPL impacts on air quality metrics and compliance relative to the NAAQS and Wyoming AAQS
- Comparison of modeled air quality impacts with applicable Prevention of Significant Deterioration (PSD) increments for Class I and sensitive Class II areas (Note that all NEPA analysis comparisons to the PSD increments are intended to evaluate a threshold of concern and do not represent a regulatory PSD Increment Consumption Analysis).

The CMAQ modeling methods and results are presented in detail in Section 4 of this document.

CALPUFF modeling was used to support the analysis of impacts from the NPL emissions on AQRVs within nearby Class I and Class II areas. The CALPUFF modeling scenarios include:

- Project-specific Emissions Scenario – The project-specific emissions were used to evaluate and quantify project-specific air quality impacts.
- Cumulative Emissions Scenario – A cumulative modeling assessment was conducted that included project specific emissions as well as future-year emissions from other sources, including Reasonably Foreseeable Development (RFD) projects in the region.

The CALPUFF model was applied using project-specific emissions corresponding to the NPL Proposed Action scenario as well as using project-specific and regional emissions (in order to assess the cumulative impacts of emissions from all other projects and sources). The cumulative emissions were based on the regional-scale Proposed Action emissions, as developed for the CMAQ modeling.

The CALPUFF modeling focused on estimating the impacts on AQRVs, including visibility, atmospheric deposition, and the impact of modeled deposition on soils and the ANC of sensitive water bodies. The CALPUFF modeling methods and results are presented in detail in Section 5 of this document.

1.4 Modeling Tools

The primary air quality modeling tools that were used for this study include AERMOD, the CMAQ model, CALPUFF, the Weather Research and Forecasting (WRF) model, and the Sparse-Matrix Operator Kernel Emissions (SMOKE) modeling/processing tool. Descriptions of each of the modeling tools and their application for this study are provided in methodology sections throughout the remainder of this document.

2.0 EMISSION INVENTORIES

This section describes the data, methods, and procedures that were used to prepare the model-ready emission inventories for the NPL regional impacts analysis. These include the NPL project-specific emission inventory reflecting the Proposed Action and the base- and future-year regional inventories that include all other anthropogenic and biogenic sources within the air quality modeling domain.

2.1 Project-Specific Emissions for NPL

The project-specific emission inventory for the Proposed Action was developed using a spreadsheet tool and information provided by Jonah Energy. The tool includes the types of equipment that are expected to be used along with estimates of their activity levels for the various phases of development of the NPL field, including construction, drilling/completion, and production. The equipment and activity information was used along with appropriate emission factors to estimate emissions for the following pollutants: volatile organic compounds (VOC), oxides of nitrogen (NO_x), carbon monoxide (CO), sulfur dioxide (SO_2), fine particulates ($PM_{2.5}$), coarse particulates (PM_{10}), and ammonia (NH_3). Emissions for hazardous air pollutants (HAPs) were estimated for the following species: acetaldehyde; acrolein; benzene, ethylbenzene, formaldehyde, n-hexane, toluene, and xylene. In addition, the inventory includes estimates of the following greenhouse gases: carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O).

The Proposed Action for the development of the NPL field reflects a planned drilling rate of an average of 350 wells per year over a 10-year period. The spreadsheet includes information for the Proposed Action that specifies assumptions regarding drilling activities including the number of pads per year (22), number of pads per section (4), pad spacing (160 acres), acreage per pad (18), and number of wells per pad (16). Assumptions regarding activities and equipment that will be used in the 10-year development period associated with the construction (roads, pads, and pipelines), drilling, completion, and production phases are also included in the spreadsheet tool. The NPL emissions tool was used as the basis for preparing project-specific emission estimates for the selected future year for the near-field and far-field modeling analyses. Additional detail regarding the calculation of project specific emissions for each development phase is provided in the following subsections.

2.1.1 Construction Emissions

Emissions of particulates and criteria pollutants will result from equipment used in the construction of new well pads, expansion of existing well pads, as well as construction of access roads, pipelines and power lines. Fugitive particulate emissions (PM, PM_{10}, and $PM_{2.5}$) will result from the disturbance of the soil during grading, as well as from wind erosion and vehicle traffic. The estimation of fugitive particulate emissions from the disturbed soil during construction activities took into consideration emissions from the construction of the well pads, local and resource roads, the pipeline and other miscellaneous activities. Emission estimates were based on the area disturbed (expansion area in acres, road or pipeline length in miles), construction activity total suspended particulate (TSP) emission factors from WRAP's fugitive dust handbook (WRAP, 2006), duration of activity, and control efficiency.

Fugitive particulate emissions due to wind erosion for the same activities were estimated based on the same disturbed areas and durations, and employed wind erosion calculations outlined in Chapter 13 of AP-42 (EPA, 2006). Meteorological data from the Big Piney National Weather Service (NWS) site for 2008-2010 were used. Fugitive particulate emissions due to traffic during pad, road, and pipeline construction were also estimated. The road type (local or resource), size and type of vehicle/equipment, silt and moisture content of road, dust control methods, emission control efficiency, speed, distance and frequency travelled, as well as fugitive emission factors from AP-42 were used.

Tailpipe emissions from heavy equipment, as well as vehicular traffic were computed based on the type of equipment (backhoes, dozers, scrapers, graders, etc.), size (horsepower), load factors, duration of operation, as well as emission factors based on age distribution of the equipment operating in the field. Emission factors for heavy equipment were obtained from the NONROAD 2008 model (EPA, 2008a) and those for vehicular traffic from the MOVES (MOVES2010a) model (EPA, 2010), which was the latest version available at the time.

2.1.2 Drilling and Completion Emissions

The operation of drill rigs as well as transport and servicing of the rigs by heavy and light duty vehicles will also generate emissions. For the proposed NPL development, natural gas fired drill rigs will be utilized. Tier 3 equivalent emission factors were assumed in the computation of emissions from drill rig equipment. Completion/fracking rig emissions were computed based on Tier 2 factors for diesel engines. Fugitive particulate emissions as well as tailpipe emissions for drilling rigs and support vehicles were computed for the drilling phases, in the manner similar to that used for the construction phase activities. In addition, during cold weather periods, boilers may be required to provide heat and steam for the drilling rigs. However, the boilers to be used in the development of the NPL field will be electrical and will not produce any on-site emissions.

2.1.3 Production Emissions

During the operation of a production well, criteria pollutants and HAPs will be emitted by equipment during the various stages of production. The movement of material and equipment in the field by haul trucks and tanker trucks will produce tailpipe and road dust emissions. All pumps, miscellaneous engines, and heaters expected to be used in the NPL field will be electrified and will not produce any emissions. Dehydrator flashing operations will utilize electric engines with a vapor recovery unit (VRU) for controlling and minimizing VOC emissions as well as a combustor backup system. Some emissions are expected when the combustor unit is in operation. Pneumatic pumps and compressors will also be electrified and produce no emissions. Fugitive VOC emissions will be produced at the well head as well as from condensate storage and loading operations. Fugitive emission factors were obtained from the WY DEQ (2010a) "Oil and Gas Production Facilities Chapter 6, Section 2 Permitting Guidance”. During all phases of development, emissions will be produced from passenger vehicles commuting to and from the NPL field from housing centers and well as from vehicles servicing various pads and facilities within the field. The truck fleet for contractors was assumed to be distributed as 50% gas and 50% diesel powered. By the start of development, Jonah Energy plans to have their entire (employee operated) truck fleet switch to compressed natural gas (CNG) vehicles

2.1.4 Greenhouse Gas Emissions

Although not used in the air quality impact modeling analysis summarized in this document, emissions of greenhouse gases (GHGs) have been estimated for all sources and activities expected to be operating in the NPL field during the construction, drilling, and production phases of development. Emissions have been estimated for carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O).

The methods for estimating GHG emissions are based on Subpart W of EPA's Greenhouse Gas Reporting Program (GHGRP). Subpart W GHG emission estimation methodologies are in part supplemented by the 1996 GRI study, the 2009 API Compendium, and EPA AP-42[1, 2, 3].

Equation 1 is the basis for quantification methods presented throughout this methodology. Wherein, data on activities are presented as an Activity Factor (AF). These data are multiplied by an emission factor (EF) to obtain an emission estimate for emission sources.

Equation 1. General Estimation Approach for GHGs

Activity Factor (AF) x Emission Factor (EF) = GHG Emissions

For most equations, the emissions units are thousand standard cubic feet (Mscf). For CH_4, the emissions have been converted into metric tonnes of CH_4 using Equation 2. CH_4 emissions have been converted from metric tonnes to metric tonnes of CO_2 equivalent ($MTCO_2E$) by multiplying by the global warming potential (GWP) of 21 taken from the IPCC Second Assessment Report (SAR)[4].

Equation 2. Thousand standard cubic feet (Mscf) CH_4 to metric tonnes CH_4 conversion

$$CH_4 \text{ Emissions (Mscf)} = 1\ [\text{Mscf } CH_4] \times 1000\ [\text{scf } CH_4/\text{Mscf } CH_4] \times 19.26\ [\text{g } CH_4/\text{scf } CH_4] \times 1\ [\text{kg } CH_4/1000\text{g } CH_4] \times 1\ [\text{metric tonne } CH_4/1000\text{kg } CH_4] = 0.01926 \text{ metric tonnes } CH_4$$

For CO_2, emissions have been converted from Mscf to metric tonnes CO_2 using Equation 3. CO_2 emissions have been converted from metric tonnes to $MTCO_2E$ by multiplying by the GWP of 1 taken from the IPCC SAR.

Equation 3. Thousand standard cubic feet (Mscf) CO_2 to metric tonnes CO_2 conversion

$$CO_2 \text{ Emissions (Mscf)} = 1\ [\text{Mscf } CO_2] \times 1000\ [\text{scf } CO_2/\text{Mscf } CO_2] \times 51.89\ [\text{g } CO_2/\text{scf } CO_2] \times 1\ [\text{kg } CO_2/1000\text{g } CO_2] \times 1\ [\text{metric tonne } CO_2/1000\text{kg } CO_2] = 0.0519 \text{ metric tonnes } CO_2$$

Similar to criteria pollutants, the equipment and activity included in the spreadsheet were used to estimate GHG emissions using appropriate source-specific emission factors.

2.1.5 Emission Summaries

Summaries of the criteria pollutants and greenhouse gas emissions follow.

2.1.5.1. Criteria Pollutant Emissions

Table 2-1 (a)-(d) presents a summary of criteria pollutant emissions by year for the Proposed Action for each major phase of the 10-year development period of the NPL field as well as a table of total emissions. Figure 2-1 (a)-(f) provides a graphical depiction of these emissions for VOC, NO_x, CO, SO_2,

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[1] *All volumes available at: www.epa.gov/gasstar/tools/related.html*

[2] *Available at: www.api.org/ehs/climate/new/upload/2009_GHG_COMPENDIUM.pdf*

[3] *Available at: http://www.epa.gov/ttnchie1/ap42/*

[4] *Available at: http://www.ipcc.ch/publications_and_data/publications_and_data_reports.shtml*

PM_{10}, and $PM_{2.5}$. The tables and figures indicate that the emissions are largest for all pollutants (except VOC) during the drilling phase of development, which requires a variety of engines and other supporting equipment for each of the wells. The largest VOC emissions are associated with the production phase of the development and these emissions peak out by the 10th year of development when the planned maximum numbers of wells are expected to be in full production mode. As noted earlier, emissions peak in the 10^{th} year of development when the field is fully developed.

Because the NPL field is located within the UGRB 8-hour ozone nonattainment area, the NPL Project must adhere to the provisions of the current nonattainment regulations contained in Chapter 8, Section 3 of the Wyoming Air Quality Standards and Regulations (WAQSR). The BLM must demonstrate that new actions occurring within the nonattainment area will conform with the Wyoming State Implementation Plan (SIP) either through an applicability analysis to demonstrate that the total of direct and indirect emissions from the proposed federal action do not exceed the de minimis emission levels specified in 40 CFR 93.153(b) and Chapter 8, Section 3 of the WAQSR, or through a conformity determination if approval of the federal action will exceed the de minimis emission levels of 100 tons/year of nitrogen oxides (NOx) or volatile organic compounds (VOC), the precursor pollutants that form ozone in the atmosphere.

In assessing whether the NPL Project emissions would be below the de minimis emissions levels for VOCs and NO_x, the emissions are calculated such that the totals do not include the drill rig sources, which will be permitted by the Wyoming DEQ. According to the requirements of the current nonattainment regulations contained in Chapter 8, Section 3 of the WAQSR, permitted sources are excluded from the conformity calculation because they are addressed under the provisions of the Clean Air Act's new source review (NSR) or prevention of significant deterioration (PSD) programs. Further, in assessing whether the NPL Project emissions would be below the de minimis emissions levels for VOCs and NO_x, the annual emissions totals only include emissions from new sources or activities that come on-line or take place during each particular year

Table 2-1 (e) presents total annual emissions for criteria pollutants, excluding emissions for the drill rigs but including emissions for those sources and activities that come on-line or occur each year. As presented in Table 2-1 (e), the emissions for the Proposed Action (350 new wells/year) exceed the de minimis levels for NO_x in years 2 through 10. As a result, Jonah Energy would be required to reduce the annual level of development such that annual emissions of NOx are below the de minimis emissions levels of 100 tons/year. A reduction in annual development could require a longer development period (longer than the proposed 10 years) to develop the proposed 3,500 wells and associated infrastructure.

Table 2-1a. Annual Criteria Pollutant Emissions (tons) During Construction Activities for the NPL Field

Year	VOC	NO_x	CO	SO_2	PM_{10}	$PM_{2.5}$
1	1.9	15.9	8.6	0.4	30.6	5.8
2	1.9	15.8	8.6	0.4	30.1	5.7
3	1.9	15.7	8.6	0.4	29.6	5.7
4	1.9	15.8	8.6	0.4	30.1	5.7
5	1.9	15.6	8.5	0.4	29.1	5.6
6	1.9	15.7	8.6	0.4	29.6	5.7
7	1.9	15.7	8.6	0.4	29.6	5.7
8	1.9	15.6	8.5	0.4	29.1	5.6

Table 2-1a. Annual Criteria Pollutant Emissions (tons) During Construction Activities for the NPL Field

Year	VOC	NO_x	CO	SO_2	PM_{10}	$PM_{2.5}$
9	1.9	15.7	8.6	0.4	29.6	5.7
10	1.9	15.6	8.5	0.4	29.1	5.6

Table 2-1b. Annual Criteria Pollutant Emissions (tons) During Drilling Activities of the NPL Field

Year	VOC	NO_x	CO	SO_2	PM_{10}	$PM_{2.5}$
1	7.2	80	125	1.6	147	21
2	21.1	231	318	4.8	441	63
3	28.0	307	414	6.4	588	84
4	40.7	445	591	9.4	857	122
5	40.7	445	589	9.4	857	122
6	40.7	445	588	9.4	857	122
7	40.7	445	587	9.4	857	122
8	40.7	445	587	9.4	857	122
9	40.7	445	586	9.4	857	122
10	40.7	445	585	9.4	857	122

Table 2-1c. Annual Criteria Pollutant Emissions (tons) During Production Activities of the NPL Field

Year	VOC	NO_x	CO	SO_2	PM_{10}	$PM_{2.5}$
1	83	2.7	1.8	0.0	100	13.2
2	162	4.4	2.8	0.0	185	24.7
3	239	5.2	3.4	0.0	254	34.4
4	318	6.9	4.3	0.0	338	45.8
5	392	6.9	4.3	0.0	391	53.7
6	468	7.8	4.8	0.0	460	63.4
7	545	8.6	5.2	0.0	529	73.1
8	618	8.6	5.2	0.0	581	81.0
9	695	9.4	5.5	0.0	650	90.7
10	768	9.4	5.5	0.0	703	98.6

Table 2-1d. Total Annual Criteria Pollutant Emissions (tons) from all Activities for the NPL Field

Year	VOC	NO_x	CO	SO_2	PM_{10}	$PM_{2.5}$
1	91	98	136	2.0	278	40
2	184	251	329	5.2	656	93
3	268	328	426	6.8	871	124
4	360	468	604	9.8	1226	174
5	433	468	602	9.8	1278	182
6	509	469	602	9.8	1347	191
7	585	469	601	9.8	1416	201
8	658	469	600	9.8	1468	209
9	735	470	600	9.8	1537	219
10	808	470	599	9.8	1589	226

Table 2-1e. Total Annual Criteria Pollutant Emissions (tons) from all New Non-Permitted Sources and Activities for Each Year for the NPL Field

Year	VOC	NO_x	CO	SO_2	PM_{10}	$PM_{2.5}$
1	86.5	52.3	45.0	1.7	277.3	39.6
2	86.6	110.4	55.3	4.4	552.9	78.9
3	85.5	139.0	59.8	5.7	682.5	97.6
4	91.4	194.1	70.7	8.1	966.6	137.0
5	85.5	192.1	68.4	8.1	933.8	133.4
6	88.4	193.0	67.8	8.1	950.2	135.2
7	88.3	192.9	66.8	8.1	950.2	135.2
8	85.5	191.9	65.5	8.1	933.8	133.4
9	88.2	192.7	65.1	8.1	950.2	135.2
10	85.5	191.7	63.9	8.1	933.8	133.4

Figure 2-1a. Annual Emissions of VOC (tons) for the Development of the NPL Field

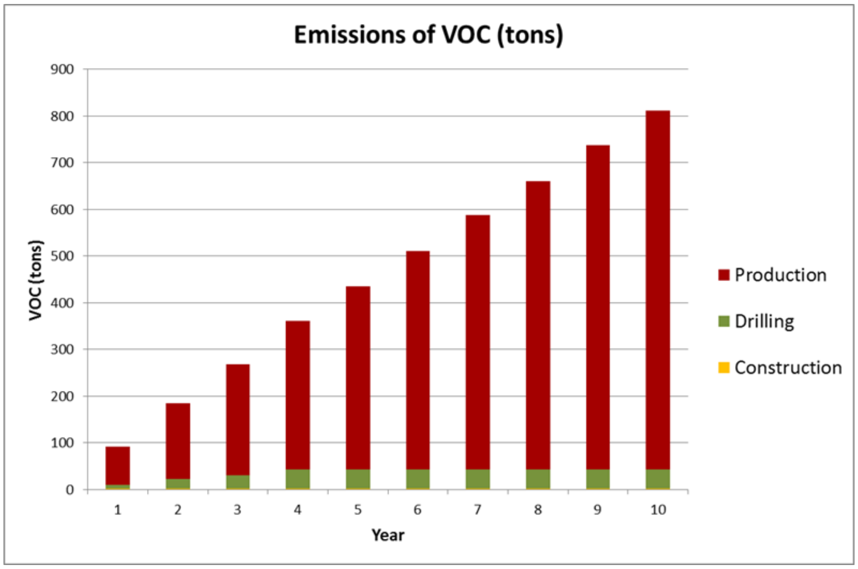


Figure 2-1b. Annual Emissions of NO_x (tons) for the Development of the NPL Field

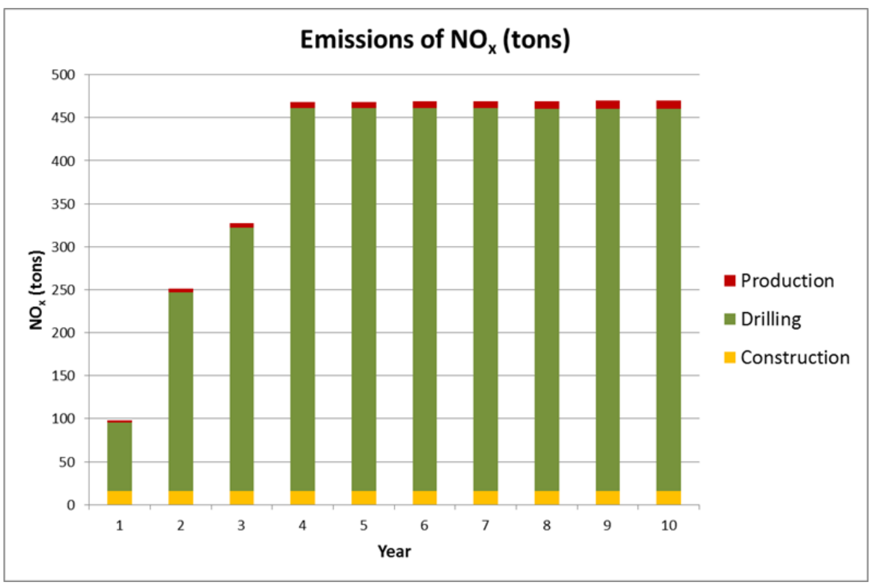


Figure 2-1c. Annual Emissions of CO (tons) for the Development of the NPL Field

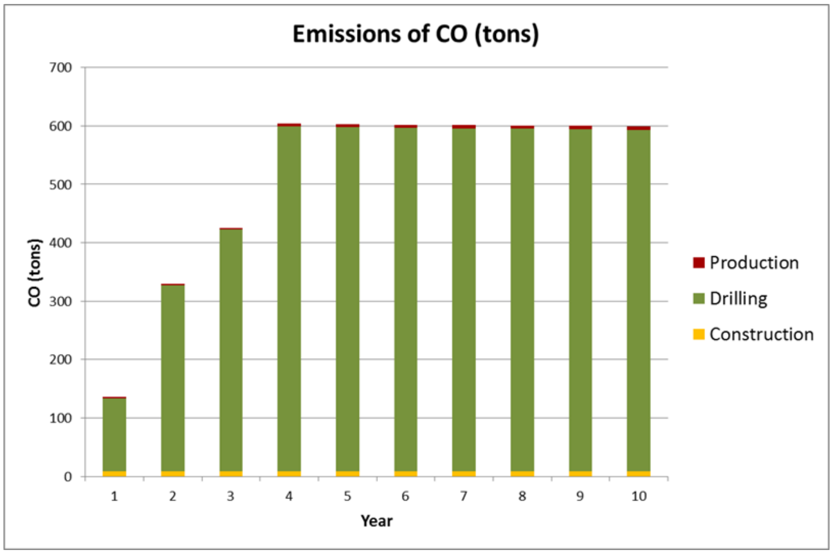


Figure 2-1d. Annual Emissions of SO_2 (tons) for the Development of the NPL Field

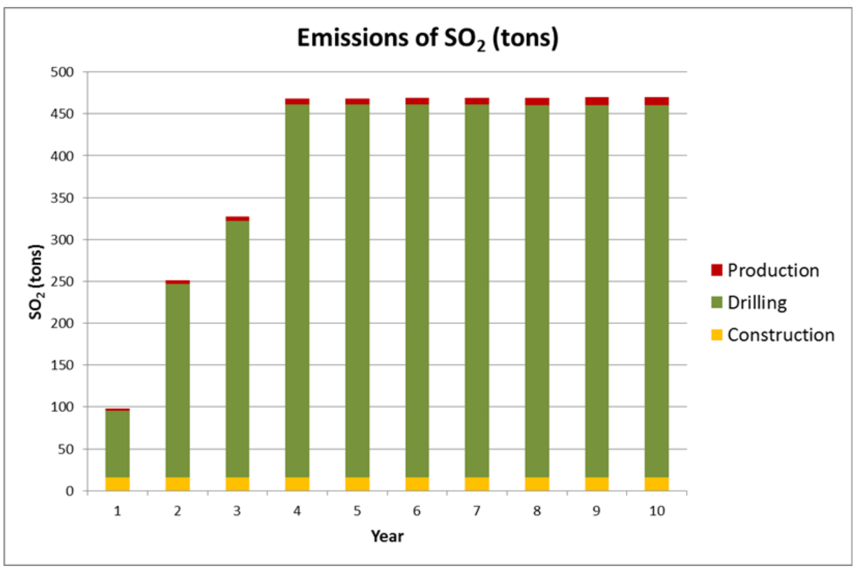


Figure 2-1e. Annual Emissions of PM_{10} (tons) for the Development of the NPL Field

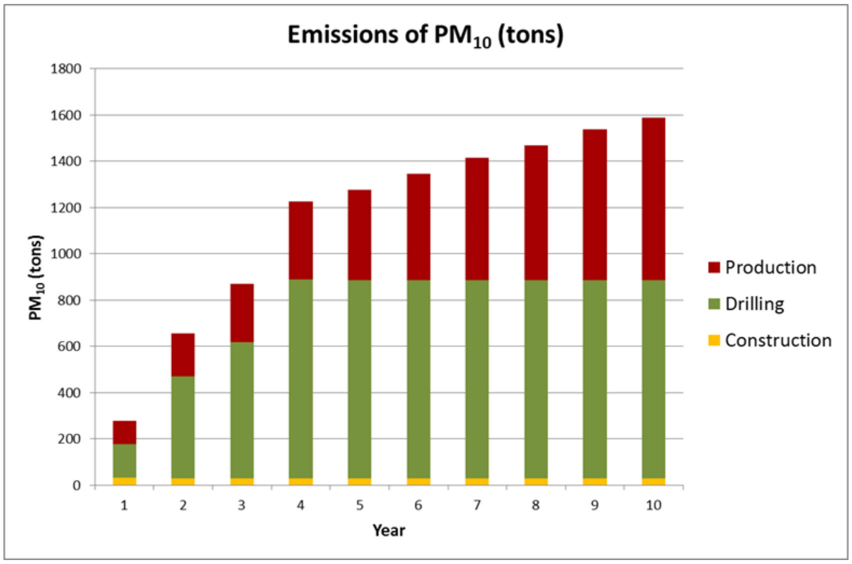
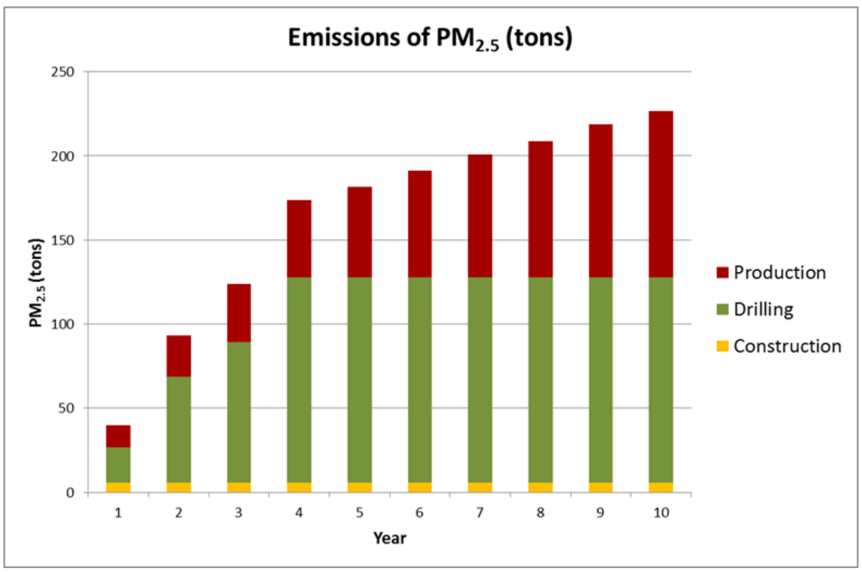


Figure 2-1f. Annual Emissions of $PM_{2.5}$ (tons) for the Development of the NPL Field



2.1.5.2. HAPS Emissions

Table 2-2 presents annual HAPs emission totals for acetaldehyde, acrolein, benzene, ethyl benzene, formaldehyde, methanol, n-hexane, toluene, and xylene for the Proposed Action for the development period. Similar to the magnitudes of overall VOC emissions, the HAPs emissions are associated with the operation of drilling, completion, and production equipment and reach their peak levels by the 10th year of the development period.

Table 2-2. Total Annual HAPs Emissions (tons) from all Activities for the NPL Field

Year	Acetal-dehyde	Acrolein	Benzene	Ethyl Benzene	Formal-dehyde	Meth-anol	n-Hexane	Toluene	Xylene
1	0.3	0.2	0.5	0.0	6.3	0.5	1.8	0.7	0.3
2	1.0	0.6	1.0	0.1	18.8	1.0	3.6	1.3	0.6
3	1.3	0.8	1.4	0.1	25.1	1.4	5.2	1.9	0.8
4	1.9	1.1	1.9	0.1	36.6	1.9	7.0	2.5	1.1
5	1.9	1.1	2.2	0.1	36.6	2.2	8.5	3.0	1.2
6	1.9	1.1	2.6	0.2	36.6	2.6	10.0	3.5	1.4
7	1.9	1.1	2.9	0.2	36.6	2.9	11.5	4.1	1.6
8	1.9	1.1	3.2	0.2	36.6	3.2	12.0	4.6	1.8
9	1.9	1.1	3.6	0.2	36.6	3.6	14.6	5.1	2.0
10	1.9	1.1	3.9	0.2	36.6	3.9	16.1	5.5	2.2

2.1.5.3. Greenhouse Gas Emissions

Table 2-3 presents annual greenhouse gas emission totals for CO_2, CH_4, N_2O, and CO_2-equivalents for the Proposed Action for the 10-year development period. The emissions for CO_2 and N_2O are highest in drilling phase of development, while the highest emissions for CH_4 are associated with the production phase of development. Similar to VOC emissions, the emissions of all GHG's are expected to reach their peak by the 10th year of development when the field is in full production. Figure 2-2 (a)-(d) provides a graphical depiction of these emissions.

Table 2-3. Total Annual GHG Emissions (tons) from all Activities for the NPL Field

Year	CO_2	CH_4	N_2O	CO_{2eq}
1	19,634	691	0.1	36,955
2	51,209	1,495	0.2	88,648
3	67,019	2,149	0.3	120,823
4	96,019	2,930	0.4	169,391
5	95,991	3,434	0.4	181,959
6	96,269	3,956	0.4	195,294
7	96,514	4,478	0.4	208,588
8	96,502	4,982	0.4	221,172
9	96,744	5,504	0.4	234,462
10	96,733	6,008	0.4	247,047

Figure 2-2a. Annual Emissions of CO_2 (tons) for the Development of the NPL Field

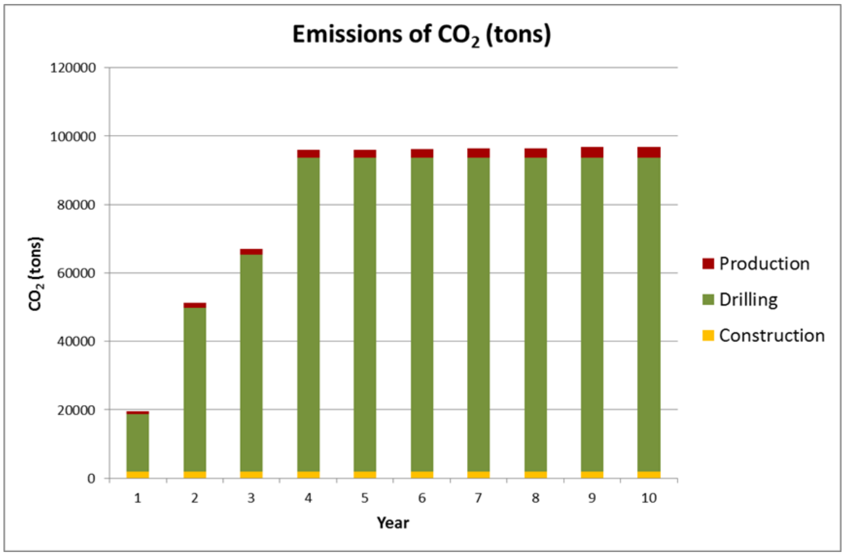


Figure 2-2b. Annual Emissions of CH_4 (tons) for the Development of the NPL Field

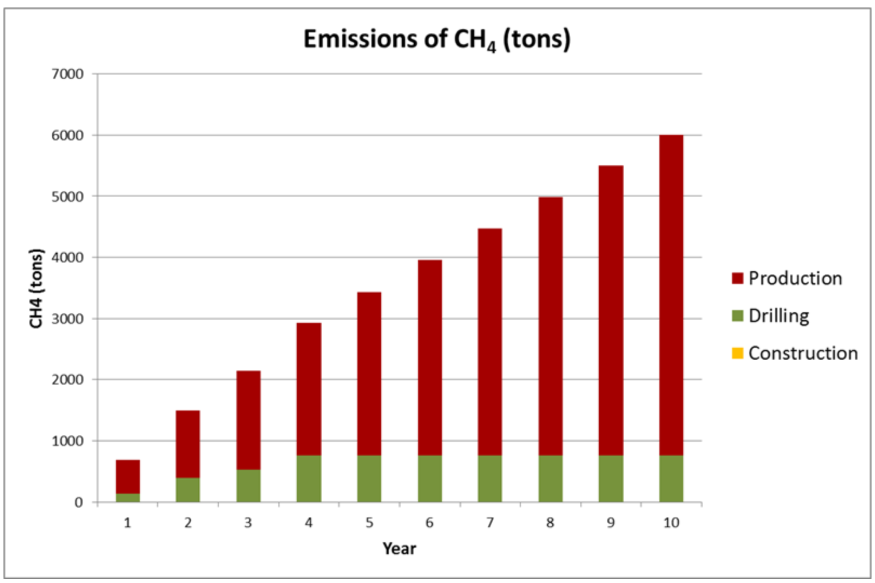


Figure 2-2c. Annual Emissions of N_2O (tons) for the Development of the NPL Field

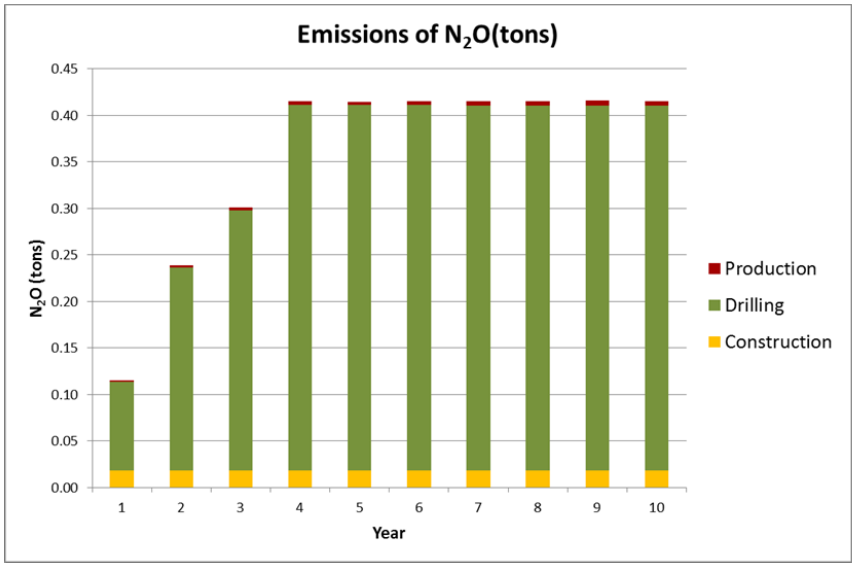
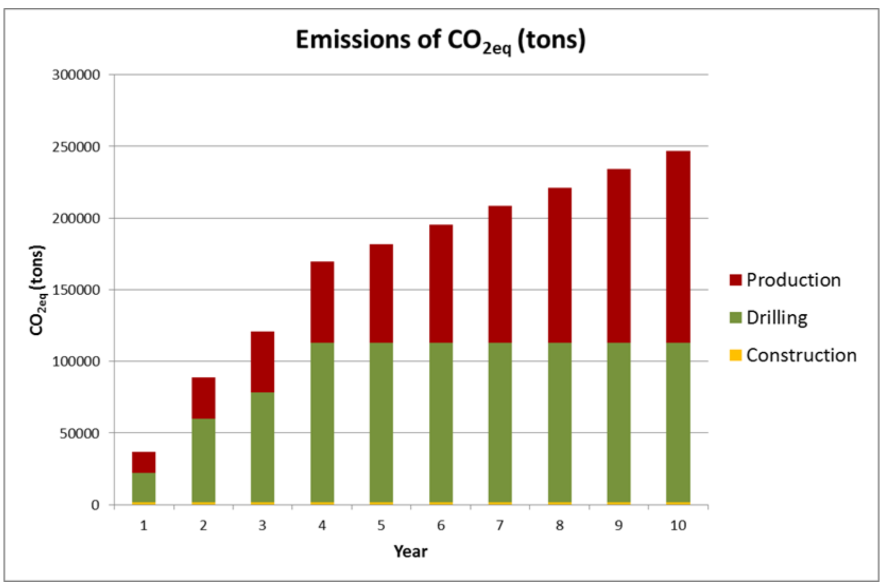


Figure 2-2d. Annual Emissions of CO_2-equivalent (tons) for the Development of the NPL Field



2.1.5.4. Emissions for the Alternatives

In addition to the Proposed Action, the NPL EIS also examined two Alternatives (A and B) that differ in a number of ways, including the total number of wells, the pace of development, the assumed density of wells, and the planned sequencing of activities, etc. The major differences of these alternatives, compared to the Proposed Action, are summarized in the following:

Alternative A:

- This alternative specifies fewer new wells be developed per year during the development period (336 wells pear year compared to 350) and a slightly longer development period (10.4 years compared to 10 years).
- Development would be conducted sequentially by phase, and would be completed in each phase prior to starting development within designated development areas (DAs) in the next phase.
- In contrast to the Proposed Action and Alternative B, which would rely on trucking produced water and condensate from regional gathering facilities (RGFs) to offsite facilities, Alternative A would utilize two separate buried pipelines to transport produced water and condensate from RGFs to existing water treatment plants or condensate sales points (i.e., heavy vehicle truck trips reduced by 121 per day, compared to Proposed Action).
- RGFs, compressor facilities, and powerlines would be prohibited within delineated mountain plover habitat in DA 3 and DA 6, within raptor nest buffers in DA 1, DA 3, and DA 5, and within burrowing owl nest buffers in DA 6. RGFs would be allowed within Sage-Grouse PHMA (core only) (DA 3) as long as disturbance would not exceed the 5 percent disturbance threshold described in the BLM Wyoming Sage-Grouse RMP Amendments.

Alternative B:

- This alternative assumes fewer new wells developed per year during the development period (336 wells pear year compared to 350) and a slightly longer development period (10.4 years compared to 10 years).
- In contrast to Alternative A, where the density of development and development limitations would be based primarily on wildlife habitat for focus species, development for Alternative B would be based on a broader range of resources including visual resources, paleontological resources, surface water features, identified lands with wilderness characteristics, and other resources (including wildlife habitat).
- Development in the DA 1 area would be reduced (one disturbance location per 640 acres compared to four disturbance locations per 640 acres for the Proposed Action). As a result, surface disturbance and miles of roads and pipelines in the DA 1 area would be reduced, compared to the Proposed Action.

In summary, the differences in assumed number of wells, activity, density, and sequencing components between the Proposed Action and Alternatives A and B are quite small and would result in minor net reductions in overall emissions (less than 5%). Because of these small differences, the emission totals were not explicitly quantified and the air quality impacts were only assessed for the Proposed Action scenario in the modeling analyses summarized in Sections 4 and 5 of this TSD.

2.2 Regional-Scale Emissions

This section presents a summary of the base-year and future-year regional emissions inventories for the CMAQ modeling analysis including emissions processing procedures, quality assurance, sources of emission data and related information, and summaries of the base- and future-year emissions. The future-year Proposed Action emissions were also used as the basis for the CALPUFF cumulative-emissions simulation, as discussed in Section 6 of this TSD.

2.2.1 Emissions Processing and Quality Assurance

SMOKE, version 3.1 was used to process the emissions and prepare CMAQ-ready inputs for the base- and future-year scenarios. SMOKE is an emissions processing system designed to create gridded, speciated, hourly emissions for input into an air quality models such as CMAQ. SMOKE can be used to process point-source, area-source, mobile (both on-road and non-road), and biogenic emissions and accommodates a wide variety of gaseous, particulate, and toxic pollutant species. SMOKE incorporates several options for biogenic emissions processing including the Biogenic Emission Inventory System (BEIS2 and BEIS3) and the Model of Emissions of Gases and Aerosols from Nature (MEGAN). SMOKE is also integrated with the on-road emissions models MOBILE6 and Motor Vehicle Emission Simulator (MOVES). The sparse matrix approach used throughout SMOKE is designed to facilitate the efficient processing of emissions data. The processing steps include chemical speciation, temporal allocation, spatial allocation, and the application of growth and control factors.

In applying SMOKE, the "in-line" point-source emissions feature was utilized. Emission files were prepared for the NPL 36-, 12- and 4-km resolution CMAQ grids. Preparation of the model-ready inventories included processing of all source sectors using various SMOKE programs and inputs, and review and quality assurance checks.

The general procedures followed in preparing the modeling inventories for CMAQ included:

- Chemical speciation of the criteria pollutant emissions into the Carbon Bond 2005 (CB05) chemical mechanism species, as required by CMAQ. The speciation of $PM_{2.5}$ includes the CMAQ required additional species generated using the EPA provided speciation profiles, which are based on the updated speciation profiles in SPECIATE 4.3.
- Temporal distribution of the input annual/monthly emissions into hourly emissions
- Spatial distribution of the emissions data to the 36-, 12- and 4-km resolution modeling grids
- Calculation of biogenic emissions using the 2008 base-year meteorological input files derived from the WRF model (base-year only)
- Extraction of the wildfire emissions for the 36-, 12- and 4-km resolution modeling grids from the University Center for Atmospheric Research (UCAR) database (UCAR, 2013) (base-year only)
- Merging of emissions from all source categories into CMAQ model-ready files
- Review and quality assurance of the processing steps and resulting emissions.

For most of the processing steps, including chemical speciation, temporal allocation, spatial distribution, and merging, standard SMOKE algorithms and utility programs were applied. Biogenic emissions were estimated using the MEGAN software system (Guenther et al., 2006).

Quality assurance of the emissions included the preparation and examination of tabular emissions summaries and graphical display products.

Tabular summaries were used to examine emissions totals for various steps of the emissions processing. Summaries for input emissions are based on the input inventory data: monthly emissions for the on-road and non-road sectors, and annual emissions for other sectors for criteria pollutants. Summaries for the emissions are based on the SMOKE output reports which include daily emissions for each CB05 species for each sector. The output daily emissions are summed over all days in the year and the CB05 species are summed for the criteria pollutants. The emissions summaries were made for each scenario by state and sector, and comparisons were made between the input emissions and output emissions for each sector to ensure consistency.

In addition to the tabular summaries, various graphical displays were prepared for one day of each month to examine the spatial distribution and temporal variation for each sector and the final merged emissions using a graphical plotting package.

2.2.2 Base-Year Emission Inventory

The base-year, CMAQ-ready modeling emission inventory was based on the 2007 base case emissions in EPA's 2008-based modeling platform (known as 2007v5), which, in turn, is based on data from the 2008 National Emission Inventory (NEI) Version 2. For their national-scale rulemaking analyses, EPA chose to simulate the year 2007, but much of the emissions information contained in the 2007v5 platform was derived from the 2008 NEI Version 2 data (EPA, 2012a). Refer to Attachment A for the emissions inventory.

The emissions from the following source categories included in the base-year inventory were based on the EPA's NEI 2008-based platform:

- Electric Generating Unit (EGU) point sources (estimated using the Integrated Planning Model (IPM))
- Non-EGU point sources
- Agriculture
- Area fugitive dust
- Class 1 & 2 commercial marine vessel and non-rail maintenance locomotives
- Category 3 (c3) commercial marine vessels
- Non-point (area)
- Non-road
- On-road
- Point sources for Canada and Mexico
- Non-point and non-road for Canada and Mexico
- On-road for Canada and Mexico
- Oceanic gaseous chlorine emissions

In addition, the following files were recently updated by AECOM as part of the LaBarge EIS analysis (AECOM, 2013) and incorporated into the NPL base-year emission inventory:

- Oil and gas point source emissions for drilling and completion activities in five counties in southwestern Wyoming during 2008. The five counties include: Sublette, Lincoln, Sweetwater, Carbon and Uinta

- Oil and gas emissions for the State of Wyoming and states outside of Wyoming (Arizona, Colorado, Montana, Nevada, New Mexico, North Dakota, South Dakota, and Utah) that are modeled as area sources, available from either the WRAP Phase III or WRAP Phase II emissions inventories
- Ancillary files used to process oil and gas emissions: oil and gas spatial surrogates, oil and gas temporal profiles, VOC speciation profiles for oil and gas sources in southwest Wyoming.

The base year (2008) coincides with scheduled updates for EPA's National Emission Inventory (NEI), which includes updates of criteria pollutant emissions from all source categories for all states, including Wyoming. Specific inventories of oil and gas sources developed for basins in Wyoming and neighboring states have been updated in recent years by the WRAP and were incorporated into the inventory. Some of these emissions have been used in recently to support other air quality modeling activities associated with regional haze and $PM_{2.5}$ planning and management activities. Table 2-4 summarizes the various source components that comprise the 2008 base-year modeling emission inventory for the NPL analysis.

Table 2-4. Data Sources for the NPL 2008 Base Year Emissions Inventory

Component/Category	Sub-category/Description	Spatial area	Data source
Major and minor point	EGU and non-EGU point sources; oil and gas sources excluded	U.S.	2008 NEI v2
Area	Area sources; oil and gas sources excluded	U.S.	2008 NEI v2
	Ammonia	U.S.	2008 NEI v2
Oil and gas	Area and point sources	5 Southwest Wyoming Counties: Sublette, Lincoln, Sweetwater, Carbon, and Uinta	Updated by AECOM for LaBarge EIS
	Point sources	U.S. (excluding the SW WY 5-counties)	2008 NEI v2
	Area sources	States with WRAP data (Colorado, Montana, New Mexico, North Dakota, South Dakota, Utah, and Wyoming)	WRAP Phase II & III
	Area sources	Non-WRAP states (e.g., Oklahoma, Texas, etc.)	2008 NEI v2
Non-road	Non-road sources	U.S.	2008 NEI v2
On-road	On-road motor vehicle sources (MOVES)	U.S.	2008 NEI v2
Non U.S.	Point, area (non-point), and mobile sources	Portions of Canada and Mexico within the 36-km domain	2008 NEI v2
Offshore	Offshore sources	Portions of Pacific and Atlantic Oceans and Gulf of Mexico within 36-km domain	2008 NEI v2
Biogenic	Biogenic sources	U.S. and portions of Canada and Mexico within the 36-km domain	MEGAN
Wildfire	Point sources	U.S. and portions of Canada and Mexico within the 36-km domain	UCAR database

Additional details for each source category are provided in the following sections.

2.2.2.1. Major and Minor Point Sources

The emissions were obtained for the State of Wyoming (except for oil and gas point sources in the five counties of southwestern Wyoming) and all other states in the modeling domain from EPA's 2008-base platform (EPA, 2012a). The point source emissions were processed using SMOKE with the "in-line" point source option, and EPA-provided speciation/temporal profiles and associated cross reference files.

2.2.2.2. Area Sources

The emissions were obtained from EPA's 2008-base platform (EPA, 2012a) for all states in the modeling domain (except for the oil and gas sources in the State of Wyoming and WRAP states outside of Wyoming). Emissions for all major area source categories were obtained from EPA's data including industrial processes, miscellaneous area sources, mobile sources (marine vessels, aircraft, railroads, paved roads, etc.), solvent utilization, stationary source fuel combustion, storage and transport, and waste disposal, treatment, and recovery. The area source emissions were processed using SMOKE with EPA-provided speciation/temporal/surrogate profiles and associated cross reference files. The gridded surrogates used for spatially allocating area emissions for the 36-km domain were obtained from EPA's database for the continental U.S. (CONUS) grid, and the surrogates for the 12-km domain were extracted from EPA's corresponding 12-km database. The surrogate data required for the NPL 4-km grid were prepared using the EPA SRGTOOLS and associated data.

2.2.2.3. On-Road and Off-Road Mobile Sources

Estimates for on-road emissions were prepared by combining the emission factors generated using EPA's Motor Vehicle Emissions Simulator MOVES2010b, activity data, and 2008 meteorological data to produce gridded, hourly emissions. There are three sets of emission factors for the non-refueling part of on-road sources: 1) rate per distance (RPD) modeling of the on-network emissions, which includes the vehicle exhaust, evaporation, evaporative permeation, brake wear, and tire wear; 2) rate per vehicle (RPV) modeling of the off-network emissions, including the vehicle exhaust, evaporative emissions, and evaporative permeation; and 3) rate per profile (RPP) modeling of the off-network emissions for parked vehicles, which includes the vehicle evaporative emissions (fuel vapor venting). There are two sets of emission factors for refueling part of on-road sources: RPD and RPV.

The emissions for non-road sources were estimated with the latest version of the NONROAD model (EPA, 2008a).

2.2.2.4. Oil & Gas Sources – Southwestern Wyoming, Rest of Wyoming and All Other States

The 2008 oil and gas point source emissions for drilling and completion activities in five counties (Sublette, Lincoln, Sweetwater, Carbon and Uinta) in southwestern Wyoming were provided by AECOM (AECOM, 2013), following updates made to the inventory as part of the LaBarge natural gas development project EIS. These emissions were processed by SMOKE using the temporal profiles and VOC speciation profiles for oil and gas sources.

The 2008 area source oil and gas emissions for the State of Wyoming and the WRAP states outside of Wyoming were also provided by AECOM (AECOM, 2013). These emissions, which are also being used for the LaBarge EIS, are based on the available WRAP II or WRAP III database, and were processed using the oil and gas temporal profiles, VOC speciation profiles, and spatial surrogates.

The point and area emissions from oil and gas sources for other states were prepared based on EPA's 2008-based platform data.

2.2.2.5. Biogenic Emissions

The 2008 biogenic emissions were estimated using the MEGAN software system (Guenther et al., 2006). MEGAN is a global model for estimating the biogenic emissions used by air quality models. The base resolution is ~ 1 km. MEGAN uses land-cover data for emissions factors, leaf-area index, and plant functional types that are available in several formats. MEGAN produces emissions estimates of isoprene, monoterpenes, oxygenated compounds, sesquiterpenes, and nitrogen oxide. The biogenic emissions were estimated using the base-year 2008 meteorological inputs provided by the application of the WRF meteorological model.

2.2.2.6. Ammonia Emissions

Emission estimates for ammonia sources were obtained from EPA's 2008-based platform. The emissions processing incorporated a new EPA temporal allocation methodology for animal-related ammonia (NH_3) that allocates emissions down to the hourly level by taking into account temperature and wind speed.

2.2.2.7. Wildfire Emissions

Estimates of emissions from wildfires for 2008 were prepared using information obtained from the Fire INventory from NCAR (FINN) (Wiedinmyer et al., 2011; Wiedinmyer et al., 2006), which is affiliated with the University Center for Atmospheric Research (UCAR). FINN files covering the years 2002 through 2012 are currently available, and the emissions files for 2008 were downloaded from http://acd.ucar.edu/~christin/fire-emissions.

The fire emissions available from UCAR provide daily total fire emissions down to a resolution of about one kilometer. The inventory includes emissions estimates for all fires, not necessarily just prescribed burns and reported wildfires. Emissions of carbon dioxide (CO_2), CO, NO, NO_2, SO_2, NH_3, methane (CH_4), non-methane organic compounds (NMOC), formaldehyde (HONO), particulate organic carbon (OC), particulate black carbon (BC), $PM_{2.5}$, and PM_{10} are included in the files available from NCAR. The NMOC emissions are available speciated for either the MOZART-4 (Emmons et al., 2010) chemical mechanism or for the SAPRC99 (Carter, 2000) mechanism.

For the NPL modeling analysis, the fire emissions were aggregated for each grid cell of each grid (36-km, 12-km, and 4-km resolution) to get a daily fire emissions total in each grid cell. These emissions were then divided equally across all 24 hours of the day to obtain hourly emissions for each day of 2008.

As noted above, the NMOC fire emissions from UCAR have been speciated into SAPRC99 and MOZART-4 species. The CMAQ modeling for the NPL Project is utilizing the CB05 chemical mechanism. A number of species have a direct correspondence between the SAPRC99 and CB05 mechanisms, but other species were converted from the SAPRC99 species to appropriate species or collections of species in the CB05 system. Species conversion tables derived from http://www.engr.ucr.edu/~carter/emitdb/#dbfiles were used to guide the development of conversion factors for translating the SAPRC99 species into CB05 species.

Tables 2-5 through 2-7 summarize the base-year (2008) emissions used for the CMAQ modeling. These tables summarize anthropogenic emissions by major source category and pollutant for the 36-km grid, the 12-km grid, and the 4-km grid. The oil and gas emissions category includes emissions from area sources for states with WRAP data (Colorado, Montana, New Mexico, North Dakota, South Dakota, Utah, and Wyoming) and point sources for five southwest Wyoming counties (Sublette, Lincoln, Sweetwater, Carbon, and Uinta). Emissions totals are provided for the following species: volatile organic compounds (VOCs), oxides of nitrogen (NO_x), carbon monoxide (CO), sulfur dioxide (SO_2), coarse particulate matter (PMC), fine particulate matter ($PM_{2.5}$), and ammonia (NH_3). The units are tons per year (tpy).

Table 2-5. NPL 2008 Base Year Emissions Summary: 36-km Grid (U.S.)

Category	VOC (tpy)	NOx (tpy)	CO (tpy)	SO2 (tpy)	PMC (tpy)	PM2.5 (tpy)	NH3 (tpy)
EGU points	41,950	3,363,272	704,919	9,151,792	107,804	330,137	25,469
Non-EGU points	1,044,167	2,067,039	2,933,115	1,583,900	174,214	410,327	67,741
Area (non-point)	6,927,179	1,499,564	11,673,037	461,597	3,809,976	2,615,564	3,896,910
Non-road	2,493,949	3,349,093	18,046,297	255,776	13,201	231,994	2,481
On-road	3,042,122	7,429,653	37,278,146	39,188	82,164	283,274	139,009
Oil & gas	563,045	130,648	56,727	2,516	79	3,211	0
Total	**14,112,412**	**17,839,269**	**70,692,242**	**11,494,769**	**4,187,439**	**3,874,508**	**4,131,610**

Table 2-6. NPL 2008 Base Year Emissions Summary: 12-km Grid

Category	VOC (tpy)	NOx (tpy)	CO (tpy)	SO2 (tpy)	PMC (tpy)	PM2.5 (tpy)	NH3 (tpy)
EGU points	2,178	237,906	23,753	163,375	10,083	9,691	838
Non-EGU points	92,722	139,057	120,710	50,029	27,567	31,089	1,758
Area (non-point)	182,786	26,596	254,831	6,223	293,142	88,576	213,716
Non-road	86,863	152,920	611,688	5,534	567	9,687	112
On-road	91,215	231,232	1,190,232	1,665	2,151	8,447	3,973
Oil & gas	387,645	55,798	32,095	1,567	79	2,734	0
Total	**843,409**	**843,508**	**2,233,309**	**228,393**	**333,589**	**150,224**	**220,398**

Table 2-7. NPL 2008 Base Year Emissions Summary: 4-km Grid

Category	VOC (tpy)	NOx (tpy)	CO (tpy)	SO2 (tpy)	PMC (tpy)	PM2.5 (tpy)	NH3 (tpy)
EGU points	522	71,971	10,499	48,492	5,844	5,419	338
Non-EGU points	19,211	34,611	35,229	20,868	7,157	10,328	19
Area (non-point)	14,317	2,184	35,325	483	30,578	9,566	12,308
Non-road	19,186	22,887	108,921	836	96	1,615	18
On-road	6,553	21,833	92,715	125	156	820	293
Oil & gas	249,540	20,603	12,661	508	52	955	0
Total	**309,330**	**174,089**	**295,349**	**71,313**	**43,882**	**28,702**	**12,976**

Figure 2-3 (a) and (b) presents annual anthropogenic emission totals for VOC, NO_x, SO_2, and $PM_{2.5}$ for the 12-km and 4-km grids broken out by source category: electric generation units (EGU), non-EGU point, area, non-road, and on-road sources. The figures show large contributions of area source VOCs which are associated with oil and natural gas development projects in the region. There are nearly equal contributions of NO_x emissions from these categories. The SO_2 emissions are predominantly from EGU emissions while the $PM_{2.5}$ emissions are predominantly from area sources.

Figure 2-3a. Annual Emissions for 2008 for the 12-km Grid

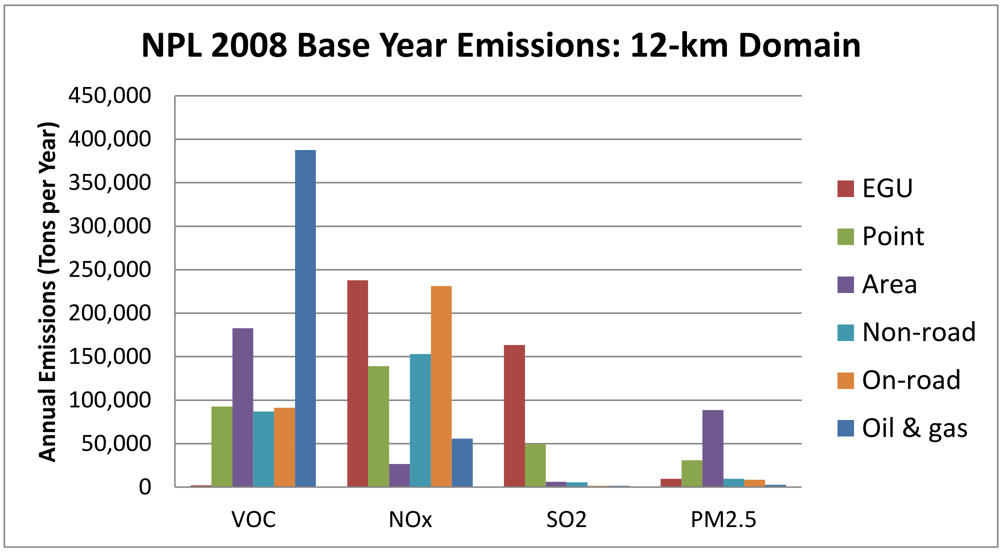
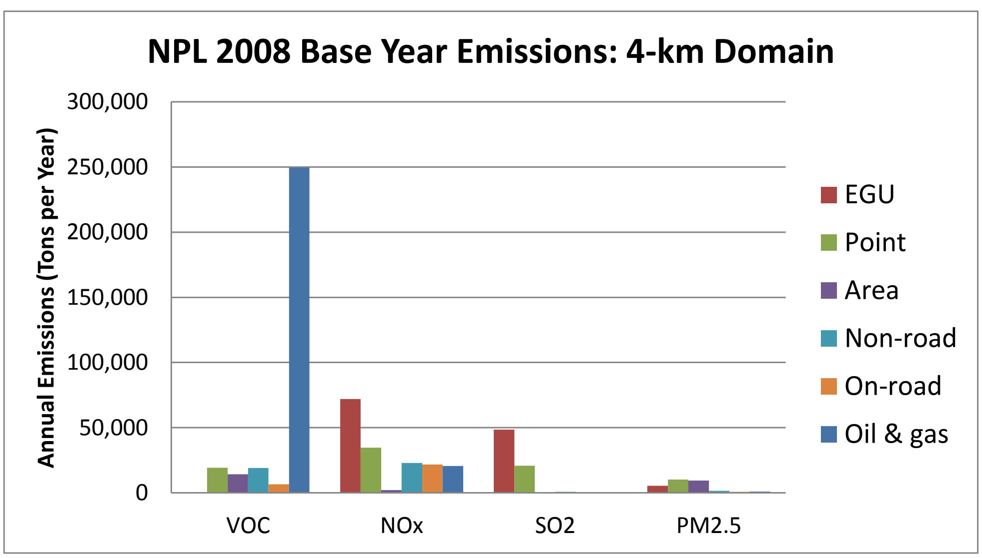


Figure 2-3b. Annual Emissions for 2008 for the 4-km Grid



To illustrate and check the reasonableness of the spatial distribution of emissions throughout the modeling domain, daily emission density plots for a selected day were prepared and examined. Figure

2-4 (a)-(f) presents daily anthropogenic emissions for the 2008 base-year inventory for July 15, 2008 for VOC, NO_x, CO, SO_2, $PM_{2.5}$, and NH_3, respectively, for the 12-km grid. The plots show that the highest emissions correspond to the locations of the major cities/population centers (Denver, Salt Lake City, Provo, etc.), major transportation corridors (I-70, I-80, I-25, etc.), as well as locations of existing energy development areas (Uintah Basin, Powder River Basin). Figure 2-5 presents biogenic VOC emissions for July 15, 2008 for the 12-km grid. The figure illustrates relatively low overall biogenic VOC emissions within the grid, but with some areas of higher emissions associated with the various forested areas of Wyoming, Colorado, Utah, Idaho, Montana, and western South Dakota.

Figure 2-4a. Daily Anthropogenic VOC Emissions (July 15, 2008) for the 12-km Grid

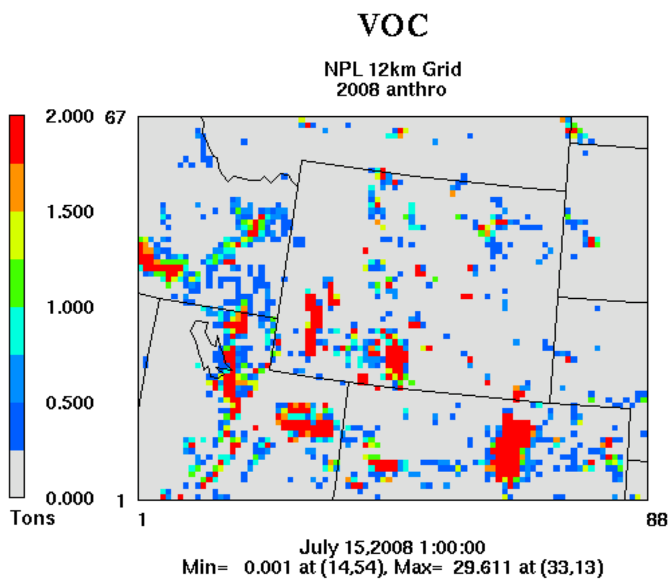


Figure 2-4b. Daily Anthropogenic NO_x Emissions (July 15, 2008) for the 12-km Grid.

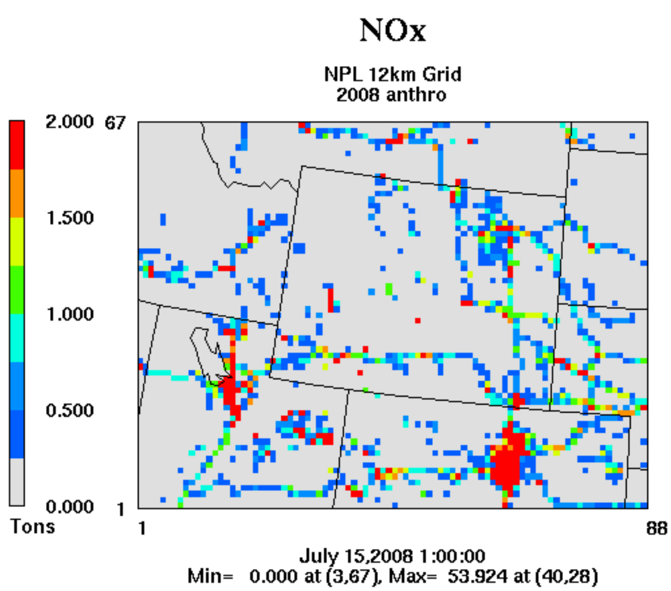


Figure 2-4c. Daily Anthropogenic CO Emissions (July 15, 2008) for the 12-km Grid

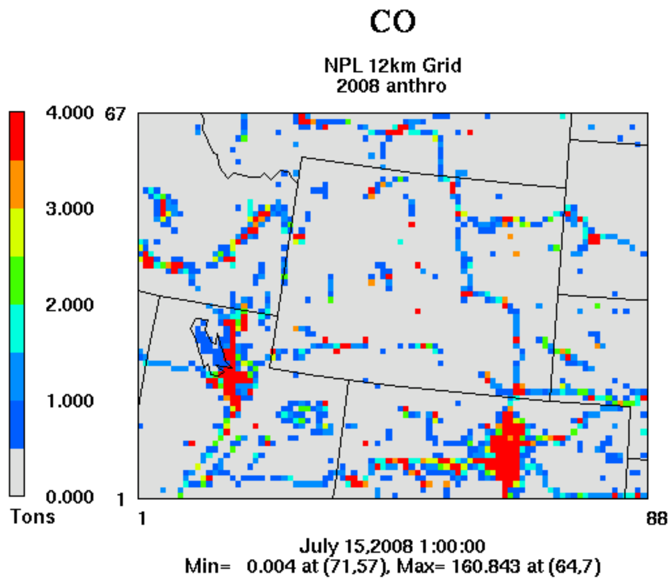


Figure 2-4d. Daily Anthropogenic SO_2 Emissions (July 15, 2008) for the 12-km Grid

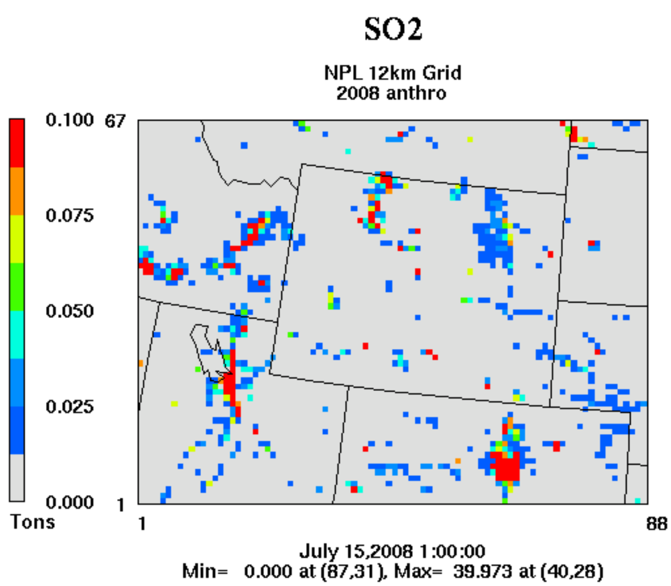


Figure 2-4e. Daily Anthropogenic $PM_{2.5}$ Emissions (July 15, 2008) for the 12-km Grid

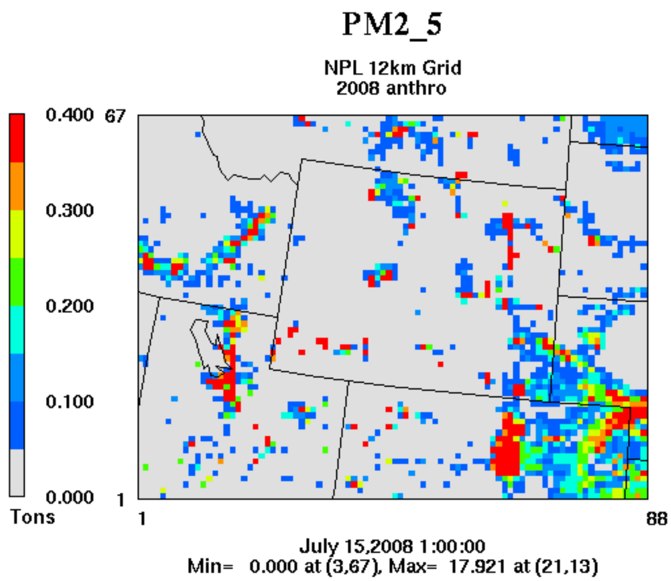


Figure 2-4f. Daily Anthropogenic NH_3 Emissions (July 15, 2008) for the 12-km Grid

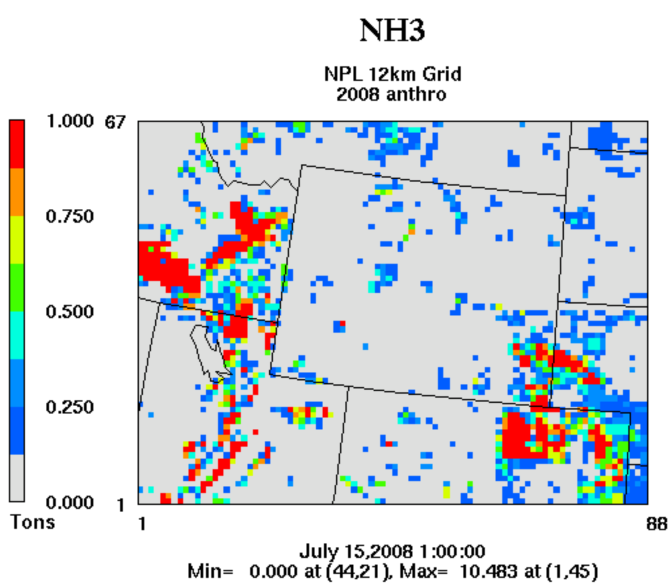
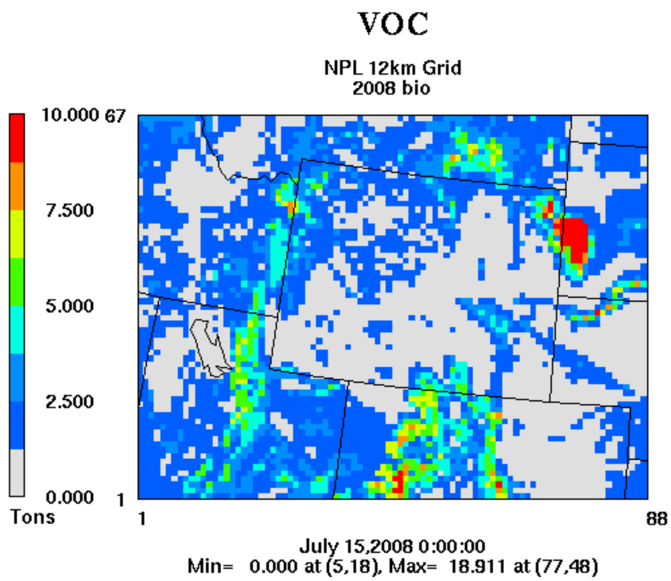


Figure 2-5. Daily Biogenic VOC Emissions (July 15, 2008) for the 12-km Grid



2.2.3 Future-Year No Action Emission Inventory

Similar to the approach being followed in other similar air quality analyses being conducted for BLM to support EIS's for natural gas development in Wyoming, modeling emission files for 2020, available from the EPA's 2008-based platform were used as the basis for the future-year No Action regional modeling inventory. Table 2-8 presents a summary of the source of information for each of the components of the NPL future year regional emission inventory.

Table 2-8. Sources for the Future No Action Alternative Emission Inventory for the NPL Air Quality Impact Assessment

Source Category	Source of Information/Explanation
Major and Minor Point Sources	2020 Inventory from the EPA's 2008-based platform
Area Sources	2020 Inventory from the EPA's 2008-based platform
On-Road Mobile Sources	2020 Inventory from the EPA's 2008-based platform and the EF are prepared using MOVES 2010a
Non-Road Mobile Sources	2020 Inventory from the EPA's 2008-based platform and modeled with NONROAD
Oil & Gas Sources (WRAP States)	WRAP Phase III oil and gas Inventory, and RFD oil and gas emissions for various projects provided by BLM
Oil & Gas Sources (non-WRAP States)	2020 Inventory from the EPA's 2008-based platform
Biogenics	Same as 2008
Ammonia	2020 Inventory from the EPA's 2008-based platform
Wildfires	Same as 2008

The biogenic and wildfire emissions for the future year are the same for the 2008 base year.

For all non-oil and gas sectors, 2020 emissions from the EPA's 2008-based platform database were used.

For oil and gas sources, the WRAP Phase III oil and gas emission estimates included in the EPA's 2008-based platform database were used. In addition, the Reasonably Foreseeable Development (RFD) oil and gas emissions and associated ancillary files provided by BLM were incorporated into the emissions inventory in Attachment A.

Because there currently are a number of other similar studies being conducted to support the development of EIS's for oil and natural gas development projects in Wyoming and neighboring states, it was important to include emissions from these other development areas into the future-year regional emission inventory prepared for the NPL analysis. Although it is difficult to accurately estimate the pace of development in these other areas because of economic, technological, and regulatory factors that may influence the development, the latest information available (February 2014) was obtained. Table 2-9 provides a summary of the projects for which updated RFD emissions were available and incorporated into the regional No Action emission inventory for the NPL analysis.

Table 2-9. List of Projects for which RFD Emissions were Received (Alphabetical Order)

Project	Project
Bird Canyon Infill Development Project - Wyoming	Little Snake, Colorado RMP
Continental Divide-Creston Natural Gas Project (Wyoming)	Monell-Arch Oil and Gas Development Project (Wyoming)
Colorado River Valley, Colorado RMP	Moneta Divide Natural Gas Development Project (Wyoming)
Grand Junction, Colorado RMP	Moxa Arch Gas Development Project (Wyoming)
Hiawatha Regional Energy Development (Wyoming)	Pinedale Anticline Oil and Gas Exploration and Development Project (Wyoming)
Jonah Infill Drilling Project (Wyoming)	Rock Springs, Wyoming RMP
Kremmling, Colorado RMP	Uncompahgre, Colorado RMP
LaBarge Platform Infill Oil and Gas Project (Wyoming)	White River, Colorado RMP

The future-year emissions are used to establish the future no action/no-build conditions within the regional-scale modeling domain and the area of interest. For this assessment, the selected year for the No Action inventory represents the future year with the greatest amount of emissions from NPL development sources. Based on project-specific emissions totals for the development of the NPL field, emissions from development activities for most criteria pollutants are comparable during the last seven years of the development, although VOC emissions are expected to be highest in the last five years of the project when the field is in full production. As such, the EPA emission files for 2020 are appropriate to represent emissions from all other anthropogenic sources that potentially influence air quality in the region.

Tables 2-10 through 2-12 summarize the future-year (2020) No Action emissions used for the CMAQ modeling. These tables summarize anthropogenic emissions by major source category and pollutant for the 36-, 12-, and 4-km resolution grids. The oil and gas category includes emissions from states with WRAP Phase III data (Colorado, Montana, New Mexico, Utah, and Wyoming) and emissions obtained from the RFD estimates provided by the BLM for various projects in the region. Emissions totals are provided for the following species: volatile organic compounds (VOCs), oxides of nitrogen (NO_x), carbon monoxide (CO), sulfur dioxide (SO_2), coarse particulate matter (PMC), fine particulate matter ($PM_{2.5}$), and ammonia (NH_3). The units are tons per year (tpy).

Table 2-10. NPL Future Year (2020) Emissions Summary: 36-km Grid (U.S.)

Category	VOC (tpy)	NO_x (tpy)	CO (tpy)	SO_2 (tpy)	PMC (tpy)	$PM_{2.5}$ (tpy)	NH_3 (tpy)
EGU points	47,641	1,885,941	865,243	2,106,199	62,725	234,227	40,561
Non-EGU points	1,020,032	2,041,141	2,647,651	995,674	170,044	372,668	67,794
Area (non-point)	6,664,511	1,625,005	12,010,201	382,329	3,801,899	2,663,973	4,069,065
Non-road	1,339,240	2,047,497	13,032,657	15,875	6,629	113,693	2,924
On-road	1,167,815	2,183,094	18,130,895	27,093	82,009	101,569	78,608
Oil & gas	465,676	113,667	92,667	2,481	11,126	6,626	0
Total	**10,704,915**	**9,896,346**	**46,779,315**	**3,529,652**	**4,134,433**	**3,492,757**	**4,258,951**

Table 2-11. NPL Future Year (2020) Emissions Summary: 12-km Grid

Category	VOC (tpy)	NO_x (tpy)	CO (tpy)	SO_2 (tpy)	PMC (tpy)	$PM_{2.5}$ (tpy)	NH_3 (tpy)
EGU points	2,508	190,103	22,231	66,150	4,369	14,065	1,180
Non-EGU points	91,235	147,331	121,489	39,984	26,994	30,246	1,772
Area (non-point)	116,256	27,099	262,981	6,160	288,773	89,313	217,118
Non-road	49,389	98,007	444,278	143	336	5,085	130
On-road	51,800	67,767	688,431	876	2,248	3,217	2,397
Oil & gas	238,155	52,397	55,426	1,557	10,694	4,011	0
Total	**549,342**	**582,702**	**1,594,835**	**114,870**	**333,413**	**145,937**	**222,598**

Table 2-12. NPL Future Year (2020) Emissions Summary: 4-km Grid

Category	VOC (tpy)	NO_x (tpy)	CO (tpy)	SO_2 (tpy)	PMC (tpy)	$PM_{2.5}$ (tpy)	NH_3 (tpy)
EGU points	742	63,015	6,020	16,254	422	3,687	312
Non-EGU points	19,186	44,358	39,629	16,170	6,760	9,914	20
Area (non-point)	14,187	2,200	35,848	483	29,914	9,571	12,461
Non-road	10,736	14,653	78,947	22	56	844	22
On-road	3,228	5,372	46,253	62	142	251	167
Oil & gas	261,163	37,856	36,535	997	6,999	2,746	0
Total	**309,242**	**167,454**	**243,232**	**33,988**	**44,294**	**27,012**	**12,980**

Figure 2-6 (a) and (b) presents annual anthropogenic emission totals for VOC, NO_x, SO_2, and $PM_{2.5}$ for the No Action emission inventory for the 12- and 4-km grids, broken out by major source category: electric generating units (EGU), point, area, non-road, and on-road sources. The figures show large contributions of area source VOCs, which are associated with oil and natural gas development projects in the region. The combination of EGU and other industrial point sources contribute about 60 percent of total NO_x emissions. The SO_2 emissions are predominantly from EGU and industrial point sources while the $PM_{2.5}$ emissions are predominantly from area sources.

Figure 2-6a. Annual Emissions for the NPL No Action Alternative for the 12-km Grid

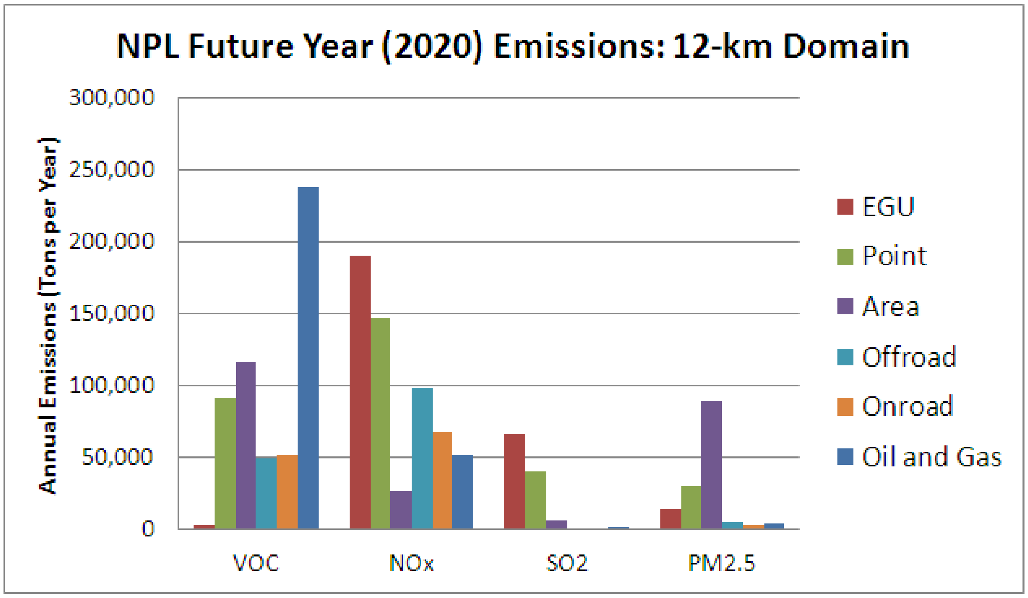
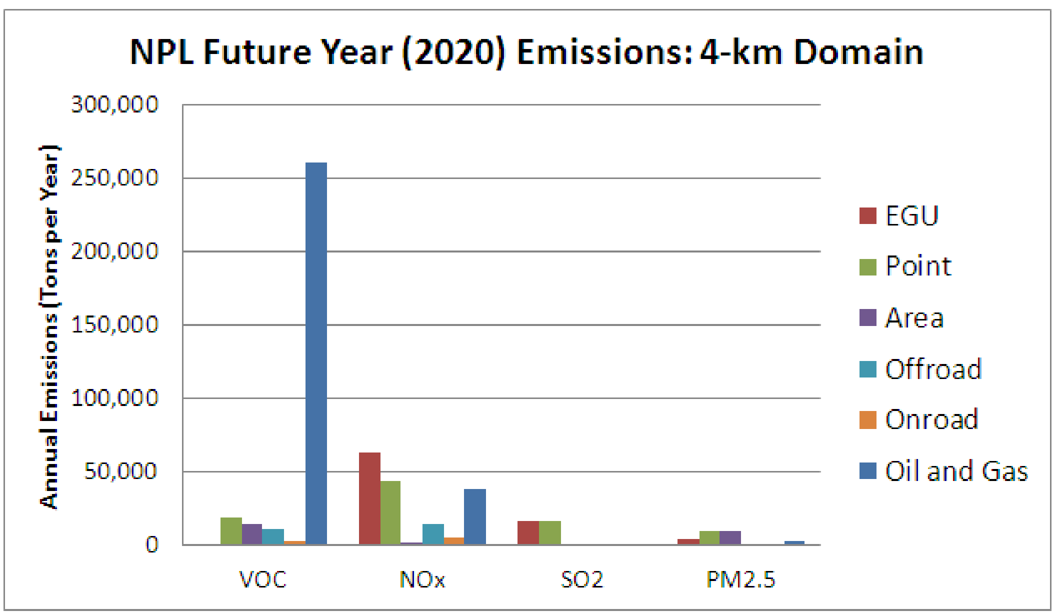


Figure 2-6b. Annual Emissions for NPL No Action Alternative for the 4-km Grid



To illustrate and check the reasonableness of the spatial distribution of emissions throughout the modeling domain, daily emission density plots for a selected day were prepared and examined. Figure 2-7 (a)-(f) presents daily anthropogenic emissions for the future year No Action Alternative inventory for July 15 for VOC, NO_x, CO, SO_2, $PM_{2.5}$, and NH_3, respectively, for the 12-km grid. The plots show that the highest emissions correspond to the locations of the major cities/population centers (Denver, Salt Lake City, Provo, etc.), major transportation corridors (I-70, I-80, I-25, etc.), as well as locations of existing energy development areas (e.g., the Uintah Basin in Utah, Powder River Basin in Wyoming).

Figure 2-7a. Daily Anthropogenic VOC Emissions (July 15) for the 12-km Grid

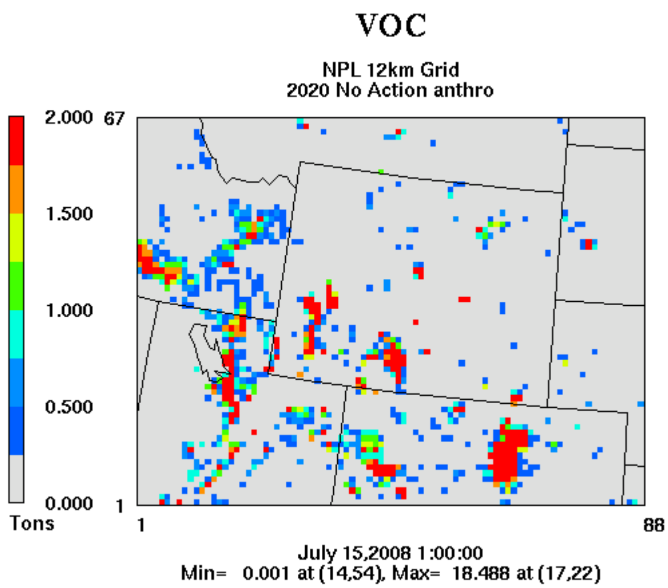


Figure 2-7b. Daily Anthropogenic NO_x Emissions (July 15) for the 12-km Grid

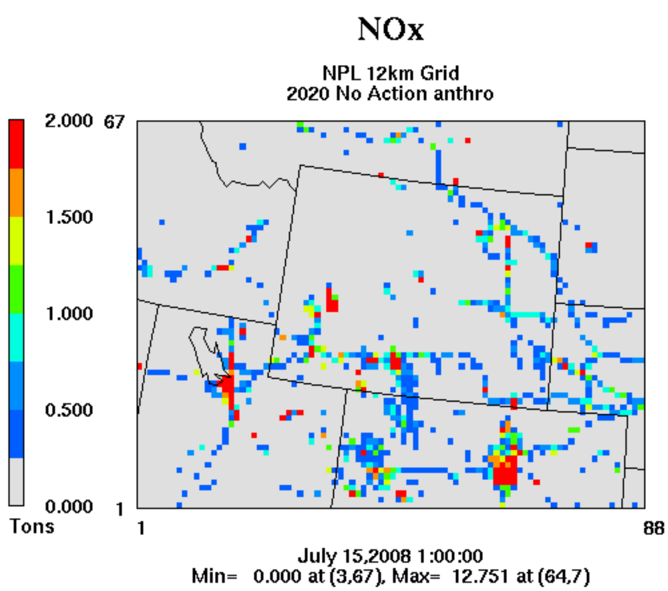


Figure 2-7c. Daily Anthropogenic CO Emissions (July 15) for the 12-km Grid

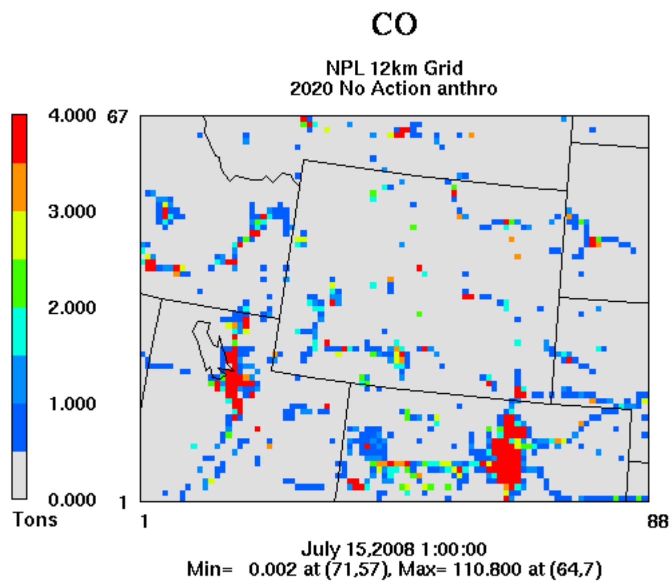


Figure 2-7d. Daily Anthropogenic SO_2 Emissions (July 15) for the 12-km Grid

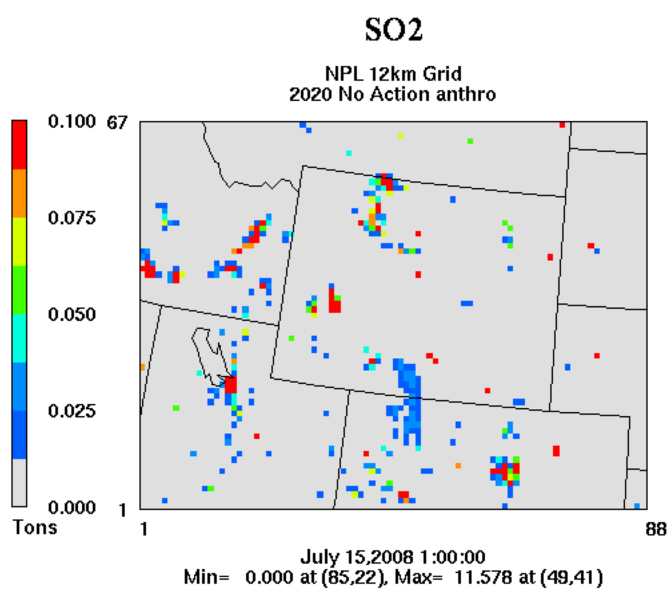


Figure 2-7e. Daily Anthropogenic $PM_{2.5}$ Emissions (July 15) for the 12-km Grid

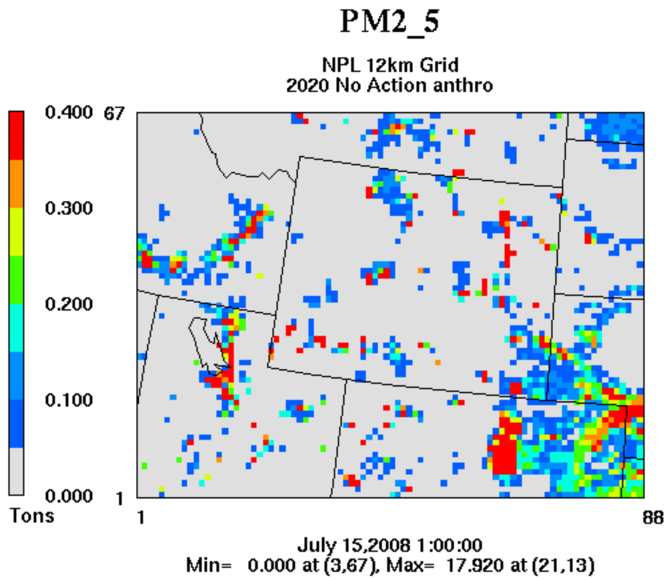
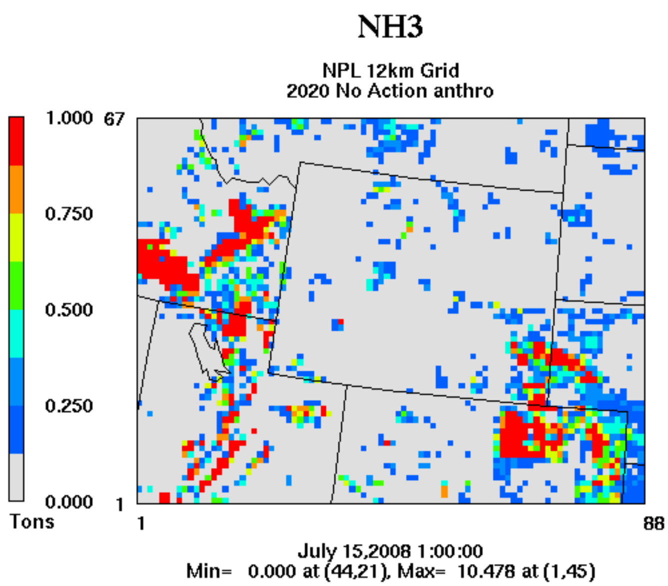


Figure 2-7f. Daily Anthropogenic NH_3 Emissions (July 15) for the 12-km Grid



2.2.4 Future-Year Proposed Action Emission Inventory

The future year Proposed Action regional emission inventory was prepared by adding the NPL project-specific emissions for Year 10 of the development into the future year No Action regional emissions inventory. All of the NPL project-specific emissions are non-point sources and the emissions were processed following the steps as specified in Section 2.2.2. Table 2-13 provides a summary of the Year 10 NPL project-specific emissions by source category that were added to the No Action regional emissions to prepare the Proposed Action regional inventory for the CMAQ analysis. Because these emissions are relatively small compared to the total emissions for the 12- and 4-km resolution grids, emission totals for those grids are not presented here for the Proposed Action inventory.

Table 2-13. NPL Project-Specific Emissions (tpy) for Year 10 by Source Category

Phase	Category	VOC (tpy)	NO_x (tpy)	CO (tpy)	SO_2 (tpy)	PMC (tpy)	$PM_{2.5}$ (tpy)
All	Passenger vehicle	0.09	3.29	18.95	0.01	0.04	0.05
Construction	Traffic dust					6.29	5.62
Construction	Construction Dust, Fugitive					12.74	1.42
Construction	Wind erosion construction					1.34	0.24
Construction	Wind erosion production					462.05	81.54
Construction	Construction heavy equipment	1.87	15.56	8.53	0.40	0.03	1.45
Drilling and Completion	Drilling unpaved road dust					172.28	19.14
Drilling and Completion	Completion unpaved road dust					611.36	96.85
Drilling and Completion	Completion/workover equipment	9.81	172.07	37.47	7.72	0.13	6.37
Drilling and Completion	Drilling equipment combustion	31.02	272.28	529.33	1.69	3.15	2.49
Production	Production traffic combustion	0.01	0.14	0.06	2.78E-04	0.00	0.01
Production	Tanker traffic combustion	0.58	5.75	2.26	0.01	0.08	0.30
Production	Production + tanker traffic dust					93.63	10.36
Production	Dehy flashing	0.76	0.77	2.02		0.00	0.04
Production	Blowdown	235.45					
Production	Fugitive VOCs - Facility	28.58					
Production	Fugitive VOCs - Well	497.42					
Production	Compressor engines	1.05					
Production	Condensate loading	0.09	1.89E-03	5.00E-03		0.00	9.46E-05
Production	Condensate tank storage	1.05	0.04	0.11		0.00	0.01
Total		**807.78**	**469.90**	**598.73**	**9.82**	**1363.12**	**225.88**

3.0 NEAR-FIELD MODELING ANALYSIS

3.1 Overview of the AERMOD Modeling System

Near-field ambient air quality impacts resulting from project-related emissions were quantified using AERMOD (EPA, 2004a and 2012b). AERMOD is a steady-state Gaussian dispersion model designed to simulate the local-scale dispersion of pollutants from low-level or elevated sources in simple or complex terrain. It is an EPA “preferred” model (40 CFR Part 51, Appendix W, Guideline on Air Quality Models). AERMOD version 12345 was used for this application.

The selection of AERMOD for this study was based on the technical formulation and capabilities of the model as well as its extensive use for other source-specific model applications. The dispersion algorithms are based on the fundamental concepts of planetary boundary layer meteorology. The airflow and stability characteristics (e.g., convective versus stable) as well as the vertical structure of the boundary layer are accounted for in simulating dispersion. Numerous features and options accommodate a variety of source types, pollutants, and land-use and topographical features.

The methodologies and results of the application of AERMOD are presented in the remainder of this section.

3.2 Modeling Approach

AERMOD was applied for a five-year simulation period spanning 2006 through 2010. The modeling scenarios were designed to examine the impacts of emissions from both the development and production phases of the NPL project.

3.2.1 Model Options

For this application, AERMOD was run using regulatory default options for the simulation parameters. For NO_2, both the Plume Volume Molar Reaction Model (PVMRM) and Ozone Limiting Method (OLM) modules were tested. Considering the conditions under which some of the highest NO_2 concentration occurred (stable conditions with high NO_x and low to moderate ozone concentrations) the OLM option was selected as better suited to simulating the ground-level NO_2 concentrations. For a given NO_x emission rate and ambient ozone concentration, the conversion of NO to NO_2 for PVMRM is relatively instantaneous (controlled somewhat by the volume of the plume), while that for OLM is more gradual and is controlled by the ground level NO_x and ozone concentrations. Sensitivity tests (Brode, 2004) have demonstrated that OLM tends to be more conservative than PVMRM. For this application, the OLMGROUP ALL option was used to combine plumes and ensure that all sources will potentially compete for the available ozone.

In applying the OLM module, hourly ozone data for the period 2006-2010 for the nearby Boulder monitoring site were used to approximate the rate of conversion of NO to NO_2. The Boulder monitoring site is the nearest site to the Project Area with ozone data for this period. Interpolation methods were used to fill in any missing data. In addition, the following assumptions were used: ambient NO_2/NO_X ratio of 90 percent and in-stack NO_2/NO_X ratio of 10 percent by mass. Data from Wyoming DEQ stack testing reports (WY DEQ, 2010b) support the use of a 10 percent or lower NO_2/NO_X ratio for diesel engines of the type used for rigs. In addition, the San Joaquin Valley Air Pollution Control District

(SJVAPCD) recommends values on the order of 10 percent for a range of different sources (SJVAPCD, 2010).

3.2.2 Pollutants and Averaging Periods

AERMOD was used to examine the impacts of emissions of the following criteria pollutants: PM_{10}, $PM_{2.5}$, NO_2, SO_2 and CO. For each criteria pollutant, the averaging period(s) were based on the relevant National and State of Wyoming Ambient Air Quality Standards (NAAQS and WAAQS). The averaging periods are as follows:

- PM_{10}: 24-hour and annual averaging periods
- $PM_{2.5}$: 24-hour and annual averaging periods
- NO_2: 1-hour and annual averaging periods
- SO_2: 1-hour averaging period
- CO: 1-hour and 8-hour averaging periods

The latest EPA guidance (Fox, 2011) was used to guide the analysis of 1-hour NO_2.

AERMOD was also used to examine the impacts of emissions of the following HAPs: acetaldehyde; acrolein; benzene; ethyl benzene; formaldehyde; methanol; n-hexane; toluene; and xylene. For the HAPs, the modeled concentrations were compared to inhalation unit risk (IUR) factors for carcinogens and reference concentrations (RfCs) or reference exposure levels (RELs) for non-carcinogens. Both short-term and long-term exposures were considered.

3.2.3 Input Preparation

AERMOD requires several input files. The simulation control file specifies which options and features of AERMOD are to be applied, and contains information about the emissions sources (location, emissions rate, stack parameters, etc.) as well as the receptor locations (elevation, topography, and land use). Two meteorological input files provide detailed information about 1) the characteristics of the boundary layer (wind, temperature, stability parameters) and 2) the vertical structure of temperature and wind near the source location.

3.2.3.1. Topographical Data

The terrain in this area consists of rolling hills and is interspersed with buttes. Digital topographical data (in the form of 7.5 minute Digital Elevation Model (DEM) files) for the analysis region were obtained from the U.S. Geological Survey (through Micropath Corporation) and processed for use in AERMOD using the AERMAP preprocessor program (version 11103) (EPA, 2004b and 2011a).

3.2.3.2. Meteorological and Land-Use Data

Meteorological inputs for AERMOD for the years 2006-2010 were developed using observed data from nearby monitoring sites. Specifically, this analysis utilized surface meteorological data from the Big Piney monitoring site and twice-daily upper-air data from Riverton, WY. The data for Big Piney are one-minute-resolution Automated Surface Observing System (ASOS) data and were processed using the AERMINUTE program (version 11325).

The meteorological inputs for AERMOD were then generated using the AERMOD Meteorological Processor (AERMET) program (EPA, 2004c and 2011b). AERMET requires additional information about the land-use characteristics of the area in which the surface meteorological monitoring site is located. This information was obtained using the AERSURFACE preprocessor program (EPA, 2008b). The remaining steps in the preparation of the meteorological inputs included processing of the hourly surface and twice-daily upper-air data, quality assurance of the data, merging of the surface and upper-air data, and application of AERMET to calculate the planetary boundary layer parameters required by AERMOD. In applying AERMET, the methods and reference levels for standard NWS data were employed (EPA, 2004c). Version 11059 of AERMET and version 08009 of AERSURFACE were used for this application. In applying AERMET, the methods and reference levels for standard NWS data were employed (EPA, 2004c). Note that a newer version of the AERMET code was released subsequent to the preparation of the meteorological inputs for the NPL modeling exercise, but, based on the release notes, the changes are not expected to affect the modeling results.

The resulting meteorological inputs consist of two files. The first file includes surface wind, temperature, pressure, relative humidity, and stability information as well as cloud cover and precipitation values. The second file contains information on the vertical structure of temperature and wind near the source location.

3.2.4 Assessment Area and Receptor Grids

The source areas for the near-field modeling include both individual well pads and one-square-mile sections that contain four well pads. The receptor grid for each source area consists of 100 x 100 meter (m) receptor cells starting at 100 m from the source area; these increase to 250 x 250 m and cover a 2500 x 2500 m (2.5 x 2.5 km) area surrounding the source(s). The breakpoints in meters from the well pad are 1000 m for the 100 x 100 m receptor cells and 2500 m for the 250 x 250 m receptor cells. A receptor-exclusion zone that is located 100 meters from the defined edge of the well or well pad area was employed to capture near source modeled impacts. All compressors will be electric with zero emissions so additional receptors with 25 m spacing are not needed. Pollutant impacts were assessed throughout the receptor grid. The HAPs analysis was based on the maximum modeled value within the area covered by to the receptor grid.

The receptor grids are illustrated in Figure 3-1 (a) and (b).

Figure 3-1a. AERMOD Receptor Grid for a Single Well Pad

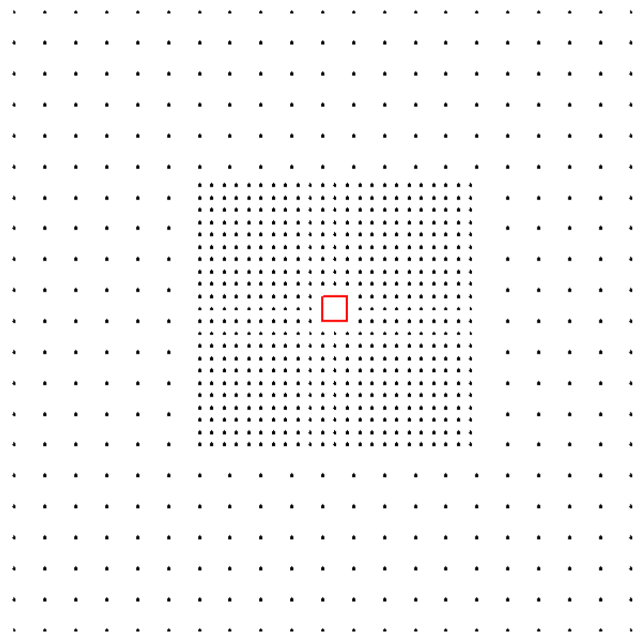
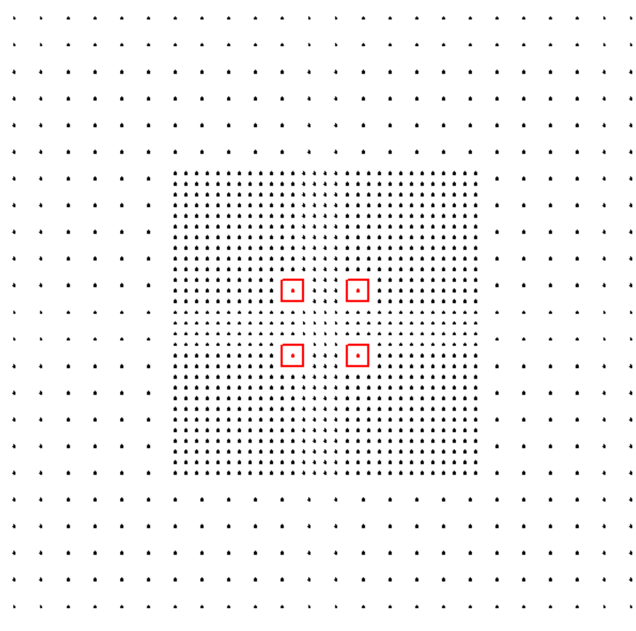


Figure 3-1b. AERMOD Receptor Grid for a Four-Well-Pad Section



3.2.5 Background Air Quality Data

Overall air quality is the sum of the AERMOD-derived impacts plus background pollutant concentrations for the region. The background concentrations were calculated based on EPA guidance (Fox, 2011). Background concentrations were calculated for each pollutant and averaging period listed in Table 3-1, using data from nearby monitoring sites (as specified in the table). The units are micrograms per cubic meter (μg/m^3).

Table 3-1. Averaging Periods and Background Concentrations for Use with the AERMOD Modeling Results

Pollutant	Averaging Period	Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec	Annual
PM_{10}[1]	24-Hour (μg/m^3)	--	--	--	--	32.7
	Annual (μg/m^3)	--	--	--	--	7.8
$PM_{2.5}$[2]	24-Hour (μg/m^3)	10.6	7.6	9.5	10.3	10.2
	Annual (μg/m^3)	--	--	--	--	4.1
NO_2[1]	1-Hour (μg/m^3)	16.3	5.0	6.9	11.3	11.9
	Annual (μg/m^3)	--	--	--	--	0.5
SO_2[3]	1-Hour (μg/m^3)	25.6	14.3	23.6	19.6	22.5
CO[4]	1-Hour (μg/m^3)	--	--	--	--	996
	8-Hour (μg/m^3)	--	--	--	--	790

[1] Background values are based on data collected at the Daniel South, Wyoming monitoring site.
[2] Background values are based on data collected at the Pinedale, Wyoming monitoring site.
[3] Background values are based on data collected at the Wamsutter, Wyoming monitoring site.
[4] Background values are based on data collected at the Murphy Ridge, Wyoming monitoring site.

Note that CO data were available for 2008 only for Murphy Ridge, Wyoming. The values were obtained from the WY DEQ annual summary report (MSI, 2009).

Per EPA guidance, the most recent three years of available data were used. Background concentrations were calculated to be consistent with the form of the standard for each pollutant and averaging time. However, in accordance with EPA guidance, the background values for $PM_{2.5}$, NO_2 and SO_2 may vary by season (in this case, by quarter) and data used to calculate the quarterly averages were selected to approximate the overall form of the standard. For example, the background values for 1-hour NO_2 were based on the 3rd highest value for each quarter, averaged over the three-year period. This is expected to be the quarterly equivalent of the use of the 98th percentile daily maximum 1-hour NO_2, as used for the annual standard. The calculation of background values for $PM_{2.5}$ and SO_2 followed similar procedures.

For this analysis, the quarterly values were used only for NO_2, since the annual results NO_2 were close to or above the NAAQS and the background values showed significant variation among the quarters. The quarterly values, therefore, give additional information about what time of year an exceedance is most likely to occur. According to EPA (Fox, 2011), the use of seasonal background concentrations calculated using this technique should ensure that the monitored contribution to the cumulative impact assessment accounts for meteorological variability, and also reflects worst-case conditions in a manner that is consistent with the probabilistic form of the NO_2 standard.

3.2.6 AERMOD Modeling Scenarios

The modeling platform established for the near-field analysis was used to simulate future-year air quality impacts resulting from project-related emissions. The modeling scenarios were designed to capture the reasonable maximum emissions year impacts for each pollutant for each of the major development phases of the project, namely, construction, drilling/completion, and production. The emissions for each AERMOD modeling scenario were based on the NPL Proposed Action scenario. The modeling scenarios focus on the emissions for one well pad (construction) or for one 640-acre section of the NPL field (drilling and production). For the NPL Proposed Action, it is expected that there would be an average of four multi-well pads per section outside of designated sage-grouse core habitat.

3.2.6.1. Construction Scenarios

Starting in the first year of development (currently planned for 2015), the construction of roads and well pads would take place throughout the expected ten-year development period. Five construction related-scenarios were developed and modeled based on information provided by the operators that on any given day there would be at most one construction crew per section and this crew would perform construction activities related to one of five construction areas: well pad, access road, resource road, pipeline, or other construction. Emissions associated with each of these areas are as follows:

Construction-related emissions associated with well pad construction include:

- Fugitive particulate emissions from well pad construction
- Fugitive particulate emissions from traffic on unpaved roads related to well pad construction
- Wind erosion from well pad construction
- Diesel combustion/tailpipe emissions from heavy equipment related to well pad construction

Construction-related emissions associated with access road construction include:

- Fugitive particulate emissions from access road construction
- Fugitive particulate emissions from traffic on unpaved roads related to access road construction
- Wind erosion from access road construction
- Diesel combustion/tailpipe emissions from heavy equipment related to access road construction

Construction-related emissions associated with resource road construction include:

- Fugitive particulate emissions from resource road construction
- Fugitive particulate emissions from traffic on unpaved roads related to resource road construction
- Wind erosion from resource road construction
- Diesel combustion/tailpipe emissions from heavy equipment related to resource road construction

Construction-related emissions associated with pipeline construction include:

- Fugitive particulate emissions from pipeline construction
- Fugitive particulate emissions from traffic on unpaved roads related to pipeline construction
- Wind erosion from pipeline construction
- Diesel combustion/tailpipe emissions from heavy equipment related to pipeline construction

Construction-related emissions associated with other construction include:

- Fugitive particulate emissions from other (e.g., central facility/compressor station) construction
- Fugitive particulate emissions from traffic on unpaved roads related to other (e.g., central facility/compressor station) construction
- Wind erosion from other (e.g., central facility/compressor station) construction
- Diesel combustion/tailpipe emissions from heavy equipment related to other (e.g., central facility/compressor station) construction

Five reasonable worst-case scenarios were examined. Each scenario included the emissions from each of the emission categories listed above (i.e., fugitive emissions from construction, fugitive emissions from unpaved roads, wind erosion, and diesel combustion/tailpipe emissions from heavy equipment). The emissions levels are consistent with new well pad construction. It was assumed that the worst-case emissions for a given day would be the same for all years during the construction period.

Consistent with the assumption that on any given day there would be at most one construction crew in a section, the construction scenarios were modeled for an individual well pad. The well pad was located in the center of the NPL Project Area, and terrain information for that area was used as input to the AERMOD model. The dimensions of the well pad are 200 x 200 meters and the nearest receptors were located 100 m from the edge of the well pad. The construction sources were treated as area sources, distributed throughout the well pad. Tailpipe emissions from haul vehicles and other large trucks were assigned a release height of 3.5 meters, which is the average height of a haul truck. Based on a recent analysis by the haul road workgroup (EPA, 2012c), fugitive particulate matter emissions from construction traffic were assigned an estimated plume top of 6 meters (1.7 times the height of the truck), a release height of 3 meters (the estimated plume top divided by 2), and an initial vertical plume width of 2.8 meters (the estimated plume top divided by 2.15) in order to account for mechanical turbulence. Since all of the construction activities have an elapsed time of 12 hours per day or less, total emissions were calculated for a reasonable worst-case day and distributed across the daytime hours (7 am to 7 pm).

Criteria pollutant emissions for the construction scenarios are summarized in Table 3-2. The total emissions for each scenario include worst-case emissions for one day for each of the activities listed above under the scenario.

Table 3-2. AERMOD Construction Scenario Emissions

Scenario	Pollutant	Emissions	
		(lbs/hour)	*(tons/year)**
Well Pad Construction	PM_{10}	3.0	13.2
	$PM_{2.5}$	0.6	2.5
	NO_2	4.2	18.3
	SO_2	0.1	0.5
	CO	1.7	7.3
Pipeline Construction	PM_{10}	1.5	6.6
	$PM_{2.5}$	0.7	3.2
	NO_2	6.4	27.9
	SO_2	0.2	0.7
	CO	4.0	17.4
Resource Road Construction	PM_{10}	3.3	14.3
	$PM_{2.5}$	0.6	2.6
	NO_2	4.1	18.0
	SO_2	0.1	0.5
	CO	1.6	7.0
Access Road Construction	PM_{10}	0.3	1.3
	$PM_{2.5}$	0.0	0.1
	NO_2	0.0	0.0
	SO_2	0.0	0.0
	CO	0.2	0.7
Other Construction	PM_{10}	1.2	5.4
	$PM_{2.5}$	0.4	1.7
	NO_2	4.1	18.2
	SO_2	0.1	0.5
	CO	1.6	7.2

*Tons per year equivalent; most construction activities last for 2-10 days.

Note that emissions for several source types were assigned to the resource road construction category and not to access road construction, the emissions for resource roads are overstated while those for access road construction are understated, but together they provide the range of impacts associated with road construction.

Assessment of the modeling results for the construction scenarios focused on short-term air quality impacts, ranging from one to 24 hours, and for the following criteria pollutants: PM_{10}, $PM_{2.5}$, NO_2, SO_2 and CO. Annual impacts (estimated using worst-case emissions for all calendar days for a full year) were also considered, but these are overestimates since most of the construction activities were limited to 10 or fewer days per well.

3.2.6.2. Well Drilling Activities

Starting in the first year of development well drilling activities would ramp up during the first four years of the ten-year development period, and then remain constant until the final two years of the period. Emissions associated well-drilling activities are as follows:

- Fugitive particulate emissions from traffic on unpaved roads related to drilling
- Fugitive particulate emissions from traffic on unpaved roads related to rig moving
- Diesel combustion/tailpipe emissions from heavy equipment related to drilling
- Diesel combustion/tailpipe emissions from haul trucks related to rig moving
- Combustion emissions from drilling engines
- Diesel combustion emissions from hydraulic fracturing/other completion engines
- Well completion emissions
- Fugitive particulate emissions from traffic on unpaved roads related to completion/testing
- Diesel combustion/tailpipe emissions from heavy equipment related to completion/testing

A reasonable worst-case scenario was examined in which it was assumed that a maximum of two wells would be drilled and two other wells would be completed at one time within a given section. For this scenario, based on guidance provided by the operators, drilling emissions were allocated to two of the well pads and completion emissions were allocated to the other two well pads within the section. The drilling scenarios were modeled for a four-well-pad section. The section was located in the center of the NPL Project Area, and terrain information for that area was used as input to the AERMOD model. The nearest receptors were located 100 m from the edge of the each well pad.

Drilling emissions included emissions from the first five categories listed above, and completion emissions included emissions from the remaining four categories. Drill rigs and well-site combustion equipment were treated as point sources, and the remaining sources were treated as area sources, distributed throughout the well pad. Tailpipe emissions from haul vehicles and other large trucks were assigned a release height of 3.5 meters, which is the average height of a haul truck. Similarly, in accordance with AERMOD modeling guidance, particulate matter emissions from drilling traffic were assigned a release height of 3 meters and an initial vertical plume width of 2.8 meters (the plume height divided by 2.15) in order to account for mechanical turbulence. For those activities (including most drilling activities) that occur 24 hours per day the total emissions were calculated for the worst day and distributed across all hours of the days. For those activities that have an elapsed time of less than 24 hours per day, total emissions were calculated for the worst-case day and distributed across the daytime hours (7 am to 7 pm).

The emissions levels are consistent with drilling on a new well pad. The worst-case emissions for a given day are the same for the third through the tenth year of development during which drilling at a planned average rate of 350 wells per year is occurring.

Criteria pollutant and HAPs emissions for the drilling and completion scenario are summarized in Table 3-3. The emissions are provided separately for drilling and completion activities and are both for one well on a day during which these activities occur. As discussed earlier in this section, the AERMOD scenario included drilling of two wells and completion of two wells – so the input emissions are double those given in the table.

Table 3-3. AERMOD Drilling and Completion Scenario Emissions

Activity	Pollutant	Emissions (per well)	
		(lbs/hour)	*(tons/year)**
Drilling	PM_{10}	0.4	2.0
	$PM_{2.5}$	0.1	0.6
	NO_2	6.2	27.4
	SO_2	0.0	0.2
	CO	12.7	55.7
	VOC	0.7	3.1
	Acetaldehyde	0.042	0.183
	Acrolein	0.025	0.111
	Benzene	0.006	0.025
	Ethyl benzene	0.000	0.002
	Formaldehyde	0.823	3.606
	Methanol	0.013	0.057
	n-Hexane	0.013	0.057
	Toluene	0.005	0.022
	Xylene	0.002	0.010
Completion	PM_{10}	7.8	34.0
	$PM_{2.5}$	1.5	6.7
	NO_2	21.0	91.9
	SO_2	1.0	4.3
	CO	4.6	20.2
	VOC	1.0	4.5
	Acetaldehyde	0.012	0.055
	Acrolein	0.002	0.007
	Benzene	0.014	0.063
	Ethyl benzene	0.000	0.000
	Formaldehyde	0.018	0.080
	Methanol	0.000	0.000
	n-Hexane	0.000	0.001
	Toluene	0.006	0.028
	Xylene	0.004	0.019

*Tons per year equivalent; most drilling and completion activities last for approximately 5 to 20 days.

Assessment of the modeling results for the production scenario focused on both short-term air quality impacts, ranging from one to 24 hours, and annual impacts. Both criteria pollutants (PM_{10}, $PM_{2.5}$, NO_2, SO_2 and CO) and HAPs were considered.

3.2.6.3. Production Operations

Starting in the first year of development, and similar to well drilling activities, production activities would ramp up during the first several years of the ten-year development period, and then would increase moderately and peak out during the final four years of the period, when the field has been fully developed. AERMOD was applied using the worst-case emissions for a given year during which production is occurring. For the criteria pollutants, the emissions are greatest for the last year of the ten-year development period, although several reach the maximum value earlier and stay the same for the remainder of the period. For VOCs and HAPs, the production emissions are greatest for the last year of development. Production related emissions include:

- Fugitive particulate emissions from traffic on unpaved roads related to production (not including tanker trucks)
- Fugitive particulate emissions from traffic on unpaved roads related to tanker trucks
- Diesel combustion/tailpipe emissions from heavy equipment related to production (not including tanker trucks)
- Diesel combustion/tailpipe emissions from heavy equipment related to tanker trucks
- Wind erosion emissions related to production
- Combustion emissions from compressor engines related to production
- Natural gas combustion emissions from miscellaneous engines related to production
- Dehydrator emissions related to production
- Pneumatic emissions related to production
- Fugitive VOC/HAPs emissions related to production
- Condensate storage tank emissions related to production
- Condensate loading emissions related to production
- Passenger vehicle emissions related to production

A reasonable worst-case scenario was examined in which the emissions were based on four (4) well pads (the maximum number to fit within one square mile based on a well-pad spacing of 160 acres (or 0.25 square miles) and 16 wells per pad (the maximum number of wells per pad). Thus the total number of wells included in the modeling is 64. The wells were evenly distributed across the well pads and the well pads were evenly distributed within the section, according to the well pad spacing criteria.

The production scenario was modeled for a four-well pad section. The section was located in the center of the NPL Project Area, and terrain information for that area was used as input to the AERMOD model. The nearest receptors were located 100 m from the edge of the each well pad. A majority of the engines used for production will be electric and will have zero emissions; the remaining sources included in the production scenario were treated as area sources, distributed throughout the four well pads. Tailpipe emissions from tanker trucks were assigned a release height of 3.5 meters particulate matter emissions from tanker truck traffic were assigned a release height of 3 meters and an initial vertical plume width of 2.8 meters. Production activities occur 24 hours per day and the daily total emissions were distributed accordingly.

Criteria pollutant and HAPs emissions for the production scenario are summarized in Table 3-4. The total emissions are for 64 wells distributed across four well pads as well as a portion of the emissions from one of the regional gathering facilities (RGFs). Eleven RGFs would be constructed in densely drilled portions of the NPL Project Area to separate and store liquids from the natural gas stream. Each fully operational RGF would include liquids separation and gas dehydration equipment, gas compression facilities, water injection wells and pumps, water and condensate storage tank batteries, liquids handling and offloading facilities, as well as electrical transformers, and power control facilities. To minimize air emissions, electric compression would be used at each RGF, powered by high-voltage distribution lines. Based on information provided by the operators, each facility is expected to service

20 well pads, so one-fifth of the emissions from the facility were included in the production emissions for the four-well-pad area. No larger centralized facilities are planned. Note that no emissions were available for acetaldehyde, acrolein or methanol and these emissions were assumed to be zero for the production scenario.

Table 3-4. AERMOD Production Scenario Emissions

Activity	Pollutant	Emissions (per 4-well pad section)	
		(lbs/hour)	*(tons/year)**
Production	PM_{10}	0.4	1.6
	$PM_{2.5}$	0.0	0.2
	NO_2	0.0	0.0
	SO_2	0.0	0.0
	CO	0.0	0.1
	VOC	0.1	0.6
	Benzene	0.001	0.004
	Ethyl benzene	0.000	0.000
	Formaldehyde	0.000	0.000
	n-Hexane	0.003	0.011
	Toluene	0.002	0.007
	Xylene	0.001	0.004

Assessment of the modeling results for the production scenario focused both short-term air quality impacts, ranging from one to 24 hours, and annual impacts. Both criteria pollutants (PM_{10}, $PM_{2.5}$, NO_2, SO_2 and CO) and HAPs were considered.

3.2.6.4. Combination Scenario

A combination scenario was examined in which the timing of the various activities was accounted for. This scenario assumed:

- Construction activity (well pad construction; one well pad at a time) during the first year
- Drilling and completion (drilling of one well on two well pads; completion of one well on two well pads) during the second year
- Production occurring on all four well pads (64 wells total) during the third through fifth years

For this scenario, the AERMOD results for each year/activity were combined and used to calculate the air quality metrics (e.g., three-year averages). All simultaneous activities were modeled together. The results overestimate the potential impacts, since the maximum values for each scenario were used in calculating the multi-year averages and were assumed to be collocated. In fact, the maximum values occur at different locations for the different scenarios. This combination scenario focused on both short-term and annual air quality impacts for criteria pollutants.

Since the impacts for any combination scenario involving concurrent activities on the individual well pads are expected to be less than those of the drilling and completion scenario (i.e., they do not represent a worst case) they were not modeled.

3.3 Criteria Pollutant Modeling and Impact Assessment

The AERMOD-derived impacts were added to representative background air quality concentrations (presented in Section 3.4) and compared to both the NAAQS and applicable WAAQS. These standards are summarized in Table 3-5. Units are µg/m3 and parts per billion (ppb).

Table 3-5. Summary of Ambient Air Quality Standards

Pollutant (Units)	Averaging Period	NAAQS	WAAQS
PM_{10} (µg/m^3)	24-hour[1]	150	150
	Annual[2]	--	50
$PM_{2.5}$ (µg/m^3)	24-hour[3]	35	35
	Annual[4]	12	12
Ozone (ppb)	8-hour[5]	70	70
NO_2 (µg/m^3)	1-hour[6]	188	188
	Annual[2]	100	100
SO_2 (µg/m^3)	1-hour[7]	196	196
CO (µg/m^3)	1-hour[8]	40,000	40,000
	8-hour[8]	10,000	10,000

[1] Not to be exceeded more than once per year on average over 3 years.
[2] Not to be exceeded.
[3] The three-year average of the 98th percentile 24-hour average concentration must not exceed this standard.
[4] The three-year average of the annual average concentration must not exceed this standard.
[5] To attain this standard, the 3-year average of the fourth-highest daily maximum 8-hour average O3 concentration measured at each monitor within an area over each year must not exceed 70 ppb.
[6] The 3-year average of the 98th percentile of the daily maximum 1-hour average is not to exceed this standard.
[7] The 3-year average of the 99th percentile of the daily maximum 1-hour average must not exceed this standard.
[8] Not to be exceeded more than once per year.

The AERMOD-derived impacts for the production scenario were also compared with applicable PSD increments for designated Class I and Class II areas. All comparisons to the PSD increments are intended to evaluate a threshold of concern and do not represent a regulatory PSD Increment Consumption Analysis.

The concentrations presented in the remainder of this section represent the maximum values for the receptor grid consistent with the form of each standard, paired in space and averaged, as appropriate, over multiple years in accordance with the form of the NAAQS/WAAQS. In most cases, the maximum value occurs at the first row of receptors (100 m from the source). If the modeled value is greater than an applicable standard, the distance at which concentration is lower than the standard is also presented.

3.3.1 Construction Scenario Results

Results for the criteria pollutants for the construction scenarios are compared with the NAAQS and WAAQS in Tables 3-6 through 3-10. The AERMOD-derived concentrations presented in these tables have been paired in space and averaged, as appropriate, over multiple years in accordance with the form of the NAAQS/WAAQS. Concentrations that are greater than either the NAAQS or the WAAQS are highlighted in bold. Concentration units for all pollutants are µg/m^3. As noted earlier in this section, both annual and quarterly background values were used for the analysis of 1-hour NO_2. Annual results are presented in the first part of each table and quarterly results are presented in the second part of each table.

Table 3-6a. AERMOD-Derived Criteria Pollutant Impacts Calculated Using Annual Background Concentrations: Well-Pad Construction Scenario

Pollutant (Units)	Averaging Period	AERMOD-Derived Concentration (µg/m³)	Background Concentration (µg/m³)	Total AERMOD-Derived + Background Concentration (µg/m³)	NAAQS	WAAQS
PM_{10} (µg/m³)	24-hour	88.4	32.7	121.1	150	150
	Annual	6.8	7.8	14.6	--	50
$PM_{2.5}$ (µg/m³)	24-hour	6.6	10.2	16.8	35	35
	Annual	0.8	4.1	4.9	12	12
NO_2 (µg/m³)	1-hour	98.9	11.9	110.8	188	188
	Annual	4.4	0.5	4.9	100	100
SO_2 (µg/m³)	1-hour	13.0	22.5	35.5	196	196
CO (µg/m³)	1-hour	281	996	1,277	40,000	40,000
	8-hour	78	790	868	10,000	10,000

Table 3-6b. AERMOD-Derived 1-Hour NO_2 Impacts Calculated Using Quarterly Background Concentrations: Well-Pad Construction Scenario

Pollutant (Units)	Averaging Period	AERMOD-Derived Concentration (µg/m³)	Background Concentration (µg/m³)	Total AERMOD-Derived + Background Concentration (µg/m³)*
1-hour NO_2 (µg/m³)	Jan-Mar	129.4	16.3	145.7
	Apr-Jun	68.2	5.0	73.2
	Jul-Sep	78.2	6.9	85.1
	Oct-Dec	91.5	11.3	102.8

*Note that the NAAQS (and WAAQS) for 1-hour NO_2 is 188 µg/m³.

Table 3-7a. AERMOD-Derived Criteria Pollutant Impacts Calculated Using Annual Background Concentrations: Pipeline Construction Scenario

Pollutant (Units)	Averaging Period	AERMOD-Derived Concentration (µg/m³)	Background Concentration (µg/m³)	Total AERMOD-Derived + Background Concentration (µg/m³)	NAAQS	WAAQS
PM_{10} (µg/m³)	24-hour	41.1	32.7	73.8	150	150
	Annual	3.2	7.8	11.0	--	50
$PM_{2.5}$ (µg/m³)	24-hour	8.0	10.2	18.2	35	35
	Annual	1.9	4.1	6.0	12	12
NO_2 (µg/m³)	1-hour	120.0	11.9	131.9	188	188
	Annual	5.7	0.5	6.2	100	100
SO_2 (µg/m³)	1-hour	16.3	22.5	38.8	196	196
CO (µg/m³)	1-hour	668	996	1,664	40,000	40,000
	8-hour	185	790	975	10,000	10,000

Table 3-7b. AERMOD-Derived NO_2 Impacts Calculated Using Quarterly Background Concentrations: Pipeline Construction Scenario

Pollutant (Units)	Averaging Period	AERMOD-Derived Concentration (µg/m³)	Background Concentration (µg/m³)	Total AERMOD-Derived + Background Concentration (µg/m³)*
1-hour NO_2 (µg/m³)	Jan-Mar	145.3	16.3	161.6
	Apr-Jun	76.7	5.0	81.7
	Jul-Sep	92.9	6.9	99.8
	Oct-Dec	110.7	11.3	122.0

*Note that the NAAQS (and WAAQS) for 1-hour NO_2 is 188 µg/m³.

Table 3-8a. AERMOD-Derived Criteria Pollutant Impacts Calculated Using Annual Background Concentrations: Resource Road Construction Scenario

Pollutant (Units)	Averaging Period	AERMOD-Derived Concentration (μg/m³)	Background Concentration (μg/m³)	Total AERMOD-Derived + Background Concentration (μg/m³)	NAAQS	WAAQS
PM_{10} (μg/m³)	24-hour	97.6	32.7	130.3	150	150
	Annual	7.4	7.8	15.2	--	50
$PM_{2.5}$ (μg/m³)	24-hour	6.9	10.2	17.1	35	35
	Annual	0.9	4.1	5.0	12	12
NO_2 (μg/m³)	1-hour	98.2	11.9	110.1	188	188
	Annual	4.4	0.5	4.9	100	100
SO_2 (μg/m³)	1-hour	12.9	22.5	35.4	196	196
CO (μg/m³)	1-hour	270	996	1,266	40,000	40,000
	8-hour	75	790	865	10,000	10,000

Table 3-8b. AERMOD-Derived NO_2 Impacts Calculated Using Quarterly Background Concentrations: Resource Road Construction Scenario

Pollutant (Units)	Averaging Period	AERMOD-Derived Concentration (μg/m³)	Background Concentration (μg/m³)	Total AERMOD-Derived + Background Concentration (μg/m³)*
1-hour NO_2 (μg/m³)	Jan-Mar	128.9	16.3	145.2
	Apr-Jun	67.9	5.0	72.9
	Jul-Sep	77.7	6.9	84.6
	Oct-Dec	90.8	11.3	102.1

*Note that the NAAQS (and WAAQS) for 1-hour NO_2 is 188 μg/m³.

Table 3-9a. AERMOD-Derived Criteria Pollutant Impacts Calculated Using Annual Background Concentrations: Access Road Construction Scenario

Pollutant (Units)	Averaging Period	AERMOD-Derived Concentration (µg/m^3)	Background Concentration (µg/m^3)	Total AERMOD-Derived + Background Concentration (µg/m^3)	NAAQS	WAAQS
PM_{10} (µg/m^3)	24-hour	9.8	32.7	42.5	150	150
	Annual	0.7	7.8	8.5	--	50
$PM_{2.5}$ (µg/m^3)	24-hour	0.4	10.2	10.6	35	35
	Annual	0.1	4.1	4.2	12	12
NO_2 (µg/m^3)	1-hour	0.1	11.9	12.0	188	188
	Annual	0.0	0.5	0.5	100	100
SO_2 (µg/m^3)	1-hour	0.0	22.5	22.5	196	196
CO (µg/m^3)	1-hour	35	996	1,031	40,000	40,000
	8-hour	9	790	799	10,000	10,000

Table 3-9b. AERMOD-Derived NO_2 Impacts Calculated Using Quarterly Background Concentrations: Access Road Construction Scenario

Pollutant (Units)	Averaging Period	AERMOD-Derived Concentration (µg/m^3)	Background Concentration (µg/m^3)	Total AERMOD-Derived + Background Concentration (µg/m^3)*
1-hour NO_2 (µg/m^3)	Jan-Mar	0.1	16.3	16.4
	Apr-Jun	0.1	5.0	5.2
	Jul-Sep	0.1	6.9	7.0
	Oct-Dec	0.1	11.3	11.4

*Note that the NAAQS (and WAAQS) for 1-hour NO_2 is 188 µg/m^3.

Table 3-10a. AERMOD-Derived Criteria Pollutant Impacts Calculated Using Annual Background Concentrations: Other Construction Scenario

Pollutant (Units)	Averaging Period	AERMOD-Derived Concentration (µg/m³)	Background Concentration (µg/m³)	Total AERMOD-Derived + Background Concentration (µg/m³)	NAAQS	WAAQS
PM_{10} (µg/m³)	24-hour	37.1	32.7	69.8	150	150
	Annual	2.8	7.8	10.6	--	50
$PM_{2.5}$ (µg/m³)	24-hour	4.5	10.2	14.7	35	35
	Annual	0.6	4.1	4.7	12	12
NO_2 (µg/m³)	1-hour	98.5	11.9	110.4	188	188
	Annual	4.4	0.5	4.9	100	100
SO_2 (µg/m³)	1-hour	12.9	22.5	35.4	196	196
CO (µg/m³)	1-hour	276	996	1,272	40,000	40,000
	8-hour	77	790	867	10,000	10,000

Table 3-10b. AERMOD-Derived NO_2 Impacts Calculated Using Quarterly Background Concentrations: Other Construction Scenario

Pollutant (Units)	Averaging Period	AERMOD-Derived Concentration (µg/m³)	Background Concentration (µg/m³)	Total AERMOD-Derived + Background Concentration (µg/m³)
1-hour NO_2 (µg/m³)	Jan-Mar	129.1	16.3	145.4
	Apr-Jun	68.1	5.0	73.1
	Jul-Sep	77.9	6.9	84.8
	Oct-Dec	91.1	11.3	102.4

*Note that the NAAQS (and WAAQS) for 1-hour NO_2 is 188 µg/m³.

In applying AERMOD, it was assumed that construction activities occur every day of the year. This is necessary to capture the worst-case impacts, but, as a result, the annual average impacts are likely overstated. Similarly, calculation of the multi-year average air quality metrics assumed that all construction on a given well pad would be completed within a two-year period. If construction is completed within one year (this is likely), these metrics are also likely to be overestimated.

Using the annual background concentrations, the modeled plus background values for all criteria pollutants and time periods are less than the NAAQS and WAAQS thresholds. Using the quarterly background concentrations the 1-hour daily maximum NO_2 concentrations are also less than the NAAQS. The values for the first quarter of the year (January through March) are about 35 to 60 percent higher than the overall annual values, indicating that many of the high 1-hour NO_2 values occur during this period.

3.3.2 Drilling Scenario Results

Results for the criteria pollutants for the drilling and completion scenario are compared with the NAAQS and WAAQS in Table 3-11. The AERMOD-derived concentrations presented in this table have been paired in space and averaged, as appropriate, over multiple years in accordance with the form of the NAAQS/WAAQS. Concentrations that are greater than either the NAAQS or the WAAQS are highlighted in bold. Concentration units for all pollutants are µg/m^3.

Table 3-11a. AERMOD-Derived Criteria Pollutant Impacts Calculated Using Annual Background Concentrations: Drilling and Completion Scenario

Pollutant (Units)	Averaging Period	AERMOD-Derived Concentration (µg/m^3)	Background Concentration (µg/m^3)	Total AERMOD-Derived + Background Concentration (µg/m^3)	NAAQS	WAAQS
PM_{10} (µg/m^3)	24-hour	477.1	32.7	**509.8**	150	150
	Annual	75.1	7.8	**82.9**	--	50
$PM_{2.5}$ (µg/m^3)	24-hour	21.4	10.2	31.6	35	35
	Annual	5.4	4.1	9.5	12	12
NO_2 (µg/m^3)	1-hour	104.5	11.9	116.4	188	188
	Annual	24.0	0.5	24.5	100	100
SO_2 (µg/m^3)	1-hour	25.0	22.5	47.5	196	196
CO (µg/m^3)	1-hour	344	996	1340	40,000	40,000
	8-hour	153	790	943	10,000	10,000

Table 3-11b. AERMOD-Derived NO_2 Impacts Calculated Using Quarterly Background Concentrations: Drilling and Completion Scenario

Pollutant (Units)	Averaging Period	AERMOD-Derived Concentration (µg/m^3)	Background Concentration (µg/m^3)	Total AERMOD-Derived + Background Concentration (µg/m^3)*
1-hour NO_2 (µg/m^3)	Jan-Mar	113.5	16.3	129.8
	Apr-Jun	100.9	5.0	105.9
	Jul-Sep	97.4	6.9	104.3
	Oct-Dec	102.4	11.3	113.7

*Note that the NAAQS (and WAAQS) for 1-hour NO_2 is 188 µg/m^3.

Calculation of the multi-year average air quality metrics assumed that all drilling and completion activities on a given section would be completed within a two-year period. If drilling and completion are completed within one year, these metrics are likely to be overestimated.

The resultant 24-hour PM_{10} concentration is greater than both the NAAQS and WAAQS thresholds. The maximum modeled value occurs 100 meters to the west of the center portion of the northeastern well pad – in between two well pads. There are several other receptors in between well pads for which the concentrations are greater than 150 µg/m^3. Outside of the four-well-pad area the maximum modeled concentration is 222 µg/m^3 and occurs 100 meters to the southwest of the southwestern corner of the southeastern well pad. At a distance of 200 m the modeled value falls to 118 µg/m^3 which when added to the background value of 32.7 µg/m^3 results in an overall value of 150.7 µg/m^3. Thus the resultant value is at the NAAQS and WAAQS at a distance of 200 m from the source, and below the NAAQS at 300 m from the source.

The modeled plus background values for all other criteria pollutants and time periods are less than the NAAQS and WAAQS thresholds. The quarterly NO_2 values show that the highest NO_2 concentrations occur during the first quarter (January through March).

3.3.3 Production Scenario Results

Results for the criteria pollutants for the production scenario are compared with the NAAQS and WAAQS in Table 3-12. Again, the AERMOD-derived concentrations presented in this table have been paired in space and averaged, as appropriate, over multiple years in accordance with the form of the NAAQS/WAAQS. Concentrations that are greater than either the NAAQS or the WAAQS are highlighted in bold. Concentration units for all pollutants are µg/m^3.

Table 3-12. AERMOD-Derived Criteria Pollutant Impacts Calculated Using Annual Background Concentrations: Production Scenario

Pollutant (Units)	Averaging Period	AERMOD-Derived Concentration (µg/m^3)	Background Concentration (µg/m^3)	Total AERMOD-Derived + Background Concentration (µg/m^3)	NAAQS	WAAQS
PM_{10} (µg/m^3)	24-hour	7.5	32.7	40.2	150	150
	Annual	1.2	7.8	9.0	--	50
$PM_{2.5}$ (µg/m^3)	24-hour	0.5	10.2	10.7	35	65
	Annual	0.1	4.1	4.2	12	12
NO_2 (µg/m^3)	1-hour	0.5	11.9	12.4	188	188
	Annual	0.0	0.5	0.5	100	100
SO_2 (µg/m^3)	1-hour	0.0	22.5	22.5	196	196
CO (µg/m^3)	1-hour	1	996	997	40,000	40,000
	8-hour	1	790	791	10,000	10,000

The modeled plus background values for all criteria pollutants and time periods are less than the NAAQS and WAAQS thresholds. Most of the engines used in production are electric and this accounts for the low criteria pollutant emissions of NO_x, SO_2, and CO.

Results for the production scenario are compared with applicable PSD consumption increments in Table 3-13. No concentrations are greater than the PSD increments.

Table 3-13. Comparison of AERMOD-Derived Criteria Pollutant Impacts with Applicable PSD Consumption Increments: Production Scenario

Pollutant (Units)	Averaging Period	AERMOD-Derived Concentration (µg/m³)	PSD Class II Increment
PM_{10} (µg/m³)	24-hour	7.5	30
	Annual	1.2	17
$PM_{2.5}$ (µg/m³)	24-hour	0.5	8
	Annual	0.1	4
NO_2 (µg/m³)	1-hour	0.5	--
	Annual	0.0	25
SO_2 (µg/m³)	1-hour	0.0	--
CO (µg/m³)	1-hour	1	--
	8-hour	1	--

3.3.4 Combination Scenario Results

For the combination scenario, the timing of the activities was examined and the AERMOD results for each year/activity were combined and used to calculate the air quality metrics. Note that the maximum values for each scenario were used in calculating the multi-year averages, and that these are not necessarily paired in space.

Results for the criteria pollutants for the combination scenario are compared with the NAAQS and WAAQS in Table 3-14 (a) and (b). Concentrations that are greater than either the NAAQS or the WAAQS are highlighted in bold. Concentration units for all pollutants are µg/m³.

Table 3-14a. AERMOD-Derived Criteria Pollutant Impacts Calculated Using Annual Background Concentrations: Combination Scenario

Pollutant (Units)	Averaging Period	AERMOD-Derived Concentration ($\mu g/m^3$)	Background Concentration ($\mu g/m^3$)	Total AERMOD-Derived + Background Concentration ($\mu g/m^3$)	NAAQS	WAAQS
PM_{10} ($\mu g/m^3$)	24-hour	**287.6**	32.7	**320.3**	150	150
	Annual	**75.1**	7.8	**82.9**	--	50
$PM_{2.5}$ ($\mu g/m^3$)	24-hour	12.5	10.2	22.7	35	35
	Annual	3.2	4.1	7.3	12	12
NO_2 ($\mu g/m^3$)	1-hour	93.1	11.9	105.0	188	188
	Annual	18.7	0.5	19.2	100	100
SO_2 ($\mu g/m^3$)	1-hour	17.0	22.5	39.5	196	196
CO ($\mu g/m^3$)	1-hour	345	996	1,341	40,000	40,000
	8-hour	145	790	935	10,000	10,000

Table 3-14b. AERMOD-Derived NO_2 Impacts Calculated Using Quarterly Background Concentrations: Combination Scenario

Pollutant (Units)	Averaging Period	AERMOD-Derived Concentration ($\mu g/m^3$)	Background Concentration ($\mu g/m^3$)	Total AERMOD-Derived + Background Concentration ($\mu g/m^3$)*
1-hour NO_2 ($\mu g/m^3$)	Jan-Mar	102.2	16.3	118.5
	Apr-Jun	78.5	5.0	83.5
	Jul-Sep	82.7	6.9	89.6
	Oct-Dec	93.8	11.3	105.1

*Note that the NAAQS (and WAAQS) for 1-hour NO_2 is 188 $\mu g/m^3$.

The modeled 24-hour and annual PM_{10} concentrations are greater than both the NAAQS and WAAQS thresholds, due primarily to the emissions associated with drilling and completion that is assumed to occur for one year of the three-year averaging period.

3.4 HAP Modeling and Impact Assessment

AERMOD was also used to simulate airborne concentrations of HAPs, and the resulting concentrations were used to assess the risks associated with both short-term and long-term exposures to the various hazardous and toxic air pollutants. Based on the available emissions data, the following HAPs were considered: benzene; ethyl benzene; formaldehyde; n-hexane; toluene; and xylene. Acetaldehyde, acrolein, and methanol are also considered for the drilling scenario only.

For modeling purposes, HAP emissions were represented in AERMOD using a unit emission rate (i.e., 1 gram per second) for each modeled source. The impacts were then scaled by the maximum emission rates for each source to estimate the concentrations of each pollutant. The resulting concentrations were compared to established IUR factors for carcinogens and RfCs or RELs for non-carcinogens. Both short-term and long-term exposures were considered. The HAPs analysis considered the maximum modeled values within the area covered by the receptor grid.

Short-term (1-hour) air toxic impacts calculated by AERMOD were compared to the acute RELs shown in Table 3-15. Acute RELs are defined as concentrations at or below which no adverse health effects are expected. Since there are no established RELs for ethyl benzene or n-hexane, Immediately Dangerous to Life or Health (IDLH) values (IDLH/10) will be used. These IDLH values are determined by the National Institute for Occupational Safety and Health and were obtained from EPA's Air Toxics Database (EPA, 2007a). Units are milligrams per cubic meter (mg/m^3).

Table 3-15. Acute Reference Exposure Levels (REL) or Immediately Dangerous to Life or Health (IDLH) for Selected Hazardous Air Pollutants (HAPs)

HAP	REL or IDLH/10 (mg/m^3)
Acetaldehyde	0.47
Acrolein	0.0025
Benzene	1.3
Ethyl benzene	350*
Formaldehyde	0.055
Methanol	28
n-Hexane	390*
Toluene	37
Xylene	22

Source: EPA 2010 (http://www.epa.gov/ttn/atw/toxsource/table2.pdf)

* IDLH/10

Long-term inhalation exposure to non-carcinogenic air toxics (based on annual average pollutant concentrations) was calculated using the AERMOD results and compared to RfCs for chronic inhalation of non-carcinogenic hazardous air pollutants, as listed in Table 3-16 (EPA, 2007a). The RfC for a given pollutant is defined as the threshold at or below which no long-term adverse health effects are expected. Units are mg/m^3.

Table 3-16. Non-Carcinogenic Chronic Reference Concentration (RfC) for Selected Hazardous Air Pollutants

HAP	RfC (mg/m^3)
Acetaldehyde	0.009
Acrolein	0.00002
Benzene	.03
Ethyl benzene	1
Formaldehyde	.01
Methanol	4
n-Hexane	0.7
Toluene	5
Xylene	0.1

Source: EPA, 2010 (http://www.epa.gov/ttn/atw/toxsource/table1.pdf)

Finally, the AERMOD results were also used to estimate the cancer risk associated with exposure to carcinogenic hazardous air pollutants. To estimate the incremental inhalation cancer risk for each toxic pollutant, annual modeled concentrations were multiplied by the EPA's IUR factors presented in Table 3-17. These are estimates of the cancer risk (on a per unit concentration unit basis) based on 70-year exposure to the carcinogenic toxic air pollutants. For example, an IUR of 7.8E-6 for benzene is equivalent to a cancer risk of 7.8 per million per $\mu g/m^3$. Each IUR is based on continuous exposure for 70 years. Although it is standard practice to adjust the IUR to reflect exposure time for specific receptor types, this was not done as part of this study since no clear receptors were identified. Thus the results represent the maximum risk, and depending upon receptor type the results would be lower.

Table 3-17. Carcinogenic Inhalation Unit Risk (IUR) Factors Selected Hazardous Air Pollutants

HAP	IUR $1/(\mu g/m^3)$
Benzene	7. 8E-6
Ethyl benzene	2.5E-6
Formaldehyde	1.3E-5

Source: EPA, 2010 (http://www.epa.gov/ttn/atw/toxsource/table1.pdf)

3.4.1 Drilling Scenario Results (HAPs)

3.4.1.1. Short-Term Impacts

AERMOD-derived maximum 1-hour air toxic impacts for the drilling scenario are compared to acute RELs and IDLH/10 values in Table 3-18. The maximum value occurs 100 meters north from the center portion of the northeast well pad. No concentrations are greater than the RELs or IDLH/10 values. Units are milligrams per cubic meter (mg/m^3).

Table 3-18. Comparison of Short-Term AERMOD-Derived HAPs Impacts with RELs and IDLH/10 Values: Drilling Scenario

Pollutant (Units)	AERMOD-Derived Concentration (mg/m^3)	REL or IDLH/10 (mg/m^3)
Acetaldehyde	9.73E-05	0.47
Acrolein	1.18E-05	0.0025
Benzene	1.26E-04	1.3
Ethyl benzene	3.83E-07	350
Formaldehyde	1.59E-04	0.055
Methanol	5.07E-08	28
n-Hexane	2.86E-05	390
Toluene	6.12E-05	37
Xylene	3.96E-05	22

Long-term impacts were not calculated for the drilling scenario.

3.4.2 Production Scenario Results (HAPs)

3.4.2.1. Short-Term Impacts

AERMOD-derived maximum 1-hour air toxic impacts for the production scenario are compared to acute RELs and IDLH values in Table 3-19. The maximum value occurs 100 meters west of the center portion of the southwestern well pad. No concentrations are greater than the RELs or IDLH/10 values. Units are milligrams per cubic meter (mg/m^3).

Table 3-19. Comparison of Short-Term AERMOD-Derived HAPs Impacts with RELs and IDLH/10 Values: Production Scenario

Pollutant (Units)	AERMOD-Derived Concentration (mg/m^3)	REL or IDLH/10 (mg/m^3)
Benzene	3.82E-04	1.3
Ethyl benzene	3.65E-05	350
Formaldehyde	6.05E-06	0.055
n-Hexane	1.11E-03	390
Toluene	7.02E-04	37
Xylene	4.42E-04	22

3.4.2.2. Long-Term Impacts (Non-Carcinogenic)

AERMOD-derived annual average air toxic impacts for the production scenario are compared to RfCs for chronic inhalation of non-carcinogenic hazardous air pollutants in Table 3-20. The maximum value, as reported in the table, occurs 100 meters west of the southwest corner of the southeastern well pad. No concentrations are greater than the RfC values. Units are milligrams per cubic meter (mg/m^3).

Table 3-20. Comparison of Long-Term AERMOD-Derived Non-Carcinogenic HAPs Impacts with RfC Values: Production Scenario

Pollutant (Units)	AERMOD-Derived Concentration (mg/m^3)	RfC (mg/m^3)
Benzene	1.922E-05	0.03
Ethyl benzene	1.836E-06	1
Formaldehyde	3.272E-07	0.01
n-Hexane	5.590E-05	0.7
Toluene	3.531E-05	5
Xylene	2.226E-05	0.1

3.4.2.3. Long-Term Impacts (Cancer Risks)

AERMOD-derived incremental inhalation cancer risk base on maximum annual-average modeled concentrations are presented in Table 3-21. These estimates of cancer are based on 70-year exposure to the carcinogenic toxic air pollutants.

Table 3-21. AERMOD-Derived Cancer Risk: Production Scenario

Pollutant (Units)	AERMOD-Derived Concentration ($\mu g/m^3$)	IUR ($1/(\mu g/m^3)$)	Cancer Risk (per million)
Benzene	1.92E-02	7.80E-06	1.50E-01
Ethyl benzene	1.84E-03	2.50E-06	4.59E-03
Formaldehyde	3.27E-04	1.30E-05	4.25E-03

The total overall cancer risk is 0.16 per million for this production scenario. This value could be further adjusted for exposure but given the location of the peak concentrations within the Project Area and considering that the overall risk is estimated to be <1 per million, no exposure adjustment was applicable. Note, however, that the additive effects of multiple chemicals are not fully understood.

4.0 Far-Field Modeling Analysis: CMAQ Modeling

4.1 Overview of the CMAQ Model

The CMAQ model is a state-of-the-science, regional air quality modeling system that can be used to simulate the physical and chemical processes that govern the formation, transport, and deposition of gaseous and particulate species in the atmosphere (Byun and Ching, 1999). The CMAQ tool was designed to improve the understanding of air quality issues (including the physical and chemical processes that influence air quality) and to support the development of effective emission control strategies on both the regional and local scales. The CMAQ model was designed as a "one-atmosphere" model. This concept refers to the ability of the model to dynamically simulate ozone, particulate matter, and other species (such as mercury) in a single simulation. In addition to addressing a variety of pollutants, CMAQ can be applied to a variety of regions (with varying geographical, land-use, and emissions characteristics) and for a range of space and time scales. The latest version of CMAQ includes state-of-the-science advection, dispersion and deposition algorithms, the latest version of the Carbon Bond (CB) chemical mechanism (CB05), and diagnostic tools for assessing source apportionment.

Numerous recent applications of the model, for both research and regulatory air quality planning purposes, have focused on the simulation of ozone and $PM_{2.5}$. The CMAQ model was used by EPA to support the development of the Clean Air Interstate Rule (CAIR) (EPA, 2005). It was also used by EPA to support the second prospective analysis of the costs and benefits of the Clean Air Act (CAA) (Douglas et al., 2008).

The CMAQ model numerically simulates the physical processes that determine the magnitude, temporal variation, and spatial distribution of the concentrations of ozone and particulate species in the atmosphere and the amount, timing, and distribution of their deposition to the earth's surface. The simulation processes include advection, dispersion (or turbulent mixing), chemical transformation, cloud processes, and wet and dry deposition. The CMAQ science algorithms are described in detail by Byun and Ching (1999).

The CMAQ model requires several different types of input files. Gridded, hourly emission inventories characterize the release of anthropogenic, biogenic, and, in some cases, geogenic emissions from sources within the modeling domain. The emissions represent both low-level and elevated sources and a variety of source categories (including, for example, point, on-road mobile, non-road mobile, area, and biogenic). The amount and spatial and temporal distribution of each emitted pollutant or precursor species are key determinants to the resultant simulated air quality values.

The CMAQ model also requires hourly, gridded input fields of several meteorological parameters including wind, temperature, mixing ratio, pressure, solar radiation, fractional cloud cover, cloud depth, and precipitation. A full list of the meteorological input parameters is provided in Byun and Ching (1999). The meteorological input fields are typically prepared using a data-assimilating prognostic meteorological model, the output of which is processed for input to the CMAQ model using version 4.1 of the Meteorology-Chemistry Interface Processor (MCIP). The prescribed meteorological conditions influence the transport, vertical mixing, and resulting distribution of the simulated pollutant concentrations. Certain meteorological parameters, such as mixing ratio, can also influence the simulated chemical reaction rates. Rainfall and near-surface meteorological characteristics govern the wet and dry deposition, respectively, of the simulated atmospheric constituents.

Initial and boundary condition (IC/BC) files provide information on pollutant concentrations throughout the domain for the first hour of the first day of the 10-day spin-up period for the simulation, and along the lateral boundaries of the domain for each hour of the simulation. Photolysis rates and other chemistry-related input files supply information needed by the gas-phase and particulate chemistry algorithms.

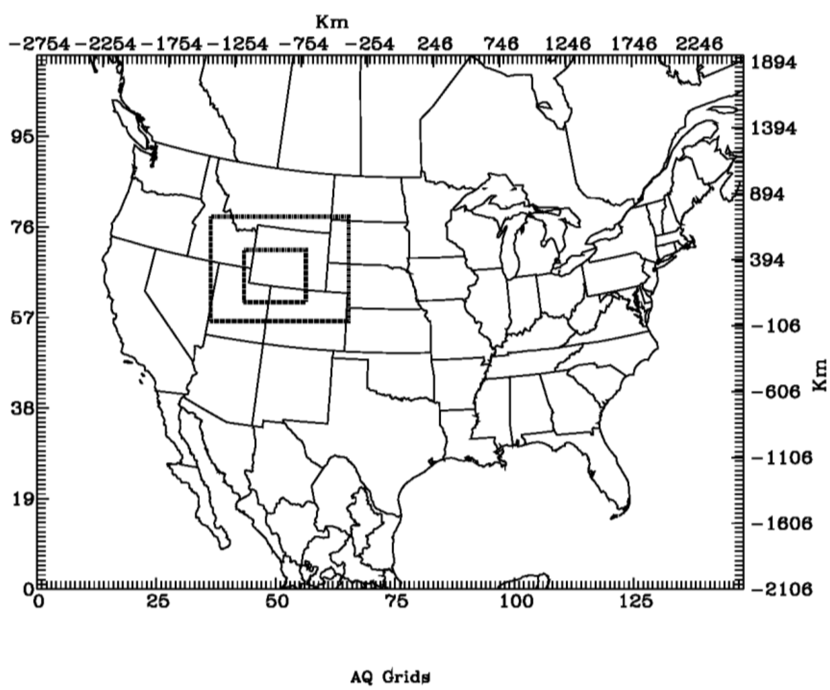
4.2 CMAQ Modeling Approach

4.2.1 CMAQ Modeling Domain

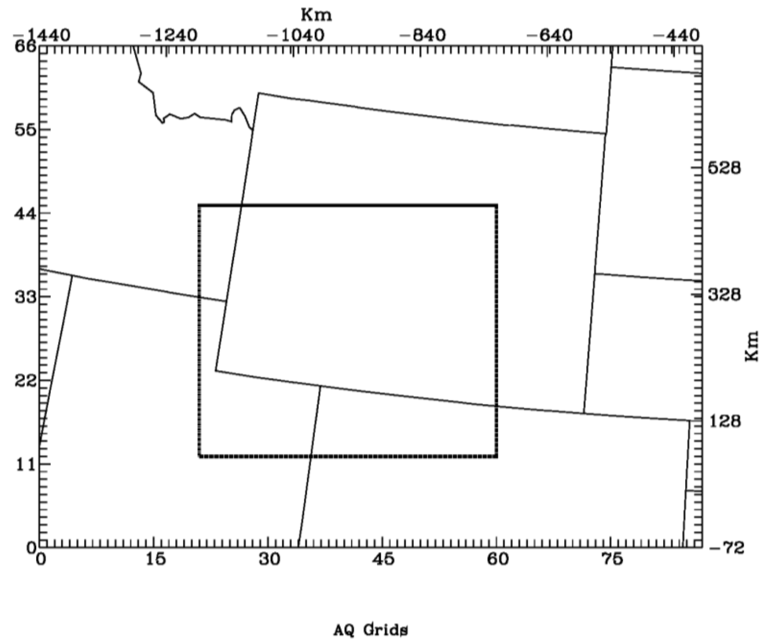
The CMAQ modeling domain was designed to accommodate both regional and subregional influences as well as to provide a detailed representation of the emissions, meteorological fields, and pollutant concentration patterns over the area of interest. The modeling domain is the same as that used for the LaBarge EIS modeling study and is illustrated in Figure 4-1 (a)-(c).

Figure 4-1. CMAQ Modeling Domain for the NPL Air Quality Impact Assessment

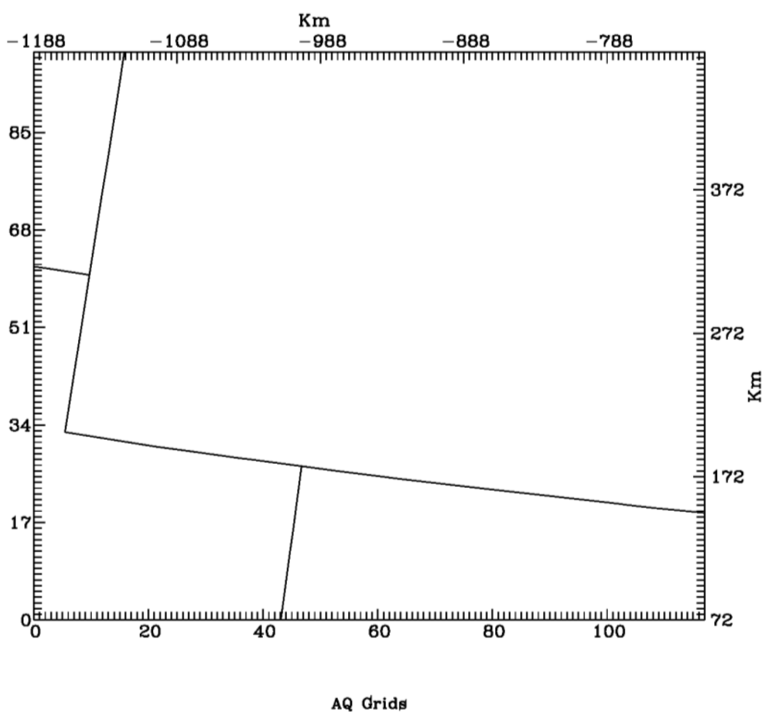
(a) 36-, 12- and 4-km Grids



(b) 12- and 4-km Grids



(c) 4-km Grid



The modeling domain includes a 36-km resolution outer grid encompassing the U.S. This domain is also referred to as the Continental U.S. or CONUS domain and has been used for numerous air quality applications conducted by EPA and Regional Planning Organizations (RPOs). The 36-km modeling grid is intended to provide model-based boundary conditions for the primary areas of interest and thus avoid some of the uncertainty introduced in the modeling results through the incomplete and sometimes arbitrary specification of boundary conditions. A one-way nesting approach was used. The 12-km grid is intended to represent the regional air quality conditions and to provide boundary conditions for the 4-km grid. The 4-km grid includes the NPL Project Area and other nearby PSD Class I and sensitive Class II areas.

The modeling grids are based on a Lambert Conformal Conic (LCC) map projection. The numbers of grid cells in the west-east and south-north directions are as follows: 36-km grid (148 x 112), 12-km grid (87 x 66), and 4-km grid (117 x 99).

In the vertical dimension, the modeling domain includes 34 layers for the months of April – October and 38 layers for January, February, March, November and December (the same layer structure that has been established for modeling studies of other, nearby project areas). The thickness of the layers increases with height above ground. The thinner layers near the surface are designed to provide enhanced resolution of the meteorological parameters and dispersion characteristics within the lowest part of the atmosphere (where they tend to be most variable) and to delineate the depth of the planetary boundary layer (PBL). Representation of the near surface meteorological characteristics and PBL depth is critical to accurate simulation of pollutant dispersion and transport. The vertical layers are presented in Table 4-1 (a) and (b). For each layer, the table lists the sigma value (this corresponds to the internal sigma-based, or terrain-following, coordinate system), the approximate pressure at the top of the layer, the estimated height of the top of the layer (based on standard atmospheric conditions), and the estimated depth of the layer. Units are millibars (mb) for pressure and meters (m) for layer height and depth.

Table 4-1a. Vertical Layer Structure for the CMAQ Modeling Domain for the NPL Air Quality Impact Assessment (34 Layers)

Layer	Sigma	Pressure (mb)	Height (m)	Depth (m)
34	0.000	100	14,662	1,840
33	0.050	145	12,822	1,466
32	0.100	190	11,356	1,228
31	0.150	235	10,127	1,062
30	0.200	280	9,066	939
29	0.250	325	8,127	843
28	0.300	370	7,284	767
27	0.350	415	6,517	705
26	0.400	460	5,812	652
25	0.450	505	5,160	607
24	0.500	550	4,553	569
23	0.550	595	3,984	536
22	0.600	640	3,448	506
21	0.650	685	2,942	480
20	0.700	730	2,462	367
19	0.740	766	2,095	267
18	0.770	793	1,828	259
17	0.800	820	1,569	169
16	0.820	838	1,400	166
15	0.840	856	1,234	163

Table 4-1a. Vertical Layer Structure for the CMAQ Modeling Domain for the NPL Air Quality Impact Assessment (34 Layers)

Layer	Sigma	Pressure (mb)	Height (m)	Depth (m)
14	0.860	874	1,071	160
13	0.880	892	911	158
12	0.900	910	753	78
11	0.910	919	675	77
10	0.920	928	598	77
9	0.930	937	521	76
8	0.940	946	445	76
7	0.950	955	369	75
6	0.960	964	294	74
5	0.970	973	220	74
4	0.980	982.0	146	37
3	0.985	986.5	109	37
2	0.990	991.0	72	37
1	0.995	995.5	36	36
Ground	1.000	1000	0	0

Table 4-1b. Vertical Layer Structure for the CMAQ Modeling Domain for the NPL Air Quality Impact Assessment (Lowest 8 Layers of 38 Layers)

Layer	Sigma	Pressure (mb)	Height (m)	Depth (m)
8	0.9800	982.0	146	37
7	0.9850	986.5	109	36
6	0.9900	991.0	73	20
5	0.9930	993.7	53	17
4	0.9950	995.5	36	12
3	0.9968	997.1	24	10
2	0.9982	998.4	14	8
1	0.9992	999.3	6	6
Ground	1.0000	1000.0	0	0

4.2.2 Air Quality Assessment Areas

The criteria pollutant assessment was performed for all monitoring sites and unmonitored areas located within in the NPL CMAQ 4-km grid.

The AQRV assessment considered PSD Class I areas and sensitive Class II areas located within and near the 4-km grid. Within the 4-km grid, these include:

- Bridger Wilderness Area, Wyoming (Class I)
- Fitzpatrick Wilderness Area, Wyoming (Class I)
- Popo Agie Wilderness Area, Wyoming (Class II)
- Wind River Roadless Area, Wyoming (Class II)
- Savage Run Wilderness Area, Wyoming (Federal Class II, Wyoming Class I)
- Mount Zirkel Wilderness Area, Colorado (Class I)
- Rawah Wilderness Area, Colorado (Class I)
- Dinosaur National Monument, Colorado-Utah (Federal Class II, Colorado Class I (SO_2 only)

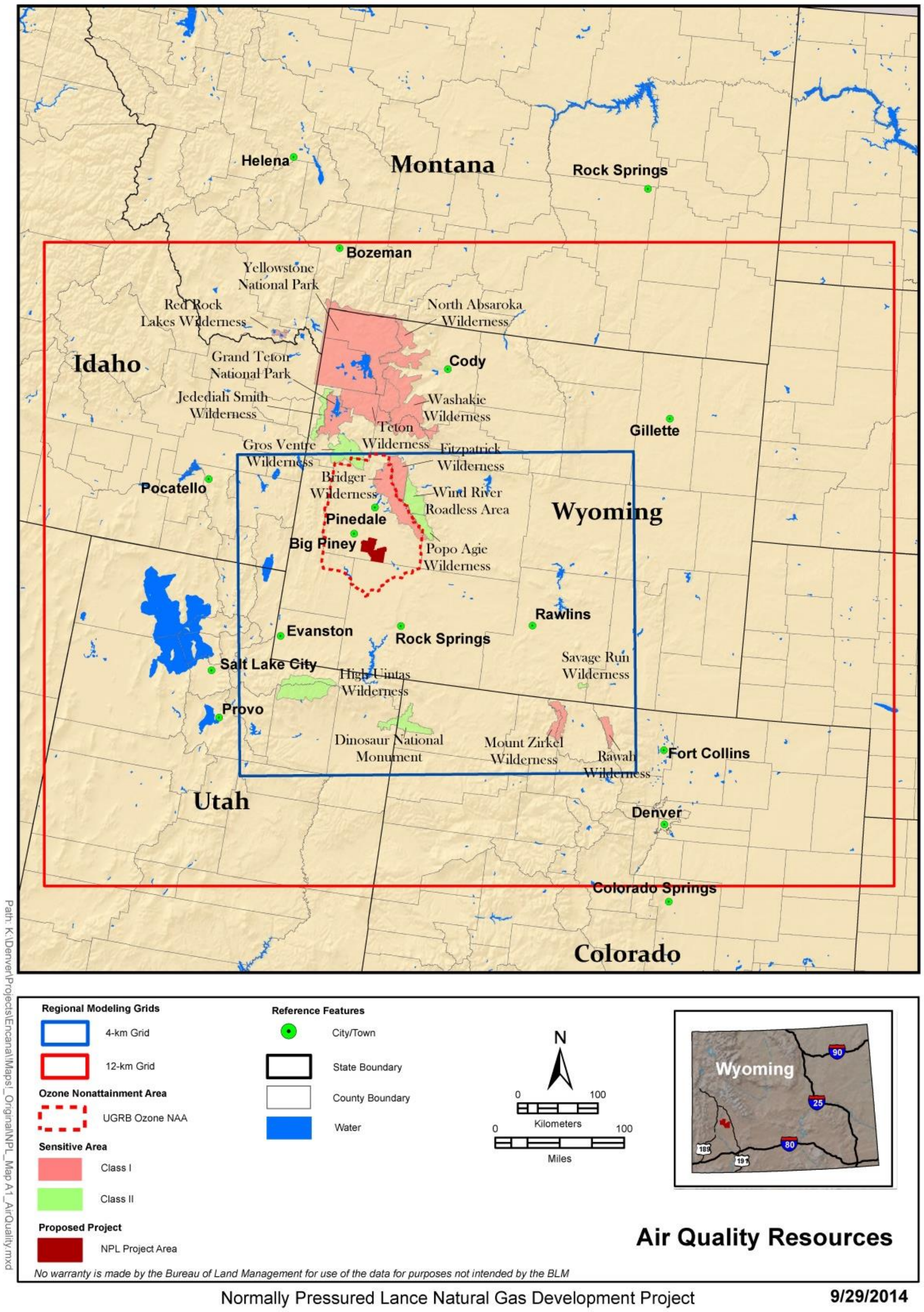
Additional areas located in the 12-km grid include:

- Yellowstone National Park, Wyoming (Class I)
- Red Rock Lakes Wilderness Area, Montana (Class I)
- Grand Teton National Park, Wyoming (Class I)
- Teton Wilderness Area, Wyoming (Class I)
- Washakie Wilderness Area, Wyoming (Class I)
- North Absaroka Wilderness Area, Wyoming (Class II)
- Gros Ventre Wilderness Area, Wyoming (Class II)
- Jedediah Smith Wilderness Area, Wyoming (Class II)
- High Uintas Wilderness Area, Utah (Class II)

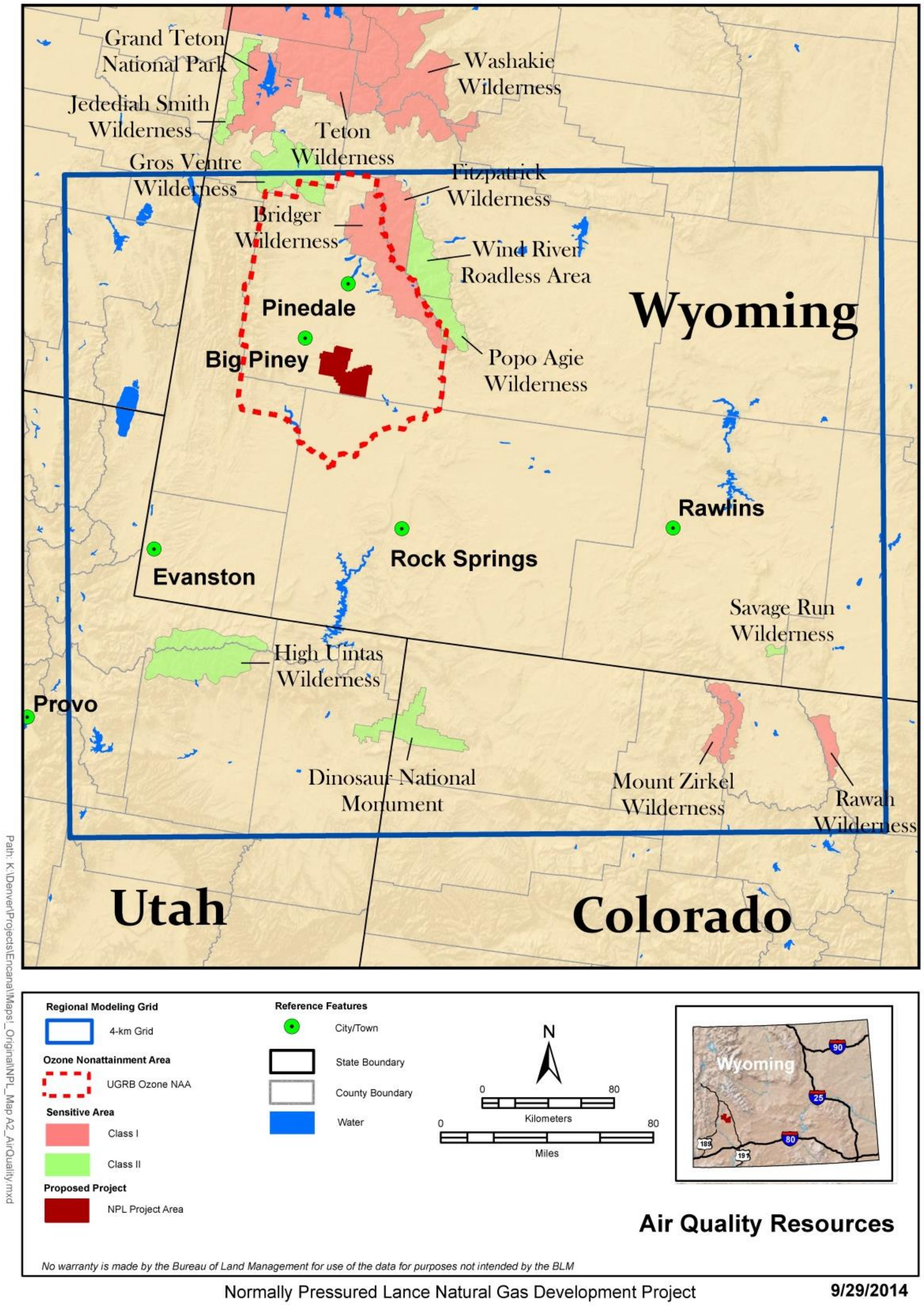
Figure 4-2 (a) and (b) illustrate the locations of these areas within the 12- and 4-km grids, respectively. The maps also depict the boundaries of the designated Upper Green River Basin (UGRB) ozone nonattainment area, which encompasses the NPL Project Area. In 2010, the Governor of Wyoming recommended to EPA that all of Sublette County and portions of adjacent Lincoln and Sweetwater Counties be designated a non-attainment area for ozone based on data collected during the winter periods of 2007, 2008, and 2009. On April 30, 2012, EPA issued final area designations for the 2008 8-hour average ozone standard and formalized the designation of this area as a Marginal ozone nonattainment area.

Figure 4-2. Location of National Parks and Wilderness Areas within the NPL CMAQ Modeling Domain

(a) 12- and 4-km Grids



(b) 4-km Grid

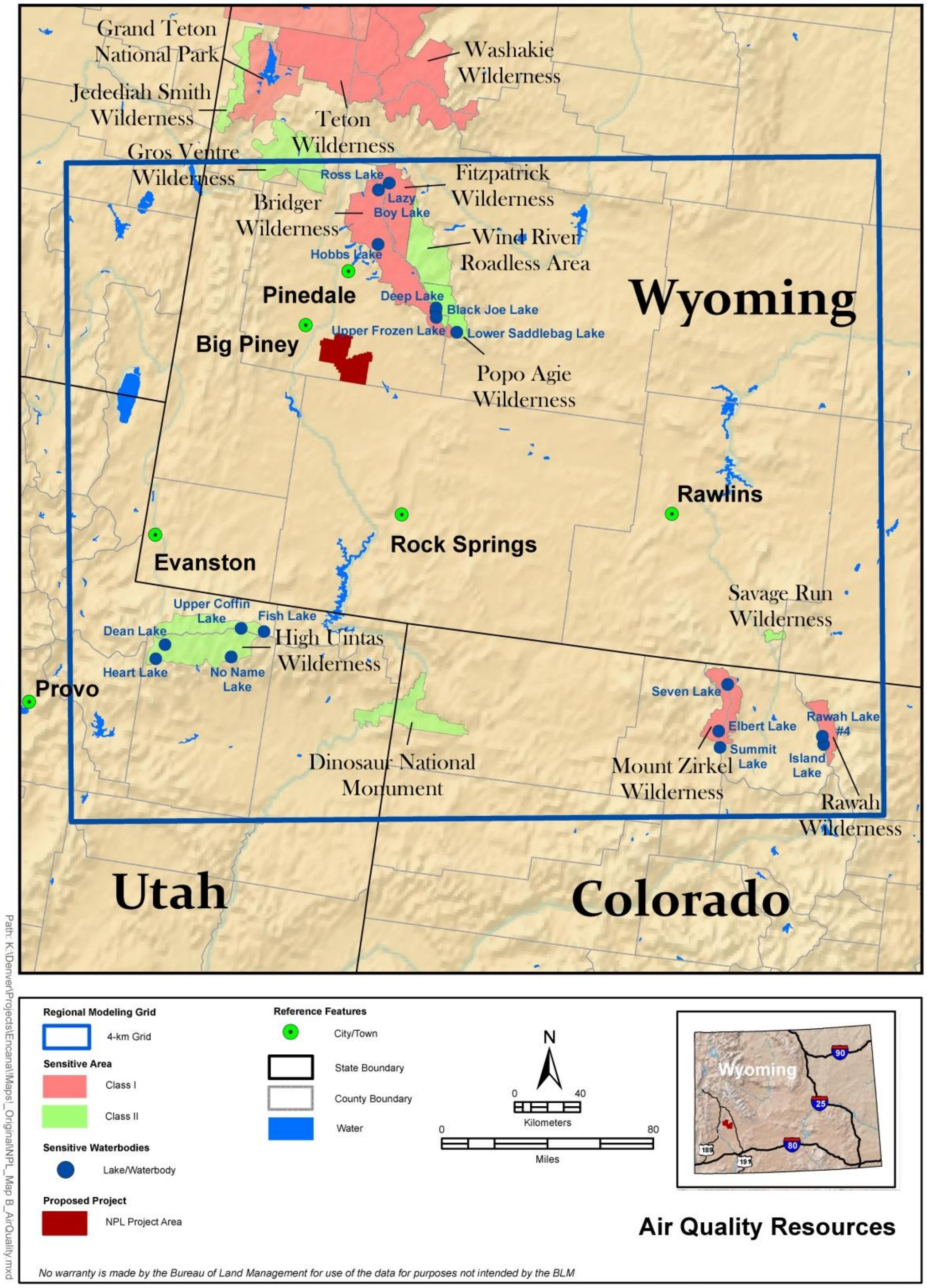

Grand Teton National Park
Washakie Wilderness
Jedediah Smith Wilderness
Teton Wilderness
Gros Ventre Wilderness
Fitzpatrick Wilderness
Bridger Wilderness
Wind River Roadless Area
Pinedale
Wyoming
Big Piney
Popo Agie Wilderness
Rawlins
Rock Springs
Evanston
Savage Run Wilderness
High Uintas Wilderness
Provo
Dinosaur National Monument
Mount Zirkel Wilderness
Rawah Wilderness
Utah
Colorado
Path: K:\Denver\Projects\Encana\Maps_Original\NPL_Map A2_AirQuality.mxd
Regional Modeling Grid
4-km Grid
Ozone Nonattainment Area
UGRB Ozone NAA
Sensitive Area
Class I
Class II
Proposed Project
NPL Project Area
Reference Features
City/Town
State Boundary
County Boundary
Water
N
0
80
Kilometers
0
80
Miles
Wyoming
Air Quality Resources
No warranty is made by the Bureau of Land Management for use of the data for purposes not intended by the BLM
Normally Pressured Lance Natural Gas Development Project
9/29/2014

In addition, 17 lakes within the PSD Class I and sensitive Class II Wilderness areas are designated acid sensitive and the assessment also examined potential lake acidification from atmospheric deposition impacts for these lakes including:

- Deep Lake in the Bridger Wilderness Area, Wyoming
- Black Joe Lake in the Bridger Wilderness Area, Wyoming
- Lazy Boy Lake in the Bridger Wilderness Area, Wyoming
- Upper Frozen Lake in the Bridger Wilderness Area, Wyoming
- Hobbs Lake in the Bridger Wilderness Area, Wyoming
- Ross Lake in the Fitzpatrick Wilderness Area, Wyoming
- Lower Saddlebag Lake in the Popo Agie Wilderness Area, Wyoming
- Dean Lake in the High Uintas Wilderness, Utah
- Heart Lake in the High Uintas Wilderness, Utah
- No Name (Duchesne – 4d2-039) Lake in the High Uintas Wilderness, Utah
- Fish Lake in the High Uintas Wilderness, Utah
- No Name (Duchesne – 4d1-044) Lake in the High Uintas Wilderness, Utah
- Lake Elbert in the Mt. Zirkel Wilderness, Colorado
- Seven Lakes in the Mt. Zirkel Wilderness, Colorado
- Summit Lake in the Mt. Zirkel Wilderness, Colorado
- Island Lake in the Rawah Wilderness, Colorado
- Rawah Lake #4 in the Rawah Wilderness, Colorado

Figure 4-3 illustrates the locations of these areas within the 4-km grid.

Figure 4-3. Location of Sensitive Lakes within the NPL CMAQ 4-km Modeling Grid



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4.2.3 Air Quality, Meteorological, and Deposition Data

A variety of aerometric and deposition data were used to support the far-field modeling analysis and air quality assessment. The primary databases used in this analysis, including data sources, availability, and use are presented in this subsection.

4.2.3.1. Ambient Air Quality Monitoring Sites

Ambient air quality data were used in the evaluation of air quality model performance and will be used in the assessment of air quality impacts. Ozone, PM, NO_x, SO_2 and CO data were obtained from the EPA Air Quality System (AQS) dataset and, as needed, the WY DEQ data archives. Additional $PM_{2.5}$ data were obtained from the Interagency Monitoring of PROtected Visual Environments (IMPROVE) monitoring network datasets. Clean Air Status and Trends Network (CASTNet) data were also obtained.

There are nearly 175 criteria pollutant monitoring sites within the NPL CMAQ 12-km modeling grid and approximately 20 monitoring sites within the 4-km grid. A list of air quality monitoring sites for criteria pollutants within the 4-km modeling grid is provided in Table 4-2. The sites are organized by dataset and then alphabetically or numerically by site identifier (ID). Additional information in the table includes the county or site name, state, location (latitude and longitude), and measured species.

Table 4-2. Air Quality Monitoring Sites within the NPL CMAQ 4-km Modeling Grid

Site ID	County or Site Name	State	Latitude (Degrees)	Longitude (Degrees)	CO	NO_X	O_3	SO_2	$PM_{2.5}$	PM_{10}
AQS										
160290031	Caribou Co	ID	42.6950	-111.594				X		
490471002	Uintah Co	UT	40.4370	-109.305			X			
560070099	Carbon Co	WY	41.5356	-107.546		X	X			
560130099	Fremont Co	WY	42.3148	-108.431		X	X			X
560131003	Fremont Co	WY	42.8411	-108.736					X	
560250001	Natrona Co	WY	42.8510	-106.330						X
560350098	Sublette Co	WY	42.4294	-109.696		X	X			X
560350099	Sublette Co	WY	42.7206	-109.753		X	X			X
560350100	Sublette Co	WY	42.7926	-110.056		X	X			X
560350705	Sublette Co	WY	42.8705	-109.861					X	
560370007	Sweetwater Co	WY	41.5916	-109.221					X	
560370010	Sweetwater Co	WY	41.6458	-109.929						X
560370200	Sweetwater Co	WY	41.4066	-108.145		X	X	X		X
560410101	Uinta Co	WY	41.3731	-111.042	X	X	X	X		X

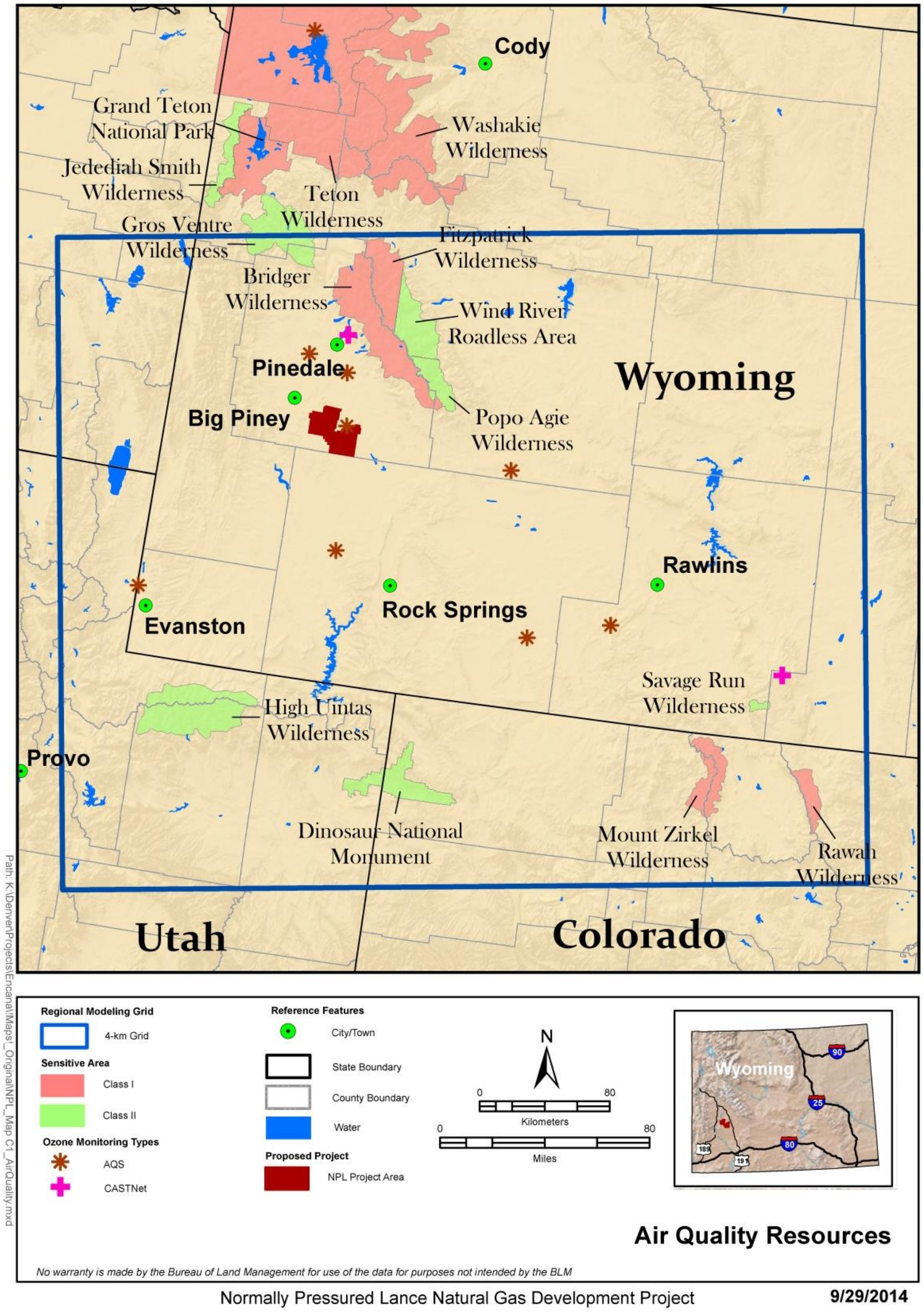
Table 4-2. Air Quality Monitoring Sites within the NPL CMAQ 4-km Modeling Grid

Site ID	County or Site Name	State	Latitude (Degrees)	Longitude (Degrees)	CO	NO_X	O_3	SO_2	$PM_{2.5}$	PM_{10}
CASTNET										
CENTNL	Centennial	WY	41.3722	-106.242			X			
PINEDL	Pinedale	WY	42.9288	-109.788			X			
IMPROVE										
Site ID	**Site Name**	**State**	**Latitude (Degrees)**	**Longitude (Degrees)**	**Speciated $PM_{2.5}$ Data**					
BRID	Bridger Wilderness	WY	42.9749	-109.758	X					
MOZI	Mount Zirkel Wilderness	CO	40.5383	-106.677	X					

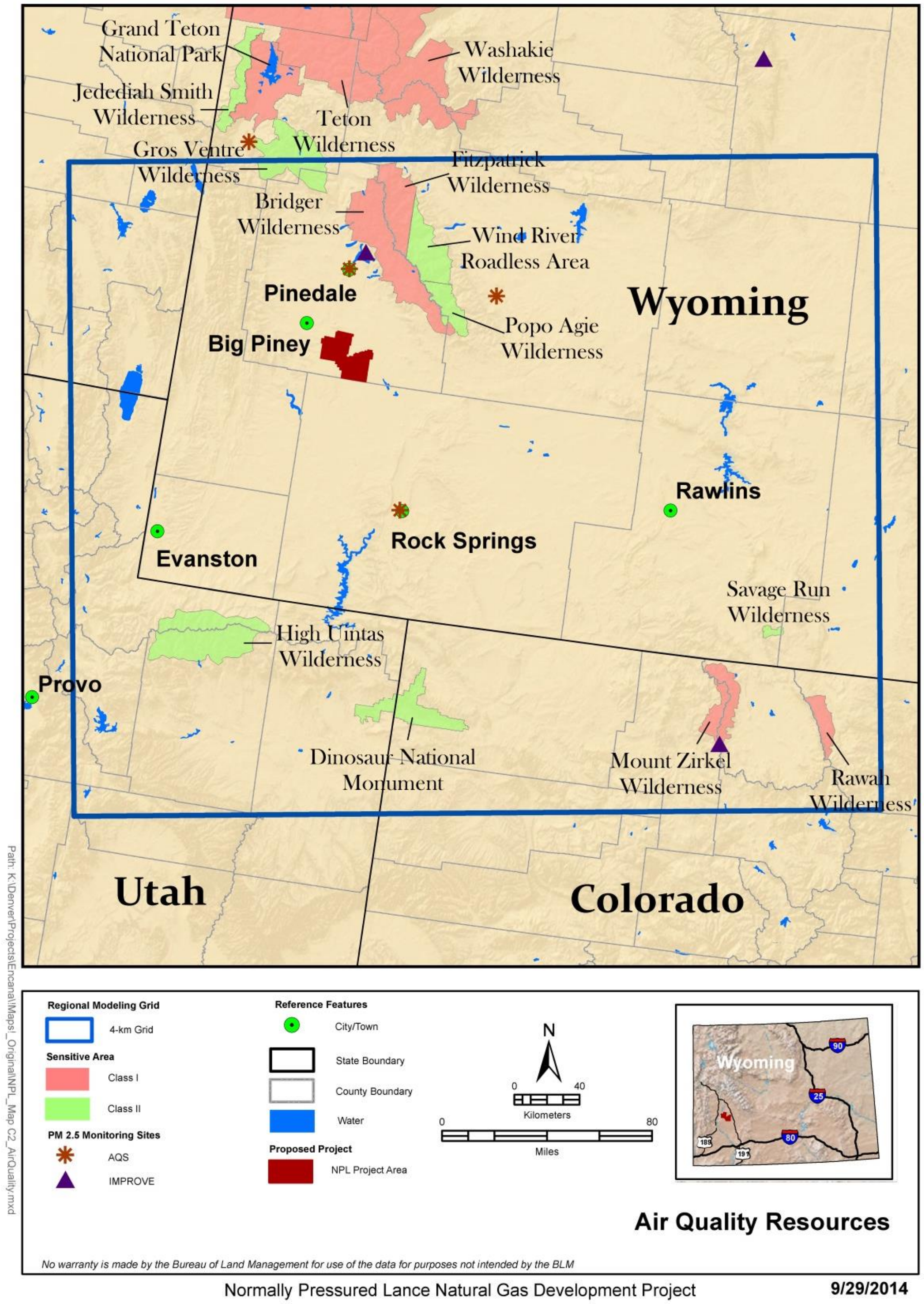
The locations of the ozone and $PM_{2.5}$ monitoring sites located within or near the NPL CMAQ 4-km grid are illustrated in Figures 4-4 (a) and (b). The monitoring sites are displayed using different symbols for each monitoring network.

Figure 4-4. Location of Criteria Pollutant Monitoring Sites within or in the Vicinity of the NPL CMAQ 4-km Modeling Grid

(a) Ozone



(b) $PM_{2.5}$



4.2.3.2. Deposition Monitoring Sites

Deposition measurements from the CASTNet and National Acid Deposition Program (NADP) monitoring networks were used in the evaluation of deposition for selected species.

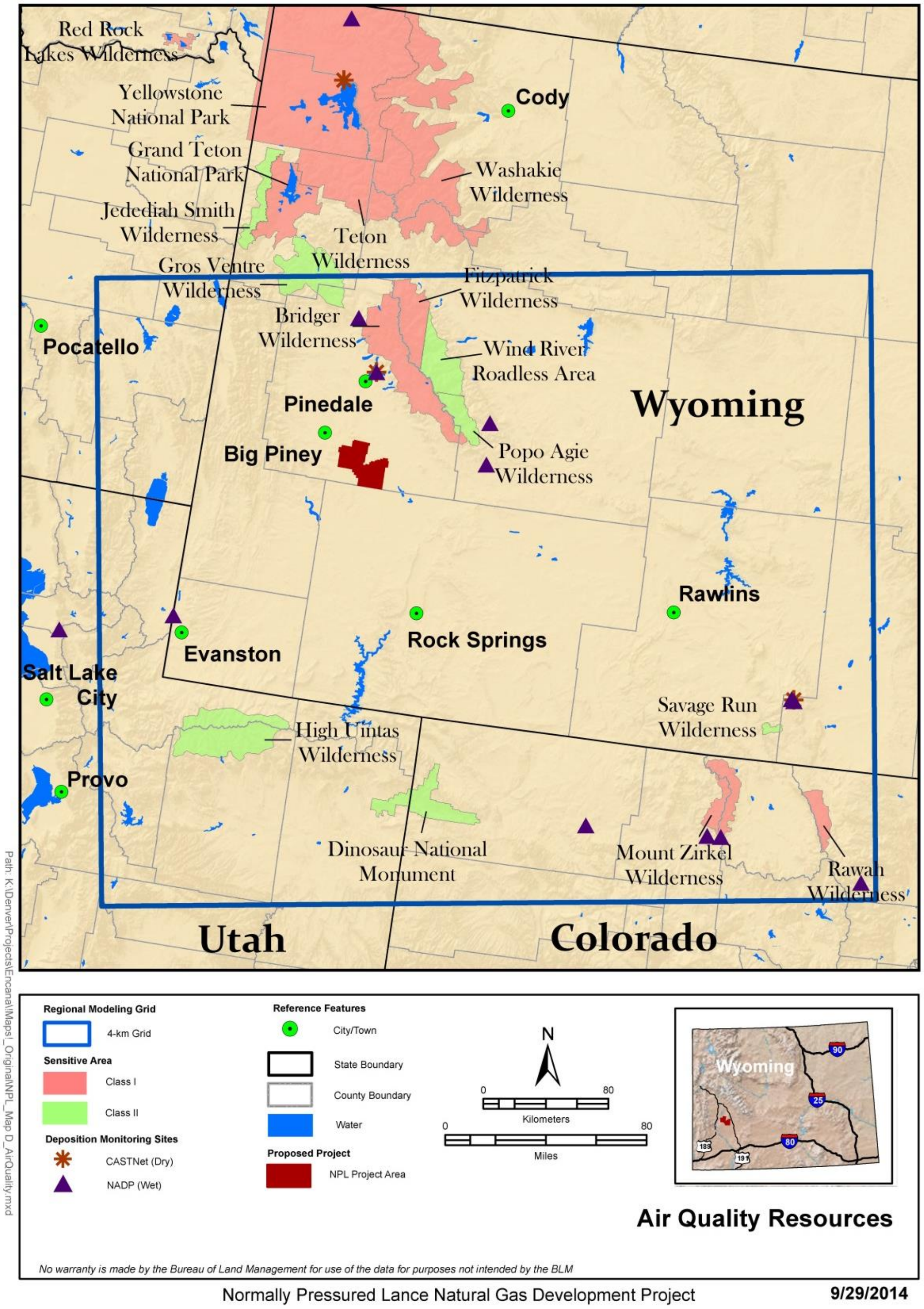
A list of deposition monitoring sites is given in Table 4-3. All sites located within the NPL CMAQ 4-km modeling grid are included in the list. The sites are organized by dataset and then alphabetically by site ID. The table also includes the site name and location (latitude and longitude).

Table 4-3. Deposition Monitoring Sites within the NPL CMAQ 4-km Modeling Grid

Site ID	County or Site Name	State	Latitude (Degrees)	Longitude (Degrees)
CASTNET				
CENTNL	Centennial	WY	41.3722	-106.242
PINEDL	Pinedale	WY	42.9288	-109.788
NADP				
CO15	Sand Spring	CO	40.5075	-107.702
CO19	Rocky Mountain National Park	CO	40.3642	-105.582
CO93	Buffalo Pass – Dry Lake	CO	40.5347	-106.780
CO95	Buffalo Pass – Summit Lake	CO	40.5378	-106.676
UT08	Murphy Ridge	UT	41.3575	-111.049
WY00	Snowy Ridge	WY	41.3761	-106.259
WY02	Sinks Canyon	WY	42.7339	-108.850
WY06	Pinedale	WY	42.9289	-109.787
WY95	Brooklyn Lakehttp://nadp.sws.uiuc.edu/nadpdata/siteinfo.asp?id=WY97&net=NTN	WY	41.3647	-106.241
WY97	South Pass City	WY	42.4947	-108.829
WY98	Gypsum Creek	WY	43.2228	-109.991

The locations of the monitoring sites located within or near the CMAQ 4-km modeling grid are illustrated in Figure 4-5. The monitoring sites for each deposition species are displayed using different symbols for each monitoring network.

Figure 4-5. Location of Deposition Monitoring Sites within or in the Vicinity of the NPL CMAQ 4-km Modeling Grid



4.2.4 Input Preparation

4.2.4.1. Meteorological Input Preparation

The CMAQ model requires hourly, gridded input fields of several meteorological parameters including wind, temperature, mixing ratio, pressure, solar radiation, fractional cloud cover, cloud depth, and precipitation. A full list of the meteorological input parameters is given in Byun and Ching (1999). The meteorological input fields are typically prepared using a data-assimilating, prognostic meteorological model, the output of which is processed for input to the CMAQ model. The prescribed meteorological conditions influence the transport, vertical mixing, and resulting distribution of the simulated pollutant concentrations. Certain meteorological parameters, such as mixing ratio, can also influence the simulated chemical reaction rates. Precipitation and near-surface meteorological characteristics govern the wet and dry deposition, respectively, of the simulated atmospheric constituents.

For this analysis, the meteorological inputs were prepared using the Weather Research and Forecasting (WRF) model (NCAR, 2010). Version 3.3.1 of the Advanced Research WRF (ARW) model was used. WRF is a state-of-the-science atmospheric modeling system designed for use in simulating meteorological fields for a broad range of scales and applications. The ARW version of the WRF model contains data assimilation capabilities which are integral to the use of the model to prepare inputs for air quality modeling of historical simulation periods. This version of the model is currently maintained by the Mesoscale and Microscale Meteorology Division of the NCAR.

The WRF model application procedures and model configuration parameters are described in detail in the meteorological modeling report (Attachment B) and are the same as those used for the WRF application to support the air quality modeling for the LaBarge project (AECOM, 2012).

The WRF modeling results are also evaluated and described in the meteorological modeling report. Key findings from the WRF model performance evaluation include:

- Synoptic-scale weather patterns both near the surface and aloft for the simulation period are well represented by WRF.
- The WRF-derived regional-scale precipitation patterns are generally similar to the observed patterns, but overall the precipitation amounts are lower than observed, with the exception of over Wyoming, where simulated precipitation amounts are generally slightly higher than observed.
- Snow cover for Wyoming and the surrounding states is very well represented by WRF, based on a limited number of analysis days.
- Based on data for Riverton, Wyoming, the observed vertical temperature profile is well simulated, especially during the summer months. The more complex vertical variations in the humidity and wind speed profiles are generally not as well represented. Winds aloft (above the boundary layer), however, are generally very well represented in the WRF simulation.
- For all months, average surface wind speeds and the day-to-day variations in wind speed (averaged over all sites within the 4-km grid) are well represented by the WRF model, but there is a tendency for underestimation.
- Similarly, surface wind directions and especially the changes in wind direction over time (averaged over all sites within the 4-km grid) are very well represented by the WRF model. The largest differences between the simulated and observed wind directions occur during periods of light and variable winds.

- The average diurnal, day-to-day, multi-day, monthly, and seasonal variations in temperature are well represented by the WRF model. For all months there is a tendency for the model to underestimate the maximum observed temperatures and overestimate the minimum observed temperatures.
- For most months, average surface moisture is overestimated. The model has some difficulty simulating the diurnal and day-to-day variations in moisture, especially during the summer months. However, longer term (multi-day and monthly) variations are captured by the model.
- Based on a detailed analysis for three nearby monitoring sites, the observed predominant wind directions and the distributions of wind direction are well represented by the simulated surface winds.

Considering statistical measures of model performance for the 12-km grid:

- Wind speed bias is within ±1 m/s for all months and within ±0.5 m/s for all months except July.
- Wind direction bias is within ±10 degrees for all months and within ±3 degrees for the non-winter months.
- Temperature bias is within ±0.5 K for most months and within ±1 K for all months, with the exception of December.
- Mixing ratio bias is within ±0.5 g/kg for all months, with the exception of December (0.51 g/kg).
- On average, observed meteorological conditions are well represented for the 12-km grid.

Considering statistical measures of model performance for the 4-km grid:

- Wind speed bias is within ±1 m/s for all months and within ±0.5 m/s for all but two months (April and July, for which the values are -0.53 and -0.62, respectively). The bias is negative (winds are slower than observed) for all months.
- Wind direction bias is within ±4 degrees for all months and within ±3 degrees for the non-winter months. The gross error is less than or equal to 40 degrees for all months.
- Temperature bias is within ±0.5 K for most months and within ±1.5 K for all months. For most months, temperatures are underestimated.
- Mixing ratio bias is within ±0.55 g/kg for all months, and is positive for all months except September. The gross error ranges from 0.6 to 1.4 g/kg.
- Based on the statistical measures, observed meteorological conditions within the 4-km grid are well represented.

The WRF output was postprocessed to correspond to the CMAQ modeling domain and the units and formats required by the modeling system using version 4.1 of the MCIP postprocessing software.

The meteorological fields needed for emissions processing were also prepared using MCIP. These include:

- temperature, surface pressure, radiation/cloud cover, rainfall, soil temperature, soil moisture and soil type for the calculation of the biogenic emissions; and
- temperature and relative humidity for the calculation of motor vehicle emissions

4.2.4.2. Emission Inventory Input Preparation

Gridded, hourly emission inventories characterize the release of anthropogenic, biogenic and, in some cases, geogenic emissions from sources within the modeling domain. The anthropogenic emissions represent both low-level and elevated sources and a variety of source categories (including, for example, point-source, on-road mobile, non-road mobile, and area-source categories). The amount and spatial and temporal distribution of each emitted pollutant or precursor species are key determinants to the resultant simulated air quality values.

For the NPL far-field modeling analysis, the modeling inventories were processed and prepared for the CMAQ modeling system with EPA's SMOKE software (Version 3.1). Various raw SMOKE emissions source sector files for 2008 and 2020 were obtained and used to prepare the anthropogenic emissions for the NPL application. Biogenic emissions were estimated using MEGAN, and wildfire emissions were obtained from NCAR (UCAR, 2013). The emissions data, processing methodologies, and resulting model-ready emission inventories is described in detail in Section 2 of this report.

4.2.4.3. Other Input Preparation

Initial and boundary conditions (IC/BC) files provide information on pollutant concentrations throughout the domain for the first hour of the first day of the simulation, and along the lateral boundaries of the domain (each grid) for each hour of the simulation. Gridded land-use information is required for the calculation of deposition and is used by other physical and numerical process algorithms. Photolysis rates and other chemistry related input files supply information needed by the gas-phase and particulate chemistry algorithms.

For this analysis, boundary conditions for the outermost domain were prepared using output from version 8-03-02 of the GEOS-Chem model for the model year 2008. The GEOS-Chem output files were obtained from EPA (EPA, 2012d). GEOS-Chem is a global model and the output from GEOS-Chem is routinely used by EPA to prepare boundary conditions for CMAQ. Boundary condition files for CMAQ were prepared using the "gc2cmaq" software, also obtained from EPA (EPA, 2012b). Boundary conditions for the inner grids were generated as part of the CMAQ application and derived from the modeling results for the next largest outer grid within which the inner grid is nested.

Land use, photolysis rates, and other chemistry related inputs were prepared using standard CMAQ procedures and pre-processing programs.

4.2.5 CMAQ Application Procedures

In applying the CMAQ model, the latest versions of the CB05 gas phase chemical mechanism, the AERO6 aerosol module, and the ISOROPIA2 aqueous partitioning routine (for the partitioning of sulfate and nitrate particulate matter) were used. CMAQ v5.0 does not include a functional plume-in-grid module, so no plume-in-grid treatment was used. Photolysis rates were calculated using the updated and improved algorithm included in CMAQ v5.0. Other options and inputs were set according to EPA recommendations for this version of CMAQ and for consistency with the emissions and meteorological data prepared in previous tasks.

The annual CMAQ simulation was divided into two parts: January – June and July – December. Each simulation part includes 10 spin-up days that were added in order to reduce the influence of the initial conditions on the simulation results.

4.3 Base-Year Modeling Results

4.3.1 Model Performance Evaluation Methodology

The overall objective of a model performance evaluation is to establish that the modeling system can be used reliably to predict the effects of changes in emissions on future-year air quality. Specific objectives for the NPL study include: (1) ensuring that the regional-scale modeling results provide appropriate boundary conditions for the Project Area, (2) ensuring that the pollutant concentration and deposition patterns and levels and the temporal variations in these are well represented, and (3) ensuring that the modeling system exhibits a reasonable response to changes in the inputs (and that the inputs do not contain significant biases or compensating errors). This was primarily accomplished by comparing the modeling results with observed data, using a variety of graphical and statistical analysis products. EPA guidance (EPA, 2007b) stresses the need to evaluate the model relative to how it will be used in the air quality assessment; that is in simulating the response to changes in emissions. Thus the evaluation also included a sensitivity test that was designed to test the response of the model to changes in the inputs.

Previous model performance evaluation studies found that the CAMx regional-scale model performed acceptably for ozone during the traditional summer ozone season (April-October), but poorly for the colder months with especially poor performance during the winter months. For this study, CMAQ model performance for ozone was evaluated for all months, with emphasis on April through October.

Analysis of results for the outer (36 and 12-km resolution) domains focused on representation of the regional-scale concentration levels and patterns, as well as seasonal variations in regional-scale air quality. A more detailed analysis of the results was performed for the innermost, high-resolution (4-km) grid. This included the analysis of the magnitude and timing of site-specific concentrations and a statistical evaluation. The model performance evaluation procedures are consistent with EPA guidance on the use of models for air quality assessment (EPA, 2007b). Version 1.1 of the Atmospheric Model Evaluation Tool (AMET) (UNC, 2008) was used to support the evaluation of the CMAQ modeling results. The graphical and statistical analysis products are listed and described the model performance evaluation report (Attachment C).

Table 4-4 summarizes key statistical measures that were used to quantify model performance.

Table 4-4. Definition and Description of Measures/Metrics for CMAQ Model Performance Evaluation for the NPL Air Quality Impact Assessment

Metric	Definition
# of data pairs	The number of observation/simulation data pairs
Mean observation value	The average observed concentration
Mean simulation value	The average simulated concentration
Normalized bias	$\left(\frac{1}{N}\right)\sum_{l=1}^{N}(S_l - O_l)/O_l \cdot 100\%$
Fractional bias	$\left(\frac{1}{N}\right)\sum_{l=1}^{N}(S_l - O_l)/0.5(S_l + O_l)\cdot 100\%$
Normalized error	$\left(\frac{1}{N}\right)\sum_{l=1}^{N}\lvert S_l - O_l\rvert/O_l \cdot 100\%$
Fractional error	$\left(\frac{1}{N}\right)\sum_{l=1}^{N}\lvert S_l - O_l\rvert/0.5(S_l + O_l)\cdot 100\%$ Where N is the number of data pairs, and S_l and O_l are the simulated and observed values at site *l*, respectively, over a given time interval.

Statistical measures for certain pollutants were compared with model performance goals and criteria used for prior studies, as suggested in EPA guidance (EPA, 2007). For ozone, these include recommended ranges for the normalized bias and normalized error from prior (ca. 1990) EPA guidance (these are still widely used for urban- and regional-scale model performance evaluation). For $PM_{2.5}$ and related species, these include goals presented by Boylan (2005).

In keeping with current EPA guidance on model performance evaluation for ozone and $PM_{2.5}$, a "weight-of-evidence" approach involving the integrated assessment of the above information was used to qualitatively and quantitatively determine that an acceptable base-case simulation was achieved.

4.3.2 Summary of Model Performance for Ozone

A detailed discussion of the model performance evaluation for ozone is provided in Attachment C.

4.3.2.1. Statistical Measures of Model Performance

Summary metrics and statistical measures calculated using hourly ozone concentrations for the 12-km grid are presented in Table 4-5 (a) and (b). Statistics were calculated for the individual months of the traditional ozone season (April through October), the traditional ozone season, and the full annual simulation period. The recommended ranges for the normalized bias and normalized error shown in this table are no longer a part of current EPA guidance but are still widely used for urban- and regional-scale model performance evaluation (EPA, 2007b). The normalized bias and error statistics were calculated using a lower bound of 40 ppb (Table 4-5a) and a lower bound of 60 ppb (Table 4-5b).

Table 4-5a. Summary Model Performance Statistics for Ozone for the 12-km Modeling Grid: 40 ppb Lower Bound

Metric	Apr	May	Jun	Jul	Aug	Sep	Oct	Apr - Oct	All	Goal
Number of Data Pairs	14,950	15,599	16,295	19,379	14,468	10,104	3,896	94,691	126,590	
Mean Observed (ppb)	51.8	52.6	51.9	55.0	51.6	47.7	44.7	51.8	50.4	
Mean Simulated (ppb)	45.7	46.2	49.6	53.7	52.2	48.9	46.5	49.5	46.6	
Normalized Bias (%)	-11.4	-11.3	-4.1	-1.4	1.8	2.7	4.1	-3.9	-7.6	± 15
Fractional Bias (%)	-13.6	-13.5	-7.3	-3.2	-0.5	0.9	2.9	-6.2	-10.5	
Normalized Error (%)	14.8	15.1	15.9	14.1	15.1	13.5	10.9	14.6	16.0	≤ 35
Fractional Error (%)	16.8	17.0	17.9	14.7	15.5	13.7	10.8	15.8	18.0	

Table 4-5b. Summary Model Performance Statistics for Ozone for the 12-km Modeling Grid: 60 ppb Lower Bound

Metric	Apr	May	Jun	Jul	Aug	Sep	Oct	Apr - Oct	All	Goal
Number of Data Pairs	2,051	3,211	3,015	5,629	2,728	444	44	17,122	18,182	
Mean Observed (ppb)	62.7	64.4	66.0	67.2	66.3	62.7	65.3	65.7	65.9	
Mean Simulated (ppb)	53.2	52.0	61.2	62.1	63.4	61.5	63.6	59.2	58.0	
Normalized Bias (%)	-15.1	-19.1	-7.0	-7.2	-3.9	-1.7	-2.4	-6.6	-11.6	± 15
Fractional Bias (%)	-16.8	-22.1	-9.6	-8.9	-5.6	-2.4	-3.4	-9.9	-14.6	
Normalized Error (%)	15.4	19.5	14.2	13.6	12.7	8.8	9.1	8.3	16.4	≤ 35
Fractional Error (%)	17.2	22.4	16.1	14.8	13.7	9.1	9.7	14.9	18.9	

Using a lower bound of 40 ppb (Table 4-5a), the normalized bias is within ±15 percent and the normalized error is well within 35 percent for all months. Ozone is underestimated for April, May and the winter months, slightly underestimated for June and July, and slightly overestimated for the remaining traditional ozone season months. Only about 20 percent of the observed concentrations are greater than 60 ppb. The statistics calculated using a lower bound of 60 ppb (Table 4-5b) indicate that the higher ozone concentrations are underestimated, especially for April and May. The normalized bias is within ±15 percent for all other months/periods; the normalized error is well within 35 percent for all months.

Summary metrics and statistical measures calculated using hourly ozone concentrations for the 4-km grid are presented in Table 4-6 (a) and (b). Statistics were calculated for the individual months of the traditional ozone season (April through October), the traditional ozone season, and the full annual simulation period. The normalized bias and error statistics were calculated using a lower bound of 40 ppb (Table 4-6a) and a lower bound of 60 ppb (Table 4-6b).

Table 4-6a. Summary Model Performance Statistics for Ozone for the 4-km Modeling Grid: 40 ppb Lower Bound

Metric	Apr	May	Jun	Jul	Aug	Sep	Oct	Apr - Oct	All	Goal
Number of Data Pairs	4,722	3,411	2,760	3,667	2,415	2,067	1,072	20,114	32,744	
Mean Observed (ppb)	52.1	51.9	49.9	52.6	49.1	47.4	43.9	50.6	49.8	
Mean Simulated (ppb)	45.9	48.2	48.7	53.0	52.6	50.8	47.8	49.4	44.6	
Normalized Bias (%)	-11.4	-6.2	-2.0	1.6	7.9	7.8	8.8	-1.5	-9.6	± 15
Fractional Bias (%)	-13.1	-7.2	-4.4	0.5	6.5	6.7	7.6	-2.9	-12.6	
Normalized Error (%)	14.1	11.1	13.5	11.1	14.2	12.7	12.7	12.8	16.8	≤ 35
Fractional Error (%)	15.6	11.8	14.8	11.0	13.4	12.0	11.9	13.2	19.1	

Table 4-6b. Summary Model Performance Statistics for Ozone for the 4-km Modeling Grid: 60 ppb Lower Bound

Metric	Apr	May	Jun	Jul	Aug	Sep	Oct	Apr - Oct	All	Goal
Number of Data Pairs	632	584	246	665	242	53	0	2,423	3,388	
Mean Observed (ppb)	62.8	63.3	63.5	62.8	64.0	63.2	--	63.1	65.3	
Mean Simulated (ppb)	52.2	52.8	59.4	58.1	60.3	60.8	--	55.7	50.8	
Normalized Bias (%)	-16.8	-16.5	-6.5	-7.4	-5.5	2.3	--	-11.6	-20.8	± 15
Fractional Bias (%)	-18.8	-18.4	-7.2	-8.3	-6.4	-3.4	--	-13.0	-26.5	
Normalized Error (%)	17.1	16.6	9.5	10.4	10.3	7.8	--	13.5	22.0	≤ 35
Fractional Error (%)	19.1	18.5	10.1	11.1	10.4	8.7	--	14.8	27.7	

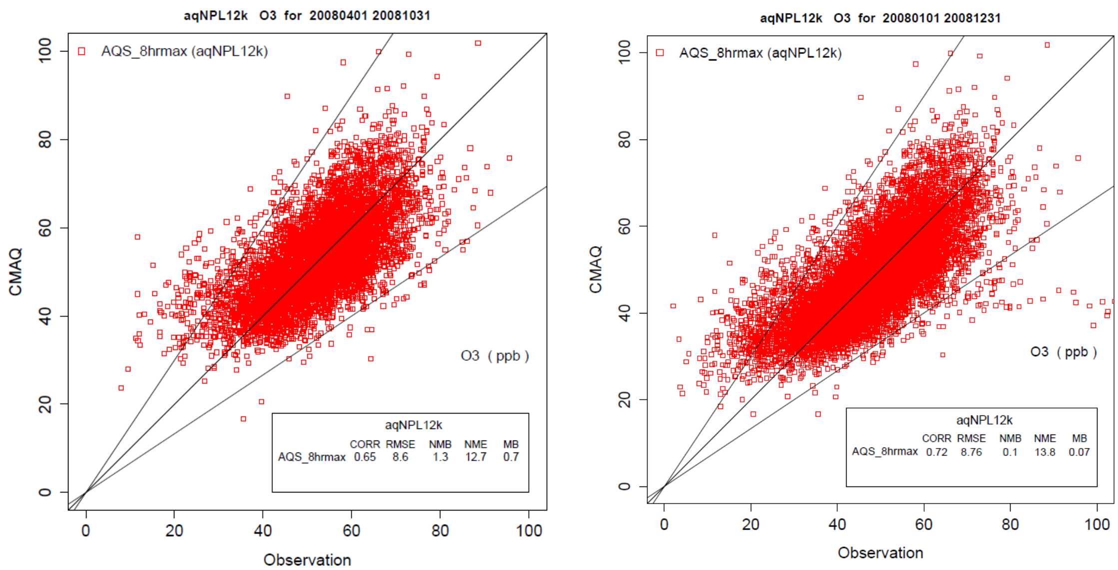
Using a lower bound of 40 ppb (Table 4-6a), the normalized bias is within ±15 percent and the normalized error is well within 35 percent for all months. The greatest differences occur for April, and ozone is underestimated for this month, on average. The bias becomes increasingly positive throughout the remaining months. Only about 10 percent of the observed concentrations are greater than 60 ppb. The statistics calculated using a lower bound of 60 ppb (Table 4-6b), indicate that the higher ozone concentrations are underestimated, especially for April, May and the winter months. The normalized bias is within ±15 percent for all other months/periods; the normalized error is well within 35 percent for all months.

4.3.2.2. Comparison of Simulated and Observed Concentrations

Scatter plots comparing simulated and observed daily maximum 8-hour ozone concentrations for the 12-km grid for April through October and the full annual simulation period are presented in Figure 4-6. The scatter plots provide a visual representation of how well the simulated values match the observations, and can reveal biases toward over- or underestimation of the observed values. Also included on the scatter plots is some statistical information further summarizing model performance. Note that these statistical measures are calculated using the 8-hour average ozone concentrations.

Figure 4-6. Comparison of Simulated and Observed Daily Maximum 8-Hour Average Ozone Concentration (ppb) for the 12-km Grid

April through October/All Months

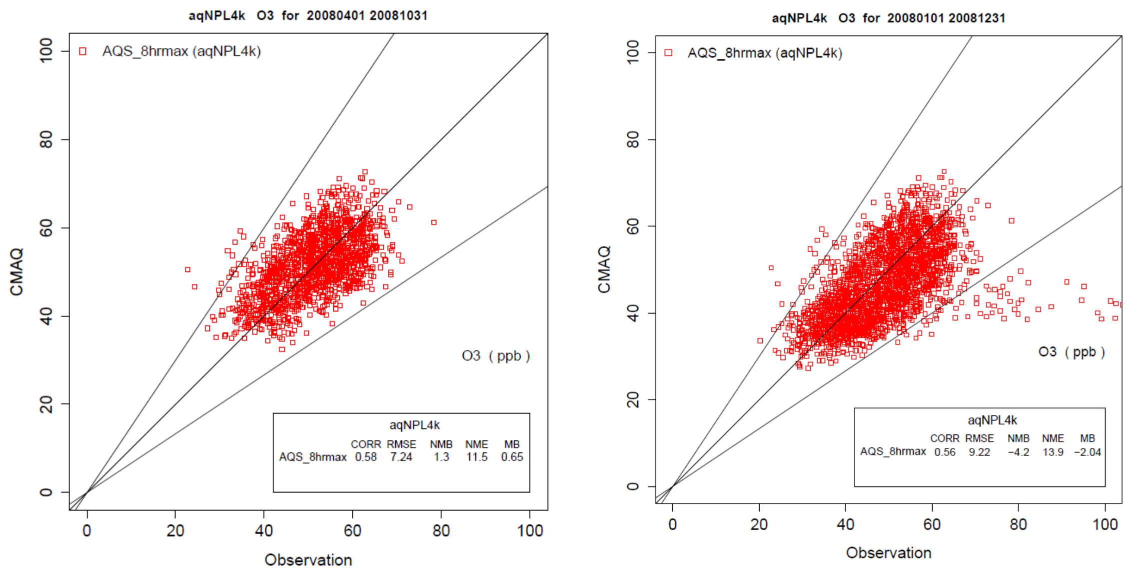


For the ozone season, there is a general tendency for CMAQ to overestimate the lower concentrations (especially those within the 20 to 40 ppb range). However, there is good correlation overall as indicated by a correlation coefficient of 0.65. For the full annual period, overall performance is similar to that for the ozone season except that the highest observed values, representing high wintertime ozone concentrations, are underestimated by a significant amount.

Scatter plots comparing simulated and observed daily maximum 8-hour ozone concentrations for the 4-km grid for April through October and the full annual simulation period are presented in Figure 4-7. Again, note that the statistical measures given on the plots are calculated using the 8-hour average ozone concentrations.

Figure 4-7. Comparison of Simulated and Observed Daily Maximum 8-Hour Average Ozone Concentration (ppb) for the 4-km Grid

April through October/All Months



For both periods, 8-hour ozone concentrations are well represented. However, the higher wintertime ozone concentrations are underestimated.

4.3.3 Summary of Model Performance for $PM_{2.5}$

A detailed discussion of the model performance evaluation for ozone is provided in Attachment C. There are two primary sources of $PM_{2.5}$ concentration data: AQS and IMPROVE. Because the measurement techniques and therefore the concentration data are different, comparisons of simulated and observed concentrations are performed separately for the datasets. In addition, because the observed concentrations can be quite small and there is no accepted minimum threshold, fractional bias and error are better suited to characterizing model performance for $PM_{2.5}$.

4.3.3.1. Statistical Measures of Model Performance

Summary metrics and statistical measures calculated using 24-hr $PM_{2.5}$ concentrations for the 12-km grid are presented in Table 4-7 (a) and (b), for the AQS and IMPROVE datasets, respectively. The recommended ranges for the fractional bias and fractional error are based on Boylan (2005) and are widely used for regional-scale model performance evaluation for $PM_{2.5}$. No lower bound was applied in calculating the statistics.

Table 4-7a. Comparison of Simulated and Observed $PM_{2.5}$ Concentrations for the 12-km Grid: AQS

Metric	Jan – Mar	Apr – Jun	Jul – Sep	Oct – Dec	Annual	Goal
Number of Data Pairs	1,257	1,229	1,211	1,183	4,880	
Mean Observed (µg/m^3)	9.2	6.9	8.4	7.6	8.0	
Mean Simulated (µg/m^3)	7.3	4.5	6.0	6.4	6.1	
Fractional Bias (%)	-14.4	-42.4	-43.3	-18.5	-29.6	± 60
Fractional Error (%)	52.6	56.3	58.8	50.6	54.6	≤ 75

Table 4-7b. Comparison of Simulated and Observed $PM_{2.5}$ Concentrations for the 12-km Grid: IMPROVE

Metric	Jan – Mar	Apr – Jun	Jul – Sep	Oct – Dec	Annual	Goal
Number of Data Pairs	369	352	357	260	1,438	
Mean Observed (µg/m^3)	1.6	3.5	5.2	2.1	3.0	
Mean Simulated (µg/m^3)	1.6	2.3	14.0	1.8	4.9	
Fractional Bias (%)	-0.9	-45.4	-43.5	-14.8	-25.8	± 60
Fractional Error (%)	41.7	52.8	59.0	45.1	49.5	≤ 75

On an annual basis, the statistical measures indicate that model performance is reasonable for both datasets, and slightly better for the IMPROVE dataset. On average, $PM_{2.5}$ concentrations at the AQS monitors (Table 4-7a) are underestimated throughout the year. The lowest bias and error values and thus the best model performance are achieved for the first and fourth quarters, when $PM_{2.5}$ concentrations are relatively low.

The results using the IMPROVE data (Table 4-7b) show that concentrations are overestimated for the July through September period. The model simulates higher than observed $PM_{2.5}$ concentrations at the Yellowstone NP monitor due to wildfire emissions in the area. Although a wildfire did occur near Yellowstone NP during that period, the effects of the fire on $PM_{2.5}$ concentrations at the monitoring site are not well represented by the model. Possible reasons for the overestimation include overestimation of the emissions, insufficient plume rise for the wildfire emissions, and errors in the wind directions or other meteorological parameters. The best model performance is achieved for the first and fourth quarters.

Summary metrics and statistical measures calculated using 24-hour average $PM_{2.5}$ concentrations for the 4-km grid are presented in Table 4-8 (a) and (b), for the AQS and IMPROVE datasets, respectively. Note that for the 4-km grid, the AQS dataset includes three sites and the IMPROVE dataset includes two sites. Recommended ranges for fractional bias and fractional error are based on Boylan (2005). No lower bound was applied in calculating the statistics.

Table 4-8a. Comparison of Simulated and Observed $PM_{2.5}$ Concentrations for the 4-km Grid: AQS

Metric	Jan – Mar	Apr – Jun	Jul – Sep	Oct – Dec	Annual	Goal
Number of Data Pairs	59	81	81	69	300	
Mean Observed (µg/m³)	10.0	4.9	7.3	6.6	7.0	
Mean Simulated (µg/m³)	3.3	2.4	7.6	-3.7	4.1	
Fractional Bias (%)	-83.3	-69.1	-60.9	-93.8	-69.8	± 60
Fractional Error (%)	87.3	76.3	75.3	72.2	77.1	≤ 75

Table 4-8b. Comparison of Simulated and Observed $PM_{2.5}$ Concentrations for the 4-km Grid: IMPROVE

Metric	Jan – Mar	Apr – Jun	Jul – Sep	Oct – Dec	Annual	Goal
Number of Data Pairs	60	57	57	54	228	
Mean Observed (µg/m³)	1.2	3.4	4.4	1.3	2.6	
Mean Simulated (µg/m³)	1.3	1.9	4.0	1.2	2.1	
Fractional Bias (%)	14.4	-54.3	-48.5	-7.3	-23.7	± 60
Fractional Error (%)	38.5	57.9	60.4	38.0	48.7	≤ 75

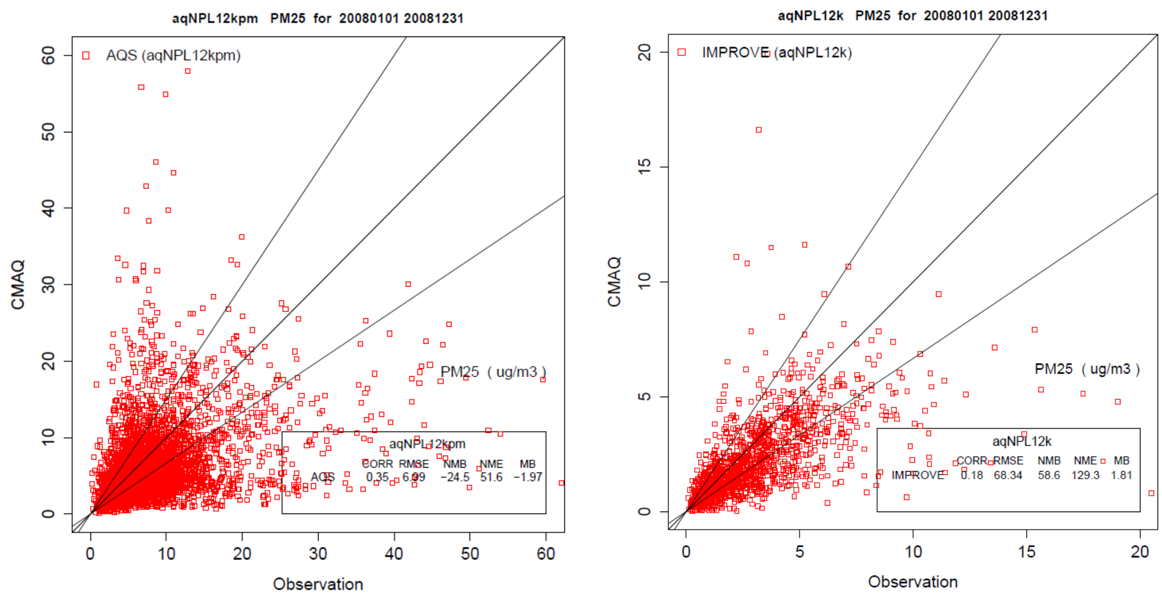
The results are similar to those for the 12-km grid and show better agreement between the simulated and observed values for the IMPROVE sites. For the AQS sites, the statistical measures indicate better agreement between the simulated and observed values for the second and third quarters, but overall the statistical measures suggest relatively poor model performance. For the IMPROVE sites, the measures indicate better agreement between the simulated and observed values for the first and fourth quarters, and overall reasonable model performance. The results indicate that the model is better able to reproduce the concentrations at the more regional-scale IMPROVE monitors, compared to the more urban-scale AQS monitors. Concentrations at AQS monitors are more likely to be influenced by local emissions and these results indicate that the model is able to simulate the overall regional-scale concentrations but not the details of the variations in concentration near emission sources. Note that there are very few monitors in the 4-km grid, and neither the background nor the urban concentrations are adequately sampled by the monitoring data.

4.3.3.2. Comparison of Simulated and Observed Concentrations

Scatter plots comparing simulated and observed 24-hour $PM_{2.5}$ concentrations for AQS sites and IMPROVE sites within the 12-km grid for the annual simulation period are presented in Figure 4-8.

Figure 4-8. Comparison of Simulated and Observed 24-Hour Average $PM_{2.5}$ Concentration (µg/m³) for the 12-km Grid (All Months)

AQS/IMPROVE

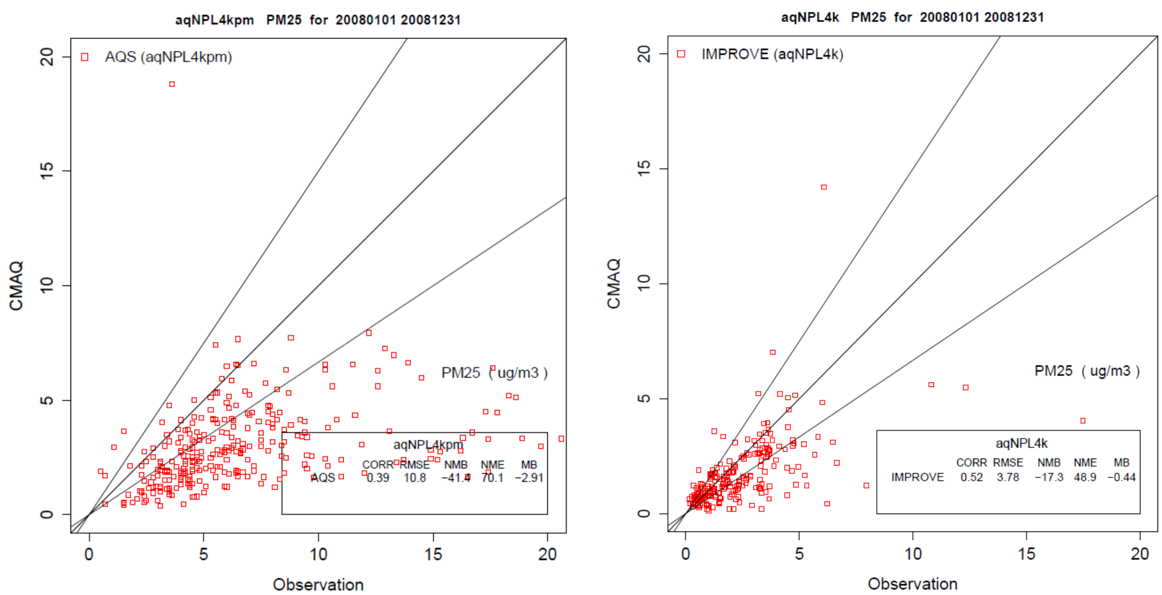


Both plots show a good deal of under- and overestimation of the observed $PM_{2.5}$ concentrations. The results indicate that the model is better able to reproduce the concentrations at the more regional-scale IMPROVE monitors, compared to the more urban-scale AQS monitors. Note that a few of the highest simulated values are off the chart, and that the scales were set to optimize viewing of a majority of the data.

Scatter plots comparing simulated and observed 24-hour $PM_{2.5}$ concentrations for AQS and IMPROVE sites within the 4-km grid for the annual simulation period are presented in Figure 4-9.

Figure 4-9. Comparison of Simulated and Observed 24-Hour Average $PM_{2.5}$ Concentration ($\mu g/m^3$) for the 4-km Grid (All Months)

AQS/IMPROVE



For both datasets, the higher concentrations are underestimated. There is much better agreement between the simulated and observed values for the IMPROVE sites. Correlation coefficients are 0.39 for the AQS sites and 0.52 for the IMPROVE sites. Note that a few of the highest simulated values are off the chart, and that the scales were set to optimize viewing of a majority of the data,

4.3.4 Summary of Model Performance for PM_{10}, NO_x, SO_2 and CO

A detailed discussion of the model performance evaluation for PM_{10}, NO_x, SO_2 and CO is provided in Attachment C.

Observed concentrations of these criteria pollutants are generally expected to represent local rather than regional scale concentrations. This is due to the fact that these pollutants are directly emitted into the atmosphere and also because the monitoring sites are typically located in urban areas and near roadways. Thus, for most sites, a grid-based model like CMAQ is not likely to capture the sub grid-scale variations in concentration reflected in the data that are due to local emissions sources. In other words, the observed data may not be representative of the 4-km square grid cell and, therefore, not directly comparable to the simulated values. Nevertheless, the assessment of model performance for these pollutants may provide important insight into overall model performance. NO_x is a precursor to ozone and both NO_x and SO_2 are precursors to $PM_{2.5}$. A large bias in the precursor pollutants may indicate model performance issues for the secondary pollutants (ozone and $PM_{2.5}$). CO is often assumed to be a tracer for vehicle emissions or other combustion sources and can help in the interpretation of model performance for other pollutants originating from these sources. With this in mind, model performance for these species was examined, with emphasis on quarterly and annual average concentrations. Note that for CO, there is only one monitoring site (Murphy Ridge) located within the 4-km grid and the data for this site are sporadic (mostly missing or zero).

As expected, agreement between the simulated and observed values is not good. PM_{10} concentrations are mostly underestimated. Model performance for 1-hour NO_x and SO_2 concentrations is characterized a tendency for underestimation of the higher observed values and overestimation of the low values.

Statistical measures were calculated for PM_{10}, NO_x, SO_2, and CO for the 4-km grid. A fractional bias within ±67 percent indicates that the simulated values are, on average, within a factor of two of the observed values. This is achieved for NO_x, SO_2, and CO, but not for PM_{10}.

4.3.5 Summary of Model Performance for Deposition

A detailed discussion of the model performance evaluation for wet and dry deposition is provided in Attachment C.

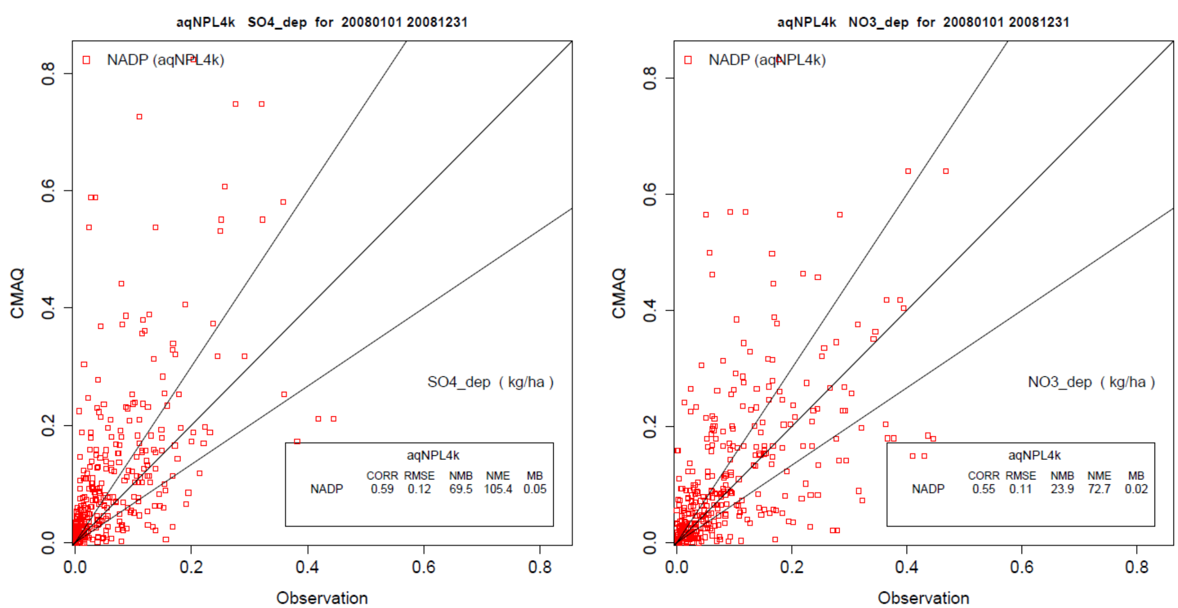
4.3.5.1. Wet Deposition

The assessment of model performance for wet deposition focused on the following ions/species: sulfate (SO_4^{2-}), nitrate (NO_3^-), and ammonium (NH_4^+) and the 4-km grid.

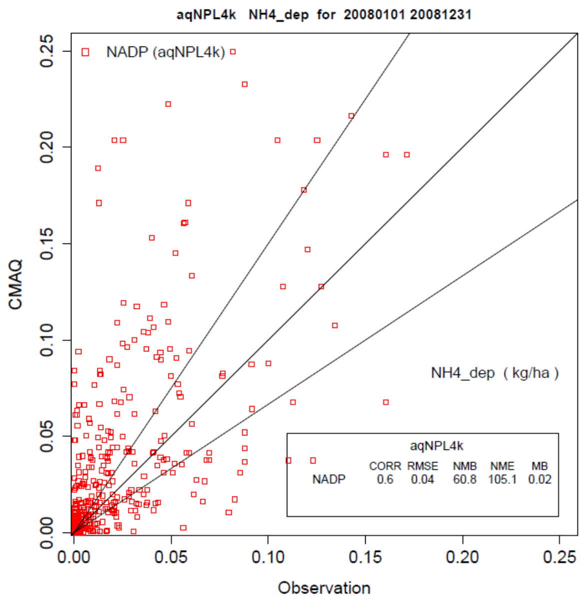
Scatter plots comparing simulated and observed weekly wet deposition values for NADP sites within the 4-km grid for the annual simulation period are presented in Figure 4-10. Units for deposition are kilograms per hectare (kg/ha).

Figure 4-10. Comparison of Simulated and Observed Total Weekly Wet Deposition (kg/ha) for the 4-km Grid (All Weeks)

SO_4^{2-}/NO_3^-



NH_4^+



Agreement between the simulated and observed values is reasonably good, with a slight tendency for overestimation, for all three species. Statistical measures indicate that the fractional bias is well within ±67 percent for all three species which indicates that the simulated values are, on average, within a factor of two of the observed values.

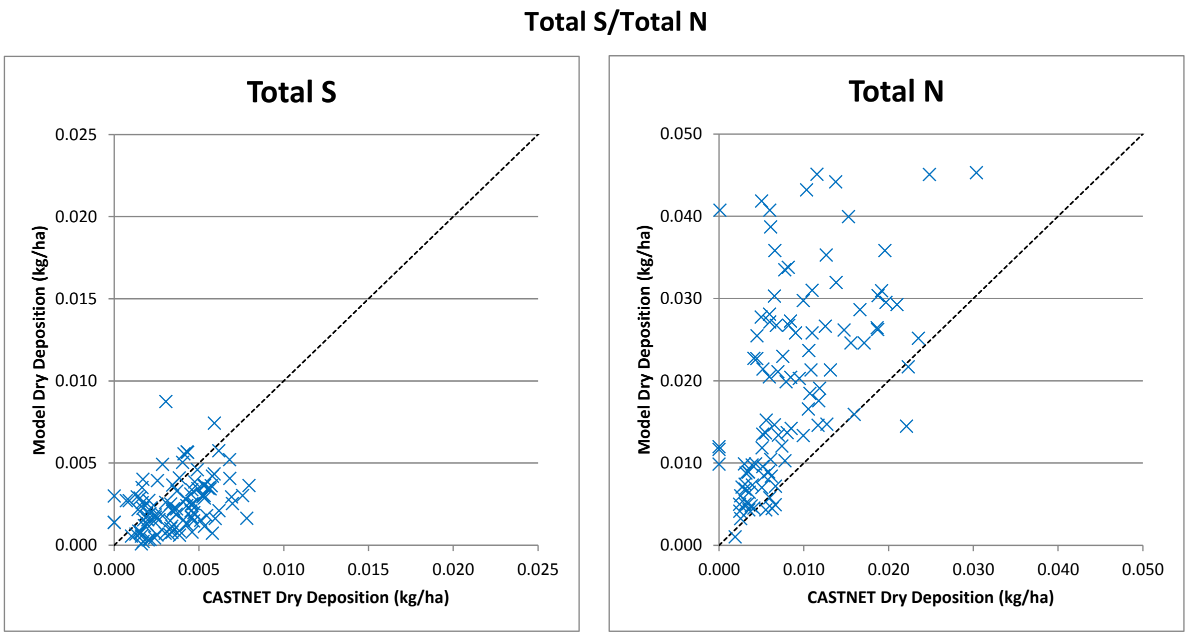
4.3.5.2. Dry Deposition

The assessment of model performance for dry deposition focused on the following ions/species: sulfur dioxide (SO_2), sulfate (SO_4^{2-}), total sulfur (S), nitrate (NO_3^-), nitric acid (HNO_3), ammonium (NH_4^+) and total nitrogen (N).

4.3.5.3. Comparison of Simulated and Observed Deposited Mass

Scatter plots comparing simulated and observed weekly dry deposition values for the two CASTNet sites within the 4-km grid for the annual simulation period are presented in Figures 4-11, for total sulfur and total nitrogen. Units for deposition are kilograms per hectare (kg/ha).

Figure 4-11. Comparison of Simulated and Observed Total Weekly Dry Deposition (kg/ha) of Total Sulfur and Total Nitrogen for the 4-km Grid (All Weeks)



Based on comparison with the CASTNet data, agreement between the simulated and observed values for total sulfur is reasonably good, with a slight tendency for underestimation of total sulfur. Total nitrogen is overestimated by the CMAQ model.

Summary metrics and statistical measures for dry deposition species were calculate for the 4-km grid. For the sulfur species, the fractional bias is well within ±67 percent for SO_2 and total sulfur. However, dry deposition of sulfate is underestimated by quite a lot. Dry deposition of nitrate and ammonium is underestimated while that for nitric acid is overestimated. This results in an overestimation of total nitrogen.

4.3.6 Key Findings from the CMAQ Model Performance Evaluation

As part of the CMAQ model performance evaluation, the ability of the model to simulate seasonal, monthly, and diurnal differences in concentration levels and patterns was examined and this provides some insight into the ability of the model to respond to changes in the inputs (e.g., variations in meteorological conditions and emissions). Key findings include:

- Model performance for ozone varies by month. For the typical ozone season months of April through October, model performance for ozone is reasonable and is characterized by underestimation of ozone for April followed by an increasingly positive bias throughout the remaining months. Overall, at the individual monitoring sites, multiday ozone events, day-to-day variations in ozone concentration, and diurnal profiles are reasonably well represented. CMAQ does not capture the high wintertime ozone concentrations observed in Sublette County.
- For $PM_{2.5}$, the CMAQ model is better able to reproduce the concentrations at the more regional-scale IMPROVE monitors, compared to the more urban-scale AQS monitors. Statistical

measures calculated using the IMPROVE data are well within established model performance goals.

- For the AQS sites, the statistical measures indicate better agreement between the simulated and observed for $PM_{2.5}$ concentrations for the second and third quarters, while for the IMPROVE sites, the measures indicate better agreement between the simulated and observed values for the first and fourth quarters.
- Comparison of simulated and observed concentrations of PM_{10}, NO_x, SO_2 and CO indicates that CMAQ is not able to capture the variations in concentration reflected in the data, especially those that are due to local emissions sources. CMAQ performs much better for secondary (formed in the atmosphere) than primary (emitted into the atmosphere) pollutants because secondary pollutants are much more likely to be representative of concentrations with a 4-km square area (or grid cell).
- Based on comparison with NAPD data, CMAQ model performance is reasonably good, with a slight tendency for overestimation. Model performance is consistent among the dry deposition species.
- Based on comparison with CASTNet data, agreement between the simulated and observed values for total sulfur is reasonably good, with a slight tendency for overestimation of total sulfur. Total nitrogen is overestimated by the CMAQ model.

Finally, a sensitivity test was conducted to examine the influence of the GEOS-Chem derived boundary conditions on the modeling results. Key findings from the sensitivity analysis include:

- Emissions account for the pronounced diurnal profile and are the predominant contributor to the peak concentration during the two-month (July/August) simulation period. There is no indication that the contribution from the boundary conditions (whether higher or lower than average) is correlated with over or underestimation of ozone.
- Emissions account for practically all of the monthly average $PM_{2.5}$ concentrations over Wyoming for the summer months of July and August. The contribution from the boundary conditions is negligible.

5.0 Far-Field Future-Year Air Quality Impact Assessment: CMAQ Modeling

5.1 Future-Year Scenarios

The future-year CMAQ modeling scenarios for the NPL air quality assessment include:

- No Action Alternative – This scenario includes future-year local and regional emissions from all source categories. It includes reasonably foreseeable development (RFD) emissions from nearby oil and gas development projects, but does not include emissions for the NPL project.
- Proposed Action – This scenario incorporates the NPL project emissions and was used to evaluate and quantify project-specific air quality impacts.

The future-year modeling results for the No Action and Proposed Action scenarios are presented in the remainder of this section.

5.2 Criteria Pollutant Impact Assessment

The criteria pollutant assessment results are presented in this section. The results are based on the modeling results for the 4-km grid and focus on differences in pollutant concentrations between the Proposed Action and No Action simulations throughout the State of Wyoming and design values and design-value-related metrics at monitoring sites and selected unmonitored areas throughout the state. Throughout this section pollutant concentrations that exceed either the NAAQS or the WAAQS are highlighted in bold.

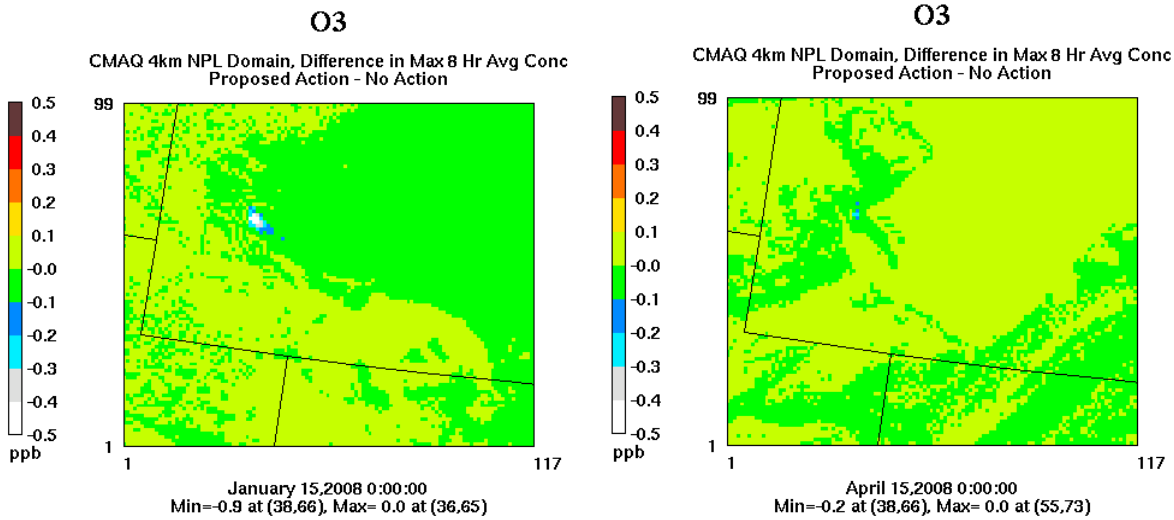
5.2.1 Ambient Air Quality Concentrations

5.2.1.1. Ozone

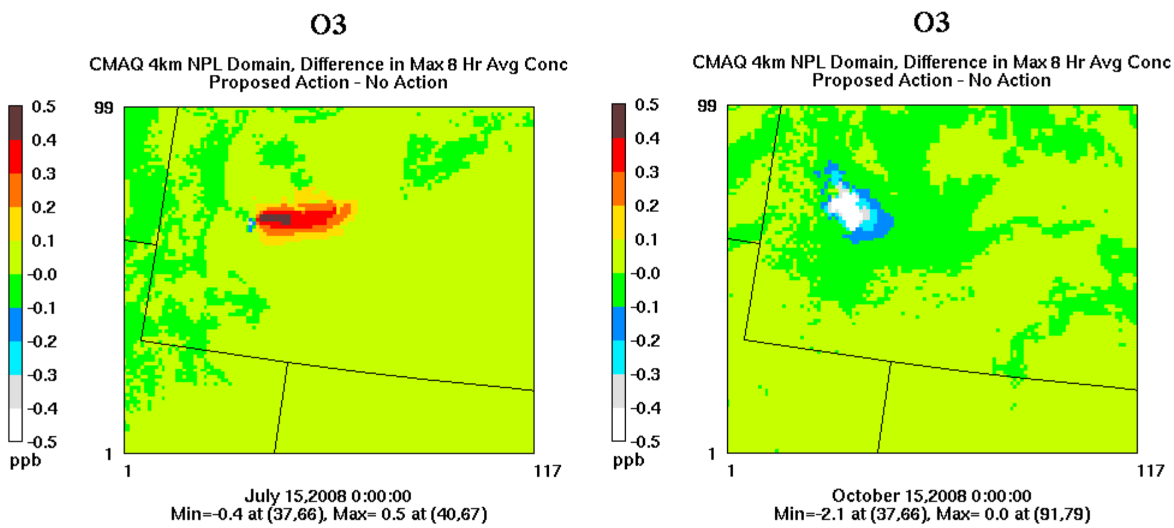
Figure 5-1 illustrates the difference in daily maximum 8-hour average ozone concentration for the 4-km grid and the 15th of January, April, July and October (every three months) between the Proposed Action and No Action simulations. The differences are calculated as Proposed Action minus No Action. The units are ppb. The date and time given on these and all subsequent difference plots refer to the meteorological base year and start hour for the selected day or averaging period. The minimum and maximum difference values for any location within the domain are also provided, along with their grid cell (x,y) locations. These plots are intended to provide perspective to the summary results that follow and to illustrate the varying spatial extent and magnitude of the differences for sample days and different times of the year. Additional plots are provided in the future-year modeling report (Attachment D).

Figure 5-1. Difference in Simulated Daily Maximum 8-Hour Ozone Concentration (ppb) for Selected Days for the CMAQ 4-km Grid: Proposed Action – No Action

January/February



July/October



The plots show a mix of small increases and decreases in daily maximum 8-hour ozone concentrations for the selected days. The increases range from 0 to 0.5 and are greatest for the warmer months. The decreases range from -0.2 to -2.1 ppb and are greatest for the cooler (fall and winter) months. Decreases in ozone are likely due to the increase in NO_x emissions in the Project Area. The response of the CMAQ model to the changes in emissions is influenced by the complex photochemistry represented by the model. Under certain conditions increases in NO_x emissions can lead to decreases in ozone. This occurs when the conversion of NO to NO_2 is inhibited (due to either relatively low VOC concentrations or limited photolysis conditions – as might be expected to occur during the nighttime hours, on cloudy days, or during the winter). Since the CMAQ model was not able to simulate the observed high wintertime ozone concentrations (as discussed in the base-case modeling report), the accuracy of the model response under wintertime conditions is also somewhat uncertain.

Based on the CMAQ results, Table 5-1 summarizes the 4th high 8-hour ozone concentration (a key NAAQS related metric) for the base- and future-year simulations. Included in the table are the simulated concentrations for ozone monitoring sites operating for one or more years during the period 2006 – 2010. These sites were selected to represent air quality conditions for the 2008 base year (later in this section "baseline" design values for 2008 are calculated using data for the 2006 – 2010 period). The difference in concentration between the Proposed Action and No Action scenarios is also provided.

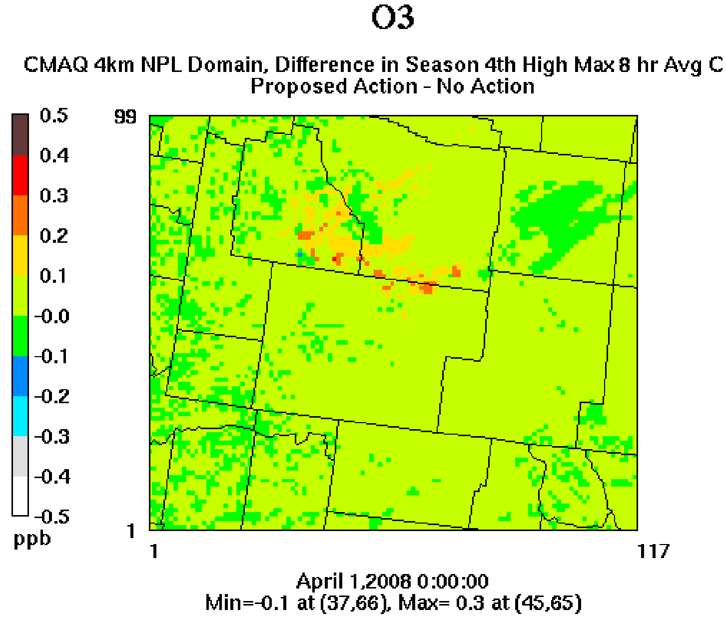
Table 5-1. Simulated 4th High Daily Maximum 8-Hour Ozone Concentration (ppb) for Monitoring Sites within the NPL 4-km Grid (Wyoming)

Site ID	Site Name	County	4th High Daily Maximum 8-Hour Ozone Concentration (ppb)			Change in Concentration due to Proposed Action (ppb)
			2008 Base Year	*Future Year No Action*	*Future Year Proposed Action*	
56-007-0100	Atlantic Rim	Carbon	63.3	62.6	62.6	0.0
56-013-0099	South Pass	Fremont	64.5	59.6	59.8	0.2
56-013-0232	Spring Creek	Fremont	62.5	58.4	58.4	0.0
56-035-0098	Jonah	Sublette	65.4	58.7	58.9	0.2
56-035-0099	Boulder	Sublette	64.4	60.1	60.2	0.1
56-035-0100	Daniel South	Sublette	62.3	58.5	58.5	0.0
56-035-0101	Pinedale	Sublette	63.5	57.2	57.3	0.1
56-035-1002	Juel Spring	Sublette	64.2	60.3	60.4	0.1
56-037-0200	Wamsutter	Sweetwater	66.6	62.7	62.7	0.0
56-037-0300	Moxa Arch	Sweetwater	66.7	61.5	61.5	0.0
56-037-0898	OCI #4	Sweetwater	67.7	61.9	61.9	0.0
56-041-0101	Murphy Ridge	Uinta	69.5	60.7	60.7	0.0

The simulated fourth highest 8-hour average ozone concentrations for all of the monitoring sites listed in Table 4-1 are all less than 70 ppb. Concentrations are projected to be lower for the future year, compared to the base year. The average decrease in this metric between the base year and the future-year No Action scenario is approximately 5 ppb. Compared to the No Action scenario, simulated concentrations for the Proposed Action scenario are 0.1 to 0.2 ppb higher for five of the ozone monitoring sites including South Pass, Jonah, Boulder, Pinedale, and Juel Spring.

The difference in simulated fourth highest daily maximum 8-hour average ozone concentration for each grid cell within the 4-km grid (for the typical ozone season months of April through October) is displayed in Figure 5-2.

Figure 5-2. Difference in Simulated 4th High Daily Maximum 8-Hour Ozone Concentration (ppb) for the CMAQ 4-km Grid: Proposed Action – No Action



The maximum difference (maximum impact on the fourth highest 8-hour ozone concentration) is 0.3 ppb. The greatest impacts occur near and to the southeast, east, and northeast of the Project Area.

To complete the ozone assessment, EPA's Modeled Attainment Test Software (MATS) (Abt, 2012) was applied using the base- and future-year modeling results and was used to estimate future-year design values for monitoring sites throughout the 4-km grid. This methodology is outlined in EPA guidance on the use of models for attainment demonstration purposes (EPA, 2007b) and is based on relative (rather than absolute) use of the modeling results. It relies on the ability of the air quality modeling system to simulate the change in concentration due to changes in emissions, but not necessarily its ability to simulate exact values for future-year concentrations. A future-year estimated design value (FDV) is calculated using the "baseline" design value and the future-year and base-year modeling results. The baseline design value for each site is multiplied by a relative response factor (RRF), which is defined as ratio of the future-year to base-year simulated concentration in the vicinity of the monitoring site. The resulting value is referred to as the future-year design value or FDV. The MATS input parameters were set to the EPA-recommended default values. This methodology was applied for both the No Action and Proposed Action scenarios.

Table 5-2 summarizes the modeled attainment test results for 8-hour ozone. The baseline design values used for this summary were calculated as the weighted average of the design values for the three overlapping three-year periods that include the modeled year (2006-2008, 2007-2009, and 2008-2010). This is the default for the application of MATS for 8-hour ozone. The baseline design values are based on the "official" data contained with the MATS database and are calculated within MATS. The baseline ozone design values are based on one to five years of monitoring data as follows: Juel Spring (1 year), Spring Creek and Pinedale (2 years), Jonah and OCI #4 (3 years), Atlantic Rim and South Pass (4 years) and all remaining sites (5 years).

Table 5-2. Estimated Future-Year 8-Hour Ozone Design Values (ppb) for Monitoring Sites within the NPL 4-km Grid (Wyoming)

Site ID	Site Name	County	8-Hour Ozone Design Value (ppb)			Change in Design Value due to Proposed Action (ppb)
			Baseline	*Future Year No Action*	*Future Year Proposed Action*	
56-007-0100	Atlantic Rim	Carbon	50.5	47.4	47.4	0.0
56-013-0099	South Pass	Fremont	70.3	64.3	64.3	0.0
56-013-0232	Spring Creek	Fremont	59.5	54.7	54.7	0.0
56-035-0098	Jonah	Sublette	**76.7**	67.5	67.6	0.1
56-035-0099	Boulder	Sublette	**78.7**	**71.9**	**72**	0.1
56-035-0100	Daniel South	Sublette	68	62.2	62.3	0.1
56-035-0101	Pinedale	Sublette	57.5	52.3	52.3	0.0
56-035-1002	Juel Spring	Sublette	64	58.4	58.5	0.1
56-037-0200	Wamsutter	Sweetwater	64	59.1	59.1	0.0
56-037-0898	OCI #4	Sweetwater	67	59.8	59.8	0.0
56-041-0101	Murphy Ridge	Uinta	64.7	55.4	55.4	0.0

Note: The NAAQS for 8-hour average ozone concentration is 70 ppb.

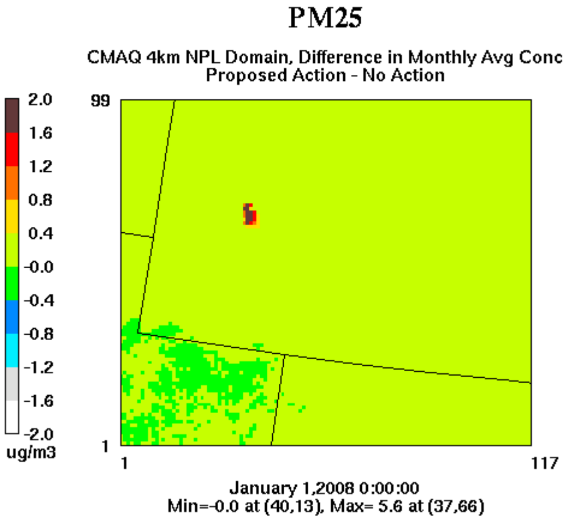
Ozone design values for the future-year No Action scenario are estimated to be approximately 3 to 9 ppb lower than the baseline values. The average reduction in this metric is 5.9 ppb. Design values for four sites (Jonah, Boulder, Daniel South, and Juel Spring) are 0.1 ppb higher for the Proposed Action scenario, compared to the No Action scenario. The estimated future-year design values for all sites except the Boulder site are below the NAAQS for both scenarios.

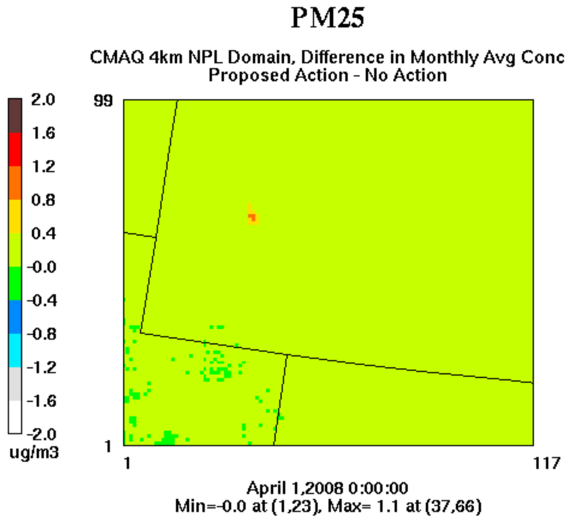
5.2.1.2. $PM_{2.5}$

Figure 5-3 illustrates the difference in monthly average $PM_{2.5}$ concentration for the 4-km grid for January, April, July, and October (every third month) between the Proposed Action and No Action simulations. The differences are calculated as Proposed Action minus No Action. The units are $\mu g/m^3$. Again, the date and time given on these and all subsequent difference plots refer to the meteorological base year and start hour for the selected day or averaging period. The minimum and maximum difference values for any location within the domain are also provided, along with their grid cell (x,y) locations. These plots are intended to provide perspective to the summary results that follow and to illustrate the varying spatial extent and magnitude of the differences for different times of the year. Additional plots are provided in the future-year modeling report (Attachment D).

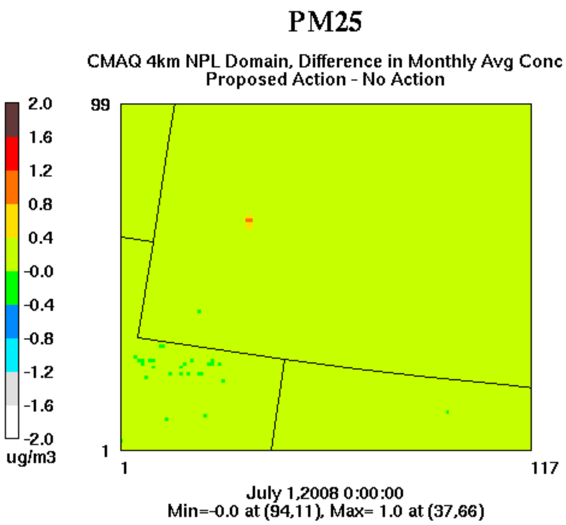
Figure 5-3. Difference in Monthly Average $PM_{2.5}$ Concentration ($\mu g/m^3$) for the CMAQ 4-km Grid: Proposed Action – No Action

January/April





July/October



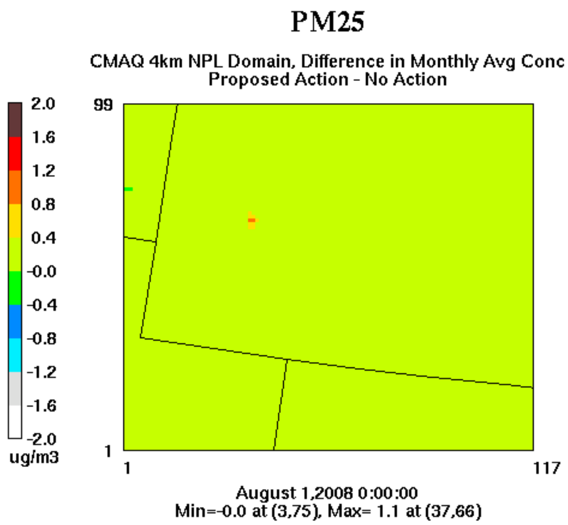
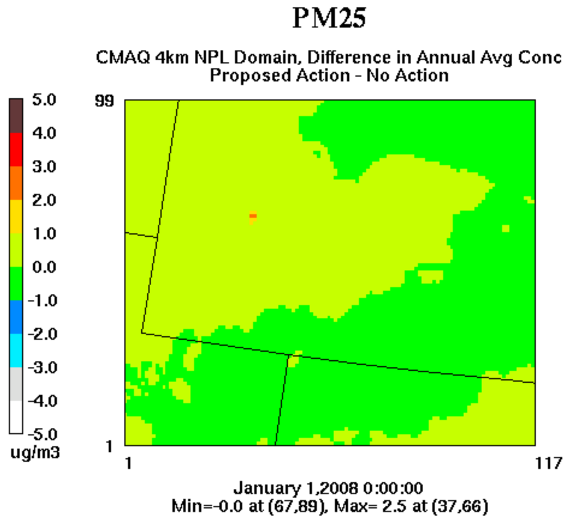


Figure 5-4 illustrates the difference in annual average $PM_{2.5}$ concentration between the Proposed Action and No Action simulations for the 4-km grid.

Figure 5-4. Difference in Annual Average $PM_{2.5}$ Concentration (µg/m³) for Selected Days for the CMAQ 4-km Grid: Proposed Action – No Action



The plots show localized increases in $PM_{2.5}$ concentrations for each month and for the annual period. The monthly increases range from approximately 1.0 to 5.6 µg/m³and are greatest for the winter months. The maximum increase in annual average $PM_{2.5}$ concentration is 2.5 µg/m³.

Focusing in on key NAAQS metrics, Table 5-3 summarizes simulated the 98th percentile 24-hour average $PM_{2.5}$ concentration (a key NAAQS related metric) for the base- and future-year simulations. Included in the table are the simulated concentrations for $PM_{2.5}$ monitoring sites operating for one or more years during the period 2006 – 2010. These sites were selected to represent air quality conditions for the 2008 base year (later in this section "baseline" design values for 2008 are calculated using data for the 2006 – 2010 period).

Table 5-3. Simulated 98th Percentile 24-Hour Average $PM_{2.5}$ Concentration (µg/m³) for Monitoring Sites within the NPL 4-km Grid (Wyoming)

Site ID	Site Name	County	98th Percentile 24-Hour $PM_{2.5}$ Concentration (µg/m³)			Change in Concentration due to Proposed Action (µg/m³)
			2008 Base Year	*Future Year No Action*	*Future Year Proposed Action*	
56-013-1003	Lander	Fremont	6.0	5.7	5.7	0.0
56-035-0101	Pinedale	Sublette	**48.3**	**48.1**	**48.1**	0.0
56-037-0007	Rock Springs	Sweetwater	9.2	6.9	6.9	0.0
56-039-1006	Jackson	Teton	5.3	5.0	5.0	0.0

The simulated 24-hour average $PM_{2.5}$ concentrations range from approximately 5 to 48 µg/m³. Concentrations are projected to be slightly lower for the future year, compared to the base year. The average decrease in this metric between the base year and the future-year scenarios is approximately 0.8 µg/m^3. Simulated concentrations for the No Action and Proposed Action scenarios for the $PM_{2.5}$ monitoring sites are the same.

Table 5-4 summarizes the annual average $PM_{2.5}$ concentration for these same sites for the base- and future-year simulations.

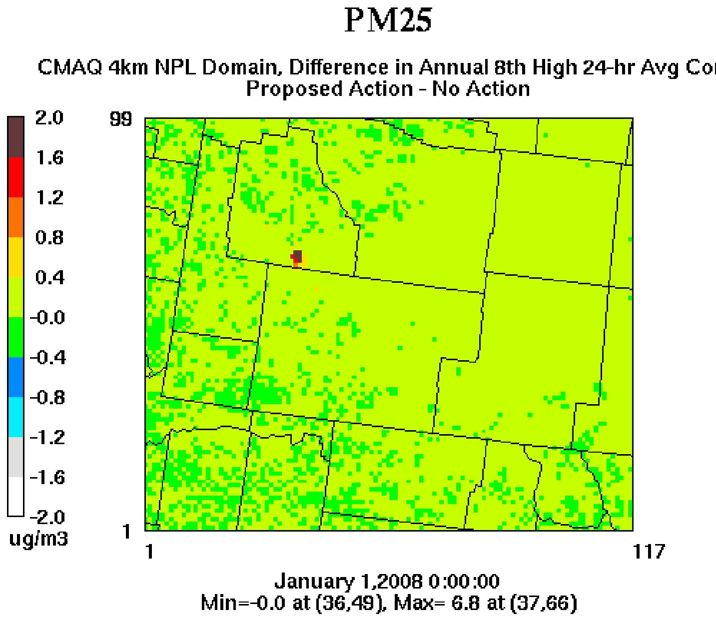
Table 5-4. Simulated Annual Average $PM_{2.5}$ Concentration (µg/m^3) for Monitoring Sites within the NPL 4-km Grid (Wyoming)

Site ID	Site Name	County	Annual Average $PM_{2.5}$ Concentration (µg/m^3)			Change in Concentration due to Proposed Action (µg/m^3)
			2008 Base Year	*Future Year No Action*	*Future Year Proposed Action*	
56-013-1003	Lander	Fremont	2.6	2.3	2.3	0.0
56-035-0705	Pinedale	Sublette	5.7	5.6	5.6	0.0
56-037-0007	Rock Springs	Sweetwater	4.0	3.2	3.2	0.0
56-039-1006	Jackson	Teton	1.9	1.7	1.7	0.0

The simulated annual average $PM_{2.5}$ concentrations for the future-year scenarios are lower than the base-year values, by an average of 0.4 µg/m^3. Simulated concentrations for the No Action and Proposed Action scenarios are the same.

The difference in simulated 98th percentile 24-hour average $PM_{2.5}$ concentration for each grid cell within the 4-km grid (for the annual simulation period) is displayed in Figure 5-5.

Figure 5-5. Difference in Simulated 98th Percentile 24-Hour $PM_{2.5}$ Concentration (µg/m³) for the CMAQ 4-km Grid: Proposed Action – No Action



The maximum difference (maximum impact on the 98th percentile 24-hour $PM_{2.5}$ concentration) is 6.8 µg/m³. The impacts are localized and occur within the Project Area.

The difference in simulated annual average $PM_{2.5}$ concentration for each grid cell within the 4-km grid is displayed in Figure 5-4 (see earlier plot). The maximum impact on annual average $PM_{2.5}$ concentration is 2.5 µg/m³. The impacts are localized and occur within the Project Area.

EPA's MATS software was applied using the base- and future-year modeling results and was used to estimate future-year design values for monitoring sites throughout the 4-km grid. The MATS input parameters were set to the EPA-recommended default values for $PM_{2.5}$ related analyses. This methodology was applied for both the No Action and Proposed Action scenarios.

Table 5-5 summarizes the modeled attainment test results for 24-hour $PM_{2.5}$. The baseline design values used for this summary were calculated using data for 2006-2010. This is the default period for the application of MATS for 24-hour $PM_{2.5}$. The baseline design values are based on the "official" data contained within the MATS database and are calculated within MATS. The baseline $PM_{2.5}$ design values are based on three years of monitoring data for Rock Springs and five years of monitoring data for all other sites.

Table 5-5. Estimated Future-Year 24-Hour $PM_{2.5}$ Design Values (ppb) for Monitoring Sites within the NPL 4-km Grid (Wyoming)

Site ID	Site Name	County	24-Hour $PM_{2.5}$ Design Value ($\mu g/m^3$)			Change in Design Value due to Proposed Action ($\mu g/m^3$)
			Baseline	*Future Year No Action*	*Future Year Proposed Action*	
56-013-1003	Lander	Fremont	27.3	25.2	25.2	0.0
56-035-0705	Pinedale	Sublette	15.1	15	15	0.0
56-037-0007	Rock Springs	Sweetwater	14.5	12.3	12.3	0.0
56-039-1006	Jackson	Teton	11	10.4	10.4	0.0

Note: The NAAQS for 24-hour average $PM_{2,5}$ concentration is 35 $\mu g/m^3$.

Daily 24-hour $PM_{2.5}$ design values for the future-year scenarios are estimated to be approximately 0.1 to 2.2 $\mu g/m^3$ lower than the baseline values. The average reduction is 1.3 $\mu g/m^3$. Design values are unchanged for the Proposed Action scenario, compared to the No Action scenario. The estimated future-year design values for all sites are below the NAAQS for both scenarios.

Table 5-6 summarizes the modeled attainment test results for annual average $PM_{2.5}$. The baseline design values used for this summary were calculated using data for 2006-2010. This is the default period for the application of MATS for annual average $PM_{2.5}$.

Table 5-6. Estimated Future-Year Annual Average $PM_{2.5}$ Design Values ($\mu g/m^3$) for Monitoring Sites within the NPL 4-km Grid (Wyoming)

Site ID	Site Name	County	Annual Average $PM_{2.5}$ Design Value ($\mu g/m^3$)			Change in Design Value due to Proposed Action ($\mu g/m^3$)
			Baseline	*Future Year No Action*	*Future Year Proposed Action*	
56-013-1003	Lander	Fremont	8.0	7.6	7.6	0.0
56-035-0101	Pinedale	Sublette	6.5	6.4	6.4	0.0
56-037-0007	Rock Springs	Sweetwater	6.2	5.3	5.3	0.0
56-039-1006	Jackson	Teton	4.7	4.5	4.5	0.0

Note: The NAAQS for annual average $PM_{2,5}$ concentration is 12 $\mu g/m^3$.

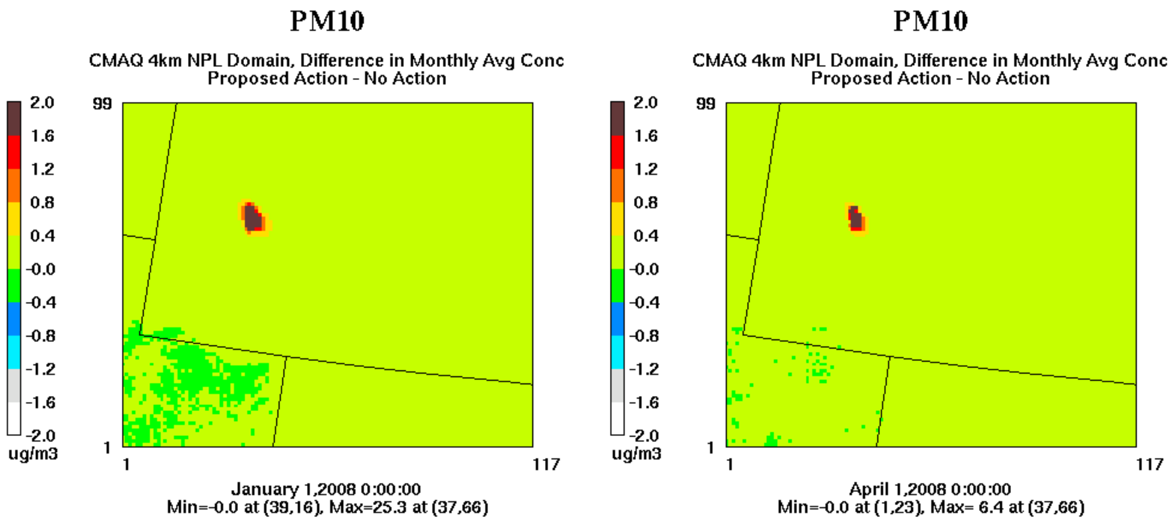
Annual $PM_{2.5}$ design values for the future-year scenarios are estimated to be approximately 0.1 to 0.9 $\mu g/m^3$ lower than the baseline values. The average reduction is 0.4 $\mu g/m^3$. Design values are unchanged for the Proposed Action scenario, compared to the No Action scenario. The estimated future-year design values for all sites are below the NAAQS for both scenarios.

5.2.1.3. PM_{10}

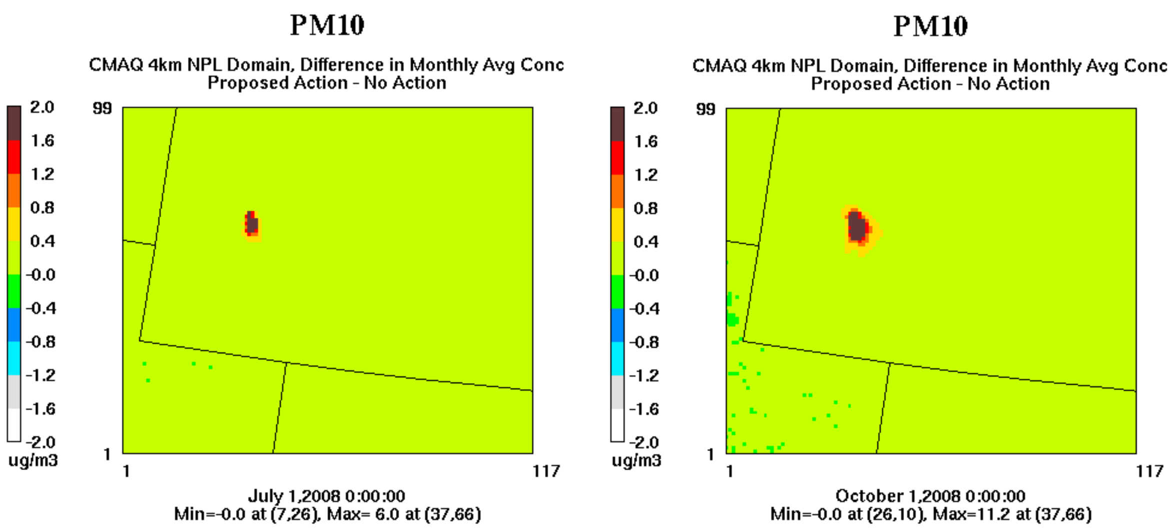
Figure 5-6 illustrates the simulated differences in monthly average PM_{10} concentration for January, April, July, and October (every third month) for the 4-km grid. These plots are intended to provide perspective to the summary results that follow and to illustrate the varying spatial extent and magnitude of the differences for different times of the year.

Figure 5-6. Difference in Monthly Average PM_{10} Concentration (µg/m³) for the CMAQ 4-km Grid: Proposed Action – No Action

January/April



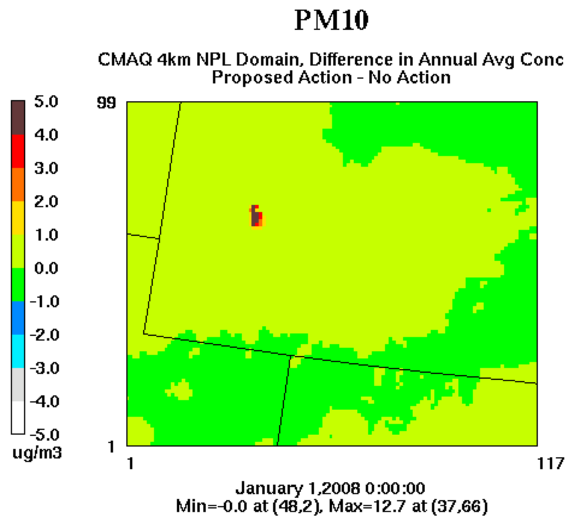
July/October



Results for the remaining months (not shown) are similar.

Figure 5-7 illustrates the difference in annual average PM_{10} concentration between the Proposed Action and No Action simulations for the 4-km grid.

Figure 5-7. Difference in Annual Average PM_{10} Concentration (µg/m³) for the CMAQ 4-km Grid: Proposed Action – No Action



The plots show localized increases in PM_{10} concentrations for each month and for the annual period. The maximum increase in annual average PM_{10} concentration is 12.7 µg/m³.

Based on the CMAQ results, Table 5-7 summarizes the simulated maximum 24-hour average PM_{10} concentration (a key NAAQS related metric) for the base- and future-year simulations. Included in the table are PM_{10} monitoring sites operating for one or more years during the period 2006 through 2010. These sites were selected to represent air quality conditions for the 2008 base year (later in this section "baseline" design values for 2008 are calculated using data for the 2007 – 2009 period).

Table 5-7. Simulated Maximum 24-Hour Average PM_{10} Concentration (µg/m3) for Monitoring Sites within the NPL 4-km Grid (Wyoming)

Site ID	Site Name	County	Maximum 24-Hour PM_{10} Concentration (µg/m³)			Change in Concentration due to Proposed Action (µg/m³)
			2008 Base Year	*Future Year No Action*	*Future Year Proposed Action*	
56-013-0099	South Pass	Fremont	20.9	20.8	20.8	0.0
56-013-0232	Spring Creek	Fremont	7.5	7.7	7.7	0.0
56-035-0098	Jonah	Sublette	43.6	43.6	44.2	0.6
56-035-0099	Boulder	Sublette	135.0	134.0	134.0	0.0
56-035-0100	Daniel South	Sublette	108.0	107.0	107.0	0.0
56-037-0200	Wamsutter	Sweetwater	9.4	10.3	10.3	0.0
56-037-0300	Moxa Arch	Sweetwater	21.9	20.0	20.2	0.2
56-041-0101	Murphy Ridge	Uinta	15.2	14.1	14.1	0.0

The simulated maximum 24-hour average PM_{10} concentrations are not consistently higher or lower for the No Action scenario, compared to the base year. On average, concentrations are projected to be slightly lower for the future year. The average decrease in this metric between the base year and the future-year scenarios is approximately 0.5 µg/m^3. The maximum simulated concentration for the Proposed Action scenario is higher by 0.2 µg/m^3 for the Moxa Arch monitoring site and by 0.6 µg/m^3 for the Jonah monitoring site, compared to the No Action scenario. The values for the remaining sites are the same for the No Action and Proposed Action scenarios.

Table 5-8 summarizes the annual average PM_{10} concentration for these same sites for the base- and future-year simulations.

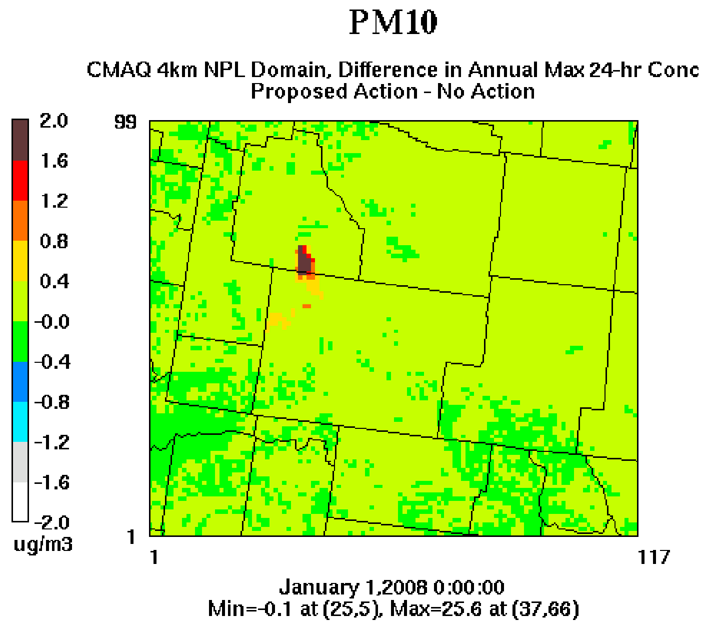
Table 5-8. Simulated Annual Average PM_{10} Concentration (µg/m3) for Monitoring Sites within the NPL 4-km Grid (Wyoming)

Site ID	Site Name	County	Annual Average PM_{10} Concentration (µg/m^3)			Change in Concentration due to Proposed Action (µg/m^3)
			2008 Base Year	*Future Year No Action*	*Future Year Proposed Action*	
56-013-0099	South Pass	Fremont	2.0	1.9	1.9	0.0
56-013-0232	Spring Creek	Fremont	2.2	2.1	2.1	0.0
56-035-0098	Jonah	Sublette	2.9	3.7	4.6	0.9
56-035-0099	Boulder	Sublette	4.1	4.1	4.2	0.1
56-035-0100	Daniel South	Sublette	3.1	2.9	2.9	0.0
56-037-0200	Wamsutter	Sweetwater	2.9	3.8	3.8	0.0
56-037-0300	Moxa Arch	Sweetwater	5.5	4.6	4.7	0.1
56-041-0101	Murphy Ridge	Uinta	3.9	3.6	3.6	0.0

Similarly, the simulated annual average PM_{10} concentrations are not consistently higher or lower for the No Action scenario, compared to the base year. On average, there is no change in concentration between the base year and the future-year No Action scenario. The maximum simulated concentration for the Proposed Action scenario is higher by 0.1 µg/m^3 for the Moxa Arch and Boulder monitoring sites and by 0.9 µg/m^3 for the Jonah monitoring site, compared to the No Action scenario. The values for the remaining sites are the same for the No Action and Proposed Action scenarios.

The difference in simulated daily maximum 24-hour average PM_{10} concentration for each grid cell within the 4-km grid is displayed in Figure 5-8.

Figure 5-8. Difference in Simulated Maximum 24-Hour PM_{10} Concentration (µg/m³) for the CMAQ 4-km Grid: Proposed Action – No Action



The maximum impact on daily maximum 24-hour PM_{10} concentration anywhere in the grid is 25.6 µg/m³. The greatest impacts occur within and to the south of the Project Area.

The difference in simulated annual average PM_{10} concentration for each grid cell within the 4-km grid is displayed in Figure 5-7 (see earlier figure). The maximum impact on annual average PM_{10} concentration is 12.7 µg/m³. The impacts are localized to the Project Area.

MATS does not accommodate PM_{10}. The results presented in the remainder of this section were calculated using the MATS procedures, but in this case the procedures were applied manually within spreadsheets containing the model output for PM_{10}.

Table 5-9 summarizes the modeled attainment test results for 24-hour PM_{10}. The baseline design values used for this summary were calculated using data for 2007-2009 and are equal to the maximum 2nd highest PM_{10} concentration during the three-year period. Only sites with data for one or more years during the three-year period were included. The baseline PM_{10} design values are based on one year of monitoring data for Spring Creek, two years of monitoring data for Jonah, and three years of monitoring data for all other sites.

Table 5-9. Estimated Future-Year 24-Hour PM_{10} Design Values (ppb) for Monitoring Sites within the NPL 4-km Grid (Wyoming)

Site ID	Site Name	County	24-Hour PM_{10} Design Value ($\mu g/m^3$)			Change in Design Value due to Proposed Action ($\mu g/m^3$)
			Baseline	***Future Year No Action***	***Future Year Proposed Action***	
56-013-0099	South Pass	Fremont	68.0	65.8	66.0	0.2
56-013-0232	Spring Creek	Fremont	22.0	21.2	21.2	0.0
56-035-0098	Jonah	Sublette	95.0	96.8	99.0	2.2
56-035-0099	Boulder	Sublette	76.0	75.6	75.6	0.0
56-035-0100	Daniel South	Sublette	43.0	42.4	42.4	0.0
56-037-0200	Wamsutter	Sweetwater	**199.0**	**209.3**	**209.6**	0.3
56-041-0101	Murphy Ridge	Uinta	100.0	96.6	96.7	0.1

Note: The NAAQS for maximum 24-hour average PM_{10} concentration is 150 $\mu g/m^3$.

Differences between the estimated future-year design values for the No Action scenario and the base year design values range from approximately -3 to 10 $\mu g/m^3$ and are characterized by a mix of increases and decreases. On average, the design values are 0.7 $\mu g/m^3$ higher for the No Action scenario. For several sites, the design values are also higher for the Proposed Action scenario compared to the No Action scenario, with an average increase of 0.3 $\mu g/m^3$. Both the base and future-year design values for Wamsutter are above the NAAQS. The design values for all other sites are below the NAAQS.

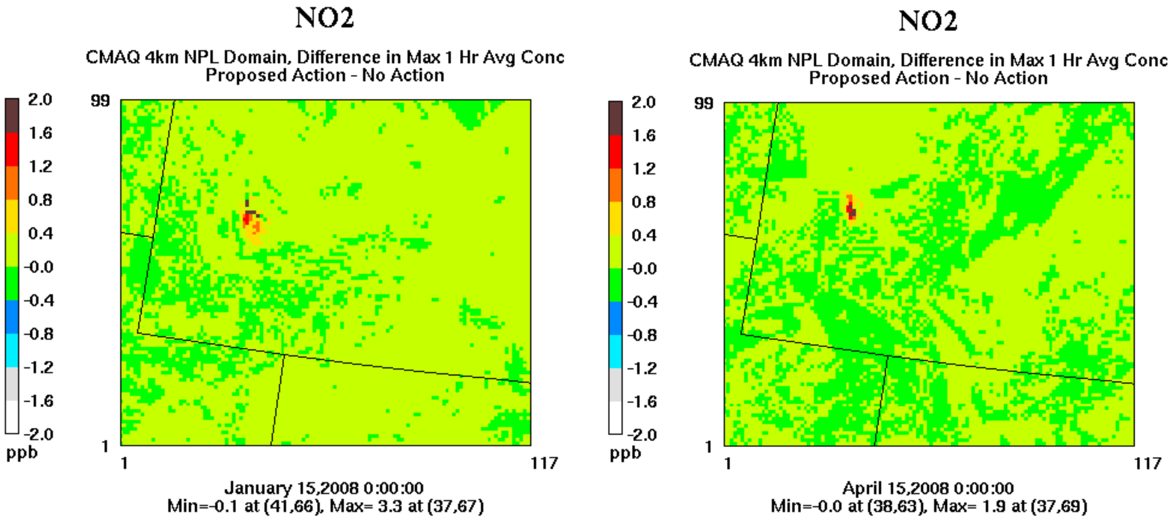
Similar relative response factors (ranging from 0.96 to 1.05) would be applied to the annual WAAQS design values. Since the PM_{10} design values for all sites are well below the annual WAAQS, the calculations were not performed.

5.2.1.4. NO_2

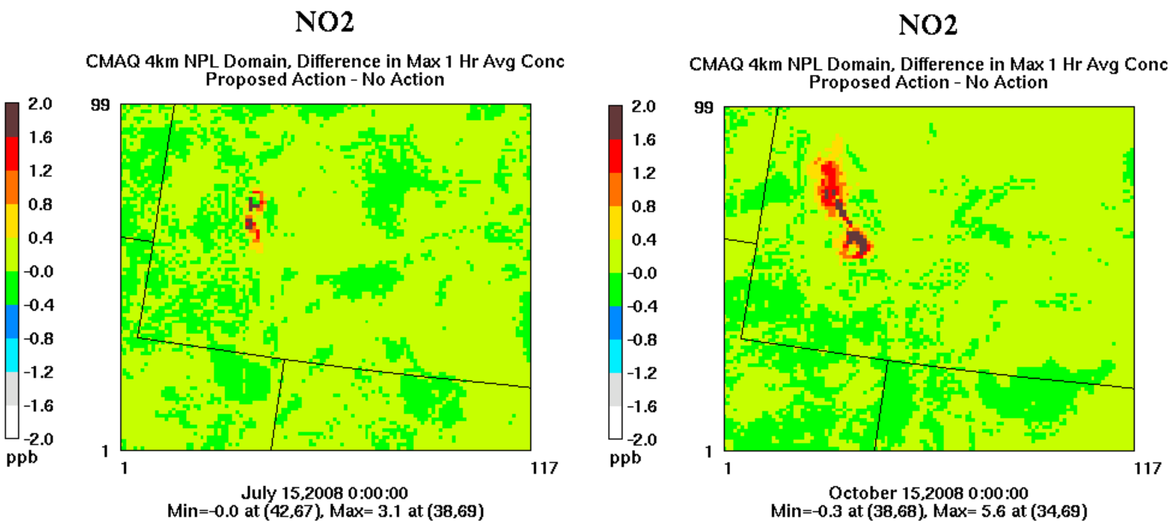
Figure 5-9 illustrates the simulated differences in daily maximum 1-hour NO_2 concentration for the 15th of each month for January, April, July, and October (every third month) for the 4-km grid.

Figure 5-9. Difference in Daily Maximum 1-Hour NO_2 Concentration (ppb) for Selected Days for the CMAQ 4-km Grid: Proposed Action – No Action

January/April



July/October



Results for the remaining months (not shown) are similar.

Based on the CMAQ results, Table 5-10 summarizes the 98th percentile daily maximum 1-hour average NO_2 concentration (a key NAAQS related metric) for the base- and future-year simulations. Included in the table are NO_2 monitoring sites operating for one or more years during the period 2006 through 2010. These sites were selected to represent air quality conditions for the 2008 base year (later in this section "baseline" design values for 2008 are calculated using data for the 2007 – 2009 period).

Table 5-10. Simulated 98th Percentile Daily Maximum 1-Hour Average NO_2 Concentration (ppb) for Monitoring Sites within the NPL 4-km Grid (Wyoming)

Site ID	Site Name	County	98th Percentile 1-Hour NO_2 Concentration (ppb)			Change in Concentration due to Proposed Action (ppb)
			2008 Base Year	*Future Year No Action*	*Future Year Proposed Action*	
56-007-0100	Atlantic Rim	Carbon	12.8	22.5	22.5	0.0
56-013-0099	South Pass	Fremont	4.8	3.7	3.7	0.0
56-013-0232	Spring Creek	Fremont	5.4	9.3	9.3	0.0
56-035-0098	Jonah	Sublette	72.0	72.0	72.1	0.1
56-035-0099	Boulder	Sublette	46.9	42.3	42.3	0.0
56-035-0100	Daniel South	Sublette	15.3	19.3	19.7	0.4
56-035-0101	Pinedale	Sublette	50.4	49.9	49.9	0.0
56-035-1002	Juel Spring	Sublette	32.4	43.7	43.9	0.2
56-037-0200	Wamsutter	Sweetwater	34.8	37.0	37.0	0.0
56-037-0300	Moxa Arch	Sweetwater	32.1	31.9	31.9	0.0
56-037-0898	OCI #4	Sweetwater	27.8	28.5	28.5	0.0
56-041-0101	Murphy Ridge	Uinta	13.8	8.8	8.8	0.0

The simulated 98th percentile 1-hour NO_2 concentrations are all less than 100 ppb. The simulated concentrations are not consistently higher or lower for the No Action scenario, compared to the base year. On average, concentrations are projected to be slightly higher (1.7 ppb) for the future year. Compared to the No Action scenario, simulated concentrations for the Proposed Action scenario are 0.1 to 0.4 ppb higher for the Jonah, Juel Spring and Daniel South monitoring sites.

Table 5-11 summarizes the annual average NO_2 concentration for these same sites for the base- and future-year simulations.

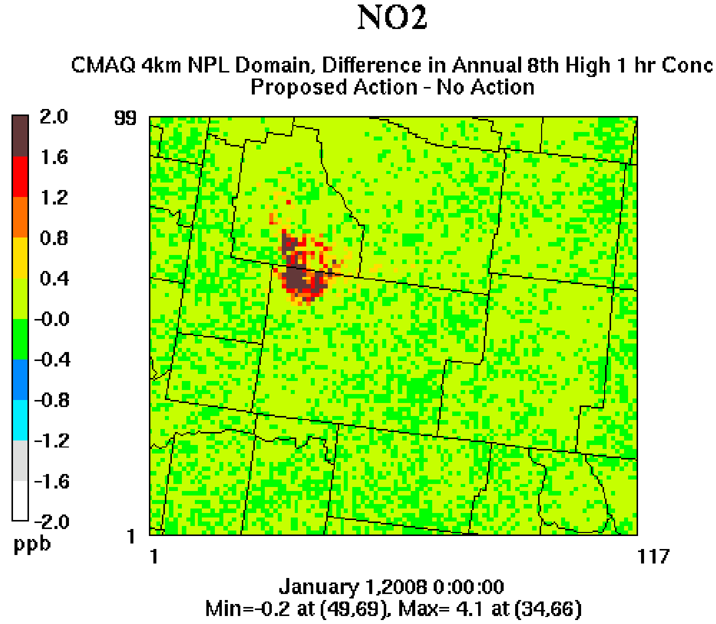
Table 5-11. Simulated Annual Average NO_2 Concentration (ppb) for Monitoring Sites within the NPL 4-km Grid (Wyoming)

Site ID	Site Name	County	Annual Average NO_2 Concentration (ppb)			Change in Concentration due to Proposed Action (ppb)
			2008 Base Year	*Future Year No Action*	*Future Year Proposed Action*	
56-007-0100	Atlantic Rim	Carbon	1.3	2.1	2.1	0.0
56-013-0099	South Pass	Fremont	0.3	0.3	0.3	0.0
56-013-0232	Spring Creek	Fremont	0.5	0.5	0.5	0.0
56-035-0098	Jonah	Sublette	12.4	18.3	18.4	0.1
56-035-0099	Boulder	Sublette	5.2	5.2	5.2	0.0
56-035-0100	Daniel South	Sublette	1.0	0.8	0.8	0.0
56-035-0101	Pinedale	Sublette	2.2	2.2	2.2	0.0
56-035-1002	Juel Spring	Sublette	3.1	5.0	5.2	0.2
56-037-0200	Wamsutter	Sweetwater	3.2	6.1	6.1	0.0
56-037-0300	Moxa Arch	Sweetwater	3.2	3.4	3.4	0.0
56-037-0898	OCI #4	Sweetwater	3.4	3.4	3.4	0.0
56-041-0101	Murphy Ridge	Uinta	1.9	1.4	1.4	0.0

The simulated annual average NO_2 concentrations are all less than 53 ppb. The simulated concentrations are not consistently higher or lower for the No Action scenario, compared to the base year. On average, concentrations are projected to be slightly higher (0.9 ppb) for the future year. Compared to the No Action scenario, simulated concentrations for the Proposed Action scenario are 0.1 higher for the Jonah monitoring site and 0.2 ppb higher for the Juel Spring. There is no change for the remaining sites.

The difference in simulated 98^{th} percentile 1-hour average NO_2 concentration for each grid cell within the 4-km grid (for the annual simulation period) is displayed in Figure 5-10.

Figure 5-10. Difference in Simulated 98th Percentile 1-Hour NO_2 Concentration (ppb) for the CMAQ 4-km Grid: Proposed Action – No Action



The maximum difference (maximum impact on the 98th percentile 1-hour NO_2 concentration) is 4.1 ppb. The greatest impacts on this metric occur within and to the south of the Project Area.

MATS also does not accommodate NO_2. The results presented in the remainder of this section were calculated using the MATS procedures, but in this case the procedures were applied manually within spreadsheets containing the model output for NO_2.

Table 5-12 summarizes the modeled attainment test results for 1-hour NO_2. The baseline design values used for this summary were calculated using data for 2007-2009. Only sites with data for one or more years during the three-year period were included. The baseline NO_2 design values are based on one year of monitoring data for Spring Creek and Pinedale, two years of monitoring data for Jonah, and three years of monitoring data for all other sites.

Table 5-12. Estimated Future-Year 1-Hour NO_2 Design Values (ppb) for Monitoring Sites within the NPL 4-km Grid (Wyoming)

Site ID	Site Name	County	1-Hour NO_2 Design Value (ppb)			Change in Design Value due to Proposed Action (ppb)
			Baseline	*Future Year No Action*	*Future Year Proposed Action*	
56-013-0099	South Pass	Fremont	11.3	18.1	18.1	0.0
56-013-0232	Spring Creek	Fremont	5.3	2.5	2.5	0.0
56-035-0098	Jonah	Sublette	6.0	9.4	9.4	0.0
56-035-0099	Boulder	Sublette	92.0	84.6	84.9	0.3
56-035-0100	Daniel South	Sublette	33.3	31.8	31.8	0.0
56-035-0101	Pinedale	Sublette	8.0	8.3	8.3	0.0
56-037-0200	Wamsutter	Sweetwater	27.0	26.7	26.7	0.0
56-041-0101	Murphy Ridge	Uinta	41.0	29.4	29.4	0.0

Note: The NAAQS for 1-hour average NO_2 concentration is 100 ppb.

Differences between the estimated future-year design values for the No Action scenario and the base year design values range from approximately -12 to 7 ppb and are a mix of increases and decreases. On average, the design values are 2.3 ppb lower for the No Action scenario. Compared to the No Action scenario, the estimated future-year design values for the Proposed Action scenario are the same as those for the No Action scenario, with one exception. There is a 0.3 ppb increase in the estimated design value for the Boulder monitoring site.

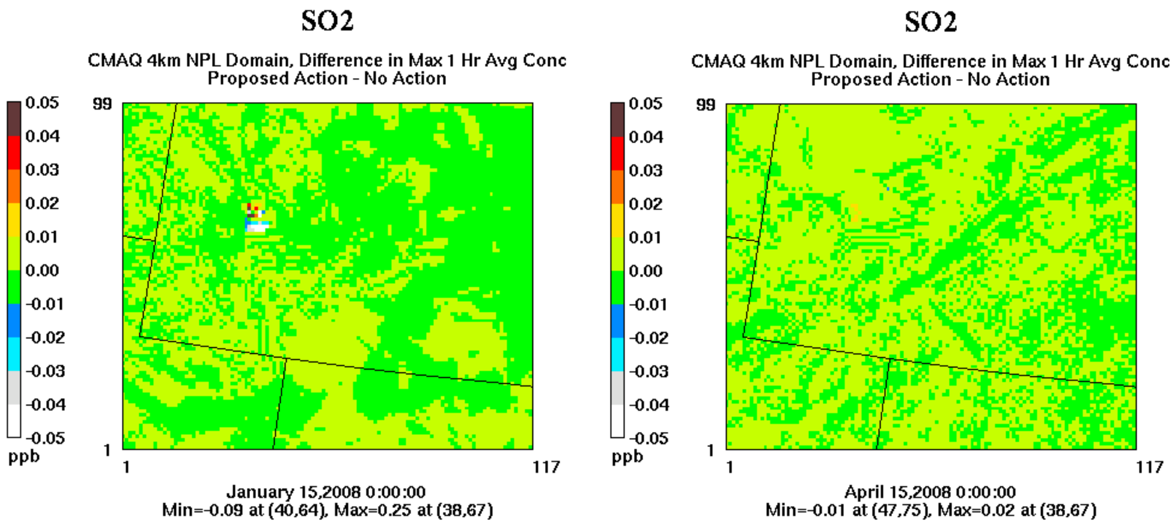
Similar relative response factors (ranging from 0.6 to 1.6) would be applied to the annual design values. Since the NO_2 design values for all sites are well below the annual NAAQS, the detailed calculations were not performed.

5.2.1.5. SO_2

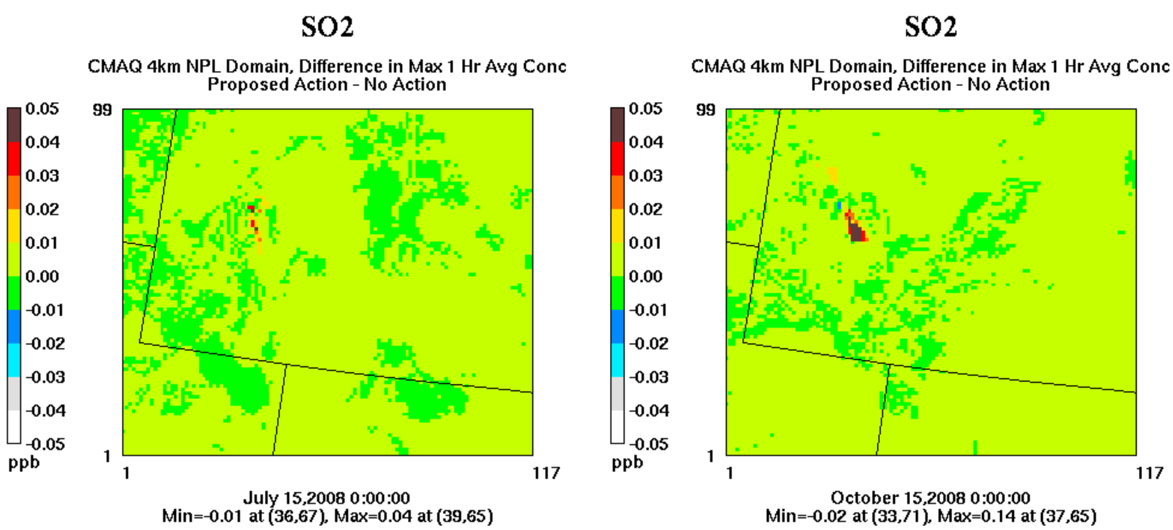
Figure 5-11 illustrates the simulated differences in daily maximum 1-hour SO_2 concentration for the 15th of each month for January, April, July, and October (every third month) for the 4-km grid. Note that the scale ranges from only -0.05 to 0.05 ppb.

Figure 5-11. Difference in Daily Maximum 1-Hour SO_2 Concentration (ppb) for Selected Days for the CMAQ 4-km Grid: Proposed Action – No Action

January/April



July/October



Results for the remaining months (not shown) are similar.

Based on the CMAQ results, Table 5-13 summarizes the 99th percentile daily maximum 1-hour SO_2 concentration (a key NAAQS related metric) for the base- and future-year simulations. Included in the table are SO_2 monitoring sites operating for one or more years during the period 2006 – 2010. These sites were selected to represent air quality conditions for the 2008 base year. In addition, Pinedale was included as a pseudo monitor for SO_2 to allow the review of the simulation results for Sublette County.

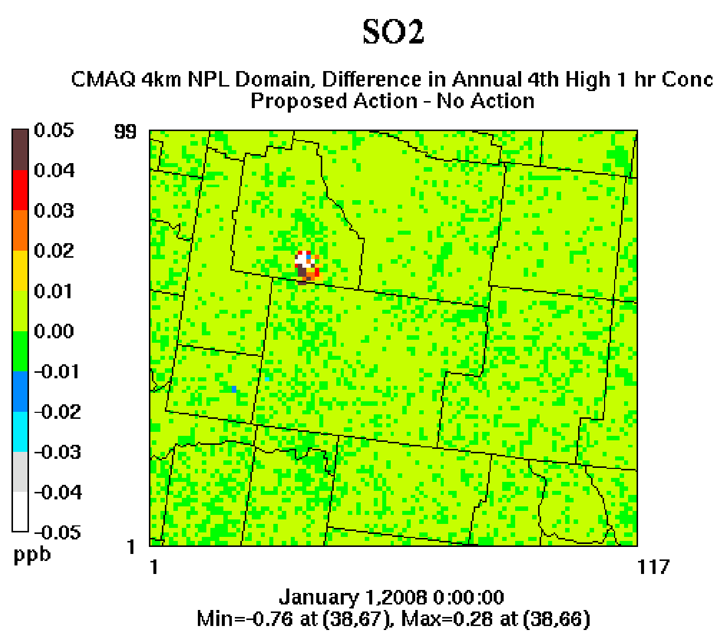
Table 5-13. Simulated 99th Percentile Daily Maximum 1-Hour SO_2 Concentration (ppb) for Monitoring Sites within the NPL 4-km Grid (Wyoming)

Site ID	Site Name	County	99th Percentile 1-Hour SO_2 Concentration (ppb)			Change in Concentration due to Proposed Action (ppb)
			2008 Base Year	*Future Year No Action*	*Future Year Proposed Action*	
56-013-0099	South Pass	Fremont	4.2	1.8	1.8	0.0
56-035-0101	Pinedale	Sublette	10.8	10.8	10.8	0.0
56-037-0200	Wamsutter	Sweetwater	15.5	2.1	2.1	0.0
56-037-0300	Moxa Arch	Sweetwater	28.3	8.4	8.4	0.0
56-041-0101	Murphy Ridge	Uinta	6.8	6.9	6.9	0.0

Concentrations are projected to be lower for the future year, compared to the base year for three of the sites (South Pass, Wamsutter and Moxa Arch) and higher or the same for the other two sites (Pinedale and Murphy Ridge). The average change in this metric between the base year and the future-year scenarios is approximately -7 ppb. Simulated concentrations for the No Action and Proposed Action scenarios for the SO_2 monitoring sites are the same.

The difference in simulated 99th percentile 1-hour average SO_2 concentration for each grid cell within the 4-km grid (for the annual simulation period) is displayed in Figure 5-12.

Figure 5-12. Difference in Simulated 99th Percentile 1-Hour SO_2 Concentration (ppb) for the CMAQ 4-km Grid: Proposed Action – No Action



The maximum impact on the 99th percentile 1-hour SO_2 concentration is 0.3 ppb. The greatest impacts on this metric occur within the Project Area.

MATS does not accommodate SO_2. The results presented in the remainder of this section were calculated using the MATS procedures, but in this case the procedures were applied manually within spreadsheets containing the model output for SO_2.

Table 5-14 summarizes the modeled attainment test results for 1-hour SO_2. The baseline design values used for this summary were calculated using data for 2007-2009. Only sites with data for one or more years during the three-year period were included. The baseline SO_2 design values are based on three years of monitoring data for all three sites.

Table 5-14. Estimated Future-Year 1-Hour SO_2 Design Values (ppb) for Monitoring Sites within the NPL 4-km Grid (Wyoming)

Site ID	Site Name	County	1-Hour SO_2 Design Value (ppb)			Change in Design Value due to Proposed Action (ppb)
			Baseline	*Future Year No Action*	*Future Year Proposed Action*	
56-013-0099	South Pass	Fremont	6.3	1.0	1.0	0.0
56-037-0200	Wamsutter	Sweetwater	9.0	0.7	0.7	0.0
56-041-0101	Murphy Ridge	Uinta	5.3	2.7	2.7	0.0

Note: The NAAQS for 1-hour average SO_2 concentration is 75 ppb.

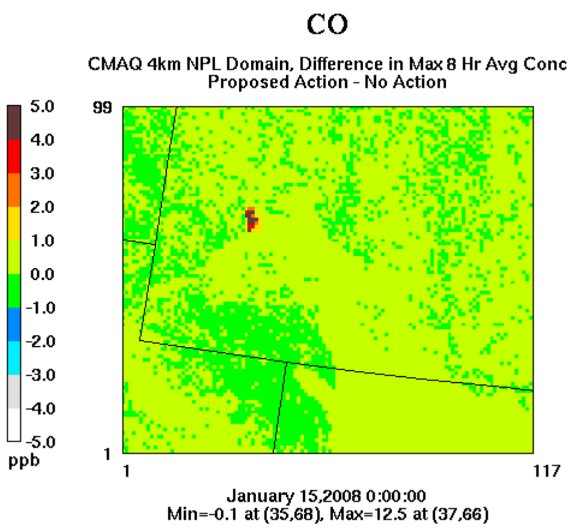
For all three sites the estimated future-year design values are much lower than the current year values. This is due in part to differences in emissions between the base and future year for a power plant located along the southern boundary of the 4-km grid (and what appears to be an error in the 2008 National Emission Inventory (NEI) that was corrected by EPA in the future-year emissions). Compared to the No Action scenario, the estimated future-year design values for the Proposed Action scenario are the same as those for the No Action scenario.

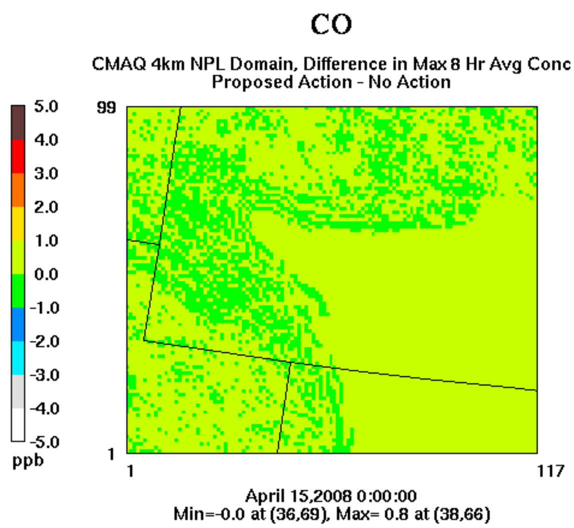
5.2.1.6. CO

Figure 5-13 illustrates the simulated differences in 8-hour average CO concentration for the 15th of each month for January, April, July, and October (every third month) for the 4-km grid.

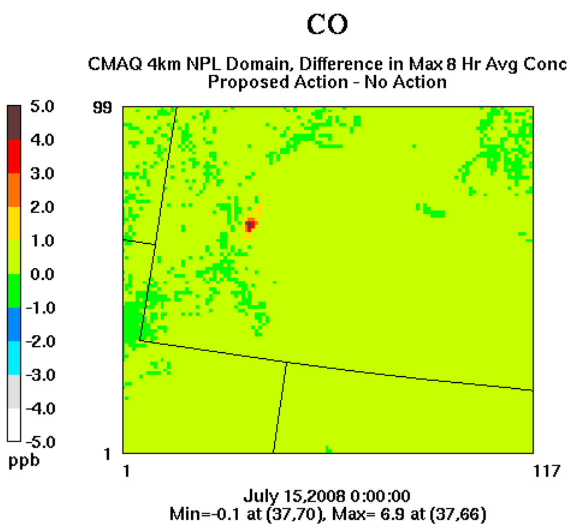
Figure 5-13. Difference in 8-Hour Average CO Concentration (ppb) for Selected Days for the CMAQ 4-km Grid: Proposed Action – No Action

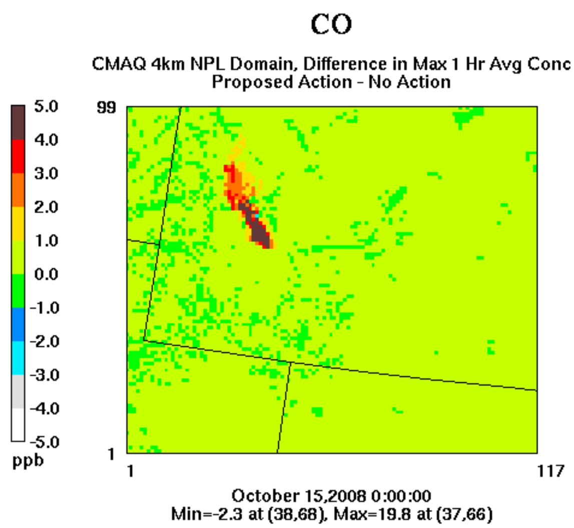
January/April





July/October





Results for the remaining months (not shown) are similar.

Based on the CMAQ results, Table 5-15 summarizes the highest daily maximum 1-hour CO concentration (a key NAAQS related metric) for the base- and future-year simulations. Since CO was monitored for one year (2008) at one site (Murphy Ridge), the actual and pseudo SO_2 monitoring sites were used as surrogate sites for CO for the purposes of sampling the simulation results for multiple locations.

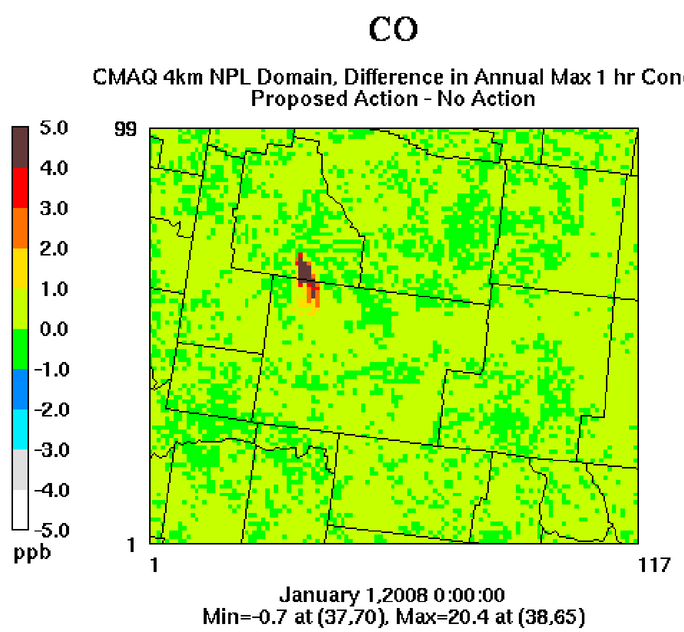
Table 5-15. Simulated Highest Daily Maximum 1-Hour CO Concentration (ppb) for Monitoring Sites within the NPL 4-km Grid (Wyoming)

Site ID	Site Name	County	Maximum 1-Hour CO Concentration (ppb)			Change in Concentration due to Proposed Action (ppb)
			2008 Base Year	*Future Year No Action*	*Future Year Proposed Action*	
56-035-0101	Pinedale	Sublette	5450	5450	5450	0
56-037-0200	Wamsutter	Sweetwater	178	303	303	0
56-037-0300	Moxa Arch	Sweetwater	267	256	256	0
56-041-0101	Murphy Ridge	Uinta	272	261	261	0

The simulated CO concentrations corresponding to the peak 1-hour concentration are not consistently higher or lower for the No Action scenario, compared to the base year. The differences vary by site. The values for all sites are the same for the No Action and Proposed Action scenarios.

The difference in simulated maximum 1-hour average CO concentration for each grid cell within the 4-km grid (for the annual simulation period) is displayed in Figure 5-14.

Figure 5-14. Difference in Simulated Maximum 1-Hour CO Concentration (ppb) for the CMAQ 4-km Grid: Proposed Action – No Action



The maximum impact on daily maximum 1-hour CO concentration is 20.4 ppb. The greatest impacts occur within and to the south of the Project Area.

There is one site with partial data during the 2007-2009 current year period, so estimated design values were not calculated. However, the relative response factors were calculated and range from 0.8 to 1 for both future-year scenarios.

5.2.2 Prevention of Significant Deterioration

The incremental increases in concentration for the Proposed Action scenario relative to the No Action scenario are compared with applicable PSD consumption increments in Table 5-16 (a) and (b). These were calculated for the grid cell with the maximum impact within each of the Class I and Class II areas listed in Section 3. For those areas within the 4-km grid, the 4-km resolution modeling results were used. For those areas located outside of the 4-km grid, the 12-km resolution modeling results were used. No increases in concentration exceed the PSD increments; all calculated increments are very small compared to the allowable increments.

Table 5-16a. Comparison of CMAQ-Derived Criteria Pollutant Impacts Based on the Proposed Action and No Action Scenarios with PSD Consumption Increments: Class I Areas

Class I Area	State	PM_{10} Increment (µg/m^3)		$PM_{2.5}$ Increment (µg/m^3)		Annual NO_2 Increment (µg/m^3)	Annual SO_2 Increment (µg/m^3)
		24-Hour	*Annual*	*24-Hour*	*Annual*		
Bridger WA	WY	0.097	0.012	0.022	0.003	0.005	0.0
Fitzpatrick WA	WY	0.063	0.004	0.018	0.002	0.002	0.0
Grand Teton NP	WY	0.044	0.002	0.0	0.001	0.001	0.0
North Absaroka WA	WY	0.007	0.0	0.003	0.0	0.0	0.0
Teton WA	WY	0.013	0.002	0.0	0.001	0.001	0.0
Washakie WA	WY	0.008	0.002	0.004	0.001	0.001	0.0
Yellowstone NP	WY	0.013	0.001	0.002	0.0	0.001	0.0
Mt. Zirkel NP	CO	0.003	0.001	0.002	0.0	0.001	0.0
Rawah WA	CO	0.0	0.002	0.001	0.001	0.002	0.0
Red Rock Lakes WA	MT	0.007	0.0	0.002	0.0	0.0	0.0
Allowable PSD Class I Increment		**8**	**4**	**2**	**1**	**2.5**	--

Table 5-16b. Comparison of CMAQ-Derived Criteria Pollutant Impacts Based on the Proposed Action and No Action Scenarios with PSD Consumption Increments: Sensitive Class II Areas

Sensitive Class II Area	State	PM_{10} Increment (µg/m³)		$PM_{2.5}$ Increment (µg/m³)		Annual NO_2 Increment (µg/m³)	Annual SO_2 Increment (µg/m³)
		24-Hour	*Annual*	*24-Hour*	*Annual*		
Cloud Peak WA	WY	0.0	0.001	0.0	0.0	0.0	0.0
Gros Ventre WA	WY	0.031	0.006	0.0	0.001	0.002	0.0
Jedediah Smith WA	WY	0.079	0.001	0.0	0.0	0.0	0.0
Popo Agie WA	WY	0.010	0.008	0.006	0.003	0.003	0.0
Savage Run WA	WY	0.001	0.0	0.001	0.0	0.001	0.0
Wind River RA	WY	0.055	0.005	0.017	0.002	0.002	0.0
Dinosaur NP	CO	0.010	0.0	0.003	0.0	0.0	0.0
High Uintas WA	UT	0.0	0.0	0.0	0.0	0.0	0.0
Allowable PSD Class II Increment		**30**	**17**	**8**	**4**	**25**	**--**

5.3 Air Quality Related Values Impact Assessment

5.3.1 Visibility

The visibility assessment focused on all grid cells that overlap a Class I or sensitive Class II area within the study region. For each modeled scenario, estimated visibility degradation was calculated for each Class I and sensitive Class II area within the 4- and 12-km grids. Two methodologies were used to evaluate visibility impacts.

The first method is described in the Federal Land Managers' Air Quality Related Values Work Group (FLAG) Phase I Report—Revised 2010 and is hereafter referred to as the FLAG 2010 method (FLAG, 2010). Changes in visibility due to project-related emissions were calculated from the difference between the modeled concentrations for the Proposed Action and No Action scenarios.

For each scenario, visibility was calculated using the latest IMPROVE algorithm (Hand and Malm, 2006), modeled species concentrations, and site-specific monthly relative humidity factors (FLAG, 2010). The IMPROVE algorithm characterizes visibility in term of an extinction coefficient (b_{ext}). For each Class I and sensitive Class II area the grid cell with the maximum impact was identified and the maximum and 98th percentile change in b_{ext} at the location of maximum impact was calculated. The percent change that these impacts represent relative to natural background was calculated. The b_{ext} values were also converted to deciview haze index, defined as equal to 10 ln(b_{ext}/10), and the change in deciviews (dv) associated with the maximum and 98th percentile impacts was calculated.

A 5 percent change in light extinction (approximately equal to 0.5 deciview [dv]) is the threshold recommended in FLAG 2010 and is considered to contribute to regional haze visibility impairment. A 10 percent change in light extinction (approximately equal to 1.0 dv) is considered to cause visibility impairment when compared to background conditions. Thus the number of days that exceed the 5 and 10 percent thresholds was also obtained.

Background values were obtained from the FLAG 2010 report (Table 5 – 20% Best Natural Conditions – Concentrations and Rayleigh Scattering by Class I Area and Table 6 – Annual Average Natural Conditions – Concentrations and Rayleigh Scattering by Class I Area). These were used along with monthly average f(RH) values, also obtained from the FLAG 2010 report (Table 7 - Monthly f(RH) – Large $(NH_4)^2$ SO_4 and NH_4NO_3 Relative Humidity Adjustment Factor), to estimate background light extinction for all Class I areas (IMPROVE data sites). Natural conditions for all Class I areas are provided in the FLAG tables. The natural condition values are based on IMPROVE data. These values for Class I areas with IMPROVE monitoring sites are also used to represent nearby Class I areas that do not have monitoring sites, in accordance with EPA guidance for tracking progress under the Regional Haze Rule (RHR) (EPA, 2003). For sensitive Class II areas, values from the closest or most climatically similar Class I area were used.

Tables 5-17 and 5-18 summarize visibility change for the Class I and Class II areas within the 12- and 4-km grids. In Table 5-17 (a) and (b), the results are presented relative to annual average natural background. In Table 5-18 (a) and (b), the results are presented relative to natural background for the 20 percent best visibility days. In these tables, WA is Wilderness Area, RA is Roadless Area, and NP is National Park. The units for b_{ext} are inverse megameters (Mm^{-1}).

Table 5-17a. Visibility Impacts for the Proposed Action Based on Annual Average Natural Background: Class I Areas

Class I Area	State	Natural Visibility b_{ext} (Mm^{-1})	98th Percentile Impact			Maximum Impact			# Days >5% Change	# Days >10% Change
			Δ b_{ext} (Mm^{-1})	*% Change in b_{ext}*	*Δ dv*	*Δ b_{ext} (Mm^{-1})*	*% Change in b_{ext}*	*Δ dv*		
Bridger WA	WY	15.02	0.02	0.14	0.01	1.05	6.98	0.67	1	0
Fitzpatrick WA	WY	15.02	0.02	0.12	0.01	0.97	6.43	0.62	1	0
Grand Teton NP	WY	15.03	0.02	0.16	0.02	0.09	0.59	0.06	0	0
North Absaroka WA	WY	15.02	0.01	0.04	0.00	0.01	0.09	0.01	0	0
Teton WA	WY	15.03	0.02	0.15	0.01	0.04	0.26	0.03	0	0
Washakie WA	WY	15.02	0.02	0.13	0.01	0.03	0.21	0.02	0	0
Yellowstone NP	WY	15.03	0.00	0.03	0.00	0.03	0.18	0.02	0	0
Mt. Zirkel NP	CO	15.01	0.01	0.06	0.01	0.03	0.18	0.02	0	0
Rawah WA	CO	15.01	0.01	0.06	0.01	0.27	1.79	0.18	0	0
Red Rock Lakes WA	MT	15.09	0.00	0.01	0.01	0.07	0.04	0.00	0	0

Table 5-17b. Visibility Impacts for the Proposed Action Based on Annual Average Natural Background: Sensitive Class II Areas

Sensitive Class II Area	State	Natural Visibility b_{ext} (Mm^{-1})	98th Percentile Impact			Maximum Impact			# Days >5% Change	# Days >10% Change
			Δ b_{ext} (Mm^{-1})	*% Change in b_{ext}*	*Δ dv*	*Δ b_{ext} (Mm^{-1})*	*% Change in b_{ext}*	*Δ dv*		
Cloud Peak WA	WY	15.02	0.01	0.04	0.00	0.01	0.08	0.01	0	0
Gros Ventre WA	WY	15.03	0.05	0.31	0.03	0.17	1.15	0.11	0	0
Jedediah Smith WA	WY	15.03	0.02	0.12	0.01	0.11	0.72	0.07	0	0
Popo Agie WA	WY	15.02	0.05	0.33	0.03	1.23	8.17	0.79	1	0
Savage Run WA	WY	15.01	0.01	0.08	0.01	0.03	0.18	0.02	0	0
Wind River RA	WY	15.02	0.04	0.24	0.02	0.86	5.71	0.56	1	0
Dinosaur NP	CO	15.01	0.01	0.07	0.01	0.02	0.10	0.01	0	0
High Uintas WA	UT	15.01	0.00	0.02	0.00	0.24	1.60	0.16	0	0

Table 5-18a. Visibility Impacts for the Proposed Action Based on 20% Best Days Natural Background: Class I Areas

Class I Area	State	Natural Visibility b_{ext} (Mm^{-1})	98th Percentile Impact			Maximum Impact			# Days >5% Change	# Days >10% Change
			Δ b_{ext} (Mm^{-1})	*% Change in b_{ext}*	*Δ dv*	*Δ b_{ext} (Mm^{-1})*	*% Change in b_{ext}*	*Δ dv*		
Bridger WA	WY	11.63	0.02	0.18	0.02	1.05	9.01	0.86	1	0
Fitzpatrick WA	WY	11.63	0.02	0.16	0.02	0.97	8.30	0.80	1	0
Grand Teton NP	WY	11.64	0.02	0.21	0.02	0.09	0.77	0.08	0	0
North Absaroka WA	WY	11.63	0.01	0.06	0.01	0.01	0.12	0.01	0	0
Teton WA	WY	11.64	0.02	0.19	0.02	0.04	0.33	0.03	0	0
Washakie WA	WY	11.63	0.02	0.17	0.02	0.03	0.27	0.03	0	0
Yellowstone NP	WY	11.64	0.00	0.04	0.00	0.03	0.24	0.02	0	0
Mt. Zirkel NP	CO	11.62	0.01	0.08	0.01	0.03	0.23	0.02	0	0
Rawah WA	CO	11.62	0.01	0.07	0.01	0.27	2.31	0.23	0	0
Red Rock Lakes WA	MT	11.68	0.0	0.01	0.0	0.01	0.06	0.01	0	0

Table 5-18b. Visibility Impacts for the Proposed Action Based on 20% Best Days Natural Background: Sensitive Class II Areas

Sensitive Class II Area	State	Natural Visibility b_{ext} (Mm^{-1})	98th Percentile Impact			Maximum Impact			# Days >5% Change	# Days >10% Change
			Δ b_{ext} (Mm^{-1})	*% Change in b_{ext}*	*Δ dv*	*Δ b_{ext} (Mm^{-1})*	*% Change in b_{ext}*	*Δ dv*		
Cloud Peak WA	WY	11.63	0.01	0.06	0.01	0.01	0.10	0.01	0	0
Gros Ventre WA	WY	11.64	0.05	0.40	0.04	0.17	1.49	0.15	0	0
Jedediah Smith WA	WY	11.64	0.02	0.15	0.02	0.11	0.92	0.09	0	0
Popo Agie WA	WY	11.63	0.05	0.43	0.04	1.23	10.55	1.00	1	1
Savage Run WA	WY	11.62	0.01	0.11	0.01	0.03	0.23	0.02	0	0
Wind River RA	WY	11.63	0.04	0.31	0.03	0.86	7.38	0.71	1	0
Dinosaur NP	CO	11.62	0.01	0.09	0.01	0.02	0.13	0.01	0	0
High Uintas WA	UT	11.62	0.00	0.02	0.00	0.24	2.06	0.20	0	0

Relative to annual average natural background (Table 5-17a), the largest 98th percentile impact is 0.03 dv, for both the Gros Ventre and Popo Agie Wilderness Areas. Maximum impacts are larger and there is one day for each of Bridger, Fitzpatrick, and Popo Agie Wilderness Areas and Wind River Roadless Area for which a greater than 5 percent change in light extinction (a greater than 0.5 dv impact) is modeled.

Relative to natural background for the 20% best visibility days (Table 5-17b), the largest 98th percentile impact is 0.04 dv, for both the Gros Ventre and Popo Agie Wilderness Areas. Maximum impacts indicate that there is one day for each of Bridger, Fitzpatrick, and Popo Agie Wilderness Areas and Wind River Roadless Area for which a greater than 5 percent change in light extinction (a greater than 0.5 dv impact) is modeled. There is also one day for the Popo Agie Wilderness Area for which a greater than 10 percent change in light extinction (a greater than 1.0 dv impact) is modeled.

The second method used to examine visibility focused on cumulative impacts and made use of the EPA MATS software to calculate future-year mean visibility for the 20 percent best and worst visibility days. The steps involved in the MATS approach can be summarized as follows:

Step 1: Calculate the average baseline visibility for each Class I and Class II area based on five years of monitoring data for the 20 percent best and 20 percent worst days.

Step 2: Estimate site-specific RRFs for each visibility component (as specified in the new IMPROVE equation) based on the future-year and base-year modeling results. As noted earlier in the section, the RRF is defined as the ratio of the future-year to base-year simulated concentration in the vicinity of a monitoring site.

Step 3: Apply the RRFs to the monitoring data to estimate future-year concentrations corresponding to the 20 percent best and 20 percent worst visibility days.

Step 4: Use the concentration estimates from Step 3 to calculate future-year visibility for the best and worst days.

Step 5: Using the information from Step 4, calculate the future-year mean visibility for the 20 percent best and worst days.

MATS was applied for the No Action and Proposed Action scenarios. The difference in estimated future-year mean visibility between the Proposed Action and No Action scenarios was calculated and used to quantify the change in cumulative visibility resulting from project-specific emissions.

Typically MATS would only be applied for Class I areas with IMPROVE monitoring sites, since the application of MATS relies on baseline visibility data. For this analysis, additional locations were added so that all Class I and sensitive Class II areas within the 12- and 4-km grids were included. Similar to the FLAG analysis, the additional locations (or pseudo sites) were assigned to the grid cell with the maximum visibility impact from the Proposed Action emissions. The average baseline visibility data for Class I areas with IMPROVE monitoring sites (Bridger Wilderness and Mount Zirkel Wilderness) were used to represent nearby Class I and sensitive Class II areas without monitoring sites. Average baseline visibility was calculated using data for the best and worst visibility days for the five-year period 2006-2010.

Tables 5-19 and 5-20 summarize the MATS results for visibility – first for the 20 percent best visibility days and then for the 20 percent worst visibility days. The units are deciviews (dv).

Table 5-19a. Estimated Future-Year Visibility (dv) for the 20 Percent Best Days: Class I Areas

Class I Area	State	Baseline Visibility (dv)	Estimated Future-Year Visibility (dv)		Change in Visibility due to Proposed Action (Δ dv)
			No Action Scenario	*Proposed Action Scenario*	
Bridger WA	WY	1.39	1.25	1.25	0
Fitzpatrick WA	WY	1.39	1.28	1.28	0
Grand Teton NP	WY	1.85	1.57	1.57	0
North Absaroka WA	WY	1.42	1.21	1.21	0
Teton WA	WY	1.85	1.58	1.58	0
Washakie WA	WY	1.42	1.22	1.22	0
Yellowstone NP	WY	1.85	1.58	1.58	0
Mt. Zirkel NP	CO	0.95	0.77	0.77	0
Rawah WA	CO	0.95	0.87	0.87	0
Red Rock Lakes WA	MT	1.85	1.60	1.60	0

Table 5-19b. Estimated Future-Year Visibility (dv) for the 20 Percent Best Days: Sensitive Class II Areas

Sensitive Class II Area	State	Baseline Visibility (dv)	Estimated Future-Year Visibility (dv)		Change in Visibility due to Proposed Action (Δ dv)
			No Action Scenario	*Proposed Action Scenario*	
Cloud Peak WA	WY	1.42	1.22	1.22	0
Gros Ventre WA	WY	1.85	1.57	1.59	0.02
Jedediah Smith WA	WY	1.85	1.56	1.56	0
Popo Agie WA	WY	1.39	1.25	1.25	0
Savage Run WA	WY	0.95	0.76	0.77	0.01
Wind River RA	WY	1.39	1.25	1.25	0
Dinosaur NP	CO	0.95	0.6	0.6	0
High Uintas WA	UT	0.95	0.75	0.75	0

Table 5-20a. Estimated Future-Year Visibility (dv) for the 20 Percent Worst Days: Class I Areas

Class I Area	State	Baseline Visibility (dv)	Estimated Future-Year Visibility (dv)		Change in Visibility due to Proposed Action (Δ dv)
			No Action Scenario	*Proposed Action Scenario*	
Bridger WA	WY	10.58	9.92	9.93	0.01
Fitzpatrick WA	WY	10.58	9.89	9.89	0
Grand Teton NP	WY	11.57	10.8	10.8	0
North Absaroka WA	WY	11.72	11.28	11.28	0
Teton WA	WY	11.57	10.79	10.80	0.01
Washakie WA	WY	11.72	11	11.01	0.01
Yellowstone NP	WY	11.57	11.19	11.19	0
Mt. Zirkel NP	CO	9.36	8.73	8.73	0
Rawah WA	CO	9.36	8.75	8.75	0
Red Rock Lakes WA	MT	11.57	10.97	10.98	0.01

Table 5-20b. Estimated Future-Year Visibility (dv) for the 20 Percent Worst Days: Sensitive Class II Areas

Sensitive Class II Area	State	Baseline Visibility (dv)	Estimated Future-Year Visibility (dv)		Change in Visibility due to Proposed Action (Δ dv)
			No Action Scenario	*Proposed Action Scenario*	
Cloud Peak WA	WY	11.72	11.05	11.06	0.01
Gros Ventre WA	WY	11.57	10.83	10.84	0.01
Jedediah Smith WA	WY	11.57	10.81	10.81	0
Popo Agie WA	WY	10.58	9.90	9.91	0.01
Savage Run WA	WY	9.36	8.79	8.80	0.01
Wind River RA	WY	10.58	9.91	9.91	0
Dinosaur NP	CO	9.36	8.58	8.58	0
High Uintas WA	UT	9.36	8.62	8.62	0

Using the MATS approach, the calculated impact on future-year visibility from the Proposed Action for the 20 percent best days is greater than zero for two areas: the Gros Ventre Wilderness Area (0.02 dv) and the Savage Run Wilderness Area (0.01 dv). The calculated impact on future-year visibility from the Proposed Action for the 20 percent worst days is 0.01 dv for seven areas including the Bridger, Teton, Washakie, Cloud Peak, Gros Ventre, Popo Agie, and Savage Run Wilderness Areas.

5.3.2 Atmospheric Deposition

The effects of atmospheric deposition of nitrogen and sulfur compounds on terrestrial and aquatic ecosystems are well documented and have been shown to cause leaching of nutrients from soils, acidification of surface waters, injury to high elevation vegetation, and changes in nutrient cycling and species composition. Project-specific and cumulative nitrogen and sulfur deposition impacts were examined for Class I areas and identified sensitive Class II areas within the project study area.

CMAQ-derived annual wet, dry, and total (wet plus dry) deposition fluxes of total S and N compounds were used to estimate the total S and N deposition fluxes at the Class I and sensitive Class II areas within the 4- and 12-km grids and are presented in Table 5-21 (a) and (b). Deposition was calculated for the No Action and Proposed Action scenarios. The difference in deposition for each species (attributable to the Proposed Action) is compared with the deposition analysis threshold (DAT) developed by the National Park Service (NPS) and the U.S. Fish and Wildlife Service (USFWS). The DATs represent values for nitrogen and sulfur deposition from project-specific emission sources below which estimated impacts are considered negligible. The DAT established for both nitrogen and sulfur in western Class I areas is 0.005 kilograms per hectare per year (kg/ha/yr).

Cumulative modeled deposition amounts are also compared to critical load thresholds to assess total deposition impacts. In this study, deposition results are compared to critical load thresholds established for the Rocky Mountain region. Critical loads vary by sensitive resource. For this analysis, the critical load for the most sensitive resource (high elevation surface waters was used). The critical load thresholds are: 3 kg/ha/yr for total S deposition and 2.2 kg/ha/yr for total N deposition. Deposition amounts that exceed the critical load values are highlighted in bold.

Table 5-21a. CMAQ-Derived Total Sulfur and Nitrogen Deposition (kg/ha/yr): Class I Areas

Class I Area	State	Total S Deposition (kg/ha/yr)			Total N Deposition (kg/ha/yr)		
		No Action Scenario	*Proposed Action Scenario*	*ΔS Deposition due to Proposed Action*	*No Action Scenario*	*Proposed Action Scenario*	*ΔN Deposition due to Proposed Action*
Bridger WA	WY	2.11	2.11	0.000	**2.11**	**2.12**	0.004
Fitzpatrick WA	WY	1.57	1.57	0.000	1.70	1.70	0.002
Grand Teton NP	WY	1.80	1.80	0.000	1.39	1.39	0.001
North Absaroka WA	WY	0.86	0.86	0.000	1.03	1.03	0.000
Teton WA	WY	1.52	1.52	0.000	1.33	1.33	0.001
Washakie WA	WY	0.92	0.92	0.000	0.99	0.99	0.001
Yellowstone NP	WY	1.44	1.44	0.000	1.23	1.23	0.000
Mt. Zirkel NP	CO	2.73	2.73	0.000	**3.36**	**3.36**	0.001
Rawah WA	CO	1.74	1.74	0.000	**2.45**	**2.45**	0.001
Red Rock Lakes WA	MT	1.02	1.02	0.000	1.0	1.0	0.000
DAT				**0.005**			**0.005**
Critical Load Threshold		**3.0**	**3.0**		**2.2**	**2.2**	

Table 5-21b. CMAQ-Derived Total Sulfur and Nitrogen Deposition (kg/ha/yr): Sensitive Class II Areas

Sensitive Class II Area	State	Total S Deposition (kg/ha/yr)			Total N Deposition (kg/ha/yr)		
		No Action Scenario	*Proposed Action Scenario*	*ΔS Deposition due to Proposed Action*	*No Action Scenario*	*Proposed Action Scenario*	*ΔN Deposition due to Proposed Action*
Cloud Peak WA	WY	1.83	1.83	0.000	1.69	1.69	0.001
Gros Ventre WA	WY	1.93	1.93	0.000	1.89	1.89	0.003
Jedediah Smith WA	WY	2.06	2.06	0.000	1.59	1.59	0.000
Popo Agie WA	WY	2.07	2.07	0.000	**2.34**	**2.35**	0.006
Savage Run WA	WY	1.46	1.46	0.000	**2.07**	**2.07**	0.002
Wind River RA	WY	1.38	1.38	0.000	1.74	1.74	0.003
Dinosaur NP	CO	0.66	0.66	0.000	1.31	1.31	0.000
High Uintas WA	UT	1.72	1.72	0.000	1.96	1.96	0.000
DAT				**0.005**			**0.005**
Critical Load Threshold		**3.0**	**3.0**		**2.2**	**2.2**	

For sulfur, the simulated change in deposition due to the Proposed Action does not exceed the DAT of 0.005 kg/ha/yr for any area. In addition, the simulated cumulative deposition amount is less than the critical load threshold of 3.0 kg/ha/yr for all areas.

For nitrogen, the simulated change in deposition due to the Proposed Action exceeds the DAT of 0.005 kg/ha/yr for the Popo Agie Wilderness Area. The simulated cumulative deposition amount is greater than the critical load threshold of 2.2 kg/ha/yr for five of the 17 areas.

Note that the cumulative simulated deposition amounts for both sulfur and nitrogen are quite a bit larger than those calculated by CALPUFF using the same emissions information. The CALPUFF results are presented in Section 5. It is expected that CMAQ has higher deposition rates than CALPUFF due to a number of factors including a more detailed wet deposition algorithm and direct simulation of the chemical transformation of NO_2 to nitric acid (HNO_3) which results in a much higher deposition rate for both wet and dry deposition, compared to CALPUFF.

5.3.3 Lake Chemistry

The change in water chemistry associated with atmospheric deposition from project sources was also calculated for 17 acid sensitive lakes located within the 4-km CMAQ grid. An estimation of potential changes in ANC was made using a procedure developed by the USFS Rocky Mountain Region (USFS, 2000).

The equation is as follows:

% ANC change = [Hdep/ANC(o)] x 100

where:

ANC(o) = baseline ANC for entire lake catchment in eq = W x P x (1-Et) x A x (10,000m^2/ha) x (eq/106 µeq) x (103 liters/m^3)

A = baseline lake sample alkalinity in µeq/l

Hdep = acid deposition in eq = [H(s) + H(n)] x W x 10,000m^2/ha

Hs = sulfur deposition in eq/m2/yr = Ds (kg/ha/yr) x (ha/10,000m^2) x (1000g/kg) x (eq/16g S)

Hn = nitrogen deposition in eq/m2/yr = Dn (kg/ha/yr) x ha/10,000m^2) x (1000g/kg) x (eq/14g N)

W = watershed area in ha

P = average annual precipitation in meters

Et = fraction of the annual precipitation lost to evaporation and transpiration (assume Et = .33)

Ds = sulfur deposition in kg/ha/yr from all sulfur species

Dn = nitrogen deposition in kg/ha/yr from all nitrogen species

The CMAQ-derived changes in ANC due to the Proposed Action, along with several of the key terms in the calculation, are presented in Table 5-22. Background ANC data for this analysis were provided by the USFS (USFS, 2011 and 2014). The 10^{th} percentile ANC values and the number of samples used in the calculation of the 10^{th} percentile lowest ANC values are also provided in the table. Note that the very small negative numbers for sulfur deposition are likely the result of numerical errors in the CMAQ advection or chemistry routines and are effectively zero.

Table 5-22. CMAQ-Derived Change in ANC for Sensitive Lakes

Class I/ Class II Area	Lake	Lat (deg)	Lon (deg)	10th Percentile Lowest ANC Value (µeq/l) (A)	No. of Samples	Precip-itation (m) (P)	∆S Deposition (eq/m2/yr) (Hs)	∆N Deposition (eq/m2/yr) (Hn)	Total S + N Dep (eq) (Hdep)	ANC(o) (eq)	% Change in ANC	Delta ANC (µeq/l)
Bridger	Deep	42.719	-109.171	61.1	62	0.28	1.65E-06	7.21E-05	0.74	112.61	0.65	0.40
Bridger	Black Joe	42.739	-109.171	70.6	72	0.28	1.65E-06	7.21E-05	0.74	130.12	0.57	0.40
Bridger	Lazy Boy	43.333	-109.73	27.8	1	0.28	4.05E-07	1.51E-05	0.15	51.24	0.30	0.08
Bridger	Upper Frozen	42.687	-109.161	13.2	3	0.28	2.28E-06	5.78E-05	0.60	24.33	2.47	0.33
Bridger	Hobbs	43.036	-109.672	69.8	76	0.28	-3.36E-06	2.24E-05	0.19	128.64	0.15	0.10
Fitzpatrick	Ross	43.378	-109.658	54	55	0.23	3.41E-07	8.16E-06	0.09	81.97	0.10	0.06
Popo Agie	Lower Saddlebag	42.623	-108.994	55.5	54	0.34	6.03E-07	2.14E-05	0.22	126.00	0.17	0.10
High Uintas	Dean	40.679	-110.761	51.4	7	0.45	-1.07E-07	1.69E-06	0.02	154.30	0.01	0.01
High Uintas	Heart	40.594	-110.811	54.6	1	0.45	-1.07E-07	1.69E-06	0.02	163.91	0.01	0.01
High Uintas	No Name (Duchesne – 4d2-039)	40.671	-110.275	65.2	3	0.45	-2.73E-07	1.79E-06	0.02	195.73	0.01	0.01
High Uintas	Fish	40.837	-110.069	104.5	6	0.45	-3.96E-08	3.24E-06	0.03	313.71	0.01	0.01
High Uintas	Upper Coffin (Duchesne – 4d1-044)	40.834	-110.237	65	2	0.60	-3.96E-08	3.24E-06	0.03	262.38	0.01	0.01
Mt. Zirkel	Elbert	40.634	-106.707	53.8	68	0.60	-1.01E-07	4.13E-06	0.04	217.17	0.02	0.01
Mt. Zirkel	Seven (Lakes)	40.896	-106.682	36.4	67	0.60	-3.55E-07	3.92E-06	0.04	146.93	0.02	0.01
Mt. Zirkel	Summit	40.545	-106.683	48	110	0.60	4.61E-08	3.64E-06	0.04	193.35	0.02	0.01
Rawah	Island	40.627	-105.942	71.9	25	0.60	3.93E-07	8.86E-06	0.09	289.62	0.03	0.02
Rawah	Rawah Lake #4	40.671	-105.958	41.5	24	0.60	3.93E-07	8.86E-06	0.09	167.17	0.06	0.02

Deposition is greatest for the lakes in the Bridger Wilderness Area. Simulated changes in ANC were compared with the applicable threshold for each identified lake: 10 percent change in ANC for lakes with background ANC values greater than 25 micro equivalents per liter [μeq/L], and less than a 1 μeq/L change in ANC for lakes with background ANC values equal to or less than 25 μeq/L. Of the 17 lakes listed in Table 5-22, only Upper Frozen Lake is considered to be extremely sensitive to atmospheric deposition by the USFS since the background ANC is less than 25 μeq/L. The percent change in ANC is less than 10 percent for all lakes considered. The change in ANC for Upper Frozen Lake is 0.33 μeq/L, less than the 1 μeq/L threshold.

6.0 FAR-FIELD MODELING ANALYSIS: CALPUFF MODELING

6.1 Overview of the CALPUFF Model

Version 5.8.4 of the CALPUFF model was used in this study to assess impacts for air quality related values (AQRVs). CALPUFF (Scire et al., 2000) is an air quality modeling system designed for the assessment of long-range transport of pollutants and their impacts on Federal Class I areas. It is well suited for applications involving complex airflow patterns, as characterized by spatially and temporally varying wind fields that are associated with complex terrain and/or other meteorological factors. CALPUFF requires hourly, gridded fields of several meteorological parameters including temperature, humidity, wind speed, wind direction, and a variety of boundary layer and dispersion parameters. The CALPUFF modeling system consists of three main components and a set of preprocessing and postprocessing programs. The main components of the modeling system are: CALMET (a diagnostic meteorological model), CALPUFF (the air quality dispersion model), and CALPOST (a postprocessing package that is used to support the analysis of impacts on criteria pollutant concentrations and visibility). Although CALPUFF includes an algorithm to calculate secondary aerosol formation, the model does not include algorithms for simulating the photochemistry of ozone formation.

6.2 CALPUFF Modeling Approach

CALPUFF was used to assess the impacts of project-related emissions at Class I and sensitive Class II areas and to model cumulative impacts from the project-related sources and other major emission sources within the modeling domain, including RFD/RFFA sources. The assessment considered visibility as well as sulfur and nitrogen deposition. The CALPUFF modeling results were post-processed using the POSTUTIL and CALPOST utility programs.

6.2.1 Air Quality Modeling Domain

An expanded version of the NPL CMAQ 4-km resolution modeling grid was used for the CALPUFF modeling. The grid was expanded to the north such that the NPL Project Area is positioned approximately 200 km away from the north, east, and south boundaries of the modeling domain. The boundaries of the domain are approximately 50 km from the nearest edge of applicable assessment areas to allow for puff recirculation. The CALPUFF modeling domain is illustrated in Section 5.1.2 (see Figure 5-1). The domain includes the NPL Project Area and nearby PSD Class I and sensitive Class II areas.

6.2.2 Air Quality Assessment Areas and Receptors

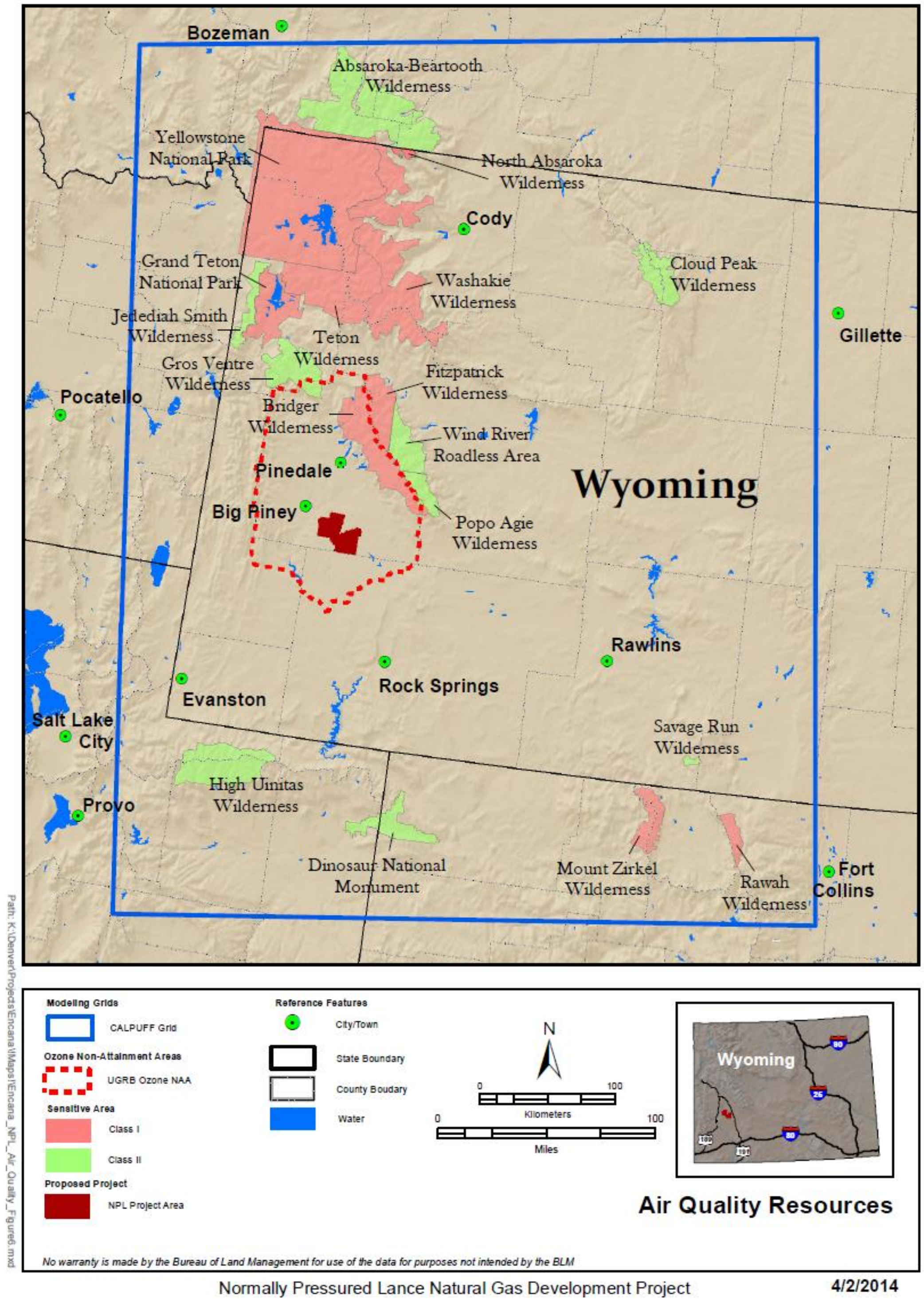
The AQRV assessment considered Class I areas and sensitive Class II areas located within the modeling domain. Key areas include:

- Bridger Wilderness Area, Wyoming (Class I)
- Fitzpatrick Wilderness Area, Wyoming (Class I)
- Yellowstone National Park, Wyoming (Class I)
- Grand Teton National Park, Wyoming (Class I)

- Teton Wilderness Area, Wyoming (Class I)
- Washakie Wilderness Area, Wyoming (Class I)
- North Absaroka Wilderness Area, Wyoming (Class I)
- Popo Agie Wilderness Area, Wyoming (Class II)
- Wind River Roadless Area, Wyoming (Class II)
- Gros Ventre Wilderness, Wyoming (Class II)
- Jedediah Smith Wilderness Area, Wyoming (Class II)
- Cloud Peak Wilderness Area, Wyoming (Class II)
- Savage Run Wilderness Area, Wyoming (Federal Class II, Wyoming Class I)
- Mount Zirkel Wilderness Area, Colorado (Class I)
- Rawah Wilderness Area, Colorado (Class I)
- Dinosaur National Monument, Colorado-Utah (Federal Class II, Colorado Class I (SO_2 only)
- High Uintas Wilderness Area, Utah (Class II)

Figure 6-1 illustrates the locations of these areas within the CALPUFF modeling domain. The map also depicts the boundaries of the designated Upper Green River Basin (UGRB) ozone nonattainment area, which encompasses the NPL Project Area.

Figure 6-1. Location of National Parks and Wilderness Areas within the NPL CALPUFF Modeling Domain



In addition, 17 lakes within the PSD Class I and sensitive Class II Wilderness areas are designated acid sensitive and the assessment also examined potential lake acidification from atmospheric deposition impacts for these lakes including:

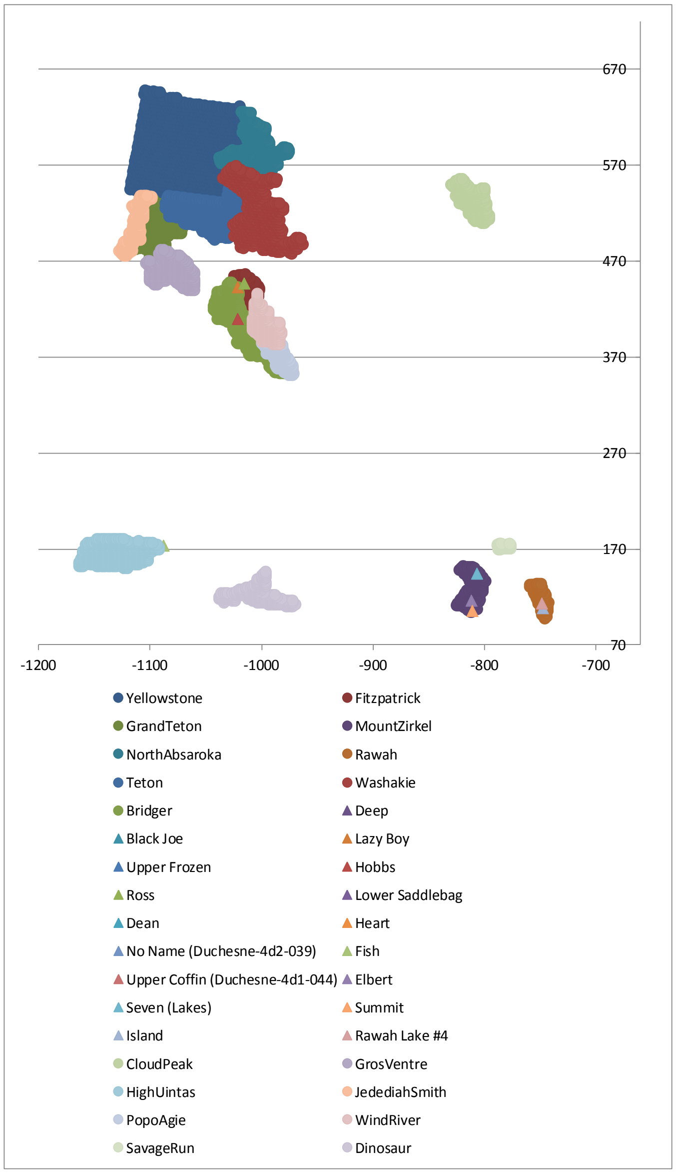
- Deep Lake in the Bridger Wilderness Area, Wyoming
- Black Joe Lake in the Bridger Wilderness Area, Wyoming
- Lazy Boy Lake in the Bridger Wilderness Area, Wyoming
- Upper Frozen Lake in the Bridger Wilderness Area, Wyoming
- Hobbs Lake in the Bridger Wilderness Area, Wyoming
- Ross Lake in the Fitzpatrick Wilderness Area, Wyoming
- Lower Saddlebag Lake in the Popo Agie Wilderness Area, Wyoming
- Dean Lake in the High Uintas Wilderness, Utah
- Heart Lake in the High Uintas Wilderness, Utah
- No Name (Duchesne – 4d2-039) Lake in the High Uintas Wilderness, Utah
- Fish Lake in the High Uintas Wilderness, Utah
- No Name (Duchesne – 4d1-044) Lake in the High Uintas Wilderness, Utah
- Lake Elbert in the Mt. Zirkel Wilderness, Colorado
- Seven Lakes in the Mt. Zirkel Wilderness, Colorado
- Summit Lake in the Mt. Zirkel Wilderness, Colorado
- Island Lake in the Rawah Wilderness, Colorado
- Rawah Lake #4 in the Rawah Wilderness, Colorado

Receptors were placed over the PSD Class I and sensitive Class II areas located within the modeling domain as listed earlier in this section. AQRV impacts were calculated for these receptors. Receptor sets available from the NPS were used as a basis for determining modeling receptors for PSD Class I areas. The complete NPS receptor set was used. For the sensitive Class II areas, receptors were placed along the boundaries and inside the sensitive area boundaries using a 1 to 2-km resolution, with a maximum of 500 receptors per area. Receptor resolution was adjusted based on the size of the area to stay within a 500 receptor maximum. Receptor elevations were estimated using U.S. Geologic Survey (USGS) Digital Elevation Model (DEM) data.

Discrete receptors were placed at the seven lakes identified as sensitive to acid deposition. Elevations for the sensitive lake receptors were derived from USGS DEM data.

The resulting total number of receptors including Class I area, sensitive Class II areas and sensitive lakes is 7,095. The receptor locations are diagramed in Figure 6-2.

Figure 6-2. Receptor Locations for Class I Areas, Sensitive Class II Areas and Sensitive Lakes within the NPL CALPUFF Modeling Domain



No of Receptors

Class I Area	*No. Rec*
Rawah	116
MountZirkel	253
Fitzpatrick	316
GrandTeton	506
Washakie	509
NorthAbsaroka	567
Bridger	684
Yellowstone	915
Teton	940
Total Class I	***4,806***
Lakes Receptors	***17***

Class II Area	*No. Rec*	*Spacing*
CloudPeak	209	2km
Dinosaur	208	2km
GrosVentre	282	2km
HighUintas	421	2km
JedediahSmith	478	1km
PopoAgie	416	1km
SavageRun	65	1km
WindRiver	193	2km
Total Class II	***2,272***	
Grand Total	**7,095**	

6.2.3 Input Preparation

6.2.3.1. Meteorological Inputs

For this study, version 3.0 of the Mesoscale Model Interface (MMIF) program (Brashers and Emery, 2013) was used to convert the WRF-derived inputs prepared for the CMAQ modeling component of the NPL air quality assessment into the meteorological input fields required by CALPUFF. MMIF is an alternative to CALMET for generating three-dimensional meteorological input fields for long-range transport assessments and air quality impact analyses. The MMIF program converts prognostic meteorological model output fields (such as those generated using the WRF model) to the parameters and formats required for direct input into the CALPUFF model.

Key parameter settings for MMIF are as follows:

- Ten model layers were employed, such that the tops of the layers are 20, 40, 80, 160, 320, 640, 1200, 2000, 3000, and 4000 meters (m) above ground level (agl). This is the default for CALPUFF.
- Stability parameters were calculated using the Golder method, in which Pasquill-Gifford stability class is based upon relationships among Monin-Obukhov lengths and surface roughness. The method is consistent with that used in AERMOD and is the default for MMIF.
- The option to recalculate planetary boundary layer (PBL) heights was not used. This is the default for MMIF.

6.2.3.2. Emission Inputs

6.2.3.3. Project-Specific Emissions

Project-specific emissions described in Section 2 were input to CALPUFF to simulate the air quality impacts from the Project. For this assessment, the modeled year coincided with the tenth year of development, which is the future year with the greatest amount of emissions from NPL sources.

Seasonal adjustment factors were applied to compensate for increased gas well-heater use in the winter months. Project emissions were modeled as area sources, allocated to the Project Area with a spatial resolution of 4 km x 4 km. The NPL emissions were represented by 56 source locations. The project-specific emissions are the same as those used for the CMAQ application and represent construction, drilling, and production emissions. The emissions were input to the model based on parameters and source types as used for CMAQ.

6.2.3.4. Regional Source Emissions

For the cumulative impacts assessment, regional sources that are expected to be operational in the future year, including permitted sources, and RFD and RFFA sources listed in Section 2, were also input to the CALPUFF model. These sources were added to the model ready emission inventory for the assessment of cumulative impacts, since they are not represented by background data.

The regional-source background emission inventory for the cumulative impacts assessment was extracted from the CMAQ emissions input data and was designed to be as similar as possible to that used for the CMAQ modeling. Source location and stack parameter data were obtained from the future-year Proposed Action CMAQ emission inventory. The emission inventory was developed using the output of SMOKE, and consisted of both point sources and area sources.

The point sources were grouped on a facility level for the larger points (i.e., more than 250 tons per year of SO_2, NO_2, and PM combined) and on a grid level for the smaller point sources. Multiple stacks within single facilities were combined into a single, representative stack. Combined stack parameters were based on the potential for the greatest long-range impacts (i.e., greater stack height, greater exhaust flow rate). After grouping of the smaller sources, the total number of point sources is 454.

Emissions from area sources including some of the oil and gas sources, all other area sources, on-road mobile sources, non-road sources, and windblown dust were allocated spatially throughout the

CALPUFF domain in a similar manner to the emission inputs for CMAQ. The spatial resolution of the CALPUFF area source groupings is 12 km x 12 km, consistent with the intermediate CMAQ modeling grid. The total number of area sources is 2,388. Further spatial grouping was not done, since total the number of sources was readily accepted by CALPUFF.

6.2.4 Background Air Quality

6.2.4.1. Ozone

Background ozone concentrations were based on hourly ozone data for the period 2008, for all EPA Air Quality System (AQS) and Clean Air Status and Trends Network (CASTNet) monitoring sites that are located within the CALPUFF modeling domain. This includes 12 AQS sites and approximately six CASTNet sites. Most of these are located in Wyoming, but there are also a few sites in both Colorado and Utah. Several of the CASTNet sites are located within the receptor areas. CALPUFF is able to utilize hourly ozone data from multiple monitoring sites. The spatial variability represented by the ozone data accommodates spatially varying ozone daytime chemical transformation rates. Only those sites with valid, hourly ozone data and sufficient data capture were used. Data for 2008 were used for consistency with the meteorological conditions.

6.2.4.2. Ammonia

Background ammonia concentrations were based on data for the Boulder monitoring site. The ammonia data consist of weekly average measurement of both gaseous (ammonia) and particulate (ammonium) and are available for the period 2007-2012. Since CALPUFF accepts a single monthly ammonia value, the weekly average measured values were used to calculate monthly averages. To avoid reliance on a single year of data, monthly averages were calculated using data for 2007-2012.

The monthly background ammonia concentrations for input to CALPUFF were based on monthly average total available ammonia, calculated using combined ammonia and ammonium measurements. Total available ammonia was defined as gaseous ammonia plus any particulate ammonium bonded with nitrate. The formation of particulate ammonium nitrate is a reversible reaction while the formation of ammonium sulfate is not a reversible reaction. Therefore, ammonium bonded to sulfate is not available for reaction with the modeled emissions and the ammonium sulfate was not included in the calculation of “total available ammonia” to be input into CALPUFF.

Table 6-1 summarizes the total available ammonia for 2007-2012 for the Boulder monitoring site. The monthly average value from this table was input to CALPUFF.

Table 6-1. Monthly Average Total Available Ammonia for the Boulder Monitoring Site, Based on Data for 2007-2012.

Calendar Month	Monthly Average Total Available Ammonia (ppb)						Recommended Monthly Average Available Ammonia (ppb)
	2007	2008	2009	2010	2011	2012	
1	0.32	0.23	0.20	0.42	0.38	0.11	0.28
2	0.24	0.22	0.30	0.25	0.22	0.26	0.25
3	0.27	0.34	0.34	0.28	0.32	0.28	0.30
4	0.29	0.12	0.44	0.24	0.18	0.32	0.26
5	0.32	0.15	0.39	0.30	0.21	0.34	0.28
6	0.24	0.40	0.62	0.50	0.35	0.54	0.44
7	0.86	1.06	0.97	0.87	0.84	1.61	1.03
8	0.98	1.34	0.94	0.60	0.57	1.25	0.95
9	0.42	0.70	0.75	0.41	0.44	0.95	0.61
10	0.17	0.33	0.26	0.28	0.18	0.39	0.27
11	0.12	0.15	0.13	0.08	0.15	0.22	0.14
12	0.23	0.13	0.31	0.25	0.24	0.12	0.21

6.2.4.3. Visibility

CALPOST (Version 6.221) was used to estimate changes in light extinction from CALPUFF model concentration results. The visibility calculation utilized CALPOST visibility Method 8 (Mode 5) for computing light extinction change in combination with Interagency Monitoring of PROtected Visual Environments (IMPROVE) data. MVISCHECK was set equal to one to ensure that the visibility parameter settings conform to recommendations of the Federal Land Managers' Air Quality Related Values Work Group (FLAG) Phase I Report—Revised 2010 (FLAG, 2010).

Method 8 uses the FLAG 2010 visibility assumptions and revised IMPROVE equation. Background extinction coefficients for each of the component visibility species were based on 1) annual average conditions and 2) 20 percent best days conditions. Results for both are reported later in this section.

6.2.4.4. Lake Chemistry

Background ANC values were based on the latest available data from the USFS. The 10th percentile lowest ANC values were used to represent the background.

6.2.5 Modeling Options and Application Procedures

The application of CALPUFF followed the methods outlined in the Federal Land Manager's CALPUFF review guide (Anderson, 2011), which recommends the use of standard default values, where applicable. Chemical transformations were modeled based on the MESOPUFF II chemistry mechanism for conversion of SO_2 to sulfate (SO_4) and NO_x to nitric acid (HNO_3) and nitrate (NO_3).

Modeled pollutant species included the following gaseous and particulate species: SO_2, NO_x, and HNO_3 (gaseous species) and SO_4, NO_3, PM_{10}, and $PM_{2.5}$ (particulate species). The PM_{10} emission rate input to CALPUFF included only that portion of the PM_{10} emission rate greater than the $PM_{2.5}$ emission rate, since

$PM_{2.5}$ is modeled as a separate species. In this manner, PM_{10} was considered as coarse particulate (PMC) and $PM_{2.5}$ was considered fine particulate (PMF). Consideration of these as separate species allows the user to specify separate mass mean diameters (for deposition modeling) in CALPUFF. A mass mean diameter of 5.0 microns was used for PM_{10} and mass mean diameter of 0.48 microns was used for $PM_{2.5}$. In both cases, the standard deviation was 2.0 microns. Total PM_{10} impacts were determined in the post-processing of modeled impacts.

Additional model options included:

- Both wet and dry deposition were included (MWET = 1 and MDRY = 1).
- Dispersion was calculated using the standard Pasquill-Gifford (PG) dispersion coefficients (MDISP = 3).
- To ensure that the CALPUFF control parameters are set to current regulatory recommendations, the default override option was invoked (MREG = 1).
- For consistency with the WRF outputs, a Lambert Conformal (LCC) map projection was used.

7.0 Far-Field Future-Year Air Quality Impact Assessment: Calpuff Modeling

7.1 Future-Year Scenarios

The CALPUFF modeling scenarios included:

- Project-specific Emissions Scenario – The project-specific emissions were used to evaluate and quantify project-specific air quality impacts.
- Cumulative Emissions Scenario – A cumulative modeling assessment was conducted that included project specific emissions as well as emissions from other sources, including Reasonably Foreseeable Development (RFD) projects in the region.

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- Project-specific Emissions Scenario – The project-specific emissions were used to evaluate and quantify project-specific air quality impacts.
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7.2 Air Quality Related Values Impact Assessment

7.2.1 Visibility

CALPOST (Version 6.221) was used to estimate change in light extinction from the CALPUFF model concentration results. The visibility calculation utilized CALPOST visibility Method 8 (Mode 5) for computing light extinction change in combination with IMPROVE data. MVISCHECK was set equal to one to ensure that the visibility parameter settings conform to recommendations contained in the FLAG 2010 report.

Method 8 uses the FLAG 2010 visibility assumptions and revised IMPROVE equation. Background extinction coefficients for each of the component visibility species were based on 1) 20 percent best conditions and 2) annual average conditions.

Background values were obtained from the FLAG 2010 report (Table 5 – 20% Best Natural Conditions – Concentrations and Rayleigh Scattering by Class I Area and Table 6 – Annual Average Natural Conditions – Concentrations and Rayleigh Scattering by Class I Area). These were used along with monthly average f(RH) values, also obtained from the FLAG 2010 report (Table 7 - Monthly f(RH) – Large $(NH_4)^2$ SO_4 and NH_4NO_3 Relative Humidity Adjustment Factor), to estimate background light extinction for all Class I areas (IMPROVE data sites).

Natural conditions for all Class I areas are provided in the FLAG tables. The natural condition values are based on IMPROVE data, which are used directly for Class I areas with IMPROVE monitoring sites (Bridger Wilderness and Mount Zirkel Wilderness) as well as for nearby Class I areas that do not have monitoring sites, in accordance with EPA guidance for tracking progress under the Regional Haze Rule

(RHR) (EPA, 2003). For sensitive Class II areas, values from the closest or most climatically similar Class I area were used.

The visibility assessment focused on all receptors in a Class I or sensitive Class II area within the study region. Estimated visibility degradation was calculated for each Class I and sensitive Class II area within the CALPUFF modeling domain. For each receptor within each Class I and sensitive Class II area the maximum and 98th percentile change in extinction coefficient (b_{ext}) was identified. The overall maximum for each area and each metric was then used to quantify visibility impacts, in terms of the percent change that these impacts represent relative to natural background. Using an estimated annual natural background value (since f(rh) values vary by month, natural background also varies by month), the b_{ext} values were also converted to deciview haze index, defined as equal to 10 $\ln(b_{ext}/10)$, and the change in deciviews (dv) associated with the maximum and 98th percentile impacts was also calculated.

A 5 percent change in light extinction (approximately equal to 0.5 dv) is the threshold recommended in FLAG 2010 and is considered to contribute to regional haze visibility impairment. A 10 percent change in light extinction (approximately equal to 1.0 dv) is considered to cause visibility impairment when compared to background conditions. Thus the number of days that exceed the 5 and 10 percent thresholds was also obtained.

7.2.1.1. Project-Specific Emissions Scenario

Tables 7-1 and 7-2 summarize visibility change for the Class I and Class II areas within the CALPUFF modeling domain for the NPL-only or project-specific emissions scenario. In Table 7-1 (a) and (b), the results are presented relative to annual average natural background. In Table 7-2 (a) and (b), the results are presented relative to natural background for the 20 percent best visibility days.

Table 7-1a. CALPUFF-Derived Visibility Impacts for the Proposed Action Based on Annual Average Natural Background: Class I Areas

Class I Area	State	Natural Visibility b_{ext} (Mm^{-1})*	98th Percentile Impact		Maximum Impact		# Days >5% Change	# Days >10% Change
			% Change in b_{ext}	*Δ dv*	*% Change in b_{ext}*	*Δ dv*		
Bridger WA	WY	15.02	4.09	0.40	4.80	0.47	0	0
Fitzpatrick WA	WY	15.02	2.77	0.27	3.62	0.36	0	0
Grand Teton NP	WY	15.03	0.37	0.04	0.40	0.04	0	0
North Absaroka WA	WY	15.02	0.30	0.03	0.32	0.03	0	0
Teton WA	WY	15.03	3.97	0.39	4.54	0.44	0	0
Washakie WA	WY	15.02	2.48	0.24	2.87	0.28	0	0
Yellowstone NP	WY	15.03	0.26	0.03	0.32	0.03	0	0
Mt. Zirkel NP	CO	15.01	1.93	0.19	2.18	0.22	0	0
Rawah WA	CO	15.01	0.18	0.02	0.20	0.02	0	0

*Estimated using EPA (2003) method and annual average f(RH) values.

Table 7-1b. CALPUFF-Derived Visibility Impacts for the Proposed Action Based on Annual Average Natural Background: Sensitive Class II Areas

Sensitive Class II Area	State	Natural Visibility b_{ext} (Mm^{-1})	98th Percentile Impact		Maximum Impact		# Days >5% Change	# Days >10% Change
			% Change in b_{ext}	*Δ dv*	*% Change in b_{ext}*	*Δ dv*		
Cloud Peak WA	WY	15.02	0.16	0.02	0.16	0.02	0	0
Gros Ventre WA	WY	15.03	3.23	0.32	4.75	0.46	0	0
Jedediah Smith WA	WY	15.03	0.36	0.04	0.37	0.04	0	0
Popo Agie WA	WY	15.02	3.56	0.35	4.68	0.46	0	0
Savage Run WA	WY	15.01	0.36	0.04	0.39	0.04	0	0
Wind River RA	WY	15.02	1.16	0.11	1.17	0.12	0	0
Dinosaur NP	CO	15.01	0.29	0.03	0.29	0.03	0	0
High Uintas WA	UT	15.01	0.38	0.04	0.40	0.04	0	0

*Estimated using EPA (2003) method and annual average f(RH) values.

Table 7-2a. CALPUFF-Derived Visibility Impacts for the Proposed Action Based on 20 Percent Best Days Natural Background: Class I Areas

Class I Area	State	Natural Visibility b_{ext} (Mm^{-1})*	98th Percentile Impact		Maximum Impact		# Days >5% Change	# Days >10% Change
			% Change in b_{ext}	*Δ dv*	*% Change in b_{ext}*	*Δ dv*		
Bridger WA	WY	11.63	5.47	0.53	6.41	0.62	3	0
Fitzpatrick WA	WY	11.63	3.66	0.36	4.78	0.47	0	0
Grand Teton NP	WY	11.64	0.61	0.06	0.66	0.07	0	0
North Absaroka WA	WY	11.63	0.40	0.04	0.42	0.04	0	0
Teton WA	WY	11.64	6.51	0.63	7.44	0.72	1	0
Washakie WA	WY	11.63	3.29	0.32	3.81	0.37	0	0
Yellowstone NP	WY	11.64	0.26	0.03	0.53	0.05	0	0
Mt. Zirkel NP	CO	11.62	2.66	0.26	3.01	0.30	0	0
Rawah WA	CO	11.62	0.26	0.03	0.27	0.03	0	0

*Estimated using EPA (2003) method and annual average f(RH) values.

Table 7-2b. CALPUFF-Derived Visibility Impacts for the Proposed Action Based on 20 Percent Best Days Natural Background: Sensitive Class II Areas

Sensitive Class II Area	State	Natural Visibility b_{ext} (Mm^{-1})	98th Percentile Impact		Maximum Impact		# Days >5% Change	# Days >10% Change
			% Change in b_{ext}	*Δ dv*	*% Change in b_{ext}*	*Δ dv*		
Cloud Peak WA	WY	11.63	0.21	0.02	0.22	0.02	0	0
Gros Ventre WA	WY	11.64	5.30	0.52	7.79	0.75	1	0
Jedediah Smith WA	WY	11.64	0.59	0.06	0.61	0.06	0	0
Popo Agie WA	WY	11.63	4.76	0.46	6.25	0.61	1	0
Savage Run WA	WY	11.62	0.50	0.05	0.53	0.05	0	0
Wind River RA	WY	11.63	1.54	0.15	1.57	0.16	0	0
Dinosaur NP	CO	11.62	0.40	0.04	0.40	0.04	0	0
High Uintas WA	UT	11.62	0.53	0.05	0.55	0.05	0	0

*Estimated using EPA (2003) method and annual average f(RH) values.

Relative to annual average natural background (Table 7-1), the largest 98th percentile impact is 0.4 dv, for the Bridger Wilderness Area. Maximum impacts are slightly larger, but there are no days for any of the areas for which a greater than 5 percent change in light extinction (a greater than 0.5 dv impact) is modeled.

Relative to natural background for the 20% best visibility days (Table 7-2), the largest 98th percentile impact is 0.63 dv, for the Teton Wilderness Area. This is followed by 0.53 and 0.52 for Bridger and Gros Ventre Wilderness Areas, respectively. Maximum impacts indicate that there are three days for Bridger and one day each for the Teton, Gros Ventre, and Popo Agie Wilderness Areas for which a greater than 5 percent change in light extinction (a greater than 0.5 dv impact) is modeled. There are no days/receptors for which a greater than 10 percent change in light extinction is modeled.

7.2.1.2. Cumulative Emissions Scenario

Tables 7-3 and 7-4 summarize visibility change for the Class I and Class II areas within the CALPUFF modeling domain for the cumulative emissions scenario. In Table 7-3 (a) and (b), the results are presented relative to annual average natural background. In Table 7-4 (a) and (b), the results are presented relative to natural background for the 20 percent best visibility days.

Table 7-3a. CALPUFF-Derived Visibility Impacts for the Cumulative Emissions Scenario Based on Annual Average Natural Background: Class I Areas

Class I Area	State	Natural Visibility b_{ext} (Mm^{-1})*	98th Percentile Cumulative Impact		Maximum Cumulative Impact	
			% Change in b_{ext}	*Δ dv*	*% Change in b_{ext}*	*Δ dv*
Bridger WA	WY	15.02	109	7.36	117	7.78
Fitzpatrick WA	WY	15.02	51.4	4.15	56.5	4.48
Grand Teton NP	WY	15.03	32.7	2.83	36.1	3.08
North Absaroka WA	WY	15.02	31.5	2.74	32.4	2.81
Teton WA	WY	15.03	26.6	2.36	27.1	2.40
Washakie WA	WY	15.02	54.1	4.33	57.2	4.52
Yellowstone NP	WY	15.03	23.2	2.09	26.8	2.37
Mt. Zirkel NP	CO	15.01	109	7.38	123.2	8.03
Rawah WA	CO	15.01	587	19.3	727.8	21.1

*Estimated using EPA (2003) method and annual average f(RH) values

Table 7-3b. CALPUFF-Derived Visibility Impacts for the Cumulative Emissions Scenario Based on Annual Average Natural Background: Sensitive Class II Areas

Sensitive Class II Area	State	Natural Visibility b_{ext} (Mm^{-1})	98th Percentile Cumulative Impact		Maximum Cumulative Impact	
			% Change in b_{ext}	*Δ dv*	*% Change in b_{ext}*	*Δ dv*
Cloud Peak WA	WY	15.02	36.9	3.14	37.6	3.19
Gros Ventre WA	WY	15.03	59.4	4.66	71.5	5.39
Jedediah Smith WA	WY	15.03	71.5	5.39	77.7	5.75
Popo Agie WA	WY	15.02	68.4	5.21	69.8	5.30
Savage Run WA	WY	15.01	46.9	3.84	47.3	3.87
Wind River RA	WY	15.02	46.7	3.83	47.9	3.92
Dinosaur NP	CO	15.01	98.3	6.85	114	7.61
High Uintas WA	UT	15.01	37.5	3.19	39.4	3.32

*Estimated using EPA (2003) method and annual average f(RH) values.

Table 7-4a. CALPUFF-Derived Visibility Impacts for the Cumulative Emissions Scenario Based on 20 Percent Best Days Natural Background: Class I Areas

Class I Area	State	Natural Visibility b_{ext} (Mm^{-1})*	98th Percentile Cumulative Impact		Maximum Cumulative Impact	
			% Change in b_{ext}	*Δ dv*	*% Change in b_{ext}*	*Δ dv*
Bridger WA	WY	11.63	146	9.02	158	9.49
Fitzpatrick WA	WY	11.63	69.3	5.26	76.1	5.66
Grand Teton NP	WY	11.64	53.8	4.31	59.4	4.66
North Absaroka WA	WY	11.63	42.4	3.54	43.7	3.63
Teton WA	WY	11.64	43.7	3.62	44.6	3.68
Washakie WA	WY	11.63	72.9	5.48	77.1	5.71
Yellowstone NP	WY	11.64	38.3	3.24	44.1	3.65
Mt. Zirkel NP	CO	11.62	151	9.19	170	149
Rawah WA	CO	11.62	812	22.1	1007	810

*Estimated using EPA (2003) method and annual average f(RH) values.

Table 7-4b. CALPUFF-Derived Visibility Impacts for the Cumulative Emissions Scenario Based on 20 Percent Best Days Natural Background: Sensitive Class II Areas

Sensitive Class II Area	State	Natural Visibility b_{ext} (Mm^{-1})	98th Percentile Cumulative Impact		Maximum Cumulative Impact	
			% Change in b_{ext}	*Δ dv*	*% Change in b_{ext}*	*Δ dv*
Cloud Peak WA	WY	11.63	49.4	4.02	50.3	4.07
Gros Ventre WA	WY	11.64	97.9	6.83	118	7.78
Jedediah Smith WA	WY	11.64	117.8	7.78	128	8.24
Popo Agie WA	WY	11.63	91.8	6.51	93.7	6.61
Savage Run WA	WY	11.62	64.6	4.98	65.2	63.1
Wind River RA	WY	11.63	62.9	4.88	64.5	4.98
Dinosaur NP	CO	11.62	135	8.56	157	134
High Uintas WA	UT	11.62	51.7	4.17	54.3	50.2

*Estimated using EPA (2003) method and annual average f(RH) values.

As expected, the cumulative contribution from all sources to visibility at the Class I and Class II areas is significant. Relative to annual average natural background (Table 7-3), the largest 98th percentile impacts range from 2.1 (Yellowstone National Park) to approximately 7.4 dv (Mt. Zirkel and Bridger Wilderness Areas), with one exception. The impact from all sources for the Rawah Wilderness Area is 19 dv. The results for Rawah do not seem plausible. One possible explanation is that the area is impacted by a nearby source. However, this same result does not occur with CMAQ.

Relative to natural background for the 20 percent best visibility days (Table 7-4), the largest 98th percentile impacts range from 3.2 dv (Yellowstone National Park) to around 9 dv (Bridger and Mt. Zirkel Wilderness Area and Dinosaur National Monument). Again the results for Rawah are extremely large and seemingly questionable.

One of the purposes of the cumulative emissions simulation is to put the project specific impacts into some perspective, relative to that from all sources. The CALPUFF-derived project-specific impacts are greatest for the Bridger and Teton Wilderness areas. For the Bridger Wilderness Area, using annual average natural background, the 98th percentile project-specific impact is 0.4 dv compared to the cumulative source impact of 7.4 dv. Using the 20% best days natural background, the project-specific impact is 0.5 dv compared to the cumulative source impact of 9 dv. For the Teton Wilderness Area, using annual average natural background, the 98th percentile project specific impact is 0.4 dv compared to the cumulative source impact of 2.3 dv. Using the 20% best days natural background, the project specific impact is 0.6 dv compared to the cumulative source impact of 3.6 dv.

7.2.2 Atmospheric Deposition

Project-specific and cumulative nitrogen and sulfur deposition impacts were examined for Class I areas and identified sensitive Class II areas within the project study area. CALPUFF-derived annual wet, dry, and total (wet plus dry) deposition fluxes of total S and N compounds were used to estimate the total S and N deposition fluxes over the Class I and sensitive Class II areas within the CALPUFF modeling domain Both average (averaged over all receptors that comprise the area) and maximum (at any receptor in the area) fluxes were calculated.

POSTUTIL was used to process the CALPUFF deposition output. The following species and scaling factors based on Anderson (2011) were applied in POSTUTIL to calculate total sulfur and total nitrogen deposition.

Sulfur: SO_2 (0.5), SO_4 (0.33)

Nitrogen: SO_4 (0.29167), NO_x (0.30435), HNO_3 (0.22222), NO_3 (0.45161)

The scaling factors are based on the molecular weight of sulfur or nitrogen to the molecular weight of the compound modeled by CALPUFF.

7.2.2.1. Project-Specific Emissions Scenario

The CALPUFF-derived project-specific deposition amounts are presented in Table 7-5 (a) and (b). The project specific impacts for each species are compared with the corresponding deposition analysis threshold (DAT) developed by the National Park Service and the Fish and Wildlife Service. The DATs represent values for nitrogen and sulfur deposition from project-specific emission sources below which estimated impacts are considered negligible. The DAT established for both nitrogen and sulfur in western Class I areas is 0.005 kilograms per hectare per year (kg/ha/yr).

Table 7-5a. CALPUFF-Derived Project Specific Sulfur and Nitrogen Deposition Impacts (kg/ha/yr): Class I Areas

Class I Area	State	Average Deposition due to Proposed Action (kg/ha/yr)		Maximum Deposition due to Proposed Action (kg/ha/yr)	
		Sulfur	*Nitrogen*	*Sulfur*	*Nitrogen*
Bridger WA	WY	0.000	0.001	0.000	0.002
Fitzpatrick WA	WY	0.000	0.001	0.000	0.001
Grand Teton NP	WY	0.000	0.000	0.000	0.000
North Absaroka WA	WY	0.000	0.000	0.000	0.000
Teton WA	WY	0.000	0.000	0.000	0.000
Washakie WA	WY	0.000	0.000	0.000	0.000
Yellowstone NP	WY	0.000	0.000	0.000	0.000
Mt. Zirkel NP	CO	0.000	0.000	0.000	0.000
Rawah WA	CO	0.000	0.000	0.000	0.000
DAT		**0.005**	**0.005**	**0.005**	**0.005**

Table 7-5b. CALPUFF-Derived Project Specific Sulfur and Nitrogen Deposition Impacts (kg/ha/yr): Sensitive Class II Areas

Sensitive Class II Area	State	Average Deposition due to Proposed Action (kg/ha/yr)		Maximum Deposition due to Proposed Action (kg/ha/yr)	
		Sulfur	*Nitrogen*	*Sulfur*	*Nitrogen*
Cloud Peak WA	WY	0.000	0.000	0.000	0.000
Gros Ventre WA	WY	0.000	0.000	0.000	0.001
Jedediah Smith WA	WY	0.000	0.000	0.000	0.000
Popo Agie WA	WY	0.000	0.001	0.000	0.002
Savage Run WA	WY	0.000	0.000	0.000	0.000
Wind River RA	WY	0.000	0.001	0.000	0.001
Dinosaur NP	WY	0.000	0.000	0.000	0.000
High Uintas WA	CO	0.000	0.000	0.000	0.000
DAT		**0.005**	**0.005**	**0.005**	**0.005**

For both sulfur and nitrogen, the simulated change in deposition due to the Proposed Action does not exceed the DAT of 0.005 kg/ha/yr for any area. Average impacts of 0.001 kg/ha/yr and maximum impacts on the order of 0.001 to 0.002 kg/ha/yr are simulated for nitrogen for several areas including the Bridger, Fitzpatrick and Popo Agie Wilderness Areas and the Wind River Roadless Area.

7.2.2.2. Cumulative Emissions Scenario

The CALPUFF-derived cumulative deposition amounts are presented in Table 7-6 (a) and (b). Cumulative modeled deposition amounts are also compared to critical load thresholds to assess total deposition impacts. In this study, deposition results are compared to critical load thresholds established for the Rocky Mountain region. The critical load thresholds are: 3 kg/ha/yr for total S deposition and 2.2 kg/ha/yr for total N deposition. Deposition amounts that exceed the critical load values are highlighted in bold.

Table 7-6a. CALPUFF-Derived Cumulative Sulfur and Nitrogen Deposition Impacts (kg/ha/yr): Class I Areas

Class I Area	State	Average Cumulative Deposition (kg/ha/yr)		Maximum Cumulative Deposition (kg/ha/yr)	
		Sulfur	*Nitrogen*	*Sulfur*	*Nitrogen*
Bridger WA	WY	0.039	0.107	0.059	0.211
Fitzpatrick WA	WY	0.033	0.080	0.038	0.103
Grand Teton NP	WY	0.034	0.091	0.137	0.687
North Absaroka WA	WY	0.018	0.044	0.035	0.134
Teton WA	WY	0.022	0.053	0.031	0.262
Washakie WA	WY	0.028	0.048	0.508	0.151
Yellowstone NP	WY	0.016	0.041	0.031	0.394
Mt. Zirkel NP	CO	0.095	0.341	0.181	1.060
Rawah WA	CO	0.059	0.451	0.090	**3.942**
Critical Load Threshold		**3.0**	**2.2**	**3.0**	**2.2**

Table 7-6b. CALPUFF-Derived Project Specific Sulfur and Nitrogen Deposition Impacts (kg/ha/yr): Sensitive Class II Areas

Sensitive Class II Area	State	Average Cumulative Deposition (kg/ha/yr)		Maximum Cumulative Deposition (kg/ha/yr)	
		Sulfur	*Nitrogen*	*Sulfur*	*Nitrogen*
Cloud Peak WA	WY	0.049	0.085	0.061	0.128
Gros Ventre WA	WY	0.032	0.115	0.060	0.691
Jedediah Smith WA	WY	0.052	0.113	0.382	0.732
Popo Agie WA	WY	0.056	0.132	0.065	0.157
Savage Run WA	WY	0.073	0.203	0.076	0.215
Wind River RA	WY	0.044	0.108	0.057	0.274
Dinosaur NP	WY	0.038	0.106	0.045	0.287
High Uintas WA	CO	0.010	0.049	0.018	0.902
Critical Load Threshold		**3.0**	**2.2**	**3.0**	**2.2**

For sulfur, both the average and maximum simulated cumulative deposition amounts are less than the critical load threshold of 3.0 kg/ha/yr for all areas.

For nitrogen, the maximum simulated cumulative deposition amount is greater than the critical load threshold of 2.2 kg/ha/yr for one area (Rawah Wilderness).

7.2.3 Lake Chemistry

POSTUTIL was also used to process the CALPUFF deposition output for use in the ANC calculations. The following species and scaling factors were applied in POSTUTIL to calculate total sulfur and total nitrogen deposition as used in the ANC calculations.

Sulfur: SO_2 (0.5), SO_4 (0.33)

Nitrogen: NO_x (0.30435), HNO_3 (0.22222), NO_3 (0.22581)

The scaling factors used for the ANC calculations for some species differ from those used for the deposition calculations in Sec. 5.2.2 because the nitrogen mass from ammonium is not included in the nitrogen total for the ANC calculations. Ammonium acts to neutralize acid, so inclusion of the ammonium mass in the ANC calculations would overstate the potential for acidification due to deposition. The above factors used for the ANC calculations are consistent with those recommended in the IWAQM-Phase2 report (IWAQM, 1998). The USFS recommendations (USFS, 2000) refer the reader to the factors in the IWAQM-Phase2 report for use in the ANC calculations.

CALPUFF-derived impacts to lake chemistry were also calculated using the USFS procedure for estimated potential changes in ANC (as presented in Section 4.3.3). Background ANC data for this analysis was provided by the NPS.

7.2.3.1. Project-Specific Emissions Scenario

The change in water chemistry associated with atmospheric deposition from project sources was calculated for 17 acid sensitive lakes located within CALPUFF domain. The CALPUFF-derived changes in ANC due to the Proposed Action, along with several of the key terms in the calculation, are presented in Table 7-7. The 10^{th} percentile ANC values and the number of samples used in the calculation of the 10^{th} percentile lowest ANC values are also provided in the table. Values that exceed ANC change thresholds are highlighted in bold.

Table 7-7. CALPUFF-Derived Change in ANC for Sensitive Lakes: Project-Specific Emissions

Class I/ Class II Area	Lake	Lat (deg)	Lon (deg)	10th Percentile Lowest ANC Value (μeq/l) (A)	No. of Samples	Precip-itation (m) (P)	ΔS Deposition (eq/m2/yr) (Hs)	ΔN Deposition (eq/m2/yr) (Hn)	Total S + N Dep (eq) (Hdep)	ANC(o) (eq)	% Change in ANC	Delta ANC (μeq/l)
Bridger	Deep	42.719	-109.171	61.1	62	0.28	4.52E-07	7.30E-06	0.08	112.61	0.07	0.04
Bridger	Black Joe	42.739	-109.171	70.6	72	0.28	4.44E-07	7.14E-06	0.08	130.12	0.06	0.04
Bridger	Lazy Boy	43.333	-109.73	27.8	1	0.28	1.12E-07	1.88E-06	0.02	51.24	0.04	0.01
Bridger	Upper Frozen	42.687	-109.161	13.2	3	0.28	4.25E-07	6.65E-06	0.07	24.33	0.29	0.04
Bridger	Hobbs	43.036	-109.672	69.8	76	0.28	2.02E-07	3.34E-06	0.04	128.64	0.03	0.02
Fitzpatrick	Ross	43.378	-109.658	54	55	0.23	1.06E-07	1.75E-06	0.02	81.97	0.02	0.01
Popo Agie	Lower Saddlebag	42.623	-108.994	55.5	54	0.34	3.90E-07	5.96E-06	0.06	126.00	0.05	0.03
High Uintas	Dean	40.679	-110.761	51.4	7	0.45	8.12E-09	1.67E-07	0.00	154.30	0.00	0.00
High Uintas	Heart	40.594	-110.811	54.6	1	0.45	6.58E-09	1.27E-07	0.00	163.91	0.00	0.00
High Uintas	No Name (Duchesne – 4d2-039)	40.671	-110.275	65.2	3	0.45	1.30E-08	2.37E-07	0.00	195.73	0.00	0.00
High Uintas	Fish	40.837	-110.069	104.5	6	0.45	2.20E-08	4.08E-07	0.00	313.71	0.00	0.00
High Uintas	Upper Coffin (Duchesne – 4d1-044)	40.834	-110.237	65	2	0.60	1.87E-08	3.69E-07	0.00	262.38	0.00	0.00
Mt. Zirkel	Elbert	40.634	-106.707	53.8	68	0.60	5.69E-08	1.11E-06	0.01	217.17	0.01	0.00
Mt. Zirkel	Seven (Lakes)	40.896	-106.682	36.4	67	0.60	8.85E-08	1.54E-06	0.02	146.93	0.01	0.00
Mt. Zirkel	Summit	40.545	-106.683	48	110	0.60	4.94E-08	9.96E-07	0.01	193.35	0.01	0.00
Rawah	Island	40.627	-105.942	71.9	25	0.60	6.32E-08	9.67E-07	0.01	289.62	0.00	0.00
Rawah	Rawah Lake #4	40.671	-105.958	41.5	24	0.60	6.76E-08	1.02E-06	0.01	167.17	0.01	0.00

Deposition is greatest for the lakes in the Bridger Wilderness Area. Simulated changes in ANC were compared with the applicable threshold for each identified lake: 10 percent change in ANC for lakes with background ANC values greater than 25 micro equivalents per liter [μeq/L], and less than a 1 μeq/L change in ANC for lakes with background ANC values equal to or less than 25 μeq/L. Of the 17 lakes listed in Table 7-7 only Upper Frozen Lake is considered to be extremely sensitive to atmospheric deposition by the USFS since the background ANC is less than 25 μeq/L. The percent change in ANC is less than 10 percent for all lakes considered. The change in ANC for Upper Frozen Lake is 0.04 μeq/L and is less than the 1 μeq/L threshold.

7.2.3.2. Cumulative Emissions Scenario

The CALPUFF-derived change in ANC due to cumulative emissions is presented in Table 7-8. Values that exceed ANC change thresholds are highlighted in bold.

Table 7-8. CALPUFF-Derived Change in ANC for Sensitive Lakes: Cumulative Emissions

Class I/ Class II Area	Lake	Lat (deg)	Lon (deg)	10th Percentile Lowest ANC Value (µeq/l) (A)	No. of Samples	Precip-itation (m) (P)	Total S Deposition (eq/m2/yr) (Hs)	N Deposition (eq/m2/yr) (Hn)	Total S + N Dep (eq) (Hdep)	ANC(o) (eq)	% Change in ANC	Delta ANC (µeq/l)
Bridger	Deep	42.719	-109.171	61.1	62	0.28	3.45E-04	5.62E-04	9.08	112.61	8.06	4.93
Bridger	Black Joe	42.739	-109.171	70.6	72	0.28	3.45E-04	5.51E-04	8.96	130.12	6.89	4.86
Bridger	Lazy Boy	43.333	-109.73	27.8	1	0.28	1.84E-04	2.66E-04	4.50	51.24	8.78	2.44
Bridger	Upper Frozen	42.687	-109.161	13.2	3	0.28	3.49E-04	5.79E-04	9.28	24.33	**38.14**	**5.03**
Bridger	Hobbs	43.036	-109.672	69.8	76	0.28	2.08E-04	3.56E-04	5.64	128.64	4.38	3.06
Fitzpatrick	Ross	43.378	-109.658	54	55	0.23	1.94E-04	2.65E-04	4.59	81.97	5.60	3.02
Popo Agie	Lower Saddlebag	42.623	-108.994	55.5	54	0.34	3.81E-04	5.59E-04	9.39	126.00	7.45	4.14
High Uintas	Dean	40.679	-110.761	51.4	7	0.45	4.03E-05	1.03E-04	1.43	154.30	0.93	0.48
High Uintas	Heart	40.594	-110.811	54.6	1	0.45	3.97E-05	9.84E-05	1.38	163.91	0.84	0.46
High Uintas	No Name (Duchesne – 4d2-039)	40.671	-110.275	65.2	3	0.45	7.60E-05	2.41E-04	3.17	195.73	1.62	1.05
High Uintas	Fish	40.837	-110.069	104.5	6	0.45	1.21E-04	3.02E-04	4.24	313.71	1.35	1.41
High Uintas	Upper Coffin (Duchesne – 4d1-044)	40.834	-110.237	65	2	0.60	9.18E-05	2.34E-04	3.26	262.38	1.24	0.81
Mt. Zirkel	Elbert	40.634	-106.707	53.8	68	0.60	4.89E-04	1.01E-03	14.98	217.17	6.90	3.71
Mt. Zirkel	Seven (Lakes)	40.896	-106.682	36.4	67	0.60	5.11E-04	1.05E-03	15.65	146.93	**10.65**	3.88
Mt. ZIrkel	Summit	40.545	-106.683	48	110	0.60	5.16E-04	1.07E-03	15.90	193.35	8.22	3.95
Rawah	Island	40.627	-105.942	71.9	25	0.60	3.19E-04	6.61E-04	9.80	289.62	3.38	2.43
Rawah	Rawah Lake #4	40.671	-105.958	41.5	24	0.60	3.34E-04	6.91E-04	10.25	167.17	6.13	2.55

For the cumulative emissions scenario, the percent change in ANC ranges from less than one to 38 percent. For two of the lakes (Seven Lakes and Upper Frozen Lake), the change is greater than 10 percent. The greatest percentage change is for Upper Frozen Lake and represents a change in ANC of 5.0 μeq/L. Thus, the contribution from regional emissions to ANC is significant.

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ATTACHMENT A. NPL PROJECT-SPECIFIC EMISSION INVENTORY

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NPL Project Air Quality Assessment Emissions Inventory

Table 1. NPL Project Developmet Scenario

NPL Natural Gas Development Field

Well Pad		2			2
pads/yr		22			22
pad/section		4			4
pad spacing (acre)		160			160
acres/pad		18			18
well/pad		16			16
wells/yr		350			350
yr		10			10

Construction

days/pad		5			5
days/road seg		3			3
days/pipe seg		3			3
resource road/pad (ft)		2640			2640
resource road acre/pad		4.55			4.545455
lateral pipe/pad (ft)		2640			2640
resource road ROW (ft)		75			75
PAD ROW Pipe (ft)		0			0
local road (ft)		574			574
local road ROW (ft)		60			60
Gathering Pipe (mile)		280			280
Gathering ROW (acre)		1229			1229
Gathering ROW Pipe (ft)		36			36

Notes: Resource ROW includes road and pipeline

Table 2. Pad, Road and Gas Gathering Pipeline Disturbance

Year	Pads (acres)	New Pads (number)	Local Roads (miles)	Local Roads (acres)	Resource Roads (Miles)	Resource Roads (acres)	Pipelines (miles)	Pipelines (acres)	Annual Total (acres)
Existing		0							
New	3937.5	218.75			109.375	994.3182	389.375	0	4931.818

Table 3. Well Pad Construction/Expansion - Per Acre

Project: Jonah NPL
Scenario: 4 Pad/Section
Activity: Well Pad Construction
Emissions: Fugitive Particulate Emissions from Well Pad Construction

Well Pad Area (Expansion)	Worst-Case Construction Activity PM_{10} Emission Factor[1]	$PM_{2.5}$/PM10 Ratio for Fugitive Dust from Construction [2]	Construction Activity Duration[3]	Construction Activity Duration	Emission Control Efficiency	PM_{10} Emissions (controlled)	$PM_{2.5}$ Emissions (controlled)
(acre)	(tons/acre-month)		(days/acre)	(hours/day)	(%)	(lb/acre)	(lb/acre)
18	0.42	0.1	0.28	10	50	70.00	7.00

[1] Countess Environmental, 2006. WRAP Fugitive Dust Handbook. WGA Contract No. 30204-111.
[2] Countess Environmental, 2006. WRAP Fugitive Dust Handbook. WGA Contract No. 30204-111, Section 3.3.1
[3] Construction Activity Duration taken from an average of durations provided by Shell, Ultra and Questar.
Monthly emissions converted to daily and hourly emissions based on 30-day month.

NPL Project Air Quality Assessment Emissions Inventory

Table 4. Local Road Construction - Per Mile

Project: **Jonah NPL**
Scenario: **4 Pad/Section**
Activity: **Access Road Construction per Pad**
Emissions: **Fugitive Particulate Emissions from Local Road Construction**

Road Length	Local Road Area[1]	Worst-Case Construction Activity PM_{10} Emission Factor[2]	$PM_{2.5}/PM_{10}$ Ratio for Fugitive Dust from Construction [3]	Construction Activity Duration[3]	Construction Activity Duration	Emission Control Efficiency	PM_{10} Emissions (controlled)	$PM_{2.5}$ Emissions (controlled)
(mi)	(acres)	(tons/acre-month)		(days/mi)	(hours/day)	(%)	(lb/mi)	(lb/mi)
0.11	1	0.42	0.1	3	12	50	33.21	3.32

[1] Construction Area taken from average of current field activity of 4.51 acres/mile for Local Roads.
[2] Countess Environmental, 2006. WRAP Fugitive Dust Handbook. WGA Contract No. 30204-111, Section 3.3.1
[3] Construction Activity Duration taken from an average of durations provided by Shell, Ultra and Questar.
Monthly emissions converted to daily and hourly emissions based on 30-day month.

NPL Project Air Quality Assessment Emissions Inventory

Table 5. Resource Road Construction - Per Mile

Project: Jonah NPL
Scenario: 4 Pad/Section
Activity: Access Road Construction per Pad
Emissions: Fugitive Particulate Emissions from Resource Road Construction

Road Length	Resource Road Area	Worst-Case Construction Activity PM_{10} Emission Factor[1]	$PM_{2.5}/PM_{10}$ Ratio for Fugitive Dust from Construction[2]	Construction Activity Duration	Construction Activity Duration	Emission Control Efficiency	PM_{10} Emissions (controlled)	$PM_{2.5}$ Emissions (controlled)
(mi)	(acres)	(tons/acre-month)		(days/mi)	(hours/day)	(%)	(lb/mi)	(lb/mi)
0.5	4.55	0.42	0.1	3	10	50	45.45	4.55

[1] Countess Environmental, 2006. WRAP Fugitive Dust Handbook. WGA Contract No. 30204-111, Section 3.3.1
[2] Construction Activity Duration taken from an average of durations provided by Shell, Ultra and Questar.
Monthly emissions converted to daily and hourly emissions based on 30-day month.

Table 6. Pipeline Construction - Per Mile

Accounted for under road construction

Project: **Jonah NPL**
Scenario: **4 Pad/Section**
Activity: **Pipeline Construction per Pad**
Emissions: **Fugitive Particulate Emissions from Pipeline Construction**

Pipeline Length	Pipeline Area[1]	Worst-Case Construction Activity PM_{10} Emission Factor[2]	$PM_{2.5}/PM_{10}$ Ratio for Fugitive Dust from Construction[3]	Construction Activity Duration[4]	Construction Activity Duration	Emission Control Efficiency	PM_{10} Emissions (controlled)	$PM_{2.5}$ Emissions (controlled)
(mi)	(acres)	(tons/acre-month)		(days/mi)	(hours/day)	(%)	(lb/mi)	(lb/mi)
1.27	5.6	0.42	0.1	14	10	50	0.55	0.05

[1] Includes both laterals and trunks.
[2] Countess Environmental, 2006. WRAP Fugitive Dust Handbook. WGA Contract No. 30204-111, Section 3.3.1
[3] Construction Activity Duration taken from an average of durations provided by Shell, Ultra and Questar.
Monthly emissions converted to daily and hourly emissions based on 30-day month.
[4] Construction Activity Duration assumed to be similar to road construction.

NPL Project Air Quality Assessment Emissions Inventory

Table 7. Other Construction Activities

Project: **Jonah NPL**
Scenario: **4 Pad/Section**
Activity: **Facility Construction**
Emissions: **Fugitive Particulate Emissions from Const. Activities**

Construction Activity	Construction Area[1]	Worst-Case Construction Activity PM_{10} Emission Factor[2]	$PM_{2.5}/PM_{10}$ Ratio for Fugitive Dust from Construction [3]	Construction Activity Duration[4]	Construction Activity Duration	Emission Control Efficiency	PM_{10} Emissions (controlled)		$PM_{2.5}$ Emissions (controlled)	
	(acres)	(tons/acre-month)		(days)	(hours/day)	(%)	(lbs)	(tpy)	(lbs)	(tpy)
Central Facility 1	15.00	0.42	0.1	4.17	10	50	875.00	0.44	87.50	0.04
Central Facility 2	15.00	0.42	0.1	4.17	10	50	875.00	0.44	87.50	0.04
Central Facility 3	15.00	0.42	0.1	4.17	10	50	875.00	0.44	87.50	0.04
Central Facility 4	15.00	0.42	0.1	4.17	10	50	875.00	0.44	87.50	0.04
Central Facility 5	15.00	0.42	0.1	4.17	10	50	875.00	0.44	87.50	0.04
Central Facility 6	15.00	0.42	0.1	4.17	10	50	875.00	0.44	87.50	0.04
Central Facility 7	15.00	0.42	0.1	4.17	10	50	875.00	0.44	87.50	0.04
Central Facility 8	15.00	0.42	0.1	4.17	10	50	875.00	0.44	87.50	0.04
Central Facility 9	15.00	0.42	0.1	4.17	10	50	875.00	0.44	87.50	0.04
Central Facility 10	15.00	0.42	0.1	4.17	10	50	875.00	0.44	87.50	0.04
Central Facility 11	15.00	0.42	0.1	4.17	10	50	875.00	0.44	87.50	0.04
Total Other Construction:	165.00	0.42	0.1	45.83	10	50	9625.00	4.81	962.50	0.48

[1] Estimated.
[2] Countess Environmental, 2006. WRAP Fugitive Dust Handbook. WGA Contract No. 30204-111, Section 3.3.1
[3] Construction Activity Duration taken from an average of durations provided by Shell, Ultra and Questar.
Monthly emissions converted to daily and hourly emissions based on 30-day month.
[4] Construction Activity Duration assumed to be similar to pad construction and pipeline construction for stabilizer faclity/compressor station and gathering system, respectively.

Table 8. Construction Wind Erosion - Per Acre of Disturbance

Project: **Jonah NPL**
Scenario: **4 Pad/Section**
Activity: **Well Pad, Resource Road, Pipeline Construction**
Emissions: **Wind Erosion**

Emission Factor (PM_{10})[1] : 0.0611 lb/hr-acre — 24 hr/day
Emission Factor ($PM_{2.5}$)[1] : 0.0092 lb/hr-acre

Control Efficiency[2]: 50 %

Disturbed Area:
Well Pad Construction/Exp.: 18 acres

Access Road Construction: 5.34 acres

Pipeline Construction 6 acres

Central Facility Construction 15 acres

Emissions Calculations:

	PM_{10} Emission Facto (lb/hr-acre)	$PM_{2.5}$ Emission Factor (lb/hr-acre)	Area (acre)	Control Efficiency (%)	Construction Hours per pad or facil	PM_{10} Emissions (lb/hr)	$PM_{2.5}$ Emissions (lb/hr)	Controlled PM_{10} Emissions (ton/pad)	Controlled $PM_{2.5}$ Emissions (ton/pad)
Well Pad Construction (per p	0.0611	0.0092	18.00	50	120.0	0.55	0.08	0.03	0.00
Road Construction (per pad)	0.0611	0.0092	5.34	50	151.3	0.16	0.02	0.01	0.00
Pipeline Construction (per pa	0.0611	0.0092	5.59	50	305.5	0.17	0.03	0.03	0.00
Central Facilty Construction (per facility)	0.0611	0.0092	15.00	50	240.0	0.46	0.07	0.06	0.01

[1] Based on AP-42 Chapter 13.2.5 (EPA 2004), Industrial Wind Erosion using Area meteorological data. See 'WindErosion Data' sheet for details.
[2] AP-42 (EPA 2004), Section 13.2.3, "Heavy Construction Operations".

NPL Project Air Quality Assessment Emissions Inventory

Table 9. Well Pad Construction Traffic

Project: Jonah NPL
Scenario: 4 Pad/Section
Activity: Pad Const. Traffic
Emissions: Fugitive Particulate Emissions from Traffic on Unpaved Roads

Vehicle Type	Road Type	Dust Control Method[1]	Average Vehicle Weight	Average Vehicle Speed	Silt Content[2]	Moisture Content[3]	Vehicle Count	Round Trips (RTs)	RT Distance	Vehicle Miles Traveled (VMT)[4]	Emission Control Efficiency[5]	PM_{10} Emission Factor[6]	$PM_{2.5}$ Emission Factor[6]	PM_{10} Emissions[7] (controlled)	$PM_{2.5}$ Emissions[7] (controlled)	
			(lb)	(mph)	(%)	(%)		(RT/pad	(miles)	(VMT/pad)	(%)	(lb/VMT)	(lb/VMT)	(lb/pad)	(lb/pad)	
3/4 ton Pickup	Local	Chemical +	5,800	25	5.1	2.4	5	11	34	1870	85	0.51	0.05	143.01	14.21	1b
	Resource	Water +	5,800	20	5.1	2.4	5	11	1	55	50	0.68	0.07	18.81	1.88	1a
1 ton Roustabout w/ trailer	Local	Chemical +	7,500	25	5.1	2.4	1	2	34	68	85	0.51	0.05	5.20	0.52	1b
	Resource	Water +	7,500	20	5.1	2.4	1	2	1	2	50	0.77	0.08	0.77	0.08	1a
Semi w/ bellydump	Local	Chemical +	70,000	25	5.1	2.4	1	10	34	340	85	0.51	0.05	26.00	2.58	1b
	Resource	Water +	70,000	20	5.1	2.4	1	10	1	10	50	2.10	0.21	10.49	1.05	1a
Semi w/ lowboy trailer	Local	Chemical +	75,000	25	5.1	2.4	2	2	34	136	85	0.51	0.05	10.40	1.03	1b
	Resource	Water +	75,000	20	5.1	2.4	2	2	1	4	50	2.16	0.22	4.33	0.43	1a
Bulk fuel truck	Local	Chemical +	35,000	25	5.1	2.4	1	1	34	34	85	0.51	0.05	2.60	0.26	1b
	Resource	Water +	35,000	20	5.1	2.4	1	1	1	1	50	1.54	0.15	0.77	0.08	1a
Water Truck	Local	Chemical +	35,000	25	5.1	2.4	1	5	34	170	85	0.51	0.05	13.00	1.29	1b
	Resource	Water +	35,000	20	5.1	2.4	1	5	1	5	50	1.54	0.15	3.84	0.38	1a
Total Unpaved Road Traffic Emissions (lb/pad)														167.78	16.69	

1 Dust control methods include using water (resource road) or chemical (loacal road) as a dust suppressants along with vehicle restriction speed limit of 25 mph.
2 AP-42 (EPA 2004), Table 13.2.2-1, Western surface coal mining - plant road, "Typical Silt Content Values of Surface Material on Industrial and Rural Unpaved Roads."
3 AP-42 (EPA 2004), Table 11.9-3, "Typical Values for Correction Factors Applicable to the Predictive Emission Factor Equations."
4 Calculated as Round Trips per Vehicle Type x Round Trip Distance.
5 AP-42 (EPA 2004), Figure 13.2.2-2, "Watering control effectiveness for unpaved travel surfaces.", Fugitive Dust Handbook (WRAP 2006) Chapter 6.
6 AP-42 (EPA 2004), Section 13.2.2 "Unpaved Roads", equations 1a and 1b.
7 Calculated as lb/VMT x VMT/pad x control efficiency.

Table 10. Road Construction Traffic - All Operators

Accounted for under Pad Construction

Project: Jonah NPL
Scenario: 4 Pad/Section
Activity: Traffic
Emissions: Fugitive Particulate Emissions from Traffic on Unpaved Roads

Vehicle Type	Road Type	Dust Control Method[1]	Average Vehicle Weight	Average Vehicle Speed	Silt Content[2]	Moisture Content[3]	Vehicle Count	Round Trips (RTs)	RT Distance	Vehicle Miles Traveled (VMT)[4]	Emission Control Efficiency[5]	PM_{10} Emission Factor[6]	$PM_{2.5}$ Emission Factor[6]	PM_{10} Emissions[7] (controlled)	$PM_{2.5}$ Emissions[7] (controlled)
			(lb)	(mph)	(%)	(%)		(RT/pad	(miles)	(VMT/pad)	(%)	(lb/VMT)	(lb/VMT)	(lb/pad)	(lb/pad)
3/4 ton Pickup	Local	Chemical +	5,800	25	5.1	2.4	5	6	34	1020	85	0.51	0.05	78.00	7.75
	Resource	Water +	5,800	20	5.1	2.4	5	6	1	30	50	0.68	0.07	10.26	1.03
1 ton Roustabout w/ trailer	Local	Chemical +	7,500	25	5.1	2.4	1	2	0	0	85	0.51	0.05	0.00	0.00
	Resource	Water +	7,500	20	5.1	2.4	1	2	0	0	50	0.77	0.08	0.00	0.00
Semi w/ bellydump	Local	Chemical +	70,000	25	5.1	2.4	1	10	0	0	85	0.51	0.05	0.00	0.00
	Resource	Water +	70,000	20	5.1	2.4	1	10	0	0	50	2.10	0.21	0.00	0.00
Semi w/ lowboy trailer	Local	Chemical +	75,000	25	5.1	2.4	2	2	0	0	85	0.51	0.05	0.00	0.00
	Resource	Water +	75,000	20	5.1	2.4	2	2	0	0	50	2.16	0.22	0.00	0.00
Bulk fuel truck	Local	Chemical +	35,000	25	5.1	2.4	1	1	0	0	85	0.51	0.05	0.00	0.00
	Resource	Water +	35,000	20	5.1	2.4	1	1	0	0	50	1.54	0.15	0.00	0.00
Water Truck	Local	Chemical +	35,000	25	5.1	2.4	1	5	0	0	85	0.51	0.05	0.00	0.00
	Resource	Water +	35,000	20	5.1	2.4	1	5	0	0	50	1.54	0.15	0.00	0.00
													Total Unpaved Road Traffic Emissions (lb/pad)	88.26	8.78

1 Dust control methods include using water (resource road) or chemical (loacal road) as a dust suppressants along with vehicle restriction speed limit of 25 mph.
2 AP-42 (EPA 2004), Table 13.2.2-1, Western surface coal mining - plant road, "Typical Silt Content Values of Surface Material on Industrial and Rural Unpaved Roads."
3 AP-42 (EPA 2004), Table 11.9-3, "Typical Values for Correction Factors Applicable to the Predictive Emission Factor Equations."
4 Calculated as Round Trips per Vehicle Type x Round Trip Distance.
5 AP-42 (EPA 2004), Figure 13.2.2-2, "Watering control effectiveness for unpaved travel surfaces.", Fugitive Dust Handbook (WRAP 2006) Chapter 6.
6 AP-42 (EPA 2004), Section 13.2.2 "Unpaved Roads", equations 1a and 1b.
7 Calculated as lb/VMT x VMT/pad x control efficiency.

NPL Project Air Quality Assessment Emissions Inventory

Table 11. Pipeline Construction Traffic

Project: Jonah NPL
Scenario: 4 Pad/Section
Activity: Pipeline Construction
Emissions: Fugitive Particulate Emissions from Unpaved Road Traffic

Vehicle Type	Road Type	Dust Control Method[1]	Average Vehicle Weight[2]	Average Vehicle Speed	Silt Content[3]	Moisture Content[4]	Vehicle Count	RTs per mile	RT Distance	VMT[5]	Emission Control Efficiency[6]	PM_{10} Emission Factor[7]	$PM_{2.5}$ Emission Factor[7]	PM_{10} Emissions[8] (controlled)	$PM_{2.5}$ Emissions[8] (controlled)
			(lb)	(mph)	(%)	(%)			(miles)	VMT/pad	(%)	(lb/VMT)	(lb/VMT)	(lb/pad)	(lb/pad)
Light truck/pick-ups	Local	Chemical +	5,800	25	5.1	2.4	10	28	34	9520	85	0.51	0.05	728.03	72.36
	Resource	Water +	5,800	20	5.1	2.4	10	28	1	280	50	0.68	0.07	95.75	9.58
Sideboom	Local	Chemical +	70,000	25	5.1	2.4	3	0.1	34	10.2	85	0.51	0.05	0.78	0.08
	Resource	Water +	70,000	20	5.1	2.4	3	0.1	1	0.3	50	2.10	0.21	0.31	0.03
Trencher	Local	Chemical +	43,000	25	5.1	2.4	1	0.1	34	3.4	85	0.51	0.05	0.26	0.03
	Resource	Water +	43,000	20	5.1	2.4	1	0.1	1	0.1	50	1.68	0.17	0.08	0.01
Track Hoe	Local	Chemical +	45,000	25	5.1	2.4	3	0.1	34	10.2	85	0.51	0.05	0.78	0.08
	Resource	Water +	45,000	20	5.1	2.4	3	0.1	1	0.3	50	1.72	0.17	0.26	0.03
Dozer	Local	Chemical +	28,500	25	5.1	2.4	1	0.1	34	3.4	85	0.51	0.05	0.26	0.03
	Resource	Water +	28,500	20	5.1	2.4	1	0.1	1	0.1	50	1.40	0.14	0.07	0.01
Grader	Local	Chemical +	51,000	25	5.1	2.4	1	0.1	34	3.4	85	0.51	0.05	0.26	0.03
	Resource	Water +	51,000	20	5.1	2.4	1	0.1	1	0.1	50	1.82	0.18	0.09	0.01
Total Unpaved Road Traffic Emissions (lb/pad)														826.59	82.21

1 Dust control methods include using water (resource road) or chemical (loacal road) as a dust suppressants along with vehicle restriction speed limit of 25 mph.
2 Semi vehicle weight range is 28,000-60,000 lbs; average weight of 44,000 lbs used for calculations.
3 AP-42 (EPA 2004), Table 13.2.2-1, Western surface coal mining - plant road, "Typical Silt Content Values of Surface Material on Industrial and Rural Unpaved Roads."
4 AP-42 (EPA 2004), Table 11.9-3, "Typical Values for Correction Factors Applicable to the Predictive Emission Factor Equations."
5 Calculated as Round Trips per Vehicle Type x Round Trip Distance.
6 AP-42 (EPA 2004), Figure 13.2.2-2, "Watering control effectiveness for unpaved travel surfaces.", Fugitive Dust Handbook (WRAP 2006) Chapter 6.
7 AP-42 (EPA 2004), Section 13.2.2 "Unpaved Roads", equations 1a and 1b.
8 Calculated as lb/VMT x VMT/pad x control efficiency.

NPL Project Air Quality Assessment Emissions Inventory

Table 12. Well Pad Construction - Heavy Equipment Tailpipe

Project: Jonah NPL
Scenario: 4 Pad/Section
Activity: Pad Construction Heavy Equip.
Emissions: Diesel Combustion Emissions from Heavy Equipment Tailpipes

Heavy Equipment	Engine Horsepower (hp)	Number Required	Operating Load Factor[1]	CO	NO_x	SO_2	VOC	PM_{10}	$PM_{2.5}$	Benzene	Ethylbenzene	Formaldehyde	H_2S	n-Hexane	Toluene	Xylenes	CH_4[3]	CO_2	N_2O[3]	Construction Activity Duration (days/pad)	(hrs/day)
				Pollutant Emission Factor[2] (g/hp-hr)																	
Cat 430D Backhoe	94	1	0.43	7.36	6.61	0.15	1.59	1.14	1.1								3.89E-02	692	1.73E-02	1.5	8
Cat D8R Dozer	350	1	0.43	1.26	3.91	0.12	0.3	0.25	0.24								3.02E-02	536.4	1.34E-02	5	9
Cat 627F Scraper	350	2.5	0.43	1.26	3.94	0.12	0.3	0.25	0.25								3.02E-02	536.4	1.34E-02	4	9
Cat 14H Grader	220	1	0.43	1.47	4.08	0.12	0.33	0.32	0.31								3.02E-02	536.3	1.34E-02	5	9

CH_4[3] factor	N_2O[3] factor	Units
0.18	0.08	g/kg fuel
7.1	7.1	lb/gal diesel
0.4536	0.4536	kg/lb
0.001	0.001	kg/g
0.0005797	0.00025764	kg/gal
10.3	10.3	kg CO_2/gal diesel fuel
5.6282E-05	2.5014E-05	factor for converting from CO2

Pollutant Emissions (lb/pad)

CO	NO_x	SO_2	VOC	PM_{10}	$PM_{2.5}$	Benzene	Ethylbenzene	Formaldehyde	H_2S	n-Hexane	Toluene	Xylenes	CH_4	CO_2	N_2O
7.9	7.1	0.2	1.7	1.2	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	740.0	0.0
18.8	58.4	1.8	4.5	3.7	3.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	8008.8	0.2
37.6	117.7	3.6	9.0	7.5	7.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	16017.5	0.4
13.8	38.3	1.1	3.1	3.0	2.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	5033.1	0.1

HD Vehicle traffic Emissions[4]

	miles/pad	CO	NO_x	SO_2	VOC	PM_{10}	$PM_{2.5}$	Benzene	Ethylbenzene	Formaldehyde	H_2S	n-Hexane	Toluene	Xylenes	CH_4[3]	CO_2	N_2O[3]
		g/mile															
1 ton Roustabout w/ trailer	70	1.59E+00	6.87E+00	1.37E-02	2.76E-01	3.47E-01	2.98E-01	2.99E-03		2.23E-02					3.19E-02	1.86E+03	1.76E-03
Semi w/ bellydump	350	1.59E+00	6.87E+00	1.37E-02	2.76E-01	3.47E-01	2.98E-01	2.99E-03		2.23E-02					3.19E-02	1.86E+03	1.76E-03
Semi w/ lowboy trailer	140	1.59E+00	6.87E+00	1.37E-02	2.76E-01	3.47E-01	2.98E-01	2.99E-03		2.23E-02					3.19E-02	1.86E+03	1.76E-03
Bulk fuel truck	35	9.69E-01	2.41E+00	6.15E-03	2.33E-01	1.63E-01	1.21E-01	2.53E-03		1.88E-02					4.06E-02	8.55E+02	1.88E-03
Water Truck	175	9.69E-01	2.41E+00	6.15E-03	2.33E-01	1.63E-01	1.21E-01	2.53E-03		1.88E-02					4.06E-02	8.55E+02	1.88E-03
		lb/pad															
1 ton Roustabout w/ trailer		2.45E-01	1.06E+00	2.11E-03	4.26E-02	5.36E-02	4.60E-02	4.62E-04		3.44E-03					4.93E-03	2.88E+02	2.72E-04
Semi w/ bellydump		1.23E+00	5.30E+00	1.05E-02	2.13E-01	2.68E-01	2.30E-01	2.31E-03		1.72E-02					2.46E-02	1.44E+03	1.36E-03
Semi w/ lowboy trailer		4.90E-01	2.12E+00	4.22E-03	8.52E-02	1.07E-01	9.19E-02	9.23E-04		6.88E-03					9.85E-03	5.76E+02	5.44E-04
Bulk fuel truck		7.48E-02	1.86E-01	4.75E-04	1.80E-02	1.26E-02	9.31E-03	1.95E-04		1.45E-03					3.13E-03	6.59E+01	1.45E-04
Water Truck		3.74E-01	9.31E-01	2.37E-03	9.01E-02	6.31E-02	4.65E-02	9.76E-04		7.27E-03					1.57E-02	3.30E+02	7.26E-04
Total Heavy Equipment Tailpipe Emissions		80.5	231.0	6.7	18.7	15.9	15.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	32497.3	0.7

[1] Taken from "Median Life Annual Activity, and Load Factor Values for Nonroad Engine Emissions Modeling, Table 9, 7-cycle average (7/2010)

[2] Emission factors from NONROADS 2008, run for 2009.

Fuel Oxygen 2.440 wt%;Dsl Sulfur 0.0351 %

[3] Table A- 106: Emission Factors for CH4 and N2O Emissions from Non-Road Mobile Combustion (g/kg fuel) of

http://www.epa.gov/climatechange/Downloads/ghgemissions/US-GHG-Inventory-2013-Annex-3-Additional-Source-or-Sink-Categories.pdf

and Nonroads emmissions by fuel type for CO2.

CO_2 = 10.3kg CO2 / gal diesel fuel. CO2 value provided in NONROADs 2008 run for 2015. NO2 and CH4 are not. CH4=0.000580 kg/gal diesel fuel, NO2 = 0.000258 kg/gal diesel fuel assuming 7.1 lb/gal diesel (NONROAD value).

Factor for CH4 = 0.00058/10.3, factor for NO2 = 0.000258/10.3

[4] MOVES 2015

NPL Project Air Quality Assessment Emissions Inventory

Table 13. Road Construction - Heavy Equipment Tailpipe

Project: Jonah NPL
Scenario: 4 Pad/Section
Activity: Road Construction Heavy Equip.
Emissions: Diesel Combustion Emissions from Heavy Equipment Tailpipes

Heavy Equipment	Engine Horsepower	Number Required	Operating Load Factor[1]	Pollutant Emission Factor[2] (g/hp-hr)																Construction Activity Duration	
	(hp)			CO	NO_x	SO_2	VOC	PM_{10}	$PM_{2.5}$	Benzene	Ethylbenzene	Formaldehyde	H_2S	n-Hexane	Toluene	Xylenes	CH_4[3]	CO_2	N_2O[3]	(days/pad)	(hrs/day)
Cat 430D Backhoe	94	1	0.43	7.36	6.61	0.15	1.59	1.14	1.1								3.89E-02	692	1.73E-02	0.9	8
Cat D8R Dozer	350	1	0.43	1.26	3.91	0.12	0.3	0.25	0.24								3.02E-02	536.4	1.34E-02	3	9
Cat 627F Scraper	350	2.5	0.43	1.26	3.94	0.12	0.3	0.25	0.25								3.02E-02	536.4	1.34E-02	2.4	9
Cat 14H Grader	220	1	0.43	1.47	4.08	0.12	0.33	0.32	0.31								3.02E-02	536.3	1.34E-02	3	9

CH_4[3] factor	N_2O[3] factor	
0.18	0.08	g/kg fuel
7.1	7.1	lb/gal diesel
0.4536	0.4536	kg/lb
0.001	0.001	kg/g
0.0005797	0.00025764	kg/gal
10.3	10.3	kg CO_2/gal diesel fuel
5.6282E-05	2.5014E-05	factor for converting from CO2

Pollutant Emissions (lb/pad)

	CO	NO_x	SO_2	VOC	PM_{10}	$PM_{2.5}$	Benzene	Ethylbenzene	Formaldehyde	H_2S	n-Hexane	Toluene	Xylenes	CH_4	CO_2	N_2O
	4.7	4.2	0.1	1.0	0.7	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	444.0	0.0
Cat 430D Backhoe	11.3	35.0	1.1	2.7	2.2	2.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	4805.3	0.1
Cat D8R Dozer	22.6	70.6	2.2	5.4	4.5	4.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	9610.5	0.2
Cat 627F Scraper	8.3	23.0	0.7	1.9	1.8	1.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	3019.9	0.1
Cat 14H Grader																
Total Heavy Equipment Tailpipe Emissions	46.9	132.8	4.0	10.9	9.3	9.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	17879.6	0.4

[1] Taken from "Median Life Annual Activity, and Load Factor Values for Nonroad Engine Emissions Modeling, Table 9, 7-cycle average (7/2010)

[2] Emission factors from NONROADS 2008, run for 2009.

Fuel Oxygen 2.440 wt%;Dsl Sulfur 0.0351 %

[3] Table A- 106: Emission Factors for CH4 and N2O Emissions from Non-Road Mobile Combustion (g/kg fuel) of

http://www.epa.gov/climatechange/Downloads/ghgemissions/US-GHG-Inventory-2013-Annex-3-Additional-Source-or-Sink-Categories.pdf

and Nonroads emmissions by fuel type for CO2.

CO_2 = 10.3kg CO2 / gal diesel fuel. CO2 value provided in NONROADs 2008 run for 2015. NO2 and CH4 are not. CH4=0.000580 kg/gal diesel fuel, NO2 = 0.000258 kg/gal diesel fuel assuming 7.1 lb/gal diesel (NONROAD value).

Factor for CH4 = 0.00058/10.3, factor for NO2 = 0.000258/10.3

Table 14. Pipeline Heavy Equipment Tailpipe

Project: Jonah NPL
Scenario: 4 Pad/Section
Activity: Pipeline Construction
Emissions: Diesel Combustion Emissions from Heavy Equipment Tailpipes

Pollutant Emission Factor[2] (g/hp-hr); Construction Activity Duration

Heavy Equipment	Engine Horsepower (hp)	Number Required	Operating Load Factor[1]	CO	NO_x	SO_2	VOC	PM_{10}	$PM_{2.5}$	Benzene	Ethylbenzene	Formaldehyde	H_2S	n-Hexane	Toluene	Xylenes	CH_4[3]	CO_2	N_2O[3]	Construction Activity Duration (days/mile)	Construction Activity Duration (hrs/day)
Sideboom	240	3	0.43	1.06	4.6	0.11	0.35	0.25	0.25								2.99E-02	530.5	1.33E-02	10	10
Trencher	215	1	0.43	1.57	4.61	0.12	0.35	0.3	0.29								3.02E-02	536.3	1.34E-02	10	10
Track Hoe	150	3	0.43	7.77	6.69	0.15	1.59	1.19	1.16								3.89E-02	691.9	1.73E-02	10	10
Dozer	125	1	0.43	3.92	4.69	0.13	0.47	0.54	0.52								3.35E-02	595.3	1.49E-02	10	10
Grader	185	1	0.43	1.47	4.08	0.12	0.33	0.32	0.31								3.02E-02	536.3	1.34E-02	10	10

CH_4[3] factor	N_2O[3] factor	
0.18	0.08	g/kg fuel
7.1	7.1	lb/gal diesel
0.4536	0.4536	kg/lb
0.001	0.001	kg/g
0.0005797	0.00025764	kg/gal
10.3	10.3	kg CO_2/gal diesel fuel
5.6282E-05	2.5014E-05	factor for converting from CO2

Pollutant Emissions (lb/pad) << these are per mile when summing multiply by miles/pad

	CO	NO_x	SO_2	VOC	PM_{10}	$PM_{2.5}$	Benzene	Ethylbenzene	Formaldehyde	H_2S	n-Hexane	Toluene	Xylenes	CH_4	CO_2	N_2O
Sideboom	72.3	314.0	7.5	23.9	17.1	17.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	36208.7	0.9
Trencher	32.0	94.0	2.4	7.1	6.1	5.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	10930.5	0.3
Track Hoe	331.5	285.4	6.4	67.8	50.8	49.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	29515.6	0.7
Dozer	46.5	55.6	1.5	5.6	6.4	6.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	7054.1	0.2
Grader	25.8	71.6	2.1	5.8	5.6	5.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	9405.3	0.2
Total Emissions from Heavy Equipment Tailpipes	508	820	20	110	86	84	0	0	0	0	0	0	0	5	93114	2

[1] Taken from "Median Life Annual Activity, and Load Factor Values for Nonroad Engine Emissions Modeling, Table 9, 7-cycle average (7/2010)

[2] Emission factors from NONROADS 2008, run for 2009.

Fuel Oxygen 2.440 wt%;Dsl Sulfur 0.0351 %

[3] Table A- 106: Emission Factors for CH4 and N2O Emissions from Non-Road Mobile Combustion (g/kg fuel) of

http://www.epa.gov/climatechange/Downloads/ghgemissions/US-GHG-Inventory-2013-Annex-3-Additional-Source-or-Sink-Categories.pdf

and Nonroads emmissions by fuel type for CO2.

CO_2 = 10.3kg CO2 / gal diesel fuel. CO2 value provided in NONROADs 2008 run for 2015. NO2 and CH4 are not. CH4=0.000580 kg/gal diesel fuel, NO2 = 0.000258 kg/gal diesel fuel assuming 7.1 lb/gal diesel (NONROAD value).

Factor for CH4 = 0.00058/10.3, factor for NO2 = 0.000258/10.3

NPL Project Air Quality Assessment Emissions Inventory

Table 15. Compressor Station Construction - Heavy Equipment Tailpipe

Project: Jonah NPL
Scenario: 4 Pad/Section
Activity: Compressor Station Construction Heavy Equip.
Emissions: Diesel Combustion Emissions from Heavy Equipment Tailpipes

Heavy Equipment	Engine Horsepower (hp)	Number Required	Operating Load Factor[1]	Pollutant Emission Factor[2] (g/hp-hr): CO	NO_x	SO_2	VOC	PM_{10}	$PM_{2.5}$	Benzene	Ethylbenzene	Formaldehyde	H_2S	n-Hexane	Toluene	Xylenes	CH_4[3]	CO_2	N_2O[3]	Construction Activity Duration (days/pad)	(hrs/day)
Cat 430D Backhoe	94	1	0.43	7.36	6.61	0.15	1.59	1.14	1.1								3.89E-02	692	1.73E-02	1.5	8
Cat D8R Dozer	350	1	0.43	1.26	3.91	0.12	0.3	0.25	0.24								3.02E-02	536.4	1.34E-02	5	9
Cat 627F Scraper	350	2.5	0.43	1.26	3.94	0.12	0.3	0.25	0.25								3.02E-02	536.4	1.34E-02	4	9
Cat 14H Grader	220	1	0.43	1.47	4.08	0.12	0.33	0.32	0.31								3.02E-02	536.3	1.34E-02	5	9

CH_4[3] factor	N_2O[3] factor	
0.18	0.08	g/kg fuel
7.1	7.1	lb/gal diesel
0.4536	0.4536	kg/lb
0.001	0.001	kg/g
0.0005797	0.00025764	kg/gal
10.3	10.3	kg CO_2/gal diesel fuel
5.6282E-05	2.5014E-05	factor for converting from CO2

Pollutant Emissions (lb/pad)

Heavy Equipment	CO	NO_x	SO_2	VOC	PM_{10}	$PM_{2.5}$	Benzene	Ethylbenzene	Formaldehyde	H_2S	n-Hexane	Toluene	Xylenes	CH_4	CO_2	N_2O
Cat 430D Backhoe	7.9	7.1	0.2	1.7	1.2	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	740.0	0.0
Cat D8R Dozer	18.8	58.4	1.8	4.5	3.7	3.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	8008.8	0.2
Cat 627F Scraper	37.6	117.7	3.6	9.0	7.5	7.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	16017.5	0.4
Cat 14H Grader	13.8	38.3	1.1	3.1	3.0	2.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	5033.1	0.1
Total Heavy Equipment Tailpipe Emissions	78.1	221.4	6.7	18.2	15.4	15.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	29799.3	0.7

[1] Taken from "Median Life Annual Activity, and Load Factor Values for Nonroad Engine Emissions Modeling, Table 9, 7-cycle average (7/2010)

[2] Emission factors from NONROADS 2008, run for 2009.

Fuel Oxygen 2.440 wt%;Dsl Sulfur 0.0351 %

[3] Table A- 106: Emission Factors for CH4 and N2O Emissions from Non-Road Mobile Combustion (g/kg fuel) of

http://www.epa.gov/climatechange/Downloads/ghgemissions/US-GHG-Inventory-2013-Annex-3-Additional-Source-or-Sink-Categories.pdf

and Nonroads emmissions by fuel type for CO2.

CO_2 = 10.3kg CO2 / gal diesel fuel. CO2 value provided in NONROADs 2008 run for 2015. NO2 and CH4 are not. CH4=0.000580 kg/gal diesel fuel, NO2 = 0.000258 kg/gal diesel fuel assuming 7.1 lb/gal diesel (NONROAD value).

Factor for CH4 = 0.00058/10.3, factor for NO2 = 0.000258/10.3

Table 16. Drilling Traffic

Project: Jonah NPL
Scenario: 4 Pad/Section
Activity: Drilling
Emissions: Fugitive Particulate Emissions from Traffic on Unpaved Roads

Vehicle Type	Road Type	Dust Control Method[1]	Average Vehicle Weight	Average Vehicle Speed	Silt Content[2]	Moisture Content[3]	Vehicle Count	RTs per Well	RT Distance	VMT [4]	Emission Control Efficiency[5]	PM_{10} Emission Factor[6]	$PM_{2.5}$ Emission Factor[6]	PM_{10} Emissions[6] (controlled)	$PM_{2.5}$ Emissions[6] (controlled)
			(lb)	(mph)	(%)	(%)			(miles)	(VMT/Well)	(%)	(lb/VMT)	(lb/VMT)	(lb/pad)	(lb/pad)
Light truck/pick-ups	Local Road	Chemical + Restriction	5,800	25	5.1	2.4	1	40	6	240	85	0.51	0.05	293.66	29.19
	Resource Road	Water + Restriction	5,800	20	5.1	2.4	1	40	10	400	50	0.68	0.07	2,188.60	218.86
Tandem Tractor Drilling muds	Local Road	Chemical + Restriction	60,000	20	5.1	2.4	1	2	34	68	85	0.46	0.05	74.41	7.39
	Resource Road	Water + Restriction	60,000	15	5.1	2.4	1	2	10	20	50	1.96	0.20	313.16	31.32
Tandem Tractor Fresh Water	Local Road	Chemical + Restriction	60,000	20	5.1	2.4	1	15	8	120	85	0.46	0.05	131.31	13.04
	Resource Road	Water + Restriction	60,000	15	5.1	2.4	1	15	10	150	50	1.96	0.20	2,348.67	234.87
Tandem Tractor Processed Water	Local Road	Chemical + Restriction	60,000	20	5.1	2.4	1	50	10	500	85	0.46	0.05	547.14	54.34
	Resource Road	Water + Restriction	60,000	15	5.1	2.4	1	50	10	500	50	1.96	0.20	7,828.91	782.89
Tandem Tractor Casing	Local Road	Chemical + Restriction	60,000	20	5.1	2.4	1	2	34	68	85	0.46	0.05	74.41	7.39
	Resource Road	Water + Restriction	60,000	15	5.1	2.4	1	2	10	20	50	1.96	0.20	313.16	31.32
Tandem Tractor Cement	Local Road	Chemical + Restriction	60,000	20	5.1	2.4	1	2	34	68	85	0.46	0.05	74.41	7.39
	Resource Road	Water + Restriction	60,000	15	5.1	2.4	1	2	10	20	50	1.96	0.20	313.16	31.32
Light Duty Misc	Local Road	Chemical + Restriction	5,000	20	5.1	2.4	1	20	34	680	85	0.46	0.05	744.12	73.90
	Resource Road	Water + Restriction	5,000	15	5.1	2.4	1	20	10	200	50	0.64	0.06	1,023.60	102.36
Company Man	Local Road	Chemical + Restriction	5,800	25	5.1	2.4	1	10	6	60	85	0.51	0.05	73.42	7.30
	Resource Road	Water + Restriction	5,800	20	5.1	2.4	1	10	10	100	50	0.68	0.07	547.15	54.71
													Total Unpaved Road Traffic Emissions (lb/pad)	16,889.28	1,687.57

[1] Dust control methods include using water (resource road) or chemical (loacal road) as a dust suppressants along with vehicle restriction speed limit of 25 mph.

[2] AP-42 (EPA 2004), Table 13.2.2-1, "Typical Silt Content Values of Surface Material on Industrial and Rural Unpaved Roads."

[3] AP-42 (EPA 2004), Table 11.9-3, "Typical Values for Correction Factors Applicable to the Predictive Emission Factor Equations."

[4] Calculated as Round Trips per Vehicle Type x Round Trip Distance.

[5] AP-42 (EPA 2004), Figure 13.2.2-2, "Watering control effectiveness for unpaved travel surfaces.", Fugitive Dust Handbook (WRAP 2006) Chapter 6.

[6] AP-42 (EPA 2004), Section 13.2.2 "Unpaved Roads", equations 1a and 1b.

[7] Calculated as lb/VMT x VMT/pad x control efficiency.

NPL Project Air Quality Assessment Emissions Inventory

Table 17. Rig Move Traffic

Project: Jonah NPL
Scenario: 4 Pad/Section
Activity: Rig Move
Emissions: Fugitive Particulate Emissions from Traffic on Unpaved Roads

Vehicle Type	Road Type	Dust Control Method[1]	Average Vehicle Weight	Average Vehicle Speed	Silt Content[2]	Moisture Content[3]	Vehicle Count	RTs per Pad	RT Distance	VMT [4]	Emission Control Efficiency[5]	PM_{10} Emission Factor[6]	$PM_{2.5}$ Emission Factor[6]	PM_{10} Emissions[7] (controlled)	$PM_{2.5}$ Emissions[7] (controlled)	
			(lb)	(mph)	(%)	(%)			(miles)	(VMT/pad)	(%)	(lb/VMT)	(lb/VMT)	(lb/pad)	(lb/pad)	
Rig Haul Trucks	Local Road	Chemical + Restriction	80,000	25	5.1	2.4	10	3	6	180	85	0.51	0.05	13.77	1.37	1b
	Resource Road	Water + Restriction	80,000	20	5.1	2.4	10	3	14	420	50	2.23	0.22	467.82	46.78	1a
Light Trucks	Local Road	Chemical + Restriction	5,800	25	5.1	2.4	2	3	6	36	85	0.51	0.05	2.75	0.27	1b
	Resource Road	Water + Restriction	5,800	20	5.1	2.4	2	3	14	84	50	0.68	0.10	28.73	4.40	1a
										Total Unpaved Road Traffic Emissions (lb/pad)				513.07	52.83	

[1] Dust control methods include using water (resource road) or chemical (loacal road) as a dust suppressants along with vehicle restriction speed limit of 25 mph.

[2] AP-42 (EPA 2004), Table 13.2.2-1, "Typical Silt Content Values of Surface Material on Industrial and Rural Unpaved Roads."

[3] AP-42 (EPA 2004), Table 11.9-3, "Typical Values for Correction Factors Applicable to the Predictive Emission Factor Equations."

[4] Calculated as Round Trips per Vehicle Type x Round Trip Distance.

[5] AP-42 (EPA 2004), Figure 13.2.2-2, "Watering control effectiveness for unpaved travel surfaces.", Fugitive Dust Handbook (WRAP 2006) Chapter 6.

[6] AP-42 (EPA 2004), Section 13.2.2 "Unpaved Roads", equations 1a and 1b.

[7] Calculated as lb/VMT x VMT/well x control efficiency.

NPL Project Air Quality Assessment Emissions Inventory

Table 18. Drilling Haul Truck Tailpipe

Project: Jonah NPL
Scenario: 4 Pad/Section
Activity: Drilling Traffic
Emissions: Diesel Combustion Emissions from Heavy Equipment Tailpipes

Vehicle Type	Pollutant	Pollutant Emission Factor[1] (g/mile)	Total Haul Truck RTs (RTs/well)	RT Distance Avg. (miles/RT)	Total Haul Truck Miles Traveled (miles/well)	Haul Activity Duration[3] (days/well)	Haul Activity Duration (hours/day)	Emissions (lb/pad)
Heavy Duty	CO	0.97	71	22	1,534	17	24	52
	NO_x	2.41	71	22	1,534	17	24	131
	PM_{10}	0.16	71	22	1,534	17	24	9
	$PM_{2.5}$	0.12	71	22	1,534	17	24	6.53E+00
	SO_2	0.01	71	22	1,534	17	24	3.33E-01
	VOC	0.23	71	22	1,534	17	24	1.26E+01
	Benzene	2.53E-03	71	22	1,534	17	24	1.37E-01
	Ethylbenzene		71	22	1,534	17	24	0.00E+00
	Formaldehyde	1.88E-02	71	22	1,534	17	24	1.02E+00
	H_2S		71	22	1,534	17	24	0.00E+00
	n-Hexane		71	22	1,534	17	24	0.00E+00
	Toluene		71	22	1,534	17	24	0.00E+00
	Xylenes		71	22	1,534	17	24	0.00E+00
	CH_4	4.06E-02	71	22	1,534	17	24	2.20E+00
	CO_2[2]	8.55E+02	71	22	1,534	17	24	46240
	N_2O	1.88E-03	71	22	1,534	17	24	1.02E-01

[1] MOVES, 2015 heavy duty short haul truck
[2] CO2 from CO2(eq) {CO2(eq)-25*CH4-298*N20}
[3] Based on average spud to release date for Jonah wells.

NPL Project Air Quality Assessment Emissions Inventory

Table 19. Rig Move Haul Truck Tailpipe

Project: Jonah NPL
Scenario: 4 Pad/Section
Activity: Rig Move
Emissions: Diesel Combustion Emissions from Haul Truck Tailpipes

Pollutant	Pollutant Emission Factor[1]	Total Haul Truck RTs	RT Distance	Total Haul Truck Miles Traveled	Haul Activity Duration	Haul Activity Duration	Emissions
	(g/mile)	(RTs/pad)	(miles/RT)	(miles/pad)	(days/move)	(hours/day)	(lb/pad)
CO	0.97	3	20	600	3	24	1.28E+00
NO_x	2.41	3	20	600	3	24	3.19E+00
PM_{10}	0.16	3	20	600	3	24	2.16E-01
$PM_{2.5}$	0.12	3	20	600	3	24	1.60E-01
SO_2[2]	0.01	3	20	600	3	24	8.14E-03
VOC	0.23	3	20	600	3	24	3.09E-01
Benzene	2.53E-03	3	20	600	3	24	3.35E-03
Ethylbenzene		3	20	600	3	24	0.00E+00
Formaldehyde	1.88E-02	3	20	600	3	24	2.49E-02
H_2S		3	20	600	3	24	0.00E+00
n-Hexane		3	20	600	3	24	0.00E+00
Toluene		3	20	600	3	24	0.00E+00
Xylenes		3	20	600	3	24	0.00E+00
CH_4	4.06E-02	3	20	600	3	24	5.37E-02
CO_2[2]	8.55E+02	3	20	600	3	24	1130
N_2O	1.88E-03	3	20	600	3	24	2.49E-03

[1] MOVES, 2015 heavy duty short haul truck

[2] CO2 from CO2(eq) {CO2(eq)-25*CH4-298*N20}

NPL Project Air Quality Assessment Emissions Inventory

Table 20. Material Balance

Gas Composition

	MW (g/mol)	Carbons	mol %	mol%*MW	Wt %	C%	Wt-C
Carbon Dioxide	44	1	0.54	23.61	1.28	27.27	34.95
Hydrogen Sulfide		0	0	0.00	0		
Nitrogen		0	0.21	0.00	0		
Methane	16.04	1	89.82	1440.67	78.19	74.81	5849.30
Ethane	30.07	2	5.59	167.97	9.12	79.81	727.57
Propane	44.09	3	2.14	94.45	5.13	81.65	418.51
Isobutane	58.12	4	0.518	30.09	1.63	82.59	134.86
n-Butane	58.12	4	0.520	30.23	1.64	82.59	135.50
Isopentane	72.15	5	0.204	14.73	0.80	83.16	66.48
n-Pentane	72.15	5	0.144	10.38	0.56	83.16	46.87
Cyclopentane	70.13	5	0	0.00	0	85.56	0
n-hexane	86.18	6	0.049	4.24	0.23	83.55	19.22
Cyclohexane	84.16	6	0.028	2.36	0.13	85.55	10.97
Other Hexanes	86.18	6	0.085	7.35	0.40	83.55	33.34
Heptanes	100.21	7	0.063	6.34	0.34	83.82	28.84
Methylcyclohexane	98.19	7	0.037	3.62	0.20	85.55	16.81
2,2,4-Trimethylpentane	114.23	8	0.005	0.53	0.029	84.04	2.43
Benzene	78.11	6	0.012	0.94	0.051	92.18	4.71
Toluene	92.14	7	0.015	1.39	0.076	91.17	6.90
Ethylbenzene	106.17	8	0.001	0.057	0.003	90.42	0.28
Xylenes	106.17	8	0.005	0.517	0.028	90.42	2.54
C8+Heavies	128.26	9	0.024	3.134	0.17	84.20	14.32
Total			*100.00*	*1842.63*	*100.00*	*1635.05*	*7554.40*
					11.42		

MW Fuel	18.43	lb fuel/lb-mol fuel
Wt% Fuel	98.72	fuel
Wt% C	0.77	lb C/lb fuel
CO_2 Factor	6.18E-05	tonne/scf
	122.25	lb/MMbtu
	0.14	lb/scf

Dehy - Post condenser gas composition

	MW (g/mol)	Carbons	mol %	mol%*MW	Wt %	C%	Wt-C
H2O		0	18.6	0.00	0.00		
Oxygen		0	0	0.00	0.00		
CO2	44	1	4.63	203.72	5.18	27.27	141.40
N2		0	0.0671	0.00	0.00		
Methane	16.04	1	31.1	498.84	12.70	74.81	949.79
Ethane	30.07	2	7.42	223.12	5.68	79.81	453.21
Propane	44.09	3	7.95	350.52	8.92	81.65	728.38
Isobutane	58.12	4	3.02	175.52	4.47	82.59	368.92
n-Butane	58.12	4	4.26	247.59	6.30	82.59	520.40

MW Fuel	39.29	lb fuel/lb-mol fuel
Wt% Fuel	100.00	fuel
Wt% C	0.79	lb C/lb fuel
CO_2 Factor	1.36E-04	tonne/scf
	144.98	lb/MMbtu
	0.30	lb/scf

Isopentane	72.15	5	1.35	97.40	2.48	83.16	206.15
n-Pentane	72.15	5	1.15	82.97	2.11	83.16	175.61
Hexane+	100.21	7	20.4529	2049.59	52.16	83.82	4372.42
Total			*100.00*	*3929.27*	*100.00*	*678.87*	*7916.28*

Dehy - Flash tank off gas composition

	MW (g/mol)	Carbons	mol %	mol%*MW	Wt %	C%	Wt-C
H2O		0	1.07	0.00	0.00		
Oxygen		0	0	0.00	0.00		
CO2	44	1	1.21	53.24	2.52	27.27	68.64
N2		0	0.189	0.00	0.00		
Methane	16.04	1	81.7	1310.47	61.95	74.81	4634.92
Ethane	30.07	2	6.59	198.16	9.37	79.81	747.71
Propane	44.09	3	3.39	149.47	7.07	81.65	576.95
I-Butane	58.12	4	1.05	61.03	2.89	82.59	238.27
N-Butane	58.12	4	2.6	151.11	7.14	82.59	590.00
I-Pentane	72.15	5	0.561	40.48	1.91	83.16	159.13
N-Pentane	72.15	5	0.465	33.55	1.59	83.16	131.90
Hexane+	100.21	7	1.175	117.75	5.57	83.82	466.61
Total			*100.00*	*2115.25*	*100.00*	*678.87*	*7614.15*

MW Fuel	21.15	lb fuel/lb-mol fuel
Wt% Fuel	100.00	fuel
Wt% C	0.76	lb C/lb fuel
CO_2 Factor	7.06E-05	tonne/scf
	124.56	lb/MMbtu
	0.16	lb/scf

Condensate Composition

	MW (g/mol)	Carbons	mol %	mol%*MW	Wt %	C%	Wt-C
Methane	16.04	1	5.19	83.24	0.81	74.81	60.36
Ethane	30.07	2	2.65	79.73	0.77	79.81	61.68
Propane	44.09	3	3.67	161.90	1.57	81.65	128.14
i-Butane	58.12	4	2.18	126.47	1.23	82.59	101.25
n-Butane	58.12	4	3.15	183.06	1.77	82.59	146.56
neoPentane	72.15	5	0.07	5.01	0.05	83.16	4.04
i-Pentane	72.15	5	2.84	204.77	1.99	83.16	165.08
n-Pentane	72.15	5	2.79	201.15	1.95	83.16	162.16
2,2-DMB	86.18	6	0.16	13.82	0.13	83.55	11.19
2,3-DMB	86.18	6	0.61	52.98	0.51	83.55	42.91
2-MP	86.18	6	1.90	163.43	1.58	83.55	132.36
3-MP	86.18	6	1.06	91.21	0.88	83.55	73.87
n-Hexane	86.18	6	1.86	159.94	1.55	83.55	129.53
Heptane	100.21	7	16.91	1694.30	16.42	83.82	1376.76
Octanes	114.23	8	7.39	844.06	8.18	84.04	687.65
Nonanes	128.26	9	12.85	1648.13	15.98	84.20	1345.32
Decanes+	156.31	11	20.29	3171.74	30.75	84.45	2596.47

MW Fuel	103.16	lb fuel/lb-mol fuel
Wt% Fuel	14.80	fuel
Wt% C	0.82	lb C/lb fuel
CO_2 Factor	3.73E-04	tonne/scf
	657.18	lb/MMbtu
	0.82	lb/scf

N2		0	0.00	0.00	0.00		
CO2	44	1	0.09	3.81	0.04	27.27	1.01
Benzene	78.11	6	1.15	89.90	0.87	92.18	80.33
Toluene	92.14	7	5.59	515.09	4.99	91.17	455.21
E-Benzene	106.17	8	0.66	70.35	0.68	90.42	61.67
m&p Xylenes	106.17	8	5.22	554.67	5.38	90.42	486.19
o Xylene	106.17	8	1.00	106.06	1.03	90.42	92.96
2,2,4-TMP	114.23	8	0.80	90.91	0.88	84.04	74.06
Total			*100.07*	*10315.74*	*100.00*	*1971.10*	*8476.78*
					98.42		

Condensate Storage Tank - Flash gas composition

	MW (g/mol)	Carbons	mol %	mol%*MW	Wt %	C%	Wt-C
CO2	44	1	0.77	33.88	1.10	27.27	29.96
Methane	16.04	1	48.32	775.05	25.13	74.81	1879.96
Ethane	30.07	2	20.10	604.41	19.60	79.81	1564.04
Propane	44.09	3	16.19	713.82	23.14	81.65	1889.69
Isobutane	58.12	4	4.80	278.98	9.04	82.59	747.00
n-Butane	58.12	4	4.97	288.86	9.37	82.59	773.46
Isopentane	72.15	5	1.64	118.33	3.84	83.16	319.03
n-Pentane	72.15	5	1.25	90.19	2.92	83.16	243.17
n-Hexane	86.18	6	0.22	18.96	0.61	83.55	51.36
other Hexanes	86.18	6	0.76	65.50	2.12	83.55	177.41
Heptanes	100.21	7	0.54	54.11	1.75	83.82	147.07
Benzene	78.11	6	0.12	9.37	0.30	92.18	28.01
Toluene	92.14	7	0.16	14.74	0.48	91.17	43.58
Ethylbenzene	106.17	8	0.01	1.06	0.03	90.42	3.11
Xylenes	106.17	8	0.04	4.25	0.14	90.42	12.45
C8+ Heavies	128.26	9	0.10	12.83	0.42	84.20	35.02
Total			*99.99*	*3084.32*	*100.00*	*1294.35*	*7944.30*
					54.18		

MW Fuel	30.84	lb fuel/lb-mol fuel
Wt% Fuel	98.90	fuel
Wt% C	0.80	lb C/lb fuel
CO_2 Factor	1.09E-04	tonne/scf
	134.55	lb/MMbtu
	0.24	lb/scf

Table 21. Drill Rigs

Project: Jonah NPL
Scenario: 4 Pad/Section
Effective Dates: 2009
Emissions: Combustion Emissions from Drilling Engines

Engine	Pollutant	EPA Tier Certification	Pollutant Emission Factor (lb/MMbtu)	Emission Factor Reference	Fuel Heating Value[2] (btu/scf) or (btu/gal)	Fuel Consumption Rate[3] (mcf/hr) or (gal/hr)	Drilling Activity Duration (days/well)	Drilling Activity Duration (hours/day)	Emissions (lb/hr)	Emissions per Well (lb)	Emissions per Pad (tons)
Cat 3516G (Main)	CO	Tier 3+	1.04	1	1115	10.11	10.5	24	11.77	2,965.70	23.73
	NOx	Tier 3+	0.44	1	1115	10.11	10.5	24	5.01	1,261.27	10.09
	SO_2	Tier 3+	5.88E-05	6	1115	10.11	10.5	24	0.00	0.17	0.00
	VOC	Tier 3+	0.05	1	1115	10.11	10.5	24	0.51	127.83	1.02
	PM_{10}	Tier 3+	0.01	1	1115	10.11	10.5	24	0.07	17.04	0.14
	$PM_{2.5}$		7.71E-05	4	1115	10.11	10.5	24	0.00	0.22	0.00
	Benzene		4.40E-04	4	1115	10.11	10.5	24	0.00	1.25	0.01
	Ethylbenzene		3.97E-05	4	1115	10.11	10.5	24	0.00	0.11	0.00
	Formaldehyde		0.07	1	1115	10.11	10.5	24	0.79	198.85	1.59
	H_2S		0.00E+00	6	1115	10.11	10.5	24	0.00	0.00	0.00
	n-Hexane		1.11E-03	4	1115	10.11	10.5	24	0.01	3.15	0.03
	Toluene		4.08E-04	4	1115	10.11	10.5	24	0.00	1.16	0.01
	Xylenes		1.84E-04	4	1115	10.11	10.5	24	0.00	0.52	0.00
	CH_4		1.52	7	1115	10.11	10.5	24	17.12	4,315.04	34.52
	CO_2		122.25	8	1115	10.11	10.5	24	1378.08	347,277	2,778.21
	N_2O		2.28E-04	9	1115	10.11	10.5	24	0.00	0.65	0.01
	Acetaldehyde		3.31E-03	11	1115	10.11	10.5	24	3.73E-02	9.40	0.08
	Acrolein		2.03E-03	11	1115	10.11	10.5	24	2.29E-02	5.77	0.05
	Methanol		9.89E-04	11	1115	10.11	10.5	24	1.11E-02	2.81	0.02
Cat C27/ Det R1237M36 (Cold Start)	CO	Tier 1+	0.34	1	137030	4.29	10.5	24	0.20	50.37	0.40
	NOx	Tier 1+	1.78	1	137030	4.29	10.5	24	1.04	262.95	2.10
	SO_2	Tier 1+	6.30E-02	1	137030	4.29	10.5	24	0.04	9.33	0.07
	VOC	Tier 1+	0.32	1	137030	4.29	10.5	24	0.19	46.66	0.37
	PM_{10}	Tier 1+	0.09	1	137030	4.29	10.5	24	0.05	13.33	0.11
	$PM_{2.5}$		0.09		137030	4.29	10.5	24	0.05	13.33	0.11
	Benzene		9.33E-04	5	137030	4.29	10.5	24	0.00	0.14	0.00
	Ethylbenzene				137030	4.29	10.5	24	0.00	0.00	0.00
	Formaldehyde		1.18E-03	5	137030	4.29	10.5	24	0.00	0.17	0.00
	H_2S				137030	4.29	10.5	24	0.00	0.00	0.00
	n-Hexane				137030	4.29	10.5	24	0.00	0.00	0.00
	Toluene		4.09E-04	5	137030	4.29	10.5	24	0.00	0.06	0.00
	Xylenes		2.85E-04	5	137030	4.29	10.5	24	0.00	0.04	0.00
	CH_4		1.60E-04	7	137030	4.29	10.5	24	0.00	0.02	0.00
	CO_2		164	10	137030	4.29	10.5	24	96.41	24,295.02	194.36
	N_2O		1.32E-03	9	137030	4.29	10.5	24	0.00	0.20	0.00
	Acetaldehyde		7.67E-04	11	137030	4.29	10.5	24	4.51E-04	0.11	0.00
	Acrolein		9.25E-05	11	137030	4.29	10.5	24	5.44E-05	0.01	0.00
	Methanol		0.00	11	137030	4.29	10.5	24	0.00E+00	0.00	0.00
William & Davis (Boiler)	CO	Tier 3+	0.08	1	1115	0.43	10.5	24	0.04	9.91	0.08
	NOx	Tier 3+	0.10	1	1115	0.43	10.5	24	0.05	11.84	0.09
	SO_2	Tier 3+	0.00	6	1115	0.43	10.5	24	0.00	0.07	0.00
	VOC	Tier 3+	0.01	1	1115	0.43	10.5	24	0.00	0.65	0.01
	PM_{10}	Tier 3+	7.50E-03	1	1115	0.43	10.5	24	0.00	0.91	0.01
	$PM_{2.5}$		7.71E-05	4	1115	0.43	10.5	24	0.00	0.01	0.00
	Benzene		4.40E-04	4	1115	0.43	10.5	24	0.00	0.05	0.00
	Ethylbenzene		3.97E-05	4	1115	0.43	10.5	24	0.00	0.00	0.00
	Formaldehyde		0.07	1	1115	0.43	10.5	24	0.03	8.46	0.07
	H_2S		0.00E+00	6	1115	0.43	10.5	24	0.00	0.00	0.00
	n-Hexane		1.11E-03	4	1115	0.43	10.5	24	0.00	0.13	0.00
	Toluene		4.08E-04	4	1115	0.43	10.5	24	0.00	0.05	0.00
	Xylenes		1.84E-04	4	1115	0.43	10.5	24	0.00	0.02	0.00
	CH_4		2.30E-03	7	1115	0.43	10.5	24	0.00	0.28	0.00
	CO_2		117.60	8	1115	0.43	10.5	24	56.38	14,209	113.67
	N_2O		2.16E-03	9	1115	0.43	10.5	24	0.00	0.26	0.00
	Acetaldehyde		8.36E-03	11	1115	0.43	10.5	24	0.00	1	0.01
	Acrolein		5.14E-03	11	1115	0.43	10.5	24	0.00	0.62	0.00
	Methanol		2.50E-03	11	1115	0.43	10.5	24	0.00	0	0.00
Total	CO							CO	12.01	3025.97	24.21
	NOx							NOx	6.10	1536.06	12.29
	SO_2							SO_2	0.04	9.57	0.08
	VOC							VOC	0.70	175.15	1.40
	PM_{10}							PM_{10}	0.12	31.28	0.25
	$PM_{2.5}$							$PM_{2.5}$	0.05	13.56	0.11
	Benzene							Benzene	0.01	1.44	0.01
	Ethylbenzene							Ethylbenzene	0.00	0.12	0.00
	Formaldehyde							Formaldehyde	0.82	207.48	1.66
	H_2S							H_2S	0.00	0.00	0.00
	n-Hexane							n-Hexane	0.01	3.29	0.03
	Toluene							Toluene	0.01	1.27	0.01
	Xylenes							Xylenes	0.00	0.59	0.00
	CH_4							CH_4	17.12	4315.34	34.52
	CO_2							CO_2	1530.87	385,780	3086.24
	N_2O							N_2O	0.00	1.10	0.01
	Acetaldehyde							Acetaldehyde	0.04	10.53	0.08
	Acrolein							Acrolein	0.03	6.40	0.05
	Methanol							Methanol	0.01	3.11	0.02

[1] Encana Drill Rig Permit (WDEQ 2010) and fuel usage (averaged from 2008-2009 reports submitted to BLM).
[2] Fuel heating value of natural gas based on average of 2008-2009 analysis in Jonah Infill. Diesel heating value from API 2004 Greenhouse Compendium, Table 3-5.
[3] Fuel consumption rate based on average of actual usage during 2009-2010 in Jonah Infill.
[4] AP-42 (EPA 2004) "Natural Gas-fired Reciprocating Engines" Table 3.2-2.
[5] AP-42 (EPA 2004) Section 3.3 "Gasoline and Diesel Industrial Engines" Table 3.3-2. Emission factor in units of lb/MMbtu.
[6] All SO_2 emissions based on S-balance equation in Section 3.4 and 1200 ppm diesel fuel.
[7] Greenhouse Gas Compendium (API 2009) Table 4-9. Natural gas fired engines have adjusted for fuel heating value.
[8] Greenhouse Gas Compendium (API 2009) Section 4-3. See 'Material Balance' sheet for calculation.
[9] Greenhouse Gas Compendium (API 2009) Table 4-5.
[10] Greenhouse Gas Compendium (API 2009) Table 4-3.
[11] HAP EF from Encana 4/23 (added 6/30)

NPL Project Air Quality Assessment Emissions Inventory

Table 22. Frac/Other Completion Engine Emissions

Project: Jonah NPL
Scenario: 4 Pad/Section
Effective Dates: All
Emissions: Diesel Combustion Emissions from Frac/Other Completion Engines

Engine	Pollutant	EPA Tier Certification	Pollutant Emission Factor	Emission Factor Reference	Engine Count	Horsepower[1]	Overall Load Factor[2]	Activity Duration	Activity Duration	Emissions per Well	Emissions per Hour	Emissions per Pad
			(g/hp-hr)			(hp)		(days/well)	(hours/day)	(lb/well)	(lb/hr)	(tons)
Cat 5EN2368	CO	Tier 2	0.87	3	1	170	0.30	2	24	4.68	0.10	0.04
	NOx	Tier 2	4.10	3	1	170	0.30	2	24	22.13	0.46	0.18
	SO_2	Tier 2	0.20	3	1	170	0.30	2	24	1.08	0.02	0.01
	VOC	Tier 2	0.34	3	1	170	0.30	2	24	1.83	0.04	0.01
	PM_{10}	Tier 2	0.18	3	1	170	0.30	2	24	0.97	0.02	0.01
	$PM_{2.5}$		0.18		1	170	0.30	2	24	0.97	0.02	0.01
	Benzene		2.96E-03	4, 8	1	170	0.30	2	24	0.02	0.00	0.00
	Ethylbenzene				1	170	0.30	2	24	0.00	0.00	0.00
	Formaldehyde		3.75E-03	4, 8	1	170	0.30	2	24	0.02	0.00	0.00
	H_2S				1	170	0.30	2	24	0.00	0.00	0.00
	n-Hexane				1	170	0.30	2	24	0.00	0.00	0.00
	Toluene		1.30E-03	4, 8	1	170	0.30	2	24	0.01	0.00	0.00
	Xylenes		9.05E-04	4, 8	1	170	0.30	2	24	0.00	0.00	0.00
	CH_4		5.08E-04	5, 8	1	170	0.30	2	24	0.00	0.00	0.00
	CO_2		521	6, 8	1	170	0.30	2	24	2,810.37	58.55	22.48
	N_2O		4.19E-03	7, 8	1	170	0.30	2	24	0.02	0.00	0.00
	Acetaldehyde		2.44E-03	4,8	1	170	0.30	2	24	0.01	0.00	0.00
	Acrolein		2.94E-04	4,8	1	170	0.30	2	24	0.00	0.00	0.00
Cat BCX00314	CO	Tier 2	0.84	3	1	425	0.30	2	24	11.37	0.24	0.09
	NOx	Tier 2	4.34	3	1	425	0.30	2	24	58.49	1.22	0.47
	SO_2	Tier 2	0.20	3	1	425	0.30	2	24	2.70	0.06	0.02
	VOC	Tier 2	0.17	3	1	425	0.30	2	24	2.25	0.05	0.02
	PM_{10}	Tier 2	0.13	3	1	425	0.30	2	24	1.78	0.04	0.01
	$PM_{2.5}$		0.13		1	425	0.30	2	24	1.78	0.04	0.01
	Benzene		2.96E-03	4, 8	1	425	0.30	2	24	0.04	0.00	0.00
	Ethylbenzene				1	425	0.30	2	24	0.00	0.00	0.00
	Formaldehyde		3.75E-03	4, 8	1	425	0.30	2	24	0.05	0.00	0.00
	H_2S				1	425	0.30	2	24	0.00	0.00	0.00
	n-Hexane				1	425	0.30	2	24	0.00	0.00	0.00
	Toluene		1.30E-03	4, 8	1	425	0.30	2	24	0.02	0.00	0.00
	Xylenes		9.05E-04	4, 8	1	425	0.30	2	24	0.01	0.00	0.00
	CH_4		5.08E-04	5, 8	1	425	0.30	2	24	0.01	0.00	0.00
	CO_2		521	6, 8	1	425	0.30	2	24	7,025.91	146.37	56.21
	N_2O		4.19E-03	7, 8	1	425	0.30	2	24	0.06	0.00	0.00
	Acetaldehyde		2.44E-03	4,8	1	425	0.30	2	24	0.03	0.00	0.00
	Acrolein		2.94E-04	4,8	1	425	0.30	2	24	0.00	0.00	0.00
Cat 2AF00204	CO	Tier 2	0.76	3	2	2,250	0.30	2	24	109.17	2.27	0.87
	NOx	Tier 2	4.10	3	2	2,250	0.30	2	24	585.73	12.20	4.69
	SO_2	Tier 2	0.20	3	2	2,250	0.30	2	24	28.57	0.60	0.23
	VOC	Tier 2	0.17	3	2	2,250	0.30	2	24	23.84	0.50	0.19
	PM_{10}	Tier 2	0.13	3	2	2,250	0.30	2	24	18.80	0.39	0.15
	$PM_{2.5}$		0.13		2	2,250	0.30	2	24	18.80	0.39	0.15

	Benzene		2.96E-03	4, 8	2	2,250	0.30	2	24	0.42	0.01	0.00
	Ethylbenzene				2	2,250	0.30	2	24	0.00	0.00	0.00
	Formaldehyde		3.75E-03	4, 8	2	2,250	0.30	2	24	0.54	0.01	0.00
	H_2S				2	2,250	0.30	2	24	0.00	0.00	0.00
	n-Hexane				2	2,250	0.30	2	24	0.00	0.00	0.00
	Toluene		1.30E-03	4, 8	2	2,250	0.30	2	24	0.19	0.00	0.00
	Xylenes		9.05E-04	4, 8	2	2,250	0.30	2	24	0.13	0.00	0.00
	CH_4		5.08E-04	5, 8	2	2,250	0.30	2	24	0.07	0.00	0.00
	CO_2		521	6, 8	2	2,250	0.30	2	24	74,392.04	1,549.83	595.14
	N_2O		4.19E-03	7, 8	2	2,250	0.30	2	24	0.60	0.01	0.00
	Acetaldehyde		2.44E-03	4,8	2	2,250	0.30	2	24	0.35	0.01	0.00
	Acrolein		2.94E-04	4,8	2	2,250	0.30	2	24	0.04	0.00	0.00
DDC 12VF014134	CO	Tier 2	0.76	3	1	750	0.30	2	24	18.20	0.38	0.15
	NOx	Tier 2	4.10	3	1	750	0.30	2	24	97.62	2.03	0.78
	SO_2	Tier 2	0.20	3	1	750	0.30	2	24	4.76	0.10	0.04
	VOC	Tier 2	0.17	3	1	750	0.30	2	24	3.97	0.08	0.03
	PM_{10}	Tier 2	0.13	3	1	750	0.30	2	24	3.13	0.07	0.03
	$PM_{2.5}$		0.13		1	750	0.30	2	24	3.13	0.07	0.03
	Benzene		2.96E-03	4, 8	1	750	0.30	2	24	0.07	0.00	0.00
	Ethylbenzene				1	750	0.30	2	24	0.00	0.00	0.00
	Formaldehyde		3.75E-03	4, 8	1	750	0.30	2	24	0.09	0.00	0.00
	H_2S				1	750	0.30	2	24	0.00	0.00	0.00
	n-Hexane				1	750	0.30	2	24	0.00	0.00	0.00
	Toluene		1.30E-03	4, 8	1	750	0.30	2	24	0.03	0.00	0.00
	Xylenes		9.05E-04	4, 8	1	750	0.30	2	24	0.02	0.00	0.00
	CH_4		5.08E-04	5, 8	1	750	0.30	2	24	0.01	0.00	0.00
	CO_2		521	6, 8	1	750	0.30	2	24	12,398.67	258.31	99.19
	N_2O		4.19E-03	7, 8	1	750	0.30	2	24	0.10	0.00	0.00
	Acetaldehyde		2.44E-03	4,8	1	750	0.30	2	24	0.06	0.00	0.00
	Acrolein		2.94E-04	4,8	1	750	0.30	2	24	0.01	0.00	0.00
CUM 10723297	CO	Tier 2	0.84	3	1	600	0.30	2	24	16.05	0.33	0.13
	NOx	Tier 2	4.34	3	1	600	0.30	2	24	82.58	1.72	0.66
	SO_2	Tier 2	0.20	3	1	600	0.30	2	24	3.81	0.08	0.03
	VOC	Tier 2	0.17	3	1	600	0.30	2	24	3.18	0.07	0.03
	PM_{10}	Tier 2	0.13	3	1	600	0.30	2	24	2.51	0.05	0.02
	$PM_{2.5}$		0.13		1	600	0.30	2	24	2.51	0.05	0.02
	Benzene		2.96E-03	4, 8	1	600	0.30	2	24	0.06	0.00	0.00
	Ethylbenzene				1	600	0.30	2	24	0.00	0.00	0.00
	Formaldehyde		3.75E-03	4, 8	1	600	0.30	2	24	0.07	0.00	0.00
	H_2S				1	600	0.30	2	24	0.00	0.00	0.00
	n-Hexane				1	600	0.30	2	24	0.00	0.00	0.00
	Toluene		1.30E-03	4, 8	1	600	0.30	2	24	0.02	0.00	0.00
	Xylenes		9.05E-04	4, 8	1	600	0.30	2	24	0.02	0.00	0.00
	CH_4		5.08E-04	5, 8	1	600	0.30	2	24	0.01	0.00	0.00
	CO_2		521	6, 8	1	600	0.30	2	24	9,918.94	206.64	79.35
	N_2O		4.19E-03	7, 8	1	600	0.30	2	24	0.08	0.00	0.00
	Acetaldehyde		2.44E-03	4,8	1	600	0.30	2	24	0.05	0.00	0.00
	Acrolein		2.94E-04	4,8	1	600	0.30	2	24	0.01	0.00	0.00
Backhoe	CO	Tier 1	2.37	3	1	100	0.40	2	6	2.50	0.21	0.02
	NOx	Tier 1	5.60	3	1	100	0.40	2	6	5.92	0.49	0.05
	SO_2	Tier 1	0.20	3	1	100	0.40	2	6	0.21	0.02	0.00
	VOC	Tier 1	0.52	3	1	100	0.40	2	6	0.55	0.05	0.00
	PM_{10}	Tier 1	0.47	3	1	100	0.40	2	6	0.50	0.04	0.00
	$PM_{2.5}$		0.47		1	100	0.40	2	6	0.50	0.04	0.00
	Benzene		2.96E-03	4, 8	1	100	0.40	2	6	0.00	0.00	0.00
	Ethylbenzene				1	100	0.40	2	6	0.00	0.00	0.00
	Formaldehyde		3.75E-03	4, 8	1	100	0.40	2	6	0.00	0.00	0.00
	H_2S				1	100	0.40	2	6	0.00	0.00	0.00

	n-Hexane				1	100	0.40	2	6	0.00	0.00	0.00
	Toluene		1.30E-03	4, 8	1	100	0.40	2	6	0.00	0.00	0.00
	Xylenes		9.05E-04	4, 8	1	100	0.40	2	6	0.00	0.00	0.00
	CH_4		5.08E-04	5, 8	1	100	0.40	2	6	0.00	0.00	0.00
	CO_2		521	6, 8	1	100	0.40	2	6	551.05	45.92	4.41
	N_2O		4.19E-03	7, 8	1	100	0.40	2	6	0.00	0.00	0.00
	Acetaldehyde		2.44E-03	4,8	1	100	0.40	2	6	0.00	0.00	0.00
	Acrolein		2.94E-04	4,8	1	100	0.40	2	6	0.00	0.00	0.00
Bulldozer	CO	Tier 1	0.75	3	1	200	0.40	1.5	6	1.19	0.13	0.01
	NOx	Tier 1	5.58	3	1	200	0.40	1.5	6	8.85	0.98	0.07
	SO_2	Tier 1	0.20	3	1	200	0.40	1.5	6	0.32	0.04	0.00
	VOC	Tier 1	0.31	3	1	200	0.40	1.5	6	0.49	0.05	0.00
	PM_{10}	Tier 1	0.25	3	1	200	0.40	1.5	6	0.40	0.04	0.00
	$PM_{2.5}$		0.25		1	200	0.40	1.5	6	0.40	0.04	0.00
	Benzene		2.96E-03	4, 8	1	200	0.40	1.5	6	0.00	0.00	0.00
	Ethylbenzene				1	200	0.40	1.5	6	0.00	0.00	0.00
	Formaldehyde		3.75E-03	4, 8	1	200	0.40	1.5	6	0.01	0.00	0.00
	H_2S				1	200	0.40	1.5	6	0.00	0.00	0.00
	n-Hexane				1	200	0.40	1.5	6	0.00	0.00	0.00
	Toluene		1.30E-03	4, 8	1	200	0.40	1.5	6	0.00	0.00	0.00
	Xylenes		9.05E-04	4, 8	1	200	0.40	1.5	6	0.00	0.00	0.00
	CH_4		5.08E-04	5, 8	1	200	0.40	1.5	6	0.00	0.00	0.00
	CO_2		521	6, 8	1	200	0.40	1.5	6	826.58	91.84	6.61
	N_2O		4.19E-03	7, 8	1	200	0.40	1.5	6	0.01	0.00	0.00
	Acetaldehyde		2.44E-03	4,8	1	200	0.40	1.5	6	0.00	0.00	0.00
	Acrolein		2.94E-04	4,8	1	200	0.40	1.5	6	0.00	0.00	0.00
Wireline	CO	Tier 1	2.37	3	1	100	0.40	2.5	7.5	3.91	0.21	0.03
	NOx	Tier 1	5.60	3	1	100	0.40	2.5	7.5	9.26	0.49	0.07
	SO_2	Tier 1	0.20	3	1	100	0.40	2.5	7.5	0.33	0.02	0.00
	VOC	Tier 1	0.52	3	1	100	0.40	2.5	7.5	0.86	0.05	0.01
	PM_{10}	Tier 1	0.47	3	1	100	0.40	2.5	7.5	0.78	0.04	0.01
	$PM_{2.5}$		0.47		1	100	0.40	2.5	7.5	0.78	0.04	0.01
	Benzene		2.96E-03	4, 8	1	100	0.40	2.5	7.5	0.00	0.00	0.00
	Ethylbenzene				1	100	0.40	2.5	7.5	0.00	0.00	0.00
	Formaldehyde		3.75E-03	4, 8	1	100	0.40	2.5	7.5	0.01	0.00	0.00
	H_2S				1	100	0.40	2.5	7.5	0.00	0.00	0.00
	n-Hexane				1	100	0.40	2.5	7.5	0.00	0.00	0.00
	Toluene		1.30E-03	4, 8	1	100	0.40	2.5	7.5	0.00	0.00	0.00
	Xylenes		9.05E-04	4, 8	1	100	0.40	2.5	7.5	0.00	0.00	0.00
	CH_4		5.08E-04	5, 8	1	100	0.40	2.5	7.5	0.00	0.00	0.00
	CO_2		521	6, 8	1	100	0.40	2.5	7.5	861.02	45.92	6.89
	N_2O		4.19E-03	7, 8	1	100	0.40	2.5	7.5	0.01	0.00	0.00
	Acetaldehyde		2.44E-03	4,8	1	100	0.40	2.5	7.5	0.00	0.00	0.00
	Acrolein		2.94E-04	4,8	1	100	0.40	2.5	7.5	0.00	0.00	0.00
Crane	CO	Tier 1	1.53	3	1	30	0.40	2.5	1	0.10	0.04	0.00
	NOx	Tier 1	4.73	3	1	30	0.40	2.5	1	0.31	0.13	0.00
	SO_2	Tier 1	0.20	3	1	30	0.40	2.5	1	0.01	0.01	0.00
	VOC	Tier 1	0.28	3	1	30	0.40	2.5	1	0.02	0.01	0.00
	PM_{10}	Tier 1	0.34	3	1	30	0.40	2.5	1	0.02	0.01	0.00
	$PM_{2.5}$		0.34		1	30	0.40	2.5	1	0.02	0.01	0.00
	Benzene		2.96E-03	4, 8	1	30	0.40	2.5	1	0.00	0.00	0.00
	Ethylbenzene				1	30	0.40	2.5	1	0.00	0.00	0.00
	Formaldehyde		3.75E-03	4, 8	1	30	0.40	2.5	1	0.00	0.00	0.00
	H_2S				1	30	0.40	2.5	1	0.00	0.00	0.00
	n-Hexane				1	30	0.40	2.5	1	0.00	0.00	0.00
	Toluene		1.30E-03	4, 8	1	30	0.40	2.5	1	0.00	0.00	0.00
	Xylenes		9.05E-04	4, 8	1	30	0.40	2.5	1	0.00	0.00	0.00
	CH_4		5.08E-04	5, 8	1	30	0.40	2.5	1	0.00	0.00	0.00

	CO_2		521	6, 8	1	30	0.40	2.5	1	34.44	13.78	0.28
	N_2O		4.19E-03	7, 8	1	30	0.40	2.5	1	0.00	0.00	0.00
	Acetaldehyde		2.44E-03	4,8	1	30	0.40	2.5	1	0.00	0.00	0.00
	Acrolein		2.94E-04	4,8	1	30	0.40	2.5	1	0.00	0.00	0.00
Wellhead Heater	CO	Tier 1	2.37	3	5	170	0.40	2	6.5	23.05	1.77	0.18
	NOx	Tier 1	5.60	3	5	170	0.40	2	6.5	54.56	4.20	0.44
	SO_2	Tier 1	0.20	3	5	170	0.40	2	6.5	1.95	0.15	0.02
	VOC	Tier 1	0.52	3	5	170	0.40	2	6.5	5.08	0.39	0.04
	PM_{10}	Tier 1	0.47	3	5	170	0.40	2	6.5	4.61	0.35	0.04
	$PM_{2.5}$		0.47		5	170	0.40	2	6.5	4.61	0.35	0.04
	Benzene		2.96E-03	4, 8	5	170	0.40	2	6.5	0.03	0.00	0.00
	Ethylbenzene				5	170	0.40	2	6.5	0.00	0.00	0.00
	Formaldehyde		3.75E-03	4, 8	5	170	0.40	2	6.5	0.04	0.00	0.00
	H_2S				5	170	0.40	2	6.5	0.00	0.00	0.00
	n-Hexane				5	170	0.40	2	6.5	0.00	0.00	0.00
	Toluene		1.30E-03	4, 8	5	170	0.40	2	6.5	0.01	0.00	0.00
	Xylenes		9.05E-04	4, 8	5	170	0.40	2	6.5	0.01	0.00	0.00
	CH_4		5.08E-04	5, 8	5	170	0.40	2	6.5	0.00	0.00	0.00
	CO_2		521	6, 8	5	170	0.40	2	6.5	5,074.27	390.33	40.59
	N_2O		4.19E-03	7, 8	5	170	0.40	2	6.5	0.04	0.00	0.00
	Acetaldehyde		2.44E-03	4,8	5	170	0.40	2	6.5	0.02	0.00	0.00
	Acrolein		2.94E-04	4,8	5	170	0.40	2	6.5	0.00	0.00	0.00
Total	CO									190.22	5.68	1.52
	NOx									925.45	23.93	7.40
	SO_2									43.74	1.08	0.35
	VOC									42.08	1.28	0.34
	PM_{10}									33.50	1.06	0.27
	$PM_{2.5}$									33.50	1.06	0.27
	Benzene									0.65	0.02	0.01
	Ethylbenzene									0.00	0.00	0.00
	Formaldehyde									0.82	0.02	0.01
	H_2S									0.00	0.00	0.00
	n-Hexane									0.00	0.00	0.00
	Toluene									0.28	0.01	0.00
	Xylenes									0.20	0.00	0.00
	CH_4									0.11	0.00	0.00
	CO_2									113,893.29	2,807.50	911.15
	N_2O									0.92	0.02	0.01
	Acetaldehyde									0.53	0.01	0.00
	Acrolein									0.06	0.00	0.00
	Methanol									0.00	0.00	0.00

[1] Horsepower based on current contractor equipment.
[2] Load factor based on weighted average of full load and idle conditions during frac operations.
[3] Emission factors from Exhaust and Crankcase Emission Factors for Nonroad Engine Modeling--Compression-Ignition, Table A-2; (EPA 420-P-04-009 April 2004).
[4] AP-42 (EPA 1996) Section 3.3 "Gasoline and Diesel Industrial Engines" Table 3.3-2.
[5] Greenhouse Gas Compendium (API 2009) Table 4-9.
[6] Greenhouse Gas Compendium (API 2009) Table 4-3.
[7] Greenhouse Gas Compendium (API 2009) Table 4-5.
[8] Emission factor converted from lb/Mmbtu to g/hp-hr assuming an average BSFC of 7,000 btu/hp-hr (AP-42 Table 3.3-1).

grams/lb	**453.6**	Acetaldehyde	7.67E-04 lb/MMBtu	2.44E-03 g/hp-hr
		Acrolein	< 9.25E-05 lb/MMBtu	2.94E-04 g/hp-hr

Table 23. Well Completion Emissions

Project: Jonah NPL
Scenario: 4 Pad/Section
Effective Dates: All
Emissions: Well completion emissions

Activity	Average Gas Volume[1]	Event Duration[2]	Wells	Pollutant	Weight Fraction[3]	Emission Factor[4]	Emissions per Well	Emissions per Pad
	(mcf/well)	(day/well)				(lb/MMbtu)	(lb/yr)	(tons/yr)
Completions	77	60	350	CO		0.37	2.56	0.02
				NOx		0.14	0.97	7.75E-03
				SO_2		0.00	0.00	0.00
	Molecular Weight	18.43		VOC	0.11		8.54	0.07
	Fuel Heating Value (actual)	1,124	Btu/scf	PM_{10}		0.007	4.85E-02	3.88E-04
	Gas Volume to Flare[5]	8	%	$PM_{2.5}$		0.007	4.85E-02	3.88E-04
	Gas Volume Vented[5]	2	%	Benzene	5.12E-04		3.83E-02	3.06E-04
				Ethylbenzene	3.07E-05		2.30E-03	1.84E-05
				Formaldehyde		8.10E-05	5.61E-04	4.49E-06
				H_2S	0.00		0.00	0.00
				n-Hexane	2.30E-03		1.72E-01	1.38E-03
				Toluene	7.57E-04		5.66E-02	4.53E-04
				Xylenes	2.80E-04		2.10E-02	1.68E-04
				CH_4	0.78		58.49	4.68E-01
				CO_2[6]	0.013	122.252	847.41	6.78
				N_2O[7]		1.04E-07	7.20E-07	5.76E-09

[1] Data from Jonah Infill well completions 2008-2010.
[2] Data from Jonah Infill well completions 2008-2010.
[3] Weight fraction based on gas composition. See 'Material Balance' sheet.
[4] Emission factors taken from WDEQ "Oil and Gas Production Facilities - Chapter 6, Section 2 Permitting Guidance" and AP-42, Table 1.4-2.
[5] Encana commited to capturing 90% of the hydrocarbons through flareless completions in the 2006 Infill ROD and proposes to continue this in the NPL.
[6] See 'Material Balance' sheet.
[7] Greenhouse Gas Compendium (API 2009) Table 4-5.

NPL Project Air Quality Assessment Emissions Inventory

Table 24. Completion/Testing Traffic

Project: Jonah NPL
Scenario: 4 Pad/Section
Activity: Completion/Testing Traffic
Emissions: Fugitive Particulate Emissions from Traffic on Unpaved Roads

Vehicle Type	Road Type	Dust Control Method[1]	Average Vehicle Weight (lb)	Average Vehicle Speed (mph)	Silt Content[2] (%)	Moisture Content[3] (%)	RTs per Well	RT Distance (miles)	VMT[4] (VMT/well)	Emission Control Efficiency[5] (%)	PM_{10} Emissions[6] (lb/VMT)	$PM_{2.5}$ Emissions[6] (lb/VMT)	PM_{10} Emissions[7] (controlled) (lb/pad)	$PM_{2.5}$ Emissions[7] (controlled) (lb/pad)	
Light Trucks/ Pickups	Local	Chemical + Restriction	5,800	25	5.1	2.4	60	10	600	85	0.51	0.05	734	73	1b
	Resource	Water + Restriction	5,800	20	5.1	2.4	60	1	60	50	0.68	0.07	328	33	1a
Water Truck	Local	Chemical + Restriction	60,000	20	5.1	2.4	240	8	1,920	85	0.46	0.05	2,101	209	1b
	Resource	Water + Restriction	60,000	15	5.1	2.4	240	10	2,400	50	1.96	0.30	37,579	5,762	1a
Sand Truck	Local	Chemical + Restriction	60,000	20	5.1	2.4	40	34	1,360	85	0.46	0.05	1,488	148	1b
	Resource	Water + Restriction	60,000	15	5.1	2.4	40	10	400	50	1.96	0.30	6,263	960	1a
Winch Truck	Local	Chemical + Restriction	60,000	20	5.1	2.4	36	6	216	85	0.46	0.05	236	23	1b
	Resource	Water + Restriction	60,000	15	5.1	2.4	36	10	360	50	1.96	0.30	5,637	864	1a
Total Unpaved Road Traffic Emissions (lb/pad)													54,367	8,072	

[1] Dust control methods include using water (resource road) or chemical (loacal road) as a dust suppressants along with vehicle restriction speed limit of 25 mph.

[2] AP-42 (EPA 2004), Table 13.2.2-1, "Typical Silt Content Values of Surface Material on Industrial and Rural Unpaved Roads."

[3] AP-42 (EPA 2004), Table 11.9-3, "Typical Values for Correction Factors Applicable to the Predictive Emission Factor Equations."

[4] Calculated as Round Trips per Vehicle Type x Round Trip Distance.

[5] AP-42 (EPA 2004), Figure 13.2.2-2, "Watering control effectiveness for unpaved travel surfaces.", Fugitive Dust Handbook (WRAP 2006) Chapter 6.

[6] AP-42 (EPA 2004), Section 13.2.2 "Unpaved Roads", equations 1a and 1b.

[7] Calculated as lb/VMT x VMT/well x control efficiency.

NPL Project Air Quality Assessment Emissions Inventory

Table 25. Completion/Testing Haul Truck Tailpipe

Project: Jonah NPL
Scenario: 4 Pad/Section
Activity: Completion/Testing
Emissions: Diesel Combustion Emissions from Heavy Equipment Tailpipes

Pollutant	Pollutant Emission Factor[1]	Total Haul Truck RTs	RT Distance	Total Haul Truck Miles Traveled	Haul Activity Duration[3]	Haul Activity Duration[3]	Emissions	Emissions
	(g/mile)	(RTs/well)	(miles/RT)	(miles/well)	(days/well)	(hours/day)	(lb/well)	(lb/pad)
CO	0.97	316	21	6,656	10	18	14.22	228
NO_x	2.41	316	21	6,656	10	18	35.42	567
PM_{10}	0.16	316	21	6,656	10	18	2.40	38
$PM_{2.5}$	0.12	316	21	6,656	10	18	1.77	28
SO_2[2]	0.01	316	21	6,656	10	18	0.09	1
VOC	0.23	316	21	6,656	10	18	3.43	55
Benzene	2.53E-03	316	21	6,656	10	18	0.04	1
Ethylbenzene		316	21	6,656	10	18	0.00	0
Formaldehyde	1.88E-02	316	21	6,656	10	18	0.28	4
H_2S		316	21	6,656	10	18	0.00	0
n-Hexane		316	21	6,656	10	18	0.00	0
Toluene		316	21	6,656	10	18	0.00	0
Xylenes		316	21	6,656	10	18	0.00	0
CH_4	4.06E-02	316	21	6,656	10	18	0.60	10
CO_2[2]	8.55E+02	316	21	6,656	10	18	12539.62	200634
N_2O	1.88E-03	316	21	6,656	10	18	0.03	0

[1] MOVES, 2015 heavy duty short haul truck

[2] CO2 from CO2(eq) {CO2(eq)-25*CH4-298*N20}

[3] Haul Activity Duration for completion activities based on an average of 10 days per well and an average of 24 hr/day for 5 days and 12 hr/day for 5 days.

Table 26. Workover Traffic

Project: Jonah NPL
Scenario: 4 Pad/Section
Activity: Workover Traffic
Emissions: Fugitive Particulate Emissions from Traffic on Unpaved Roads

Vehicle Type	Road Type	Dust Control Method[1]	Average Vehicle Weight	Average Vehicle Speed	Silt Content[2]	Moisture Content[3]	RTs per Well	RT Distance	VMT[4]	Emission Control Efficiency[5]	PM_{10} Emissions[6]	$PM_{2.5}$ Emissions[6]	PM_{10} Emissions[7] (controlled)	$PM_{2.5}$ Emissions[7] (controlled)	
			(lb)	(mph)	(%)	(%)		(miles)	(VMT/well)	(%)	(lb/VMT)	(lb/VMT)	(lb/pad)	(lb/pad)	
Light Trucks/ Pickups	Local	Chemical + Restriction	5,800	25	5.1	2.4	6	10	60	85	0.51	0.05	73	7	1b
	Resource	Water + Restriction	5,800	20	5.1	2.4	6	1	6	50	0.68	0.07	33	3	1a
Water Truck	Local	Chemical + Restriction	60,000	20	5.1	2.4	24	8	192	85	0.46	0.05	210	21	1b
	Resource	Water + Restriction	60,000	15	5.1	2.4	24	10	240	50	1.96	0.20	3,758	376	1a
Sand Truck	Local	Chemical + Restriction	60,000	20	5.1	2.4	4	34	136	85	0.46	0.05	149	15	1b
	Resource	Water + Restriction	60,000	15	5.1	2.4	4	10	40	50	1.96	0.20	626	63	1a
Winch Truck	Local	Chemical + Restriction	60,000	20	5.1	2.4	4	6	24	85	0.46	0.05	26	3	1b
	Resource	Water + Restriction	60,000	15	5.1	2.4	4	10	40	50	1.96	0.20	626	63	1a
Total Unpaved Road Traffic Emissions (lb/pad)													5,502	550	

[1] Dust control methods include using water (resource road) or chemical (loacal road) as a dust suppressants along with vehicle restriction speed limit of 25 mph.

[2] AP-42 (EPA 2004), Table 13.2.2-1, "Typical Silt Content Values of Surface Material on Industrial and Rural Unpaved Roads."

[3] AP-42 (EPA 2004), Table 11.9-3, "Typical Values for Correction Factors Applicable to the Predictive Emission Factor Equations."

[4] Calculated as Round Trips per Vehicle Type x Round Trip Distance.

[5] AP-42 (EPA 2004), Figure 13.2.2-2, "Watering control effectiveness for unpaved travel surfaces.", Fugitive Dust Handbook (WRAP 2006) Chapter 6.

[6] AP-42 (EPA 2004), Section 13.2.2 "Unpaved Roads", equations 1a and 1b.

[7] Calculated as lb/VMT x VMT/well x control efficiency.

NPL Project Air Quality Assessment Emissions Inventory

Table 27. Workover Tailpipe

Project: Jonah NPL
Scenario: 4 Pad/Section
Activity: Well Workover
Emissions: Diesel Combustion Emissions from Heavy Equipment Tailpipes

Pollutant	Pollutant Emission Factor[1]	Total Haul Truck RTs	RT Distance	Total Haul Truck Miles Traveled	Haul Activity Duration[3]	Haul Activity Duration[3]	Emissions	Emissions
	(g/mile)	(RTs/well)	(miles/RT)	(miles/well)	(days/well)	(hours/day)	(lb/well)	(lb/pad)
CO	0.97	32	21	664	10	18	1.42	23
NO_x	2.41	32	21	664	10	18	3.53	57
PM_{10}	0.16	32	21	664	10	18	0.24	4
$PM_{2.5}$	0.12	32	21	664	10	18	0.18	3
SO_2[2]	0.01	32	21	664	10	18	0.01	0
VOC	0.23	32	21	664	10	18	0.34	5
Benzene	2.53E-03	32	21	664	10	18	0.00	0
Ethylbenzene		32	21	664	10	18	0.00	0
Formaldehyde	1.88E-02	32	21	664	10	18	0.03	0
H_2S		32	21	664	10	18	0.00	0
n-Hexane		32	21	664	10	18	0.00	0
Toluene		32	21	664	10	18	0.00	0
Xylenes		32	21	664	10	18	0.00	0
CH_4	4.06E-02	32	21	664	10	18	0.06	1
CO_2[2]	8.55E+02	32	21	664	10	18	1250.19	20003
N_2O	1.88E-03	32	21	664	10	18	0.00	0

[1] MOVES, 2015 heavy duty short haul truck

[2] CO2 from CO2(eq) {CO2(eq)-25*CH4-298*N20}

[3] Haul Activity Duration for completion activities based on an average of 10 days per well and an average of 24 hr/day for 5 days and 12 hr/day for 5 days.

NPL Project Air Quality Assessment Emissions Inventory

Table 28. Well Workover and Blowdown Emissions

Project: Jonah NPL
Scenario: 4 Pad/Section
Effective Dates: All
Emissions: Well workover and blowdown emissions

Activity	Volume Gas Vented[1]	Event Duration[2]	Events	Wells	Control Efficiency[3]	Pollutant	Weight Fraction[4]	Emissions per Well	Emissions per Pad
	(mcf/well)	(hour/well)	(well/year)		(%)			(lb/well-yr)	(tons/yr)
Venting	53.6	0.15	0.5	350	0	CO	0.00		
						NOx	0.00		
						SO_2	0.00		
Molecular Weight		18.43				VOC	0.11	133.78	1.07
Fuel Heating Value (actual)		1,124	Btu/scf			PM_{10}	0.00		
						$PM_{2.5}$	0.00		
						Benzene	5.12E-04	0.60	0.00
						Ethylbenzene	3.07E-05	0.04	0.00
						Formaldehyde	0.00		
						H_2S	0.00		
						n-Hexane	2.30E-03	2.70	0.02
						Toluene	7.57E-04	0.89	0.01
						Xylenes	2.80E-04	0.33	0.00
						CH_4	0.78	916.14	7.33
						CO_2	0.013	15.01	0.12
						N_2O	0.00		

[1] Based on volume of gas vented from NPL wells during 2010 and proposed operations for the NPL development.
[2] Operator knowledge of actual vent time for NPL wells.
[3] None
[4] Weight fraction based on gas composition. See 'Material Balance' sheet.

Table 29. Production Facility Development

Project: Jonah NPL
Scenario: Gas Throughput (MMscfd)
Activity: Production Facility Development
Emissions:

Facility	Year									
	1	2	3	4	5	6	7	8	9	10
1	75	75	75	75	75	75	75	75	75	70
2	45	50	50	50	50	50	50	50	50	45
3	43	65	65	65	75	75	75	75	75	70
4		26	50	50	50	50	50	50	50	45
5		27	48	50	50	50	50	50	50	45
6			17	29	41	51	61	69	75	75
7				20	28	28	40	40	40	35
8				15	30	44	44	50	50	50
9						15	18	31	40	40
10							12	17	25	25
11									10	10
Totals	163	243	305	354	399	438	475	507	540	510

Project: Jonah NPL
Scenario: Horsepower
Activity: Production Facility Development
Emissions:

Date:

Facility	Year									
	1	2	3	4	5	6	7	8	9	10
1	10118	10118	10118	10118	10118	10118	10118	10118	10118	10118
2	6475	6475	6475	6475	6475	6475	6475	6475	6475	6475
3	6475	10118	6475	10118	10118	10118	10118	10118	10118	10118
4		3373	6475	6475	6475	6475	6475	6475	6475	6475
5		3373	6475	6475	6475	6475	6475	6475	6475	6475
6			3373	6475	6475	10118	10118	10118	10118	10118
7				3373	6475	6475	6475	6475	6475	6475
8				3373	6475	6475	6475	6475	6475	6475
9						3373	3373	6475	6475	6475
10							3373	3373	3373	3373
11									3373	3373
Totals	23068	33457	39391	52882	59086	66102	69475	72577	75950	75950

Table 30. Production Traffic – Per Round Trip

Project: **Jonah NPL**
Scenario: **4 Pad/Section**
Activity: **Production Traffic**
Emissions: **Fugitive Particulate Emissions from Traffic on Unpaved Roads**

Vehicle Type	Road Type	Dust Control Method[1]	Average Vehicle Weight	Average Vehicle Speed	Silt Content[2]	Moisture Content[3]	RTs	RT Distance	VMT[4]	Emission Control Efficiency[5]	PM_{10} Emission Factor[6]	$PM_{2.5}$ Emission Factor[6]	PM_{10} Emissions[7] (controlled)	$PM_{2.5}$ Emissions[7] (controlled)	
			(lb)	(mph)	(%)	(%)	(RTs)	(miles\pad)	(VMT)	(%)	(lb/VMT)	(lb/VMT)	(lb/pad)	(lb/pad)	
Light Truck	Local	Chemical + Restriction	5,800	25	5.1	2.4	365	9	3,285	85	0.51	0.05	251.22	24.97	1b
	Resource	Water + Restriction	5,800	20	5.1	2.4	365	1	365	50	0.68	0.07	124.82	12.48	1a
Total Access and Unimproved Road Emissions (lb/pad)													376.04	37.45	

[1] Dust control methods include using water (resource road) or chemical (loacal road) as a dust suppressants along with vehicle restriction speed limit of 25 mph.
[2] AP-42 (EPA 2004), Table 13.2.2-1, "Typical Silt Content Values of Surface Material on Industrial and Rural Unpaved Roads."
[3] AP-42 (EPA 2004), Table 11.9-3, "Typical Values for Correction Factors Applicable to the Predictive Emission Factor Equations."
[4] Calculated as Round Trips per Vehicle Type x Round Trip Distance
[5] AP-42 (EPA 2004), Figure 13.2.2-2, "Watering control effectiveness for unpaved travel surfaces.", Fugitive Dust Handbook (WRAP 2006) Chapter 6.
[6] AP-42 (EPA 2004), Section 13.2.2 "Unpaved Roads", equations 1a and 1b.
[7] Calculated as lb/VMT x VMT/RT x control efficiency.

NPL Project Air Quality Assessment Emissions Inventory

Table 31. Liquids Gathering Traffic - Per Round Trip

Project: Jonah NPL
Scenario: 4 Pad/Section
Activity: Production Traffic
Emissions: Fugitive Particulate Emissions from Traffic on Unpaved Roads

Vehicle Type	Road Type	Dust Control Method[1]	Average Vehicle Weight	Average Vehicle Speed	Silt Content[2]	Moisture Content[3]	RTs	RT Distance	VMT[4]	Emission Control Efficiency[5]	PM_{10} Emission Factor[6]	$PM_{2.5}$ Emission Factor[6]	PM_{10} Emissions[7] (controlled)	$PM_{2.5}$ Emissions[7] (controlled)	
			(lb)	(mph)	(%)	(%)	(RT)	(miles)	(VMT/RT)	(%)	(lb/VMT)	(lb/VMT)	(lb/yr)	(lb/yr)	
Haul Truck	Local	Chemical + Restriction	54,000	25	5.1	2.4	4,149	34	141,082	85	0.51	0.05	10,789.11	1,072.29	1b
	Resource	Water + Restriction	54,000	20	5.1	2.4	4,149	2	8,299	50	1.87	0.19	7,745.39	774.54	1a
Total Access and Unimproved Road Emissions (lb/RT)													18,534.50	1,846.83	

[1] Dust control methods include using water (resource road) or chemical (loacal road) as a dust suppressants along with vehicle restriction speed limit of 25 mph.
[2] AP-42 (EPA 2004), Table 13.2.2-1, "Typical Silt Content Values of Surface Material on Industrial and Rural Unpaved Roads."
[3] AP-42 (EPA 2004), Table 11.9-3, "Typical Values for Correction Factors Applicable to the Predictive Emission Factor Equations."
[4] Calculated as Round Trips per Vehicle Type x Round Trip Distance
[5] AP-42 (EPA 2004), Figure 13.2.2-2, "Watering control effectiveness for unpaved travel surfaces.", Fugitive Dust Handbook (WRAP 2006) Chapter 6.
[6] AP-42 (EPA 2004), Section 13.2.2 "Unpaved Roads", equations 1a and 1b.
[7] Calculated as lb/VMT x VMT/RT x control efficiency.

NPL Project Air Quality Assessment Emissions Inventory

Table 32. Tanker Traffic Tailpipe - Per Round Trip

Project: Jonah NPL
Scenario: 4 Pad/Section
Activity: Production Tailpipe
Emissions: Diesel Combustion Emissions from Heavy Equipment Tailpipes

Pollutant	Pollutant Emission Factor[1]	RT	Single Round Trip Distance	Yearly VMT	Central Facility Emissions
	(g/mile)	(RT)	(mi/RT)	(mi)	(lb/yr)
CO	0.97	365	10	3650	7.80
NO_x	2.41	365	10	3650	19.43
PM_{10}	0.16	365	10	3650	1.32
$PM_{2.5}$	0.12	365	10	3650	0.97
SO_2[2]	0.01	365	10	3650	0.05
VOC	0.23	365	10	3650	1.88
Benzene	2.53E-03	365	10	3650	0.02
Ethylbenzene		365	10	3650	0.00
Formaldehyde	1.88E-02	365	10	3650	0.15
H_2S		365	10	3650	0.00
n-Hexane		365	10	3650	0.00
Toluene		365	10	3650	0.00
Xylenes		365	10	3650	0.00
CH_4	4.06E-02	365	10	3650	0.33
CO_2[2]	8.55E+02	365	10	3650	6876.60
N_2O	1.88E-03	365	10	3650	0.02

[1] MOVES, 2015 heavy duty short haul truck
[2] CO2 from CO2(eq) {CO2(eq)-25*CH4-298*N20}

NPL Project Air Quality Assessment Emissions Inventory

Table 33. Tanker Traffic Tailpipe - Per Round Trip

Project: Jonah NPL
Scenario: 4 Pad/Section
Activity: Tanker Tailpipe
Emissions: Diesel Combustion Emissions from Heavy Equipment Tailpipes

Pollutant	Pollutant Emission Factor[1]	RT	Single Round Trip Distance	Yearly VMT	Central Facility Emissions
	(g/mile)	(RT)	(mi/RT)	(mi)	(lb/yr)
CO	0.97	4,149	36	149381	319.21
NO_x	2.41	4,149	36	149381	795.06
PM_{10}	0.16	4,149	36	149381	53.83
$PM_{2.5}$	0.12	4,149	36	149381	39.72
SO_2[2]	0.01	4,149	36	149381	2.03
VOC	0.23	4,149	36	149381	76.88
Benzene	2.53E-03	4,149	36	149381	0.83
Ethylbenzene		4,149	36	149381	0.00
Formaldehyde	1.88E-02	4,149	36	149381	6.21
H_2S		4,149	36	149381	0.00
n-Hexane		4,149	36	149381	0.00
Toluene		4,149	36	149381	0.00
Xylenes		4,149	36	149381	0.00
CH_4	4.06E-02	4,149	36	149381	13.37
CO_2[2]	8.55E+02	4,149	36	149381	281433.82
N_2O	1.88E-03	4,149	36	149381	0.62

[1] MOVES, 2015 heavy duty short haul truck
[2] CO2 from CO2(eq) {CO2(eq)-25*CH4-298*N20}

NPL Project Air Quality Assessment Emissions Inventory

Table 34. Wind Erosion Data

Year	Month	Day	Peak Wind Speed (mph)	u^+_{10} (m/s)[1]	Friction Velocity u* (m/s)[2]	Threshold Friction Velocity u^*_t[3]	Exceed Threshold Friction Velocity	P (g/m^2)[4]	ΣP (g/m^2-yr)	
2008	1	1	7	3.13	0.17	1.02	No			
2008	1	2	7	3.13	0.17	1.02	No			
2008	1	3	6	2.68	0.14	1.02	No			
2008	1	4	7	3.13	0.17	1.02	No			
2008	1	5	31	13.86	0.73	1.02	No			
2008	1	6	10	4.47	0.24	1.02	No			
2008	1	7	9	4.02	0.21	1.02	No			
2008	1	8	9	4.02	0.21	1.02	No			
2008	1	9	12	5.36	0.28	1.02	No			
2008	1	10	8	3.58	0.19	1.02	No			
2008	1	11	21	9.39	0.50	1.02	No			
2008	1	12	8	3.58	0.19	1.02	No			
2008	1	13	14	6.26	0.33	1.02	No			
2008	1	14	10	4.47	0.24	1.02	No			
2008	1	15	33	14.75	0.78	1.02	No			
2008	1	16	13	5.81	0.31	1.02	No			
2008	1	17	22	9.83	0.52	1.02	No			
2008	1	18	14	6.26	0.33	1.02	No			
2008	1	19	8	3.58	0.19	1.02	No			
2008	1	20	14	6.26	0.33	1.02	No			
2008	1	21	14	6.26	0.33	1.02	No			
2008	1	22	7	3.13	0.17	1.02	No			
2008	1	23	10	4.47	0.24	1.02	No			
2008	1	24	9	4.02	0.21	1.02	No			
2008	1	25	9	4.02	0.21	1.02	No			
2008	1	26	10	4.47	0.24	1.02	No			
2008	1	27	16	7.15	0.38	1.02	No			
2008	1	28	37	16.54	0.88	1.02	No			
2008	1	29	13	5.81	0.31	1.02	No			
2008	1	30	22	9.83	0.52	1.02	No			

2008	1	31	7	3.13	0.17	1.02	No			
2008	2	1	12	5.36	0.28	1.02	No			
2008	2	2	7	3.13	0.17	1.02	No			
2008	2	3	7	3.13	0.17	1.02	No			
2008	2	4	12	5.36	0.28	1.02	No			
2008	2	5	13	5.81	0.31	1.02	No			
2008	2	6	20	8.94	0.47	1.02	No			
2008	2	7	38	16.99	0.90	1.02	No			
2008	2	8	21	9.39	0.50	1.02	No			
2008	2	9	16	7.15	0.38	1.02	No			
2008	2	10	10	4.47	0.24	1.02	No			
2008	2	11	21	9.39	0.50	1.02	No			
2008	2	12	17	7.60	0.40	1.02	No			
2008	2	13	23	10.28	0.54	1.02	No			
2008	2	14	13	5.81	0.31	1.02	No			
2008	2	15	6	2.68	0.14	1.02	No			
2008	2	16	22	9.83	0.52	1.02	No			
2008	2	17	18	8.05	0.43	1.02	No			
2008	2	18	17	7.60	0.40	1.02	No			
2008	2	19	10	4.47	0.24	1.02	No			
2008	2	20	6	2.68	0.14	1.02	No			
2008	2	21	6	2.68	0.14	1.02	No			
2008	2	22	9	4.02	0.21	1.02	No			
2008	2	23	8	3.58	0.19	1.02	No			
2008	2	24	10	4.47	0.24	1.02	No			
2008	2	25	10	4.47	0.24	1.02	No			
2008	2	26	15	6.71	0.36	1.02	No			
2008	2	27	8	3.58	0.19	1.02	No			
2008	2	28	16	7.15	0.38	1.02	No			
2008	2	29	9	4.02	0.21	1.02	No			
2008	3	1	23	10.28	0.54	1.02	No			
2008	3	2	21	9.39	0.50	1.02	No			
2008	3	3	10	4.47	0.24	1.02	No			
2008	3	4	21	9.39	0.50	1.02	No			
2008	3	5	21	9.39	0.50	1.02	No			
2008	3	6	17	7.60	0.40	1.02	No			
2008	3	7	16	7.15	0.38	1.02	No			

2008	3	8	12	5.36	0.28	1.02	No			
2008	3	9	8	3.58	0.19	1.02	No			
2008	3	10	9	4.02	0.21	1.02	No			
2008	3	11	23	10.28	0.54	1.02	No			
2008	3	12	15	6.71	0.36	1.02	No			
2008	3	13	17	7.60	0.40	1.02	No			
2008	3	14	18	8.05	0.43	1.02	No			
2008	3	15	13	5.81	0.31	1.02	No			
2008	3	16	14	6.26	0.33	1.02	No			
2008	3	17	15	6.71	0.36	1.02	No			
2008	3	18	13	5.81	0.31	1.02	No			
2008	3	19	18	8.05	0.43	1.02	No			
2008	3	20	25	11.18	0.59	1.02	No			
2008	3	21	29	12.96	0.69	1.02	No			
2008	3	22	13	5.81	0.31	1.02	No			
2008	3	23	8	3.58	0.19	1.02	No			
2008	3	24	30	13.41	0.71	1.02	No			
2008	3	25	18	8.05	0.43	1.02	No			
2008	3	26	49	21.90	1.16	1.02	Yes	4.68		
2008	3	27	31	13.86	0.73	1.02	No			
2008	3	28	18	8.05	0.43	1.02	No			
2008	3	29	29	12.96	0.69	1.02	No			
2008	3	30	9	4.02	0.21	1.02	No			
2008	3	31	35	15.65	0.83	1.02	No			
2008	4	1	15	6.71	0.36	1.02	No			
2008	4	2	15	6.71	0.36	1.02	No			
2008	4	3	20	8.94	0.47	1.02	No			
2008	4	4	20	8.94	0.47	1.02	No			
2008	4	5	35	15.65	0.83	1.02	No			
2008	4	6	15	6.71	0.36	1.02	No			
2008	4	7	30	13.41	0.71	1.02	No			
2008	4	8	20	8.94	0.47	1.02	No			
2008	4	9	21	9.39	0.50	1.02	No			
2008	4	10	23	10.28	0.54	1.02	No			
2008	4	11	26	11.62	0.62	1.02	No			
2008	4	12	22	9.83	0.52	1.02	No			
2008	4	13	17	7.60	0.40	1.02	No			

2008	4	14	30	13.41	0.71	1.02	No			
2008	4	15	29	12.96	0.69	1.02	No			
2008	4	16	18	8.05	0.43	1.02	No			
2008	4	17	20	8.94	0.47	1.02	No			
2008	4	18	39	17.43	0.92	1.02	No			
2008	4	19	31	13.86	0.73	1.02	No			
2008	4	20	44	19.67	1.04	1.02	Yes	0.59		
2008	4	21	32	14.31	0.76	1.02	No			
2008	4	22	23	10.28	0.54	1.02	No			
2008	4	23	31	13.86	0.73	1.02	No			
2008	4	24	29	12.96	0.69	1.02	No			
2008	4	25	41	18.33	0.97	1.02	No			
2008	4	26	22	9.83	0.52	1.02	No			
2008	4	27	17	7.60	0.40	1.02	No			
2008	4	28	32	14.31	0.76	1.02	No			
2008	4	29	41	18.33	0.97	1.02	No			
2008	4	30	24	10.73	0.57	1.02	No			
2008	5	1	26	11.62	0.62	1.02	No			
2008	5	2	25	11.18	0.59	1.02	No			
2008	5	3	14	6.26	0.33	1.02	No			
2008	5	4	21	9.39	0.50	1.02	No			
2008	5	5	28	12.52	0.66	1.02	No			
2008	5	6	24	10.73	0.57	1.02	No			
2008	5	7	18	8.05	0.43	1.02	No			
2008	5	8	28	12.52	0.66	1.02	No			
2008	5	9	30	13.41	0.71	1.02	No			
2008	5	10	23	10.28	0.54	1.02	No			
2008	5	11	36	16.09	0.85	1.02	No			
2008	5	12	23	10.28	0.54	1.02	No			
2008	5	13	21	9.39	0.50	1.02	No			
2008	5	14	23	10.28	0.54	1.02	No			
2008	5	15	16	7.15	0.38	1.02	No			
2008	5	16	22	9.83	0.52	1.02	No			
2008	5	17	24	10.73	0.57	1.02	No			
2008	5	18	37	16.54	0.88	1.02	No			
2008	5	19	29	12.96	0.69	1.02	No			
2008	5	20	68	30.40	1.61	1.02	Yes	35.05		

2008	5	21	24	10.73	0.57	1.02	No			
2008	5	22	14	6.26	0.33	1.02	No			
2008	5	23	21	9.39	0.50	1.02	No			
2008	5	24	32	14.31	0.76	1.02	No			
2008	5	25	15	6.71	0.36	1.02	No			
2008	5	26	35	15.65	0.83	1.02	No			
2008	5	27	25	11.18	0.59	1.02	No			
2008	5	28	32	14.31	0.76	1.02	No			
2008	5	29	36	16.09	0.85	1.02	No			
2008	5	30	23	10.28	0.54	1.02	No			
2008	5	31	18	8.05	0.43	1.02	No			
2008	6	1	26	11.62	0.62	1.02	No			
2008	6	2	35	15.65	0.83	1.02	No			
2008	6	3	26	11.62	0.62	1.02	No			
2008	6	4	23	10.28	0.54	1.02	No			
2008	6	5	31	13.86	0.73	1.02	No			
2008	6	6	43	19.22	1.02	1.02	No			
2008	6	7	32	14.31	0.76	1.02	No			
2008	6	8	30	13.41	0.71	1.02	No			
2008	6	9	31	13.86	0.73	1.02	No			
2008	6	10	32	14.31	0.76	1.02	No			
2008	6	11	31	13.86	0.73	1.02	No			
2008	6	12	32	14.31	0.76	1.02	No			
2008	6	13	30	13.41	0.71	1.02	No			
2008	6	14	32	14.31	0.76	1.02	No			
2008	6	15	31	13.86	0.73	1.02	No			
2008	6	16	28	12.52	0.66	1.02	No			
2008	6	17	37	16.54	0.88	1.02	No			
2008	6	18	26	11.62	0.62	1.02	No			
2008	6	19	26	11.62	0.62	1.02	No			
2008	6	20	28	12.52	0.66	1.02	No			
2008	6	21	28	12.52	0.66	1.02	No			
2008	6	22	36	16.09	0.85	1.02	No			
2008	6	23	36	16.09	0.85	1.02	No			
2008	6	24	32	14.31	0.76	1.02	No			
2008	6	25	26	11.62	0.62	1.02	No			
2008	6	26	66	29.50	1.56	1.02	Yes	30.74		

2008	6	27	29	12.96	0.69	1.02	No			
2008	6	28	28	12.52	0.66	1.02	No			
2008	6	29	16	7.15	0.38	1.02	No			
2008	6	30	56	25.03	1.33	1.02	Yes	13.13		
2008	7	1	35	15.65	0.83	1.02	No			
2008	7	2	30	13.41	0.71	1.02	No			
2008	7	3	29	12.96	0.69	1.02	No			
2008	7	4	36	16.09	0.85	1.02	No			
2008	7	5	26	11.62	0.62	1.02	No			
2008	7	6	31	13.86	0.73	1.02	No			
2008	7	7	25	11.18	0.59	1.02	No			
2008	7	8	30	13.41	0.71	1.02	No			
2008	7	9	26	11.62	0.62	1.02	No			
2008	7	10	30	13.41	0.71	1.02	No			
2008	7	11	28	12.52	0.66	1.02	No			
2008	7	12	23	10.28	0.54	1.02	No			
2008	7	13	24	10.73	0.57	1.02	No			
2008	7	14	31	13.86	0.73	1.02	No			
2008	7	15	26	11.62	0.62	1.02	No			
2008	7	16	25	11.18	0.59	1.02	No			
2008	7	17	24	10.73	0.57	1.02	No			
2008	7	18	36	16.09	0.85	1.02	No			
2008	7	19	32	14.31	0.76	1.02	No			
2008	7	20	24	10.73	0.57	1.02	No			
2008	7	21	26	11.62	0.62	1.02	No			
2008	7	22	37	16.54	0.88	1.02	No			
2008	7	23	28	12.52	0.66	1.02	No			
2008	7	24	32	14.31	0.76	1.02	No			
2008	7	25	21	9.39	0.50	1.02	No			
2008	7	26	31	13.86	0.73	1.02	No			
2008	7	27	28	12.52	0.66	1.02	No			
2008	7	28	28	12.52	0.66	1.02	No			
2008	7	29	29	12.96	0.69	1.02	No			
2008	7	30	36	16.09	0.85	1.02	No			
2008	7	31	29	12.96	0.69	1.02	No			
2008	8	1	31	13.86	0.73	1.02	No			
2008	8	2	31	13.86	0.73	1.02	No			

2008	8	3	33	14.75	0.78	1.02	No			
2008	8	4	31	13.86	0.73	1.02	No			
2008	8	5	30	13.41	0.71	1.02	No			
2008	8	6	28	12.52	0.66	1.02	No			
2008	8	7	32	14.31	0.76	1.02	No			
2008	8	8	31	13.86	0.73	1.02	No			
2008	8	9	37	16.54	0.88	1.02	No			
2008	8	10	48	21.46	1.14	1.02	Yes	3.73		
2008	8	11	30	13.41	0.71	1.02	No			
2008	8	12	25	11.18	0.59	1.02	No			
2008	8	13	33	14.75	0.78	1.02	No			
2008	8	14	33	14.75	0.78	1.02	No			
2008	8	15	24	10.73	0.57	1.02	No			
2008	8	16	17	7.60	0.40	1.02	No			
2008	8	17	17	7.60	0.40	1.02	No			
2008	8	18	15	6.71	0.36	1.02	No			
2008	8	19	21	9.39	0.50	1.02	No			
2008	8	20	33	14.75	0.78	1.02	No			
2008	8	21	43	19.22	1.02	1.02	No			
2008	8	22	23	10.28	0.54	1.02	No			
2008	8	23	20	8.94	0.47	1.02	No			
2008	8	24	21	9.39	0.50	1.02	No			
2008	8	25	43	19.22	1.02	1.02	No			
2008	8	26	33	14.75	0.78	1.02	No			
2008	8	27	39	17.43	0.92	1.02	No			
2008	8	28	28	12.52	0.66	1.02	No			
2008	8	29	17	7.60	0.40	1.02	No			
2008	8	30	25	11.18	0.59	1.02	No			
2008	8	31	44	19.67	1.04	1.02	Yes	0.59		
2008	9	1	32	14.31	0.76	1.02	No			
2008	9	2	15	6.71	0.36	1.02	No			
2008	9	3	30	13.41	0.71	1.02	No			
2008	9	4	39	17.43	0.92	1.02	No			
2008	9	5	26	11.62	0.62	1.02	No			
2008	9	6	26	11.62	0.62	1.02	No			
2008	9	7	28	12.52	0.66	1.02	No			
2008	9	8	15	6.71	0.36	1.02	No			

2008	9	9	36	16.09	0.85	1.02	No			
2008	9	10	35	15.65	0.83	1.02	No			
2008	9	11	23	10.28	0.54	1.02	No			
2008	9	12	26	11.62	0.62	1.02	No			
2008	9	13	28	12.52	0.66	1.02	No			
2008	9	14	22	9.83	0.52	1.02	No			
2008	9	15	12	5.36	0.28	1.02	No			
2008	9	16	14	6.26	0.33	1.02	No			
2008	9	17	23	10.28	0.54	1.02	No			
2008	9	18	35	15.65	0.83	1.02	No			
2008	9	19	17	7.60	0.40	1.02	No			
2008	9	20	29	12.96	0.69	1.02	No			
2008	9	21	26	11.62	0.62	1.02	No			
2008	9	22	26	11.62	0.62	1.02	No			
2008	9	23	24	10.73	0.57	1.02	No			
2008	9	24	28	12.52	0.66	1.02	No			
2008	9	25	30	13.41	0.71	1.02	No			
2008	9	26	25	11.18	0.59	1.02	No			
2008	9	27	30	13.41	0.71	1.02	No			
2008	9	28	22	9.83	0.52	1.02	No			
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2008	9	30		0.00	0.00	1.02	No			
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2008	10	2	25	11.18	0.59	1.02	No			
2008	10	3	23	10.28	0.54	1.02	No			
2008	10	4	21	9.39	0.50	1.02	No			
2008	10	5	26	11.62	0.62	1.02	No			
2008	10	6	23	10.28	0.54	1.02	No			
2008	10	7	26	11.62	0.62	1.02	No			
2008	10	8	41	18.33	0.97	1.02	No			
2008	10	9	38	16.99	0.90	1.02	No			
2008	10	10	21	9.39	0.50	1.02	No			
2008	10	11	31	13.86	0.73	1.02	No			
2008	10	12	18	8.05	0.43	1.02	No			
2008	10	13	15	6.71	0.36	1.02	No			
2008	10	14	24	10.73	0.57	1.02	No			
2008	10	15	10	4.47	0.24	1.02	No			

2008	10	16	18	8.05	0.43	1.02	No			
2008	10	17	12	5.36	0.28	1.02	No			
2008	10	18	23	10.28	0.54	1.02	No			
2008	10	19	13	5.81	0.31	1.02	No			
2008	10	20		0.00	0.00	1.02	No			
2008	10	21	41	18.33	0.97	1.02	No			
2008	10	22		0.00	0.00	1.02	No			
2008	10	23	27	12.07	0.64	1.02	No			
2008	10	24	24	10.73	0.57	1.02	No			
2008	10	25	35	15.65	0.83	1.02	No			
2008	10	26	17	7.60	0.40	1.02	No			
2008	10	27	14	6.26	0.33	1.02	No			
2008	10	28	12	5.36	0.28	1.02	No			
2008	10	29	26	11.62	0.62	1.02	No			
2008	10	30	14	6.26	0.33	1.02	No			
2008	10	31	8	3.58	0.19	1.02	No			
2008	11	1	20	8.94	0.47	1.02	No			
2008	11	2	31	13.86	0.73	1.02	No			
2008	11	3	22	9.83	0.52	1.02	No			
2008	11	4	26	11.62	0.62	1.02	No			
2008	11	5	37	16.54	0.88	1.02	No			
2008	11	6	37	16.54	0.88	1.02	No			
2008	11	7	24	10.73	0.57	1.02	No			
2008	11	8	16	7.15	0.38	1.02	No			
2008	11	9	14	6.26	0.33	1.02	No			
2008	11	10	25	11.18	0.59	1.02	No			
2008	11	11	21	9.39	0.50	1.02	No			
2008	11	12	29	12.96	0.69	1.02	No			
2008	11	13	44	19.67	1.04	1.02	Yes	0.59		
2008	11	14	24	10.73	0.57	1.02	No			
2008	11	15	33	14.75	0.78	1.02	No			
2008	11	16	13	5.81	0.31	1.02	No			
2008	11	17	15	6.71	0.36	1.02	No			
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2008	11	20	22	9.83	0.52	1.02	No			
2008	11	21	30	13.41	0.71	1.02	No			

2008	11	22	13	5.81	0.31	1.02	No			
2008	11	23	26	11.62	0.62	1.02	No			
2008	11	24	13	5.81	0.31	1.02	No			
2008	11	25	10	4.47	0.24	1.02	No			
2008	11	26	12	5.36	0.28	1.02	No			
2008	11	27	12	5.36	0.28	1.02	No			
2008	11	28	38	16.99	0.90	1.02	No			
2008	11	29	51	22.80	1.21	1.02	Yes	6.77		
2008	11	30	47	21.01	1.11	1.02	Yes	2.85		
2008	12	1	25	11.18	0.59	1.02	No			
2008	12	2	35	15.65	0.83	1.02	No			
2008	12	3	25	11.18	0.59	1.02	No			
2008	12	4	16	7.15	0.38	1.02	No			
2008	12	5	29	12.96	0.69	1.02	No			
2008	12	6	20	8.94	0.47	1.02	No			
2008	12	7	20	8.94	0.47	1.02	No			
2008	12	8	26	11.62	0.62	1.02	No			
2008	12	9	20	8.94	0.47	1.02	No			
2008	12	10	30	13.41	0.71	1.02	No			
2008	12	11	25	11.18	0.59	1.02	No			
2008	12	12	22	9.83	0.52	1.02	No			
2008	12	13	26	11.62	0.62	1.02	No			
2008	12	14	12	5.36	0.28	1.02	No			
2008	12	15	10	4.47	0.24	1.02	No			
2008	12	16	17	7.60	0.40	1.02	No			
2008	12	17	17	7.60	0.40	1.02	No			
2008	12	18	15	6.71	0.36	1.02	No			
2008	12	19	26	11.62	0.62	1.02	No			
2008	12	20	26	11.62	0.62	1.02	No			
2008	12	21	8	3.58	0.19	1.02	No			
2008	12	22	15	6.71	0.36	1.02	No			
2008	12	23	15	6.71	0.36	1.02	No			
2008	12	24	15	6.71	0.36	1.02	No			
2008	12	25	18	8.05	0.43	1.02	No			
2008	12	26	36	16.09	0.85	1.02	No			
2008	12	27	20	8.94	0.47	1.02	No			
2008	12	28	12	5.36	0.28	1.02	No			

2008	12	29	48	21.46	1.14	1.02	Yes	3.73		
2008	12	30	48	21.46	1.14	1.02	Yes	3.73		
2008	12	31		0.00	0.00	1.02	No		106.17	
2009	1	1	37	16.54	0.88	1.02	No			
2009	1	2	49	21.90	1.16	1.02	Yes	4.68		
2009	1	3	24	10.73	0.57	1.02	No			
2009	1	4	10	4.47	0.24	1.02	No			
2009	1	5	13	5.81	0.31	1.02	No			
2009	1	6	28	12.52	0.66	1.02	No			
2009	1	7	29	12.96	0.69	1.02	No			
2009	1	8	37	16.54	0.88	1.02	No			
2009	1	9	29	12.96	0.69	1.02	No			
2009	1	10	23	10.28	0.54	1.02	No			
2009	1	11	38	16.99	0.90	1.02	No			
2009	1	12	30	13.41	0.71	1.02	No			
2009	1	13	35	15.65	0.83	1.02	No			
2009	1	14	29	12.96	0.69	1.02	No			
2009	1	15	23	10.28	0.54	1.02	No			
2009	1	16	24	10.73	0.57	1.02	No			
2009	1	17	25	11.18	0.59	1.02	No			
2009	1	18	10	4.47	0.24	1.02	No			
2009	1	19	10	4.47	0.24	1.02	No			
2009	1	20	9	4.02	0.21	1.02	No			
2009	1	21	8	3.58	0.19	1.02	No			
2009	1	22	12	5.36	0.28	1.02	No			
2009	1	23	17	7.60	0.40	1.02	No			
2009	1	24	13	5.81	0.31	1.02	No			
2009	1	25	23	10.28	0.54	1.02	No			
2009	1	26	25	11.18	0.59	1.02	No			
2009	1	27	26	11.62	0.62	1.02	No			
2009	1	28	24	10.73	0.57	1.02	No			
2009	1	29	35	15.65	0.83	1.02	No			
2009	1	30	25	11.18	0.59	1.02	No			
2009	1	31	17	7.60	0.40	1.02	No			
2009	2	1	22	9.83	0.52	1.02	No			
2009	2	2	30	13.41	0.71	1.02	No			
2009	2	3	21	9.39	0.50	1.02	No			

2009	2	4	9	4.02	0.21	1.02	No			
2009	2	5	14	6.26	0.33	1.02	No			
2009	2	6	31	13.86	0.73	1.02	No			
2009	2	7	12	5.36	0.28	1.02	No			
2009	2	8	12	5.36	0.28	1.02	No			
2009	2	9	14	6.26	0.33	1.02	No			
2009	2	10	24	10.73	0.57	1.02	No			
2009	2	11	10	4.47	0.24	1.02	No			
2009	2	12	12	5.36	0.28	1.02	No			
2009	2	13	12	5.36	0.28	1.02	No			
2009	2	14	14	6.26	0.33	1.02	No			
2009	2	15	12	5.36	0.28	1.02	No			
2009	2	16	10	4.47	0.24	1.02	No			
2009	2	17	22	9.83	0.52	1.02	No			
2009	2	18	26	11.62	0.62	1.02	No			
2009	2	19	21	9.39	0.50	1.02	No			
2009	2	20	33	14.75	0.78	1.02	No			
2009	2	21	10	4.47	0.24	1.02	No			
2009	2	22	12	5.36	0.28	1.02	No			
2009	2	23	10	4.47	0.24	1.02	No			
2009	2	24	35	15.65	0.83	1.02	No			
2009	2	25	31	13.86	0.73	1.02	No			
2009	2	26	38	16.99	0.90	1.02	No			
2009	2	27	33	14.75	0.78	1.02	No			
2009	2	28	12	5.36	0.28	1.02	No			
2009	3	1	13	5.81	0.31	1.02	No			
2009	3	2	14	6.26	0.33	1.02	No			
2009	3	3	36	16.09	0.85	1.02	No			
2009	3	4	43	19.22	1.02	1.02	No			
2009	3	5	41	18.33	0.97	1.02	No			
2009	3	6	26	11.62	0.62	1.02	No			
2009	3	7	29	12.96	0.69	1.02	No			
2009	3	8	32	14.31	0.76	1.02	No			
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2009	3	11	10	4.47	0.24	1.02	No			
2009	3	12	24	10.73	0.57	1.02	No			

2009	3	13	14	6.26	0.33	1.02	No			
2009	3	14	17	7.60	0.40	1.02	No			
2009	3	15	35	15.65	0.83	1.02	No			
2009	3	16	51	22.80	1.21	1.02	Yes	6.77		
2009	3	17	33	14.75	0.78	1.02	No			
2009	3	18	24	10.73	0.57	1.02	No			
2009	3	19	16	7.15	0.38	1.02	No			
2009	3	20	31	13.86	0.73	1.02	No			
2009	3	21	35	15.65	0.83	1.02	No			
2009	3	22	40	17.88	0.95	1.02	No			
2009	3	23	46	20.56	1.09	1.02	Yes	2.03		
2009	3	24	30	13.41	0.71	1.02	No			
2009	3	25	35	15.65	0.83	1.02	No			
2009	3	26	20	8.94	0.47	1.02	No			
2009	3	27	29	12.96	0.69	1.02	No			
2009	3	28	30	13.41	0.71	1.02	No			
2009	3	29	44	19.67	1.04	1.02	Yes	0.59		
2009	3	30	37	16.54	0.88	1.02	No			
2009	3	31	35	15.65	0.83	1.02	No			
2009	4	1	38	16.99	0.90	1.02	No			
2009	4	2	26	11.62	0.62	1.02	No			
2009	4	3	29	12.96	0.69	1.02	No			
2009	4	4	26	11.62	0.62	1.02	No			
2009	4	5	21	9.39	0.50	1.02	No			
2009	4	6	16	7.15	0.38	1.02	No			
2009	4	7	10	4.47	0.24	1.02	No			
2009	4	8	31	13.86	0.73	1.02	No			
2009	4	9	35	15.65	0.83	1.02	No			
2009	4	10	24	10.73	0.57	1.02	No			
2009	4	11	25	11.18	0.59	1.02	No			
2009	4	12	32	14.31	0.76	1.02	No			
2009	4	13	36	16.09	0.85	1.02	No			
2009	4	14	32	14.31	0.76	1.02	No			
2009	4	15	55	24.59	1.30	1.02	Yes	11.73		
2009	4	16	28	12.52	0.66	1.02	No			
2009	4	17	22	9.83	0.52	1.02	No			
2009	4	18	30	13.41	0.71	1.02	No			

2009	4	19	31	13.86	0.73	1.02	No			
2009	4	20	36	16.09	0.85	1.02	No			
2009	4	21	41	18.33	0.97	1.02	No			
2009	4	22	45	20.12	1.07	1.02	Yes	1.28		
2009	4	23	46	20.56	1.09	1.02	Yes	2.03		
2009	4	24	35	15.65	0.83	1.02	No			
2009	4	25	22	9.83	0.52	1.02	No			
2009	4	26	29	12.96	0.69	1.02	No			
2009	4	27	31	13.86	0.73	1.02	No			
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2009	4	29	38	16.99	0.90	1.02	No			
2009	4	30	39	17.43	0.92	1.02	No			
2009	5	1	17	7.60	0.40	1.02	No			
2009	5	2	26	11.62	0.62	1.02	No			
2009	5	3	28	12.52	0.66	1.02	No			
2009	5	4	30	13.41	0.71	1.02	No			
2009	5	5	43	19.22	1.02	1.02	No			
2009	5	6	48	21.46	1.14	1.02	Yes	3.73		
2009	5	7		0.00	0.00	1.02	No			
2009	5	8	25	11.18	0.59	1.02	No			
2009	5	9	22	9.83	0.52	1.02	No			
2009	5	10	26	11.62	0.62	1.02	No			
2009	5	11	43	19.22	1.02	1.02	No			
2009	5	12	48	21.46	1.14	1.02	Yes	3.73		
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2009	5	15	24	10.73	0.57	1.02	No			
2009	5	16	22	9.83	0.52	1.02	No			
2009	5	17	23	10.28	0.54	1.02	No			
2009	5	18	26	11.62	0.62	1.02	No			
2009	5	19	36	16.09	0.85	1.02	No			
2009	5	20	38	16.99	0.90	1.02	No			
2009	5	21	25	11.18	0.59	1.02	No			
2009	5	22	35	15.65	0.83	1.02	No			
2009	5	23	41	18.33	0.97	1.02	No			
2009	5	24	37	16.54	0.88	1.02	No			
2009	5	25	38	16.99	0.90	1.02	No			

2009	5	26	30	13.41	0.71	1.02	No			
2009	5	27	26	11.62	0.62	1.02	No			
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2009	5	29	30	13.41	0.71	1.02	No			
2009	5	30	36	16.09	0.85	1.02	No			
2009	5	31	32	14.31	0.76	1.02	No			
2009	6	1	26	11.62	0.62	1.02	No			
2009	6	2		0.00	0.00	1.02	No			
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2009	6	4	39	17.43	0.92	1.02	No			
2009	6	5	58	25.93	1.37	1.02	Yes	16.13		
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2009	6	8	40	17.88	0.95	1.02	No			
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2009	6	18	24	10.73	0.57	1.02	No			
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2009	6	20	52	23.25	1.23	1.02	Yes	7.91		
2009	6	21	47	21.01	1.11	1.02	Yes	2.85		
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2009	6	30	31	13.86	0.73	1.02	No			
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2009	7	12	32	14.31	0.76	1.02	No			
2009	7	13	40	17.88	0.95	1.02	No			
2009	7	14	23	10.28	0.54	1.02	No			
2009	7	15	28	12.52	0.66	1.02	No			
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2009	7	18	31	13.86	0.73	1.02	No			
2009	7	19	39	17.43	0.92	1.02	No			
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2009	7	23	15	6.71	0.36	1.02	No			
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2009	7	25	30	13.41	0.71	1.02	No			
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2009	7	30	23	10.28	0.54	1.02	No			
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2009	8	2	24	10.73	0.57	1.02	No			
2009	8	3	36	16.09	0.85	1.02	No			
2009	8	4	25	11.18	0.59	1.02	No			
2009	8	5	39	17.43	0.92	1.02	No			
2009	8	6	44	19.67	1.04	1.02	Yes	0.59		
2009	8	7	33	14.75	0.78	1.02	No			

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2009	8	9	23	10.28	0.54	1.02	No			
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2009	8	11	24	10.73	0.57	1.02	No			
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2009	8	13	51	22.80	1.21	1.02	Yes	6.77		
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2009	8	16	30	13.41	0.71	1.02	No			
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2009	9	5	36	16.09	0.85	1.02	No			
2009	9	6	26	11.62	0.62	1.02	No			
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2009	9	17	16	7.15	0.38	1.02	No			
2009	9	18	17	7.60	0.40	1.02	No			
2009	9	19	35	15.65	0.83	1.02	No			
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2009	10	21	14	6.26	0.33	1.02	No			
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2009	12	17	18	8.05	0.43	1.02	No			
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2009	12	20	33	14.75	0.78	1.02	No			
2009	12	21	15	6.71	0.36	1.02	No			
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2009	12	23	38	16.99	0.90	1.02	No			
2009	12	24	33	14.75	0.78	1.02	No			
2009	12	25	33	14.75	0.78	1.02	No			
2009	12	26	8	3.58	0.19	1.02	No			
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2010	2	16	32	14.31	0.76	1.02	No			
2010	2	17	6	2.68	0.14	1.02	No			
2010	2	18		0.00	0.00	1.02	No			
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2010	2	20	13	5.81	0.31	1.02	No			
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2010	3	4	16	7.15	0.38	1.02	No			
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2010	4	1	33	14.75	0.78	1.02	No			
2010	4	2	26	11.62	0.62	1.02	No			
2010	4	3	48	21.46	1.14	1.02	Yes	3.73		
2010	4	4	20	8.94	0.47	1.02	No			
2010	4	5	13	5.81	0.31	1.02	No			
2010	4	6	48	21.46	1.14	1.02	Yes	3.73		
2010	4	7	26	11.62	0.62	1.02	No			
2010	4	8	27	12.07	0.64	1.02	No			
2010	4	9	27	12.07	0.64	1.02	No			
2010	4	10	16	7.15	0.38	1.02	No			
2010	4	11	35	15.65	0.83	1.02	No			
2010	4	12	56	25.03	1.33	1.02	Yes	13.13		
2010	4	13	32	14.31	0.76	1.02	No			
2010	4	14	43	19.22	1.02	1.02	No			
2010	4	15		0.00	0.00	1.02	No			
2010	4	16	31	13.86	0.73	1.02	No			
2010	4	17	30	13.41	0.71	1.02	No			
2010	4	18		0.00	0.00	1.02	No			
2010	4	19	21	9.39	0.50	1.02	No			
2010	4	20	20	8.94	0.47	1.02	No			
2010	4	21	44	19.67	1.04	1.02	Yes	0.59		
2010	4	22	23	10.28	0.54	1.02	No			
2010	4	23	41	18.33	0.97	1.02	No			

2010	4	24	32	14.31	0.76	1.02	No			
2010	4	25	31	13.86	0.73	1.02	No			
2010	4	26	30	13.41	0.71	1.02	No			
2010	4	27	56	25.03	1.33	1.02	Yes	13.13		
2010	4	28	58	25.93	1.37	1.02	Yes	16.13		
2010	4	29	35	15.65	0.83	1.02	No			
2010	4	30	46	20.56	1.09	1.02	Yes	2.03		
2010	5	1	32	14.31	0.76	1.02	No			
2010	5	2	37	16.54	0.88	1.02	No			
2010	5	3	45	20.12	1.07	1.02	Yes	1.28		
2010	5	4	50	22.35	1.18	1.02	Yes	5.69		
2010	5	5		0.00	0.00	1.02	No			
2010	5	6	31	13.86	0.73	1.02	No			
2010	5	7	17	7.60	0.40	1.02	No			
2010	5	8	27	12.07	0.64	1.02	No			
2010	5	9	31	13.86	0.73	1.02	No			
2010	5	10	38	16.99	0.90	1.02	No			
2010	5	11	55	24.59	1.30	1.02	Yes	11.73		
2010	5	12		0.00	0.00	1.02	No			
2010	5	13	32	14.31	0.76	1.02	No			
2010	5	14	16	7.15	0.38	1.02	No			
2010	5	15	37	16.54	0.88	1.02	No			
2010	5	16		0.00	0.00	1.02	No			
2010	5	17	21	9.39	0.50	1.02	No			
2010	5	18	30	13.41	0.71	1.02	No			
2010	5	19	38	16.99	0.90	1.02	No			
2010	5	20	31	13.86	0.73	1.02	No			
2010	5	21	24	10.73	0.57	1.02	No			
2010	5	22	38	16.99	0.90	1.02	No			
2010	5	23	39	17.43	0.92	1.02	No			
2010	5	24	39	17.43	0.92	1.02	No			
2010	5	25	18	8.05	0.43	1.02	No			
2010	5	26	33	14.75	0.78	1.02	No			
2010	5	27	43	19.22	1.02	1.02	No			
2010	5	28	47	21.01	1.11	1.02	Yes	2.85		
2010	5	29	37	16.54	0.88	1.02	No			
2010	5	30	25	11.18	0.59	1.02	No			

2010	5	31	35	15.65	0.83	1.02	No			
2010	6	1		0.00	0.00	1.02	No			
2010	6	2	24	10.73	0.57	1.02	No			
2010	6	3	27	12.07	0.64	1.02	No			
2010	6	4	38	16.99	0.90	1.02	No			
2010	6	5	24	10.73	0.57	1.02	No			
2010	6	6	32	14.31	0.76	1.02	No			
2010	6	7	32	14.31	0.76	1.02	No			
2010	6	8	21	9.39	0.50	1.02	No			
2010	6	9	32	14.31	0.76	1.02	No			
2010	6	10	25	11.18	0.59	1.02	No			
2010	6	11	27	12.07	0.64	1.02	No			
2010	6	12		0.00	0.00	1.02	No			
2010	6	13	33	14.75	0.78	1.02	No			
2010	6	14	25	11.18	0.59	1.02	No			
2010	6	15	37	16.54	0.88	1.02	No			
2010	6	16	53	23.69	1.26	1.02	Yes	9.12		
2010	6	17	32	14.31	0.76	1.02	No			
2010	6	18	17	7.60	0.40	1.02	No			
2010	6	19	30	13.41	0.71	1.02	No			
2010	6	20	32	14.31	0.76	1.02	No			
2010	6	21	25	11.18	0.59	1.02	No			
2010	6	22	35	15.65	0.83	1.02	No			
2010	6	23	17	7.60	0.40	1.02	No			
2010	6	24	31	13.86	0.73	1.02	No			
2010	6	25	25	11.18	0.59	1.02	No			
2010	6	26	31	13.86	0.73	1.02	No			
2010	6	27	21	9.39	0.50	1.02	No			
2010	6	28		0.00	0.00	1.02	No			
2010	6	29		0.00	0.00	1.02	No			
2010	6	30	28	12.52	0.66	1.02	No			
2010	7	1	36	16.09	0.85	1.02	No			
2010	7	2	39	17.43	0.92	1.02	No			
2010	7	3	25	11.18	0.59	1.02	No			
2010	7	4	31	13.86	0.73	1.02	No			
2010	7	5	30	13.41	0.71	1.02	No			
2010	7	6	30	13.41	0.71	1.02	No			

2010	7	7	30	13.41	0.71	1.02	No			
2010	7	8	31	13.86	0.73	1.02	No			
2010	7	9		0.00	0.00	1.02	No			
2010	7	10	41	18.33	0.97	1.02	No			
2010	7	11	25	11.18	0.59	1.02	No			
2010	7	12	37	16.54	0.88	1.02	No			
2010	7	13	39	17.43	0.92	1.02	No			
2010	7	14	23	10.28	0.54	1.02	No			
2010	7	15	22	9.83	0.52	1.02	No			
2010	7	16	32	14.31	0.76	1.02	No			
2010	7	17		0.00	0.00	1.02	No			
2010	7	18	45	20.12	1.07	1.02	Yes	1.28		
2010	7	19	32	14.31	0.76	1.02	No			
2010	7	20	25	11.18	0.59	1.02	No			
2010	7	21		0.00	0.00	1.02	No			
2010	7	22	33	14.75	0.78	1.02	No			
2010	7	23	25	11.18	0.59	1.02	No			
2010	7	24		0.00	0.00	1.02	No			
2010	7	25	20	8.94	0.47	1.02	No			
2010	7	26	48	21.46	1.14	1.02	Yes	3.73		
2010	7	27		0.00	0.00	1.02	No			
2010	7	28	29	12.96	0.69	1.02	No			
2010	7	29	40	17.88	0.95	1.02	No			
2010	7	30		0.00	0.00	1.02	No			
2010	7	31		0.00	0.00	1.02	No			
2010	8	1	31	13.86	0.73	1.02	No			
2010	8	2	18	8.05	0.43	1.02	No			
2010	8	3	40	17.88	0.95	1.02	No			
2010	8	4	32	14.31	0.76	1.02	No			
2010	8	5		0.00	0.00	1.02	No			
2010	8	6	55	24.59	1.30	1.02	Yes	11.73		
2010	8	7	43	19.22	1.02	1.02	No			
2010	8	8	28	12.52	0.66	1.02	No			
2010	8	9	43	19.22	1.02	1.02	No			
2010	8	10	24	10.73	0.57	1.02	No			
2010	8	11	36	16.09	0.85	1.02	No			
2010	8	12	43	19.22	1.02	1.02	No			

2010	8	13	23	10.28	0.54	1.02	No			
2010	8	14	25	11.18	0.59	1.02	No			
2010	8	15		0.00	0.00	1.02	No			
2010	8	16	37	16.54	0.88	1.02	No			
2010	8	17	16	7.15	0.38	1.02	No			
2010	8	18	32	14.31	0.76	1.02	No			
2010	8	19	30	13.41	0.71	1.02	No			
2010	8	20	24	10.73	0.57	1.02	No			
2010	8	21	28	12.52	0.66	1.02	No			
2010	8	22	54	24.14	1.28	1.02	Yes	10.39		
2010	8	23	23	10.28	0.54	1.02	No			
2010	8	24		0.00	0.00	1.02	No			
2010	8	25		0.00	0.00	1.02	No			
2010	8	26	23	10.28	0.54	1.02	No			
2010	8	27	36	16.09	0.85	1.02	No			
2010	8	28	41	18.33	0.97	1.02	No			
2010	8	29	39	17.43	0.92	1.02	No			
2010	8	30	24	10.73	0.57	1.02	No			
2010	8	31	23	10.28	0.54	1.02	No			
2010	9	1	33	14.75	0.78	1.02	No			
2010	9	2		0.00	0.00	1.02	No			
2010	9	3		0.00	0.00	1.02	No			
2010	9	4	51	22.80	1.21	1.02	Yes	6.77		
2010	9	5	44	19.67	1.04	1.02	Yes	0.59		
2010	9	6	20	8.94	0.47	1.02	No			
2010	9	7	21	9.39	0.50	1.02	No			
2010	9	8	32	14.31	0.76	1.02	No			
2010	9	9	64	28.61	1.52	1.02	Yes	26.70		
2010	9	10	25	11.18	0.59	1.02	No			
2010	9	11	20	8.94	0.47	1.02	No			
2010	9	12	18	8.05	0.43	1.02	No			
2010	9	13	32	14.31	0.76	1.02	No			
2010	9	14	48	21.46	1.14	1.02	Yes	3.73		
2010	9	15		0.00	0.00	1.02	No			
2010	9	16	39	17.43	0.92	1.02	No			
2010	9	17	31	13.86	0.73	1.02	No			
2010	9	18	21	9.39	0.50	1.02	No			

2010	9	19	36	16.09	0.85	1.02	No			
2010	9	20	37	16.54	0.88	1.02	No			
2010	9	21	30	13.41	0.71	1.02	No			
2010	9	22	40	17.88	0.95	1.02	No			
2010	9	23	23	10.28	0.54	1.02	No			
2010	9	24	31	13.86	0.73	1.02	No			
2010	9	25		0.00	0.00	1.02	No			
2010	9	26		0.00	0.00	1.02	No			
2010	9	27	18	8.05	0.43	1.02	No			
2010	9	28	21	9.39	0.50	1.02	No			
2010	9	29		0.00	0.00	1.02	No			
2010	9	30		0.00	0.00	1.02	No			
2010	10	1		0.00	0.00	1.02	No			
2010	10	2		0.00	0.00	1.02	No			
2010	10	3		0.00	0.00	1.02	No			
2010	10	4	37	16.54	0.88	1.02	No			
2010	10	5		0.00	0.00	1.02	No			
2010	10	6	55	24.59	1.30	1.02	Yes	11.73		
2010	10	7	31	13.86	0.73	1.02	No			
2010	10	8	30	13.41	0.71	1.02	No			
2010	10	9	33	14.75	0.78	1.02	No			
2010	10	10	23	10.28	0.54	1.02	No			
2010	10	11	30	13.41	0.71	1.02	No			
2010	10	12		0.00	0.00	1.02	No			
2010	10	13		0.00	0.00	1.02	No			
2010	10	14		0.00	0.00	1.02	No			
2010	10	15	23	10.28	0.54	1.02	No			
2010	10	16	25	11.18	0.59	1.02	No			
2010	10	17	22	9.83	0.52	1.02	No			
2010	10	18		0.00	0.00	1.02	No			
2010	10	19	20	8.94	0.47	1.02	No			
2010	10	20		0.00	0.00	1.02	No			
2010	10	21		0.00	0.00	1.02	No			
2010	10	22	18	8.05	0.43	1.02	No			
2010	10	23	23	10.28	0.54	1.02	No			
2010	10	24	25	11.18	0.59	1.02	No			
2010	10	25	40	17.88	0.95	1.02	No			

2010	10	26	27	12.07	0.64	1.02	No			
2010	10	27	25	11.18	0.59	1.02	No			
2010	10	28		0.00	0.00	1.02	No			
2010	10	29		0.00	0.00	1.02	No			
2010	10	30		0.00	0.00	1.02	No			
2010	10	31		0.00	0.00	1.02	No			
2010	11	1		0.00	0.00	1.02	No			
2010	11	2	27	12.07	0.64	1.02	No			
2010	11	3		0.00	0.00	1.02	No			
2010	11	4		0.00	0.00	1.02	No			
2010	11	5		0.00	0.00	1.02	No			
2010	11	6	22	9.83	0.52	1.02	No			
2010	11	7		0.00	0.00	1.02	No			
2010	11	8	28	12.52	0.66	1.02	No			
2010	11	9	33	14.75	0.78	1.02	No			
2010	11	10		0.00	0.00	1.02	No			
2010	11	11	30	13.41	0.71	1.02	No			
2010	11	12	31	13.86	0.73	1.02	No			
2010	11	13	32	14.31	0.76	1.02	No			
2010	11	14	33	14.75	0.78	1.02	No			
2010	11	15	36	16.09	0.85	1.02	No			
2010	11	16	44	19.67	1.04	1.02	Yes	0.59		
2010	11	17	20	8.94	0.47	1.02	No			
2010	11	18	35	15.65	0.83	1.02	No			
2010	11	19	23	10.28	0.54	1.02	No			
2010	11	20	35	15.65	0.83	1.02	No			
2010	11	21	29	12.96	0.69	1.02	No			
2010	11	22	32	14.31	0.76	1.02	No			
2010	11	23	38	16.99	0.90	1.02	No			
2010	11	24	28	12.52	0.66	1.02	No			
2010	11	25	23	10.28	0.54	1.02	No			
2010	11	26	10	4.47	0.24	1.02	No			
2010	11	27	10	4.47	0.24	1.02	No			
2010	11	28	25	11.18	0.59	1.02	No			
2010	11	29	29	12.96	0.69	1.02	No			
2010	11	30	16	7.15	0.38	1.02	No			
2010	12	1	9	4.02	0.21	1.02	No			

2010	12	2	17	7.60	0.40	1.02	No			
2010	12	3	21	9.39	0.50	1.02	No			
2010	12	4	9	4.02	0.21	1.02	No			
2010	12	5		0.00	0.00	1.02	No			
2010	12	6		0.00	0.00	1.02	No			
2010	12	7	14	6.26	0.33	1.02	No			
2010	12	8	9	4.02	0.21	1.02	No			
2010	12	9	13	5.81	0.31	1.02	No			
2010	12	10	44	19.67	1.04	1.02	Yes	0.59		
2010	12	11	16	7.15	0.38	1.02	No			
2010	12	12		0.00	0.00	1.02	No			
2010	12	13	29	12.96	0.69	1.02	No			
2010	12	14	24	10.73	0.57	1.02	No			
2010	12	15	25	11.18	0.59	1.02	No			
2010	12	16	14	6.26	0.33	1.02	No			
2010	12	17	8	3.58	0.19	1.02	No			
2010	12	18	16	7.15	0.38	1.02	No			
2010	12	19	15	6.71	0.36	1.02	No			
2010	12	20	41	18.33	0.97	1.02	No			
2010	12	21	9	4.02	0.21	1.02	No			
2010	12	22	9	4.02	0.21	1.02	No			
2010	12	23	21	9.39	0.50	1.02	No			
2010	12	24	9	4.02	0.21	1.02	No			
2010	12	25	10	4.47	0.24	1.02	No			
2010	12	26	10	4.47	0.24	1.02	No			
2010	12	27	12	5.36	0.28	1.02	No			
2010	12	28	12	5.36	0.28	1.02	No			
2010	12	29	31	13.86	0.73	1.02	No			
2010	12	30	24	10.73	0.57	1.02	No			
2010	12	31	20	8.94	0.47	1.02	No		165.63	

Notes: Meteorological data from the Big Piney Station, National Weather Service.

1 The conversion from miles per hour to meter per second is 0.44704.

2 The friction velocity is calculated using AP-42 Chapter 13 Section 2.5 "Industrial Wind Erosion" Equation 4.

3 The threshold velocity is taken from AP-42 Chapter 13 Section 2.5 "Industrial Wind Erosion" Table 13.2.5-2.

4 The erosion potential P is calculated using AP-42 Chapter 13 Section 2.5 "Industrial Wind Erosion" Equation 3.

ΣP (avg)	120.02	g/m^2-yr
ΣP (avg)	0.122	lb/hr-acre
k (PM_{10})[5]	0.5	
k ($PM_{2.5}$)[5]	0.075	

5 k, the particle size multiplier is from AP-42 Chapter 13 Section 2.5 "Industrial Wind Erosion" page 13.2.5-3.

Emission Factor (PM_{10})	0.061	lb/hr-acre
Emission Factor ($PM_{2.5}$)	0.009	lb/hr-acre

4/15/2014 added 25* factor to P eqn

Table 35. Production Wind Erosion - Per Acre of Disturbance

Project: **Jonah NPL**
Scenario: **4 Pad/Section**
Activity: **Production Wind Erosion**

Emissions: **Wind Erosion**

Emission Factor (PM_{10})[1] : 0.0611 lb/hr-acre
Emission Factor ($PM_{2.5}$)[1] : 0.0092 lb/hr-acre

Control Efficiency[2]: 50 %

Disturbed Area:

Well Pad and Road:	18	acres	assume 30% of pads/facility will have equipment on it
Central Facility:	11	acres	assume 30% of pads/facility will have equipment on it

Emissions Calculations:

	PM_{10} Emission Factor	$PM_{2.5}$ Emission Factor	Area	Control Efficiency	PM_{10} Emissions	$PM_{2.5}$ Emissions	Controlled PM_{10} Emissions	Controlled $PM_{2.5}$ Emissions
	(lb/hr-acre)	(lb/hr-acre)	(acre)	(%)	(lb/hr)	(lb/hr)	(tons/yr)	(tons/yr)
Well Pad and Road	0.0611	0.0092	17.94	50	0.55	0.08	2.40	0.36
Compressor Station	0.0611	0.0092	10.50	50	0.32	0.05	1.41	0.21
Total							3.81	0.57

[1] Based on AP-42 Chapter 13.2.5 (EPA 2004), Industrial Wind Erosion using Area meteorological data. See 'WindErosion Data' sheet for details.
[2] AP-42 (EPA 2004), Section 13.2.3, "Heavy Construction Operations".

Table 36. Compressor Engine Emissions

Project: Jonah NPL
Scenario: Option 3 - Electric Engines
Effective Dates: All
Emissions: Combustion Emissions from Compressor Engines

Engine	Pollutant	EPA Tier Certification	Pollutant Emission Factor[1]	Engine Count	Horse-power[2]	Overall Load Factor[3]	Annual Activity	Daily Ops	Emissions per Facility	Emissions per Hour	Emissions per Facility	
			(g/hp-hr)		(hp)		(days/yr)	(hrs/day)	(lb/facility)	(lb/hr)	(tons)	
Cat 3612 w/SCO AFRC	CO	Electric	0.00	1	3,500	0.90	365	24	0.00	0.00	0.00	
Combustion	NOx	Electric	0.00	1	3,500	0.90	365	24	0.00	0.00	0.00	0.170732
	SO_2	Electric	0.00	1	3,500	0.90	365	24	0.00	0.00	0.00	
	VOC	Electric	0.00	1	3,500	0.90	365	24	0.00	0.00	0.00	
	PM_{10}	Electric	0.00	1	3,500	0.90	365	24	0.00	0.00	0.00	
	$PM_{2.5}$	Electric	0.00	1	3,500	0.90	365	24	0.00	0.00	0.00	
	Benzene	Electric	0.00	1	3,500	0.90	365	24	0.00	0.00	0.00	
	Ethylbenzene	Electric	0.00	1	3,500	0.90	365	24	0.00	0.00	0.00	
	Formaldehyde	Electric	0.00	1	3,500	0.90	365	24	0.00	0.00	0.00	
	H_2S	Electric	0.00	1	3,500	0.90	365	24	0.00	0.00	0.00	
	n-Hexane	Electric	0.00	1	3,500	0.90	365	24	0.00	0.00	0.00	
	Toluene	Electric	0.00	1	3,500	0.90	365	24	0.00	0.00	0.00	
	Xylenes	Electric	0.00	1	3,500	0.90	365	24	0.00	0.00	0.00	
	CH_4	Electric	0.00	1	3,500	0.90	365	24	0.00	0.00	0.00	
	CO_2	Electric	0.00	1	3,500	0.90	365	24	0.00	0.00	0.00	
	N_2O	Electric	0.00	1	3,500	0.90	365	24	0.00	0.00	0.00	

Engine	Pollutant	Compressor Volume (scf)[b]	Events per Year	MW Gas	Weight Fraction	lb/compressor-'	lb/hr	ı/compressor-yr
Cat 3612 w/SCO AFRC	CO							
Blowdown	NOx							
	SO_2							
	VOC	650	24	18.53	0.12	91.45	0.01	0.05
	PM_{10}							
	$PM_{2.5}$							
	Benzene	650	24	18.53	5.12E-04	0.39	0.00	0.00
	Ethylbenzene	650	24	18.53	3.07E-05	0.02	0.00	0.00
	Formaldehyde							
	H_2S							
	n-Hexane	650	24	18.53	2.30E-03	1.75	0.00	0.00
	Toluene	650	24	18.53	7.57E-04	0.58	0.00	0.00
	Xylenes	650	24	18.53	2.80E-04	0.21	0.00	0.00
	CH_4	650	24	18.53	0.782	595.86	0.07	0.30
	CO_2	650	24	18.53	1.28E-02	9.77	0.00	0.00
	N_2O							

Engine	Pollutant	Emissions per Facility (lb/facility)	Emissions per Hour (lb/hr)	Emissions per Facility (tons)
Total	CO	0.00	0.00	0.00
	NOx	0.00	0.00	0.00
	SO_2	0.00	0.00	0.00
	VOC	91.45	0.01	0.05
	PM_{10}	0.00	0.00	0.00
	$PM_{2.5}$	0.00	0.00	0.00
	Benzene	0.39	0.00	0.00
	Ethylbenzene	0.02	0.00	0.00
	Formaldehyde	0.00	0.00	0.00
	H_2S	0.00	0.00	0.00
	n-Hexane	1.75	0.00	0.00
	Toluene	0.58	0.00	0.00
	Xylenes	0.21	0.00	0.00
	CH_4	595.86	0.07	0.30
	CO_2	9.77	0.00	0.00
	N_2O	0.00	0.00	0.00

Facility	Year	HP	Engine Count	CO	NOx	PM_{10}	$PM_{2.5}$	SO_2	VOC	Benzene	Ethylbenzen	ormaldehyc	H_2S	n-Hexane	Toluene	Xylenes	CH_4	CO_2	N_2O
							ton/yr												

1	9	10118	3	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.89	0.01	0.00
2	9	6475	2	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.60	0.01	0.00
3	9	10118	3	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.89	0.01	0.00
4	9	6475	2	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.60	0.01	0.00
5	9	6475	2	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.60	0.01	0.00
6	9	10118	3	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.89	0.01	0.00
7	9	6475	2	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.60	0.01	0.00
8	9	6475	2	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.60	0.01	0.00
9	9	6475	2	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.60	0.01	0.00
10	9	3373	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.00	0.00
11	9	3373	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.00	0.00
									1.05										

[1] Emission factors taken from EMIT quotes for emissions control devices and used for previously permitted engines.
[2] Justin Barberio - assume 140hp/MMscfd.
[3] Justin Barberio.
[4] xxx.
[5] API Greenhouse Gas Compendium Table 5-21 (2004). Includes both start-ups and blowdown

Project: Jonah NPL
Scenario: Horsepower
Activity: Production Facility Development
Emissions:

Date:

Facility	Year									
	1	2	3	4	5	6	7	8	9	10
1	10118	10118	10118	10118	10118	10118	10118	10118	10118	10118
2	6475	6475	6475	6475	6475	6475	6475	6475	6475	6475
3	6475	10118	6475	10118	10118	10118	10118	10118	10118	10118
4		3373	6475	6475	6475	6475	6475	6475	6475	6475
5		3373	6475	6475	6475	6475	6475	6475	6475	6475
6			3373	6475	6475	10118	10118	10118	10118	10118
7				3373	6475	6475	6475	6475	6475	6475
8				3373	6475	6475	6475	6475	6475	6475
9						3373	3373	6475	6475	6475
10							3373	3373	3373	3373
11									3373	3373
Totals	23068	33457	39391	52882	59086	66102	69475	72577	75950	75950

NPL Project Air Quality Assessment Emissions Inventory

Table 37. Compressor Engine Emissions

Project: Jonah NPL
Scenario: Option 3 - Electric Engines
Effective Dates: All
Emissions: Natural Gas Combustion Emissions from Misc Engines - none as electric

Engine	Pollutant	EPA Tier Certification	Pollutant Emission Factor	Engine Count	Horse power	Overall Load Factor	Annual Activity	Daily Ops	Emissions per Hour	Emissions per Year
			(g/hp-hr)		(hp)		(days/yr)	(hrs/day)	(lb/hr)	(tons/yr)
Generac GS140	CO	Electric	0.00	3	175	0.90	365	24	0.00	0.00
Generator	NOx	Electric	0.00	3	175	0.90	365	24	0.00	0.00
Water Mng Facilities	SO_2	Electric	0.00	3	175	0.90	365	24	0.00	0.00
	VOC	Electric	0.00	3	175	0.90	365	24	0.00	0.00
	PM_{10}	Electric	0.00	3	175	0.90	365	24	0.00	0.00
	$PM_{2.5}$	Electric	0.00	3	175	0.90	365	24	0.00	0.00
	Benzene	Electric	0.00	3	175	0.90	365	24	0.00	0.00
	Ethylbenzene	Electric	0.00	3	175	0.90	365	24	0.00	0.00
	Formaldehyde	Electric	0.00	3	175	0.90	365	24	0.00	0.00
	H_2S	Electric	0.00	3	175	0.90	365	24	0.00	0.00
	n-Hexane	Electric	0.00	3	175	0.90	365	24	0.00	0.00
	Toluene	Electric	0.00	3	175	0.90	365	24	0.00	0.00
	Xylenes	Electric	0.00	3	175	0.90	365	24	0.00	0.00
	CH_4	Electric	0.00	3	175	0.90	365	24	0.00	0.00
	CO_2	Electric	0.00	3	175	0.90	365	24	0.00	0.00
	N_2O	Electric	0.00	3	175	0.90	365	24	0.00	0.00
Caterpillar 3512	CO	Electric	0.00	3	950	0.90	365	24	0.00	0.00
Water Injection	NOx	Electric	0.00	3	950	0.90	365	24	0.00	0.00
Water Mng Facilities	SO_2	Electric	0.00	3	950	0.90	365	24	0.00	0.00
	VOC	Electric	0.00	3	950	0.90	365	24	0.00	0.00
	PM_{10}	Electric	0.00	3	950	0.90	365	24	0.00	0.00
	$PM_{2.5}$	Electric	0.00	3	950	0.90	365	24	0.00	0.00
	Benzene	Electric	0.00	3	950	0.90	365	24	0.00	0.00
	Ethylbenzene	Electric	0.00	3	950	0.90	365	24	0.00	0.00
	Formaldehyde	Electric	0.00	3	950	0.90	365	24	0.00	0.00
	H_2S	Electric	0.00	3	950	0.90	365	24	0.00	0.00
	n-Hexane	Electric	0.00	3	950	0.90	365	24	0.00	0.00
	Toluene	Electric	0.00	3	950	0.90	365	24	0.00	0.00
	Xylenes	Electric	0.00	3	950	0.90	365	24	0.00	0.00
	CH_4	Electric	0.00	3	950	0.90	365	24	0.00	0.00
	CO_2	Electric	0.00	3	950	0.90	365	24	0.00	0.00
	N_2O	Electric	0.00	3	950	0.90	365	24	0.00	0.00
VRU Compression	CO	Electric	0.00							
	NOx	Electric	0.00							
	SO_2	Electric	0.00							
	VOC	Electric	0.00							
	PM_{10}	Electric	0.00							
	$PM_{2.5}$	Electric	0.00							
	Benzene	Electric	0.00							
	Ethylbenzene	Electric	0.00							
	Formaldehyde	Electric	0.00							
	H_2S	Electric	0.00							
	n-Hexane	Electric	0.00							
	Toluene	Electric	0.00							
	Xylenes	Electric	0.00							
	CH_4	Electric	0.00							
	CO_2	Electric	0.00							
	N_2O	Electric	0.00							

Facility (VRU)	HP	Hours	Load	CO	NOx	PM_{10}	$PM_{2.5}$	SO_2	VOC	Benzene	Ethylbenzene	Formaldehyde	H_2S	n-Hexane	Toluene	Xylenes	CH_4	CO_2	N_2O
				ton/yr															
1	240	8585	100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	160	8585	100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	240	8585	100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	160	8585	100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	160	8585	100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	240	8585	100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	130	8585	100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	160	8585	100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	130	8585	100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	80	8585	100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	35	8585	100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

NPL Project Air Quality Assessment Emissions Inventory

Table 38. Separator/Indirect Line Heaters

Project: Jonah NPL
Scenario: All
Activity: Production
Emissions: Separator/Line Heaters

Fuel Combustion Source:

Unit Description	Separator/Line Heaters	
Average Design Firing Rate	0.33	MMBTU/hr Electric therefore emissions are set to zero

Operating Parameters:

	Total Hours	% Operating
Annual Operating hours	4380	
Winter (Nov. - Apr.)	4344	85
Summer (May - Oct.)	4416	15.6

Actual Fuel Combustion for the Year for Unit:

Average Natural Gas Combusted	1.29	MMscf/yr
Fuel Heating Value (actual)	1,124	Btu/scf
Fuel Heating Value (Em. Factor)	1,020	Btu/scf

1.04E-06

Potential Emission Data:

	Emission Factor[1] (lb/MMscf)	(lb/hr) Winter	(lb/hr) Summer	(lb/facility) Total
Total PM	0.0	0.00000	0.00000	0.000
SO_2	0.0	0.00000	0.00000	0.000
NO_x	0.0	0.00000	0.00000	0.000
CO	0.0	0.00000	0.00000	0.000
VOC	0.0	0.00000	0.00000	0.000

	Emission Factor[2] (lb/MMscf)	(lb/hr) Winter	(lb/hr) Summer	(lb/facility) Total
Benzene	0.0	0.00000	0.00000	0.000
Ethylbenzene	0.0	0.00000	0.00000	0.000
Formaldehyde	0.0	0.00000	0.00000	0.000
H_2S	0.0	0.00000	0.00000	0.000
n-Hexane	0.0	0.00000	0.00000	0.000

	Emission Factor[2] (lb/MMscf)	(lb/hr) Winter	(lb/hr) Summer	(lb/facility) Total
Toluene	0.00E+00	0.00000	0.00000	0.000
Xylenes	0.0	0.00000	0.00000	0.000
CH_4	0.00	0.00000	0.00000	0.000
CO_2	0.00E+00	0.00000	0.00000	0.000
N_2O	0.00	0.00000	0.00000	0.000

ton/yr

Facility	MMbtu/hr	CO	NOx	PM_{10}	$PM_{2.5}$	SO_2	VOC	Benzene	Ethylbenzen	Formaldehyd	H_2S	n-Hexane	Toluene	Xylenes	CH_4	CO_2	N_2O
1	0.5	0.00	0.00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00
2	0.35	0.00	0.00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00
3	0.5	0.00	0.00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00
4	0.35	0.00	0.00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00
5	0.35	0.00	0.00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00
6	0.5	0.00	0.00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00
7	0.25	0.00	0.00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00
8	0.35	0.00	0.00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00
9	0.25	0.00	0.00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00
10	0.16	0.00	0.00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00
11	0.1	0.00	0.00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00

[1] Emission factors taken from WDEQ "Oil and Gas Production Facilities - Chapter 6, Section 2 Permitting Guidance" and AP-42, Table 1.4-2.

[2] Electric

NPL Project Air Quality Assessment Emissions Inventory

Table 39. Dehy Reboiler Heater

Project: Jonah NPL
Scenario: All
Activity: Production
Emissions: Dehy Reboiler Heater

Fuel Combustion Source:

Unit Description	Dehy Reboiler Heater		
Average Design Firing Rate	1.47	MMBTU/hr	Electric therefore emissions are set to zero

Operating Parameters:

Annual Operating hours	6570	
	Total Hours	Operation %
Winter (Nov. - Apr.)	4344	100
Summer (May - Oct.)	4416	50.5

Actual Fuel Combustion for the Year for Unit:

Average Natural Gas Combusted	8.59	MMscf/yr
Fuel Heating Value (actual)	1,124	Btu/scf
Fuel Heating Value (Em. Factor)	1,020	Btu/scf

Potential Emission Data:

	Emission Factor[1]	(lb/hr)		(lb/facility)
	(lb/MMscf)	Winter	Summer	Total
Total PM	0.0	0.00000	0.00000	0.000
SO_2	0.0	0.00000	0.00000	0.000
NO_x	0.0	0.00000	0.00000	0.000
CO	0.0	0.00000	0.00000	0.000
VOC	0.0	0.00000	0.00000	0.000

	Emission Factor[2]	(lb/hr)		(lb/facility)
	(lb/MMscf)	Winter	Summer	Total
Benzene	0.0E+00	0.00000	0.00000	0.000
Ethylbenzene	0.0	0.00000	0.00000	0.000
Formaldehyde	0.0E+00	0.00000	0.00000	0.000
H_2S	0.0	0.00000	0.00000	0.000
n-Hexane	0.0	0.00000	0.00000	0.000

	Emission Factor[2]	(lb/hr)		(lb/facility)
	(lb/MMscf)	Winter	Summer	Total
Toluene	0.00E+00	0.00000	0.00000	0.000
Xylenes	0.0	0.00000	0.00000	0.000
CH_4	0.00	0.00000	0.00000	0.000
CO_2	0.00E+00	0.00000	0.00000	0.000
N_2O	0.00	0.00000	0.00000	0.000

ton/yr

Facility	MMbtu/hr	CO	NOx	PM_{10}	$PM_{2.5}$	SO_2	VOC	Benzene	Ethylbenzen	Formaldehyd	H_2S	n-Hexane	Toluene	Xylenes	CH_4	CO_2	N_2O
1	2.25	0.00	0.00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00
2	1.5	0.00	0.00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00
3	2.25	0.00	0.00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00
4	1.5	0.00	0.00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00
5	1.5	0.00	0.00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00
6	2.25	0.00	0.00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00
7	1.2	0.00	0.00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00
8	1.5	0.00	0.00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00
9	1.2	0.00	0.00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00
10	0.75	0.00	0.00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00
11	0.3	0.00	0.00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00

[1] Emission factors taken from WDEQ "Oil and Gas Production Facilities - Chapter 6, Section 2 Permitting Guidance" and AP-42, Table 1.4-2.
[2] Electric

Table 40. Dehy Flash Tank Heater

Project: Jonah NPL
Scenario: All
Activity: Production
Emissions: Dehy Flash Tank Heater

Fuel Combustion Source:

Unit Description	Flash Tank Heaters	
Average Design Firing Rate	0.12	MMBTU/hr Electric therefore emissions are set to zero in spreadsheet

Operating Parameters:

Annual Operating hours	4380	
	Total Hours	Operation %
Winter (Nov. - Apr.)	4344	85
Summer (May - Oct.)	4416	15.6

Actual Fuel Combustion for the Year for Unit:

Average Natural Gas Combusted	0.47	MMscf/yr
Fuel Heating Value (actual)	1,124	Btu/scf
Fuel Heating Value (Em. Factor)	1,020	Btu/scf

Potential Emission Data:

	Emission Factor[1] (lb/MMscf)	(lb/hr) Winter	(lb/hr) Summer	(lb/facility) Total		Emission Factor[2] (lb/MMscf)	(lb/hr) Winter	(lb/hr) Summer	(lb/facility) Total		Emission Factor[2] (lb/MMscf)	(lb/hr) Winter	(lb/hr) Summer	(lb/facility) Total
Total PM	0.0	0.00000	0.00000	0.000	Benzene	0.0E+00	0.00000	0.00000	0.000	Toluene	0.00E+00	0.00000	0.00000	0.000
SO_2	0.0	0.00000	0.00000	0.000	Ethylbenzene	0.0	0.00000	0.00000	0.000	Xylenes	0.0	0.00000	0.00000	0.000
NO_x	0.0	0.00000	0.00000	0.000	Formaldehyde	0.0E+00	0.00000	0.00000	0.000	CH_4	0.00	0.00000	0.00000	0.000
CO	0.0	0.00000	0.00000	0.000	H_2S	0.0	0.00000	0.00000	0.000	CO_2	0.00E+00	0.00000	0.00000	0.000
VOC	0.0	0.00000	0.00000	0.000	n-Hexane	0.0	0.00000	0.00000	0.000	N_2O	0.00	0.00000	0.00000	0.000

ton/yr

Facility	MMbtu/hr	CO	NOx	PM_{10}	$PM_{2.5}$	SO_2	VOC	Benzene	Ethylbenzen	Formaldehyd	H_2S	n-Hexane	Toluene	Xylenes	CH_4	CO_2	N_2O
1	0.12	0.00	0.00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00
2	0.12	0.00	0.00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00
3	0.12	0.00	0.00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00
4	0.12	0.00	0.00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00
5	0.12	0.00	0.00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00
6	0.12	0.00	0.00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00
7	0.12	0.00	0.00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00
8	0.12	0.00	0.00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00
9	0.12	0.00	0.00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00
10	0.12	0.00	0.00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00
11	0.12	0.00	0.00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00

[1] Emission factors taken from WDEQ "Oil and Gas Production Facilities - Chapter 6, Section 2 Permitting Guidance" and AP-42, Table 1.4-2.

[2] Electric

NPL Project Air Quality Assessment Emissions Inventory

Table 41. Condensate Tank Heater

Project: Jonah NPL
Scenario: All
Activity: Production
Emissions: Condensate Tank Heater

Fuel Combustion Source:

Unit Description	Condensate Tank Heaters	
Average Design Firing Rate	0.16	MMBTU/hr Electric therefore emissions are set to zero

Operating Parameters:

Annual Operating hours	6570	
	Total Hours	Operation %
Winter (Nov. - Apr.)	4344	100
Summer (May - Oct.)	4416	34

Actual Fuel Combustion for the Year for Unit:

Average Natural Gas Combusted	0.94	MMscf/yr
Fuel Heating Value (actual)	1,124	Btu/scf
Fuel Heating Value (Em. Factor)	1,020	Btu/scf

0

Potential Emission Data:

	Emission Factor[1]	(lb/hr)		(lb/facility)		Emission Factor[2]	(lb/hr)		(lb/facility)		Emission Factor[2]	(lb/hr)		(lb/facility)
	(lb/MMscf)	Winter	Summer	Total		(lb/MMscf)	Winter	Summer	Total		(lb/MMscf)	Winter	Summer	Total
Total PM	0.0	0.00000	0.00000	0.000	Benzene	0.0E+00	0.00000	0.00000	0.000	Toluene	0.00E+00	0.00000	0.00000	0.000
SO_2	0.0	0.00000	0.00000	0.000	Ethylbenzene		0.00000	0.00000	0.000	Xylenes	0.0	0.00000	0.00000	0.000
NO_x	0.0	0.00000	0.00000	0.000	Formaldehyde	0.0E+00	0.00000	0.00000	0.000	CH_4	0.00	0.00000	0.00000	0.000
CO	0.0	0.00000	0.00000	0.000	H_2S		0.00000	0.00000	0.000	CO_2	0.00E+00	0.00000	0.00000	0.000
VOC	0.0	0.00000	0.00000	0.000	n-Hexane	0.0	0.00000	0.00000	0.000	N_2O	0.00	0.00000	0.00000	0.000

		ton/yr															
Facility	MMbtu/hr	CO	NOx	PM_{10}	$PM_{2.5}$	SO_2	VOC	Benzene	Ethylbenzen	Formaldehyd	H_2S	n-Hexane	Toluene	Xylenes	CH_4	CO_2	N_2O
1	0.16	0.00	0.00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00
2	0.16	0.00	0.00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00
3	0.16	0.00	0.00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00
4	0.16	0.00	0.00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00
5	0.16	0.00	0.00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00
6	0.16	0.00	0.00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00
7	0.16	0.00	0.00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00
8	0.16	0.00	0.00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00
9	0.16	0.00	0.00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00
10	0.16	0.00	0.00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00
11	0.16	0.00	0.00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00

[1] Emission factors taken from WDEQ "Oil and Gas Production Facilities - Chapter 6, Section 2 Permitting Guidance" and AP-42, Table 1.4-2.
[2] Electric

NPL Project Air Quality Assessment Emissions Inventory

Table 42. Dehydrator Flashing

Project: Jonah NPL
Scenario: Option 3 - Electric Engines and VRU Control/Combustor backup
Activity: Production
Emissions: TEG Dehydrator Emissions

Pollutant	Uncontrolled[1] (tpy)	Uncontrolled[1] (lb/hr)	Controlled[2] (tpy)	Controlled[2] (lb/hr)
VOC	171.47	39.15	0.07	0.02
HAP	101.95	23.28	0.04	0.01
Benzene	16.63	3.80	0.01	0.00
Ethylbenzene	2.76	0.63	0.00	0.00
Formaldehyde	0.00			
H_2S	0.00			
n-Hexane	2.00	0.46	0.00	0.00
Toluene	41.64	9.51	0.02	0.00
Xylenes	38.67	8.83	0.02	0.00
CH_4	74.06	16.91	0.03	0.01
CO_2	3.74	0.86	0.00	0.00

Parameter	Value
Throughput (MMscf/day)	49
Regenerator Flow (scf/day)	802
Regenerator HV (btu/scf)	2074
Flash Tank Flow (scf/day)	107448
Flash Tank HV (btu/scf)	1250
Combustor Control Efficiency	0.98
Fraction Combustor Operation	0.02
VRU Control Efficiency	1
Fraction VRU Operation	0.98

Combustion Emission Factor[3]

Pollutant	Factor	Unit	
CO	0.37	lb/MMbtu	
CO_2[4]	0.30	lb/scf	Regenator
CO_2[4]	0.16	lb/scf	Flash Tank
Formaldehyde	8.10E-05	lb/MMbtu	
NOx	0.14	lb/MMbtu	
PM_{10}	0.007	lb/MMbtu	
$PM_{2.5}$	0.007	lb/MMbtu	
N_2O[5]	1.04E-07	lb/MMbtu	
SO_2	0	lb/MMbtu	

		From Combustor					ton/yr									From Combustor	
Facility	Throughput (MMscf/day)	CO	NOx	PM_{10}	$PM_{2.5}$	SO_2	VOC	Benzene	Ethylbenzene	Formaldehyde	H_2S	n-Hexane	Toluene	Xylenes	CH_4	CO_2	N_2O
1	75	0.28	0.11	0.005	0.005	0	0.10	1.02E-02	1.69E-03	6.16E-05	0	0.00	0.03	0.02	0.05	94.81	7.90E-08
2	50	0.19	0.07	0.004	0.004	0	0.07	6.79E-03	1.12E-03	4.10E-05	0	0.00	0.02	0.02	0.03	63.21	5.27E-08
3	75	0.28	0.11	0.005	0.005	0	0.10	1.02E-02	1.69E-03	6.16E-05	0	0.00	0.03	0.02	0.05	94.81	7.90E-08
4	50	0.19	0.07	0.004	0.004	0	0.07	6.79E-03	1.12E-03	4.10E-05	0	0.00	0.02	0.02	0.03	63.21	5.27E-08
5	50	0.19	0.07	0.004	0.004	0	0.07	6.79E-03	1.12E-03	4.10E-05	0	0.00	0.02	0.02	0.03	63.21	5.27E-08
6	75	0.28	0.11	0.005	0.005	0	0.10	1.02E-02	1.69E-03	6.16E-05	0	0.00	0.03	0.02	0.05	94.81	7.90E-08
7	40	0.15	0.06	0.003	0.003	0	0.06	5.43E-03	9.00E-04	3.28E-05	0	0.00	0.01	0.01	0.02	50.56	4.21E-08
8	50	0.19	0.07	0.004	0.004	0	0.07	6.79E-03	1.12E-03	4.10E-05	0	0.00	0.02	0.02	0.03	63.21	5.27E-08
9	40	0.15	0.06	0.003	0.003	0	0.06	5.43E-03	9.00E-04	3.28E-05	0	0.00	0.01	0.01	0.02	50.56	4.21E-08
10	25	0.09	0.04	0.002	0.002	0	0.03	3.39E-03	5.62E-04	2.05E-05	0	0.00	0.01	0.01	0.02	31.60	2.63E-08
11	10	0.04	0.01	0.001	0.001	0	0.01	1.36E-03	2.25E-04	8.21E-06	0	0.00	0.00	0.00	0.01	12.64	1.05E-08

[1] Data based on GRI-GLYCalc V. 4.0, 49 MMSCFD, max glycol flow rate, average representative gas analysis. See supporting documentation for details.
[2] 100% VRU control efficiency 98% of the operational time and 98% combustor control efficiency 2% of the operational time.
[3] Emission factors taken from WDEQ "Oil and Gas Production Facilities - Chapter 6, Section 2 Permitting Guidance", AP-42 (EPA 1998) Table 1.4-2, and (API 2009).
[4] For composition of vented streams, see 'Material Balance' sheet.
[5] Greenhouse Gas Compendium (API 2009) Table 4-5.

NPL Project Air Quality Assessment Emissions Inventory

Table 43. Pneumatic Venting

Project: Jonah NPL
Scenario: Option 3 - Electric Engines and VRU Control/Combustor backup
Activity: Production
Emissions: Pneumatic Emissions

Pollutant	Weight Fractions[1]	Uncontrolled (tpy)	Uncontrolled (lb/hr)	Controlled[2] (tpy)	Controlled[2] (lb/hr)
VOC	0.00	0.00	0.00	0.00	0.00
HAP	0	0.00	0.00	0.00	0.00
Benzene	0.00E+00	0.00	0.00	0.00	0.00
Ethylbenzene	0.00E+00	0.00	0.00	0.00	0.00
Formaldehyde	0.00E+00				
H_2S	0.00E+00				
n-Hexane	0.00E+00	0.00	0.00	0.00	0.00
Toluene	0.00E+00	0.00	0.00	0.00	0.00
Xylenes	0.00E+00	0.00	0.00	0.00	0.00
CH_4	0.00	0.00	0.00	0.00	0.00
CO_2	0.000	0.00	0.00	0.00	0.00

Model	Flow (scf/hr)	Count	Op Hours
Textsteam 5000 Methai	50	2	4380
Husky-Wilden 1040 Gly	600	5	4380

Parameter	Value	Units
Gas Molecular Weight	18.426	lb/lb-mol
Fuel Heating Value (actual)	0	Btu/scf
Fuel Heating Value (Em. Factor)[1]	1,020	Btu/scf
Combustor Control Efficiency	0.98	
Fraction Combustor Operation	0.02	
VRU Control Efficiency	1	
Fraction VRU Operation	0.98	

Combustor Emission Factor[3]		
CO	0.37	lb/MMbtu
CO_2[4]	0.00	lb/scf
Formaldehyde	8.10E-05	lb/MMbtu
NOx	0.14	lb/MMbtu
PM_{10}	0.007	lb/MMbtu
$PM_{2.5}$	0.007	lb/MMbtu
N_2O[5]	1.04E-07	lb/MMbtu
SO_2	0	lb/MMbtu

ton/yr

Facility	CO (From Combustor)	NOx (From Combustor)	PM_{10} (From Combustor)	$PM_{2.5}$ (From Combustor)	SO_2 (From Combustor)	VOC	Benzene	Ethylbenzen	ormaldehyd	H_2S	n-Hexane	Toluene	Xylenes	CH_4	CO_2 (From Combustor)	N_2O (From Combustor)
1	0.00	0.00	0.00E+00	0.00E+00	0	0.00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00E+00
2	0.00	0.00	0.00E+00	0.00E+00	0	0.00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00E+00
3	0.00	0.00	0.00E+00	0.00E+00	0	0.00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00E+00
4	0.00	0.00	0.00E+00	0.00E+00	0	0.00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00E+00
5	0.00	0.00	0.00E+00	0.00E+00	0	0.00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00E+00
6	0.00	0.00	0.00E+00	0.00E+00	0	0.00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00E+00
7	0.00	0.00	0.00E+00	0.00E+00	0	0.00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00E+00
8	0.00	0.00	0.00E+00	0.00E+00	0	0.00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00E+00
9	0.00	0.00	0.00E+00	0.00E+00	0	0.00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00E+00
10	0.00	0.00	0.00E+00	0.00E+00	0	0.00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00E+00
11	0.00	0.00	0.00E+00	0.00E+00	0	0.00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00E+00

Air or Electric, so no emissions

[1] See 'Material Balance' sheet for gas composition.

[2] 100% VRU control efficiency 98% of the operational time and 98% combustor control efficiency 2% of the operational time.

[3] Emission factors taken from WDEQ "Oil and Gas Production Facilities - Chapter 6, Section 2 Permitting Guidance" and AP-42, Table 1.4-2.

[4] For gas composition, see 'Material Balance' sheet.

[5] Greenhouse Gas Compendium (API 2009) Table 4-5.

NPL Project Air Quality Assessment Emissions Inventory

Table 44. Fugitive Emissions - Per Facility

Project: **Jonah NPL**
Scenario: **All**
Activity: **Production**
Emissions: **Fugitive VOC/HAP Emissions**

Gas Analysis Weight Fraction[1]		**Condensate Analysis Weight Fraction**[1]		**Water Analysis Weight Fraction**[2]		**DI&M Control Efficiency**
VOC	0.11417	VOC	0.98420	VOC	0.29200	75.0%
Benzene	0.00051	Benzene	0.00871	Benzene	0.00052	
Toluene	0.00076	Toluene	0.04993	Toluene	0.00091	
Ethlybenzene	0.00003	Ethlybenzene	0.00682	Ethlybenze	0.00003	
Xylene	0.00028	Xylene	0.05377	Xylene	0.00036	
n-hexane	0.00230	n-hexane	0.01550	n-hexane	0.00131	
CH_4	0.78186	CH_4	0.00807	CH_4	0.00239	
CO_2	0.01281	CO_2	0.00037	CO_2	0.00011	

Source	Service	Quantity	Emission Factor[2] (lb/hr/component)	Non-methane Hydrocarbons[3] (lb/hr)	Non-methane Hydrocarbons (tpy)	Benzene[3] (lb/hr)	Benzene (tpy)	Toluene[3] (lb/hr)	Toluene (tpy)	Ethlybenzene[3] (lb/hr)	Ethlybenzene (tpy)	Xylenes[3] (lb/hr)	Xylenes (tpy)	n-Hexane[3] (lb/hr)	n-Hexane (tpy)	CH_4[3] (lb/hr)	CH_4 (tpy)	CO_2[3] (lb/hr)	CO_2 (tpy)
Valves	Gas	577	0.01	0.1647	0.721	0.00074	0.00323	0.00109	0.00478	0.000044	0.000194	0.00040	0.00177	0.00332	0.0145	1.1278	4.9399	0.0185	0.0810
Flanges	Gas	407	0.000875	0.0102	0.045	0.00005	0.00020	0.00007	0.00030	0.000003	0.000012	0.00002	0.00011	0.00020	0.0009	0.0696	0.3049	0.0011	0.0050
Connections	Gas	5386	0.000458	0.0704	0.308	0.00032	0.00138	0.00047	0.00204	0.000019	0.000083	0.00017	0.00076	0.00142	0.0062	0.4822	2.1119	0.0079	0.0346
Pump seals	Gas	2	0.00542	0.0003	0.001	0.00000	0.00001	0.00000	0.00001	0.000000	0.000000	0.00000	0.00000	0.00001	0.0000	0.0021	0.0093	0.0000	0.0002
Open ended lines	Gas	80	0.004583	0.0105	0.046	0.00005	0.00021	0.00007	0.00030	0.000003	0.000012	0.00003	0.00011	0.00021	0.0009	0.0717	0.3139	0.0012	0.0051
Other	Gas	522	0.01958	0.2917	1.278	0.00131	0.00572	0.00193	0.00847	0.000079	0.000344	0.00072	0.00314	0.00588	0.0258	1.9978	8.7503	0.0327	0.1434
Valves	Light Liquids	40	0.00542	0.0062	0.027	0.00003	0.00012	0.00004	0.00018	0.000002	0.000007	0.00002	0.00007	0.00012	0.0005	0.0424	0.1855	0.0007	0.0030
Flanges	Light Liquids	0	0.00024	0.0000	0.000	0.00000	0.00000	0.00000	0.00000	0.000000	0.000000	0.00000	0.00000	0.00000	0.0000	0.0000	0.0000	0.0000	0.0000
Connections	Light Liquids	1084	0.00046	0.0142	0.062	0.00006	0.00028	0.00009	0.00041	0.000004	0.000017	0.00003	0.00015	0.00029	0.0013	0.0970	0.4250	0.0016	0.0070
Pump seals	Light Liquids	0	0.02875	0.0000	0.000	0.00000	0.00000	0.00000	0.00000	0.000000	0.000000	0.00000	0.00000	0.00000	0.0000	0.0000	0.0000	0.0000	0.0000
Open ended lines	Light Liquids	0	0.00310	0.0000	0.000	0.00000	0.00000	0.00000	0.00000	0.000000	0.000000	0.00000	0.00000	0.00000	0.0000	0.0000	0.0000	0.0000	0.0000
Other	Light Liquids	0	0.01667	0.0000	0.000	0.00000	0.00000	0.00000	0.00000	0.000000	0.000000	0.00000	0.00000	0.00000	0.0000	0.0000	0.0000	0.0000	0.0000
Valves	Water-Oil	108	0.00022	0.0007	0.003	0.00000	0.00001	0.00000	0.00002	0.000000	0.000001	0.00000	0.00001	0.00001	0.0001	0.0046	0.0201	0.0001	0.0003
Flanges	Water-Oil	0	0.00001	0.0000	0.000	0.00000	0.00000	0.00000	0.00000	0.000000	0.000000	0.00000	0.00000	0.00000	0.0000	0.0000	0.0000	0.0000	0.0000
Connections	Water-Oil	1488	0.00024	0.0103	0.045	0.00005	0.00020	0.00007	0.00030	0.000003	0.000012	0.00003	0.00011	0.00021	0.0009	0.0704	0.3083	0.0012	0.0051
Pump seals	Water-Oil	6	0.00005	0.0000	0.000	0.00000	0.00000	0.00000	0.00000	0.000000	0.000000	0.00000	0.00000	0.00000	0.0000	0.0001	0.0003	0.0000	0.0000
Open ended lines	Water-Oil	0	0.00054	0.0000	0.000	0.00000	0.00000	0.00000	0.00000	0.000000	0.000000	0.00000	0.00000	0.00000	0.0000	0.0000	0.0000	0.0000	0.0000
Other	Water-Oil	16	0.03083	0.0141	0.062	0.00006	0.00028	0.00009	0.00041	0.000004	0.000017	0.00003	0.00015	0.00028	0.0012	0.0964	0.4224	0.0016	0.0069
			Total Emissions/Facility	0.5932	2.5980	0.0027	0.0116	0.0039	0.0172	0.0002	0.0007	0.0015	0.0064	0.0120	0.0524	4.0620	17.7917	0.0666	0.2916

[1] See 'Material Balance' sheet.
[1] "Oil and Gas Production Facilities Chapter 6, Section 2 Permitting Guidance" (WDEQ 2010).

Table 45. Fugitive HAPs and VOC - Per Wellhead

Project: Jonah NPL
Scenario: All
Activity: Production
Emissions: Fugitive VOC/HAP Emissions

Gas Analysis Weight Fraction		Condensate Analysis Weight Fraction		Water Analysis Weight Fraction	
VOC	0.11417	VOC	0.98420	VOC	0.29200
Benzene	0.00051	Benzene	0.00871	Benzene	0.00052
Toluene	0.00076	Toluene	0.04993	Toluene	0.00091
Ethlybenzene	0.00003	Ethlybenzene	0.00682	Ethlybenze	0.00003
Xylene	0.00028	Xylene	0.05377	Xylene	0.00036
n-hexane	0.00230	n-hexane	0.01550	n-hexane	0.00131
CH_4	0.78186	CH_4	0.00807	CH_4	0.00239
CO_2	0.01281	CO_2	0.00037	CO_2	0.00011

Source	Service	Quantity	Emission Factor[1] (lb/hr/component)	Non-methane Hydrocarbons[2] (lb/hr)	Non-methane Hydrocarbons (tpy)	Benzene[2] (lb/hr)	Benzene (tpy)	Toluene[2] (lb/hr)	Toluene (tpy)	Ethlybenzene[2] (lb/hr)	Ethlybenzene (tpy)	Xylene[2] (lb/hr)	Xylene (tpy)	n-Hexane[2] (lb/hr)	n-Hexane (tpy)	CH_4[3] (lb/hr)	CH_4 (tpy)	CO_2[3] (lb/hr)	CO_2 (tpy)
Valves	Gas	22	0.01	0.0251	0.110	0.00011	0.00049	0.00017	0.00073	0.000007	0.000030	0.00006	0.00027	0.00051	0.0022	0.1720	0.7534	0.0028	0.0123
Flanges	Gas	15	0.000875	0.0015	0.007	0.00001	0.00003	0.00001	0.00004	0.000000	0.000002	0.00000	0.00002	0.00003	0.0001	0.0103	0.0449	0.0002	0.0007
Connections	Gas	6	0.000458	0.0003	0.001	0.00000	0.00001	0.00000	0.00001	0.000000	0.000000	0.00000	0.00000	0.00001	0.0000	0.0021	0.0094	0.0000	0.0002
Pump seals	Gas	0	0.00542	0.0000	0.000	0.00000	0.00000	0.00000	0.00000	0.000000	0.000000	0.00000	0.00000	0.00000	0.0000	0.0000	0.0000	0.0000	0.0000
Open ended lines	Gas	2	0.004583	0.0010	0.005	0.00000	0.00002	0.00001	0.00003	0.000000	0.000001	0.00000	0.00001	0.00002	0.0001	0.0072	0.0314	0.0001	0.0005
Other	Gas	2	0.01958	0.0045	0.020	0.00002	0.00009	0.00003	0.00013	0.000001	0.000005	0.00001	0.00005	0.00009	0.0004	0.0306	0.1341	0.0005	0.0022
Valves	Light Liquids	0	0.00542	0.0000	0.000	0.00000	0.00000	0.00000	0.00000	0.000000	0.000000	0.00000	0.00000	0.00000	0.0000	0.0000	0.0000	0.0000	0.0000
Flanges	Light Liquids	0	0.00024	0.0000	0.000	0.00000	0.00000	0.00000	0.00000	0.000000	0.000000	0.00000	0.00000	0.00000	0.0000	0.0000	0.0000	0.0000	0.0000
Connections	Light Liquids	0	0.00046	0.0000	0.000	0.00000	0.00000	0.00000	0.00000	0.000000	0.000000	0.00000	0.00000	0.00000	0.0000	0.0000	0.0000	0.0000	0.0000
Pump seals	Light Liquids	0	0.02875	0.0000	0.000	0.00000	0.00000	0.00000	0.00000	0.000000	0.000000	0.00000	0.00000	0.00000	0.0000	0.0000	0.0000	0.0000	0.0000
Open ended lines	Light Liquids	0	0.00310	0.0000	0.000	0.00000	0.00000	0.00000	0.00000	0.000000	0.000000	0.00000	0.00000	0.00000	0.0000	0.0000	0.0000	0.0000	0.0000
Other	Light Liquids	0	0.01667	0.0000	0.000	0.00000	0.00000	0.00000	0.00000	0.000000	0.000000	0.00000	0.00000	0.00000	0.0000	0.0000	0.0000	0.0000	0.0000
Valves	Water-Oil	0	0.00022	0.0000	0.000	0.00000	0.00000	0.00000	0.00000	0.000000	0.000000	0.00000	0.00000	0.00000	0.0000	0.0000	0.0000	0.0000	0.0000
Flanges	Water-Oil	0	0.00001	0.0000	0.000	0.00000	0.00000	0.00000	0.00000	0.000000	0.000000	0.00000	0.00000	0.00000	0.0000	0.0000	0.0000	0.0000	0.0000
Connections	Water-Oil	0	0.00024	0.0000	0.000	0.00000	0.00000	0.00000	0.00000	0.000000	0.000000	0.00000	0.00000	0.00000	0.0000	0.0000	0.0000	0.0000	0.0000
Pump seals	Water-Oil	0	0.00005	0.0000	0.000	0.00000	0.00000	0.00000	0.00000	0.000000	0.000000	0.00000	0.00000	0.00000	0.0000	0.0000	0.0000	0.0000	0.0000
Open ended lines	Water-Oil	0	0.00054	0.0000	0.000	0.00000	0.00000	0.00000	0.00000	0.000000	0.000000	0.00000	0.00000	0.00000	0.0000	0.0000	0.0000	0.0000	0.0000
Other	Water-Oil	0	0.03083	0.0000	0.000	0.00000	0.00000	0.00000	0.00000	0.000000	0.000000	0.00000	0.00000	0.00000	0.0000	0.0000	0.0000	0.0000	0.0000
			Total Emissions/Facility	0.0324	0.1421	0.0001	0.0006	0.0002	0.0009	0.0000	0.0000	0.0001	0.0003	0.0007	0.0029	0.2222	0.9732	0.0036	0.0160

[1] Taken from the WDEQ (2010) "Oil and Gas Production Facilities Chapter 6, Section 2 Permitting Guidance".
[2] Calculated as weight fraction * emissions factor * quantity of source.

Table 46. Condensate Storage Emissions - Per Facility

Project: **Jonah NPL**
Scenario: **Option 3 - Electric Engines and VRU Control/Combustor backup**
Activity: **Production**
Emissions: **Condensate Storage Tanks**

Pollutant	Tank Flash[1]				Working Breathing[2]		Total
	Uncontrolled		Controlled[3]		Uncontrolled	Controlled[3]	Controlled[3]
	(tpy)	(lb/hr)	(tpy)	(lb/hr)	(tpy)	(tpy)	(tpy)
HC	442.60	101.05	0.18	0.04			0.18
VOC	239.30	54.63	0.10	0.02	5.30	0.00	0.10
HAP	7.30	1.67	0.00	0.00			0.00
Benzene	1.40	0.32	0.00	0.00			0.00
Ethylbenzene	0.08	0.02	0.00	0.00			0.00
Formaldehyde	0.00	0.00	0.00	0.00			0.00
H_2S	0.00	0.00	0.00	0.00			0.00
n-Hexane	2.70	0.62	0.00	0.00			0.00
Toluene	2.07	0.47	0.00	0.00			0.00
Xylenes	0.60	0.14	0.00	0.00			0.00
CH_4	111.20	25.39	0.04	0.01			0.04
CO_2	4.90	1.12	0.00	0.00			0.00

Average Condensate Production	294	bbl/day
Flash Gas Flow Rate	1243.33	scf/hr
Flash Gas Heating Value	1780	btu/scf
Oil to Gas Ratio	6	bbl/MMscf
Combustor Control Efficiency	0.98	
Fraction Combustor Operation	0.02	
VRU Control Efficiency	1	
Fraction VRU Operation	0.98	

Combustor Emission Factor[2]		
CO	0.37	lb/MMbtu
CO_2[4]	0.24	lb/scf
Formaldehyde	8.10E-05	lb/MMbtu
NOx	0.14	lb/MMbtu
PM_{10}	0.007	lb/MMbtu
$PM_{2.5}$	0.007	lb/MMbtu
N_2O[5]	1.04E-07	lb/MMbtu
SO_2	0	lb/MMbtu

Facility	Throughput (MMscf/day)	CO (From Combustor)	NOx (From Combustor)	PM_{10} (From Combustor)	$PM_{2.5}$ (From Combustor)	SO_2 (From Combustor)	VOC (ton/yr)	Benzene	Ethylbenzen	Formaldehyd	H_2S	n-Hexane	Toluene	Xylenes	CH_4	CO_2 (From Combustor)	N_2O (From Combustor)
1	75	0.11	0.04	2.08E-03	2.08E-03	0	0.15	8.56E-04	4.72E-05	2.40E-05	0	1.65E-03	1.27E-03	3.67E-04	0.07	0.00	3.09E-08
2	50	0.00	0.00	1.38E-03	1.38E-03	0	0.10	5.70E-04	3.15E-05	1.60E-05	0	1.10E-03	8.47E-04	2.45E-04	0.05	0.00	2.06E-08
3	75	0.00	0.00	2.08E-03	2.08E-03	0	0.15	8.56E-04	4.72E-05	2.40E-05	0	1.65E-03	1.27E-03	3.67E-04	0.07	0.00	3.09E-08
4	50	0.00	0.00	1.38E-03	1.38E-03	0	0.10	5.70E-04	3.15E-05	1.60E-05	0	1.10E-03	8.47E-04	2.45E-04	0.05	0.00	2.06E-08
5	50	0.00	0.00	1.38E-03	1.38E-03	0	0.10	5.70E-04	3.15E-05	1.60E-05	0	1.10E-03	8.47E-04	2.45E-04	0.05	0.00	2.06E-08
6	75	0.00	0.00	2.08E-03	2.08E-03	0	0.15	8.56E-04	4.72E-05	2.40E-05	0	1.65E-03	1.27E-03	3.67E-04	0.07	0.00	3.09E-08
7	40	0.00	0.00	1.11E-03	1.11E-03	0	0.08	4.56E-04	2.52E-05	1.28E-05	0	8.82E-04	6.77E-04	1.96E-04	0.04	0.00	1.65E-08
8	50	0.00	0.00	1.38E-03	1.38E-03	0	0.10	5.70E-04	3.15E-05	1.60E-05	0	1.10E-03	8.47E-04	2.45E-04	0.05	0.00	2.06E-08
9	40	0.00	0.00	1.11E-03	1.11E-03	0	0.08	4.56E-04	2.52E-05	1.28E-05	0	8.82E-04	6.77E-04	1.96E-04	0.04	0.00	1.65E-08
10	25	0.00	0.00	6.92E-04	6.92E-04	0	0.05	2.85E-04	1.57E-05	8.01E-06	0	5.51E-04	4.23E-04	1.22E-04	0.02	0.00	1.03E-08
11	10	0.00	0.00	2.77E-04	2.77E-04	0	0.02	1.14E-04	6.29E-06	3.21E-06	0	2.20E-04	1.69E-04	4.90E-05	0.01	0.00	4.11E-09

[1] HYSYS output based on average of 294 bbl/day. See 'Material Balance' sheet.
[2] Emission factors taken from WDEQ "Oil and Gas Production Facilities - Chapter 6, Section 2 Permitting Guidance" and AP-42, Table 1.4-2.
[3] 100% VRU control efficiency 98% of the operational time and 98% combustor control efficiency 2% of the operational time.
[4] For flash gas composition, see 'Material Balance' sheet.
[5] Greenhouse Gas Compendium (API 2009) Table 4-5.

NPL Project Air Quality Assessment Emissions Inventory

Table 47. Condensate Loading Emissions - Per Facility

Project: Jonah NPL
Scenario: Option 3 - Electric Engines and VRU Control/Combustor backup
Activity: Production
Emissions: Condensate Loading

Average Condensate Loadout Emissions

Uncontrolled Emissions[1]			Controlled Emissions[2]		
CO	0	ton/facility	CO	4.54E-04	ton/facility
NOx	0	ton/facility	NOx	1.72E-04	ton/facility
PM_{10}	0	ton/facility	PM_{10}	8.58E-06	ton/facility
$PM_{2.5}$	0	ton/facility	$PM_{2.5}$	8.58E-06	ton/facility
SO_2	0	ton/facility	SO_2	0.0000	ton/facility
VOC	4.54	ton/facility	VOC	0.0081	ton/facility
Benzene	0.0265	ton/facility	Benzene	2.76E-07	ton/facility
Ethylbenzene	0.0015	ton/facility	Ethylbenzene	8.38E-10	ton/facility
Formaldehyde	0		Formaldehyde	0	ton/facility
H_2S	0		H_2S	0	ton/facility
n-Hexane	0.0512		n-Hexane	1.03E-06	ton/facility
Toluene	0.0394		Toluene	6.07E-07	ton/facility
Xylenes	0.0114		Xylenes	5.08E-08	ton/facility
CH_4	2.1097		CH_4	1.74E-03	ton/facility
CO_2	0		CO_2	0.16	ton/facility
N_2O	0		N_2O	1.28E-10	ton/facility

Average Condensate Production	294	bbl/day
Oil to Gas Ratio	6	bbl/MMscf
Vapor Molecular Weight	50	lb/lb-mol
Vapor Heating Value	1780	btu/scf
Combustor Control Efficiency	0.98	
Fraction Combustor Operation	0.02	
VRU Control Efficiency	1	
Fraction VRU Operation	0.98	

Combustor Emission Factor[3]

CO	0.37	lb/MMbtu
CO_2[4]	0.24	lb/scf
Formaldehyde	8.10E-05	lb/MMbtu
NOx	0.14	lb/MMbtu
PM_{10}	0.007	lb/MMbtu
$PM_{2.5}$	0.007	lb/MMbtu
N_2O[5]	1.04E-07	lb/MMbtu
SO_2	0	lb/MMbtu

181.6
1377.62
2452159

		From Combustor					ton/yr									From Combustor	
Facility	Throughput (MMscf/day)	CO	NOx	PM_{10}	$PM_{2.5}$	SO_2	VOC	Benzene	Ethylbenzen	Formaldehyd	H_2S	n-Hexane	Toluene	Xylenes	CH_4	CO_2	N_2O
1	75	6.94E-04	2.63E-04	1.31E-05	1.31E-05	0	0.012367	4.22E-07	1.28E-09	1.52E-07	0	1.57E-06	9.30E-07	7.77E-08	2.67E-03	0.252503	1.95E-10
2	50	4.63E-04	1.75E-04	8.76E-06	8.76E-06	0	0.008245	2.81E-07	8.56E-10	1.01E-07	0	1.05E-06	6.20E-07	5.18E-08	1.78E-03	0.168336	1.30E-10
3	75	6.94E-04	2.63E-04	1.31E-05	1.31E-05	0	0.012367	4.22E-07	1.28E-09	1.52E-07	0	1.57E-06	9.30E-07	7.77E-08	2.67E-03	0.252503	1.95E-10
4	50	4.63E-04	1.75E-04	8.76E-06	8.76E-06	0	0.008245	2.81E-07	8.56E-10	1.01E-07	0	1.05E-06	6.20E-07	5.18E-08	1.78E-03	0.168336	1.30E-10
5	50	4.63E-04	1.75E-04	8.76E-06	8.76E-06	0	0.008245	2.81E-07	8.56E-10	1.01E-07	0	1.05E-06	6.20E-07	5.18E-08	1.78E-03	0.168336	1.30E-10
6	75	6.94E-04	2.63E-04	1.31E-05	1.31E-05	0	0.012367	4.22E-07	1.28E-09	1.52E-07	0	1.57E-06	9.30E-07	7.77E-08	2.67E-03	0.252503	1.95E-10
7	40	3.70E-04	1.40E-04	7.01E-06	7.01E-06	0	0.006596	2.25E-07	6.84E-10	8.11E-08	0	8.40E-07	4.96E-07	4.15E-08	1.42E-03	0.134668	1.04E-10
8	50	4.63E-04	1.75E-04	8.76E-06	8.76E-06	0	0.008245	2.81E-07	8.56E-10	1.01E-07	0	1.05E-06	6.20E-07	5.18E-08	1.78E-03	0.168336	1.30E-10
9	40	3.70E-04	1.40E-04	7.01E-06	7.01E-06	0	0.006596	2.25E-07	6.84E-10	8.11E-08	0	8.40E-07	4.96E-07	4.15E-08	1.42E-03	0.134668	1.04E-10
10	25	2.31E-04	8.76E-05	4.38E-06	4.38E-06	0	0.004122	1.41E-07	4.28E-10	5.07E-08	0	5.25E-07	3.10E-07	2.59E-08	8.90E-04	0.084168	6.51E-11
11	10	9.26E-05	3.50E-05	1.75E-06	1.75E-06	0	0.001649	5.62E-08	1.71E-10	2.03E-08	0	2.10E-07	1.24E-07	1.04E-08	3.56E-04	0.033667	2.60E-11

1 Based on average of 294 bbl/day production and AP-42 (EPA 1995) Section 5.2 Loadout emissions calculation.
2 100% VRU control efficiency 98% of the operational time and 98% combustor control efficiency 2% of the operational time.
3 Emission factors taken from WDEQ "Oil and Gas Production Facilities - Chapter 6, Section 2 Permitting Guidance" and AP-42 (EPA 2008), Section 5.2.
4 For flash gas composition, see 'Material Balance' sheet.
5 Greenhouse Gas Compendium (API 2009) Table 4-5.

facilities	NOx	VOC
	t/y	t/y
540	#######	0.089

LL= 12.46 * S P M /T

LL = Loading loss (Lb/1,000 gal.), of liquid loaded
S = Saturation factor (from AP-42 Table 5.2-1)
P = True vapor pressure of liquid loaded (psia), (from AP-42 Table 7.1-2)
M = Molecular weight of vapors (Lb/Lb-mole)
T = Temperature of liquid loaded (0R = 460 + 0F)

S= **0.6** (For dedicated Hydrocarbon service)
P= **2.8** True Vapor Pressure (psia) @ T=60 for a RVP=10 fluid
M= **50** Lb/Lb-mole (from composition of vapor phase as per Tanks 4.09)
T= **60** 0F or **520** 0R

LL= 2.0128 Lb/1,000 gal. Loaded

-For a facility making: **0** bbl/yr or **294** bbl/day

LL (TPY) = LL (Lb/1,000 gal) * annual production (bbl/yr) * 42 gal/bbl * 1ton/2000Lbs

Truck Loadout Emissions = 0.0 TPY of VOC

LL (lb/hr) = LL (Lb/1,000 gal) * 240 bbl tank truck * 42 gal/bbl * 1 hr loadout duration

Truck Loadout Emissions = 20.29 lb/hr of VOC

Truck Loadout Emissions = 0.1 TPY of HAP

Truck Loadout Emissions = 0.60 lb/hr of HAP

NPL Project Air Quality Assessment Emissions Inventory

Table 48. Passenger Vehicles

	Construction[1]	Drilling -Completion[2]	Production
	(mile/pad)	(mile/well)	mile/operator)
	12775	1,646	3,650
	Pads	Wells	Operators
	(per year)	(per year)	(per year)
	22	350	28
Total mile/ye	281050	576100	102200

Commuters

	one-way	round trip	no. people	trips/year	total
	(miles)	(miles)			miles/year
Contractors	35	70	60	52	218400
Employees	35	70	28	300	588000

Assume contractors are 50/50 dielsel/gas
Assume workers are CNG
[1] Includes Pad, Road, Pipeline
[2] Includes Tabs 16,17,24&26 (added company man 4/9/2014)

T/year

	NOx	PM10	PM2.5	SO2	CO	VOC	CO2	CH4	N_2O^a	Benzene	Formaldehyde
2013											
Pad											
Gas	0.15	0.01	0.00	0.00	0.78	0.02	68.01	1.12E-03	6.74E-04	8.01E-04	2.97E-04
Diesel	0.33	0.02	0.02	0.00	0.20	0.04	97.53	2.43E-03	2.34E-04	4.52E-04	3.36E-03
Well											
Gas	0.30	0.01	0.01	0.00	1.59	0.05	139.40	2.31E-03	1.38E-03	1.64E-03	6.10E-04
Diesel	0.68	0.05	0.04	0.00	0.42	0.09	199.92	4.99E-03	4.79E-04	9.26E-04	6.90E-03
CNG											
Operators	0.40	0.01	0.00	0.00	4.21	0.00	104.11	2.49E-03	4.49E-03	0.00E+00	0.00E+00

Contractors											
Gas	0.11	0.00	0.00	0.00	0.60	0.02	52.85	8.74E-04	5.24E-04	6.22E-04	2.31E-04
Diesel	0.26	0.02	0.02	0.00	0.16	0.03	75.79	1.89E-03	1.82E-04	3.51E-04	2.61E-03
Employees	2.30	0.03	0.01	0.00	24.23	0.00	598.98	1.43E-02	2.58E-02	0.00E+00	0.00E+00
Total:	4.53	0.14	0.10	0.01	32.20	0.25	1336.58	3.04E-02	3.38E-02	4.79E-03	1.40E-02

2014											
Pad											
Gas	0.13	0.01	0.00	0.00	0.73	0.02	66.81	1.05E-03	6.06E-04	7.23E-04	2.70E-04
Diesel	0.30	0.02	0.02	0.00	0.19	0.04	97.14	2.62E-03	2.34E-04	3.94E-04	2.93E-03
Well											
Gas	0.27	0.01	0.01	0.00	1.50	0.04	136.94	2.16E-03	1.24E-03	1.48E-03	5.53E-04
Diesel	0.61	0.04	0.04	0.00	0.38	0.07	199.11	5.36E-03	4.79E-04	8.07E-04	6.01E-03
CNG											
Operators	0.39	0.01	0.00	0.00	3.93	0.00	104.11	2.30E-03	4.49E-03	0.00E+00	0.00E+00
Contractors											
Gas	0.10	0.00	0.00	0.00	0.57	0.02	51.91	8.18E-04	4.71E-04	5.62E-04	2.09E-04
Diesel	0.23	0.02	0.01	0.00	0.15	0.03	75.48	2.03E-03	1.82E-04	3.06E-04	2.28E-03
Employees	2.27	0.03	0.01	0.00	22.59	0.00	598.98	1.32E-02	2.58E-02	0.00E+00	0.00E+00
Total:	4.31	0.13	0.09	0.01	30.05	0.22	1330.48	2.96E-02	3.35E-02	4.27E-03	1.22E-02
2015											
Pad											
Gas	0.12	0.00	0.00	0.00	0.69	0.02	65.56	9.80E-04	5.46E-04	6.53E-04	2.44E-04
Diesel	0.27	0.02	0.02	0.00	0.17	0.03	96.71	2.78E-03	2.34E-04	3.43E-04	2.55E-03
Well											
Gas	0.25	0.01	0.01	0.00	1.42	0.04	134.38	2.01E-03	1.12E-03	1.34E-03	5.00E-04
Diesel	0.55	0.04	0.03	0.00	0.35	0.06	198.24	5.70E-03	4.79E-04	7.03E-04	5.23E-03
CNG											
Operators	0.39	0.01	0.00	0.00	3.66	0.00	104.11	2.12E-03	4.49E-03	0.00E+00	0.00E+00
Contractors											
Gas	0.09	0.00	0.00	0.00	0.54	0.01	50.94	7.61E-04	4.25E-04	5.08E-04	1.90E-04
Diesel	0.21	0.01	0.01	0.00	0.13	0.02	75.15	2.16E-03	1.82E-04	2.66E-04	1.98E-03
Employees	2.23	0.03	0.01	0.00	21.05	0.00	598.99	1.22E-02	2.58E-02	0.00E+00	0.00E+00
Total:	4.12	0.12	0.08	0.01	28.03	0.19	1324.08	2.87E-02	3.33E-02	3.81E-03	1.07E-02
2016											
Pad											

Gas	0.11	0.00	0.00	0.00	0.65	0.02	64.17	8.89E-04	4.94E-04	5.79E-04	2.23E-03
Diesel	0.25	0.02	0.01	0.00	0.16	0.03	96.20	2.93E-03	2.34E-04	2.99E-04	2.23E-03
Well											
Gas	0.23	0.01	0.01	0.00	1.34	0.04	131.54	1.82E-03	1.01E-03	1.19E-03	4.56E-03
Diesel	0.50	0.03	0.03	0.00	0.33	0.06	197.19	6.01E-03	4.79E-04	6.13E-04	4.56E-03
CNG											
Operators	0.38	0.01	0.00	0.00	3.41	0.00	104.11	1.97E-03	4.49E-03	0.00E+00	0.00E+00
Contractors											
Gas	0.09	0.00	0.00	0.00	0.51	0.01	49.87	6.91E-04	3.84E-04	4.50E-04	1.73E-03
Diesel	0.19	0.01	0.01	0.00	0.12	0.02	74.75	2.28E-03	1.82E-04	2.32E-04	1.73E-03
Employees	2.20	0.03	0.01	0.00	19.64	0.00	598.99	1.13E-02	2.58E-02	0.00E+00	0.00E+00
Total:	3.95	0.11	0.07	0.01	26.17	0.17	1316.81	2.79E-02	3.31E-02	3.36E-03	1.70E-02
2017											
Pad											
Gas	0.10	0.00	0.00	0.00	0.62	0.02	62.88	8.22E-04	4.49E-04	5.23E-04	1.97E-04
Diesel	0.22	0.01	0.01	0.00	0.15	0.02	95.77	3.07E-03	2.34E-04	2.60E-04	1.94E-03
Well											
Gas	0.21	0.01	0.01	0.00	1.28	0.03	128.89	1.68E-03	9.20E-04	1.07E-03	4.04E-04
Diesel	0.46	0.03	0.02	0.00	0.31	0.05	196.31	6.29E-03	4.80E-04	5.33E-04	3.97E-03
CNG											
Operators	0.38	0.01	0.00	0.00	3.20	0.00	104.11	1.85E-03	4.49E-03	0.00E+00	0.00E+00
Contractors											
Gas	0.08	0.00	0.00	0.00	0.49	0.01	48.86	6.38E-04	3.49E-04	4.06E-04	1.53E-04
Diesel	0.17	0.01	0.01	0.00	0.12	0.02	74.42	2.39E-03	1.82E-04	2.02E-04	1.51E-03
Employees	2.18	0.03	0.01	0.00	18.39	0.00	598.99	1.06E-02	2.58E-02	0.00E+00	0.00E+00
Total:	3.80	0.11	0.07	0.01	24.55	0.15	1310.24	2.74E-02	3.29E-02	3.00E-03	8.17E-03
2018											
Pad											
Gas	0.09	0.00	0.00	0.00	0.60	0.01	61.64	7.63E-04	4.09E-04	4.76E-04	1.80E-04
Diesel	0.20	0.01	0.01	0.00	0.14	0.02	95.33	3.20E-03	2.34E-04	2.27E-04	1.69E-03
Well											
Gas	0.19	0.01	0.01	0.00	1.23	0.03	126.35	1.56E-03	8.38E-04	9.75E-04	3.69E-04
Diesel	0.42	0.03	0.02	0.00	0.29	0.04	195.40	6.55E-03	4.80E-04	4.66E-04	3.47E-03
CNG											
Operators	0.37	0.01	0.00	0.00	3.00	0.00	104.11	1.74E-03	4.49E-03	0.00E+00	0.00E+00

Contractors											
Gas	0.07	0.00	0.00	0.00	0.46	0.01	47.90	5.93E-04	3.18E-04	3.70E-04	1.40E-04
Diesel	0.16	0.01	0.01	0.00	0.11	0.02	74.08	2.48E-03	1.82E-04	1.77E-04	1.32E-03
Employees	2.15	0.03	0.01	0.00	17.28	0.00	598.99	1.00E-02	2.58E-02	0.00E+00	0.00E+00
Total:	3.67	0.10	0.06	0.01	23.12	0.13	1303.81	2.69E-02	3.28E-02	2.69E-03	7.17E-03
2019											
Pad											
Gas	0.09	0.00	0.00	0.00	0.57	0.01	60.49	7.07E-04	3.74E-04	4.34E-04	1.65E-04
Diesel	0.19	0.01	0.01	0.00	0.14	0.02	94.87	3.31E-03	2.34E-04	1.99E-04	1.49E-03
Well											
Gas	0.18	0.01	0.01	0.00	1.18	0.03	123.99	1.45E-03	7.66E-04	8.89E-04	3.38E-04
Diesel	0.39	0.02	0.02	0.00	0.28	0.04	194.48	6.78E-03	4.80E-04	4.09E-04	3.05E-03
CNG											
Operators	0.37	0.01	0.00	0.00	2.83	0.00	104.11	1.60E-03	4.49E-03	0.00E+00	0.00E+00
Contractors											
Gas	0.07	0.00	0.00	0.00	0.45	0.01	47.01	5.50E-04	2.90E-04	3.37E-04	1.28E-04
Diesel	0.15	0.01	0.01	0.00	0.11	0.01	73.73	2.57E-03	1.82E-04	1.55E-04	1.15E-03
Employees	2.13	0.03	0.01	0.00	16.30	0.00	598.99	9.23E-03	2.58E-02	0.00E+00	0.00E+00
Total:	3.55	0.10	0.06	0.01	21.85	0.12	1297.67	2.62E-02	3.26E-02	2.42E-03	6.32E-03
2020											
Pad											
Gas	0.08	0.00	0.00	0.00	0.55	0.01	59.43	6.59E-04	3.43E-04	3.98E-04	1.52E-04
Diesel	0.17	0.01	0.01	0.00	0.13	0.02	94.46	3.41E-03	2.34E-04	1.75E-04	1.31E-03
Well											
Gas	0.17	0.01	0.01	0.00	1.13	0.02	121.81	1.35E-03	7.04E-04	8.16E-04	3.11E-04
Diesel	0.36	0.02	0.02	0.00	0.27	0.03	193.62	7.00E-03	4.80E-04	3.59E-04	2.68E-03
CNG											
Operators	0.37	0.01	0.00	0.00	2.68	0.00	104.11	1.49E-03	4.49E-03	0.00E+00	0.00E+00
Contractors											
Gas	0.06	0.00	0.00	0.00	0.43	0.01	46.18	5.12E-04	2.67E-04	3.09E-04	1.18E-04
Diesel	0.13	0.01	0.01	0.00	0.10	0.01	73.40	2.65E-03	1.82E-04	1.36E-04	1.01E-03
Employees	2.11	0.03	0.01	0.00	15.45	0.00	599.00	8.56E-03	2.58E-02	0.00E+00	0.00E+00
Total:	3.45	0.09	0.05	0.01	20.76	0.11	1292.01	2.56E-02	3.25E-02	2.19E-03	5.58E-03
2021											
Pad											

Gas	0.07	0.00	0.00	0.00	0.54	0.01	58.44	6.26E-04	3.17E-04	3.66E-04	1.40E-04
Diesel	0.16	0.01	0.01	0.00	0.13	0.01	94.07	3.51E-03	2.34E-04	1.54E-04	1.15E-03
Well											
Gas	0.15	0.01	0.01	0.00	1.10	0.02	119.79	1.28E-03	6.50E-04	7.51E-04	2.87E-04
Diesel	0.33	0.02	0.01	0.00	0.27	0.03	192.83	7.19E-03	4.80E-04	3.16E-04	2.36E-03
CNG											
Operators	0.36	0.01	0.00	0.00	2.55	0.00	104.11	1.42E-03	4.49E-03	0.00E+00	0.00E+00
Contractors											
Gas	0.06	0.00	0.00	0.00	0.42	0.01	45.41	4.86E-04	2.46E-04	2.85E-04	1.09E-04
Diesel	0.13	0.01	0.01	0.00	0.10	0.01	73.10	2.72E-03	1.82E-04	1.20E-04	8.93E-04
Employees	2.10	0.03	0.01	0.00	14.69	0.00	599.00	8.16E-03	2.58E-02	0.00E+00	0.00E+00
Total:	3.37	0.09	0.05	0.01	19.80	0.10	1286.76	2.54E-02	3.24E-02	1.99E-03	4.94E-03
2022											
Pad											
Gas	0.07	0.00	0.00	0.00	0.52	0.01	57.55	5.99E-04	2.94E-04	3.39E-04	1.30E-04
Diesel	0.15	0.01	0.01	0.00	0.13	0.01	93.72	3.58E-03	2.34E-04	1.36E-04	1.01E-03
Well											
Gas	0.14	0.01	0.01	0.00	1.07	0.02	117.97	1.23E-03	6.03E-04	6.96E-04	2.67E-04
Diesel	0.31	0.02	0.01	0.00	0.26	0.03	192.10	7.35E-03	4.80E-04	2.79E-04	2.07E-03
CNG											
Operators	0.36	0.01	0.00	0.00	2.44	0.00	104.11	1.36E-03	4.49E-03	0.00E+00	0.00E+00
Contractors											
Gas	0.05	0.00	0.00	0.00	0.41	0.01	44.72	4.66E-04	2.29E-04	2.64E-04	1.01E-04
Diesel	0.12	0.01	0.00	0.00	0.10	0.01	72.83	2.79E-03	1.82E-04	1.06E-04	7.86E-04
Employees	2.09	0.03	0.01	0.00	14.03	0.00	599.00	7.82E-03	2.58E-02	0.00E+00	0.00E+00
Total:	3.29	0.09	0.05	0.01	18.95	0.09	1282.00	2.52E-02	3.23E-02	1.82E-03	4.37E-03
2023											
Pad											
Gas	0.07	0.00	0.00	0.00	0.51	0.01	56.74	5.69E-04	2.74E-04	3.16E-04	1.22E-04
Diesel	0.14	0.01	0.01	0.00	0.12	0.01	93.39	3.65E-03	2.34E-04	1.20E-04	8.93E-04
Well											
Gas	0.13	0.01	0.01	0.00	1.04	0.02	116.30	1.17E-03	5.62E-04	6.47E-04	2.50E-04
Diesel	0.29	0.02	0.01	0.00	0.25	0.02	191.43	7.48E-03	4.80E-04	2.46E-04	1.83E-03
CNG											
Operators	0.36	0.01	0.00	0.00	2.33	0.00	104.11	1.28E-03	4.49E-03	0.00E+00	0.00E+00

Contractors											
Gas	0.05	0.00	0.00	0.00	0.39	0.01	44.09	4.42E-04	2.13E-04	2.45E-04	9.47E-05
Diesel	0.11	0.01	0.00	0.00	0.10	0.01	72.57	2.84E-03	1.82E-04	9.31E-05	6.94E-04
Employees	2.07	0.03	0.01	0.00	13.41	0.00	599.01	7.36E-03	2.58E-02	0.00E+00	0.00E+00
Total:	3.22	0.08	0.04	0.01	18.15	0.08	1277.63	2.48E-02	3.22E-02	1.67E-03	3.88E-03
2024											
Pad											
Gas	0.06	0.00	0.00	0.00	0.49	0.01	55.99	5.32E-04	2.56E-04	2.93E-04	1.14E-04
Diesel	0.13	0.01	0.00	0.00	0.12	0.01	93.11	3.71E-03	2.34E-04	1.06E-04	7.87E-04
Well											
Gas	0.13	0.01	0.01	0.00	1.01	0.02	114.77	1.09E-03	5.24E-04	6.00E-04	2.33E-04
Diesel	0.27	0.01	0.01	0.00	0.25	0.02	190.85	7.60E-03	4.80E-04	2.17E-04	1.61E-03
CNG											
Operators	0.36	0.01	0.00	0.00	2.22	0.00	104.11	1.18E-03	4.49E-03	0.00E+00	0.00E+00
Contractors											
Gas	0.05	0.00	0.00	0.00	0.38	0.01	43.51	4.13E-04	1.99E-04	2.27E-04	8.82E-05
Diesel	0.10	0.01	0.00	0.00	0.09	0.01	72.35	2.88E-03	1.82E-04	8.21E-05	6.11E-04
Employees	2.06	0.03	0.01	0.00	12.78	0.00	599.01	6.77E-03	2.58E-02	0.00E+00	0.00E+00
Total:	3.16	0.08	0.04	0.01	17.36	0.07	1273.71	2.42E-02	3.22E-02	1.52E-03	3.45E-03
2025											
Pad											
Gas	0.06	0.00	0.00	0.00	0.48	0.01	55.32	5.01E-04	2.39E-04	2.72E-04	1.06E-04
Diesel	0.12	0.01	0.00	0.00	0.12	0.01	92.83	3.75E-03	2.34E-04	9.36E-05	6.97E-04
Well											
Gas	0.12	0.01	0.01	0.00	0.98	0.02	113.39	1.03E-03	4.91E-04	5.57E-04	2.17E-04
Diesel	0.25	0.01	0.01	0.00	0.25	0.02	190.28	7.70E-03	4.80E-04	1.92E-04	1.43E-03
CNG											
Operators	0.36	0.01	0.00	0.00	2.14	0.00	104.11	1.10E-03	4.49E-03	0.00E+00	0.00E+00
Contractors											
Gas	0.05	0.00	0.00	0.00	0.37	0.01	42.99	3.89E-04	1.86E-04	2.11E-04	8.23E-05
Diesel	0.10	0.01	0.00	0.00	0.09	0.01	72.13	2.92E-03	1.82E-04	7.28E-05	5.42E-04
Employees	2.05	0.03	0.01	0.00	12.29	0.00	599.01	6.32E-03	2.58E-02	0.00E+00	0.00E+00
Total:	3.10	0.08	0.04	0.01	16.73	0.06	1270.06	2.37E-02	3.21E-02	1.40E-03	3.07E-03

Notes: Fuel - assume construction, drilling and completion vehicles

will be 50% gasoline and 50% diesel. Production vehicles
will be compressed natural gas.

Mobile Source - Moves run for 2013-2005, WY
Emission factors for Commuting Vehicles Exhau

Emission Factors for Commuting Vehicles											
Emission Factors (gm/mile)											
Year	**NOx**	**PM10**	**PM2.5**	**SO2**	**CO**	**VOC**	**CO2**	**CH_4**	**N_2O^a**	**Benzene**	**Form**
2013											
LDGT2	0.94	0.03	0.02	0.01	5.01	0.15	439.03	0.01	0.00	0.01	0.00
LDDT	2.14	0.15	0.13	0.00	1.32	0.27	629.63	0.02	0.00	0.00	0.02
CNG (transi	3.55	0.05	0.02	0.00	37.38	0.00	924.14	0.02	0.04	0.00	0.00
2014											
LDGT2	0.86	0.03	0.02	0.01	4.74	0.14	431.28	0.01	0.00	0.00	0.00
LDDT	1.93	0.13	0.11	0.00	1.21	0.23	627.09	0.02	0.00	0.00	0.02
CNG (transi	3.50	0.05	0.02	0.00	34.86	0.00	924.14	0.02	0.04	0.00	0.00
2015											
LDGT2	0.79	0.03	0.02	0.01	4.48	0.12	423.22	0.01	0.00	0.00	0.00
LDDT	1.74	0.11	0.10	0.00	1.11	0.20	624.34	0.02	0.00	0.00	0.02
CNG (transi	3.45	0.05	0.02	0.00	32.48	0.00	924.15	0.02	0.04	0.00	0.00
2016											
LDGT2	0.72	0.03	0.02	0.01	4.23	0.11	414.27	0.01	0.00	0.00	0.01
LDDT	1.58	0.10	0.09	0.00	1.04	0.18	621.03	0.02	0.00	0.00	0.01
CNG (transi	3.40	0.05	0.02	0.00	30.30	0.00	924.15	0.02	0.04	0.00	0.00
2017											
LDGT2	0.66	0.03	0.02	0.01	4.03	0.10	405.94	0.01	0.00	0.00	0.00
LDDT	1.44	0.09	0.07	0.00	0.97	0.15	618.27	0.02	0.00	0.00	0.01
CNG (transi	3.36	0.05	0.02	0.00	28.37	0.00	924.16	0.02	0.04	0.00	0.00
2018											
LDGT2	0.61	0.03	0.02	0.01	3.86	0.09	397.94	0.00	0.00	0.00	0.00
LDDT	1.32	0.08	0.06	0.00	0.92	0.14	615.41	0.02	0.00	0.00	0.01
CNG (transi	3.32	0.05	0.02	0.00	26.66	0.00	924.16	0.02	0.04	0.00	0.00
2019											
LDGT2	0.56	0.03	0.02	0.01	3.70	0.08	390.51	0.00	0.00	0.00	0.00
LDDT	1.21	0.07	0.06	0.00	0.88	0.12	612.49	0.02	0.00	0.00	0.01
CNG (transi	3.29	0.05	0.02	0.00	25.14	0.00	924.16	0.01	0.04	0.00	0.00
2020											
LDGT2	0.52	0.03	0.02	0.01	3.57	0.08	383.65	0.00	0.00	0.00	0.00
LDDT	1.12	0.07	0.05	0.00	0.86	0.10	609.78	0.02	0.00	0.00	0.01
CNG (transi	3.26	0.05	0.02	0.00	23.83	0.00	924.17	0.01	0.04	0.00	0.00

2021											
LDGT2	0.48	0.03	0.02	0.01	3.46	0.07	377.28	0.00	0.00	0.00	0.00
LDDT	1.04	0.06	0.05	0.00	0.84	0.09	607.30	0.02	0.00	0.00	0.01
CNG	3.24	0.05	0.02	0.00	22.67	0.00	924.18	0.01	0.04	0.00	0.00
2022											
LDGT2	0.45	0.03	0.02	0.01	3.37	0.07	371.53	0.00	0.00	0.00	0.00
LDDT	0.97	0.05	0.04	0.00	0.82	0.08	605.02	0.02	0.00	0.00	0.01
CNG	3.22	0.05	0.02	0.00	21.65	0.00	924.18	0.01	0.04	0.00	0.00
2023											
LDGT2	0.43	0.03	0.02	0.01	3.27	0.06	366.28	0.00	0.00	0.00	0.00
LDDT	0.90	0.05	0.04	0.00	0.80	0.07	602.89	0.02	0.00	0.00	0.01
CNG	3.20	0.05	0.02	0.00	20.68	0.00	924.18	0.01	0.04	0.00	0.00
2024											
LDGT2	0.40	0.03	0.02	0.01	3.18	0.06	361.47	0.00	0.00	0.00	0.00
LDDT	0.85	0.05	0.03	0.00	0.79	0.06	601.08	0.02	0.00	0.00	0.01
CNG	3.18	0.05	0.02	0.00	19.73	0.00	924.19	0.01	0.04	0.00	0.00
2025											
LDGT2	0.37	0.03	0.02	0.01	3.10	0.05	357.13	0.00	0.00	0.00	0.00
LDDT	0.80	0.04	0.03	0.00	0.78	0.06	599.27	0.02	0.00	0.00	0.00
CNG	3.16	0.05	0.01	0.00	18.97	0.00	924.19	0.01	0.04	0.00	0.00

NPL Project Air Quality Assessment Emissions Inventory

Table 49. Construction Summary

	ton																Pads per
per	CO	NOx	PM_{10}	$PM_{2.5}$	SO_2	VOC	Benzene	Ethylbenzene	Formaldehyde	H_2S	n-Hexane	Toluene	Xylenes	CH_4	CO_2	N_2O	year
Pad/Road/Pipeline	0.39	0.70	1.32	0.26	0.02	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	84.44	0.00	22
Facility	0.04	0.11	0.50	0.06	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.90	0.00	

	ton																	Facility
Year	CO	NOx	PM_{10}	$PM_{2.5}$	SO_2	VOC	Benzene	Ethylbenzene	Formaldehyde	H_2S	n-Hexane	Toluene	Xylenes	CH_4	CO_2	N_2O	CO2e	
2015	8.6	15.8	30.6	5.8	0.4	1.9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.1	1,902	4.7E-02	1,919	3
2016	8.6	15.7	30.1	5.7	0.4	1.9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.1	1,888	4.7E-02	1,904	2
2017	8.6	15.6	29.6	5.7	0.4	1.9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.1	1,873	4.6E-02	1,889	1
2018	8.6	15.7	30.1	5.7	0.4	1.9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.1	1,888	4.7E-02	1,904	2
2019	8.5	15.5	29.1	5.6	0.4	1.9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.1	1,858	4.6E-02	1,874	0
2020	8.6	15.6	29.6	5.7	0.4	1.9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.1	1,873	4.6E-02	1,889	1
2021	8.6	15.6	29.6	5.7	0.4	1.9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.1	1,873	4.6E-02	1,889	1
2022	8.5	15.5	29.1	5.6	0.4	1.9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.1	1,858	4.6E-02	1,874	0
2023	8.6	15.6	29.6	5.7	0.4	1.9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.1	1,873	4.6E-02	1,889	1
2024	8.5	15.5	29.1	5.6	0.4	1.9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.1	1,858	4.6E-02	1,874	0

NPL Project Air Quality Assessment Emissions Inventory

Table 50. Drilling Summary

Wells/Pad 16

Combined ton

	CO	NOx	PM_{10}	$PM_{2.5}$	SO_2	VOC	Benzene	Ethylbenzene	Formaldehyde	H_2S	n-Hexane	Toluene	Xylenes	CH_4	CO_2	N_2O	Pads	Acetaldehyde	Acrolein	Methanol
Per Pad	25.9	20.1	39.2	5.6	0.4	1.8	0.0	0.0	1.7	0.0	0.0	0.0	0.0	35.0	4138.2	0.0	22.0	0.09	0.05	0.02
						per pad														

Drilling ton

	CO	NOx	PM_{10}	$PM_{2.5}$	SO_2	VOC	Benzene	Ethylbenzene	Formaldehyde	H_2S	n-Hexane	Toluene	Xylenes	CH_4	CO_2	N_2O	Pads	Acetaldehyde	Acrolein	Methanol
Per Pad	24.23	12.36	8.96	0.98	0.08	1.41	0.01	0.00	1.66	0.00	0.03	0.01	0.00	34.52	3109.93	0.01	22.0	0.08	0.05	0.02

yes, per pad

Completion ton

	CO	NOx	PM_{10}	$PM_{2.5}$	SO_2	VOC	Benzene	Ethylbenzene	Formaldehyde	H_2S	n-Hexane	Toluene	Xylenes	CH_4	CO_2	N_2O	Pads	Acetaldehyde	Acrolein	Methanol
Per Pad	1.7	7.7	30.2	4.6	0.4	0.4	5.82E-03	0.0	8.99E-03	0.0	0.0	0.0	0.0	0.5	1028.2	0.0	22.0	4.3E-03	5.1E-04	0.0E+00

per pad

Commuter

2015	28.03	4.12	0.12	0.08	0.01	0.19	3.81E-03		1.07E-02					0.03	1324.08	0.03
2016	26.17	3.95	0.11	0.07	0.01	0.17	3.36E-03		1.70E-02					0.03	1316.81	0.03
2017	24.55	3.80	0.11	0.07	0.01	0.15	3.00E-03		8.17E-03					0.03	1310.24	0.03
2018	23.12	3.67	0.10	0.06	0.01	0.13	2.69E-03		7.17E-03					0.03	1303.81	0.03
2019	21.85	3.55	0.10	0.06	0.01	0.12	2.42E-03		6.32E-03					0.03	1297.67	0.03
2020	20.76	3.45	0.09	0.05	0.01	0.11	2.19E-03		5.58E-03					0.03	1292.01	0.03
2021	19.80	3.37	0.09	0.05	0.01	0.10	1.99E-03		4.94E-03					0.03	1286.76	0.03
2022	18.95	3.29	0.09	0.05	0.01	0.09	1.82E-03		4.37E-03					0.03	1282.00	0.03
2023	18.15	3.22	0.08	0.04	0.01	0.08	1.67E-03		3.88E-03					0.02	1277.63	0.03
2024	17.36	3.16	0.08	0.04	0.01	0.07	1.52E-03		3.45E-03					0.02	1273.71	0.03

ton

Year	CO	NOx	PM_{10}	$PM_{2.5}$	SO_2	VOC	Benzene	Ethylbenzene	Formaldehyde	H_2S	n-Hexane	Toluene	Xylenes	CH_4	CO_2	N_2O	CO2e	Acetaldehyde	Acrolein	Methanol	Pads	Wells
2015	125	79	147	21	1.6	7.1	0.1	0.0	6.3	0.0	0.1	0.0	0.0	131	16,842	9.5E-02	20,152	0.3	0.2	0.1		60
2016	318	230	441	63	4.8	20.9	0.2	0.0	18.8	0.0	0.3	0.1	0.1	394	47,871	2.2E-01	57,780	1.0	0.6	0.3		180
2017	413	305	588	84	6.4	27.8	0.3	0.0	25.0	0.0	0.4	0.2	0.1	525	63,383	2.8E-01	76,591	1.3	0.8	0.4		240
2018	590	443	857	122	9.4	40.4	0.4	0.0	36.5	0.0	0.6	0.3	0.1	766	91,826	3.9E-01	111,084	1.9	1.1	0.5		350
2019	588	443	857	122	9.4	40.4	0.4	0.0	36.5	0.0	0.6	0.3	0.1	766	91,820	3.9E-01	111,077	1.9	1.1	0.5		350
2020	587	443	857	122	9.4	40.4	0.4	0.0	36.5	0.0	0.6	0.3	0.1	766	91,814	3.9E-01	111,072	1.9	1.1	0.5		350
2021	586	443	857	122	9.4	40.4	0.4	0.0	36.5	0.0	0.6	0.3	0.1	766	91,809	3.9E-01	111,066	1.9	1.1	0.5		350
2022	586	443	857	122	9.4	40.4	0.4	0.0	36.5	0.0	0.6	0.3	0.1	766	91,804	3.9E-01	111,062	1.9	1.1	0.5		350
2023	585	442	857	122	9.4	40.4	0.4	0.0	36.5	0.0	0.6	0.3	0.1	766	91,800	3.9E-01	111,057	1.9	1.1	0.5		350
2024	584	442	857	122	9.4	40.4	0.4	0.0	36.5	0.0	0.6	0.3	0.1	766	91,796	3.9E-01	111,053	1.9	1.1	0.5		350

Table 51. Production Summary

Option - Electric Engines and VRU control of Vent Streams with Flare Backup

ton

Facility	CO	NOx	PM_{10}	$PM_{2.5}$	SO_2	VOC	Benzene	Ethylbenzene	Formaldehyde	H_2S	n-Hexane	Toluene	Xylenes	CH_4	CO_2	N_2O	Year
1	0.6	0.7	14.5	1.5	0.0	3.1	0.02	0.002	0.005	0.000	0.058	0.045	0.031	18.81	304.8	0.000	1
2	0.4	0.7	14.5	1.5	0.0	2.9	0.02	0.002	0.005	0.000	0.056	0.036	0.023	18.47	273.2	0.000	1
3	0.5	0.7	14.5	1.5	0.0	3.1	0.02	0.002	0.005	0.000	0.058	0.045	0.031	18.81	304.8	0.000	1
4	0.4	0.7	14.5	1.5	0.0	2.9	0.02	0.002	0.005	0.000	0.056	0.036	0.023	18.47	273.2	0.000	2
5	0.4	0.7	14.5	1.5	0.0	2.9	0.02	0.002	0.005	0.000	0.056	0.036	0.023	18.47	273.2	0.000	2
6	0.5	0.7	14.5	1.5	0.0	3.1	0.02	0.002	0.005	0.000	0.058	0.045	0.031	18.81	304.8	0.000	3
7	0.4	0.6	14.5	1.5	0.0	2.9	0.02	0.002	0.005	0.000	0.056	0.032	0.019	18.46	260.5	0.000	4
8	0.4	0.7	14.5	1.5	0.0	2.9	0.02	0.002	0.005	0.000	0.056	0.036	0.023	18.47	273.2	0.000	4
9	0.4	0.6	14.5	1.5	0.0	2.9	0.02	0.002	0.005	0.000	0.056	0.032	0.019	18.46	260.5	0.000	6
10	0.3	0.6	14.5	1.5	0.0	2.8	0.02	0.001	0.005	0.000	0.054	0.026	0.015	18.14	241.5	0.000	7
11	0.3	0.6	14.5	1.5	0.0	2.7	0.01	0.001	0.005	0.000	0.054	0.021	0.010	18.12	222.5	0.000	9

Blowdown

Per Pad	0.00	0.00	0.00	0.00	0.00	1.07	0.00	0.00	0.00	0.00	0.02	0.01	0.00	7.33	0.12	0.00	22	Pad/year

Wind Erosion Production

Year			PM_{10}	$PM_{2.5}$			Facility cummulativ	pads
2015			57.03	8.55			3	22
2016			112.65	16.90			5	44
2017			166.87	25.03			6	66
2018			222.49	33.37			8	88
2019			275.31	41.30			8	110
2020			329.53	49.43			9	132
2021			383.74	57.56			10	154
2022			436.56	65.48			10	176
2023			490.78	73.62			11	198
2024			543.59	81.54			11	220

ton

Year	CO	NOx	PM_{10}	$PM_{2.5}$	SO_2	VOC	Benzene	Ethylbenzene	Formaldehyde	H_2S	n-Hexane	Toluene	Xylenes	CH_4	CO_2	N_2O	CO2e
2015	1.6	2.1	100	13.2	0.0	82	0.4	0.0	0.014	0.0	1.6	0.6	0.3	558	886	1.4E-03	14,835
2016	2.4	3.4	185	24.6	0.0	161	0.8	0.1	0.023	0.0	3.2	1.2	0.5	1,097	1,446	2.3E-03	28,866
2017	2.9	4.1	254	34.3	0.0	238	1.1	0.1	0.028	0.0	4.8	1.7	0.7	1,617	1,759	2.8E-03	42,197
2018	3.8	5.4	338	45.7	0.0	317	1.5	0.1	0.037	0.0	6.4	2.3	0.9	2,156	2,301	3.7E-03	56,209
2019	3.8	5.4	391	53.6	0.0	390	1.8	0.1	0.037	0.0	7.8	2.7	1.1	2,658	2,309	3.7E-03	68,764
2020	4.1	6.1	460	63.3	0.0	466	2.2	0.1	0.042	0.0	9.4	3.3	1.3	3,179	2,578	4.2E-03	82,042
2021	4.5	6.7	529	73.0	0.0	542	2.5	0.2	0.047	0.0	10.9	3.8	1.5	3,699	2,827	4.6E-03	95,292
2022	4.5	6.7	581	80.9	0.0	616	2.8	0.2	0.047	0.0	11.4	4.3	1.7	4,200	2,835	4.6E-03	107,847
2023	4.8	7.3	650	90.6	0.0	692	3.2	0.2	0.051	0.0	13.9	4.8	1.9	4,720	3,066	5.1E-03	121,078
2024	4.8	7.3	703	98.5	0.0	765	3.5	0.2	0.051	0.0	15.4	5.2	2.0	5,222	3,074	5.1E-03	133,633

Well fugitives - add to production above

Year	Wells/ye	350						Tons							
1						49.7	0.2	0.0			1.0	0.3	0.1	340.6	5.6
2						99.5	0.4	0.0			2.0	0.7	0.2	681.3	11.2
3						149.2	0.7	0.0			3.0	1.0	0.4	1021.9	16.7
4						199.0	0.9	0.1			4.0	1.3	0.5	1362.5	22.3
5						248.7	1.1	0.1			5.0	1.6	0.6	1703.2	27.9
6						298.4	1.3	0.1			6.0	2.0	0.7	2043.8	33.5
7						348.2	1.6	0.1			7.0	2.3	0.9	2384.5	39.1
8						397.9	1.8	0.1			8.0	2.6	1.0	2725.1	44.7
9						447.7	2.0	0.1			9.0	3.0	1.1	3065.7	50.2
10						497.4	2.2	0.1			10.0	3.3	1.2	3406.4	55.8

NPL Project Air Quality Assessment Emissions Inventory

Table 52. Overall Summary

Option - Electric Engines and VRU control of Vent Streams with Flare Backup

ton

Year	CO	NOx	PM_{10}	$PM_{2.5}$	SO_2	VOC	Benzene	Ethylbenzene	Formaldehyde	H_2S	n-Hexane	Toluene	Xylenes	CH_4	CO_2	N_2O	CO2e	Acetaldehyde	Acrolein	Methanol
2015	135	97	278	40	2.0	91	0.5	0.0	6.3	0.0	1.8	0.7	0.3	689	19630	0.1	36,907	0.3	0.2	0.1
2016	329	249	656	93	5.2	184	1.0	0.1	18.8	0.0	3.5	1.3	0.6	1491	51204	0.3	88,551	1.0	0.6	0.3
2017	425	325	871	124	6.8	267	1.4	0.1	25.1	0.0	5.2	1.9	0.8	2143	67014	0.3	120,677	1.3	0.8	0.4
2018	602	464	1226	174	9.8	359	1.9	0.1	36.6	0.0	7.0	2.5	1.1	2922	96014	0.4	169,197	1.9	1.1	0.5
2019	601	464	1277	181	9.8	432	2.2	0.1	36.6	0.0	8.4	3.0	1.2	3424	95987	0.4	181,716	1.9	1.1	0.5
2020	600	464	1347	191	9.8	509	2.5	0.2	36.6	0.0	10.0	3.5	1.4	3944	96265	0.4	195,002	1.9	1.1	0.5
2021	599	465	1415	201	9.8	585	2.9	0.2	36.6	0.0	11.5	4.0	1.6	4464	96509	0.4	208,247	1.9	1.1	0.5
2022	599	465	1468	209	9.8	658	3.2	0.2	36.6	0.0	12.0	4.5	1.8	4966	96498	0.4	220,782	1.9	1.1	0.5
2023	598	465	1537	218	9.8	734	3.6	0.2	36.6	0.0	14.5	5.0	2.0	5486	96739	0.4	234,024	1.9	1.1	0.5
2024	597	465	1589	226	9.8	807	3.9	0.2	36.6	0.0	16.0	5.5	2.2	5988	96728	0.4	246,560	1.9	1.1	0.5
Year	CO	NOx	PM_{10}	$PM_{2.5}$	SO_2	VOC	Benzene	Ethylbenzene	Formaldehyde	H_2S	n-Hexane	Toluene	Xylenes	CH_4	CO_2	N_2O	CO2e	Acetaldehyde	Acrolein	Methanol

NPL Project Air Quality Assessment Emissions Inventory

PLOT DATA

CO (tons)

Year	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Construction	8.63	8.59	8.55	8.59	8.51	8.55	8.55	8.51	8.55	8.51
Drilling	125.16	317.57	413.08	589.73	588.46	587.36	586.40	585.56	584.76	583.96
Production	1.57	2.42	2.94	3.76	3.76	4.15	4.48	4.48	4.75	4.75

NOx (tons)

Year	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Construction	15.82	15.71	15.60	15.71	15.49	15.60	15.60	15.49	15.60	15.49
Drilling	79.42	229.83	304.97	442.88	442.77	442.67	442.58	442.50	442.43	442.37
Production	2.10	3.43	4.13	5.44	5.44	6.09	6.71	6.71	7.32	7.32

PM10 (tons)

Year	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Construction	30.62	30.12	29.62	30.12	29.12	29.62	29.62	29.12	29.62	29.12
Drilling	147.05	440.89	587.80	857.16	857.16	857.15	857.15	857.14	857.14	857.14
Production	100.47	185.05	253.74	338.32	391.13	459.83	528.52	581.33	650.02	702.84

PM2.5 (tons)

Year	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Construction	5.80	5.74	5.68	5.74	5.62	5.68	5.68	5.62	5.68	5.62
Drilling	20.99	62.82	83.72	122.06	122.06	122.05	122.05	122.05	122.04	122.04
Production	13.19	24.62	34.30	45.73	53.65	63.32	73.00	80.92	90.59	98.51

VOC (tons)

Year	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Construction	1.90	1.89	1.88	1.89	1.87	1.88	1.88	1.87	1.88	1.87

Drilling	7.11	20.90	27.79	40.44	40.43	40.42	40.41	40.40	40.39	40.38
Production	82.32	161.45	237.80	316.89	390.18	466.35	542.43	615.72	691.74	765.03

CH4 (tons)

Year	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Construction	0.11	0.11	0.10	0.11	0.10	0.10	0.10	0.10	0.10	0.10
Drilling	131.27	393.75	525.00	765.61	765.61	765.60	765.60	765.60	765.60	765.60
Production	557.97	1096.80	1617.49	2156.30	2658.18	3178.51	3698.53	4200.41	4720.40	5222.27

CO2 (tons)

Year	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Construction	1902.45	1887.55	1872.65	1887.55	1857.75	1872.65	1872.65	1857.75	1872.65	1857.75
Drilling	16842.22	47871.23	63382.79	91826.28	91820.15	91814.49	91809.24	91804.48	91800.11	91796.19
Production	885.62	1445.62	1758.70	2300.57	2308.79	2577.50	2827.19	2835.42	3066.10	3074.32

N2O (tons)

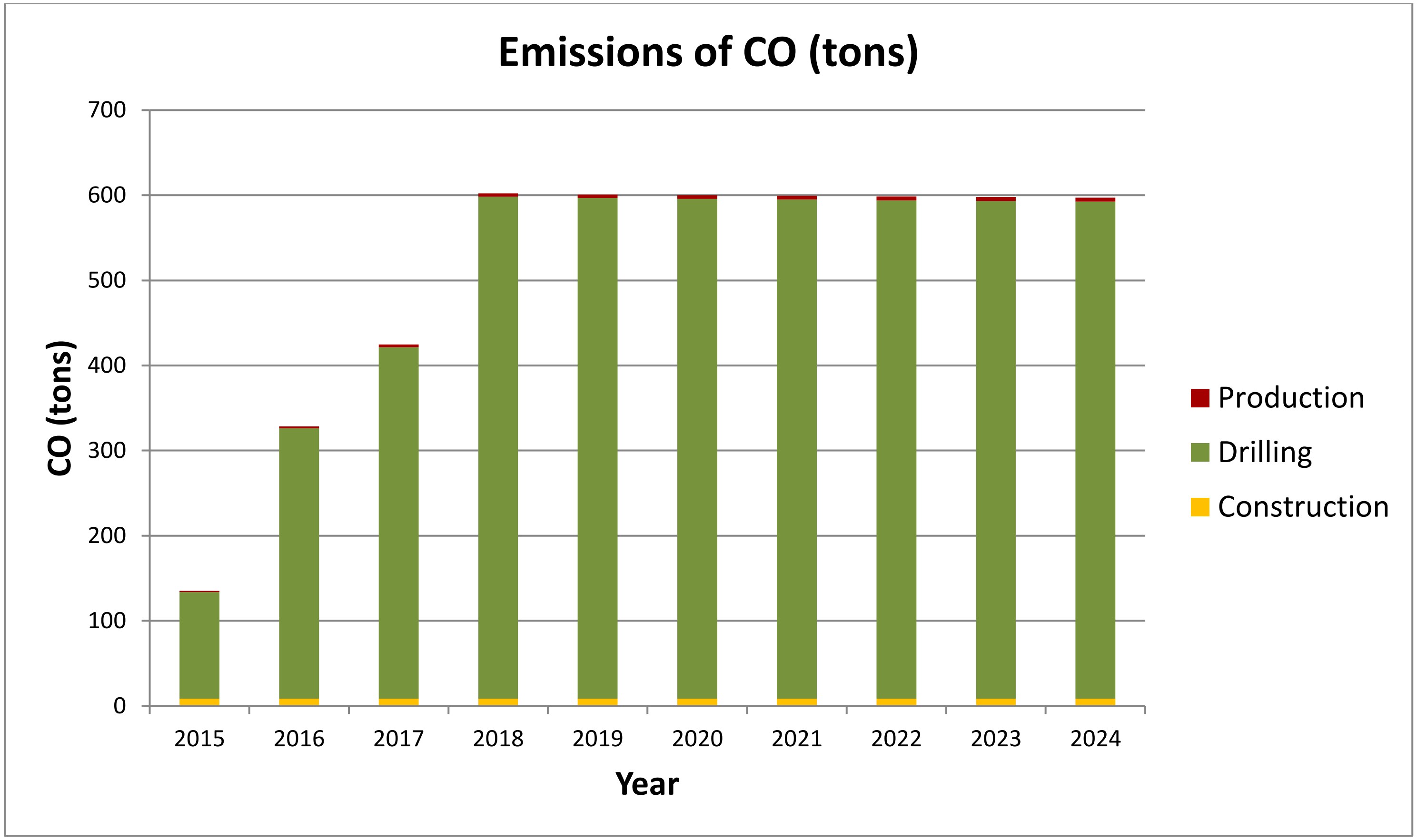
Year	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Construction	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Drilling	0.10	0.22	0.28	0.39	0.39	0.39	0.39	0.39	0.39	0.39
Production	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01

SO2 (tons)

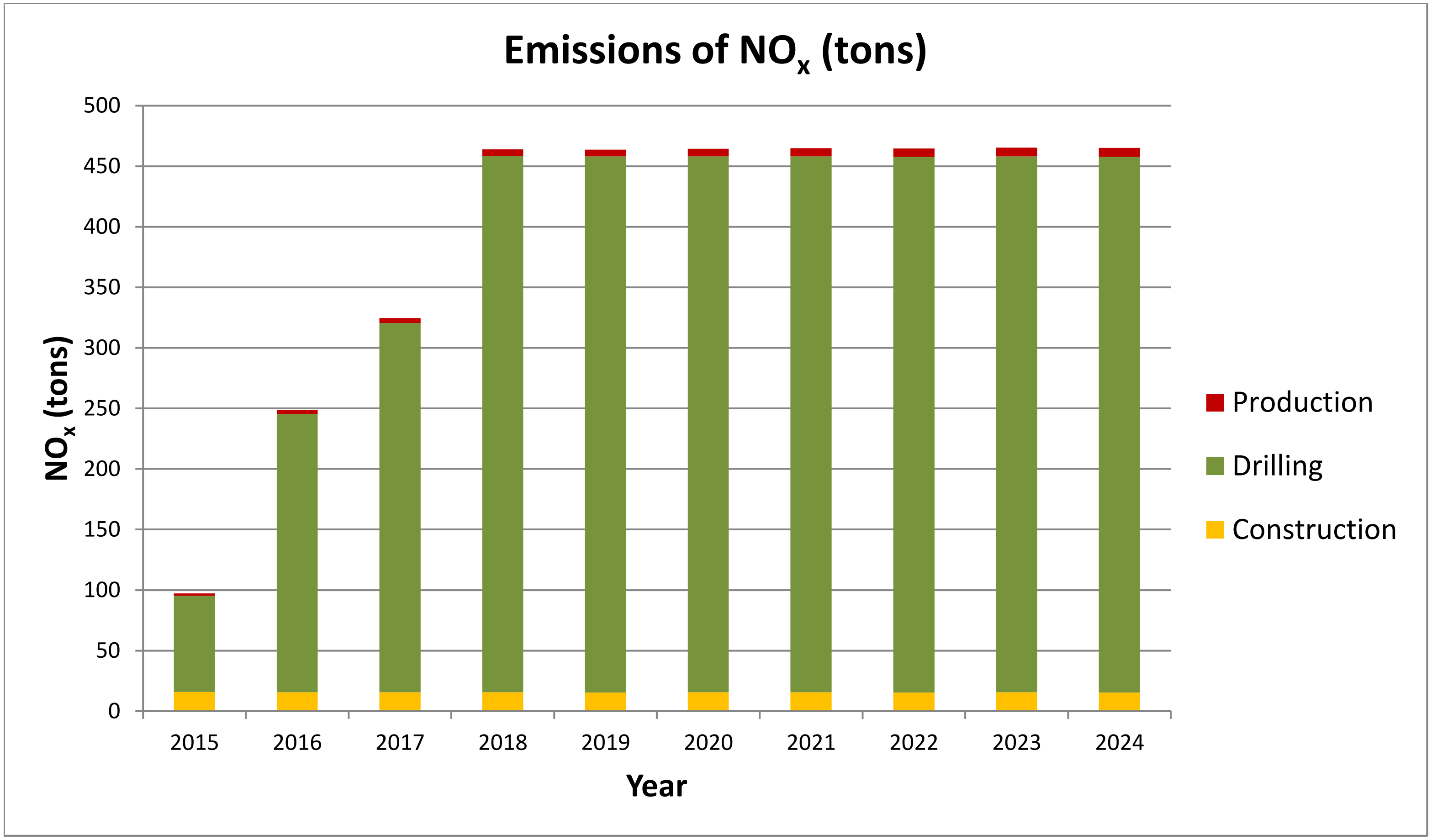
Year	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Construction	0.41	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
Drilling	1.61	4.82	6.42	9.36	9.36	9.36	9.36	9.36	9.36	9.36
Production	0.00	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02

CO2-eq (tons)

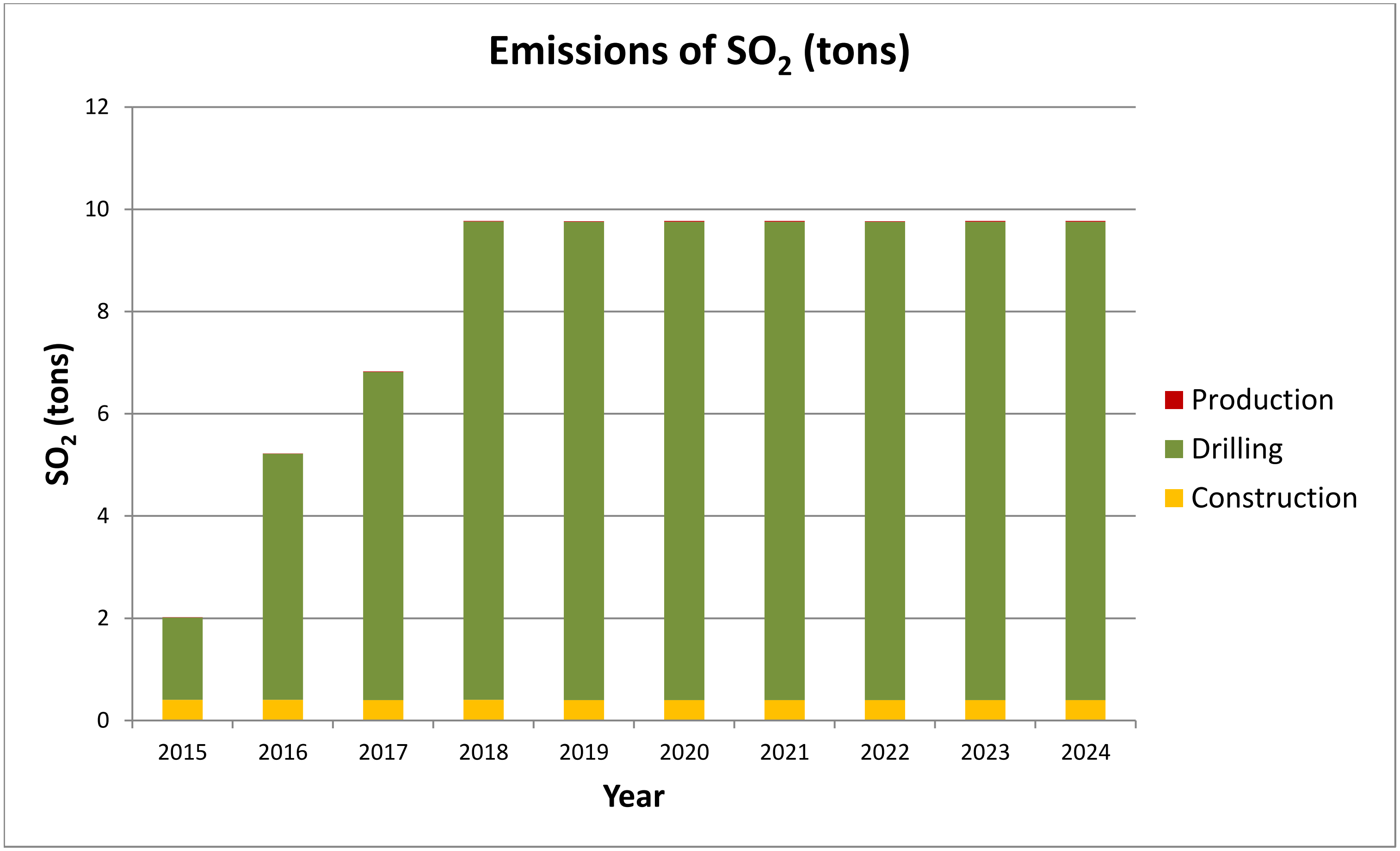
Year	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Construction	1919.07	1904.03	1889.00	1904.03	1873.97	1889.00	1889.00	1873.97	1889.00	1873.97
Drilling	20152.30	57780.13	76591.08	111083.50	111077.31	111071.60	111066.31	111061.53	111057.12	111053.17
Production	14835.40	28866.34	42196.76	56209.18	68764.32	82041.57	95291.78	107846.92	121077.53	133632.68

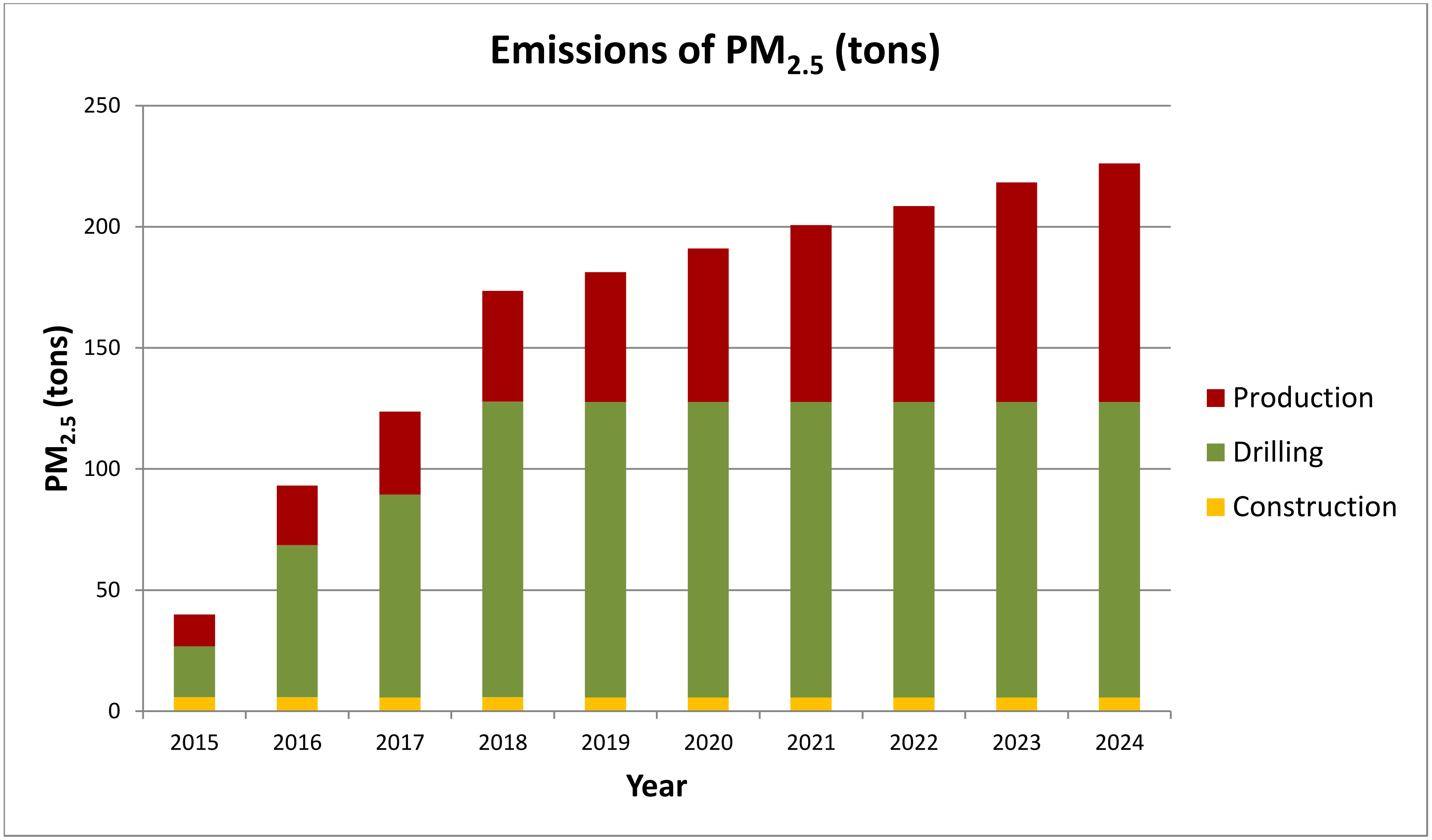


Emissions of CO (tons)
CO (tons)
700
600
500
400
300
200
100
0
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
Year
Production
Drilling
Construction

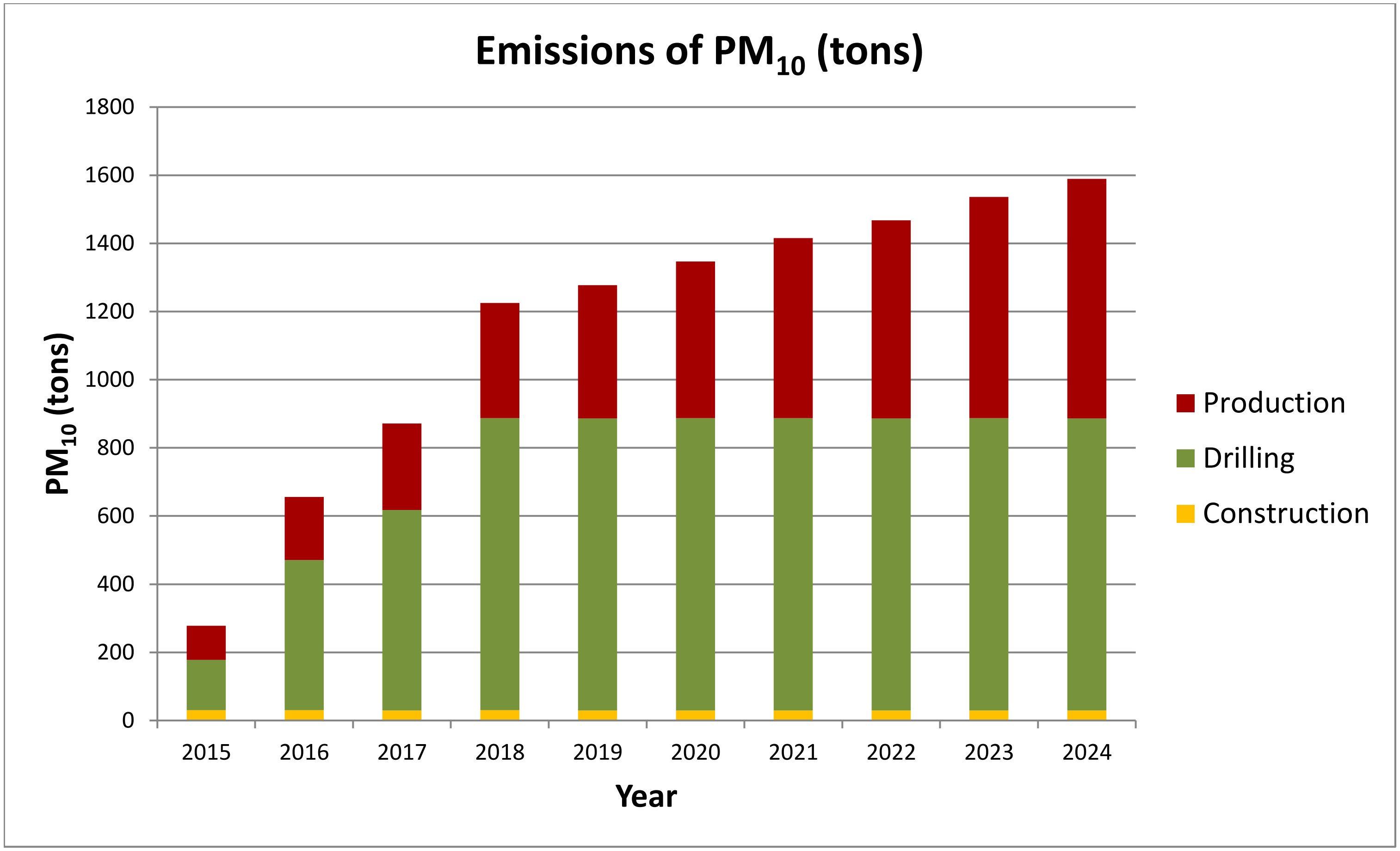


Emissions of NO_x (tons)
500
450
400
350
300
250
200
150
100
50
0
NO_x (tons)
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
Year
Production
Drilling
Construction

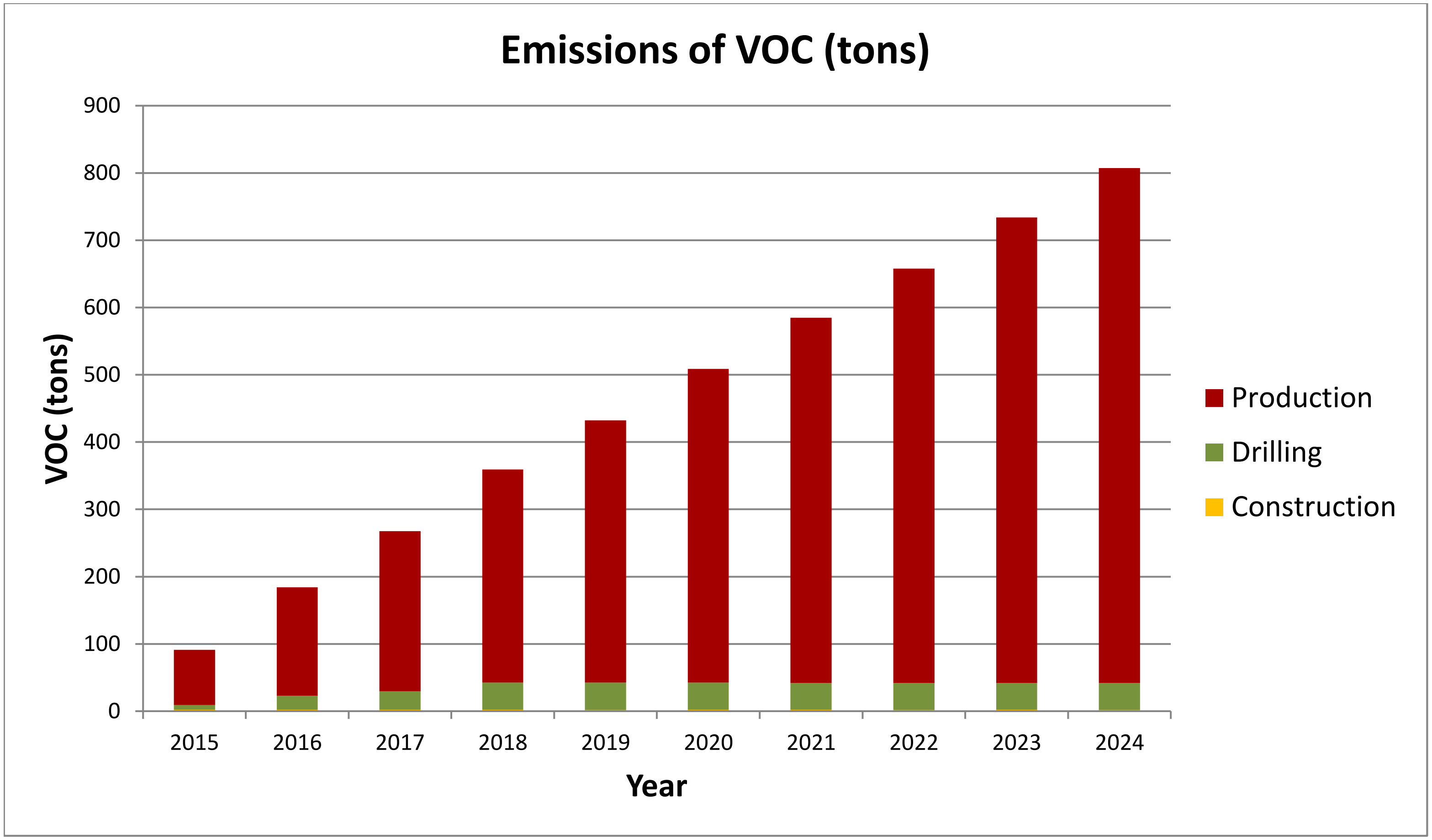

Emissions of SO_2 (tons)
12
10
8
6
4
2
0
SO_2 (tons)
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
Year
Production
Drilling
Construction

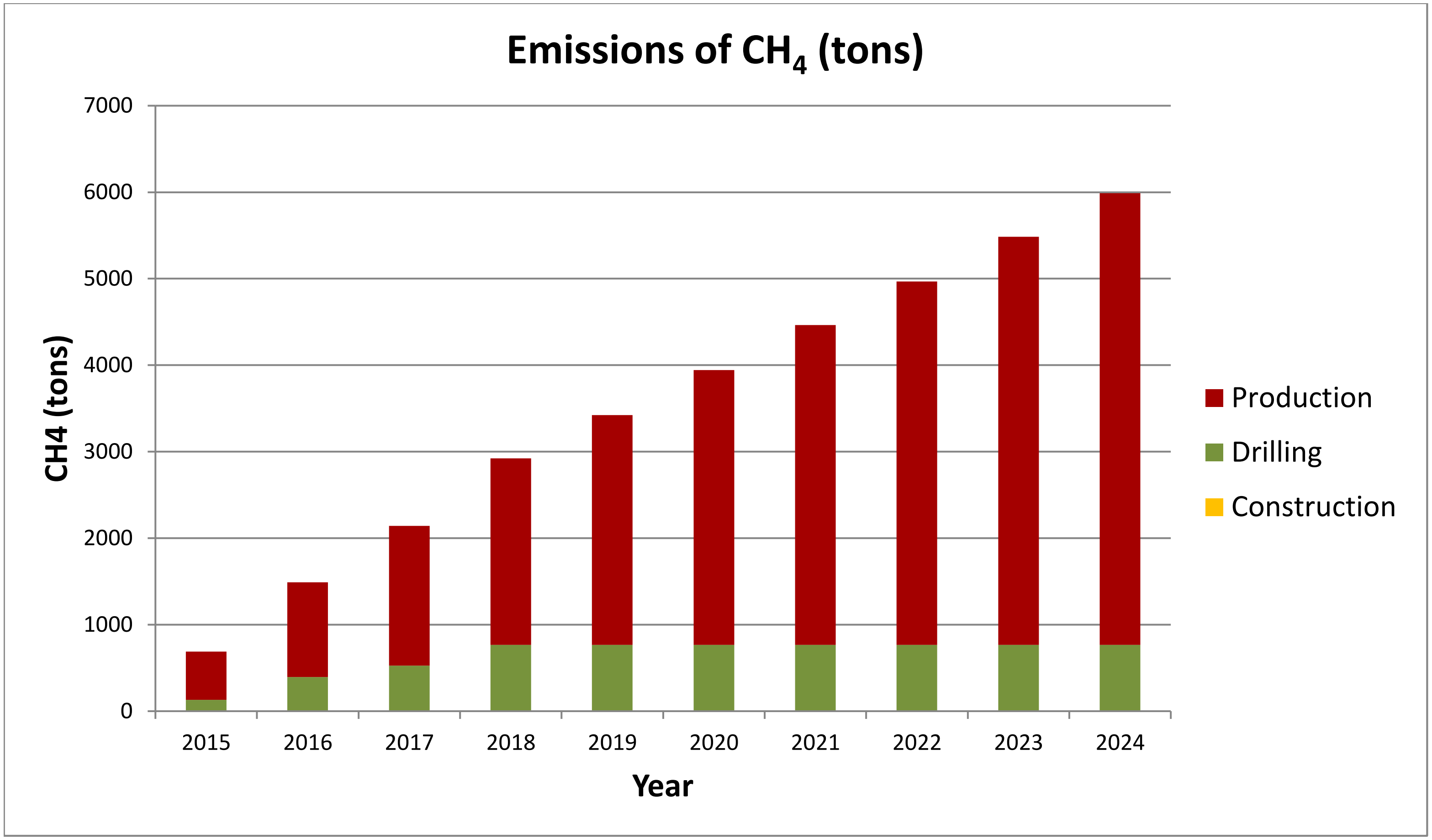


Emissions of $PM_{2.5}$ (tons)
250
200
150
100
50
0
$PM_{2.5}$ (tons)
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
Year
Production
Drilling
Construction

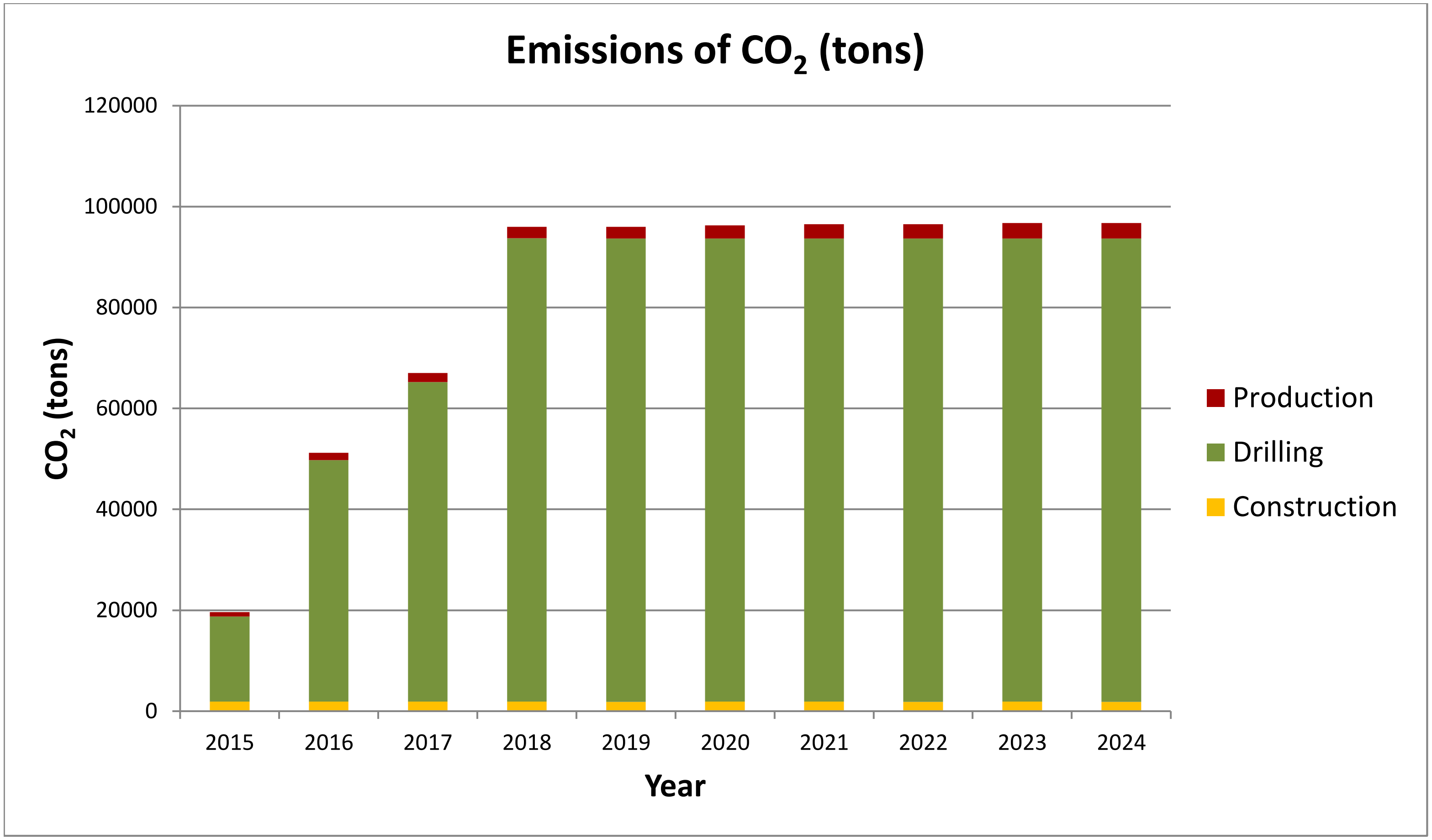


Emissions of PM10 (tons)
1800
1600
1400
1200
1000
800
600
400
200
0
PM10 (tons)
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
Year
Production
Drilling
Construction

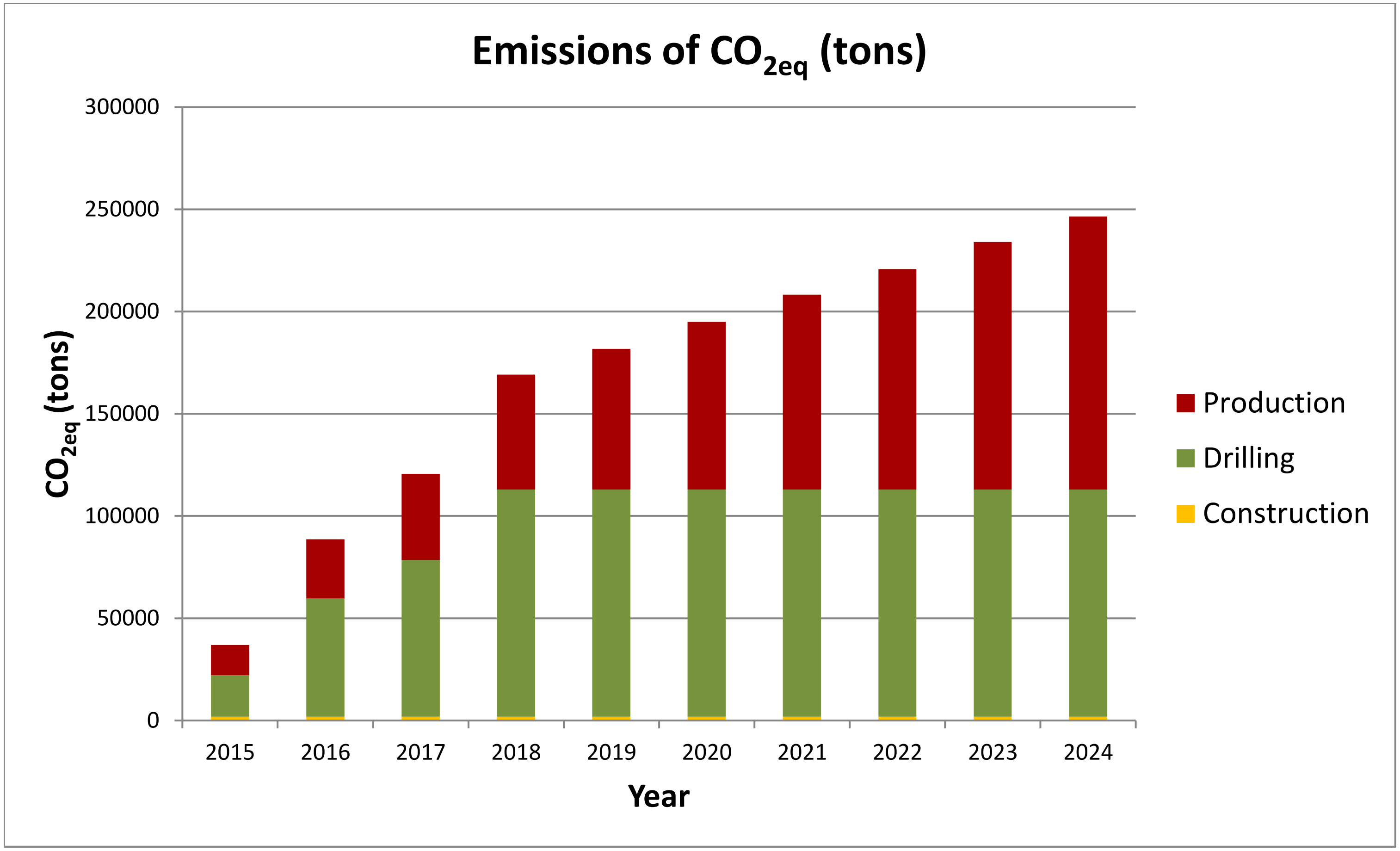

Emissions of VOC (tons)
VOC (tons)
0
100
200
300
400
500
600
700
800
900
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
Year
Production
Drilling
Construction



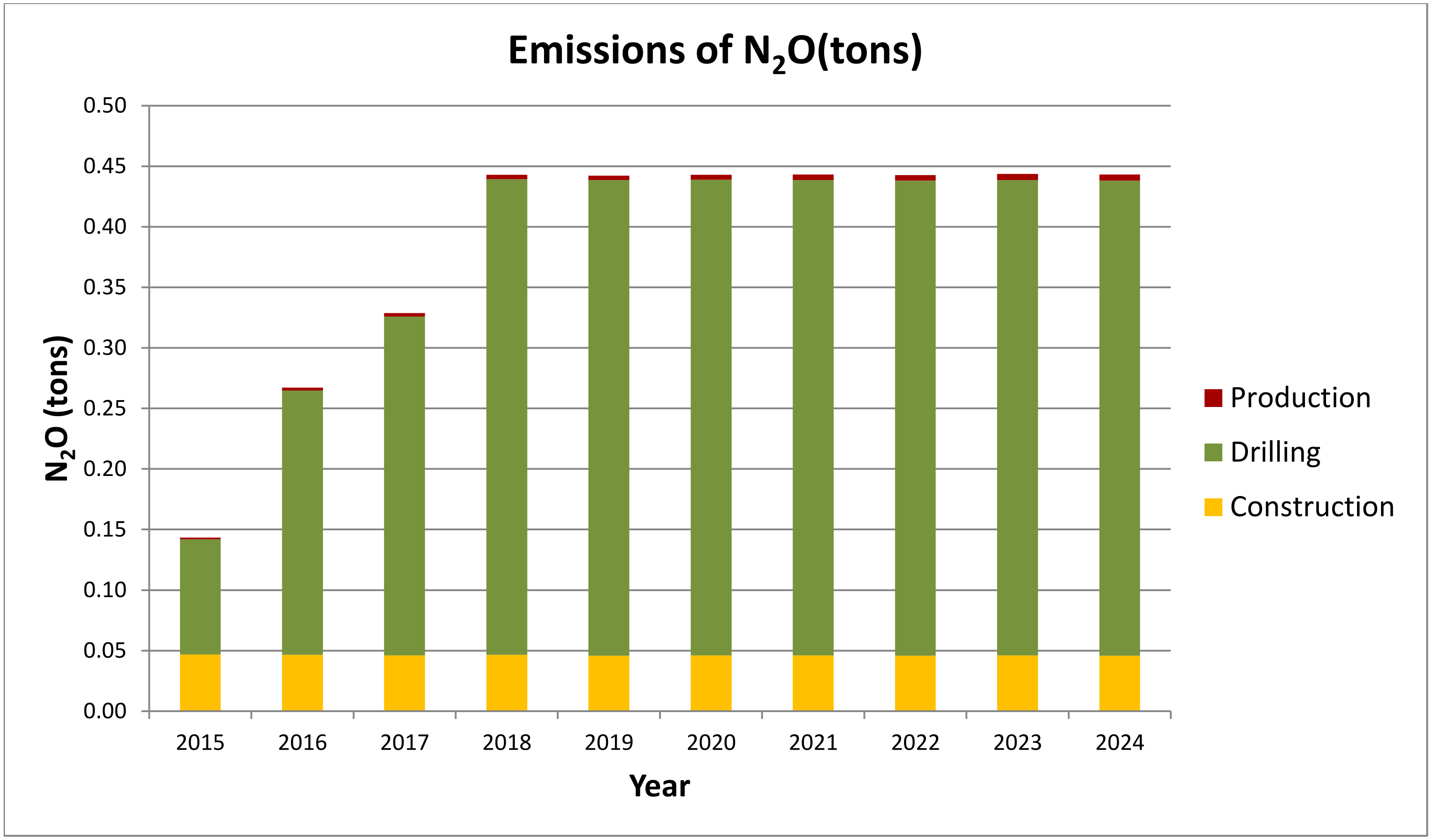
Emissions of CH_4 (tons)
7000
6000
5000
4000
3000
2000
1000
0
CH4 (tons)
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
Year
Production
Drilling
Construction



Emissions of CO2 (tons)
120000
100000
80000
60000
40000
20000
0
CO2 (tons)
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
Year
Production
Drilling
Construction



Emissions of CO_{2eq} (tons)
300000
250000
200000
150000
100000
50000
0
CO_{2eq} (tons)
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
Year
Production
Drilling
Construction



Emissions of N2O(tons)
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
N2O (tons)
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
Year
Production
Drilling
Construction

MOVES DATA

Sum of emisRate | Pollutant | RateUnit

=CO2(eq)-(CH4*25)-(NO2*298)

RoadType	yearID	FuelType	SourceType	PM2.5 Tirewear	PM2.5 Brakewear	PM10 Tirewear	PM10 Brakewear	PM10 Total Exh	VOC	SO2	NOx	CO	Methane (CH4)	N2O	Benzene	Formaldehyde	CO2 Equivalent	PM2.5 Total Exh	NOx	PM10	PM2.5	SO2	CO	VOC	CO2	Methane (CH4)	N2O	Benzene	Formaldehyde	CO2 Equivalent
				g/mi	g/mi	g/mi	g/mi	g/mi	g/mi	g/mi	g/mi	g/mi	g/mi	g/mi	g/mi	g/mi	g/mi	g/mi												
Rural Unrestricted Access	2013	Diesel Fuel	Combination Long-haul Truck	4.44E-03	1.07E-02	1.85E-02	4.09E-02	4.42E-01	3.76E-01	#######	9.64E+00	2.25E+00	2.67E-02	#######	4.07E-03	3.03E-02	1.95E+03	4.29E-01	9.64E+00	#######	#######	1.47E-02	2.25E+00	3.76E-01	1.94E+03	2.67E-02	#######	4.07E-03	3.03E-02	1.95E+03
			Combination Short-haul Truck	4.04E-03	9.93E-03	1.69E-02	3.79E-02	3.96E-01	3.65E-01	#######	8.98E+00	2.06E+00	2.80E-02	#######	3.96E-03	2.95E-02	1.87E+03	3.84E-01	8.98E+00	#######	#######	1.40E-02	2.06E+00	3.65E-01	1.86E+03	2.80E-02	#######	3.96E-03	2.95E-02	1.87E+03
			Intercity Bus	4.86E-03	1.62E-02	2.03E-02	6.17E-02	5.77E-01	4.55E-01	#######	1.17E+01	2.80E+00	2.56E-02	#######	4.94E-03	3.68E-02	1.62E+03	5.60E-01	1.17E+01	#######	#######	1.24E-02	2.80E+00	4.55E-01	1.62E+03	2.56E-02	#######	4.94E-03	3.68E-02	1.62E+03
			Passenger Car	1.27E-03	1.92E-03	5.30E-03	7.33E-03	1.47E-02	2.26E-02	#######	5.73E-01	3.73E-01	2.29E-03	#######	2.45E-04	1.83E-03	3.51E+02	1.43E-02	5.73E-01	#######	#######	2.62E-03	3.73E-01	2.26E-02	3.50E+02	2.29E-03	#######	2.45E-04	1.83E-03	3.51E+02
			Passenger Truck	1.62E-03	3.03E-03	6.75E-03	1.16E-02	1.27E-01	2.69E-01	#######	2.14E+00	1.32E+00	1.57E-02	#######	2.92E-03	2.17E-02	6.30E+02	1.23E-01	2.14E+00	#######	#######	4.75E-03	1.32E+00	2.69E-01	6.30E+02	1.57E-02	#######	2.92E-03	2.17E-02	6.30E+02
			School Bus	3.93E-03	1.37E-02	1.64E-02	5.25E-02	2.97E-01	4.17E-01	#######	5.56E+00	1.72E+00	2.20E-02	#######	4.52E-03	3.37E-02	8.14E+02	2.88E-01	5.56E+00	#######	#######	6.22E-03	1.72E+00	4.17E-01	8.13E+02	2.20E-02	#######	4.52E-03	3.37E-02	8.14E+02
			Single Unit Long-haul Truck	2.89E-03	1.07E-02	1.21E-02	4.10E-02	1.53E-01	3.37E-01	#######	3.03E+00	1.29E+00	3.67E-02	#######	3.65E-03	2.72E-02	8.01E+02	1.48E-01	3.03E+00	#######	#######	5.91E-03	1.29E+00	3.37E-01	8.00E+02	3.67E-02	#######	3.65E-03	2.72E-02	8.01E+02
			Single Unit Short-haul Truck	2.89E-03	1.08E-02	1.21E-02	4.11E-02	1.56E-01	3.18E-01	#######	3.18E+00	1.25E+00	3.73E-02	#######	3.45E-03	2.57E-02	8.56E+02	1.52E-01	3.18E+00	#######	#######	6.28E-03	1.25E+00	3.18E-01	8.55E+02	3.73E-02	#######	3.45E-03	2.57E-02	8.56E+02
			Transit Bus	2.61E-03	8.11E-03	1.09E-02	3.10E-02	4.34E-01	4.72E-01	#######	8.75E+00	2.79E+00	2.12E-02	#######	5.11E-03	3.81E-02	1.19E+03	4.21E-01	8.75E+00	#######	#######	9.01E-03	2.79E+00	4.72E-01	1.19E+03	2.12E-02	#######	5.11E-03	3.81E-02	1.19E+03
			Motor Home	2.28E-03	8.51E-03	9.53E-03	3.25E-02	2.31E-01	4.82E-01	#######	4.46E+00	1.63E+00	3.26E-02	#######	5.23E-03	3.89E-02	8.84E+02	2.24E-01	4.46E+00	#######	#######	6.65E-03	1.63E+00	4.82E-01	8.83E+02	3.26E-02	#######	5.23E-03	3.89E-02	8.84E+02
			Refuse Truck	4.57E-03	1.26E-02	1.90E-02	4.81E-02	4.07E-01	4.00E-01	#######	8.64E+00	2.16E+00	2.76E-02	#######	4.33E-03	3.23E-02	1.53E+03	3.95E-01	8.64E+00	#######	#######	1.15E-02	2.16E+00	4.00E-01	1.52E+03	2.76E-02	#######	4.33E-03	3.23E-02	1.53E+03
			Light Commercial Truck	1.65E-03	3.31E-03	6.88E-03	1.27E-02	1.65E-01	3.58E-01	#######	2.63E+00	1.67E+00	1.23E-02	#######	3.89E-03	2.89E-02	6.25E+02	1.60E-01	2.63E+00	#######	#######	4.80E-03	1.67E+00	3.58E-01	6.24E+02	1.23E-02	#######	3.89E-03	2.89E-02	6.25E+02
		Gasoline	Combination Short-haul Truck	2.29E-03	6.47E-03	9.55E-03	2.47E-02	1.31E-01	3.75E+00	#######	1.67E+01	1.34E+02	9.24E-02	#######	1.27E-01	4.60E-02	1.72E+03	1.21E-01	1.67E+01	#######	#######	3.02E-02	1.34E+02	3.75E+00	1.72E+03	9.24E-02	#######	1.27E-01	4.60E-02	1.72E+03
			Motorcycle	6.37E-04	1.66E-04	2.66E-03	6.33E-04	4.70E-02	7.62E-01	#######	8.50E-01	1.57E+01	2.90E-02	#######	2.57E-02	1.03E-02	3.71E+02	4.33E-02	8.50E-01	#######	#######	6.49E-03	1.57E+01	7.62E-01	3.70E+02	2.90E-02	#######	2.57E-02	1.03E-02	3.71E+02
			Passenger Car	1.27E-03	1.92E-03	5.30E-03	7.33E-03	9.03E-03	5.17E-02	#######	3.69E-01	2.31E+00	4.85E-03	#######	1.77E-03	6.56E-04	3.18E+02	8.31E-03	3.69E-01	#######	#######	5.56E-03	2.31E+00	5.17E-02	3.17E+02	4.85E-03	#######	1.77E-03	6.56E-04	3.18E+02
			Passenger Truck	1.30E-03	3.16E-03	5.42E-03	1.21E-02	1.52E-02	1.52E-01	#######	9.37E-01	5.01E+00	7.26E-03	#######	5.17E-03	1.92E-03	4.41E+02	1.40E-02	9.37E-01	#######	#######	7.71E-03	5.01E+00	1.52E-01	4.39E+02	7.26E-03	#######	5.17E-03	1.92E-03	4.41E+02
			School Bus	2.27E-03	8.84E-03	9.46E-03	3.38E-02	3.30E-02	1.18E+00	#######	4.42E+00	3.12E+01	5.54E-02	#######	3.99E-02	1.47E-02	7.73E+02	3.04E-02	4.42E+00	#######	#######	1.35E-02	3.12E+01	1.18E+00	7.67E+02	5.54E-02	#######	3.99E-02	1.47E-02	7.73E+02
			Single Unit Long-haul Truck	2.30E-03	9.22E-03	9.60E-03	3.52E-02	8.28E-03	3.91E-01	#######	3.32E+00	1.43E+01	8.55E-03	#######	1.32E-02	5.17E-03	8.04E+02	7.63E-03	3.32E+00	#######	#######	1.41E-02	1.43E+01	3.91E-01	8.01E+02	8.55E-03	#######	1.32E-02	5.17E-03	8.04E+02
			Single Unit Short-haul Truck	2.30E-03	9.23E-03	9.60E-03	3.53E-02	9.81E-03	4.38E-01	#######	3.51E+00	1.58E+01	1.06E-02	#######	1.48E-02	5.76E-03	8.56E+02	9.03E-03	3.51E+00	#######	#######	1.50E-02	1.58E+01	4.38E-01	8.53E+02	1.06E-02	#######	1.48E-02	5.76E-03	8.56E+02
			Transit Bus	2.27E-03	8.40E-03	9.46E-03	3.21E-02	1.05E-02	8.81E-01	#######	4.09E+00	2.90E+01	1.55E-02	#######	2.98E-02	1.15E-02	1.13E+03	9.67E-03	4.09E+00	#######	#######	1.97E-02	2.90E+01	8.81E-01	1.12E+03	1.55E-02	#######	2.98E-02	1.15E-02	1.13E+03
			Motor Home	2.21E-03	8.33E-03	9.22E-03	3.18E-02	2.30E-02	7.35E-01	#######	4.47E+00	2.52E+01	2.51E-02	#######	2.49E-02	9.36E-03	8.72E+02	2.11E-02	4.47E+00	#######	#######	1.52E-02	2.52E+01	7.35E-01	8.67E+02	2.51E-02	#######	2.49E-02	9.36E-03	8.72E+02
			Refuse Truck	2.21E-03	7.31E-03	9.22E-03	2.79E-02	1.56E-02	9.05E-01	#######	5.61E+00	3.79E+01	1.49E-02	#######	3.06E-02	1.18E-02	1.42E+03	1.44E-02	5.61E+00	#######	#######	2.49E-02	3.79E+01	9.05E-01	1.42E+03	1.49E-02	#######	3.06E-02	1.18E-02	1.42E+03
			Light Commercial Truck	1.33E-03	3.17E-03	5.53E-03	1.21E-02	1.49E-02	1.62E-01	#######	1.02E+00	5.23E+00	7.61E-03	#######	5.51E-03	2.06E-03	4.36E+02	1.37E-02	1.02E+00	#######	#######	7.62E-03	5.23E+00	1.62E-01	4.34E+02	7.61E-03	#######	5.51E-03	2.06E-03	4.36E+02
		Compressed Natural Gas (CNG)	Transit Bus	2.27E-03	8.41E-03	9.47E-03	3.21E-02	5.37E-03	0.00E+00		3.55E+00	3.74E+01	2.21E-02	#######			9.37E+02	5.37E-03	3.55E+00	#######	#######	#######	3.74E+01	0.00E+00	9.24E+02	2.21E-02	#######	#######	0.00E+00	9.37E+02
	2014	Diesel Fuel	Combination Long-haul Truck	4.44E-03	1.07E-02	1.85E-02	4.09E-02	3.89E-01	3.32E-01	#######	8.58E+00	2.00E+00	2.87E-02	#######	3.59E-03	2.68E-02	1.95E+03	3.77E-01	8.58E+00	#######	#######	1.45E-02	2.00E+00	3.32E-01	1.94E+03	2.87E-02	#######	3.59E-03	2.68E-02	1.95E+03
			Combination Short-haul Truck	4.04E-03	9.93E-03	1.69E-02	3.79E-02	3.41E-01	3.18E-01	#######	7.87E+00	1.81E+00	3.01E-02	#######	3.45E-03	2.57E-02	1.87E+03	3.31E-01	7.87E+00	#######	#######	1.38E-02	1.81E+00	3.18E-01	1.86E+03	3.01E-02	#######	3.45E-03	2.57E-02	1.87E+03
			Intercity Bus	4.86E-03	1.62E-02	2.03E-02	6.17E-02	5.15E-01	4.15E-01	#######	1.06E+01	2.56E+00	2.77E-02	#######	4.50E-03	3.35E-02	1.62E+03	5.00E-01	1.06E+01	#######	#######	1.23E-02	2.56E+00	4.15E-01	1.62E+03	2.77E-02	#######	4.50E-03	3.35E-02	1.62E+03
			Passenger Car	1.27E-03	1.92E-03	5.30E-03	7.33E-03	1.22E-02	1.95E-02	#######	5.00E-01	4.57E-01	2.83E-03	#######	2.11E-04	1.57E-03	3.43E+02	1.18E-02	5.00E-01	#######	#######	2.53E-03	4.57E-01	1.95E-02	3.43E+02	2.83E-03	#######	2.11E-04	1.57E-03	3.43E+02
			Passenger Truck	1.62E-03	3.03E-03	6.75E-03	1.16E-02	1.10E-01	2.34E-01	#######	1.93E+00	1.21E+00	1.69E-02	#######	2.54E-03	1.89E-02	6.28E+02	1.07E-01	1.93E+00	#######	#######	4.68E-03	1.21E+00	2.34E-01	6.27E+02	1.69E-02	#######	2.54E-03	1.89E-02	6.28E+02
			School Bus	3.93E-03	1.37E-02	1.64E-02	5.25E-02	2.68E-01	3.83E-01	#######	5.07E+00	1.58E+00	2.39E-02	#######	4.15E-03	3.09E-02	8.14E+02	2.60E-01	5.07E+00	#######	#######	6.16E-03	1.58E+00	3.83E-01	8.13E+02	2.39E-02	#######	4.15E-03	3.09E-02	8.14E+02
			Single Unit Long-haul Truck	2.89E-03	1.07E-02	1.21E-02	4.10E-02	1.31E-01	2.94E-01	#######	2.68E+00	1.15E+00	3.86E-02	#######	3.19E-03	2.37E-02	8.01E+02	1.27E-01	2.68E+00	#######	#######	5.84E-03	1.15E+00	2.94E-01	8.00E+02	3.86E-02	#######	3.19E-03	2.37E-02	8.01E+02
			Single Unit Short-haul Truck	2.89E-03	1.08E-02	1.21E-02	4.11E-02	1.31E-01	2.72E-01	#######	2.76E+00	1.10E+00	3.91E-02	#######	2.95E-03	2.20E-02	8.56E+02	1.27E-01	2.76E+00	#######	#######	6.21E-03	1.10E+00	2.72E-01	8.55E+02	3.91E-02	#######	2.95E-03	2.20E-02	8.56E+02
			Transit Bus	2.61E-03	8.11E-03	1.09E-02	3.10E-02	3.84E-01	4.28E-01	#######	7.76E+00	2.52E+00	2.35E-02	#######	4.64E-03	3.45E-02	1.19E+03	3.73E-01	7.76E+00	#######	#######	8.91E-03	2.52E+00	4.28E-01	1.19E+03	2.35E-02	#######	4.64E-03	3.45E-02	1.19E+03
			Motor Home	2.28E-03	8.51E-03	9.53E-03	3.25E-02	2.04E-01	4.38E-01	#######	4.03E+00	1.51E+00	3.49E-02	#######	4.74E-03	3.53E-02	8.84E+02	1.98E-01	4.03E+00	#######	#######	6.59E-03	1.51E+00	4.38E-01	8.83E+02	3.49E-02	#######	4.74E-03	3.53E-02	8.84E+02
			Refuse Truck	4.58E-03	1.26E-02	1.91E-02	4.83E-02	3.52E-01	3.50E-01	#######	7.58E+00	1.90E+00	2.99E-02	#######	3.79E-03	2.82E-02	1.53E+03	3.41E-01	7.58E+00	#######	#######	1.14E-02	1.90E+00	3.50E-01	1.52E+03	2.99E-02	#######	3.79E-03	2.82E-02	1.53E+03
			Light Commercial Truck	1.65E-03	3.30E-03	6.88E-03	1.26E-02	1.46E-01	3.21E-01	#######	2.41E+00	1.54E+00	1.37E-02	#######	3.48E-03	2.59E-02	6.23E+02	1.42E-01	2.41E+00	#######	#######	4.73E-03	1.54E+00	3.21E-01	6.22E+02	1.37E-02	#######	3.48E-03	2.59E-02	6.23E+02
		Gasoline	Combination Short-haul Truck	2.30E-03	6.49E-03	9.59E-03	2.48E-02	1.29E-01	3.75E+00	#######	1.67E+01	1.34E+02	9.18E-02	#######	1.27E-01	4.60E-02	1.72E+03	1.19E-01	1.67E+01	#######	#######	3.02E-02	1.34E+02	3.75E+00	1.72E+03	9.18E-02	#######	1.27E-01	4.60E-02	1.72E+03
			Motorcycle	6.37E-04	1.66E-04	2.66E-03	6.33E-04	4.70E-02	7.36E-01	#######	8.39E-01	1.53E+01	2.89E-02	#######	2.48E-02	9.93E-03	3.71E+02	4.33E-02	8.39E-01	#######	#######	6.50E-03	1.53E+01	7.36E-01	3.70E+02	2.89E-02	#######	2.48E-02	9.93E-03	3.71E+02
			Passenger Car	1.27E-03	1.92E-03	5.30E-03	7.33E-03	8.58E-03	4.32E-02	#######	3.11E-01	2.15E+00	4.58E-03	#######	1.47E-03	5.50E-04	3.14E+02	7.90E-03	3.11E-01	#######	#######	5.50E-03	2.15E+00	4.32E-02	3.13E+02	4.58E-03	#######	1.47E-03	5.50E-04	3.14E+02
			Passenger Truck	1.30E-03	3.16E-03	5.41E-03	1.21E-02	1.49E-02	1.37E-01	#######	8.58E-01	4.74E+00	6.80E-03	#######	4.67E-03	1.74E-03	4.33E+02	1.37E-02	8.58E-01	#######	#######	7.57E-03	4.74E+00	1.37E-01	4.31E+02	6.80E-03	#######	4.67E-03	1.74E-03	4.33E+02
			School Bus	2.27E-03	8.84E-03	9.46E-03	3.38E-02	2.90E-02	1.10E+00	#######	4.22E+00	2.96E+01	4.99E-02	#######	3.73E-02	1.38E-02	7.73E+02	2.67E-02	4.22E+00	#######	#######	1.35E-02	2.96E+01	1.10E+00	7.67E+02	4.99E-02	#######	3.73E-02	1.38E-02	7.73E+02
			Single Unit Long-haul Truck	2.30E-03	9.22E-03	9.60E-03	3.52E-02	8.22E-03	3.86E-01	#######	3.29E+00	1.41E+01	8.04E-03	#######	1.30E-02	5.11E-03	8.04E+02	7.57E-03	3.29E+00	#######	#######	1.41E-02	1.41E+01	3.86E-01	8.01E+02	8.04E-03	#######	1.30E-02	5.11E-03	8.04E+02
			Single Unit Short-haul Truck	2.30E-03	9.23E-03	9.60E-03	3.53E-02	9.22E-03	4.23E-01	#######	3.44E+00	1.53E+01	9.50E-03	#######	1.42E-02	5.58E-03	8.56E+02	8.49E-03	3.44E+00	#######	#######	1.50E-02	1.53E+01	4.23E-01	8.53E+02	9.50E-03	#######	1.42E-02	5.58E-03	8.56E+02
			Transit Bus	2.27E-03	8.40E-03	9.46E-03	3.21E-02	1.05E-02	8.68E-01	#######	4.03E+00	2.75E+01	1.45E-02	#######	2.92E-02	1.14E-02	1.13E+03	9.68E-03	4.03E+00	#######	#######	1.97E-02	2.75E+01	8.68E-01	1.12E+03	1.45E-02	#######	2.92E-02	1.14E-02	1.13E+03
			Motor Home	2.21E-03	8.33E-03	9.22E-03	3.18E-02	2.13E-02	7.01E-01	#######	4.33E+00	2.43E+01	2.25E-02	#######	2.37E-02	8.95E-03	8.71E+02	1.96E-02	4.33E+00	#######	#######	1.52E-02	2.43E+01	7.01E-01	8.67E+02	2.25E-02	#######	2.37E-02	8.95E-03	8.71E+02
			Refuse Truck	2.21E-03	7.31E-03	9.22E-03	2.79E-02	1.50E-02	8.61E-01	#######	5.46E+00	3.52E+01	1.34E-02	#######	2.90E-02	1.12E-02	1.42E+03	1.39E-02	5.46E+00	#######	#######	2.49E-02	3.52E+01	8.61E-01	1.42E+03	1.34E-02	#######	2.90E-02	1.12E-02	1.42E+03
			Light Commercial Truck	1.33E-03	3.17E-03	5.53E-03	1.21E-02	1.46E-02	1.48E-01	#######	9.45E-01	4.96E+00	7.11E-03	#######	5.01E-03	1.88E-03	4.29E+02	1.34E-02	9.45E-01	#######	#######	7.50E-03	4.96E+00	1.48E-01	4.27E+02	7.11E-03	#######	5.01E-03	1.88E-03	4.29E+02
		Compressed Natural Gas (CNG)	Transit Bus	2.27E-03	8.41E-03	9.47E-03	3.21E-02	5.34E-03	0.00E+00		3.50E+00	3.49E+01	2.04E-02	#######			9.37E+02	5.34E-03	3.50E+00	#######	#######	#######	3.49E+01	0.00E+00	9.24E+02	2.04E-02	#######	#######	0.00E+00	9.37E+02
	2015	Diesel Fuel	Combination Long-haul Truck	4.44E-03	1.07E-02	1.85E-02	4.09E-02	3.40E-01	2.91E-01	#######	7.61E+00	1.77E+00	3.05E-02	#######	3.16E-03	2.35E-02	1.95E+03	3.30E-01	7.61E+00	#######	#######	1.43E-02	1.77E+00	2.91E-01	1.94E+03	3.05E-02	#######	3.16E-03	2.35E-02	1.95E+03
			Combination Short-haul Truck	4.04E-03	9.92E-03	1.68E-02	3.79E-02	2.93E-01	2.76E-01	#######	6.87E+00	1.59E+00	3.19E-02	#######	2.99E-03	2.23E-02	1.87E+03	2.84E-01	6.87E+00	#######	#######	1.37E-02	1.59E+00	2.76E-01	1.86E+03	3.19E-02	#######	2.99E-03	2.23E-02	1.87E+03
			Intercity Bus	4.86E-03	1.62E-02	2.03E-02	6.17E-02	4.53E-01	3.76E-01	#######	9.51E+00	2.32E+00	2.98E-02	#######	4.07E-03	3.03E-02	1.62E+03	4.40E-01	9.51E+00	#######	#######	1.21E-02	2.32E+00	3.76E-01	1.62E+03	2.98E-02	#######	4.07E-03	3.03E-02	1.62E+03
			Passenger Car	1.27E-03	1.92E-03	5.30E-03	7.33E-03	9.99E-03	1.66E-02	#######	4.30E-01	5.37E-01	3.35E-03	#######	1.80E-04	1.34E-03	3.34E+02	9.69E-03	4.30E-01	#######	#######	2.44E-03	5.37E-01	1.66E-02	3.34E+02	3.35E-03	#######	1.80E-04	1.34E-03	3.34E+02
			Passenger Truck	1.62E-03	3.02E-03	6.75E-03	1.16E-02	9.56E-02	2.04E-01	#######	1.74E+00	1.11E+00	1.79E-02	#######	2.21E-03	1.65E-02	6.25E+02	9.27E-02	1.74E+00	#######	#######	4.61E-03	1.11E+00	2.04E-01	6.24E+02	1.79E-02	#######	2.21E-03	1.65E-02	6.25E+02
			School Bus	3.93E-03	1.37E-02	1.64E-02	5.25E-02	2.41E-01	3.49E-01	#######	4.61E+00	1.45E+00	2.56E-02	#######	3.78E-03	2.82E-02	8.15E+02	2.34E-01	4.61E+00	#######	#######	6.11E-03	1.45E+00	3.49E-01	8.13E+02	2.56E-02	#######	3.78E-03	2.82E-02	8.15E+02
			Single Unit Long-haul Truck	2.89E-03	1.07E-02	1.21E-02	4.10E-02	1.12E-01	2.58E-01	#######	2.38E+00	1.04E+00	4.01E-02	#######	2.79E-03	2.08E-02	8.01E+02	1.09E-01	2.38E+00	#######	#######	5.79E-03	1.04E+00	2.58E-01	8.00E+02	4.01E-02	#######	2.79E-03	2.08E-02	8.01E+02
			Single Unit Short-haul Truck	2.89E-03	1.08E-02	1.21E-02	4.11E-02	1.10E-01	2.33E-01	#######	2.41E+00	9.69E-01	4.06E-02	#######	2.53E-03	1.88E-02	8.56E+02	1.07E-01	2.41E+00	#######	#######	6.15E-03	9.69E-01	2.33E-01	8.55E+02	4.06E-02	#######	2.53E-03	1.88E-02	8.56E+02
			Transit Bus	2.61E-03	8.11E-03	1.09E-02	3.10E-02	3.37E-01	3.83E-01	#######	6.86E+00	2.25E+00	2.62E-02	#######	4.15E-03	3.09E-02	1.19E+03	3.27E-01	6.86E+00	#######	#######	8.82E-03	2.25E+00	3.83E-01	1.19E+03	2.62E-02	#######	4.15E-03	3.09E-02	1.19E+03
			Motor Home	2.28E-03	8.51E-03	9.53E-03	3.25E-02	1.80E-01	3.97E-01	#######	3.64E+00	1.39E+00	3.70E-02	#######	4.30E-03	3.21E-02	8.84E+02	1.75E-01	3.64E+00	#######	#######	6.53E-03	1.39E+00	3.97E-01	8.83E+02	3.70E-02	#######	4.30E-03	3.21E-02	8.84E+02
			Refuse Truck	4.60E-03	1.27E-02	1.92E-02	4.84E-02	3.02E-01	3.03E-01	#######	6.60E+00	1.67E+00	3.20E-02	#######	3.29E-03	2.45E-02	1.53E+03	2.93E-01	6.60E+00	#######	#######	1.12E-02	1.67E+00	3.03E-01	1.52E+03	3.20E-02	#######	3.29E-03	2.45E-02	1.53E+03
			Light Commercial Truck	1.65E-03	3.30E-03	6.88E-03	1.26E-02	1.29E-01	2.86E-01	#######	2.21E+00	1.42E+00	1.49E-02	#######	3.10E-03	2.31E-02	6.21E+02	1.26E-01	2.21E+00	#######	#######	4.67E-03	1.42E+00	2.86E-01	6.20E+02	1.49E-02	#######	3.10E-03	2.31E-02	6.21E+02
		Gasoline	Combination Short-haul Truck	2.33E-03	6.56E-03	9.73E-03	2.50E-02	1.19E-01	3.76E+00	#######	1.67E+01	1.34E+02	8.91E-02	#######	1.27E-01	4.60E-02	1.72E+03	1.09E-01	1.67E+01	#######	#######	3.02E-02	1.34E+02	3.76E+00	1.72E+03	8.91E-02	#######	1.27E-01	4.60E-02	1.72E+03
			Motorcycle	6.37E-04	1.66E-04	2.66E-03	6.33E-04	4.70E-02	7.16E-01	#######	8.30E-01	1.49E+01	2.89E-02	#######	2.41E-02	9.65E-03	3.71E+02	4.33E-02	8.30E-01	#######	#######	6.50E-03	1.49E+01	7.16E-01	3.70E+02	2.89E-02	#######	2.41E-02	9.65E-03	3.71E+02
			Passenger Car	1.27E-03	1.92E-03	5.30E-03	7.33E-03	8.17E-03	3.63E-02	#######	2.61E-01	2.01E+00	4.39E-03	#######	1.23E-03	4.63E-04	3.08E+02	7.52E-03	2.61E-01	#######	#######	5.41E-03	2.01E+00	3.63E-02	3.08E+02	4.39E-03	#######	1.23E-03	4.63E-04	3.08E+02
			Passenger Truck	1.30E-03	3.16E-03	5.41E-03	1.21E-02	1.45E-02	1.25E-01	#######	7.86E-01	4.48E+00	6.33E-03	#######	4.22E-03	1.58E-03	4.24E+02	1.34E-02	7.86E-01	#######	#######	7.43E-03	4.48E+00	1.25E-01	4.23E+02	6.33E-03	#######	4.22E-03	1.58E-03	4.24E+02
			School Bus	2.27E-03	8.84E-03	9.46E-03	3.38E-02	2.17E-02	1.00E+00	#######	3.95E+00	2.75E+01	4.25E-02	#######	3.39E-02	1.26E-02	7.72E+02	2.00E-02	3.95E+00	#######	#######	1.35E-02	2.75E+01	1.00E+00	7.67E+02	4.25E-02	#######	3.39E-02	1.26E-02	7.72E+02
			Single Unit Long-haul Truck	2.30E-03	9.22E-03	9.60E-03	3.52E-02	7.99E-03	3.79E-01	#######	3.25E+00	1.38E+01	7.61E-03	#######	1.27E-02	5.02E-03	8.04E+02	7.36E-03	3.25E+00	#######	#######	1.41E-02	1.38E+01	3.79E-01	8.01E+02	7.61E-03	#######	1.27E-02	5.02E-03	8.04E+02
			Single Unit Short-haul Truck	2.30E-03	9.23E-03	9.60E-03	3.53E-02	8.63E-03	4.09E-01	#######	3.38E+00	1.48E+01	8.67E-03	#######	1.37E-02	5.40E-03	8.56E+02	7.95E-03	3.38E+00	#######	#######	1.50E-02	1.48E+01	4.09E-01	8.53E+02	8.67E-03	#######	1.37E-02	5.40E-03	8.56E+02
			Transit Bus	2.27E-03	8.40E-03	9.46E-03	3.21E-02	1.04E-02	8.51E-01	#######	3.97E+00	2.61E+01	1.35E-02	#######	2.86E-02	1.12E-02	1.13E+03	9.55E-03	3.97E+00	#######	#######	1.97E-02	2.61E+01	8.51E-01	1.12E+03	1.35E-02	#######	2.86E-02	1.12E-02	1.13E+03
			Motor Home	2.21E-03	8.33E-03	9.22E-03	3.18E-02	1.86E-02	6.64E-01	#######	4.19E+00	2.33E+01	1.99E-02	#######	2.24E-02	8.49E-03	8.71E+02	1.71E-02	4.19E+00	#######	#######	1.52E-02	2.33E+01	6.64E-01	8.67E+02	1.99E-02	#######	2.24E-02	8.49E-03	8.71E+02
			Refuse Truck	2.21E-03	7.31E-03	9.22E-03	2.79E-02	1.42E-02	8.16E-01	#######	5.32E+00	3.26E+01	1.20E-02	#######	2.74E-02	1.07E-02	1.42E+03	1.31E-02	5.32E+00	#######	#######	2.49E-02	3.26E+01	8.16E-01	1.42E+03	1.20E-02	#######	2.74E-02	1.07E-02	1.42E+03
			Light Commercial Truck	1.32E-03	3.17E-03	5.52E-03	1.21E-02	1.43E-02	1.35E-01	#######	8.75E-01	4.71E+00	6.61E-03	#######	4.55E-03	1.71E-03	4.21E+02	1.31E-02	8.75E-01	#######	#######	7.37E-03	4.71E+00	1.35E-01	4.20E+02	6.61E-03	#######	4.55E-03	1.71E-03	4.21E+02
		Compressed Natural Gas (CNG)	Transit Bus	2.27E-03	8.41E-03	9.47E-03	3.21E-02	5.25E-03	0.00E+00		3.45E+00	3.25E+01	1.88E-02	#######			9.36E+02	5.25E-03	3.45E+00	#######	#######	#######	3.25E+01	0.00E+00	9.24E+02	1.88E-02	#######	#######	0.00E+00	9.36E+02
	2016	Diesel Fuel	Combination Long-haul Truck	4.44E-03	1.07E-02	1.85E-02	4.09E-02	2.96E-01	2.55E-01	#######	6.74E+00	1.56E+00	3.21E-02	#######	2.76E-03	2.05E-02	1.95E+03	2.87E-01	6.74E+00	#######	#######	1.42E-02	1.56E+00	2.55E-01	1.94E+03	3.21E-02	#######	2.76E-03	2.05E-02	1.95E+03
			Combination Short-haul Truck	4.04E-03	9.92E-03	1.68E-02	3.79E-02	2.49E-01	2.38E-01	#######	5.99E+00	1.39E+00	3.35E-02	#######	2.57E-03	1.92E-02	1.87E+03	2.42E-01	5.99E+00	#######	#######	1.35E-02	1.39E+00	2.38E-01	1.86E+03	3.35E-02	#######	2.57E-03	1.92E-02	1.87E+03
			Intercity Bus	4.86E-03	1.62E-02	2.03E-02	6.17E-02	3.95E-01	3.39E-01	#######	8.51E+00	2.10E+00	3.17E-02	#######	3.67E-03	2.74E-02	1.62E+03	3.83E-01	8.51E+00	#######	#######	1.20E-02	2.10E+00	3.39E-01	1.62E+03	3.17E-02	#######	3.67E-03	2.74E-02	1.62E+03
			Passenger Car	1.27E-03	1.92E-03	5.30E-03	7.33E-03	8.17E-03	1.42E-02	#######	3.66E-01	6.30E-01	4.04E-03	#######	1.54E-04	1.15E-03	3.24E+02	7.92E-03	3.66E-01	#######	#######	2.35E-03	6.30E-01	1.42E-02	3.24E+02	4.04E-03	#######	1.54E-04	1.15E-03	3.24E+02
			Passenger Truck	1.62E-03	3.02E-03	6.75E-03	1.15E-02	8.30E-02	1.78E-01	#######	1.58E+00	1.04E+00	1.89E-02	#######	1.93E-03	1.44E-02	6.22E+02	8.05E-02	1.58E+00	#######	#######	4.55E-03	1.04E+00	1.78E-01	6.21E+02	1.89E-02	#######	1.93E-03	1.44E-02	6.22E+02
			School Bus	3.93E-03	1.37E-02	1.64E-02	5.25E-02	2.15E-01	3.17E-01	#######	4.18E+00	1.33E+00	2.71E-02	#######	3.44E-03	2.56E-02	8.15E+02	2.08E-01	4.18E+00	#######	#######	6.06E-03	1.33E+00	3.17E-01	8.13E+02	2.71E-02	#######	3.44E-03	2.56E-02	8.15E+02
			Single Unit Long-haul Truck	2.89E-03	1.07E-02	1.21E-02	4.10E-02	9.63E-02	2.25E-01	#######	2.12E+00	9.29E-01	4.12E-02	#######	2.44E-03	1.82E-02	8.01E+02	9.34E-02	2.12E+00	#######	#######	5.74E-03	9.29E-01	2.25E-01	8.00E+02	4.12E-02	#######	2.44E-03	1.82E-02	8.01E+02
			Single Unit Short-haul Truck	2.89E-03	1.08E-02	1.21E-02	4.11E-02	9.25E-02	2.00E-01	#######	2.12E+00	8.59E-01	4.16E-02	#######	2.17E-03	1.62E-02	8.56E+02	8.97E-02	2.12E+00	#######	#######	6.10E-03	8.59E-01	2.00E-01	8.55E+02	4.16E-02	#######	2.17E-03	1.62E-02	8.56E+02
			Transit Bus	2.61E-03	8.11E-03	1.09E-02	3.10E-02	2.94E-01	3.41E-01	#######	6.06E+00	2.00E+00	2.82E-02	#######	3.69E-03	2.75E-02	1.19E+03	2.85E-01	6.06E+00	#######	#######	8.74E-03	2.00E+00	3.41E-01	1.19E+03	2.82E-02	#######	3.69E-03	2.75E-02	1.19E+03
			Motor Home	2.28E-03	8.51E-03	9.53E-03	3.25E-02	1.58E-01	3.60E-01	#######	3.30E+00	1.29E+00	3.85E-02	#######	3.90E-03	2.91E-02	8.85E+02	1.54E-01	3.30E+00	#######	#######	6.48E-03	1.29E+00	3.60E-01	8.83E+02	3.85E-02	#######	3.90E-03	2.91E-02	8.85E+02
			Refuse Truck	4.61E-03	1.27E-02	1.92E-02	4.85E-02	2.56E-01	2.61E-01	#######	5.73E+00	1.46E+00	3.39E-02	#######	2.82E-03	2.10E-02	1.53E+03	2.49E-01	5.73E+00	#######	#######	1.11E-02	1.46E+00	2.61E-01	1.52E+03	3.39E-02	#######	2.82E-03	2.10E-02	1.53E+03
			Light Commercial Truck	1.65E-03	3.29E-03	6.87E-03	1.26E-02	1.14E-01	2.54E-01	#######	2.02E+00	1.31E+00	1.61E-02	#######	2.76E-03	2.05E-02	6.18E+02	1.11E-01	2.02E+00	#######	#######	4.60E-03	1.31E+00	2.54E-01	6.17E+02	1.61E-02	#######	2.76E-03	2.05E-02	6.18E+02
		Gasoline	Combination Short-haul Truck	2.65E-03	7.18E-03	1.10E-02	2.74E-02	1.16E-01	3.76E+00	#######	1.67E+01	1.34E+02	8.72E-02	#######	1.27E-01	4.60E-02	1.72E+03	1.07E-01	1.67E+01	#######	#######	3.02E-02	1.34E+02	3.76E+00	1.72E+03	8.72E-02	#######	1.27E-01	4.60E-02	1.72E+03
			Motorcycle	6.37E-04	1.66E-04	2.66E-03	6.33E-04	4.70E-02	6.99E-01	#######	8.23E-01	1.46E+01	2.89E-02	#######	2.35E-02	9.42E-03	3.72E+02	4.33E-02	8.23E-01	#######	#######	6.50E-03	1.46E+01	6.99E-01	3.70E+02	2.89E-02	#######	2.35E-02	9.42E-03	3.72E+02
			Passenger Car	1.27E-03	1.92E-03	5.30E-03	7.33E-03	7.88E-03	3.05E-02	#######	2.18E-01	1.89E+00	4.22E-03	#######	1.03E-03	3.90E-04	3.02E+02	7.26E-03	2.18E-01	#######	#######	5.29E-03	1.89E+00	3.05E-02	3.01E+02	4.22E-03	#######	1.03E-03	3.90E-04	3.02E+02
			Passenger Truck	1.30E-03	3.16E-03	5.41E-03	1.21E-02	1.42E-02	1.11E-01	#######	7.16E-01	4.23E+00	5.74E-03	#######	3.74E-03	1.40E-03	4.15E+02	1.31E-02	7.16E-01	#######	#######	7.27E-03	4.23E+00	1.11E-01	4.14E+02	5.74E-03	#######	3.74E-03	1.40E-03	4.15E+02
			School Bus	2.27E-03	8.84E-03	9.46E-03	3.38E-02	1.73E-02	8.98E-01	#######	3.67E+00	2.54E+01	3.55E-02	#######	3.02E-02	1.14E-02	7.72E+02	1.59E-02	3.67E+00	#######	#######	1.35E-02	2.54E+01	8.98E-01	7.67E+02	3.55E-02	#######	3.02E-02	1.14E-02	7.72E+02
			Single Unit Long-haul Truck	2.30E-03	9.22E-03	9.60E-03	3.52E-02	7.82E-03	3.73E-01	#######	3.22E+00	1.36E+01	7.25E-03	#######	1.25E-02	4.95E-03	8.03E+02	7.21E-03	3.22E+00	#######	#######	1.41E-02	1.36E+01	3.73E-01	8.01E+02	7.25E-03	#######	1.25E-02	4.95E-03	8.03E+02
			Single Unit Short-haul Truck	2.30E-03	9.23E-03	9.60E-03	3.53E-02	8.20E-03	3.97E-01	#######	3.33E+00	1.44E+01	8.00E-03	#######	1.33E-02	5.25E-03	8.55E+02	7.55E-03	3.33E+00	#######	#######	1.50E-02	1.44E+01	3.97E-01	8.53E+02	8.00E-03	#######	1.33E-02	5.25E-03	8.55E+02
			Transit Bus	2.27E-03	8.40E-03	9.46E-03	3.21E-02	1.02E-02	8.36E-01	#######	3.92E+00	2.48E+01	1.27E-02	#######	2.80E-02	1.10E-02	1.13E+03	9.43E-03	3.92E+00	#######	#######	1.97E-02	2.48E+01	8.36E-01	1.12E+03	1.27E-02	#######	2.80E-02	1.10E-02	1.13E+03
			Motor Home	2.21E-03	8.33E-03	9.22E-03	3.18E-02	1.67E-02	6.30E-01	#######	4.05E+00	2.24E+01	1.77E-02	#######	2.12E-02	8.07E-03	8.71E+02	1.54E-02	4.05E+00	#######	#######	1.52E-02	2.24E+01	6.30E-01	8.67E+02	1.77E-02	#######	2.12E-02	8.07E-03	8.71E+02
			Refuse Truck	2.21E-03	7.31E-03	9.22E-03	2.79E-02	1.35E-02	7.77E-01	#######	5.19E+00	3.03E+01	1.08E-02	#######	2.60E-02	1.02E-02	1.42E+03	1.25E-02	5.19E+00	#######	#######	2.49E-02	3.03E+01	7.77E-01	1.42E+03	1.08E-02	#######	2.60E-02	1.02E-02	1.42E+03
			Light Commercial Truck	1.32E-03	3.17E-03	5.52E-03	1.21E-02	1.39E-02	1.21E-01	#######	8.09E-01	4.46E+00	5.98E-03	#######	4.08E-03	1.54E-03	4.13E+02	1.28E-02	8.09E-01	#######	#######	7.22E-03	4.46E+00	1.21E-01	4.11E+02	5.98E-03	#######	4.08E-03	1.54E-03	4.13E+02
		Compressed Natural Gas (CNG)	Transit Bus	2.27E-03	8.41E-03	9.47E-03	3.21E-02	5.13E-03	0.00E+00		3.40E+00	3.03E+01	1.74E-02	#######			9.36E+02	5.13E-03	3.40E+00	#######	#######	#######	3.03E+01	0.00E+00	9.24E+02	1.74E-02	#######	#######	0.00E+00	9.36E+02
	2017	Diesel Fuel	Combination Long-haul Truck	4.44E-03	1.07E-02	1.85E-02	4.09E-02	2.57E-01	2.22E-01	#######	5.96E+00	1.38E+00	3.34E-02	#######	2.41E-03	1.79E-02	1.95E+03	2.49E-01	5.96E+00	#######	#######	1.41E-02	1.38E+00	2.22E-01	1.94E+03	3.34E-02	#######	2.41E-03	1.79E-02	1.95E+03
			Combination Short-haul Truck	4.03E-03	9.91E-03	1.68E-02	3.79E-02	2.10E-01	2.04E-01	#######	5.21E+00	1.21E+00	3.47E-02	#######	2.21E-03	1.65E-02	1.87E+03	2.04E-01	5.21E+00	#######	#######	1.34E-02	1.21E+00	2.04E-01	1.86E+03	3.47E-02	#######	2.21E-03	1.65E-02	1.87E+03
			Intercity Bus	4.86E-03	1.62E-02	2.03E-02	6.17E-02	3.41E-01	3.04E-01	#######	7.58E+00	1.89E+00	3.34E-02	#######	3.30E-03	2.46E-02	1.62E+03	3.31E-01	7.58E+00	#######	#######	1.19E-02	1.89E+00	3.04E-01	1.62E+03	3.34E-02	#######	3.30E-03	2.46E-02	1.62E+03
			Passenger Car	1.27E-03	1.92E-03	5.30E-03	7.33E-03	6.91E-03	1.23E-02	#######	3.06E-01	7.17E-01	4.68E-03	#######	1.33E-04	9.90E-04	3.15E+02	6.71E-03	3.06E-01	#######	#######	2.26E-03	7.17E-01	1.23E-02	3.15E+02	4.68E-03	#######	1.33E-04	9.90E-04	3.15E+02
			Passenger Truck	1.62E-03	3.02E-03	6.75E-03	1.15E-02	7.14E-02	1.55E-01	#######	1.44E+00	9.72E-01	1.98E-02	#######	1.68E-03	1.25E-02	6.19E+02	6.93E-02	1.44E+00	#######	#######	4.49E-03	9.72E-01	1.55E-01	6.18E+02	1.98E-02	#######	1.68E-03	1.25E-02	6.19E+02
			School Bus	3.93E-03	1.37E-02	1.64E-02	5.25E-02	1.89E-01	2.86E-01	#######	3.77E+00	1.21E+00	2.84E-02	#######	3.10E-03	2.31E-02	8.15E+02	1.84E-01	3.77E+00	#######	#######	6.01E-03	1.21E+00	2.86E-01	8.13E+02	2.84E-02	#######	3.10E-03	2.31E-02	8.15E+02
			Single Unit Long-haul Truck	2.89E-03	1.07E-02	1.21E-02	4.10E-02	8.26E-02	1.96E-01	#######	1.90E+00	8.33E-01	4.18E-02	#######	2.13E-03	1.58E-02	8.01E+02	8.01E-02	1.90E+00	#######	#######	5.70E-03	8.33E-01	1.96E-01	8.00E+02	4.18E-02	#######	2.13E-03	1.58E-02	8.01E+02
			Single Unit Short-haul Truck	2.89E-03	1.08E-02	1.21E-02	4.11E-02	7.73E-02	1.72E-01	#######	1.87E+00	7.63E-01	4.21E-02	#######	1.86E-03	1.38E-02	8.56E+02	7.50E-02	1.87E+00	#######	#######	6.06E-03	7.63E-01	1.72E-01	8.55E+02	4.21E-02	#######	1.86E-03	1.38E-02	8.56E+02
			Transit Bus	2.61E-03	8.11E-03	1.09E-02	3.10E-02	2.53E-01	2.99E-01	#######	5.33E+00	1.77E+00	3.01E-02	#######	3.24E-03	2.42E-02	1.19E+03	2.46E-01	5.33E+00	#######	#######	8.67E-03	1.77E+00	2.99E-01	1.19E+03	3.01E-02	#######	3.24E-03	2.42E-02	1.19E+03
			Motor Home	2.28E-03	8.51E-03	9.53E-03	3.25E-02	1.40E-01	3.24E-01	#######	2.99E+00	1.18E+00	3.96E-02	#######	3.52E-03	2.62E-02	8.85E+02	1.35E-01	2.99E+00	#######	#######	6.43E-03	1.18E+00	3.24E-01	8.83E+02	3.96E-02	#######	3.52E-03	2.62E-02	8.85E+02
			Refuse Truck	4.62E-03	1.27E-02	1.93E-02	4.86E-02	2.15E-01	2.23E-01	#######	4.95E+00	1.27E+00	3.54E-02	#######	2.41E-03	1.80E-02	1.53E+03	2.08E-01	4.95E+00	#######	#######	1.10E-02	1.27E+00	2.23E-01	1.52E+03	3.54E-02	#######	2.41E-03	1.80E-02	1.53E+03
			Light Commercial Truck	1.65E-03	3.29E-03	6.87E-03	1.26E-02	1.01E-01	2.25E-01	#######	1.85E+00	1.22E+00	1.73E-02	#######	2.44E-03	1.82E-02	6.15E+02	9.80E-02	1.85E+00	#######	#######	4.54E-03	1.22E+00	2.25E-01	6.14E+02	1.73E-02	#######	2.44E-03	1.82E-02	6.15E+02
		Gasoline	Combination Short-haul Truck	2.65E-03	7.18E-03	1.10E-02	2.74E-02	1.17E-01	3.75E+00	#######	1.67E+01	1.34E+02	8.16E-02	#######	1.27E-01	4.60E-02	1.72E+03	1.08E-01	1.67E+01	#######	#######	3.02E-02	1.34E+02	3.75E+00	1.72E+03	8.16E-02	#######	1.27E-01	4.60E-02	1.72E+03
			Motorcycle	6.37E-04	1.66E-04	2.66E-03	6.33E-04	4.70E-02	6.85E-01	#######	8.17E-01	1.44E+01	2.89E-02	#######	2.30E-02	9.23E-03	3.72E+02	4.33E-02	8.17E-01	#######	#######	6.50E-03	1.44E+01	6.85E-01	3.70E+02	2.89E-02	#######	2.30E-02	9.23E-03	3.72E+02
			Passenger Car	1.27E-03	1.92E-03	5.30E-03	7.33E-03	7.62E-03	2.61E-02	#######	1.84E-01	1.79E+00	4.11E-03	#######	8.76E-04	3.35E-04	2.96E+02	7.01E-03	1.84E-01	#######	#######	5.19E-03	1.79E+00	2.61E-02	2.96E+02	4.11E-03	#######	8.76E-04	3.35E-04	2.96E+02
			Passenger Truck	1.30E-03	3.16E-03	5.41E-03	1.21E-02	1.40E-02	1.00E-01	#######	6.57E-01	4.03E+00	5.30E-03	#######	3.38E-03	1.27E-03	4.07E+02	1.29E-02	6.57E-01	#######	#######	7.13E-03	4.03E+00	1.00E-01	4.06E+02	5.30E-03	#######	3.38E-03	1.27E-03	4.07E+02
			School Bus	2.27E-03	8.84E-03	9.46E-03	3.38E-02	1.51E-02	8.13E-01	#######	3.44E+00	2.35E+01	2.99E-02	#######	2.73E-02	1.03E-02	7.72E+02	1.39E-02	3.44E+00	#######	#######	1.35E-02	2.35E+01	8.13E-01	7.67E+02	2.99E-02	#######	2.73E-02	1.03E-02	7.72E+02
			Single Unit Long-haul Truck	2.30E-03	9.22E-03	9.60E-03	3.52E-02	7.70E-03	3.69E-01	#######	3.20E+00	1.34E+01	7.14E-03	#######	1.23E-02	4.89E-03	8.03E+02	7.09E-03	3.20E+00	#######	#######	1.41E-02	1.34E+01	3.69E-01	8.01E+02	7.14E-03	#######	1.23E-02	4.89E-03	8.03E+02
			Single Unit Short-haul Truck	2.30E-03	9.23E-03	9.60E-03	3.53E-02	7.87E-03	3.87E-01	#######	3.30E+00	1.41E+01	7.60E-03	#######	1.29E-02	5.14E-03	8.55E+02	7.25E-03	3.30E+00	#######	#######	1.50E-02	1.41E+01	3.87E-01	8.53E+02	7.60E-03	#######	1.29E-02	5.14E-03	8.55E+02
			Transit Bus	2.27E-03	8.40E-03	9.46E-03	3.21E-02	1.01E-02	8.25E-01	#######	3.87E+00	2.37E+01	1.23E-02	#######	2.76E-02	1.08E-02	1.13E+03	9.32E-03	3.87E+00	#######	#######	1.97E-02	2.37E+01	8.25E-01	1.12E+03	1.23E-02	#######	2.76E-02	1.08E-02	1.13E+03
			Motor Home	2.21E-03	8.33E-03	9.22E-03	3.18E-02	1.56E-02	6.00E-01	#######	3.94E+00	2.16E+01	1.59E-02	#######	2.01E-02	7.71E-03	8.71E+02	1.44E-02	3.94E+00	#######	#######	1.52E-02	2.16E+01	6.00E-01	8.67E+02	1.59E-02	#######	2.01E-02	7.71E-03	8.71E+02
			Refuse Truck	2.21E-03	7.31E-03	9.22E-03	2.79E-02	1.28E-02	7.42E-01	#######	5.08E+00	2.83E+01	9.89E-03	#######	2.48E-02	9.74E-03	1.42E+03	1.18E-02	5.08E+00	#######	#######	2.49E-02	2.83E+01	7.42E-01	1.42E+03	9.89E-03	#######	2.48E-02	9.74E-03	1.42E+03

		Light Commercial Truck	1.32E-03	3.17E-03	5.52E-03	1.21E-02	1.37E-02	1.11E-01	#######	7.52E-01	4.28E+00	5.53E-03	#######	3.72E-03	1.41E-03	4.05E+02	1.26E-02	7.52E-01	#######	#######	7.08E-03	4.28E+00	1.11E-01	4.04E+02	5.53E-03	#######	3.72E-03	1.41E-03	4.05E+02
	Compressed Natural Gas (CNG)	Transit Bus	2.27E-03	8.41E-03	9.47E-03	3.21E-02	5.09E-03	0.00E+00		3.36E+00	2.84E+01	1.64E-02	#######			9.36E+02	5.09E-03	3.36E+00	#######	#######	#######	2.84E+01	0.00E+00	9.24E+02	1.64E-02	#######	#######	0.00E+00	9.36E+02
2018	Diesel Fuel	Combination Long-haul Truck	4.44E-03	1.07E-02	1.85E-02	4.09E-02	2.22E-01	1.92E-01	#######	5.26E+00	1.21E+00	3.45E-02	#######	2.09E-03	1.55E-02	1.95E+03	2.15E-01	5.26E+00	#######	#######	1.40E-02	1.21E+00	1.92E-01	1.94E+03	3.45E-02	#######	2.09E-03	1.55E-02	1.95E+03
		Combination Short-haul Truck	4.03E-03	9.91E-03	1.68E-02	3.79E-02	1.76E-01	1.74E-01	#######	4.53E+00	1.06E+00	3.57E-02	#######	1.88E-03	1.40E-02	1.87E+03	1.71E-01	4.53E+00	#######	#######	1.33E-02	1.06E+00	1.74E-01	1.86E+03	3.57E-02	#######	1.88E-03	1.40E-02	1.87E+03
		Intercity Bus	4.86E-03	1.62E-02	2.03E-02	6.17E-02	2.87E-01	2.73E-01	#######	6.73E+00	1.70E+00	3.49E-02	#######	2.96E-03	2.20E-02	1.62E+03	2.78E-01	6.73E+00	#######	#######	1.18E-02	1.70E+00	2.73E-01	1.62E+03	3.49E-02	#######	2.96E-03	2.20E-02	1.62E+03
		Passenger Car	1.27E-03	1.92E-03	5.30E-03	7.33E-03	5.91E-03	1.07E-02	#######	2.53E-01	8.04E-01	5.45E-03	#######	1.16E-04	8.65E-04	3.07E+02	5.74E-03	2.53E-01	#######	#######	2.19E-03	8.04E-01	1.07E-02	3.07E+02	5.45E-03	#######	1.16E-04	8.65E-04	3.07E+02
		Passenger Truck	1.62E-03	3.02E-03	6.75E-03	1.15E-02	6.20E-02	1.35E-01	#######	1.32E+00	9.23E-01	2.06E-02	#######	1.47E-03	1.09E-02	6.16E+02	6.01E-02	1.32E+00	#######	#######	4.44E-03	9.23E-01	1.35E-01	6.15E+02	2.06E-02	#######	1.47E-03	1.09E-02	6.16E+02
		School Bus	3.93E-03	1.37E-02	1.64E-02	5.25E-02	1.64E-01	2.55E-01	#######	3.39E+00	1.10E+00	2.95E-02	#######	2.76E-03	2.06E-02	8.15E+02	1.59E-01	3.39E+00	#######	#######	5.96E-03	1.10E+00	2.55E-01	8.13E+02	2.95E-02	#######	2.76E-03	2.06E-02	8.15E+02
		Single Unit Long-haul Truck	2.89E-03	1.07E-02	1.21E-02	4.10E-02	7.09E-02	1.68E-01	#######	1.71E+00	7.43E-01	4.24E-02	#######	1.82E-03	1.35E-02	8.01E+02	6.88E-02	1.71E+00	#######	#######	5.66E-03	7.43E-01	1.68E-01	8.00E+02	4.24E-02	#######	1.82E-03	1.35E-02	8.01E+02
		Single Unit Short-haul Truck	2.90E-03	1.08E-02	1.21E-02	4.11E-02	6.47E-02	1.45E-01	#######	1.67E+00	6.76E-01	4.26E-02	#######	1.57E-03	1.17E-02	8.56E+02	6.28E-02	1.67E+00	#######	#######	6.02E-03	6.76E-01	1.45E-01	8.55E+02	4.26E-02	#######	1.57E-03	1.17E-02	8.56E+02
		Transit Bus	2.61E-03	8.11E-03	1.09E-02	3.10E-02	2.15E-01	2.61E-01	#######	4.69E+00	1.55E+00	3.14E-02	#######	2.83E-03	2.11E-02	1.19E+03	2.09E-01	4.69E+00	#######	#######	8.60E-03	1.55E+00	2.61E-01	1.19E+03	3.14E-02	#######	2.83E-03	2.11E-02	1.19E+03
		Motor Home	2.28E-03	8.51E-03	9.53E-03	3.25E-02	1.23E-01	2.87E-01	#######	2.72E+00	1.08E+00	4.05E-02	#######	3.11E-03	2.32E-02	8.85E+02	1.19E-01	2.72E+00	#######	#######	6.39E-03	1.08E+00	2.87E-01	8.83E+02	4.05E-02	#######	3.11E-03	2.32E-02	8.85E+02
		Refuse Truck	4.63E-03	1.27E-02	1.93E-02	4.87E-02	1.78E-01	1.89E-01	#######	4.27E+00	1.10E+00	3.67E-02	#######	2.05E-03	1.53E-02	1.53E+03	1.73E-01	4.27E+00	#######	#######	1.09E-02	1.10E+00	1.89E-01	1.52E+03	3.67E-02	#######	2.05E-03	1.53E-02	1.53E+03
		Light Commercial Truck	1.65E-03	3.28E-03	6.87E-03	1.25E-02	8.88E-02	1.99E-01	#######	1.69E+00	1.14E+00	1.83E-02	#######	2.16E-03	1.61E-02	6.13E+02	8.62E-02	1.69E+00	#######	#######	4.48E-03	1.14E+00	1.99E-01	6.12E+02	1.83E-02	#######	2.16E-03	1.61E-02	6.13E+02
	Gasoline	Combination Short-haul Truck	2.65E-03	7.18E-03	1.10E-02	2.74E-02	1.17E-01	3.76E+00	#######	1.67E+01	1.34E+02	7.69E-02	#######	1.27E-01	4.60E-02	1.72E+03	1.08E-01	1.67E+01	#######	#######	3.02E-02	1.34E+02	3.76E+00	1.72E+03	7.69E-02	#######	1.27E-01	4.60E-02	1.72E+03
		Motorcycle	6.37E-04	1.66E-04	2.66E-03	6.33E-04	4.70E-02	6.73E-01	#######	8.12E-01	1.42E+01	2.89E-02	#######	2.26E-02	9.07E-03	3.72E+02	4.33E-02	8.12E-01	#######	#######	6.51E-03	1.42E+01	6.73E-01	3.70E+02	2.89E-02	#######	2.26E-02	9.07E-03	3.72E+02
		Passenger Car	1.27E-03	1.92E-03	5.30E-03	7.33E-03	7.42E-03	2.28E-02	#######	1.58E-01	1.72E+00	4.03E-03	#######	7.64E-04	2.95E-04	2.90E+02	6.83E-03	1.58E-01	#######	#######	5.09E-03	1.72E+00	2.28E-02	2.90E+02	4.03E-03	#######	7.64E-04	2.95E-04	2.90E+02
		Passenger Truck	1.30E-03	3.16E-03	5.41E-03	1.21E-02	1.38E-02	9.15E-02	#######	6.06E-01	3.86E+00	4.92E-03	#######	3.07E-03	1.16E-03	3.99E+02	1.27E-02	6.06E-01	#######	#######	6.99E-03	3.86E+00	9.15E-02	3.98E+02	4.92E-03	#######	3.07E-03	1.16E-03	3.99E+02
		School Bus	2.27E-03	8.84E-03	9.46E-03	3.38E-02	1.34E-02	7.44E-01	#######	3.24E+00	2.18E+01	2.48E-02	#######	2.49E-02	9.51E-03	7.71E+02	1.23E-02	3.24E+00	#######	#######	1.35E-02	2.18E+01	7.44E-01	7.67E+02	2.48E-02	#######	2.49E-02	9.51E-03	7.71E+02
		Single Unit Long-haul Truck	2.30E-03	9.22E-03	9.60E-03	3.52E-02	7.58E-03	3.66E-01	#######	3.18E+00	1.33E+01	7.01E-03	#######	1.22E-02	4.86E-03	8.03E+02	6.98E-03	3.18E+00	#######	#######	1.41E-02	1.33E+01	3.66E-01	8.01E+02	7.01E-03	#######	1.22E-02	4.86E-03	8.03E+02
		Single Unit Short-haul Truck	2.30E-03	9.23E-03	9.60E-03	3.53E-02	7.62E-03	3.81E-01	#######	3.27E+00	1.39E+01	7.26E-03	#######	1.27E-02	5.07E-03	8.55E+02	7.01E-03	3.27E+00	#######	#######	1.50E-02	1.39E+01	3.81E-01	8.53E+02	7.26E-03	#######	1.27E-02	5.07E-03	8.55E+02
		Transit Bus	2.27E-03	8.40E-03	9.46E-03	3.21E-02	9.99E-03	8.16E-01	#######	3.83E+00	2.28E+01	1.19E-02	#######	2.72E-02	1.07E-02	1.13E+03	9.20E-03	3.83E+00	#######	#######	1.97E-02	2.28E+01	8.16E-01	1.12E+03	1.19E-02	#######	2.72E-02	1.07E-02	1.13E+03
		Motor Home	2.21E-03	8.33E-03	9.22E-03	3.18E-02	1.45E-02	5.73E-01	#######	3.83E+00	2.08E+01	1.41E-02	#######	1.92E-02	7.38E-03	8.70E+02	1.33E-02	3.83E+00	#######	#######	1.52E-02	2.08E+01	5.73E-01	8.67E+02	1.41E-02	#######	1.92E-02	7.38E-03	8.70E+02
		Refuse Truck	2.21E-03	7.31E-03	9.22E-03	2.79E-02	1.22E-02	7.13E-01	#######	4.99E+00	2.67E+01	9.08E-03	#######	2.38E-02	9.39E-03	1.42E+03	1.12E-02	4.99E+00	#######	#######	2.49E-02	2.67E+01	7.13E-01	1.42E+03	9.08E-03	#######	2.38E-02	9.39E-03	1.42E+03
		Light Commercial Truck	1.32E-03	3.17E-03	5.52E-03	1.21E-02	1.35E-02	1.02E-01	#######	7.04E-01	4.12E+00	5.14E-03	#######	3.43E-03	1.30E-03	3.97E+02	1.24E-02	7.04E-01	#######	#######	6.95E-03	4.12E+00	1.02E-01	3.96E+02	5.14E-03	#######	3.43E-03	1.30E-03	3.97E+02
	Compressed Natural Gas (CNG)	Transit Bus	2.27E-03	8.41E-03	9.47E-03	3.21E-02	5.00E-03	0.00E+00		3.32E+00	2.67E+01	1.55E-02	#######			9.36E+02	5.00E-03	3.32E+00	#######	#######	#######	2.67E+01	0.00E+00	9.24E+02	1.55E-02	#######	#######	0.00E+00	9.36E+02
2019	Diesel Fuel	Combination Long-haul Truck	4.44E-03	1.07E-02	1.85E-02	4.09E-02	1.91E-01	1.67E-01	#######	4.65E+00	1.07E+00	3.55E-02	#######	1.81E-03	1.34E-02	1.95E+03	1.85E-01	4.65E+00	#######	#######	1.39E-02	1.07E+00	1.67E-01	1.94E+03	3.55E-02	#######	1.81E-03	1.34E-02	1.95E+03
		Combination Short-haul Truck	4.03E-03	9.90E-03	1.68E-02	3.78E-02	1.49E-01	1.48E-01	#######	3.95E+00	9.21E-01	3.66E-02	#######	1.60E-03	1.19E-02	1.87E+03	1.45E-01	3.95E+00	#######	#######	1.32E-02	9.21E-01	1.48E-01	1.86E+03	3.66E-02	#######	1.60E-03	1.19E-02	1.87E+03
		Intercity Bus	4.86E-03	1.62E-02	2.03E-02	6.17E-02	2.55E-01	2.44E-01	#######	5.98E+00	1.53E+00	3.62E-02	#######	2.64E-03	1.97E-02	1.62E+03	2.47E-01	5.98E+00	#######	#######	1.18E-02	1.53E+00	2.44E-01	1.62E+03	3.62E-02	#######	2.64E-03	1.97E-02	1.62E+03
		Passenger Car	1.27E-03	1.92E-03	5.30E-03	7.33E-03	5.19E-03	9.54E-03	#######	2.10E-01	8.88E-01	6.19E-03	#######	1.03E-04	7.71E-04	3.00E+02	5.04E-03	2.10E-01	#######	#######	2.12E-03	8.88E-01	9.54E-03	2.99E+02	6.19E-03	#######	1.03E-04	7.71E-04	3.00E+02
		Passenger Truck	1.62E-03	3.02E-03	6.75E-03	1.15E-02	5.44E-02	1.19E-01	#######	1.21E+00	8.83E-01	2.14E-02	#######	1.29E-03	9.59E-03	6.13E+02	5.27E-02	1.21E+00	#######	#######	4.39E-03	8.83E-01	1.19E-01	6.12E+02	2.14E-02	#######	1.29E-03	9.59E-03	6.13E+02
		School Bus	3.93E-03	1.37E-02	1.64E-02	5.25E-02	1.46E-01	2.26E-01	#######	3.04E+00	9.93E-01	3.06E-02	#######	2.45E-03	1.83E-02	8.15E+02	1.41E-01	3.04E+00	#######	#######	5.92E-03	9.93E-01	2.26E-01	8.13E+02	3.06E-02	#######	2.45E-03	1.83E-02	8.15E+02
		Single Unit Long-haul Truck	2.89E-03	1.07E-02	1.21E-02	4.10E-02	6.10E-02	1.43E-01	#######	1.55E+00	6.65E-01	4.28E-02	#######	1.55E-03	1.16E-02	8.01E+02	5.91E-02	1.55E+00	#######	#######	5.63E-03	6.65E-01	1.43E-01	8.00E+02	4.28E-02	#######	1.55E-03	1.16E-02	8.01E+02
		Single Unit Short-haul Truck	2.90E-03	1.08E-02	1.21E-02	4.11E-02	5.47E-02	1.23E-01	#######	1.49E+00	6.03E-01	4.30E-02	#######	1.33E-03	9.90E-03	8.56E+02	5.31E-02	1.49E+00	#######	#######	5.99E-03	6.03E-01	1.23E-01	8.55E+02	4.30E-02	#######	1.33E-03	9.90E-03	8.56E+02
		Transit Bus	2.61E-03	8.11E-03	1.09E-02	3.10E-02	1.87E-01	2.28E-01	#######	4.12E+00	1.36E+00	3.25E-02	#######	2.47E-03	1.84E-02	1.19E+03	1.82E-01	4.12E+00	#######	#######	8.53E-03	1.36E+00	2.28E-01	1.19E+03	3.25E-02	#######	2.47E-03	1.84E-02	1.19E+03
		Motor Home	2.29E-03	8.51E-03	9.53E-03	3.25E-02	1.08E-01	2.51E-01	#######	2.48E+00	9.77E-01	4.14E-02	#######	2.73E-03	2.03E-02	8.85E+02	1.05E-01	2.48E+00	#######	#######	6.35E-03	9.77E-01	2.51E-01	8.83E+02	4.14E-02	#######	2.73E-03	2.03E-02	8.85E+02
		Refuse Truck	4.63E-03	1.28E-02	1.93E-02	4.87E-02	1.50E-01	1.61E-01	#######	3.68E+00	9.60E-01	3.78E-02	#######	1.74E-03	1.30E-02	1.53E+03	1.46E-01	3.68E+00	#######	#######	1.08E-02	9.60E-01	1.61E-01	1.52E+03	3.78E-02	#######	1.74E-03	1.30E-02	1.53E+03
		Light Commercial Truck	1.65E-03	3.28E-03	6.87E-03	1.25E-02	7.82E-02	1.76E-01	#######	1.55E+00	1.07E+00	1.93E-02	#######	1.90E-03	1.42E-02	6.10E+02	7.58E-02	1.55E+00	#######	#######	4.43E-03	1.07E+00	1.76E-01	6.09E+02	1.93E-02	#######	1.90E-03	1.42E-02	6.10E+02
	Gasoline	Motorcycle	6.37E-04	1.66E-04	2.66E-03	6.33E-04	4.70E-02	6.63E-01	#######	8.07E-01	1.40E+01	2.88E-02	#######	2.23E-02	8.94E-03	3.72E+02	4.33E-02	8.07E-01	#######	#######	6.51E-03	1.40E+01	6.63E-01	3.71E+02	2.88E-02	#######	2.23E-02	8.94E-03	3.72E+02
		Passenger Car	1.27E-03	1.92E-03	5.30E-03	7.33E-03	7.29E-03	2.04E-02	#######	1.37E-01	1.66E+00	4.02E-03	#######	6.82E-04	2.65E-04	2.85E+02	6.71E-03	1.37E-01	#######	#######	5.00E-03	1.66E+00	2.04E-02	2.85E+02	4.02E-03	#######	6.82E-04	2.65E-04	2.85E+02
		Passenger Truck	1.30E-03	3.16E-03	5.41E-03	1.21E-02	1.36E-02	8.37E-02	#######	5.60E-01	3.70E+00	4.57E-03	#######	2.80E-03	1.06E-03	3.91E+02	1.25E-02	5.60E-01	#######	#######	6.86E-03	3.70E+00	8.37E-02	3.91E+02	4.57E-03	#######	2.80E-03	1.06E-03	3.91E+02
		School Bus	2.27E-03	8.84E-03	9.46E-03	3.38E-02	1.13E-02	6.83E-01	#######	3.07E+00	2.02E+01	2.07E-02	#######	2.28E-02	8.79E-03	7.71E+02	1.04E-02	3.07E+00	#######	#######	1.35E-02	2.02E+01	6.83E-01	7.67E+02	2.07E-02	#######	2.28E-02	8.79E-03	7.71E+02
		Single Unit Long-haul Truck	2.30E-03	9.22E-03	9.60E-03	3.52E-02	7.46E-03	3.64E-01	#######	3.17E+00	1.32E+01	6.62E-03	#######	1.21E-02	4.84E-03	8.03E+02	6.87E-03	3.17E+00	#######	#######	1.41E-02	1.32E+01	3.64E-01	8.01E+02	6.62E-03	#######	1.21E-02	4.84E-03	8.03E+02
		Single Unit Short-haul Truck	2.30E-03	9.23E-03	9.60E-03	3.53E-02	7.40E-03	3.77E-01	#######	3.25E+00	1.37E+01	6.78E-03	#######	1.26E-02	5.02E-03	8.55E+02	6.81E-03	3.25E+00	#######	#######	1.50E-02	1.37E+01	3.77E-01	8.53E+02	6.78E-03	#######	1.26E-02	5.02E-03	8.55E+02
		Transit Bus	2.27E-03	8.40E-03	9.46E-03	3.21E-02	9.86E-03	8.10E-01	#######	3.80E+00	2.21E+01	1.11E-02	#######	2.69E-02	1.06E-02	1.13E+03	9.08E-03	3.80E+00	#######	#######	1.97E-02	2.21E+01	8.10E-01	1.12E+03	1.11E-02	#######	2.69E-02	1.06E-02	1.13E+03
		Motor Home	2.21E-03	8.33E-03	9.22E-03	3.18E-02	1.32E-02	5.50E-01	#######	3.74E+00	2.02E+01	1.24E-02	#######	1.83E-02	7.10E-03	8.70E+02	1.22E-02	3.74E+00	#######	#######	1.52E-02	2.02E+01	5.50E-01	8.67E+02	1.24E-02	#######	1.83E-02	7.10E-03	8.70E+02
		Refuse Truck	2.21E-03	7.31E-03	9.22E-03	2.79E-02	1.17E-02	6.90E-01	#######	4.91E+00	2.53E+01	8.30E-03	#######	2.30E-02	9.10E-03	1.42E+03	1.08E-02	4.91E+00	#######	#######	2.49E-02	2.53E+01	6.90E-01	1.42E+03	8.30E-03	#######	2.30E-02	9.10E-03	1.42E+03
		Light Commercial Truck	1.32E-03	3.17E-03	5.52E-03	1.21E-02	1.33E-02	9.47E-02	#######	6.60E-01	3.97E+00	4.73E-03	#######	3.16E-03	1.21E-03	3.90E+02	1.22E-02	6.60E-01	#######	#######	6.83E-03	3.97E+00	9.47E-02	3.89E+02	4.73E-03	#######	3.16E-03	1.21E-03	3.90E+02
	Compressed Natural Gas (CNG)	Transit Bus	2.27E-03	8.41E-03	9.47E-03	3.21E-02	4.87E-03	0.00E+00		3.29E+00	2.51E+01	1.42E-02	#######			9.36E+02	4.87E-03	3.29E+00	#######	#######	#######	2.51E+01	0.00E+00	9.24E+02	1.42E-02	#######	#######	0.00E+00	9.36E+02
2020	Diesel Fuel	Combination Long-haul Truck	4.44E-03	1.07E-02	1.85E-02	4.09E-02	1.64E-01	1.44E-01	#######	4.11E+00	9.45E-01	3.63E-02	#######	1.56E-03	1.16E-02	1.95E+03	1.59E-01	4.11E+00	#######	#######	1.38E-02	9.45E-01	1.44E-01	1.94E+03	3.63E-02	#######	1.56E-03	1.16E-02	1.95E+03
		Combination Short-haul Truck	4.03E-03	9.90E-03	1.68E-02	3.78E-02	1.26E-01	1.26E-01	#######	3.46E+00	8.08E-01	3.73E-02	#######	1.36E-03	1.01E-02	1.87E+03	1.22E-01	3.46E+00	#######	#######	1.31E-02	8.08E-01	1.26E-01	1.86E+03	3.73E-02	#######	1.36E-03	1.01E-02	1.87E+03
		Intercity Bus	4.86E-03	1.62E-02	2.03E-02	6.17E-02	2.25E-01	2.18E-01	#######	5.30E+00	1.37E+00	3.74E-02	#######	2.36E-03	1.76E-02	1.62E+03	2.19E-01	5.30E+00	#######	#######	1.17E-02	1.37E+00	2.18E-01	1.62E+03	3.74E-02	#######	2.36E-03	1.76E-02	1.62E+03
		Passenger Car	1.27E-03	1.92E-03	5.30E-03	7.33E-03	4.66E-03	8.86E-03	#######	1.76E-01	9.82E-01	7.07E-03	#######	9.61E-05	7.16E-04	2.93E+02	4.52E-03	1.76E-01	#######	#######	2.05E-03	9.82E-01	8.86E-03	2.93E+02	7.07E-03	#######	9.61E-05	7.16E-04	2.93E+02
		Passenger Truck	1.62E-03	3.02E-03	6.75E-03	1.15E-02	4.77E-02	1.04E-01	#######	1.12E+00	8.57E-01	2.20E-02	#######	1.13E-03	8.43E-03	6.11E+02	4.63E-02	1.12E+00	#######	#######	4.34E-03	8.57E-01	1.04E-01	6.10E+02	2.20E-02	#######	1.13E-03	8.43E-03	6.11E+02
		School Bus	3.93E-03	1.37E-02	1.64E-02	5.25E-02	1.29E-01	2.01E-01	#######	2.74E+00	8.99E-01	3.15E-02	#######	2.18E-03	1.62E-02	8.15E+02	1.26E-01	2.74E+00	#######	#######	5.88E-03	8.99E-01	2.01E-01	8.13E+02	3.15E-02	#######	2.18E-03	1.62E-02	8.15E+02
		Single Unit Long-haul Truck	2.90E-03	1.07E-02	1.21E-02	4.10E-02	5.24E-02	1.23E-01	#######	1.41E+00	5.98E-01	4.32E-02	#######	1.33E-03	9.90E-03	8.01E+02	5.09E-02	1.41E+00	#######	#######	5.61E-03	5.98E-01	1.23E-01	8.00E+02	4.32E-02	#######	1.33E-03	9.90E-03	8.01E+02
		Single Unit Short-haul Truck	2.90E-03	1.08E-02	1.21E-02	4.11E-02	4.64E-02	1.04E-01	#######	1.35E+00	5.43E-01	4.33E-02	#######	1.13E-03	8.41E-03	8.56E+02	4.50E-02	1.35E+00	#######	#######	5.97E-03	5.43E-01	1.04E-01	8.55E+02	4.33E-02	#######	1.13E-03	8.41E-03	8.56E+02
		Transit Bus	2.61E-03	8.11E-03	1.09E-02	3.10E-02	1.63E-01	1.98E-01	#######	3.61E+00	1.19E+00	3.32E-02	#######	2.15E-03	1.60E-02	1.19E+03	1.58E-01	3.61E+00	#######	#######	8.48E-03	1.19E+00	1.98E-01	1.19E+03	3.32E-02	#######	2.15E-03	1.60E-02	1.19E+03
		Motor Home	2.29E-03	8.51E-03	9.53E-03	3.25E-02	9.53E-02	2.20E-01	#######	2.26E+00	8.87E-01	4.21E-02	#######	2.38E-03	1.78E-02	8.85E+02	9.25E-02	2.26E+00	#######	#######	6.31E-03	8.87E-01	2.20E-01	8.83E+02	4.21E-02	#######	2.38E-03	1.78E-02	8.85E+02
		Refuse Truck	4.64E-03	1.28E-02	1.94E-02	4.88E-02	1.26E-01	1.36E-01	#######	3.19E+00	8.40E-01	3.87E-02	#######	1.47E-03	1.10E-02	1.53E+03	1.22E-01	3.19E+00	#######	#######	1.08E-02	8.40E-01	1.36E-01	1.52E+03	3.87E-02	#######	1.47E-03	1.10E-02	1.53E+03
		Light Commercial Truck	1.65E-03	3.28E-03	6.87E-03	1.25E-02	6.84E-02	1.54E-01	#######	1.42E+00	1.01E+00	2.03E-02	#######	1.67E-03	1.25E-02	6.07E+02	6.64E-02	1.42E+00	#######	#######	4.38E-03	1.01E+00	1.54E-01	6.06E+02	2.03E-02	#######	1.67E-03	1.25E-02	6.07E+02
	Gasoline	Motorcycle	6.37E-04	1.66E-04	2.66E-03	6.33E-04	4.70E-02	6.54E-01	#######	8.03E-01	1.38E+01	2.88E-02	#######	2.20E-02	8.82E-03	3.72E+02	4.33E-02	8.03E-01	#######	#######	6.51E-03	1.38E+01	6.54E-01	3.71E+02	2.88E-02	#######	2.20E-02	8.82E-03	3.72E+02
		Passenger Car	1.27E-03	1.92E-03	5.30E-03	7.33E-03	7.20E-03	1.88E-02	#######	1.22E-01	1.62E+00	4.01E-03	#######	6.24E-04	2.44E-04	2.81E+02	6.63E-03	1.22E-01	#######	#######	4.92E-03	1.62E+00	1.88E-02	2.80E+02	4.01E-03	#######	6.24E-04	2.44E-04	2.81E+02
		Passenger Truck	1.30E-03	3.16E-03	5.41E-03	1.21E-02	1.35E-02	7.69E-02	#######	5.20E-01	3.57E+00	4.26E-03	#######	2.57E-03	9.79E-04	3.84E+02	1.24E-02	5.20E-01	#######	#######	6.73E-03	3.57E+00	7.69E-02	3.84E+02	4.26E-03	#######	2.57E-03	9.79E-04	3.84E+02
		School Bus	2.27E-03	8.84E-03	9.46E-03	3.38E-02	9.39E-03	6.28E-01	#######	2.92E+00	1.90E+01	1.71E-02	#######	2.09E-02	8.13E-03	7.71E+02	8.65E-03	2.92E+00	#######	#######	1.35E-02	1.90E+01	6.28E-01	7.67E+02	1.71E-02	#######	2.09E-02	8.13E-03	7.71E+02
		Single Unit Long-haul Truck	2.30E-03	9.22E-03	9.60E-03	3.52E-02	7.34E-03	3.63E-01	#######	3.15E+00	1.32E+01	6.30E-03	#######	1.21E-02	4.82E-03	8.03E+02	6.76E-03	3.15E+00	#######	#######	1.41E-02	1.32E+01	3.63E-01	8.01E+02	6.30E-03	#######	1.21E-02	4.82E-03	8.03E+02
		Single Unit Short-haul Truck	2.30E-03	9.23E-03	9.60E-03	3.53E-02	7.22E-03	3.73E-01	#######	3.23E+00	1.36E+01	6.43E-03	#######	1.24E-02	4.97E-03	8.55E+02	6.65E-03	3.23E+00	#######	#######	1.50E-02	1.36E+01	3.73E-01	8.53E+02	6.43E-03	#######	1.24E-02	4.97E-03	8.55E+02
		Transit Bus	2.27E-03	8.40E-03	9.46E-03	3.21E-02	9.75E-03	8.04E-01	#######	3.77E+00	2.14E+01	1.04E-02	#######	2.67E-02	1.06E-02	1.13E+03	8.98E-03	3.77E+00	#######	#######	1.97E-02	2.14E+01	8.04E-01	1.12E+03	1.04E-02	#######	2.67E-02	1.06E-02	1.13E+03
		Motor Home	2.21E-03	8.33E-03	9.22E-03	3.18E-02	1.20E-02	5.27E-01	#######	3.64E+00	1.96E+01	1.09E-02	#######	1.75E-02	6.83E-03	8.70E+02	1.10E-02	3.64E+00	#######	#######	1.52E-02	1.96E+01	5.27E-01	8.67E+02	1.09E-02	#######	1.75E-02	6.83E-03	8.70E+02
		Refuse Truck	2.21E-03	7.31E-03	9.22E-03	2.79E-02	1.13E-02	6.71E-01	#######	4.84E+00	2.42E+01	7.69E-03	#######	2.24E-02	8.87E-03	1.42E+03	1.04E-02	4.84E+00	#######	#######	2.49E-02	2.42E+01	6.71E-01	1.42E+03	7.69E-03	#######	2.24E-02	8.87E-03	1.42E+03
		Light Commercial Truck	1.32E-03	3.17E-03	5.52E-03	1.21E-02	1.32E-02	8.83E-02	#######	6.23E-01	3.85E+00	4.39E-03	#######	2.94E-03	1.13E-03	3.84E+02	1.22E-02	6.23E-01	#######	#######	6.72E-03	3.85E+00	8.83E-02	3.83E+02	4.39E-03	#######	2.94E-03	1.13E-03	3.84E+02
	Compressed Natural Gas (CNG)	Transit Bus	2.27E-03	8.41E-03	9.47E-03	3.21E-02	4.74E-03	0.00E+00		3.26E+00	2.38E+01	1.32E-02	#######			9.36E+02	4.74E-03	3.26E+00	#######	#######	#######	2.38E+01	0.00E+00	9.24E+02	1.32E-02	#######	#######	0.00E+00	9.36E+02
2021	Diesel Fuel	Combination Long-haul Truck	4.44E-03	1.07E-02	1.85E-02	4.09E-02	1.41E-01	1.25E-01	#######	3.66E+00	8.37E-01	3.71E-02	#######	1.35E-03	1.01E-02	1.95E+03	1.37E-01	3.66E+00	#######	#######	1.37E-02	8.37E-01	1.25E-01	1.94E+03	3.71E-02	#######	1.35E-03	1.01E-02	1.95E+03
		Combination Short-haul Truck	4.03E-03	9.90E-03	1.68E-02	3.78E-02	1.06E-01	1.07E-01	#######	3.06E+00	7.14E-01	3.79E-02	#######	1.16E-03	8.67E-03	1.87E+03	1.03E-01	3.06E+00	#######	#######	1.31E-02	7.14E-01	1.07E-01	1.86E+03	3.79E-02	#######	1.16E-03	8.67E-03	1.87E+03
		Intercity Bus	4.86E-03	1.62E-02	2.03E-02	6.17E-02	1.99E-01	1.94E-01	#######	4.74E+00	1.23E+00	3.85E-02	#######	2.10E-03	1.57E-02	1.62E+03	1.93E-01	4.74E+00	#######	#######	1.16E-02	1.23E+00	1.94E-01	1.62E+03	3.85E-02	#######	2.10E-03	1.57E-02	1.62E+03
		Passenger Car	1.27E-03	1.92E-03	5.30E-03	7.33E-03	4.27E-03	8.46E-03	#######	1.50E-01	1.07E+00	7.88E-03	#######	9.17E-05	6.83E-04	2.87E+02	4.14E-03	1.50E-01	#######	#######	2.00E-03	1.07E+00	8.46E-03	2.87E+02	7.88E-03	#######	9.17E-05	6.83E-04	2.87E+02
		Passenger Truck	1.62E-03	3.02E-03	6.75E-03	1.15E-02	4.17E-02	9.19E-02	#######	1.04E+00	8.35E-01	2.26E-02	#######	9.97E-04	7.42E-03	6.08E+02	4.04E-02	1.04E+00	#######	#######	4.30E-03	8.35E-01	9.19E-02	6.07E+02	2.26E-02	#######	9.97E-04	7.42E-03	6.08E+02
		School Bus	3.93E-03	1.37E-02	1.64E-02	5.25E-02	1.14E-01	1.77E-01	#######	2.46E+00	8.10E-01	3.24E-02	#######	1.92E-03	1.43E-02	8.15E+02	1.10E-01	2.46E+00	#######	#######	5.84E-03	8.10E-01	1.77E-01	8.13E+02	3.24E-02	#######	1.92E-03	1.43E-02	8.15E+02
		Single Unit Long-haul Truck	2.90E-03	1.07E-02	1.21E-02	4.10E-02	4.52E-02	1.05E-01	#######	1.29E+00	5.43E-01	4.35E-02	#######	1.14E-03	8.51E-03	8.01E+02	4.38E-02	1.29E+00	#######	#######	5.59E-03	5.43E-01	1.05E-01	8.00E+02	4.35E-02	#######	1.14E-03	8.51E-03	8.01E+02
		Single Unit Short-haul Truck	2.90E-03	1.08E-02	1.21E-02	4.11E-02	3.95E-02	8.92E-02	#######	1.23E+00	4.93E-01	4.35E-02	#######	9.66E-04	7.20E-03	8.56E+02	3.84E-02	1.23E+00	#######	#######	5.94E-03	4.93E-01	8.92E-02	8.55E+02	4.35E-02	#######	9.66E-04	7.20E-03	8.56E+02
		Transit Bus	2.61E-03	8.11E-03	1.09E-02	3.10E-02	1.41E-01	1.71E-01	#######	3.19E+00	1.04E+00	3.38E-02	#######	1.86E-03	1.38E-02	1.19E+03	1.36E-01	3.19E+00	#######	#######	8.43E-03	1.04E+00	1.71E-01	1.19E+03	3.38E-02	#######	1.86E-03	1.38E-02	1.19E+03
		Motor Home	2.29E-03	8.51E-03	9.53E-03	3.25E-02	8.40E-02	1.93E-01	#######	2.08E+00	8.07E-01	4.28E-02	#######	2.09E-03	1.55E-02	8.85E+02	8.15E-02	2.08E+00	#######	#######	6.28E-03	8.07E-01	1.93E-01	8.83E+02	4.28E-02	#######	2.09E-03	1.55E-02	8.85E+02
		Refuse Truck	4.64E-03	1.28E-02	1.94E-02	4.88E-02	1.06E-01	1.16E-01	#######	2.80E+00	7.38E-01	3.94E-02	#######	1.26E-03	9.35E-03	1.53E+03	1.03E-01	2.80E+00	#######	#######	1.07E-02	7.38E-01	1.16E-01	1.52E+03	3.94E-02	#######	1.26E-03	9.35E-03	1.53E+03
		Light Commercial Truck	1.65E-03	3.27E-03	6.87E-03	1.25E-02	5.97E-02	1.36E-01	#######	1.30E+00	9.62E-01	2.11E-02	#######	1.47E-03	1.10E-02	6.05E+02	5.79E-02	1.30E+00	#######	#######	4.33E-03	9.62E-01	1.36E-01	6.04E+02	2.11E-02	#######	1.47E-03	1.10E-02	6.05E+02
	Gasoline	Motorcycle	6.37E-04	1.66E-04	2.66E-03	6.33E-04	4.70E-02	6.47E-01	#######	8.00E-01	1.37E+01	2.88E-02	#######	2.17E-02	8.72E-03	3.72E+02	4.33E-02	8.00E-01	#######	#######	6.51E-03	1.37E+01	6.47E-01	3.71E+02	2.88E-02	#######	2.17E-02	8.72E-03	3.72E+02
		Passenger Car	1.27E-03	1.92E-03	5.30E-03	7.33E-03	7.16E-03	1.77E-02	#######	1.11E-01	1.60E+00	3.97E-03	#######	5.86E-04	2.30E-04	2.77E+02	6.60E-03	1.11E-01	#######	#######	4.85E-03	1.60E+00	1.77E-02	2.76E+02	3.97E-03	#######	5.86E-04	2.30E-04	2.77E+02
		Passenger Truck	1.30E-03	3.16E-03	5.41E-03	1.21E-02	1.33E-02	7.10E-02	#######	4.84E-01	3.46E+00	4.04E-03	#######	2.37E-03	9.05E-04	3.78E+02	1.23E-02	4.84E-01	#######	#######	6.62E-03	3.46E+00	7.10E-02	3.77E+02	4.04E-03	#######	2.37E-03	9.05E-04	3.78E+02
		School Bus	2.27E-03	8.84E-03	9.46E-03	3.38E-02	8.84E-03	6.08E-01	#######	2.86E+00	1.77E+01	1.48E-02	#######	2.02E-02	7.90E-03	7.70E+02	8.14E-03	2.86E+00	#######	#######	1.35E-02	1.77E+01	6.08E-01	7.67E+02	1.48E-02	#######	2.02E-02	7.90E-03	7.70E+02
		Single Unit Long-haul Truck	2.30E-03	9.22E-03	9.60E-03	3.52E-02	7.31E-03	3.62E-01	#######	3.14E+00	1.31E+01	6.27E-03	#######	1.20E-02	4.81E-03	8.03E+02	6.73E-03	3.14E+00	#######	#######	1.41E-02	1.31E+01	3.62E-01	8.01E+02	6.27E-03	#######	1.20E-02	4.81E-03	8.03E+02
		Single Unit Short-haul Truck	2.30E-03	9.23E-03	9.60E-03	3.53E-02	7.17E-03	3.72E-01	#######	3.22E+00	1.35E+01	6.34E-03	#######	1.24E-02	4.95E-03	8.54E+02	6.60E-03	3.22E+00	#######	#######	1.50E-02	1.35E+01	3.72E-01	8.53E+02	6.34E-03	#######	1.24E-02	4.95E-03	8.54E+02
		Transit Bus	2.27E-03	8.40E-03	9.46E-03	3.21E-02	9.67E-03	8.00E-01	#######	3.74E+00	2.08E+01	1.02E-02	#######	2.65E-02	1.05E-02	1.13E+03	8.90E-03	3.74E+00	#######	#######	1.97E-02	2.08E+01	8.00E-01	1.12E+03	1.02E-02	#######	2.65E-02	1.05E-02	1.13E+03
		Motor Home	2.21E-03	8.33E-03	9.22E-03	3.18E-02	1.15E-02	5.14E-01	#######	3.60E+00	1.90E+01	9.93E-03	#######	1.71E-02	6.68E-03	8.70E+02	1.06E-02	3.60E+00	#######	#######	1.52E-02	1.90E+01	5.14E-01	8.67E+02	9.93E-03	#######	1.71E-02	6.68E-03	8.70E+02
		Refuse Truck	2.21E-03	7.31E-03	9.22E-03	2.79E-02	1.10E-02	6.56E-01	#######	4.80E+00	2.32E+01	7.30E-03	#######	2.19E-02	8.70E-03	1.42E+03	1.01E-02	4.80E+00	#######	#######	2.49E-02	2.32E+01	6.56E-01	1.42E+03	7.30E-03	#######	2.19E-02	8.70E-03	1.42E+03
		Light Commercial Truck	1.32E-03	3.17E-03	5.52E-03	1.21E-02	1.31E-02	8.27E-02	#######	5.90E-01	3.75E+00	4.18E-03	#######	2.75E-03	1.06E-03	3.78E+02	1.20E-02	5.90E-01	#######	#######	6.62E-03	3.75E+00	8.27E-02	3.77E+02	4.18E-03	#######	2.75E-03	1.06E-03	3.78E+02
	Compressed Natural Gas (CNG)	Transit Bus	2.27E-03	8.41E-03	9.47E-03	3.21E-02	4.62E-03	0.00E+00		3.24E+00	2.27E+01	1.26E-02	#######			9.36E+02	4.62E-03	3.24E+00	#######	#######	#######	2.27E+01	0.00E+00	9.24E+02	1.26E-02	#######	#######	0.00E+00	9.36E+02
2022	Diesel Fuel	Combination Long-haul Truck	4.44E-03	1.07E-02	1.85E-02	4.09E-02	1.21E-01	1.08E-01	#######	3.27E+00	7.46E-01	3.77E-02	#######	1.17E-03	8.74E-03	1.95E+03	1.18E-01	3.27E+00	#######	#######	1.36E-02	7.46E-01	1.08E-01	1.94E+03	3.77E-02	#######	1.17E-03	8.74E-03	1.95E+03
		Combination Short-haul Truck	4.03E-03	9.90E-03	1.68E-02	3.78E-02	9.05E-02	9.21E-02	#######	2.73E+00	6.35E-01	3.84E-02	#######	9.98E-04	7.43E-03	1.87E+03	8.78E-02	2.73E+00	#######	#######	1.30E-02	6.35E-01	9.21E-02	1.86E+03	3.84E-02	#######	9.98E-04	7.43E-03	1.87E+03
		Intercity Bus	4.86E-03	1.62E-02	2.03E-02	6.17E-02	1.76E-01	1.73E-01	#######	4.28E+00	1.11E+00	3.94E-02	#######	1.88E-03	1.40E-02	1.62E+03	1.71E-01	4.28E+00	#######	#######	1.15E-02	1.11E+00	1.73E-01	1.62E+03	3.94E-02	#######	1.88E-03	1.40E-02	1.62E+03
		Passenger Car	1.27E-03	1.92E-03	5.30E-03	7.33E-03	4.00E-03	8.24E-03	#######	1.31E-01	1.14E+00	8.60E-03	#######	8.93E-05	6.65E-04	2.82E+02	3.88E-03	1.31E-01	#######	#######	1.96E-03	1.14E+00	8.24E-03	2.82E+02	8.60E-03	#######	8.93E-05	6.65E-04	2.82E+02
		Passenger Truck	1.62E-03	3.02E-03	6.75E-03	1.15E-02	3.67E-02	8.09E-02	#######	9.66E-01	8.16E-01	2.31E-02	#######	8.77E-04	6.53E-03	6.06E+02	3.56E-02	9.66E-01	#######	#######	4.27E-03	8.16E-01	8.09E-02	6.05E+02	2.31E-02	#######	8.77E-04	6.53E-03	6.06E+02
		School Bus	3.93E-03	1.37E-02	1.64E-02	5.25E-02	1.00E-01	1.56E-01	#######	2.22E+00	7.32E-01	3.32E-02	#######	1.69E-03	1.26E-02	8.15E+02	9.74E-02	2.22E+00	#######	#######	5.81E-03	7.32E-01	1.56E-01	8.13E+02	3.32E-02	#######	1.69E-03	1.26E-02	8.15E+02
		Single Unit Long-haul Truck	2.90E-03	1.07E-02	1.21E-02	4.10E-02	3.94E-02	9.15E-02	#######	1.19E+00	4.98E-01	4.38E-02	#######	9.92E-04	7.39E-03	8.01E+02	3.82E-02	1.19E+00	#######	#######	5.57E-03	4.98E-01	9.15E-02	8.00E+02	4.38E-02	#######	9.92E-04	7.39E-03	8.01E+02
		Single Unit Short-haul Truck	2.90E-03	1.08E-02	1.21E-02	4.12E-02	3.42E-02	7.72E-02	#######	1.14E+00	4.54E-01	4.37E-02	#######	8.37E-04	6.23E-03	8.56E+02	3.31E-02	1.14E+00	#######	#######	5.93E-03	4.54E-01	7.72E-02	8.55E+02	4.37E-02	#######	8.37E-04	6.23E-03	8.56E+02
		Transit Bus	2.61E-03	8.11E-03	1.09E-02	3.10E-02	1.21E-01	1.49E-01	#######	2.84E+00	9.11E-01	3.44E-02	#######	1.61E-03	1.20E-02	1.19E+03	1.18E-01	2.84E+00	#######	#######	8.39E-03	9.11E-01	1.49E-01	1.19E+03	3.44E-02	#######	1.61E-03	1.20E-02	1.19E+03
		Motor Home	2.29E-03	8.51E-03	9.53E-03	3.25E-02	7.50E-02	1.69E-01	#######	1.93E+00	7.39E-01	4.33E-02	#######	1.83E-03	1.36E-02	8.85E+02	7.27E-02	1.93E+00	#######	#######	6.25E-03	7.39E-01	1.69E-01	8.83E+02	4.33E-02	#######	1.83E-03	1.36E-02	8.85E+02
		Refuse Truck	4.65E-03	1.28E-02	1.94E-02	4.89E-02	8.95E-02	9.88E-02	#######	2.47E+00	6.55E-01	4.01E-02	#######	1.07E-03	7.98E-03	1.53E+03	8.69E-02	2.47E+00	#######	#######	1.07E-02	6.55E-01	9.88E-02	1.52E+03	4.01E-02	#######	1.07E-03	7.98E-03	1.53E+03
		Light Commercial Truck	1.65E-03	3.27E-03	6.87E-03	1.25E-02	5.26E-02	1.20E-01	#######	1.20E+00	9.21E-01	2.18E-02	#######	1.30E-03	9.66E-03	6.03E+02	5.11E-02	1.20E+00	#######	#######	4.29E-03	9.21E-01	1.20E-01	6.02E+02	2.18E-02	#######	1.30E-03	9.66E-03	6.03E+02
	Gasoline	Motorcycle	6.37E-04	1.66E-04	2.66E-03	6.33E-04	4.70E-02	6.40E-01	#######	7.97E-01	1.36E+01	2.88E-02	#######	2.15E-02	8.63E-03	3.72E+02	4.33E-02	7.97E-01	#######	#######	6.51E-03	1.36E+01	6.40E-01	3.71E+02	2.88E-02	#######	2.15E-02	8.63E-03	3.72E+02
		Passenger Car	1.27E-03	1.92E-03	5.30E-03	7.33E-03	7.15E-03	1.69E-02	#######	1.03E-01	1.58E+00	4.00E-03	#######	5.58E-04	2.21E-04	2.73E+02	6.58E-03	1.03E-01	#######	#######	4.79E-03	1.58E+00	1.69E-02	2.73E+02	4.00E-03	#######	5.58E-04	2.21E-04	2.73E+02
		Passenger Truck	1.30E-03	3.16E-03	5.41E-03	1.21E-02	1.33E-02	6.59E-02	#######	4.53E-01	3.37E+00	3.87E-03	#######	2.19E-03	8.42E-04	3.72E+02	1.22E-02	4.53E-01	#######	#######	6.52E-03	3.37E+00	6.59E-02	3.72E+02	3.87E-03	#######	2.19E-03	8.42E-04	3.72E+02
		School Bus	2.27E-03	8.84E-03	9.46E-03	3.38E-02	8.29E-03	5.93E-01	#######	2.81E+00	1.66E+01	1.30E-02	#######	1.96E-02	7.72E-03	7.70E+02	7.64E-03	2.81E+00	#######	#######	1.35E-02	1.66E+01	5.93E-01	7.67E+02	1.30E-02	#######	1.96E-02	7.72E-03	7.70E+02
		Single Unit Long-haul Truck	2.30E-03	9.22E-03	9.60E-03	3.52E-02	7.29E-03	3.61E-01	#######	3.14E+00	1.31E+01	6.28E-03	#######	1.20E-02	4.80E-03	8.03E+02	6.71E-03	3.14E+00	#######	#######	1.41E-02	1.31E+01	3.61E-01	8.01E+02	6.28E-03	#######	1.20E-02	4.80E-03	8.03E+02
		Single Unit Short-haul Truck	2.30E-03	9.23E-03	9.60E-03	3.53E-02	7.12E-03	3.71E-01	#######	3.21E+00	1.34E+01	6.29E-03	#######	1.23E-02	4.94E-03	8.54E+02	6.55E-03	3.21E+00	#######	#######	1.50E-02	1.34E+01	3.71E-01	8.53E+02	6.29E-03	#######	1.23E-02	4.94E-03	8.54E+02
		Transit Bus	2.27E-03	8.40E-03	9.46E-03	3.21E-02	9.62E-03	7.98E-01	#######	3.73E+00	2.05E+01	1.02E-02	#######	2.65E-02	1.05E-02	1.13E+03	8.86E-03	3.73E+00	#######	#######	1.97E-02	2.05E+01	7.98E-01	1.12E+03	1.02E-02	#######	2.65E-02	1.05E-02	1.13E+03
		Motor Home	2.21E-03	8.33E-03	9.22E-03	3.18E-02	1.11E-02	5.05E-01	#######	3.57E+00	1.85E+01	9.21E-03	#######	1.67E-02	6.56E-03	8.69E+02	1.02E-02	3.57E+00	#######	#######	1.52E-02	1.85E+01	5.05E-01	8.67E+02	9.21E-03	#######	1.67E-02	6.56E-03	8.69E+02
		Refuse Truck	2.21E-03	7.31E-03	9.22E-03	2.79E-02	1.07E-02	6.44E-01	#######	4.76E+00	2.24E+01	6.97E-03	#######	2.15E-02	8.56E-03	1.42E+03	9.87E-03	4.76E+00	#######	#######	2.49E-02	2.24E+01	6.44E-01	1.42E+03	6.97E-03	#######	2.15E-02	8.56E-03	1.42E+03
		Light Commercial Truck	1.32E-03	3.17E-03	5.52E-03	1.21E-02	1.30E-02	7.78E-02	#######	5.61E-01	3.66E+00	4.01E-03	#######	2.58E-03	1.00E-03	3.72E+02	1.20E-02	5.61E-01	#######	#######	6.53E-03	3.66E+00	7.78E-02	3.72E+02	4.01E-03	#######	2.58E-03	1.00E-03	3.72E+02
	Compressed Natural Gas (CNG)	Transit Bus	2.27E-03	8.41E-03	9.47E-03	3.21E-02	4.52E-03	0.00E+00		3.22E+00	2.16E+01	1.21E-02	#######			9.36E+02	4.52E-03	3.22E+00	#######	#######	#######	2.16E+01	0.00E+00	9.24E+02	1.21E-02	#######	#######	0.00E+00	9.36E+02
2023	Diesel Fuel	Combination Long-haul Truck	4.44E-03	1.07E-02	1.85E-02	4.09E-02	1.05E-01	9.44E-02	#######	2.95E+00	6.69E-01	3.82E-02	#######	1.02E-03	7.62E-03	1.95E+03	1.01E-01	2.95E+00	#######	#######	1.36E-02	6.69E-01	9.44E-02	1.94E+03	3.82E-02	#######	1.02E-03	7.62E-03	1.95E+03
		Combination Short-haul Truck	4.03E-03	9.90E-03	1.68E-02	3.78E-02	7.73E-02	7.98E-02	#######	2.46E+00	5.72E-01	3.88E-02	#######	8.65E-04	6.44E-03	1.87E+03	7.50E-02	2.46E+00	#######	#######	1.30E-02	5.72E-01	7.98E-02	1.86E+03	3.88E-02	#######	8.65E-04	6.44E-03	1.87E+03
		Intercity Bus	4.86E-03	1.62E-02	2.03E-02	6.17E-02	1.56E-01	1.55E-01	#######	3.87E+00	1.01E+00	4.02E-02	#######	1.68E-03	1.25E-02	1.62E+03	1.51E-01	3.87E+00	#######	#######	1.15E-02	1.01E+00	1.55E-01	1.62E+03	4.02E-02	#######	1.68E-03	1.25E-02	1.62E+03
		Passenger Car	1.27E-03	1.92E-03	5.30E-03	7.33E-03	3.80E-03	8.13E-03	#######	1.16E-01	1.20E+00	9.19E-03	#######	8.82E-05	6.57E-04	2.77E+02	3.68E-03	1.16E-01	#######	#######	1.92E-03	1.20E+00	8.13E-03	2.77E+02	9.19E-03	#######	8.82E-05	6.57E-04	2.77E+02
		Passenger Truck	1.62E-03	3.02E-03	6.75E-03	1.15E-02	3.23E-02	7.14E-02	#######	9.02E-01	8.00E-01	2.36E-02	#######	7.74E-04	5.76E-03	6.04E+02	3.13E-02	9.02E-01	#######	#######	4.23E-03	8.00E-01	7.14E-02	6.03E+02	2.36E-02	#######	7.74E-04	5.76E-03	6.04E+02

		School Bus	3.93E-03	1.37E-02	1.64E-02	5.25E-02	8.84E-02	1.39E-01	#######	2.01E+00	6.66E-01	3.39E-02	#######	1.50E-03	1.12E-02	8.15E+02	8.58E-02	2.01E+00	#######	#######	5.78E-03	6.66E-01	1.39E-01	8.13E+02	3.39E-02	#######	1.50E-03	1.12E-02	8.15E+02
		Single Unit Long-haul Truck	2.90E-03	1.07E-02	1.21E-02	4.10E-02	3.45E-02	8.12E-02	#######	1.11E+00	4.63E-01	4.40E-02	#######	8.80E-04	6.56E-03	8.01E+02	3.35E-02	1.11E+00	#######	#######	5.55E-03	4.63E-01	8.12E-02	8.00E+02	4.40E-02	#######	8.80E-04	6.56E-03	8.01E+02
		Single Unit Short-haul Truck	2.90E-03	1.08E-02	1.21E-02	4.12E-02	2.98E-02	6.84E-02	#######	1.06E+00	4.24E-01	4.38E-02	#######	7.41E-04	5.52E-03	8.56E+02	2.89E-02	1.06E+00	#######	#######	5.91E-03	4.24E-01	6.84E-02	8.55E+02	4.38E-02	#######	7.41E-04	5.52E-03	8.56E+02
		Transit Bus	2.61E-03	8.11E-03	1.09E-02	3.10E-02	1.05E-01	1.29E-01	#######	2.55E+00	8.03E-01	3.48E-02	#######	1.40E-03	1.04E-02	1.19E+03	1.02E-01	2.55E+00	#######	#######	8.35E-03	8.03E-01	1.29E-01	1.19E+03	3.48E-02	#######	1.40E-03	1.04E-02	1.19E+03
		Motor Home	2.29E-03	8.51E-03	9.53E-03	3.25E-02	6.69E-02	1.52E-01	#######	1.79E+00	6.87E-01	4.38E-02	#######	1.65E-03	1.23E-02	8.85E+02	6.49E-02	1.79E+00	#######	#######	6.23E-03	6.87E-01	1.52E-01	8.83E+02	4.38E-02	#######	1.65E-03	1.23E-02	8.85E+02
		Refuse Truck	4.65E-03	1.28E-02	1.94E-02	4.89E-02	7.62E-02	8.54E-02	#######	2.21E+00	5.89E-01	4.06E-02	#######	9.26E-04	6.89E-03	1.53E+03	7.39E-02	2.21E+00	#######	#######	1.06E-02	5.89E-01	8.54E-02	1.52E+03	4.06E-02	#######	9.26E-04	6.89E-03	1.53E+03
		Light Commercial Truck	1.65E-03	3.27E-03	6.87E-03	1.25E-02	4.65E-02	1.06E-01	#######	1.11E+00	8.87E-01	2.24E-02	#######	1.15E-03	8.53E-03	6.00E+02	4.51E-02	1.11E+00	#######	#######	4.25E-03	8.87E-01	1.06E-01	5.99E+02	2.24E-02	#######	1.15E-03	8.53E-03	6.00E+02
	Gasoline	Motorcycle	6.37E-04	1.66E-04	2.66E-03	6.33E-04	4.70E-02	6.34E-01	#######	7.95E-01	1.35E+01	2.88E-02	#######	2.13E-02	8.55E-03	3.72E+02	4.33E-02	7.95E-01	#######	#######	6.51E-03	1.35E+01	6.34E-01	3.71E+02	2.88E-02	#######	2.13E-02	8.55E-03	3.72E+02
		Passenger Car	1.27E-03	1.92E-03	5.30E-03	7.33E-03	7.15E-03	1.64E-02	#######	9.67E-02	1.57E+00	4.01E-03	#######	5.42E-04	2.15E-04	2.70E+02	6.58E-03	9.67E-02	#######	#######	4.73E-03	1.57E+00	1.64E-02	2.69E+02	4.01E-03	#######	5.42E-04	2.15E-04	2.70E+02
		Passenger Truck	1.30E-03	3.16E-03	5.41E-03	1.21E-02	1.32E-02	6.14E-02	#######	4.25E-01	3.27E+00	3.67E-03	#######	2.04E-03	7.87E-04	3.67E+02	1.22E-02	4.25E-01	#######	#######	6.43E-03	3.27E+00	6.14E-02	3.66E+02	3.67E-03	#######	2.04E-03	7.87E-04	3.67E+02
		School Bus	2.27E-03	8.84E-03	9.46E-03	3.38E-02	8.21E-03	5.91E-01	#######	2.80E+00	1.63E+01	1.26E-02	#######	1.95E-02	7.69E-03	7.70E+02	7.56E-03	2.80E+00	#######	#######	1.35E-02	1.63E+01	5.91E-01	7.67E+02	1.26E-02	#######	1.95E-02	7.69E-03	7.70E+02
		Single Unit Long-haul Truck	2.30E-03	9.22E-03	9.60E-03	3.52E-02	7.27E-03	3.62E-01	#######	3.13E+00	1.31E+01	6.17E-03	#######	1.20E-02	4.81E-03	8.02E+02	6.70E-03	3.13E+00	#######	#######	1.41E-02	1.31E+01	3.62E-01	8.01E+02	6.17E-03	#######	1.20E-02	4.81E-03	8.02E+02
		Single Unit Short-haul Truck	2.30E-03	9.23E-03	9.60E-03	3.53E-02	7.08E-03	3.70E-01	#######	3.21E+00	1.34E+01	6.14E-03	#######	1.23E-02	4.94E-03	8.54E+02	6.52E-03	3.21E+00	#######	#######	1.50E-02	1.34E+01	3.70E-01	8.53E+02	6.14E-03	#######	1.23E-02	4.94E-03	8.54E+02
		Transit Bus	2.27E-03	8.40E-03	9.46E-03	3.21E-02	9.48E-03	7.93E-01	#######	3.70E+00	1.99E+01	9.66E-03	#######	2.63E-02	1.04E-02	1.13E+03	8.73E-03	3.70E+00	#######	#######	1.97E-02	1.99E+01	7.93E-01	1.12E+03	9.66E-03	#######	2.63E-02	1.04E-02	1.13E+03
		Motor Home	2.21E-03	8.33E-03	9.22E-03	3.18E-02	1.07E-02	4.96E-01	#######	3.53E+00	1.81E+01	8.44E-03	#######	1.64E-02	6.46E-03	8.69E+02	9.88E-03	3.53E+00	#######	#######	1.52E-02	1.81E+01	4.96E-01	8.67E+02	8.44E-03	#######	1.64E-02	6.46E-03	8.69E+02
		Refuse Truck	2.21E-03	7.31E-03	9.22E-03	2.79E-02	1.05E-02	6.36E-01	#######	4.73E+00	2.18E+01	6.68E-03	#######	2.12E-02	8.46E-03	1.42E+03	9.70E-03	4.73E+00	#######	#######	2.49E-02	2.18E+01	6.36E-01	1.42E+03	6.68E-03	#######	2.12E-02	8.46E-03	1.42E+03
		Light Commercial Truck	1.32E-03	3.17E-03	5.52E-03	1.21E-02	1.30E-02	7.35E-02	#######	5.35E-01	3.57E+00	3.79E-03	#######	2.44E-03	9.47E-04	3.68E+02	1.19E-02	5.35E-01	#######	#######	6.44E-03	3.57E+00	7.35E-02	3.67E+02	3.79E-03	#######	2.44E-03	9.47E-04	3.68E+02
	Compressed Natural Gas (CNG)	Transit Bus	2.27E-03	8.41E-03	9.47E-03	3.21E-02	4.42E-03	0.00E+00		3.20E+00	2.07E+01	1.14E-02	#######			9.36E+02	4.42E-03	3.20E+00	#######	#######	#######	2.07E+01	0.00E+00	9.24E+02	1.14E-02	#######	#######	0.00E+00	9.36E+02
2024	Diesel Fuel	Combination Long-haul Truck	4.44E-03	1.07E-02	1.85E-02	4.09E-02	9.03E-02	8.24E-02	#######	2.67E+00	6.03E-01	3.86E-02	#######	8.93E-04	6.65E-03	1.95E+03	8.76E-02	2.67E+00	#######	#######	1.35E-02	6.03E-01	8.24E-02	1.94E+03	3.86E-02	#######	8.93E-04	6.65E-03	1.95E+03
		Combination Short-haul Truck	4.02E-03	9.89E-03	1.68E-02	3.78E-02	6.64E-02	6.97E-02	#######	2.24E+00	5.20E-01	3.91E-02	#######	7.55E-04	5.62E-03	1.87E+03	6.44E-02	2.24E+00	#######	#######	1.29E-02	5.20E-01	6.97E-02	1.86E+03	3.91E-02	#######	7.55E-04	5.62E-03	1.87E+03
		Intercity Bus	4.86E-03	1.62E-02	2.03E-02	6.17E-02	1.37E-01	1.38E-01	#######	3.50E+00	9.12E-01	4.09E-02	#######	1.50E-03	1.12E-02	1.62E+03	1.33E-01	3.50E+00	#######	#######	1.14E-02	9.12E-01	1.38E-01	1.62E+03	4.09E-02	#######	1.50E-03	1.12E-02	1.62E+03
		Passenger Car	1.27E-03	1.92E-03	5.30E-03	7.33E-03	3.67E-03	8.09E-03	#######	1.06E-01	1.25E+00	9.67E-03	#######	8.77E-05	6.53E-04	2.73E+02	3.56E-03	1.06E-01	#######	#######	1.88E-03	1.25E+00	8.09E-03	2.73E+02	9.67E-03	#######	8.77E-05	6.53E-04	2.73E+02
		Passenger Truck	1.62E-03	3.02E-03	6.75E-03	1.15E-02	2.85E-02	6.29E-02	#######	8.46E-01	7.85E-01	2.39E-02	#######	6.82E-04	5.08E-03	6.02E+02	2.76E-02	8.46E-01	#######	#######	4.21E-03	7.85E-01	6.29E-02	6.01E+02	2.39E-02	#######	6.82E-04	5.08E-03	6.02E+02
		School Bus	3.93E-03	1.37E-02	1.64E-02	5.25E-02	7.81E-02	1.23E-01	#######	1.83E+00	6.09E-01	3.45E-02	#######	1.34E-03	9.96E-03	8.15E+02	7.58E-02	1.83E+00	#######	#######	5.75E-03	6.09E-01	1.23E-01	8.13E+02	3.45E-02	#######	1.34E-03	9.96E-03	8.15E+02
		Single Unit Long-haul Truck	2.90E-03	1.07E-02	1.21E-02	4.10E-02	3.04E-02	7.24E-02	#######	1.04E+00	4.34E-01	4.41E-02	#######	7.84E-04	5.84E-03	8.01E+02	2.95E-02	1.04E+00	#######	#######	5.54E-03	4.34E-01	7.24E-02	8.00E+02	4.41E-02	#######	7.84E-04	5.84E-03	8.01E+02
		Single Unit Short-haul Truck	2.90E-03	1.08E-02	1.21E-02	4.12E-02	2.62E-02	6.12E-02	#######	1.00E+00	3.99E-01	4.39E-02	#######	6.63E-04	4.94E-03	8.56E+02	2.54E-02	1.00E+00	#######	#######	5.90E-03	3.99E-01	6.12E-02	8.55E+02	4.39E-02	#######	6.63E-04	4.94E-03	8.56E+02
		Transit Bus	2.61E-03	8.11E-03	1.09E-02	3.10E-02	9.10E-02	1.13E-01	#######	2.29E+00	7.11E-01	3.52E-02	#######	1.22E-03	9.09E-03	1.19E+03	8.83E-02	2.29E+00	#######	#######	8.32E-03	7.11E-01	1.13E-01	1.19E+03	3.52E-02	#######	1.22E-03	9.09E-03	1.19E+03
		Motor Home	2.28E-03	8.51E-03	9.53E-03	3.25E-02	6.00E-02	1.37E-01	#######	1.67E+00	6.41E-01	4.42E-02	#######	1.48E-03	1.10E-02	8.85E+02	5.82E-02	1.67E+00	#######	#######	6.21E-03	6.41E-01	1.37E-01	8.83E+02	4.42E-02	#######	1.48E-03	1.10E-02	8.85E+02
		Refuse Truck	4.65E-03	1.28E-02	1.94E-02	4.89E-02	6.50E-02	7.42E-02	#######	1.99E+00	5.33E-01	4.10E-02	#######	8.04E-04	5.99E-03	1.53E+03	6.31E-02	1.99E+00	#######	#######	1.06E-02	5.33E-01	7.42E-02	1.52E+03	4.10E-02	#######	8.04E-04	5.99E-03	1.53E+03
		Light Commercial Truck	1.65E-03	3.27E-03	6.86E-03	1.25E-02	4.10E-02	9.32E-02	#######	1.03E+00	8.55E-01	2.29E-02	#######	1.01E-03	7.53E-03	5.98E+02	3.98E-02	1.03E+00	#######	#######	4.22E-03	8.55E-01	9.32E-02	5.97E+02	2.29E-02	#######	1.01E-03	7.53E-03	5.98E+02
	Gasoline	Motorcycle	6.37E-04	1.66E-04	2.66E-03	6.33E-04	4.70E-02	6.29E-01	#######	7.92E-01	1.34E+01	2.88E-02	#######	2.11E-02	8.48E-03	3.72E+02	4.33E-02	7.92E-01	#######	#######	6.51E-03	1.34E+01	6.29E-01	3.71E+02	2.88E-02	#######	2.11E-02	8.48E-03	3.72E+02
		Passenger Car	1.27E-03	1.92E-03	5.30E-03	7.33E-03	7.15E-03	1.60E-02	#######	9.24E-02	1.57E+00	4.05E-03	#######	5.30E-04	2.11E-04	2.67E+02	6.58E-03	9.24E-02	#######	#######	4.68E-03	1.57E+00	1.60E-02	2.67E+02	4.05E-03	#######	5.30E-04	2.11E-04	2.67E+02
		Passenger Truck	1.30E-03	3.16E-03	5.41E-03	1.21E-02	1.32E-02	5.71E-02	#######	3.98E-01	3.18E+00	3.43E-03	#######	1.89E-03	7.33E-04	3.62E+02	1.21E-02	3.98E-01	#######	#######	6.35E-03	3.18E+00	5.71E-02	3.61E+02	3.43E-03	#######	1.89E-03	7.33E-04	3.62E+02
		School Bus	2.27E-03	8.84E-03	9.46E-03	3.38E-02	8.11E-03	5.81E-01	#######	2.76E+00	1.57E+01	1.11E-02	#######	1.92E-02	7.59E-03	7.70E+02	7.47E-03	2.76E+00	#######	#######	1.35E-02	1.57E+01	5.81E-01	7.67E+02	1.11E-02	#######	1.92E-02	7.59E-03	7.70E+02
		Single Unit Long-haul Truck	2.30E-03	9.22E-03	9.60E-03	3.52E-02	7.28E-03	3.62E-01	#######	3.13E+00	1.31E+01	5.97E-03	#######	1.20E-02	4.81E-03	8.02E+02	6.70E-03	3.13E+00	#######	#######	1.41E-02	1.31E+01	3.62E-01	8.01E+02	5.97E-03	#######	1.20E-02	4.81E-03	8.02E+02
		Single Unit Short-haul Truck	2.30E-03	9.23E-03	9.60E-03	3.53E-02	7.08E-03	3.70E-01	#######	3.20E+00	1.34E+01	5.96E-03	#######	1.23E-02	4.94E-03	8.54E+02	6.52E-03	3.20E+00	#######	#######	1.50E-02	1.34E+01	3.70E-01	8.53E+02	5.96E-03	#######	1.23E-02	4.94E-03	8.54E+02
		Transit Bus	2.27E-03	8.40E-03	9.46E-03	3.21E-02	9.41E-03	7.89E-01	#######	3.68E+00	1.94E+01	9.07E-03	#######	2.61E-02	1.04E-02	1.12E+03	8.66E-03	3.68E+00	#######	#######	1.97E-02	1.94E+01	7.89E-01	1.12E+03	9.07E-03	#######	2.61E-02	1.04E-02	1.12E+03
		Motor Home	2.21E-03	8.33E-03	9.22E-03	3.18E-02	1.06E-02	4.89E-01	#######	3.51E+00	1.77E+01	7.61E-03	#######	1.62E-02	6.38E-03	8.69E+02	9.81E-03	3.51E+00	#######	#######	1.52E-02	1.77E+01	4.89E-01	8.67E+02	7.61E-03	#######	1.62E-02	6.38E-03	8.69E+02
		Refuse Truck	2.21E-03	7.31E-03	9.22E-03	2.79E-02	1.04E-02	6.29E-01	#######	4.71E+00	2.14E+01	6.41E-03	#######	2.09E-02	8.38E-03	1.42E+03	9.60E-03	4.71E+00	#######	#######	2.49E-02	2.14E+01	6.29E-01	1.42E+03	6.41E-03	#######	2.09E-02	8.38E-03	1.42E+03
		Light Commercial Truck	1.32E-03	3.17E-03	5.52E-03	1.21E-02	1.29E-02	6.94E-02	#######	5.10E-01	3.48E+00	3.52E-03	#######	2.29E-03	8.96E-04	3.63E+02	1.19E-02	5.10E-01	#######	#######	6.36E-03	3.48E+00	6.94E-02	3.62E+02	3.52E-03	#######	2.29E-03	8.96E-04	3.63E+02
	Compressed Natural Gas (CNG)	Transit Bus	2.27E-03	8.41E-03	9.47E-03	3.21E-02	4.33E-03	0.00E+00		3.18E+00	1.97E+01	1.04E-02	#######			9.36E+02	4.33E-03	3.18E+00	#######	#######	#######	1.97E+01	0.00E+00	9.24E+02	1.04E-02	#######	#######	0.00E+00	9.36E+02
2025	Diesel Fuel	Combination Long-haul Truck	4.44E-03	1.07E-02	1.85E-02	4.09E-02	7.80E-02	7.23E-02	#######	2.43E+00	5.47E-01	3.90E-02	#######	7.84E-04	5.84E-03	1.95E+03	7.57E-02	2.43E+00	#######	#######	1.35E-02	5.47E-01	7.23E-02	1.94E+03	3.90E-02	#######	7.84E-04	5.84E-03	1.95E+03
		Combination Short-haul Truck	4.02E-03	9.89E-03	1.68E-02	3.78E-02	5.73E-02	6.13E-02	#######	2.06E+00	4.77E-01	3.94E-02	#######	6.65E-04	4.95E-03	1.87E+03	5.56E-02	2.06E+00	#######	#######	1.29E-02	4.77E-01	6.13E-02	1.86E+03	3.94E-02	#######	6.65E-04	4.95E-03	1.87E+03
		Intercity Bus	4.86E-03	1.62E-02	2.03E-02	6.17E-02	1.21E-01	1.23E-01	#######	3.17E+00	8.26E-01	4.16E-02	#######	1.34E-03	9.96E-03	1.62E+03	1.17E-01	3.17E+00	#######	#######	1.14E-02	8.26E-01	1.23E-01	1.62E+03	4.16E-02	#######	1.34E-03	9.96E-03	1.62E+03
		Passenger Car	1.27E-03	1.92E-03	5.30E-03	7.33E-03	3.58E-03	8.13E-03	#######	9.87E-02	1.30E+00	1.01E-02	#######	8.81E-05	6.56E-04	2.69E+02	3.47E-03	9.87E-02	#######	#######	1.85E-03	1.30E+00	8.13E-03	2.69E+02	1.01E-02	#######	8.81E-05	6.56E-04	2.69E+02
		Passenger Truck	1.62E-03	3.02E-03	6.75E-03	1.15E-02	2.49E-02	5.57E-02	#######	7.97E-01	7.76E-01	2.42E-02	#######	6.04E-04	4.50E-03	6.00E+02	2.42E-02	7.97E-01	#######	#######	4.18E-03	7.76E-01	5.57E-02	5.99E+02	2.42E-02	#######	6.04E-04	4.50E-03	6.00E+02
		School Bus	3.93E-03	1.37E-02	1.64E-02	5.25E-02	6.89E-02	1.10E-01	#######	1.68E+00	5.58E-01	3.50E-02	#######	1.19E-03	8.90E-03	8.15E+02	6.68E-02	1.68E+00	#######	#######	5.73E-03	5.58E-01	1.10E-01	8.13E+02	3.50E-02	#######	1.19E-03	8.90E-03	8.15E+02
		Single Unit Long-haul Truck	2.90E-03	1.07E-02	1.21E-02	4.10E-02	2.68E-02	6.49E-02	#######	9.82E-01	4.08E-01	4.43E-02	#######	7.03E-04	5.24E-03	8.01E+02	2.60E-02	9.82E-01	#######	#######	5.53E-03	4.08E-01	6.49E-02	8.00E+02	4.43E-02	#######	7.03E-04	5.24E-03	8.01E+02
		Single Unit Short-haul Truck	2.90E-03	1.08E-02	1.21E-02	4.12E-02	2.32E-02	5.52E-02	#######	9.47E-01	3.79E-01	4.40E-02	#######	5.98E-04	4.45E-03	8.56E+02	2.25E-02	9.47E-01	#######	#######	5.89E-03	3.79E-01	5.52E-02	8.55E+02	4.40E-02	#######	5.98E-04	4.45E-03	8.56E+02
		Transit Bus	2.61E-03	8.11E-03	1.09E-02	3.10E-02	7.84E-02	9.79E-02	#######	2.07E+00	6.30E-01	3.55E-02	#######	1.06E-03	7.90E-03	1.19E+03	7.61E-02	2.07E+00	#######	#######	8.29E-03	6.30E-01	9.79E-02	1.19E+03	3.55E-02	#######	1.06E-03	7.90E-03	1.19E+03
		Motor Home	2.28E-03	8.51E-03	9.53E-03	3.25E-02	5.30E-02	1.23E-01	#######	1.56E+00	5.98E-01	4.45E-02	#######	1.33E-03	9.91E-03	8.85E+02	5.14E-02	1.56E+00	#######	#######	6.19E-03	5.98E-01	1.23E-01	8.83E+02	4.45E-02	#######	1.33E-03	9.91E-03	8.85E+02
		Refuse Truck	4.66E-03	1.28E-02	1.94E-02	4.89E-02	5.57E-02	6.49E-02	#######	1.81E+00	4.87E-01	4.13E-02	#######	7.03E-04	5.24E-03	1.53E+03	5.40E-02	1.81E+00	#######	#######	1.05E-02	4.87E-01	6.49E-02	1.52E+03	4.13E-02	#######	7.03E-04	5.24E-03	1.53E+03
		Light Commercial Truck	1.65E-03	3.27E-03	6.86E-03	1.25E-02	3.58E-02	8.21E-02	#######	9.56E-01	8.29E-01	2.34E-02	#######	8.90E-04	6.63E-03	5.96E+02	3.47E-02	9.56E-01	#######	#######	4.19E-03	8.29E-01	8.21E-02	5.95E+02	2.34E-02	#######	8.90E-04	6.63E-03	5.96E+02
	Gasoline	Motorcycle	6.37E-04	1.66E-04	2.66E-03	6.33E-04	4.70E-02	6.24E-01	#######	7.90E-01	1.33E+01	2.88E-02	#######	2.09E-02	8.41E-03	3.72E+02	4.33E-02	7.90E-01	#######	#######	6.51E-03	1.33E+01	6.24E-01	3.71E+02	2.88E-02	#######	2.09E-02	8.41E-03	3.72E+02
		Passenger Car	1.27E-03	1.92E-03	5.30E-03	7.33E-03	7.17E-03	1.59E-02	#######	8.94E-02	1.57E+00	4.06E-03	#######	5.24E-04	2.09E-04	2.64E+02	6.60E-03	8.94E-02	#######	#######	4.64E-03	1.57E+00	1.59E-02	2.64E+02	4.06E-03	#######	5.24E-04	2.09E-04	2.64E+02
		Passenger Truck	1.30E-03	3.16E-03	5.41E-03	1.21E-02	1.30E-02	5.31E-02	#######	3.74E-01	3.10E+00	3.24E-03	#######	1.75E-03	6.84E-04	3.58E+02	1.20E-02	3.74E-01	#######	#######	6.27E-03	3.10E+00	5.31E-02	3.57E+02	3.24E-03	#######	1.75E-03	6.84E-04	3.58E+02
		School Bus	2.27E-03	8.84E-03	9.46E-03	3.38E-02	7.15E-03	5.71E-01	#######	2.73E+00	1.49E+01	9.55E-03	#######	1.88E-02	7.47E-03	7.69E+02	6.59E-03	2.73E+00	#######	#######	1.35E-02	1.49E+01	5.71E-01	7.67E+02	9.55E-03	#######	1.88E-02	7.47E-03	7.69E+02
		Single Unit Long-haul Truck	2.30E-03	9.22E-03	9.60E-03	3.52E-02	7.19E-03	3.62E-01	#######	3.13E+00	1.30E+01	5.81E-03	#######	1.20E-02	4.81E-03	8.02E+02	6.63E-03	3.13E+00	#######	#######	1.41E-02	1.30E+01	3.62E-01	8.01E+02	5.81E-03	#######	1.20E-02	4.81E-03	8.02E+02
		Single Unit Short-haul Truck	2.30E-03	9.23E-03	9.60E-03	3.53E-02	7.00E-03	3.70E-01	#######	3.20E+00	1.33E+01	5.82E-03	#######	1.23E-02	4.94E-03	8.54E+02	6.44E-03	3.20E+00	#######	#######	1.50E-02	1.33E+01	3.70E-01	8.53E+02	5.82E-03	#######	1.23E-02	4.94E-03	8.54E+02
		Transit Bus	2.27E-03	8.40E-03	9.46E-03	3.21E-02	9.22E-03	7.86E-01	#######	3.66E+00	1.89E+01	8.58E-03	#######	2.60E-02	1.04E-02	1.12E+03	8.49E-03	3.66E+00	#######	#######	1.97E-02	1.89E+01	7.86E-01	1.12E+03	8.58E-03	#######	2.60E-02	1.04E-02	1.12E+03
		Motor Home	2.21E-03	8.33E-03	9.22E-03	3.18E-02	9.56E-03	4.82E-01	#######	3.48E+00	1.73E+01	6.81E-03	#######	1.59E-02	6.29E-03	8.69E+02	8.80E-03	3.48E+00	#######	#######	1.52E-02	1.73E+01	4.82E-01	8.67E+02	6.81E-03	#######	1.59E-02	6.29E-03	8.69E+02
		Refuse Truck	2.21E-03	7.31E-03	9.22E-03	2.79E-02	1.02E-02	6.24E-01	#######	4.69E+00	2.10E+01	6.21E-03	#######	2.07E-02	8.31E-03	1.42E+03	9.38E-03	4.69E+00	#######	#######	2.49E-02	2.10E+01	6.24E-01	1.42E+03	6.21E-03	#######	2.07E-02	8.31E-03	1.42E+03
		Light Commercial Truck	1.32E-03	3.17E-03	5.52E-03	1.21E-02	1.28E-02	6.55E-02	#######	4.88E-01	3.41E+00	3.29E-03	#######	2.16E-03	8.49E-04	3.59E+02	1.18E-02	4.88E-01	#######	#######	6.29E-03	3.41E+00	6.55E-02	3.58E+02	3.29E-03	#######	2.16E-03	8.49E-04	3.59E+02
	Compressed Natural Gas (CNG)	Transit Bus	2.27E-03	8.41E-03	9.47E-03	3.21E-02	4.19E-03	0.00E+00		3.16E+00	1.90E+01	9.76E-03	#######			9.36E+02	4.19E-03	3.16E+00	#######	#######	#######	1.90E+01	0.00E+00	9.24E+02	9.76E-03	#######	#######	0.00E+00	9.36E+02

ATTACHMENT B. METEOROLOGICAL MODELING RESULTS AND MODEL PERFORMANCE EVALUATION

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NORMALLY PRESSURED LANCE (NPL)

NATURAL GAS DEVELOPMENT PROJECT

AIR QUALITY ASSESSMENT TECHNICAL SUPPORT DOCUMENT

ATTACHMENT B: METEOROLOGICAL MODELING RESULTS AND MODEL PERFORMANCE EVALUATION

U.S. Department of the Interior
Bureau of Land Management

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The BLM manages more land—253 million acres—than any other Federal agency. This land, known as the National System of Public Lands, is primarily located in 12 Western States, including Alaska. The Bureau, with a budget of about $1 billion, also administers 700 million acres of sub-surface mineral estate throughout the nation. The BLM's multiple-use mission is to sustain the health and productivity of the public lands for the use and enjoyment of present and future generations. The Bureau accomplishes this by managing such activities as outdoor recreation, livestock grazing, mineral development, and energy production, and by conserving natural, historical, cultural, and other resources on public lands.

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ACRONYMS AND ABBREVIATIONS

ADP	Automated Data Processing
AMET	Atmospheric Model Evaluation Tool
ANC	Acid Neutralizing Capacity
AQRV	Air Quality Related Value
ARW	Advanced Research WRF
ASOS	Automated Surface Observation System
BLM	Bureau of Land Management
CISL	Computational and Information Systems Laboratory
CMAQ	Community Multiscale Air Quality
CO	Carbon monoxide
EIS	Environmental Impact Statement
EPA	U.S. Environmental Protection Agency
FDDA	Four-dimensional data assimilation
HAP	Hazardous Air Pollutant
HPRCC	High Plains Regional Climate Center
IOA	Index of Agreement
LCC	Lambert Conformal Conic
LSM	Land surface model
KBPI	Big Piney
KPNA	Pinedale
KRKS	Rock Springs
m	Meter(s)
mb	Millibars
MCIP	Meteorology-chemistry Interface Processor
NARR	North American Regional Reanalysis
NCAR	National Center for Atmospheric Research
NWS	National Weather Service
NCEP	National Center for Environmental Prediction
NOAA	National Oceanic and Atmospheric Administration
NEPA	National Environmental Policy Act
NO_2	Nitrogen dioxide
NPL	Normally Pressured Lance
O_3	Ozone
PBL	Planetary boundary layer
PM	Particulate matter
$PM_{2.5}$	Fine particulate matter
PM_{10}	Coarse particulate matter
q	Water vapor mixing ratio
QA	Quality Assurance
QNSE	Quasi-Normal Scale Elimination
RDA	Research Data Archive
RRTM	Rapid Radiative Transfer Model
RFD	Reasonably Foreseeable Development
RGF	Regional Gathering Facility
RMP	Resource Management Plan
RMSE	Root Mean Squared Error
ROD	Record of Decision
SMOKE	Sparse-Matrix Operator Kernel Emissions
SO_2	Sulfur dioxide
T	Temperature
u	East-west wind component
U.S.	United States
v	North-south wind component
WRAP	Western Regional Air Partnership
WRF	Weather Research and Forecasting
WY DEQ	Wyoming Department of Environmental Quality
WY	Wyoming

1.0 INTRODUCTION

This document summarizes the methods and results of the application of the Weather Research and Forecasting (WRF) meteorological modeling system to support the assessment of impacts from emissions associated with the development of the Normally Pressured Lance (NPL) natural gas field on regional air quality. The NPL natural gas field is located northwest of Rock Springs, Wyoming, south of Pinedale, Wyoming, and adjacent to the existing Jonah Field; the project area comprises approximately 140,000 acres of land. A number of natural gas wells have already been drilled in the NPL. Jonah Energy proposes to drill an average of 350 wells per year over a 10-year period for a total of approximately 3,500 wells. Many outside factors, including economic, technological, and regulatory factors, may influence the rate of development as well as the total number of wells that will ultimately be drilled over the duration of the project.

The BLM oversees and administers the public lands within the proposed NPL project from the BLM Pinedale and Rock Springs field offices. Oil and gas development activities in the area are governed by the Pinedale Resource Management Plan (RMP) (2008) and the Green River RMP (1997). An Environmental Impact Statement (EIS) for the proposed project will be prepared by BLM in accordance with National Environmental Policy Act (NEPA) guidelines. Other NEPA analyses have been conducted for the area and management plans have been previously prepared for sections of the project area. These include the Green River RMP and Final EIS and Record of Decision (ROD) (1997), and the Pinedale RMP and Final EIS and ROD (2008).

1.1 Project Description

The primary purpose of Jonah Energy's proposal to develop the NPL field is the recovery of natural gas and other hydrocarbon resources. Target formations for the development include the Lance Pool, and potentially the Unnamed Tertiary, Mesa Verde, and other possible productive formations evaluated during exploration and testing. Jonah Energy's planned development of the NPL field will include the building and/or installation of new access roads, well pads, pipelines, compressor stations, and other supporting facilities. At the present time, Jonah Energy proposes to use directional drilling from no more than four centralized surface locations per section. Drill pads are proposed to encompass up to approximately 18 acres per location for a total initial surface disturbance of approximately 6,854 acres of the NPL area. Upon completion of reclamation activities, approximately 2,348 acres would remain disturbed. Although the exact location of each well is not known at this time, the bottom-hole-location density is expected to be no less than a 10-acre spacing pattern to retrieve natural gas in the formations identified during exploration and testing.

To transport products (gas, condensate, and produced water), a three-phase pipeline gathering system is proposed to be installed from the well heads to designated Regional Gathering Facilities (RGF). For the development of the NPL, each RGF would be designed with facilities that support gas/liquid separation, gas compression and dehydration, liquid storage, and truck loading for condensate sales. Jonah Energy proposes to minimize emissions by employing natural-gas-powered drill rigs, and using electric compressors in place of diesel-powered compressors. Jonah Energy also proposes to undertake simultaneous completion operations whenever possible in an effort to minimize emissions associated with equipment use and movement. In addition, Jonah Energy proposes to limit emissions with the use of flare-less flow back technology for the completion operations.

1.2 Overview of the Air Quality Assessment

The NPL air quality analysis will include an assessment of expected future impacts of emissions from equipment and activities associated with the development of the NPL field. Air quality modeling will be conducted to assess impacts for criteria pollutants and other air quality related values (AQRVs). Near-field impacts will be evaluated using the Environmental Protection Agency (EPA) guideline model AERMOD, and far-field (or regional) impacts will be evaluated using Version 5.0 of EPA's Community Multiscale Air Quality (CMAQ) modeling system (Byun and Ching, 1999).

1.2.1 Study Objectives

The objectives of this air quality assessment are to examine and quantify the potential air quality impacts from emissions associated with the development of the NPL natural gas field using the best available data and state-of-the-science data processing and modeling tools. This information will be used to support the development of an EIS for the NPL project area.

1.2.2 Modeling Analysis Components

The air quality modeling analysis will include an assessment of "current" conditions for a recent historical period (2008). Potential future impacts will then be evaluated for a selected future year (2022) by applying the modeling systems using the historical meteorological inputs and estimated emissions for sources associated with the development of the field, as well as other regional sources. The assessment will consider both near-field and far-field air quality impacts and will focus on:

- Criteria pollutants including ozone (O_3), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), carbon monoxide (CO), and particulate matter (PM), including both coarse (PM_{10}) and fine particulates ($PM_{2.5}$).
- Hazardous Air Pollutants (HAPs), including benzene, toluene, ethyl benzene, and xylene (BTEX), n-hexane, and formaldehyde, and;
- AQRV's including visibility, acid neutralizing capacity (ANC) of sensitive water bodies, and atmospheric deposition to soils.

The HAPs assessment will focus only on the NPL project area, and the ANC analysis will be conducted for acid sensitive water bodies within nearby Class I and Class II areas identified in the analysis. The remaining air quality impacts will be evaluated for the NPL project area, nearby Class I areas, nearby sensitive Class II areas, and throughout the regional-scale air quality modeling domain.

The current- and future-year regional modeling analyses will be conducted using emissions data available from BLM, the Wyoming Department of Environmental Quality (WY DEQ), the Western Regional Air Partnership (WRAP), and EPA. The NPL impacts analysis modeling will be conducted using emissions specifically developed by Jonah Energy for the NPL field development operations. Detailed information on the emissions is provided in Section 2 of this document.

For the near-field assessment, the modeling scenarios will be designed to capture the reasonable maximum emissions year impacts for each pollutant for each phase of the project.

The far-field or regional-scale air quality modeling will include a detailed model performance evaluation. The regional modeling scenarios will include:

- 2008 Base Case—The current air quality conditions will be established using the base-year meteorological inputs and emissions data.
- No Action Alternative—This alternative will utilize reasonably foreseeable development (RFD) emissions for the selected future year (2022), excluding emissions from NPL. This scenario will include local and regional emissions from all source categories, including emissions from nearby oil and gas development projects (e.g., Jonah, Pinedale Anticline, LaBarge, Continental Divide-Creston, Moxa Arch, Hiawatha, etc.), if available.
- Proposed Action—Using the project-specific emission inventory developed for the NPL, this scenario will be used to evaluate and quantify project-specific air quality impacts.
- Alternative Scenario—In consultation with BLM, this scenario will represent a different development scenario for the NPL field as an alternative to the proposed scenario.

1.2.3 Modeling Tools

The primary air quality modeling tools that will be used for this study include AERMOD, the CMAQ model, the Weather Research and Forecasting (WRF) model, and the Sparse-Matrix Operator Kernel Emissions (SMOKE) modeling/processing tool.

1.3 Overview of the Meteorological Modeling Component

Regional air quality impacts will be examined using the CMAQ modeling system. The CMAQ model requires hourly, gridded input fields of several meteorological parameters including wind, temperature, mixing ratio, pressure, solar radiation, fractional cloud cover, cloud depth, and precipitation. The prescribed meteorological conditions influence the transport, vertical mixing, and resulting distribution of the simulated pollutant concentrations. Certain meteorological parameters, such as water vapor mixing ratio, can also influence the simulated chemical reaction rates. Rainfall and near-surface meteorological characteristics govern the wet and dry deposition, respectively, of the simulated atmospheric constituents.

Meteorological input fields for the CMAQ model for the NPL air quality assessment were prepared using the WRF meteorological model. Specifically, version 3.3.1 of the Advanced Research WRF (ARW) model was used. WRF is a state-of-the-science atmospheric modeling system designed for use in simulating meteorological fields for a broad range of scales and applications. The ARW version of the WRF model contains data assimilation capabilities which are integral to the use of the model for air quality modeling of historical simulation periods. The WRF/ARW model is currently maintained by the Mesoscale and Microscale Meteorology Division of the National Center for Atmospheric Research (NCAR).

The WRF model was applied for the calendar year 2008. The modeling domain includes three nested grids with approximately 36-, 12-, and 4-kilometer (km) horizontal resolution. These encompass the corresponding CMAQ grids. The 4-km grid is approximately centered over the NPL project area. This modeling domain is the same as that used for the LaBarge application (AECOM, 2012). Different simulation parameters and options were used for the non-winter months (April through October) and the winter months (January, February, March, November, and December) and these are detailed in Section 2 of the report (Table 2-2). The WRF configuration is the same as that used for the LaBarge project (AECOM, 2012).

The WRF simulation results were evaluated using graphical and statistical analysis. The output from WRF was then processed for input to the CMAQ model using the Meteorology-Chemistry Interface Processor (MCIP).

2.0 WRF APPLICATION PROCEDURES

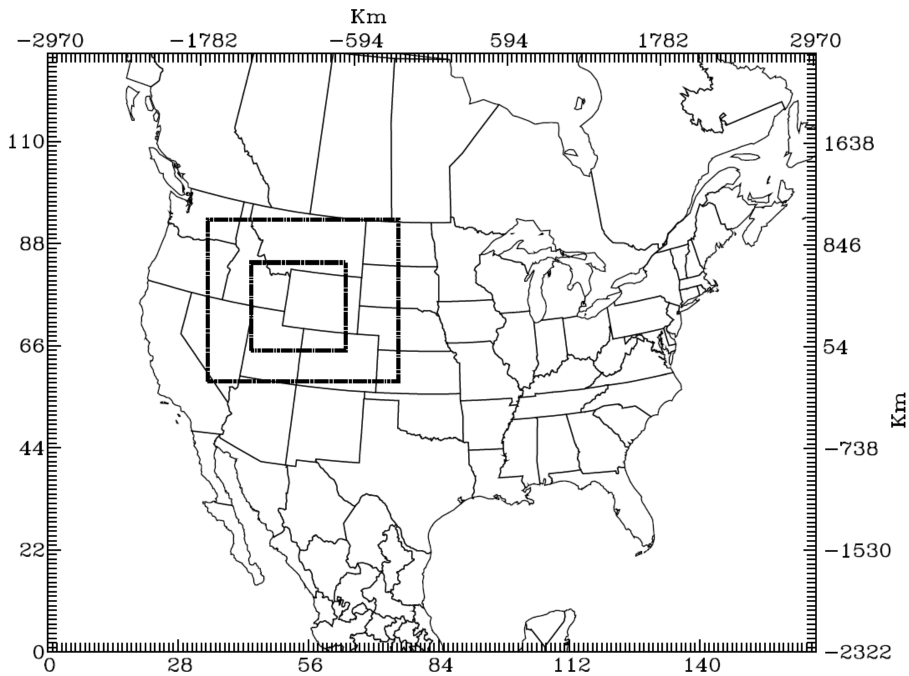
2.1 Description of the WRF Model

WRF is a state-of-the-science atmospheric modeling system designed for use in simulating meteorological fields for a broad range of scales and applications. Version 3.3.1 of the Advanced Research WRF (ARW) model, as used for this analysis, includes numerous features to support both idealized and real-data simulations. Key features for this application include: a terrain following vertical coordinate system; fully compressible no hydrostatic equations (for the simulation of the effects of terrain on airflow); two-way grid nesting; variable vertical grid spacing; full physics options for the surface layer, planetary boundary layer, atmospheric and surface radiation, microphysics and cumulus convection; and data assimilation (both analysis and observation nudging). The data assimilation capabilities, through which observed data are used to guide the simulation, are integral to the use of the model to represent historical simulation periods. This version of the model is currently maintained by the Mesoscale and Microscale Meteorology Division of the NCAR.

2.2 WRF Modeling Domain and Simulation Period

The WRF modeling domain is designed to accommodate both regional and sub-regional meteorological influences and to provide a detailed representation of the meteorology over the area of interest. The modeling domain includes three nested grids with approximately 36-, 12-, and 4-kilometer (km) horizontal resolution. The 4-km grid is approximately centered over the NPL project area. This modeling domain is the same as that used for the LaBarge WRF application (AECOM, 2012) and is illustrated in Figure 2-1. The left and bottom axes indicate the number of 36-km grid cells. The right and top axes show the distance from the center of the 36-km grid based on the Lambert Conformal Conic (LCC) map projection.

Figure 2-1. WRF Modeling Domain for the NPL Air Quality Impact Assessment: 36-, 12- and 4-km Grids



Note that the WRF grids encompass and extend beyond the corresponding CMAQ grids with the same horizontal resolution. This is to ensure that regional-scale weather systems influencing the area of interest are represented along the boundaries of the domain. The modeling grids are based on a LCC map projection.

In the vertical dimension, the modeling domain includes 34 layers for the months of April–October and 38 layers for January, February, March, November and December (the same layer structure that has been established for modeling studies of other, nearby project areas). The thickness of the layers increases with height above ground. The thinner layers near the surface are designed to provide enhanced resolution of the meteorological parameters and dispersion characteristics within the lowest part of the atmosphere (where they tend to be most variable) and to delineate the depth of the planetary boundary layer (PBL). Representation of the near surface meteorological characteristics and PBL depth is critical to accurate simulation of pollutant dispersion and transport. Additional layers were used for the winter months in order to better simulate the low-level radiation inversions (temperature gradients) that occur under conditions of cold surface temperatures and snow cover and that can limit vertical mixing and thus influence air quality within the lowest part of the atmosphere. The vertical layers for the 34 layer domain are presented in Table 2-1a; the lowest 8 layers for the 38 layer domain (equivalent to the lowest 4 layers of the 34 layer domain) are presented in Table 2-1b. Above layer 8, the vertical structure of the 38 layer domain is the same as that for the 34 layer domain. For each layer, the table lists the sigma value (this corresponds to the internal sigma-based, or terrain-following, coordinate system), the approximate pressure at the top of the layer, the estimated height of the top of the layer (based on standard atmospheric conditions), and the estimated depth of the layer. Units are millibars (mb) for pressure and meters (m) for layer height and depth.

Table 2-1a. Vertical Layer Structure for the WRF Modeling Domain for the NPL Air Quality Impact Assessment (34 Layers)

Layer	Sigma	Pressure (mb)	Height (m)	Depth (m)
34	0.000	100	14,662	1,840
33	0.050	145	12,822	1,466
32	0.100	190	11,356	1,228
31	0.150	235	10,128	1,062
30	0.200	280	9,066	939
29	0.250	325	8,127	843
28	0.300	370	7,284	767
27	0.350	415	6,517	705
26	0.400	460	5,812	652
25	0.450	505	5,160	607
24	0.500	550	4,553	569
23	0.550	595	3,984	536
22	0.600	640	3,448	506
21	0.650	685	2,942	480
20	0.700	730	2,462	367
19	0.740	766	2,095	267
18	0.770	793	1,828	259
17	0.800	820	1,569	169
16	0.820	838	1,400	166
15	0.840	856	1,234	163
14	0.860	874	1,071	160
13	0.880	892	911	158
12	0.900	910	753	78
11	0.910	919	675	77
10	0.920	928	598	77
9	0.930	937	521	76
8	0.940	946	445	76
7	0.950	955	369	75
6	0.960	964	294	74
5	0.970	973	220	74
4	0.980	982.0	146	37
3	0.985	986.5	109	37
2	0.990	991.0	72	36
1	0.995	995.5	36	36
Ground	1.000	1000	0	0

Table 2-1b. Vertical Layer Structure for the WRF Modeling Domain for the NPL Air Quality Impact Assessment (Lowest 8 Layers of 38 Layers)

Layer	Sigma	Pressure (mb)	Height (m)	Depth (m)
8	0.9800	982.0	153	39
7	0.9850	986.5	114	38
6	0.9900	991.0	76	23
5	0.9930	993.7	53	15
4	0.9950	995.5	38	14
3	0.9968	997.1	24	10
2	0.9982	998.4	14	8
1	0.9992	999.3	6	6
Ground	1.0000	1000.0	0	0

The WRF model was applied for the calendar year 2008. In applying WRF, the annual simulation period was divided into multiple sub-periods. Each sub-period included a 12-hour initialization period followed by a 5-day simulation period (a total of 5.5 days). Each successive initialization period overlapped the previous simulation period by 12 hours. This resulted in a total of approximately 75 multi-day simulations to complete the application for the entire year (including a ten-day start-up period as required by CMAQ).

2.3 WRF Model Configuration

As noted earlier in this report, different simulation parameters and options were used for April through October (the non-winter months or summer “ozone season”) and January, February, March, November and December (the winter months or winter “ozone season”). The WRF configuration is summarized in Table 2-2.

Table 2-2. Summary of WRF Simulation Parameters and Options for the NPL Project

Parameter	Non-Winter Months (April–October)	Winter Months (January–March, November & December)
General Information		
WRF model version	3.3.1	3.3.1
Modeling Domain		
Number of grids	3	3
Grid resolution	36, 12 & 4 km	36, 12 & 4 km
Number of grid cells (36-km grid)	165 x 129	165 x 129
Number of grid cells (12-km grid)	124 x 106	124 x 106
Number of grid cells (4-km grid)	184 x 172	184 x 172
Nesting approach	Two-way nesting	Two-way nesting
Number of vertical layers	34	38

Table 2-2. Summary of WRF Simulation Parameters and Options for the NPL Project (Continued)t

Parameter	Non-Winter Months (April–October)	Winter Months (January–March, November & December)
Meteorological Datasets		
Initial and boundary conditions	NCEP/NARR 32-km ds608.0	NCEP/NARR 32-km ds608.0
Sea surface temperature	NARR	NARR
Observed data for surface analysis nudging	NCEP/ADP ds461.0	NCEP/ADP ds461.0
Observed data for observational (“obs”) nudging	NCAR ds472.0	NCAR ds472.0
Data Assimilation		
Analysis nudging aloft (36-km grid)	u, v, T, q*	u, v, T, q
Analysis nudging aloft (12-km grid)	u, v, T, q	u, v, T, q
Analysis nudging aloft (4-km grid)	None	None
Analysis nudging coefficient (aloft; all nudged parameters)	$3x10^{-4}$	$3x10^{-4}$
Analysis nudging (surface) (36-km grid)	u, v	u, v
Analysis) nudging (surface) (12-km grid)	u, v	u, v
Analysis nudging (surface) (4-km grid)	None	None
Analysis nudging coefficient (surface; all nudged parameters)	$3x10^{-4}$	$3x10^{-4}$
Obs nudging (36-km grid)	None	None
Obs nudging (12-km grid)	None	None
Obs nudging (4-km grid)	u, v	u, v
Obs nudging coefficient (all nudged parameters)	$6x10^{-4}$	$6x10^{-4}$
Physics		
Microphysics	WRF single-moment 3-class scheme	Morrison double-moment scheme
Long wave radiation	Rapid Radiative Transfer Model (RRTM)	RRTM
Short wave radiation	Dudhia	Goddard
Surface layer physics	Eta similarity	Quasi-Normal Scale Elimination (QNSE)
Land-surface model	Noah LSM	Noah LSM
PBL	Mellor-Yamada-Janic scheme	QNSE
Cumulus parameterization (36 & 12-km grids only)	Grell-Devenyi ensemble scheme	Grell-Devenyi ensemble scheme
Surface fluxes	Yes	Yes
Snow cover effects	Yes	Yes

Table 2-2. Summary of WRF Simulation Parameters and Options for the NPL Project (Concluded)

Parameter	Non-Winter Months (April–October)	Winter Months (January–March, November & December)
Cloud cover effects	Yes	Yes
Number of soil layers	4	4
Urban physics	No	No
Dynamics		
Vertical velocity damping	No	No
Diffusion	Simple diffusion	Simple diffusion
Eddy coefficient	2-d deformation	2-d deformation
Sixth-order numerical diffusion	No	No
Base sea-level temperature (K)	290	290
Upper-level damping	No	No
Horizontal diffusion coefficient (m^2/s)	0	0
Vertical diffusion coefficient (m^2/s)	0	0
Non-hydrostatic	Yes	Yes
Moist advection	Positive-definite advection	Positive-definite advection
Scalar advection	Positive-definite advection	Positive-definite advection
Boundary Condition Controls		
Number of rows for boundary value nudging	5	5
Number of points in specified zone	1	1
Number of points in relaxation zone	4	4

* u = east-west wind component, v = north-south wind component, T = temperature, q = water vapor mixing ratio (moisture)

For this application, surface temperature and moisture were characterized using the Noah Land Surface Model (LSM) which has been recently updated (in version 3.1 of ARW) to better represent processes over ice and snow covered areas.

For the coarser grids, the Grell-Devenyi ensemble cumulus parameterization scheme was used to parameterize the effects of convection on the simulated environment. This feature was not employed for the 4-km grid where an explicit moisture scheme was applied.

The WRF-ARW model supports four-dimensional data assimilation (FDDA), a procedure by which observed data are incorporated into the simulation. Analysis nudging, in which the simulation variables are relaxed or "nudged" toward an objective analysis that incorporates the observed data, was used for all parameters (wind, temperature, moisture) for the outer modeling grids. Analysis nudging of temperature and moisture was applied only for layers that are above the planetary boundary layer. Observational ("obs") nudging, in which the simulation parameters are nudged directly toward selected observations, was used for surface winds within the high-resolution 4-km grid, using NCAR ds472 data.

The WRF model configuration parameters are the same as those used for the WRF application to support the air quality modeling for the LaBarge project (AECOM, 2012).

2.4 WRF Model Inputs

Inputs required for application of the WRF model include topographic, land-use, and vegetation information for each grid cell (and modeling grid), initial and boundary conditions, and meteorological analysis fields and observed data (for use in the data assimilation schemes).

For this application, high-resolution data for preparation of the terrain, land-use, and vegetation input files were obtained from NCAR. The WRF input files were prepared using the preprocessor programs that are part of the WRF modeling system (NCAR, 2010).

Meteorological data for this application were obtained from the National Center for Environmental Prediction (NCEP) and NCAR and specifically from the Research Data Archive (RDA) which is maintained by the Computational and Information Systems Laboratory (CISL) at NCAR: http://rda.ucar.edu/datasets/.

The NCEP/North American Regional Reanalysis (NARR) 32-km model analyses (ds608.0) were used to specify the initial and boundary conditions as well as sea surface temperatures for WRF. The analysis fields were also used for the analysis nudging (above the PBL) for the 36- and 12-km grids. In addition, the analysis fields were combined with the NCEP Automated Data Processing (ADP) surface observational weather data (ds461.0) (in “little_r” format) and used for the surface analysis nudging (also for the 36- and 12-km grids).

The NCAR ds472.0 datasets contain surface and upper-air wind, temperature, moisture, and pressure data for all routine monitoring sites within the domain and these data were used for the observational (“obs”) nudging. These data are from a variety of monitoring sites including National Weather Service (NWS) Automated Surface Observing System (ASOS) monitoring sites and routine aviation weather reporting stations.

The ds472.0 dataset includes both surface and upper-air data. A total of 118 surface and 9 upper-air meteorological monitoring sites are located within the WRF 12-km modeling grid and 41 surface and two upper-air sites are located within the WRF 4-km grid. A list of the routine surface meteorological monitoring sites within the WRF 4-km modeling domain is given in Table 2-3. A list of the routine upper-air monitoring sites is given Table 2-4. The sites are organized alphabetically by site ID.

Table 2-3. Routine Surface Meteorological Monitoring Sites within the NPL WRF 4-km Modeling Grid

Station ID	Latitude	Longitude
K20V	40.05	-106.37
K3MW	40.45	-106.75
K77M	42.32	-113.32
KBIL	45.8	-108.55
KBPI	42.58	-110.1
KBYG	44.38	-106.72
KBYI	42.55	-113.77
KCAG	40.5	-107.52
KCOD	44.52	-109.02

Table 2-3. Routine Surface Meteorological Monitoring Sites within the NPL WRF 4-km Modeling Grid (Concluded)

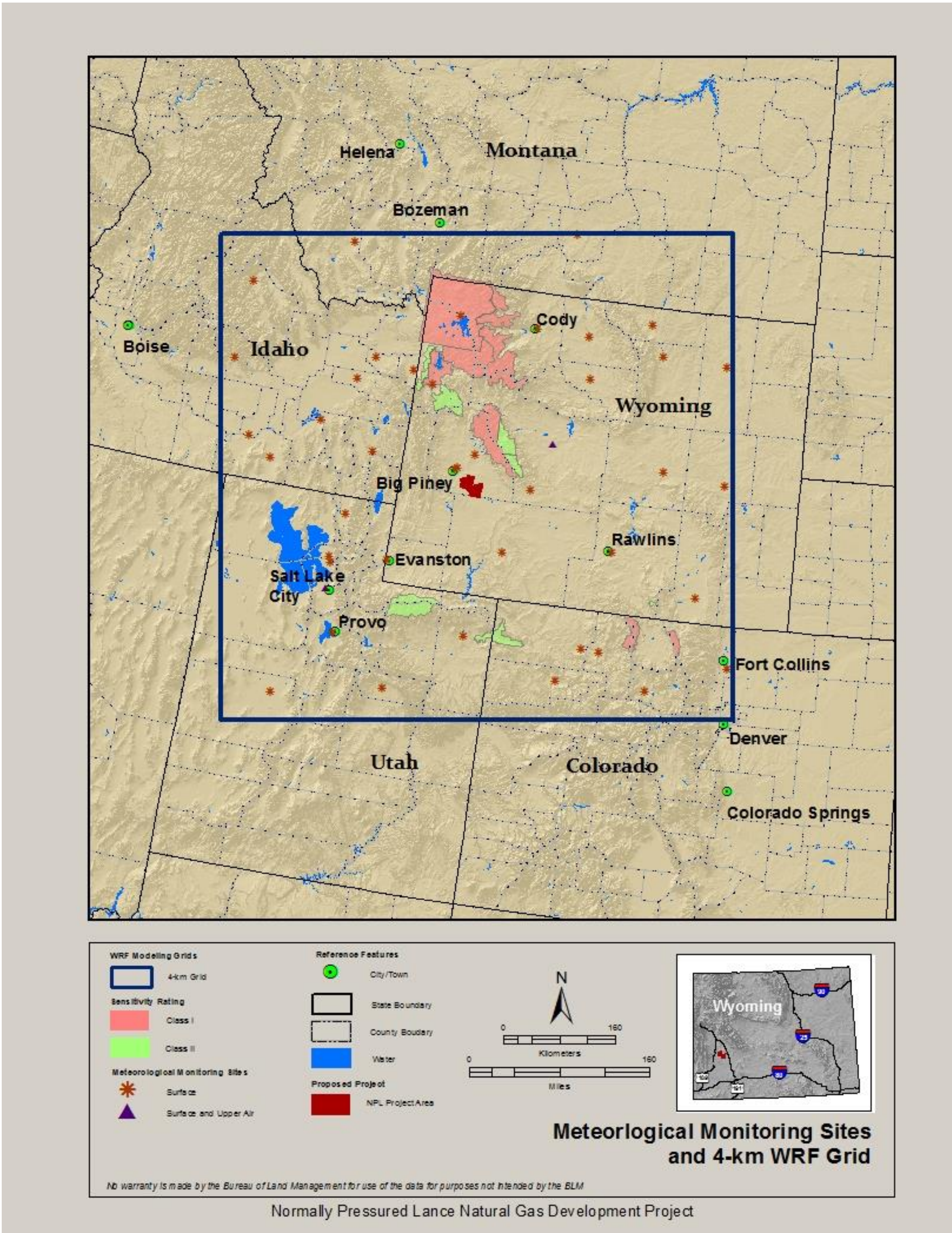
Station ID	Latitude	Longitude
KCPR	42.9	-106.47
KDGW	42.8	-105.38
KDIJ	43.75	-111.1
KDLN	45.25	-112.55
KEEO	40.05	-107.88
KEVW	41.27	-111.03
KFNL	40.45	-105.02
KGCC	44.33	-105.55
KGEY	44.52	-108.08
KHDN	40.47	-107.22
KHIF	41.12	-111.97
KIDA	43.52	-112.07
KJAC	43.62	-110.73
KLAR	41.32	-105.67
KLGU	41.78	-111.85
KLLJ	44.52	-114.22
KOGD	41.2	-112.02
KP60	44.55	-110.42
KPIH	42.92	-112.57
KPNA	42.8	-109.8
KPUC	39.62	-110.75
KPVU	40.22	-111.72
KRKS	41.6	-109.07
KRWL	41.78	-107.2
KRXE	43.83	-111.8
KSHR	44.77	-106.97
KSMN	45.12	-113.87
KSUN	43.5	-114.28
KU24	39.33	-112.58
KU78	42.63	-111.57
KVEL	40.45	-109.52
KWRL	43.97	-107.95

Table 2-4. Routine Upper-Air Meteorological Monitoring Sites within the NPL WRF 4-km Modeling Grid

Station ID	Latitude	Longitude
KRIW	43.07	-108.47
KSLC	40.78	-111.97

The locations of the meteorological monitoring sites within the WRF 4-km grid are illustrated in Figure 2-2.

Figure 2-2. Location of Meteorological Monitoring Sites within the NPL WRF 4-km Modeling Grid (Grid Outline in Blue)



2.5 Use of WRF Output Files for Air Quality Modeling and Emissions Processing

The WRF output will be postprocessed to correspond to the CMAQ modeling domain and the units and formats required by the modeling system using the MCIP postprocessing software.

MCIP also outputs directly the meteorological fields needed for emissions processing. These include:

- temperature, surface pressure, radiation/cloud cover, rainfall, soil temperature, soil moisture and soil type for the calculation of the biogenic emissions; and
- temperature and relative humidity for the calculation of motor vehicle emissions

3.0 MODEL PERFORMANCE EVALUATION METHODOLOGY

The WRF model performance evaluation methodology was designed to examine whether the WRF model (configured and applied as discussed in Section 2) was able to reproduce the observed meteorological conditions of the (historical) simulation period, especially those features that are important in air quality modeling (and influence the transport, chemical transformation and deposition processes). Information obtained from the WRF model performance evaluation is also expected to aid the evaluation and interpretation of the air quality modeling results.

Key components of the evaluation include: 1) the qualitative assessment of the ability of the WRF model to represent the synoptic- and regional-scale spatial patterns and temporal variations of wind, temperature, water vapor mixing ratio, and precipitation of the simulation period and 2) the qualitative and quantitative assessment of the ability of the WRF model to represent site-specific conditions including vertical profiles and diurnal profiles of wind, temperature, and mixing ratio for sites located within the high-resolution (4-km) modeling grid. A variety of graphical and statistical methods were used to examine the WRF results, consistent with EPA guidance on the preparation of meteorological inputs for air quality modeling (EPA, 2007).

3.1 Overview of the WRF Model Performance Evaluation Methodology

For the outermost (36-km) grid, examination of the WRF output focused on representation of the regional-scale meteorological features and airflow patterns. Plots of selected meteorological fields were prepared and compared with regional-scale weather maps.

For the intermediate (12-km) grid, the evaluation also included an examination of the regional-scale patterns and a comparison with weather maps. In addition, statistical measures comparing the simulated values of wind, temperature and mixing ratio (moisture) with observed values were calculated using the METSTAT program (Environ, 2012).

A more detailed evaluation of the results was performed for the innermost (4-km) grid, emphasizing representation of the observed data, terrain-related airflow features, vertical temperature structure of the lower atmosphere, PBL heights, and vertical mixing parameters. The modeling results were compared with observed data. Statistical measures comparing the simulated values of wind, temperature and water vapor mixing ratio with observed values were calculated. In the absence of observed data, the modeling results were examined for physical reasonableness as well as spatial and temporal consistency.

For all three grids, the ability of the WRF model to reproduce observed precipitation patterns was qualitatively assessed by comparing the simulated and observed precipitation patterns (based on NWS data). A detailed analysis of the timing and amount of the precipitation was not performed.

3.2 Qualitative Assessment of Synoptic- and Regional-Scale Meteorological Patterns

As a starting point in the evaluation, spatial plots of selected meteorological parameters were prepared for each grid for approximately the 15th of each month (the exact date varied according to run segmentation and was chosen so that each plot was of the fifth day of a 5-day simulation period). The plots included surface temperature, surface pressure, surface specific humidity, surface wind speed and wind direction, 700 mb temperature, 700 mb wind speed and wind direction, 500 mb wind speed and wind direction, monthly total precipitation amounts, and snow cover. These were inspected in several ways including: comparison of the WRF results with NWS analysis products, comparison of the results for all three grids, and inspection of the WRF results relative to the terrain and land-use features.

3.3 Qualitative and Quantitative Assessment of Site-Specific Conditions

3.3.1 Methods and Tools

Statistical measures were used to quantify model performance for the 12- and 4-km grids. Statistical measures were calculated using the METSTAT program. METSTAT was applied for each grid, for each month, and for the following parameters: wind speed, wind direction, temperature, and mixing ratio. The calculated metrics and statistics are summarized in Table 3-1.

Table 3-1. Definition and Description of Measures/Metrics for WRF Model Performance Evaluation for the NPL Air Quality Impact Assessment

Metric	Definition
# of data pairs	The number of observation/simulation data pairs
Mean observation value	The average observed value of the meteorological parameter
Mean simulation value	The average simulated value of the meteorological parameter
Mean bias (Bias)	$\left(\frac{1}{N}\right)\sum_{l=1}^{N}(S_l - O_l)$ Where N is the number of data pairs, and S_l and O_l are the simulated and observed values at site l, respectively, over a given time interval.
Mean error (Gross error)	$\left(\frac{1}{N}\right)\sum_{l=1}^{N}\lvert S_l - O_l\rvert$
Root mean-squared error (RMSE)	$\left(\left(\frac{1}{N}\right)\sum_{l=1}^{N}(S_l - O_l)^2\right)^{1/2}$
Index of agreement (IOA)	A measure of how well the model represents the pattern of perturbation about the mean value; ranges from 0 to 1.

In calculating the statistical measures, METSTAT pairs the WRF model output with the observed data for the appropriate locations and time intervals.

The statistical measures were examined and potential biases in the meteorological inputs were identified, with emphasis on those that could affect the use of the meteorological fields in simulating air quality. The statistical measures were also compared with benchmarks derived from prior simulations (Tesche et al., 2002). Since data assimilation was used for selected parameters, a comparison with the observed data (for those parameters) primarily serves as a check on the data assimilation.

Additional plots and summaries were prepared to facilitate the overall evaluation of the results for the 4-km grid. These include:

- Time-series plots comparing simulated and observed values for a variety of meteorological parameters for a) all monitoring sites with the grid (average of all site) and b) selected monitoring sites.
- Comparison wind frequency diagrams for selected sites and time periods.
- Plots of simulated and observed vertical temperature and wind profiles for selected sites and time periods, prepared using EPA's Atmospheric Model Evaluation Tool (AMET) model evaluation software (UNC, 2008) .

3.3.2 Meteorological Data

The routine surface and upper-air meteorological data used for model evaluation (ds472.0) are described in Section 2. The dataset contains hourly airways data for approximately 2,000 monitoring sites. These include 118 surface and 9 upper-air meteorological monitoring sites located within the WRF 12-km modeling grid and 41 surface and two upper-air sites located within the WRF 4-km grid.

Additionally, some research meteorological monitoring data may be used at a later date (during the course of the air quality assessment) as an independent check on WRF model performance. These include temperature data from the BLM's Wyoming Air Resource Monitoring System (WARMS) database (which consists of several monitoring sites throughout Wyoming) as well as surface and upper-air monitoring data from the 2008 Upper Green River Winter Ozone Study (UGWOS) field program. The UGWOS monitoring sites are listed Table 3-2.

Table 3-2. Meteorological Monitoring Sites for the Upper Green River Winter Ozone Study (UGWOS)

Station ID	Latitude	Longitude
BLDUM	42.607	-109.865
BOULD	42.71866	-109.754
CAMPB	44.1469	-105.53
CENTNL	41.3722	-106.242
CORA1	43.00665	-110.009
DANIE	42.7913	-110.065
HAYS4	42.22205	-109.463
JONAH	42.43647	-109.696
LABA8	42.25853	-110.194
MURPH	41.37328	-111.042
OCITR	41.7369	-109.639
PINEDL	42.9288	-109.788
SIMP5	42.02828	-109.582

Table 3-2. Meteorological Monitoring Sites for the Upper Green River Winter Ozone Study (UGWOS) (Concluded)

Station ID	Latitude	Longitude
SOPAS	42.5111	-108.72
THBAS	44.6722	-105.29
WAMSU	41.6777	-108.024
WARB3	42.5702	-109.702
WENZF	42.7982	-109.805
YELSTN	44.5597	-110.401

Meteorological data from the 2008 Upper Green River Special Study were obtained from:
http://deq.state.wy.us/aqd/Upper%20Green%20Winter%20Ozone%20Study.asp

3.3.3 Statistical Benchmarks

There are no specific criteria as to what constitutes an acceptable set of meteorological inputs. Nevertheless, many studies refer to a set of statistical benchmarks (Tesche et al., 2002) that can be used to support a finding of acceptable model performance. These benchmarks were developed based on evaluation of approximately 30 applications of the MM5 meteorological model (a predecessor to the WRF model) for specific multi-day simulation periods. The benchmarks are summarized in Table 3-3.

Table 3-3. Statistical Benchmarks for Evaluating Meteorological Model Performance

Metric	Wind Speed (m/s)	Wind Direction (degrees)	Temperature (K)	Water Vapor Mixing Ratio (g/kg)
Bias	±0.5	±10	±0.5	±1.0
Gross Error	--	<30	≤2	≤2
RMSE	<2	--	--	--
IOA	≥0.6	--	≥0.8	≥0.6

Note that not all metrics are applicable to all parameters.

4.0 WRF MODELING RESULTS

4.1 Synoptic- and Regional-Scale Weather Patterns

Quantitative analysis was used to examine how well the WRF modeling results for this application represent the synoptic- and regional-scale weather patterns and key meteorological features (such as high and low-pressure systems, frontal systems, precipitation and snow cover) that characterize the annual simulation period. Plots of the WRF simulation results were compared with weather maps and standard weather analysis products available from the National Oceanic and Atmospheric Administration (NOAA, 2008a and b) and the High Plains Regional Climate Center (HPRCC, 2011). For ease of comparison with available national-scale weather products, this analysis focused on the 36-km grid. The assessment considered representation of the weather patterns both near the surface and aloft (500 mb). Note that the 500 mb level (typically about 5,500 m above sea level [asl]) is a standard pressure level used extensively for synoptic-scale weather forecasting and analysis. With the exception of precipitation and snow cover, the comparison was done for approximately the 15th of each month (the exact date varied according to run segmentation and was chosen so that each plot was of the fifth day of a 5-day simulation period). This was done for consistency and to ensure that the evaluation focused on the simulation results (and not the initial conditions). Precipitation was examined on a monthly basis and snow cover was examined for selected winter days. The qualitative assessment of synoptic- and regional-scale weather patterns is summarized in the remainder of this section.

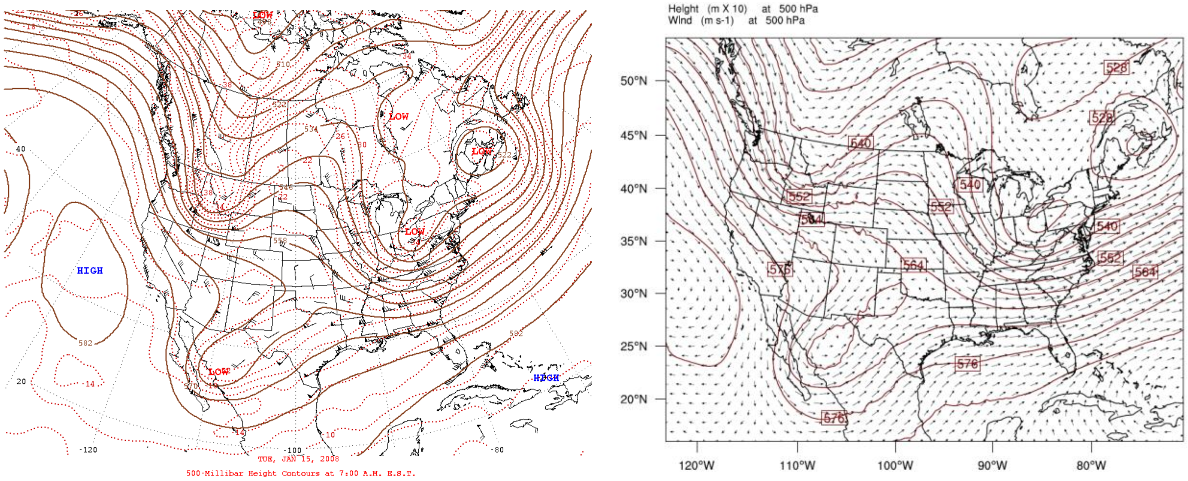
4.1.1 Upper-Air Weather Patterns

Accurate simulation of synoptic-scale (large-scale) weather patterns is important since the synoptic-scale weather patterns determine the range of regional and local conditions that can occur within their region of influence (in this case, within the 12- and 4-km domains). In the following figures, the WRF-derived synoptic-scale weather patterns are compared with standard NWS 500-mb charts that illustrate the synoptic-scale weather patterns that characterize the selected analysis days. Specifically, the 500-mb charts depict the location of pressure ridges and troughs (areas of relatively high and low pressure, respectively), frontal systems, and airflow patterns at the 500-mb level. The 500-mb level is a standard constant-pressure level used for meteorological analysis and forecasting; the average height of the 500 mb surface is approximately 5,500 asl. The plots are for 1200 GMT (0500 MST). The comparison was done for one day for each month as a check on the reasonableness of the WRF-derived synoptic-scale patterns. Plots for January, April, July, and October are presented to illustrate the comparison. For ease of reading, the plots are presented at the end of this subsection.

Figure 4-1 compares simulated and observation-based 500-mb charts for 1200 GMT (0500 MST) for January 15, April 14, July 13, and October 16, 2008. The observation-based 500-mb analyses (shown on the left) were obtained from the Daily Weather Map Archive for 2008 (NOAA, 2008a). The simulated 500-mb patterns are very similar to the observed patterns. The patterns show high-pressure ridges over Wyoming for the January and April days and more zonal flow for the July and October days. The synoptic-scale weather patterns aloft for the selected days are very well represented by WRF.

Figure 4-1. Observed (Left) and Simulated (Right) 500-mb Geopotential Heights (m) and Winds for the Continental U.S. and the NPL 36-km Grid

January 15



April 14

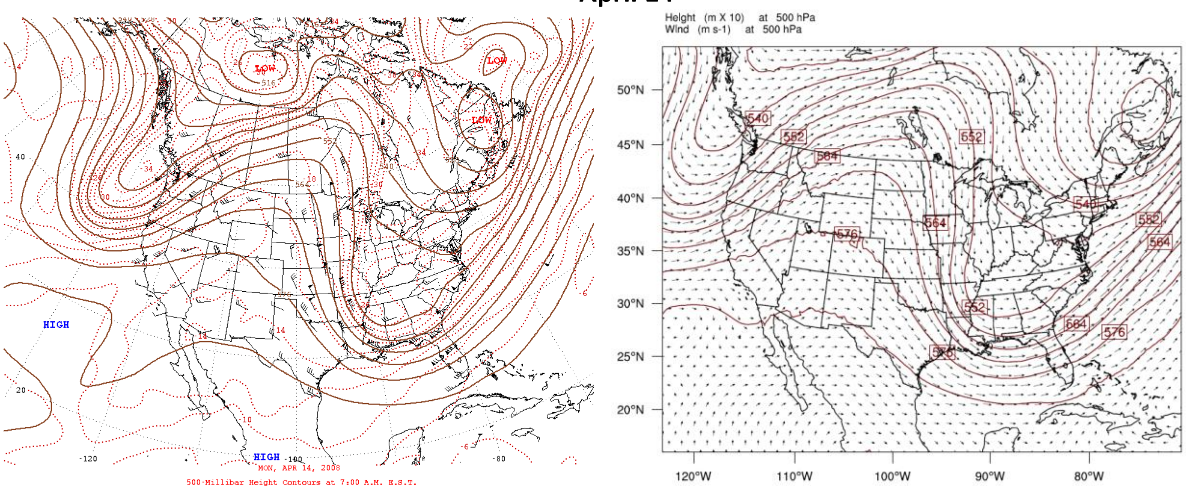
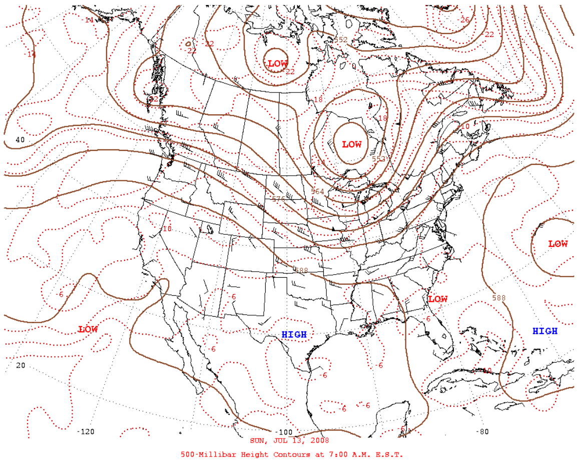
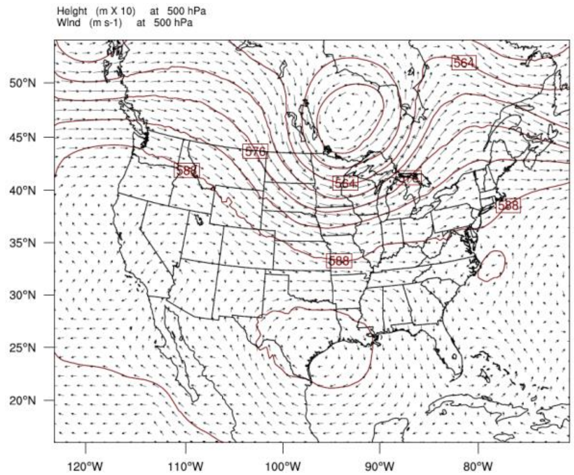


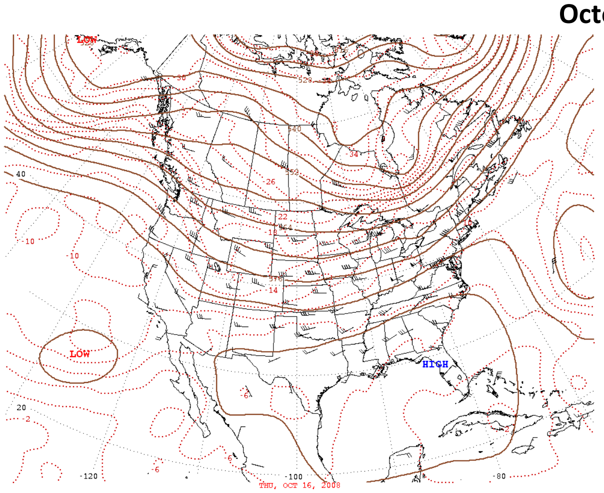
Figure 4-1. Observed (Left) and Simulated (Right) 500-mb Geopotential Heights (m) and Winds for the Continental U.S. and the NPL 36-km Grid (Concluded)

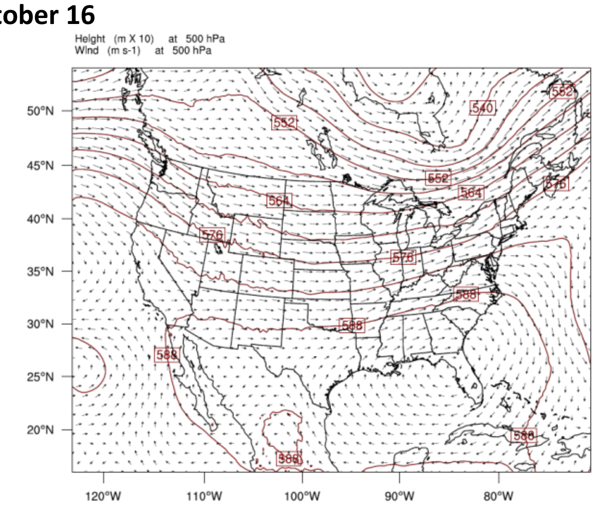
July 13





October 16





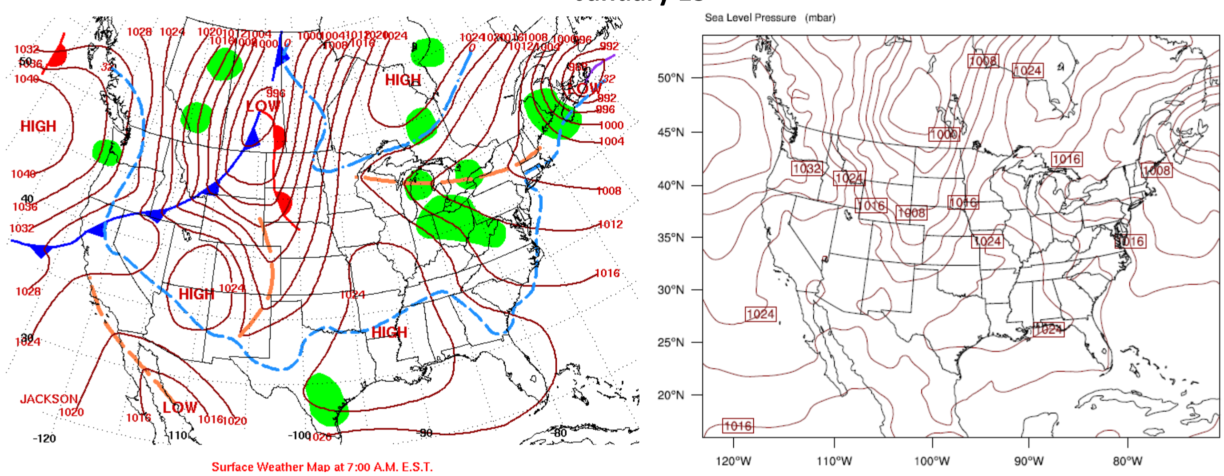
4.1.2 Surface Weather Patterns

The regional-scale surface weather patterns further define the prevailing wind and dispersion conditions that affect the air quality within a given area. For many areas in the U.S., episodes of poor air quality are often characterized relative to regional-scale meteorological high- and low-pressure systems and specifically the presence of a surface-based high-pressure system within the area of interest. The location, persistence, and strength of the high-pressure system can be important determinants of air quality. In the following figures, the WRF-derived surface weather patterns are compared with standard NWS surface analysis charts for the selected analysis days. The surface analysis charts depict the location of high and low pressure systems, frontal systems, and airflow patterns at the surface level. The plots are for 1200 GMT (0500 MST). The comparison was done for one day for each month as a check on the reasonableness of the WRF-derived surface weather patterns. Plots for January, April, July, and October are presented to illustrate the comparison. For ease of reading, the plots are presented at the end of this subsection.

Figure 4-2 compares simulated and observation-based surface analysis charts for 1200 GMT (0500 MST) for January 15, April 14, July 13, and October 16, 2008. The observation-based surface analyses (shown on the left) were obtained from the Daily Weather Map Archive for 2008 (NOAA, 2008a). For all four days, the WRF-derived pressure patterns show many of the same features as the surface analysis, indicating that the synoptic-scale weather patterns near the surface are well represented at all times of the year.

Figure 4-2. Observed (Left) and Simulated (Right) Sea Level Pressure (mb) for the Continental U.S. and the NPL 36-km Grid

January 15



April 14

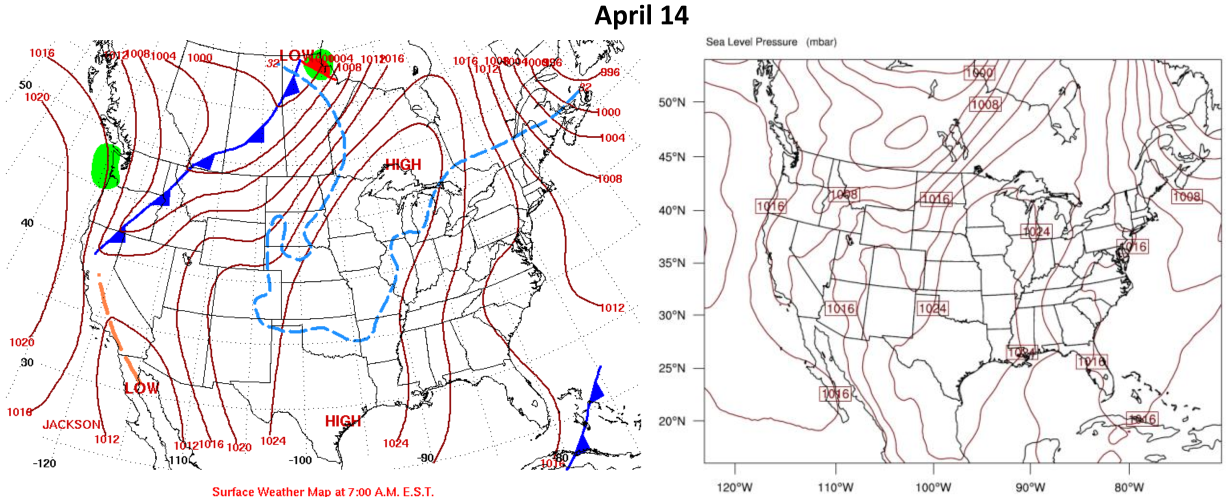
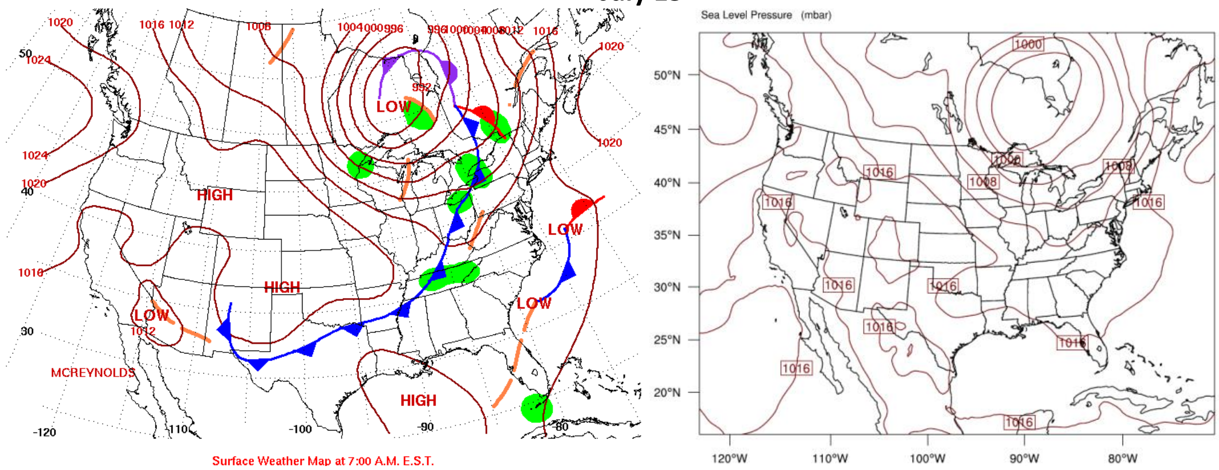
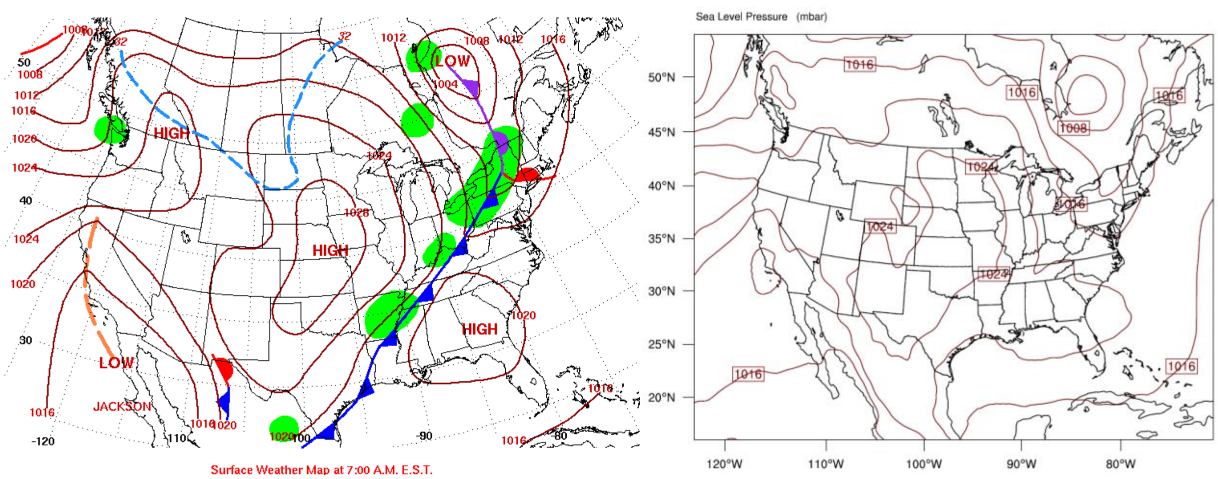


Figure 4-2. Observed (Left) and Simulated (Right) 500-mb Geopotential Heights (m) and Winds for the Continental U.S. and the NPL 36-km Grid (Concluded)

July 13



October 16



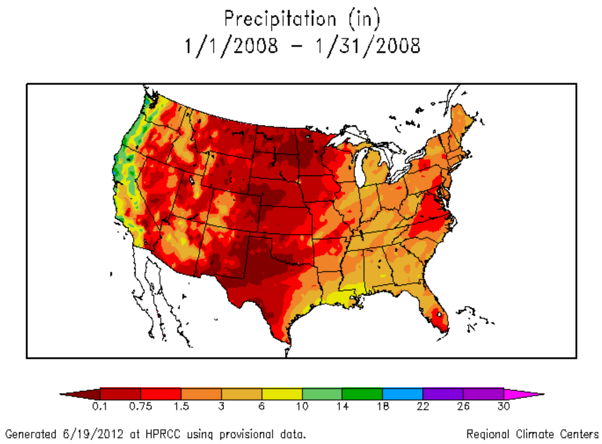
4.1.3 Precipitation

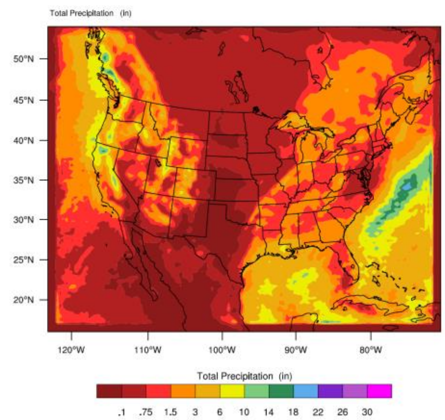
The timing and amount of cloud cover and precipitation can affect both air quality and deposition, through both direct and indirect effects on various meteorological and air quality processes. For example, cloud cover directly affects incoming (and outgoing) radiation, temperature, and stability which, in turn, affect the dispersion characteristics of the atmosphere. Similarly, precipitation affects the moisture content of the soil, which affects the moisture content and stability of the atmosphere, which, in turn, affect various atmospheric chemistry and dispersion processes. In addition, pollutants are removed from the atmosphere through wet deposition. Because they are the combined result of numerous meteorological and geographical factors (including the presence or absence of weather systems, terrain, and land use) and feedback mechanisms, the accurate simulation of cloud cover and precipitation is challenging. In the following figures, WRF-derived monthly precipitation totals are compared with observed precipitation totals. The comparison was done for each month as a check on the reasonableness of overall timing and distribution of the WRF-derived precipitation. For ease of reading, the plots are presented at the end of this subsection.

Figure 4-3 compares simulated and observed total precipitation for each calendar month. Note that the scales vary from month to month. The plots of observed precipitation (shown on the left) were obtained from the High Plains Regional Climate Center (HPRCC, 2011). The WRF-derived regional-scale precipitation patterns are generally similar to the observed patterns, but overall the precipitation amounts are lower than observed. An exception to this occurs over Wyoming, where simulated precipitation amounts are generally slightly higher than observed. For most months, observed monthly precipitation totals for Wyoming range from less than 1 to 4 inches. Observed precipitation totals are greatest for May, during which some areas of the state received 8 inches of rainfall. Observed precipitation totals are also relatively high for September and October, compared to the remainder of 2008. For most months, simulated monthly precipitation totals for Wyoming are similar to or slightly greater than observed. Simulated precipitation totals are greatest for May, with a maximum value of approximately 9.5 inches of rainfall. Overall, the simulation of precipitation is reasonably good for Wyoming, and qualitatively better than much of the rest of the 36-km domain. Feedback from the two-way interactive nested grid likely enhances WRF model performance over Wyoming.

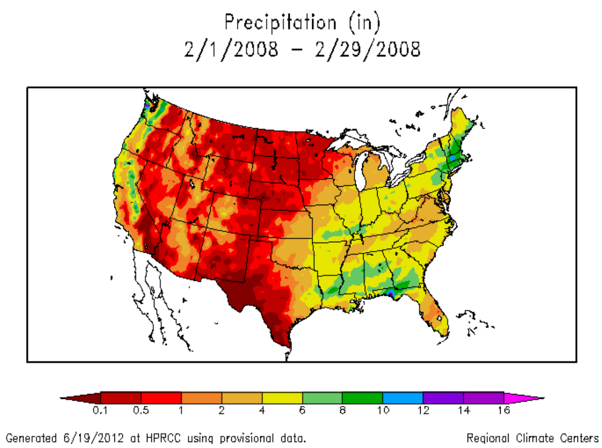
Figure 4-3. Observed (Left) and Simulated (Right) Monthly Precipitation Totals (in) for the Continental U.S. and the NPL 36-km Grid

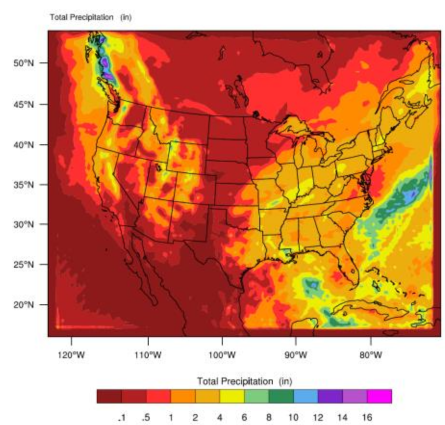
January



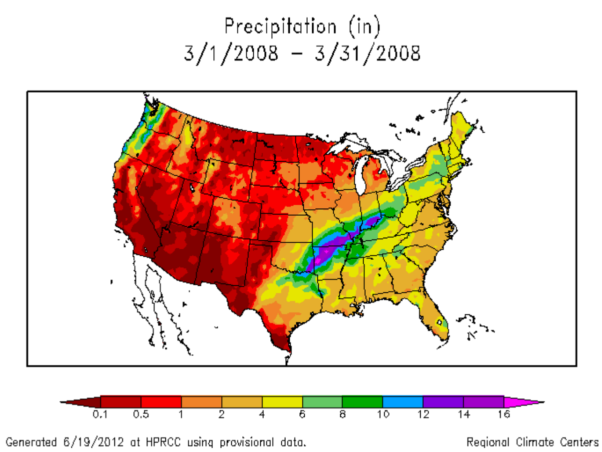


February





March



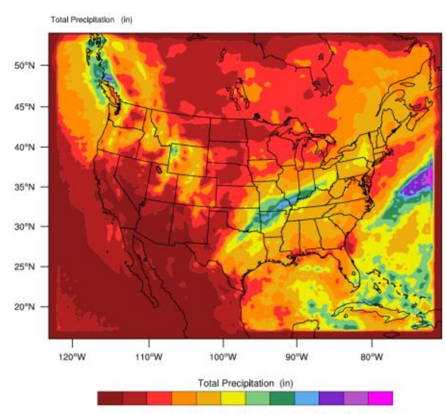
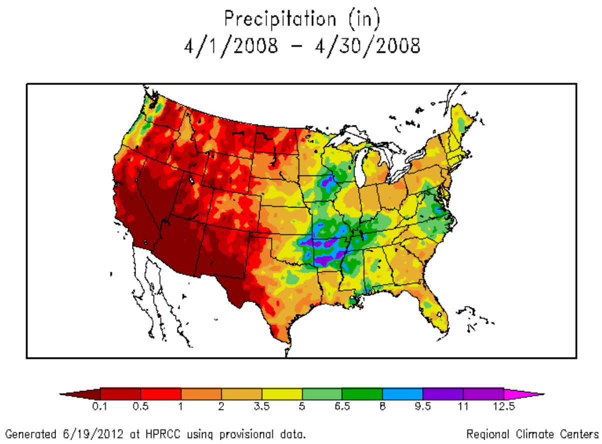
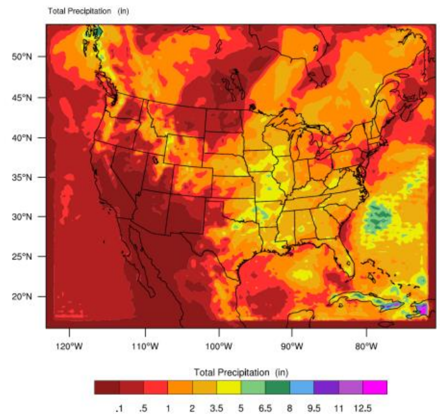


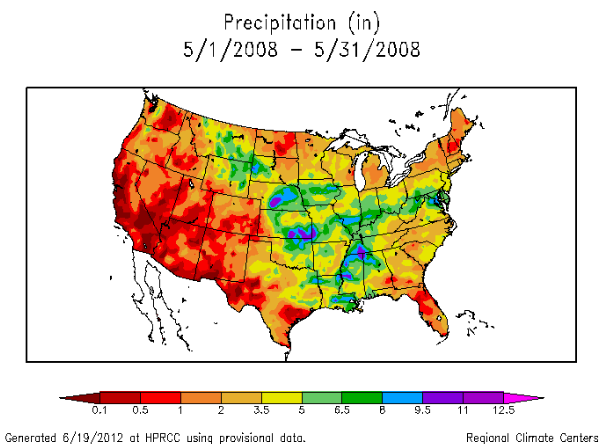
Figure 4-3. Observed (Left) and Simulated (Right) Monthly Precipitation Totals (in) for the Continental U.S. and the NPL 36-km Grid (Continued)

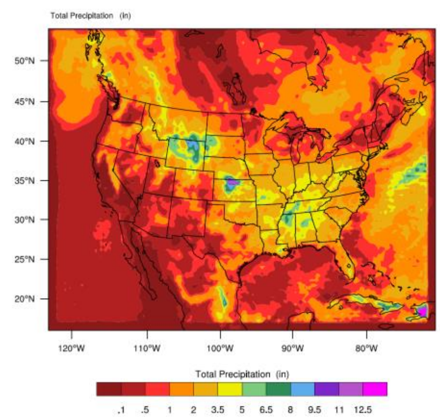
April



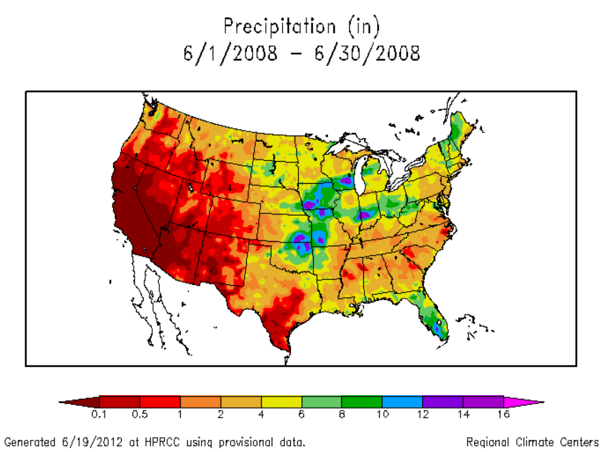


May





June



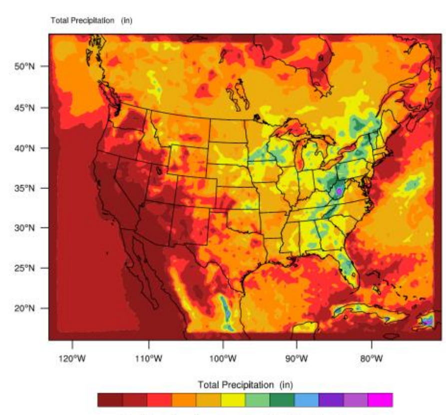
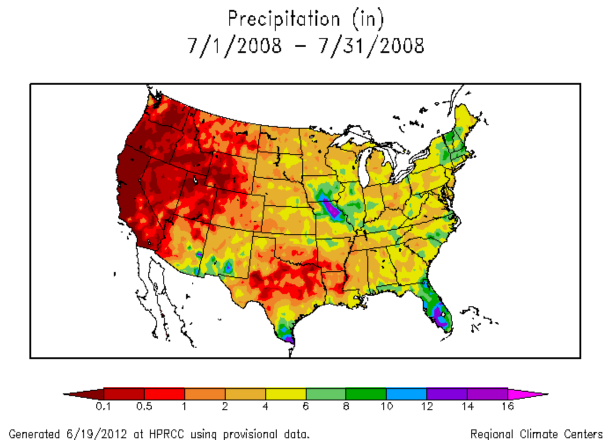
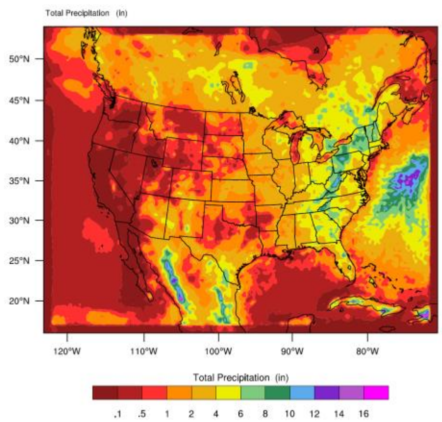


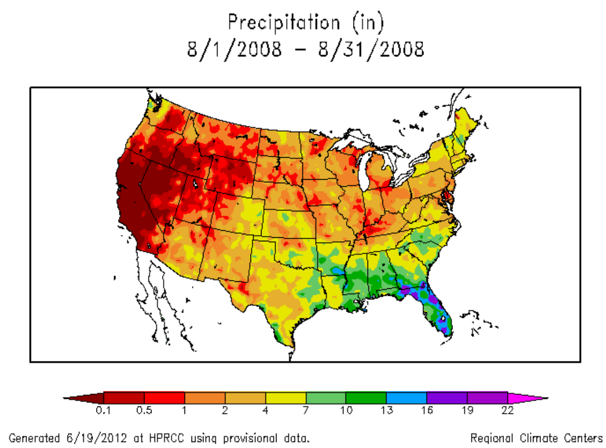
Figure 4-3. Observed (Left) and Simulated (Right) Monthly Precipitation Totals (in) for the Continental U.S. and the NPL 36-km Grid (Continued)

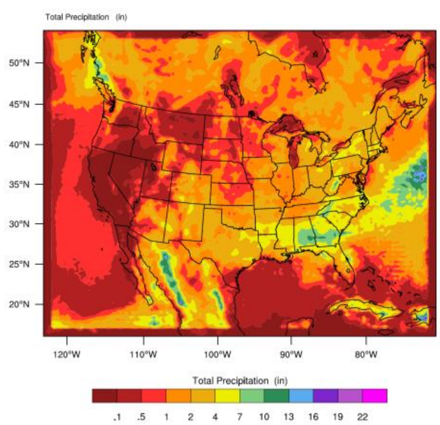
July



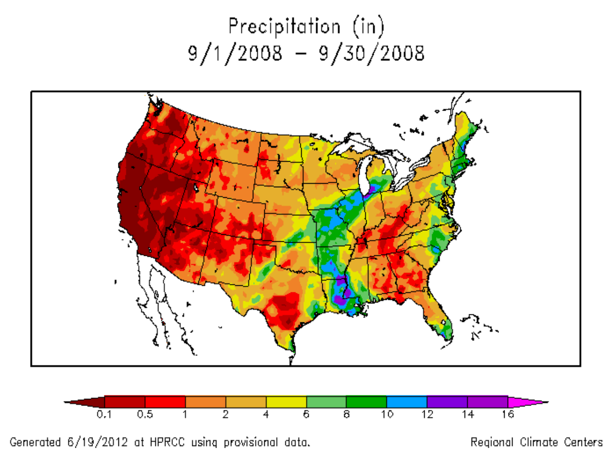


August





September



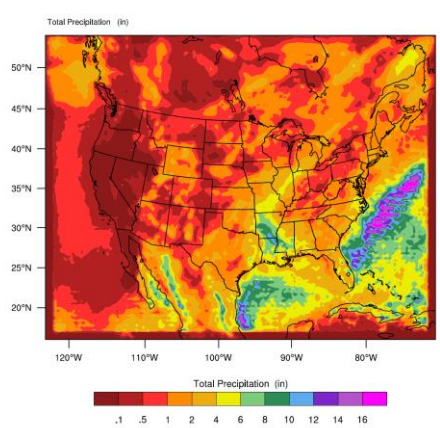
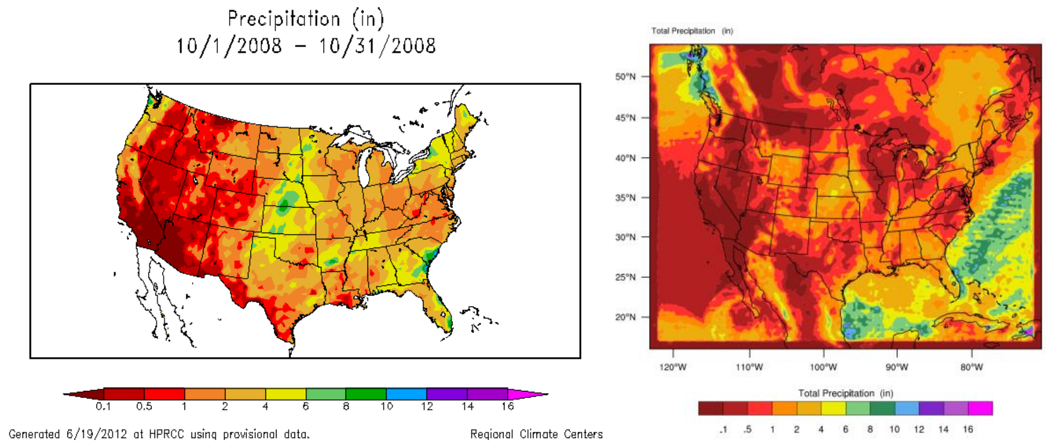
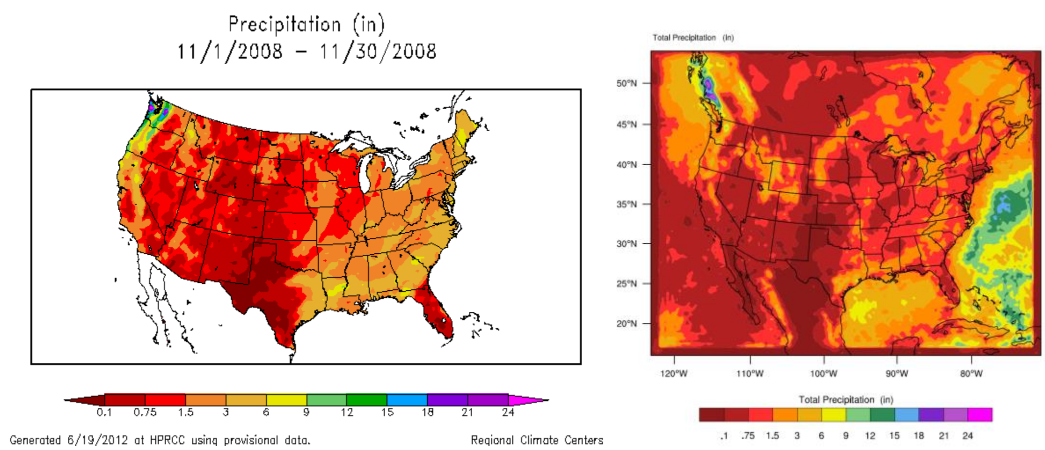


Figure 4-3. Observed (Left) and Simulated (Right) Monthly Precipitation Totals (in) for the Continental U.S. and the NPL 36-km Grid (Concluded)

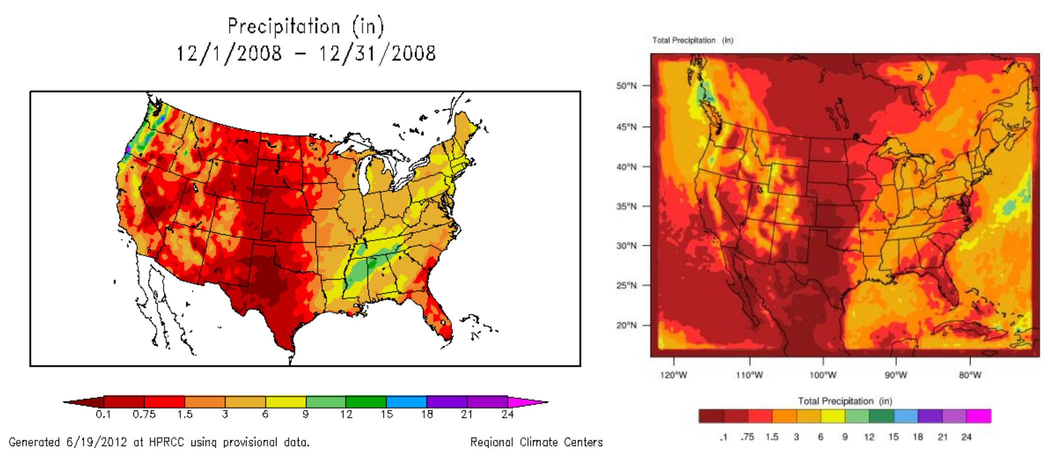
October



November



December



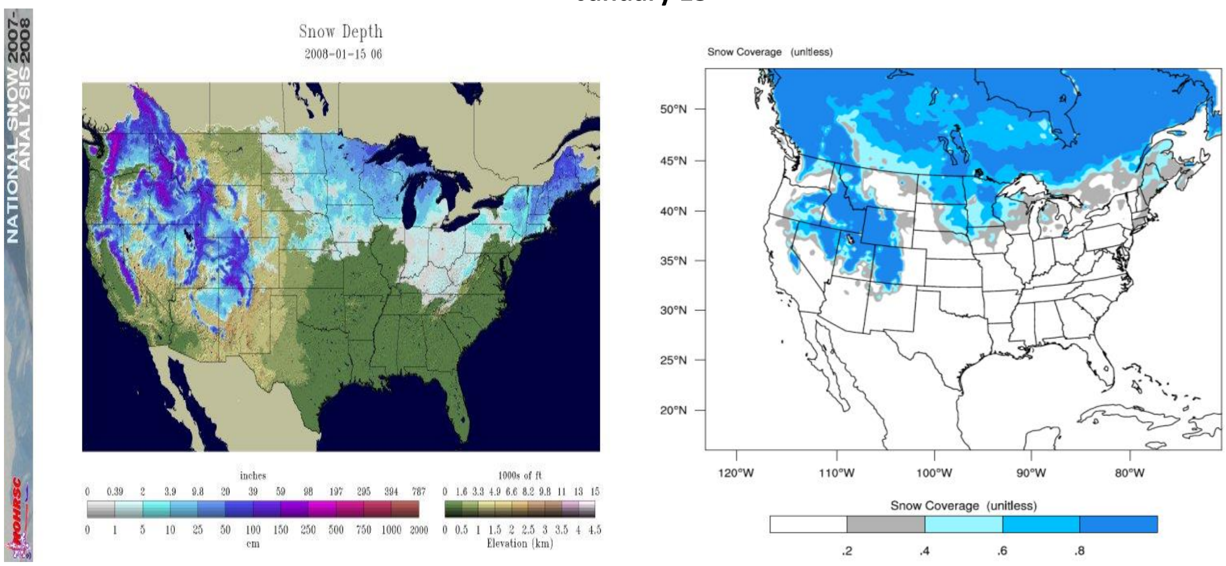
4.1.4 Snow Cover

Numerous studies including Keslar (2007) and Stoeckenius and Ma (2010) have indicated that snow cover is an important factor contributing to high wintertime ozone concentrations in southwestern Wyoming. In the following figures, WRF-derived snow-cover patterns are compared with snow pack data from NOAA (2008b). The WRF results indicate the presence of snow cover while the observation-based plots show snow depth. The WRF-derived snow cover patterns can be qualitatively compared with snow pack data to examine whether the regional-scale snow cover patterns are represented by the model and specifically whether snow is simulated to be present in the area of interest if indicated by the snow pack data. The plots show snow cover for approximately the 15^{th} of each winter month (the same days, where possible, as the surface and upper-air pattern analyses). For ease of reading, the plots are presented at the end of this subsection.

Figure 4-4 compares observed and simulated snow cover for January 15, February 14, March 15, November 15, and December 15, 2008. Plots of observed snow depth were obtained from the National Snow Analyses for 2008 (NOAA, 2008b). Overall, the WRF modeling results do not capture the extent of snow cover over the midwestern and northeastern states (for the January, February, March and December days). The model also does not indicate snow over the Cascade and Sierra Nevada mountain ranges in the west, especially for the February and March days, as depicted by the observations. However, snow cover for Wyoming and the surrounding states is very well represented by WRF for all days shown.

Figure 4-4. Observed (Left) and Simulated (Right) Snow Cover for the Continental U.S. and the NPL 36-km Grid

January 15



February 14

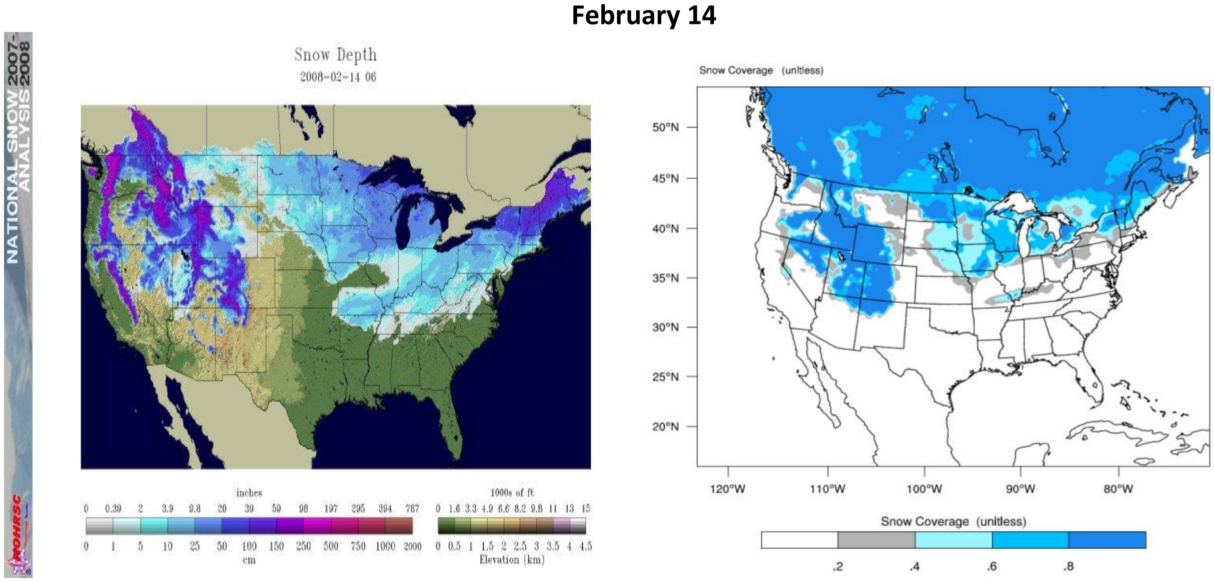
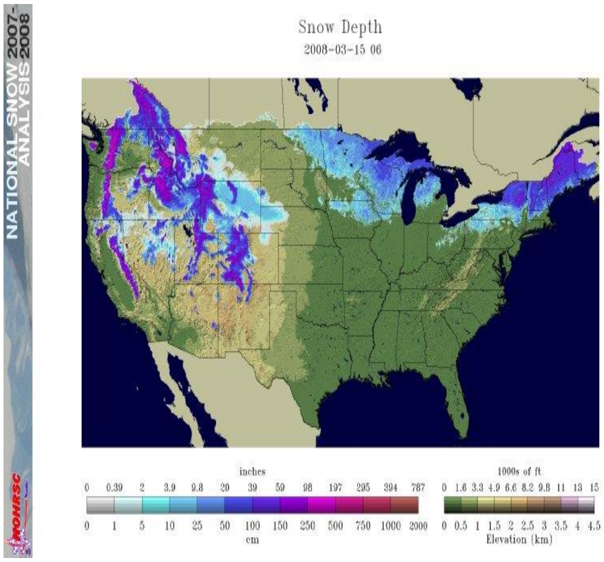
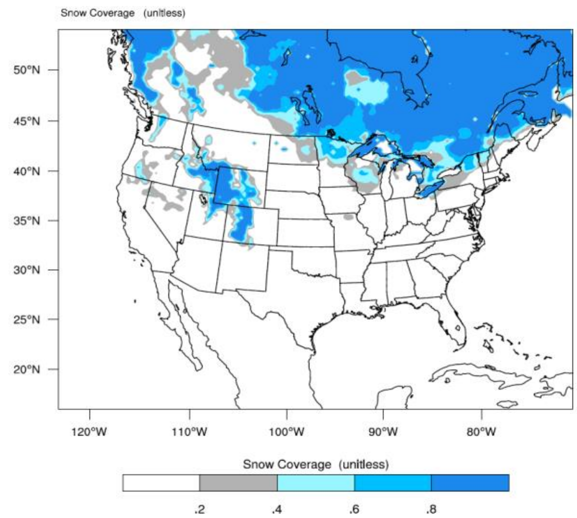


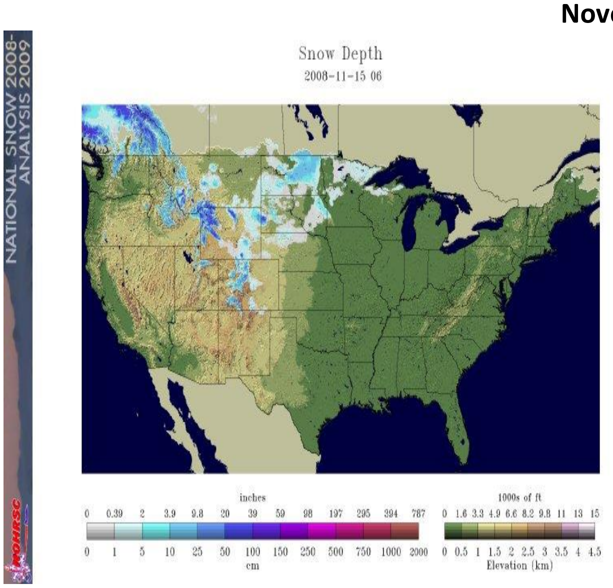
Figure 4-4. Observed (Left) and Simulated (Right) Snow Cover for the Continental U.S. and the NPL 36-km Grid (Continued)

March 15





November 15



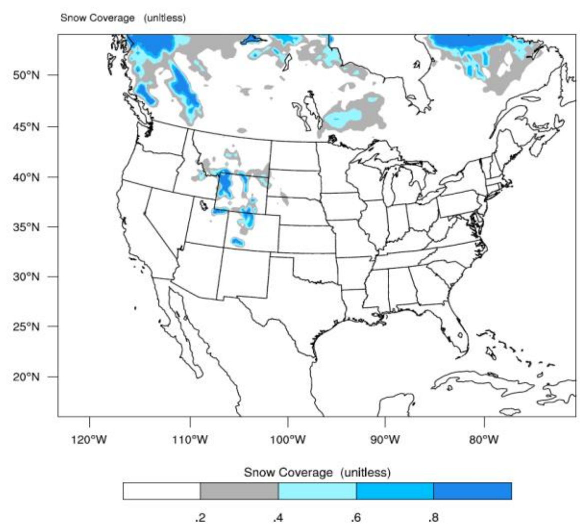
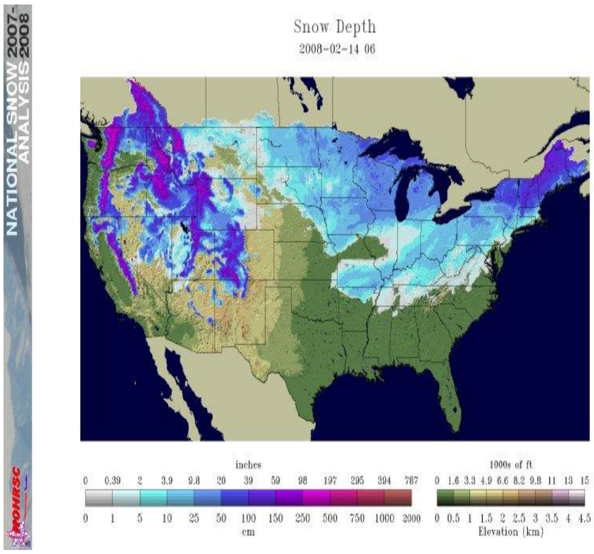
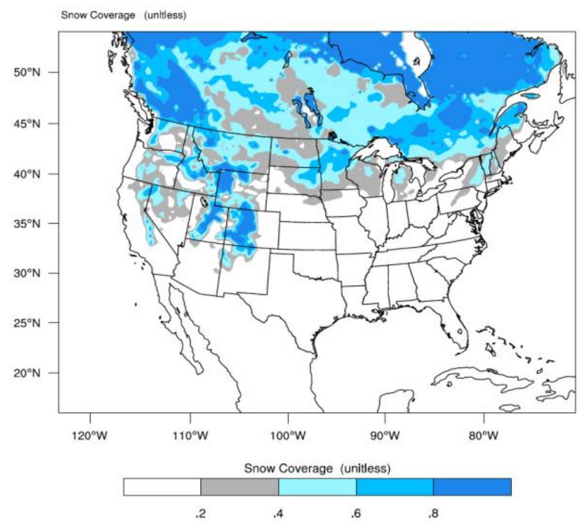


Figure 4-4. Observed (Left) and Simulated (Right) Snow Cover for the Continental U.S. and the NPL 36-km Grid (Concluded)

December 15





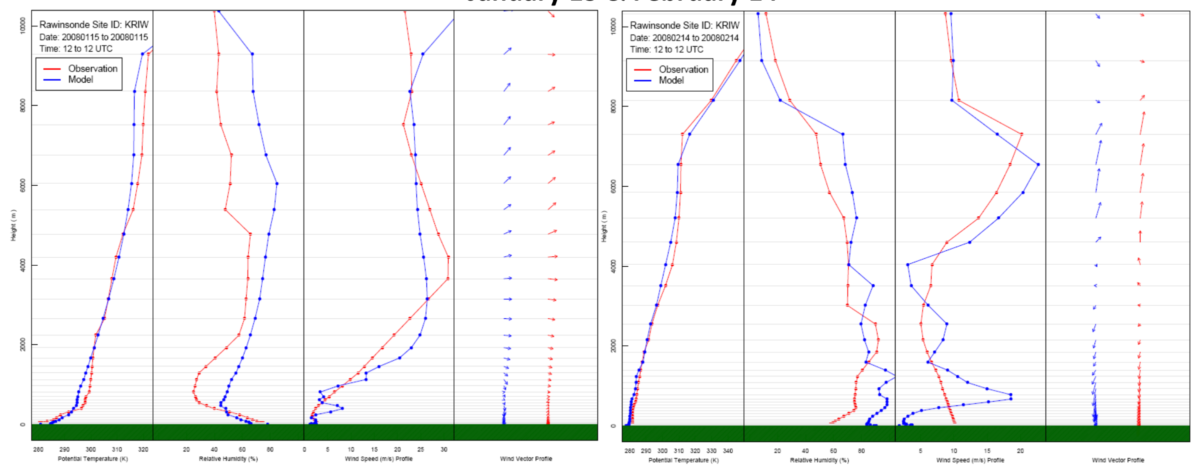
4.2 Vertical Profiles of Wind, Temperature and Moisture

For air quality modeling purposes, reasonable representation of the vertical profiles of wind, temperature, and moisture is required so that the meteorological fields are able to represent the dispersion characteristics of the modeled atmosphere and the dispersion of pollutants within the modeling domain. The vertical profiles determine the stability of the atmosphere and affect vertical mixing, vertical diffusion, horizontal and vertical transport, and deposition of pollutants. Quantitative analysis was used to examine how well the WRF modeling results for this application represent the vertical structure of the atmosphere for a key upper-air meteorological monitoring site, approximately centrally located within the 4-km grid (at Riverton, Wyoming). The WRF-derived vertical profiles were compared with observed data from the twice-daily upper-air sounding for Riverton. Although Riverton is the closest routine upper-air site to the NPL project area (with complete data for the 2008 annual simulation period), it is approximately 135 km away and separated from the area of interest by the Wind River Mountain Range. Radiosondes are released from this site at 0000 and 1200 GMT (1700 and 0500 MST) and the simulation results for both times were compared with the sounding data. As for the spatial weather patterns, the comparison was done for approximately the 15th of each month (such that each plot was of the fifth day of a 5-day simulation period). The qualitative assessment of the WRF-derived vertical profiles is summarized in the remainder of this section. The results vary by day and are generally better for summer months. All plots are presented at the end of this section.

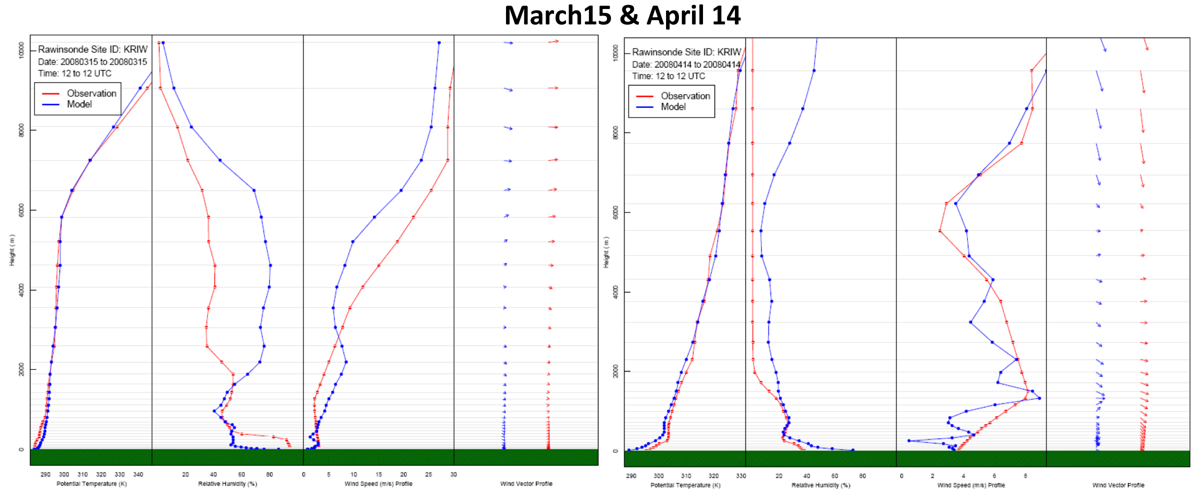
Figure 4-5 compares simulated and observed vertical profiles of potential temperature, humidity, wind speed, and wind vectors for 1200 GMT (0500 MST) for a middle day for each month for Riverton, Wyoming (WY). The observed morning temperature profiles for the selected days are well represented in the simulation results, especially above the boundary layer which (based on visual inspection of the plots) ranges from about 500 to 2000 meters above ground level (agl). During the summer months (for example, July and August), the entire vertical temperature profile is well simulated. While the simulated values of humidity and wind speed are generally reasonable, the intermittently complex vertical variations in the humidity and wind speed profiles are generally not as well represented in the WRF modeling results. For example, low-level jets (areas of high wind speed) apparent in the observed profiles (most pronounced for February 14, September 16 and November 15) are not captured by the WRF simulation. However, the wind vectors illustrate that winds aloft (above the boundary layer) are generally very well represented in the WRF simulation. The findings for 0000 GMT (1700 MST) (not shown) are similar.

Figure 4-5. Simulated and Observed Vertical Profiles of Potential Temperature, Humidity, Wind Speed, and Wind Vectors (Shown in the Order Listed) for 1200 GMT (0500 MST) for Riverton, WY. Observed Values are in Red; Simulated Values are in Blue

January 15 & February 14



March15 & April 14



May 14 & June 13

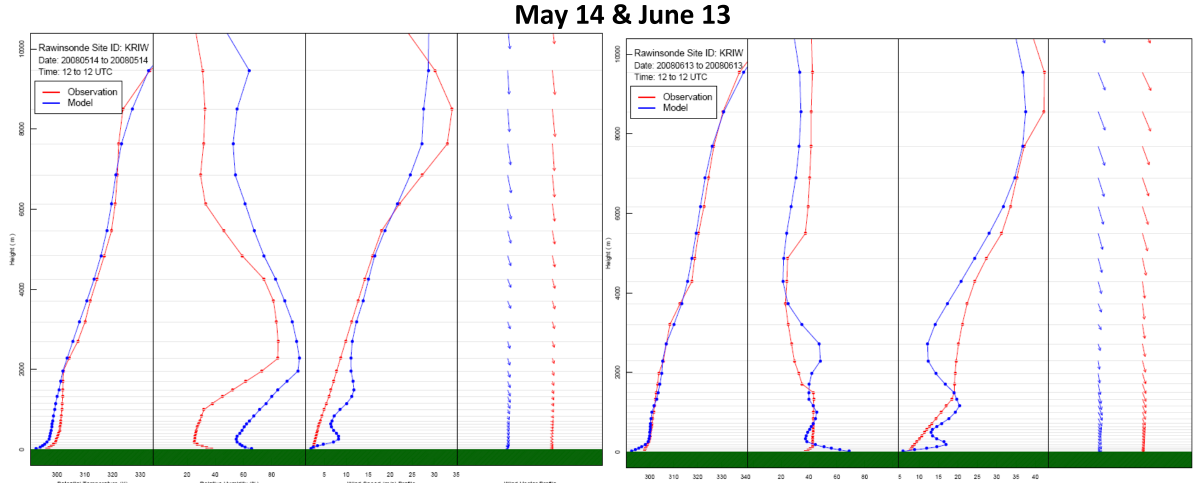
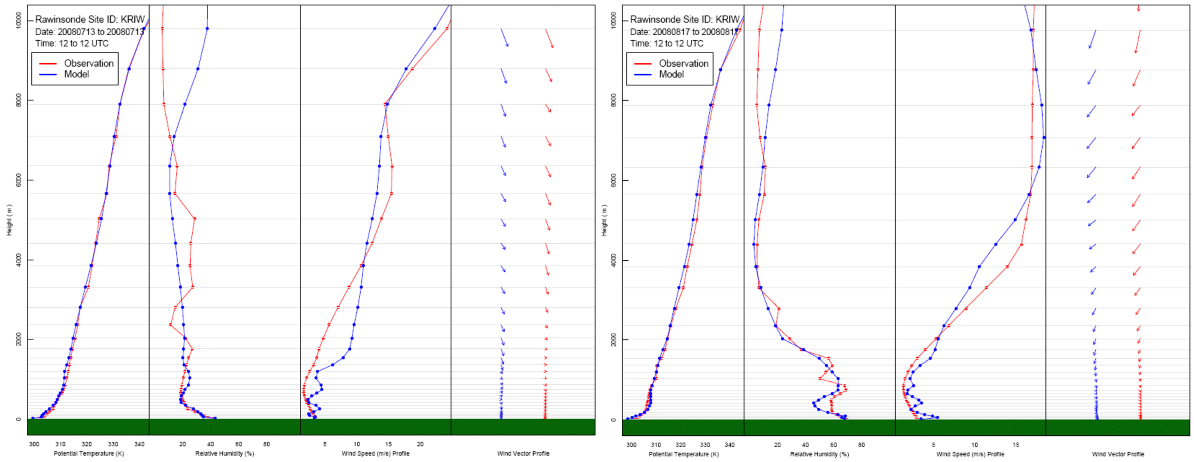
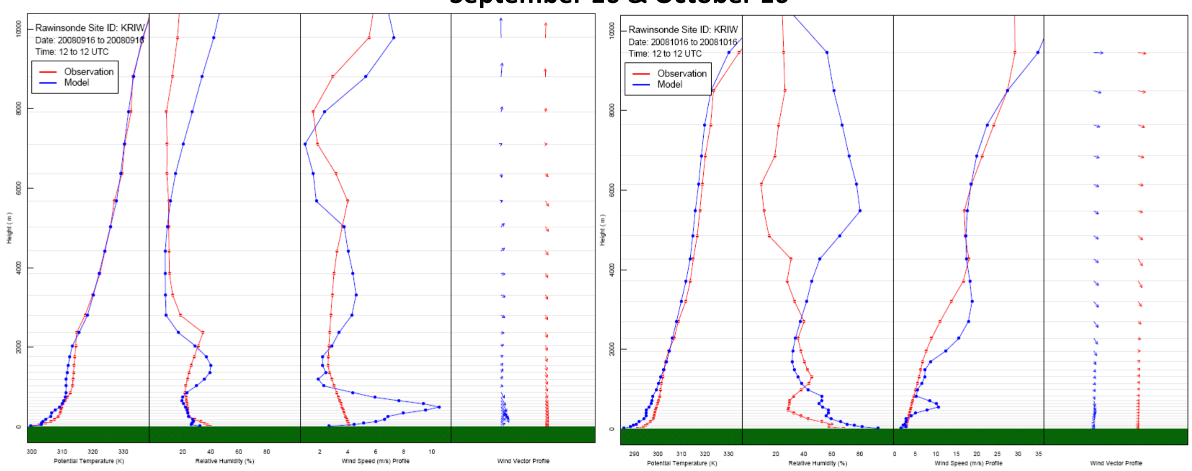


Figure 4-5. Simulated and Observed Vertical Profiles of Potential Temperature, Humidity, Wind Speed, and Wind Vectors (Shown in the Order Listed) for 1200 GMT (0500 MST) for Riverton, WY. Observed Values are in Red; Simulated Values are in Blue (Concluded)

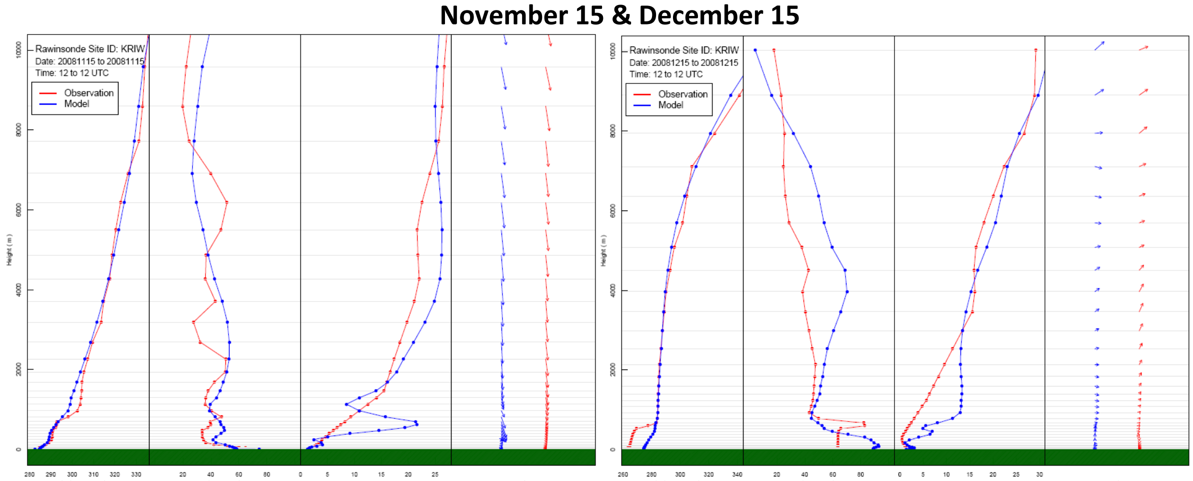
July 13 & August 12



September 16 & October 16



November 15 & December 15



4.3 Temporal Variations in Key Parameters for the High-Resolution Modeling Grid

A more detailed examination of how well the WRF modeling results for this application represent observed meteorological conditions was obtained by comparing the simulated values and temporal variations of wind speed, wind direction, temperature and water vapor mixing ratio with observed data for surface monitoring sites located within the high-resolution (4-km) grid. For an overall comparison, average simulated values (averaged over all sites in the 4-km grid) were compared with average observed values for each hour and each simulation day. The data (NCAR ds472.0) correspond to the monitoring sites shown in Figure 2-2. The grid-average time series plots are presented in the remainder of this section. For ease of reading, all plots are presented at the end of this section.

Figure 4-6 compares hourly average values of simulated and observed wind speed for each hour and day of the annual simulation. Each time-series plot displays the values for one month. The averages (both observed and simulated) are for all site locations in the 4-km modeling grid. The plots illustrate that, for all months, average surface wind speeds and the day-to-day variations in wind speed are very well represented by the WRF model. Overall, the model tends to underestimate wind speeds. The underestimation occurs for a range of observed wind speeds (and is not limited to high or low wind speed conditions).

Figure 4-7 compares hourly average values of simulated and observed wind direction for each hour and day of the annual simulation. Again each time-series plot displays the values for one month and the averages (both observed and simulated) are for all site locations in the 4-km modeling grid. Note that the wind direction plots can sometimes indicate large differences that are not indicative of poor model performance (this can occur when the simulated and observed values are close to 360 degrees but one has a more westerly component and the other a more easterly component (for example 355 and 5 degrees are only 10 degrees apart but would show up as a large difference on the plots)). The largest differences between the simulated and observed wind directions occur during periods of light and variable winds (for example, during portions of July and August). Overall, however, surface wind directions and especially the changes in wind direction over time are very well represented by the WRF model. The use of “obs” nudging for the surface winds in the 4-km grid likely contributes to the good representation of surface wind speed and directions. Note that the same observations used for the model performance evaluation are also used for the nudging.

Figure 4-8 compares hourly average values of simulated and observed temperature for each hour and day of the annual simulation, for the 4-km modeling grid. The diurnal, day-to-day, multi-day, monthly, and seasonal variations in temperature are well represented by the WRF model. Performance is better for the non-winter months, and among the non-winter months, better for the warmer months (May through September). For all months there is a tendency for the model to underestimate the maximum observed temperatures and overestimate the minimum observed temperatures. This is only very slightly noticeable for the summer months and more pronounced for the transitional seasons (autumn/spring) and winter months. There are some cases for which the diurnal and day-to-day variations are represented, but the temperature values are either too high (for example in mid- to late January and mid-December) or too low (for example in mid-February and April).

Figure 4-9 compares hourly average values of simulated and observed mixing ratio for each hour and day of the annual simulation, for the 4-km modeling grid. The time-series plots for water vapor mixing ratio indicate less skill in simulating this parameter, compared to wind speed, wind direction, and temperature. For most months, moisture is overestimated. The model has some difficulty simulating the diurnal and day-to-day variations in moisture, especially during the summer months. However, longer term (multi-day and monthly) variations are captured by the model.

Figure 4-6. Average Observed (Obs) and Simulated (WRF) Surface Wind Speed (m/s) for the NPL 4-km Grid

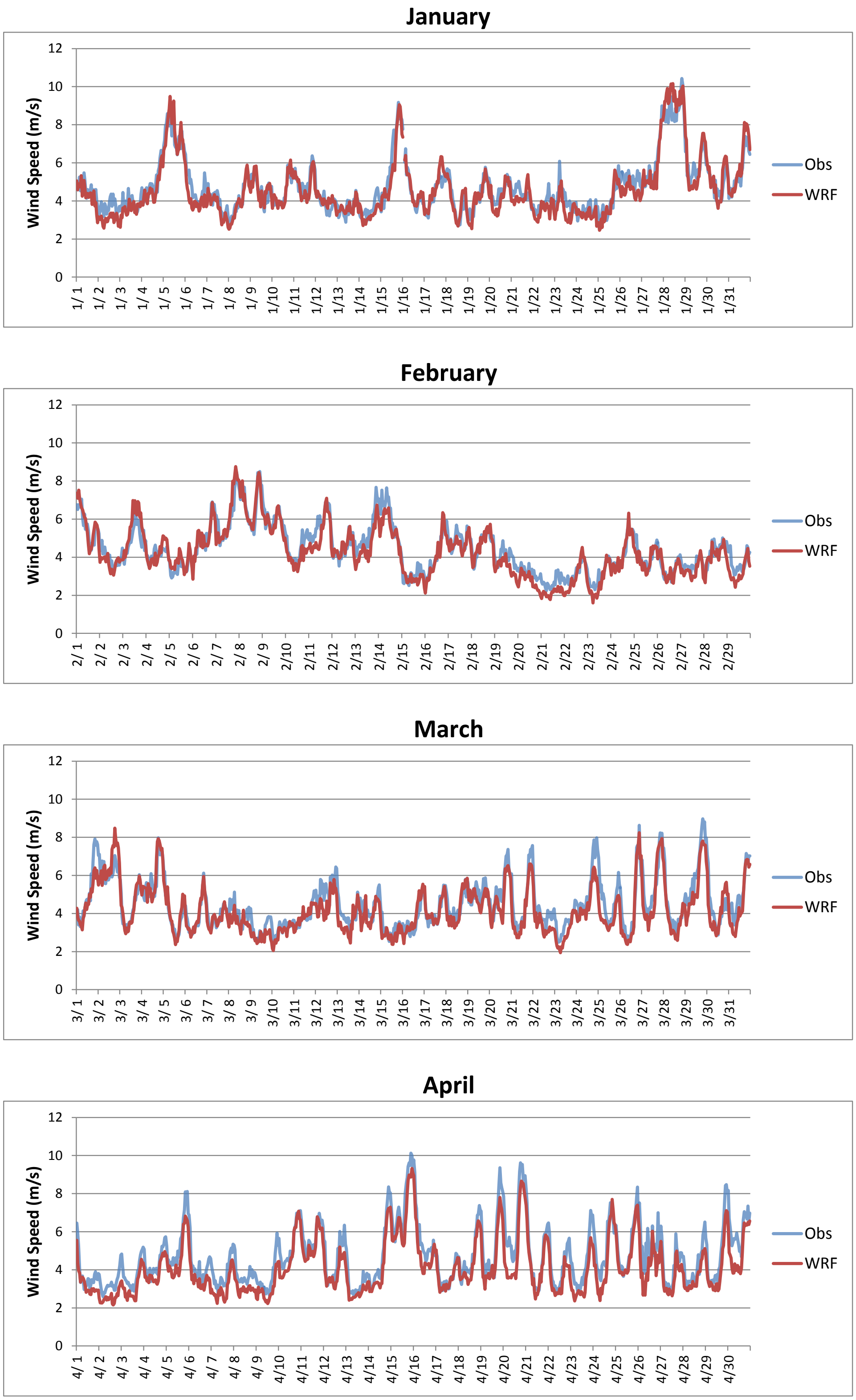


Figure 4-6. Average Observed (Obs) and Simulated (WRF) Surface Wind Speed (m/s) for the NPL 4-km Grid (Continued)

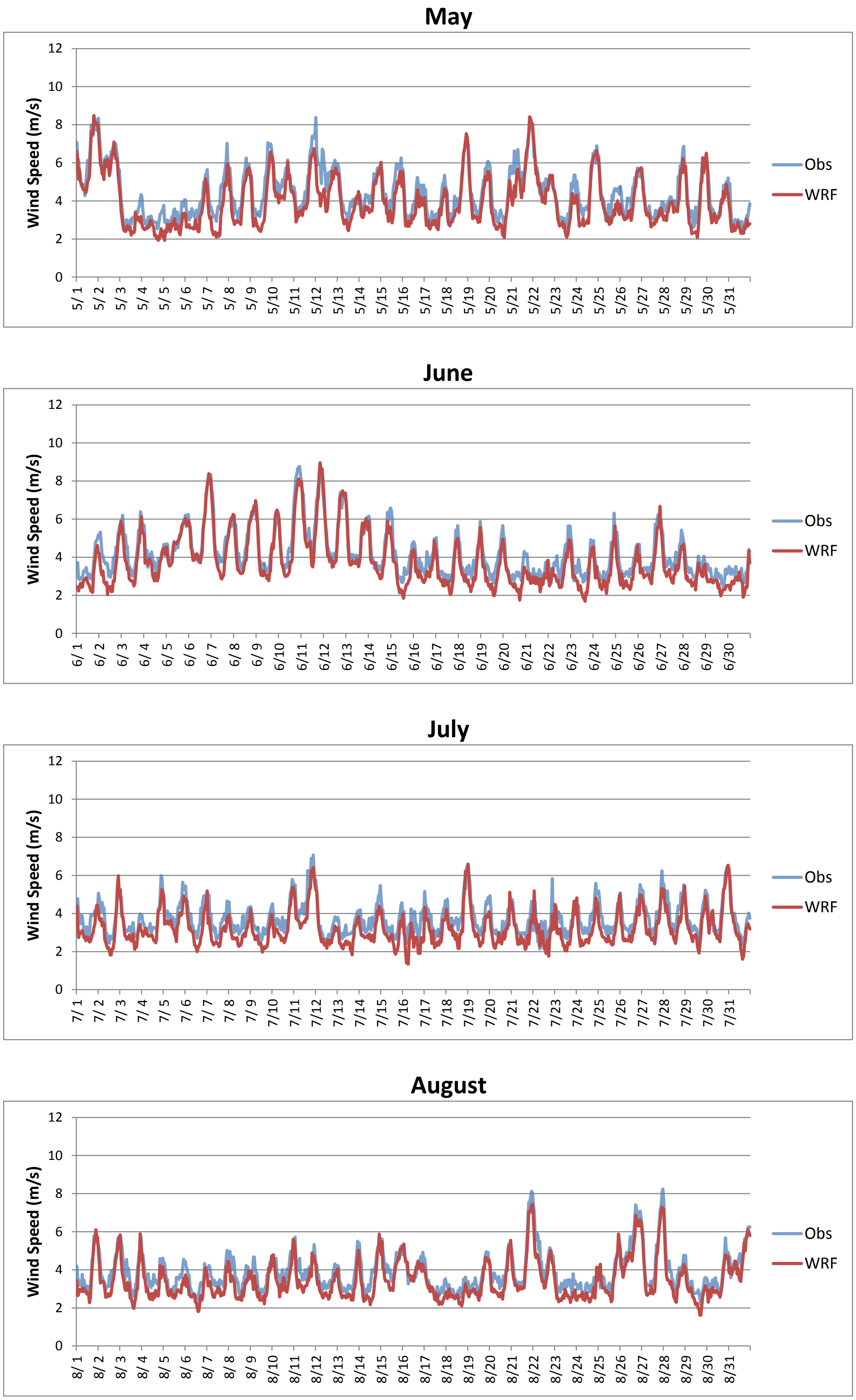
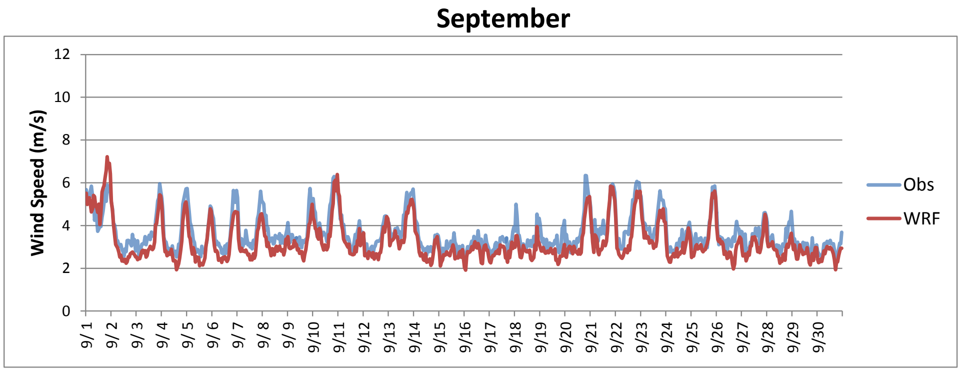
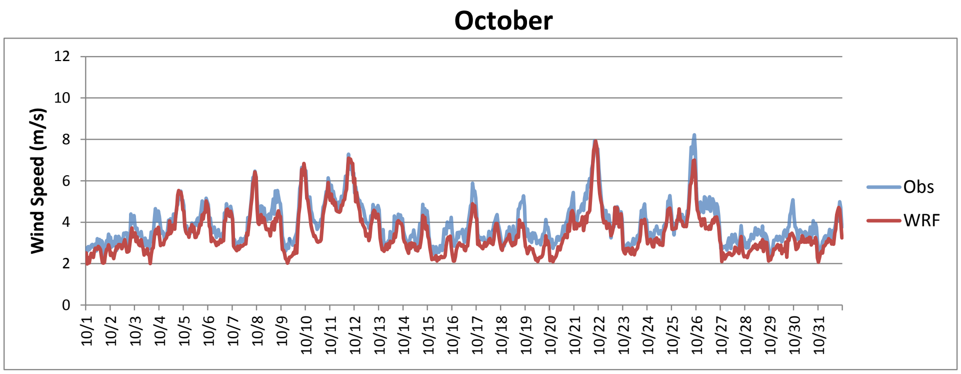
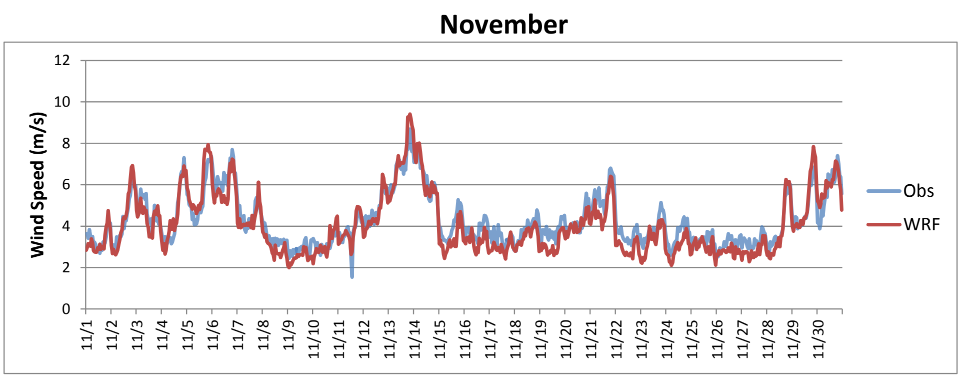


Figure 4-6. Average Observed (Obs) and Simulated (WRF) Surface Wind Speed (m/s) for the NPL 4-km Grid (Concluded)







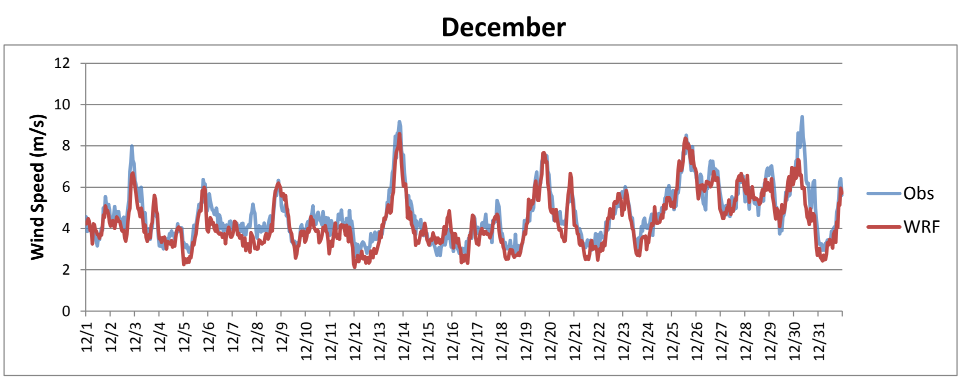


Figure 4-7. Average Observed (Obs) and Simulated (WRF) Surface Wind Direction (degrees) for the NPL 4-km Grid

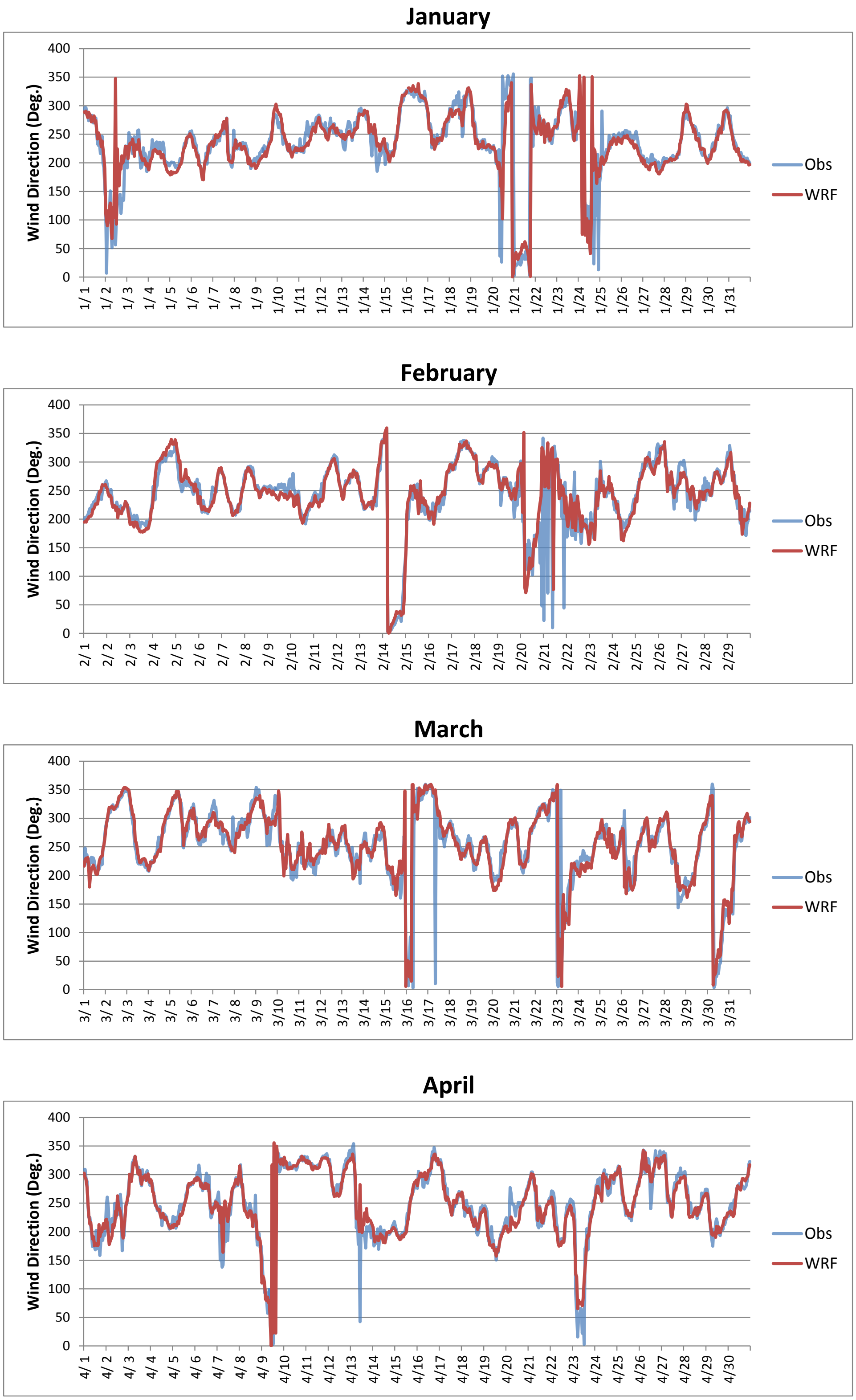
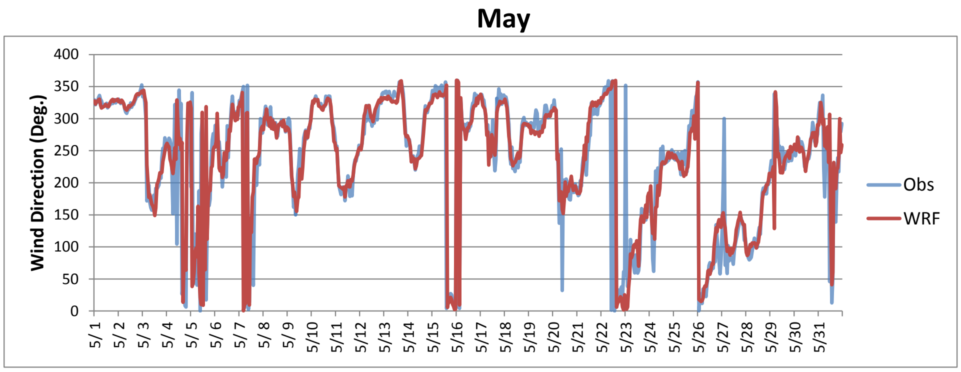
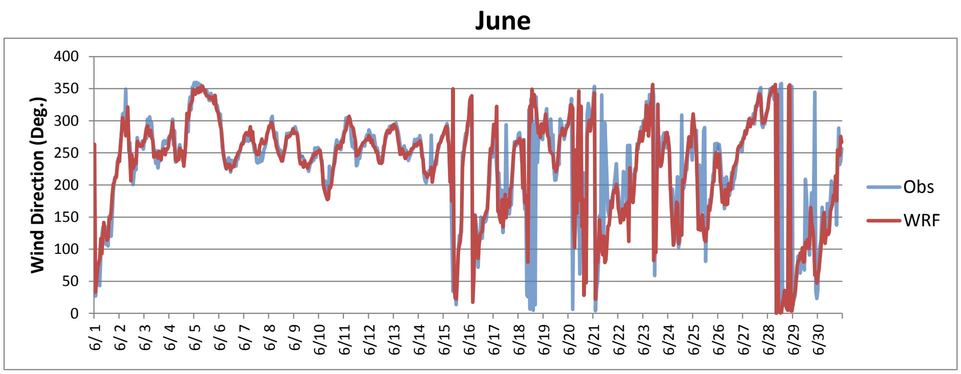
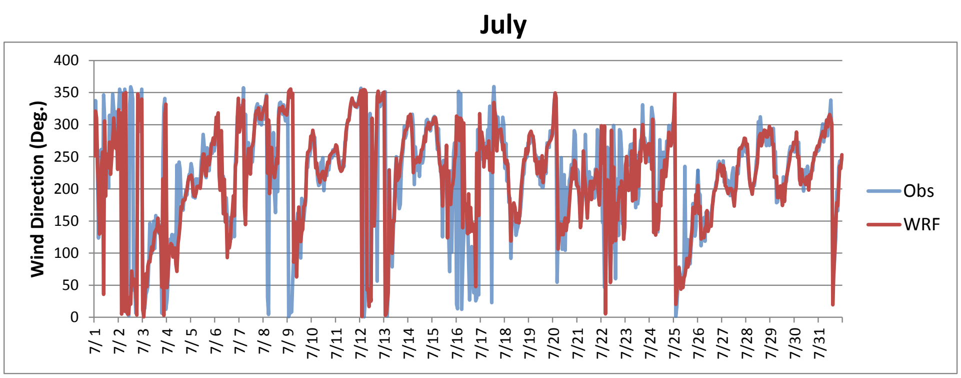


Figure 4-7. Average Observed (Obs) and Simulated (WRF) Surface Wind Direction (degrees) for the NPL 4-km Grid (Continued)







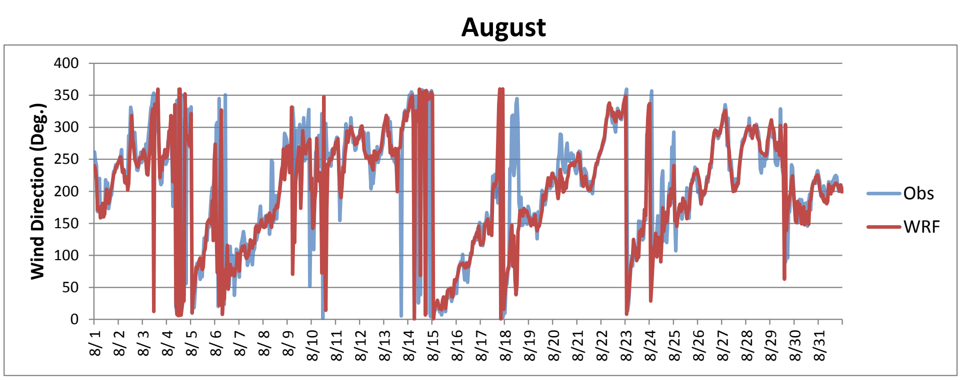


Figure 4-7. Average Observed (Obs) and Simulated (WRF) Surface Wind Direction (degrees) for the NPL 4-km Grid (Concluded)

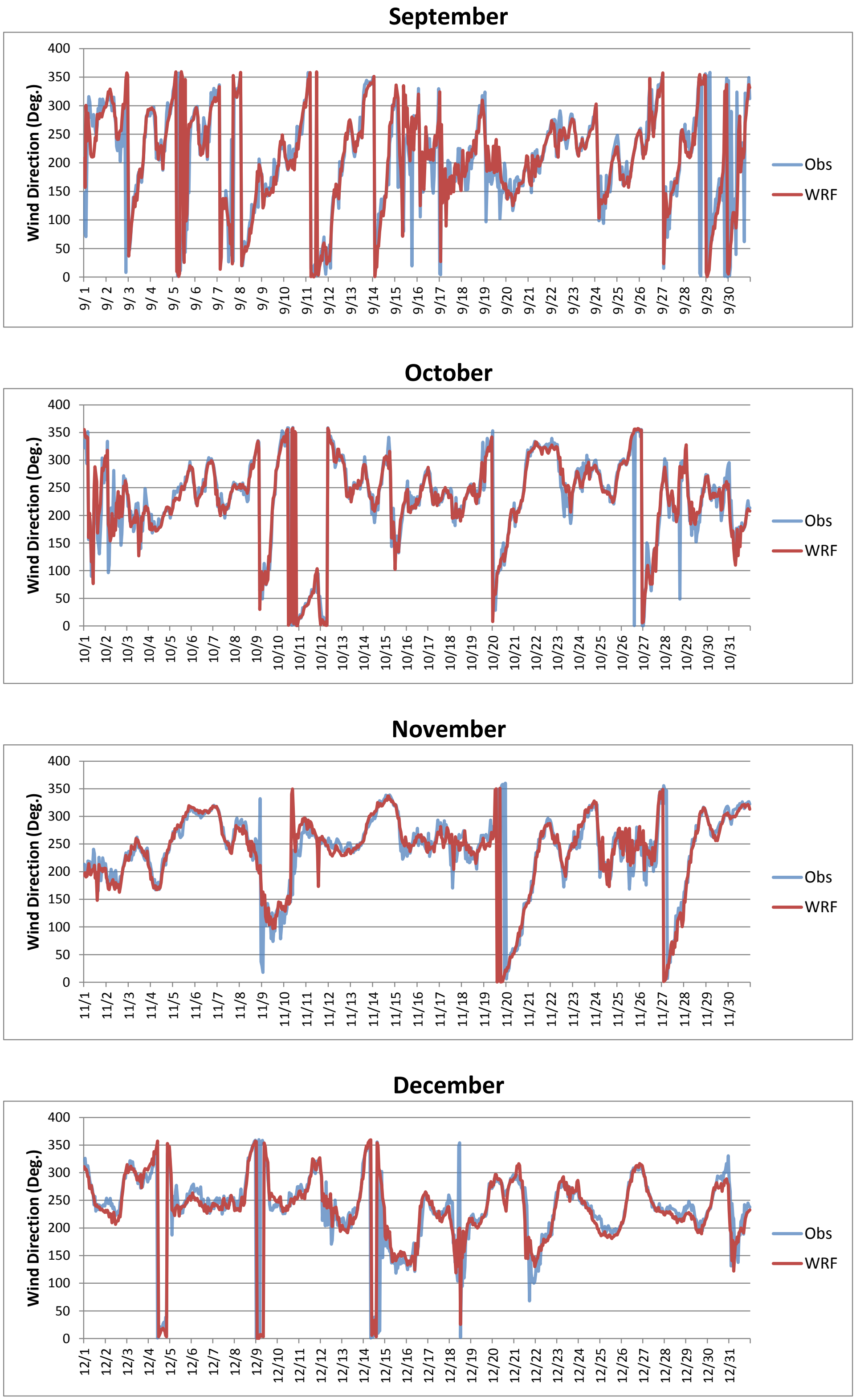


Figure 4-8. Average Observed (Obs) and Simulated (WRF) Surface Temperature (K) for the NPL 4-km Grid

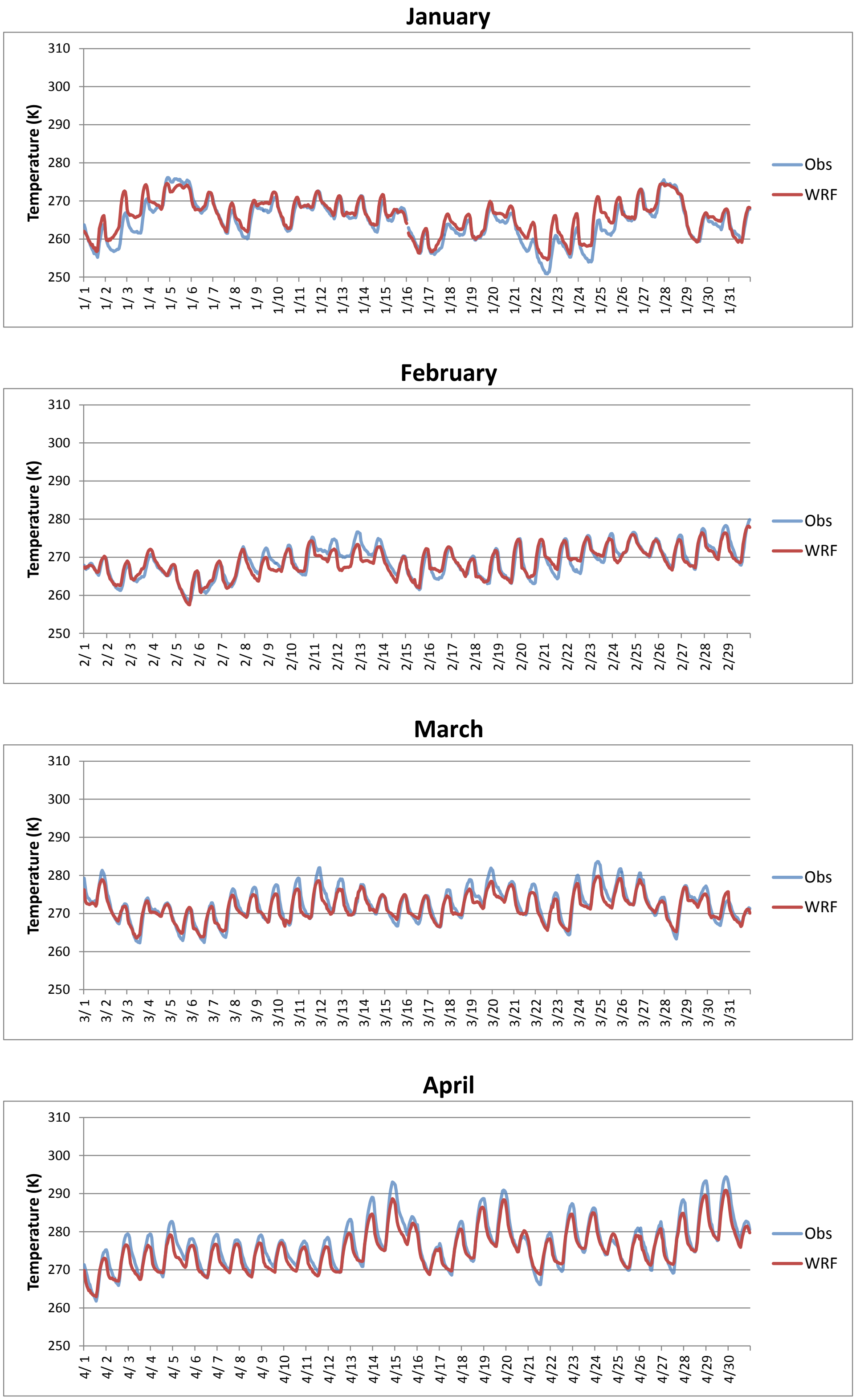
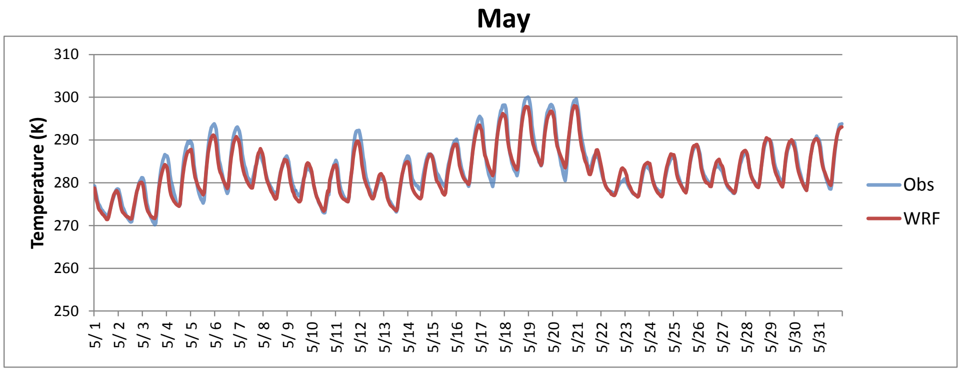
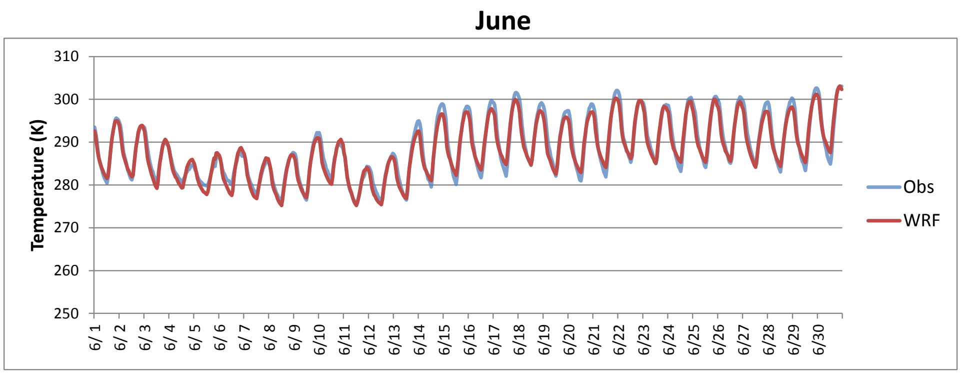
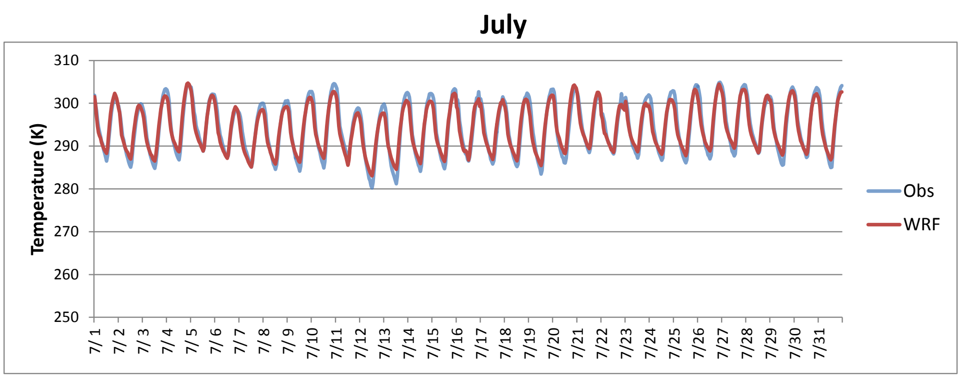


Figure 4-8. Average Observed (Obs) and Simulated (WRF) Surface Temperature (K) for the NPL 4-km Grid (Continued)







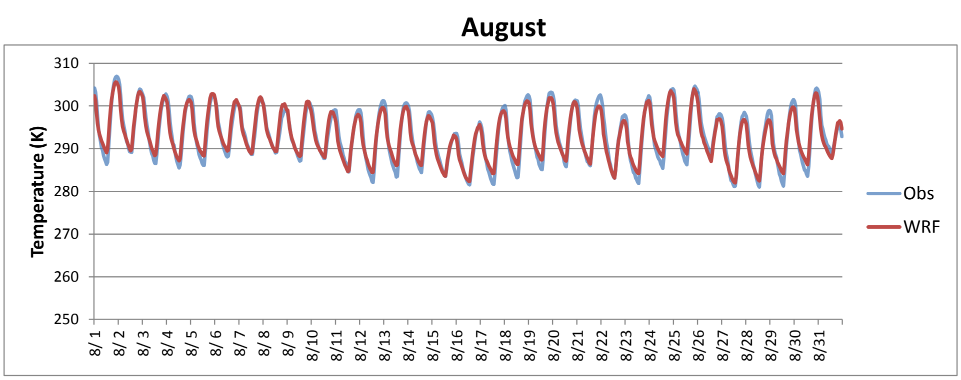
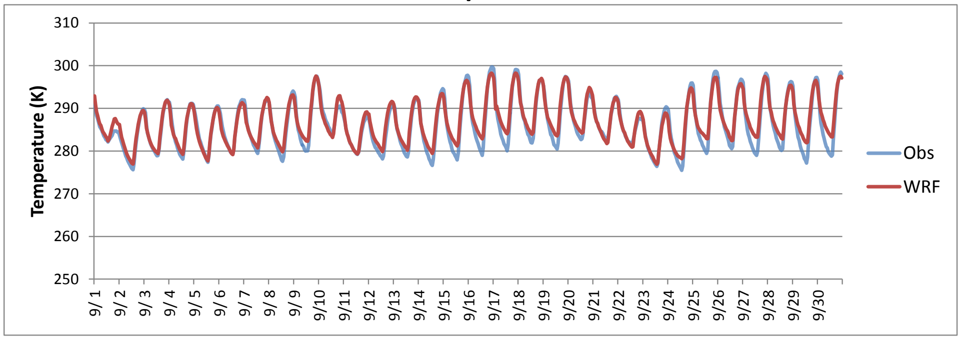
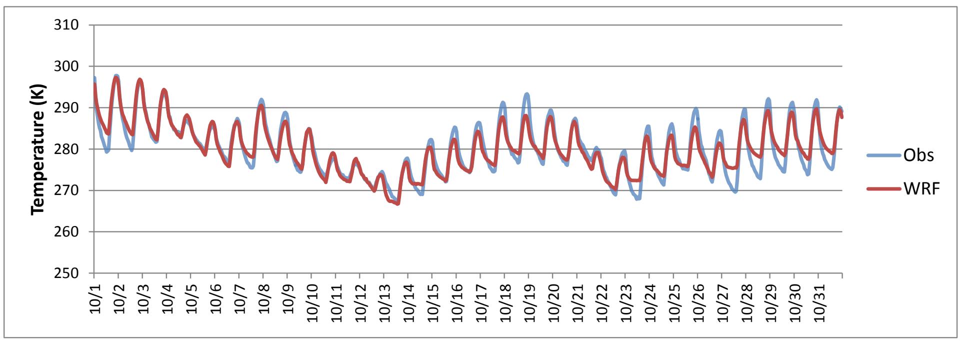


Figure 4-8. Average Observed (Obs) and Simulated (WRF) Surface Temperature (K) for the NPL 4-km Grid (Concluded)

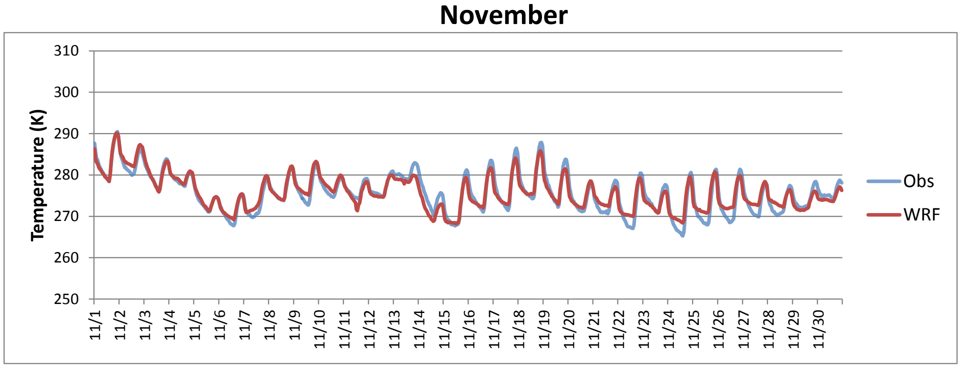
September



October



November



December

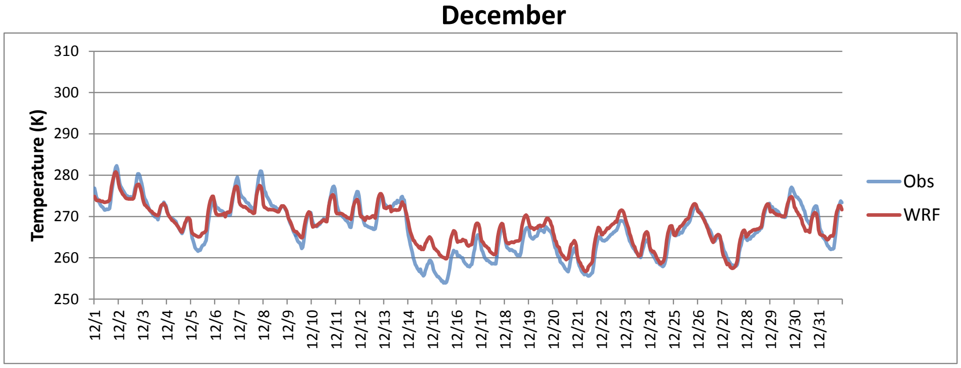


Figure 4-9. Average Observed (Obs) and Simulated (WRF) Surface Water Vapor Mixing Ratio (g/kg) for the NPL 4-km Grid

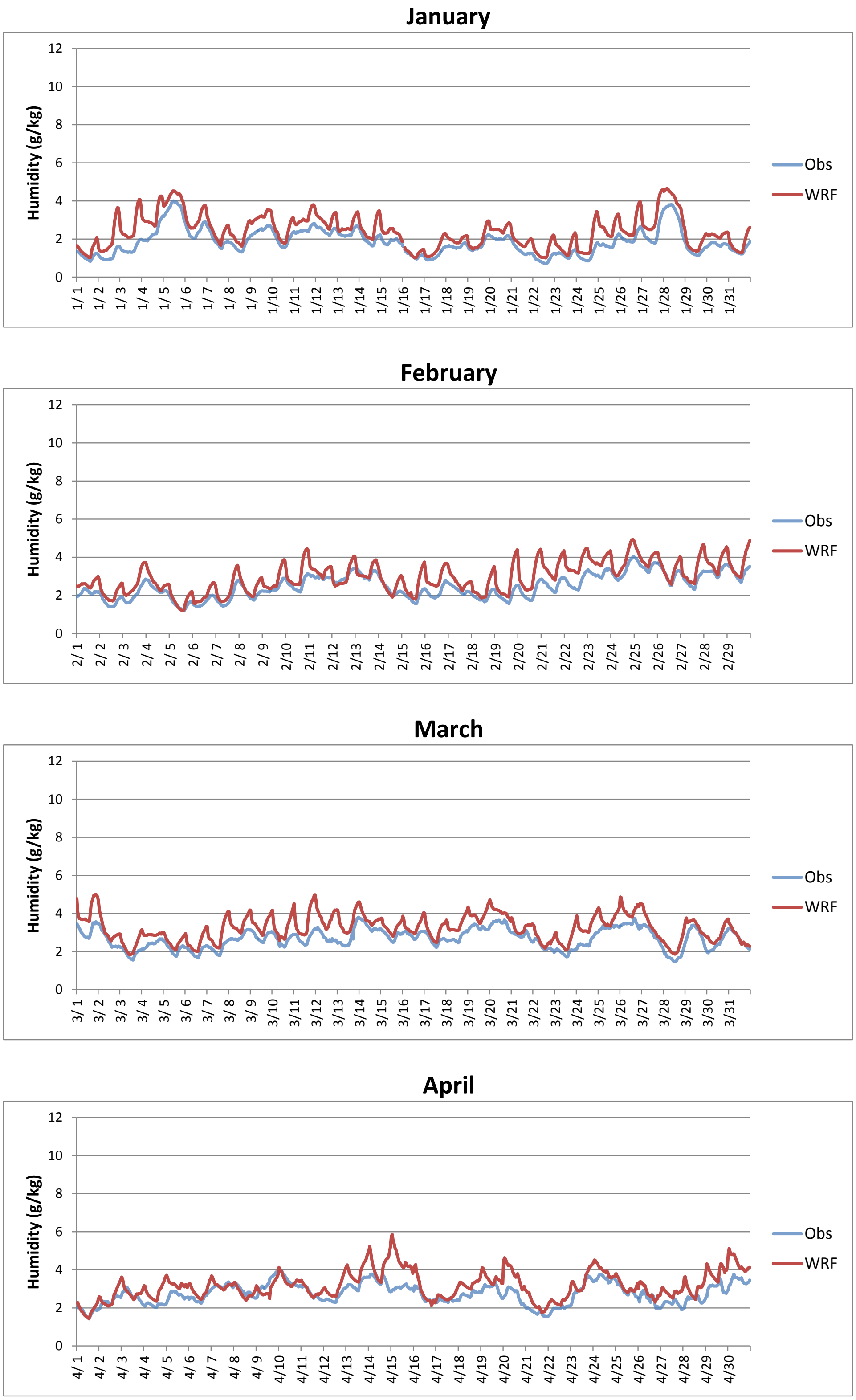
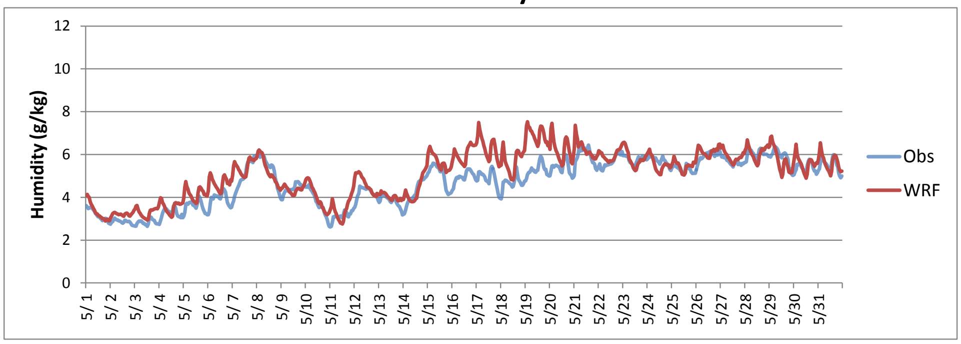
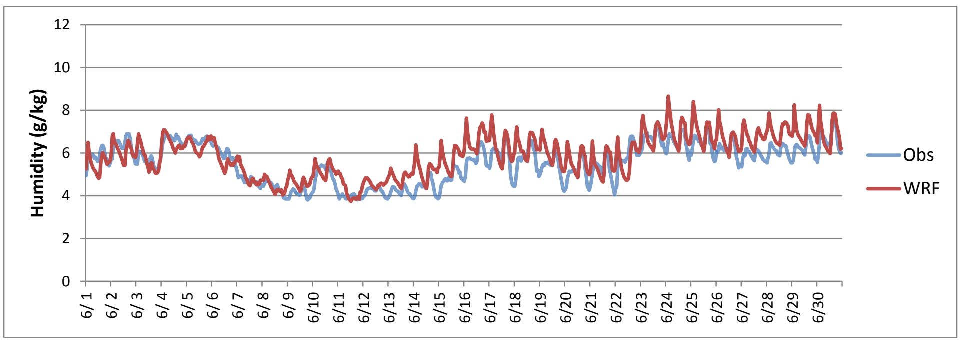


Figure 4-9. Average Observed (Obs) and Simulated (WRF) Surface Water Vapor Mixing Ratio (g/kg) for the NPL 4-km Grid (Continued)

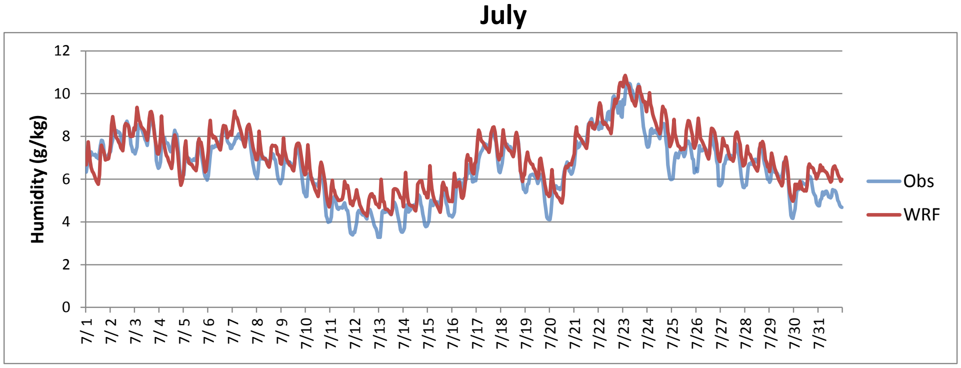
May



June



July



August

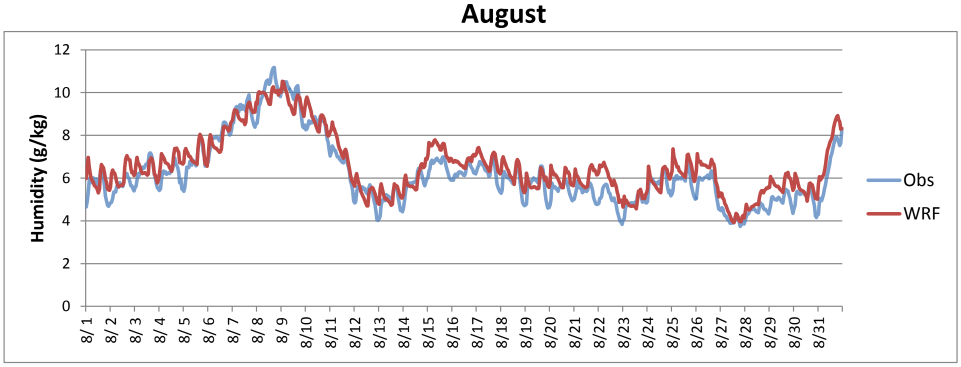
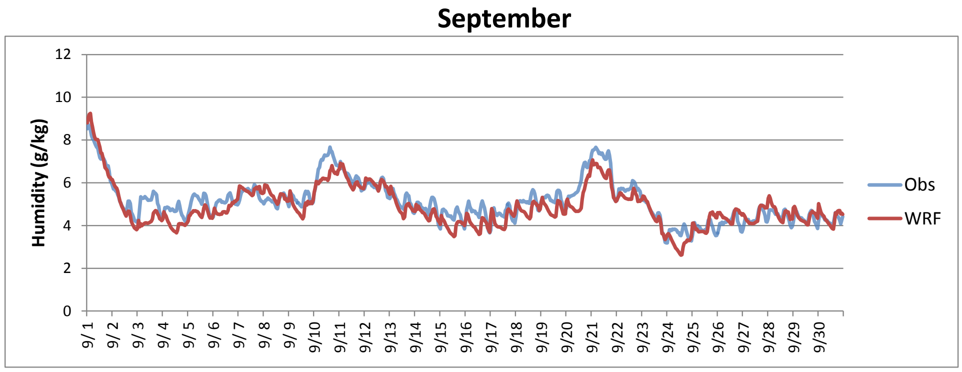
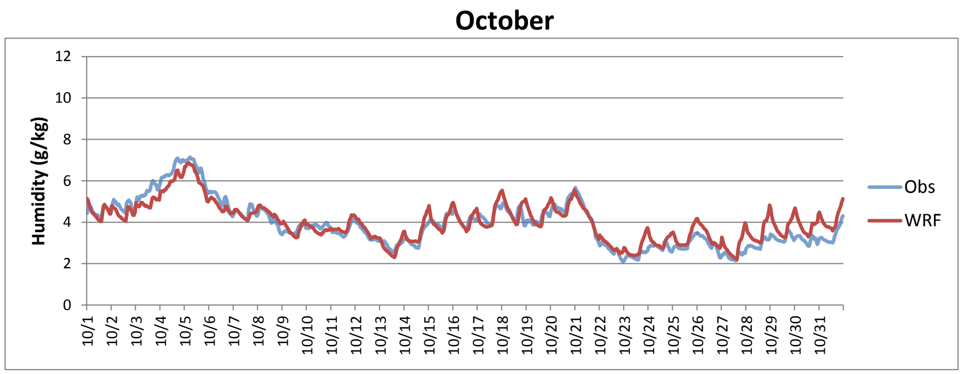
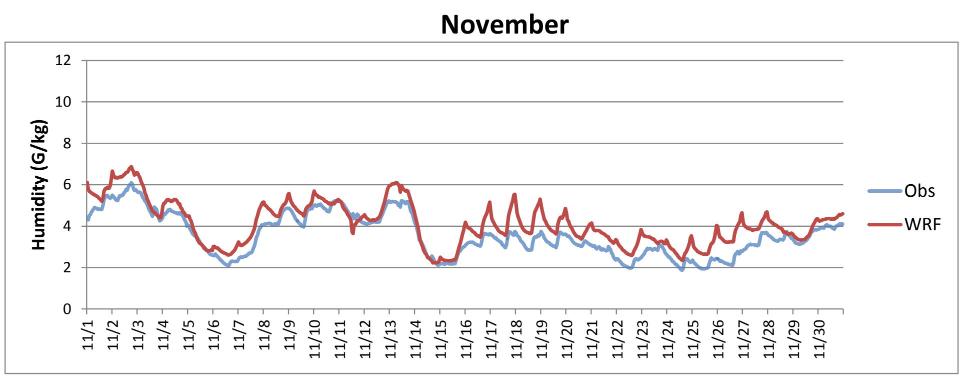
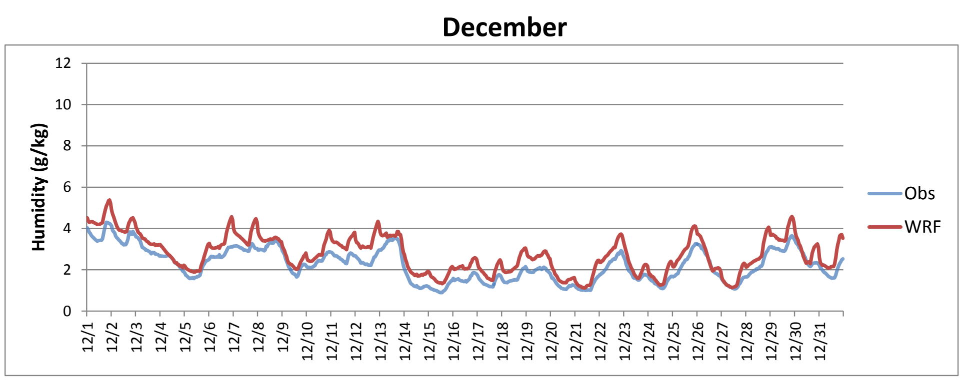


Figure 4-9. Average Observed (Obs) and Simulated (WRF) Surface Water Vapor Mixing Ratio (g/kg) for the NPL 4-km Grid (Concluded)









4.4 Temporal Variations in Key Parameters for Specific Monitoring Sites

WRF model performance was also examined for selected sites in the vicinity of the NPL project area. Three sites were selected for this comparison based on proximity to the NPL project area and terrain and these are Big Piney (KBPI), Pinedale (KPNA), and Rock Springs (KRKS). Big Piney is located approximately 30 km northwest of the center of the project area, Pinedale is approximately 50 km northeast of the project area, and Rock Springs is approximately 105 km to the southeast. All are ASOS monitoring sites with complete data records for the 2008 simulation period. All three sites are also located within the Upper Green River Basin and meteorological conditions at these sites are expected to be coupled with (or at certain times similar to) the conditions affecting the project area. Simulated values of wind speed, wind direction, temperature, and mixing ratio were compared with observed values for these sites for each simulation day. The site-specific time series plots are presented in the remainder of this section. Plots for January, April, July, and October are presented to illustrate the comparison, and the overall findings are similar to those for the other months (not shown). Note that, in some cases, the vertical axis scales differ by month and/or by site to accommodate the range in site-specific data for each month. Also note that hours with missing observed data are left blank, and that there are quite a number of missing data for January (as well as other winter months ([not shown]). For ease of reading, the plots are presented at the end of this subsection.

Figure 4-10 compares simulated and observed wind speed for each hour and day for January, April, July, and October for the KBPI monitoring site. Each time-series plot displays the values for one month. Figure 4-11 compares simulated and observed wind direction for the KBPI monitoring site. Figure 4-12 compares simulated and observed temperature for the KBPI monitoring site. Figure 4-13 compares simulated and observed mixing ratio for the KBPI monitoring site.

Figures 4-14 through 4-17 provide the same series of plots for the KPNA monitoring site.

Figures 4-18 through 4-21 provide the same series of plots for the KRKS monitoring site.

For the three monitoring sites, the diurnal and day-to-day variations in wind speed are clearly represented in the modeling results, but under conditions of high wind speeds the peak simulated wind speeds are frequently much lower than observed.

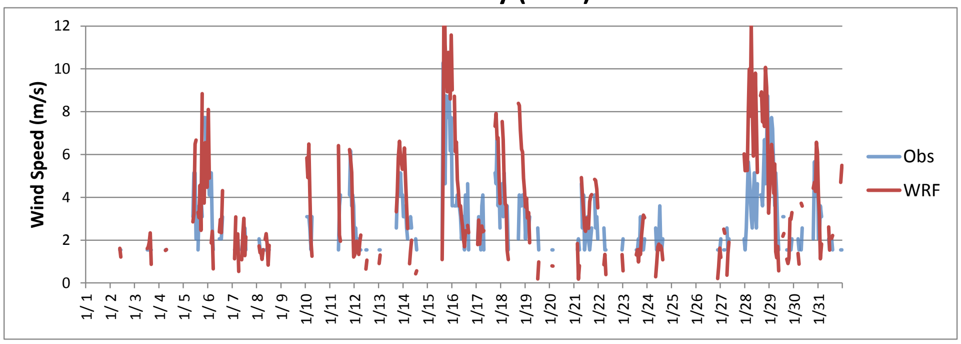
Although the plots are a bit difficult to assess due to a predominance of northerly wind components and considerable diurnal variation in wind direction, surface wind directions are well represented at all three sites, and especially for KPNA and KRKS. Much of the apparent error occurs when the simulated and observed values are close to 360 degrees and, as noted in the previous section, this can show up as a large difference when the simulated and observed wind directions are on different sides of 360 degrees, even if they are not too far apart. To supplement this analysis, site-specific wind directions are further examined in Section 4.1.5.

At the site level, model performance for surface temperature is mixed. For all three sites, temperatures are very well represented for July and well represented for January. For the transitional months, April and October, WRF tends to underestimate the maximum temperatures and overestimate the minimum temperatures. For portions of these two months, maximum temperatures are significantly underestimated for KBPI and KPNA. This tendency for the simulated diurnal profiles to be flatter than observed, especially for the transitional months, is also apparent in the grid-based average plots presented in the previous section.

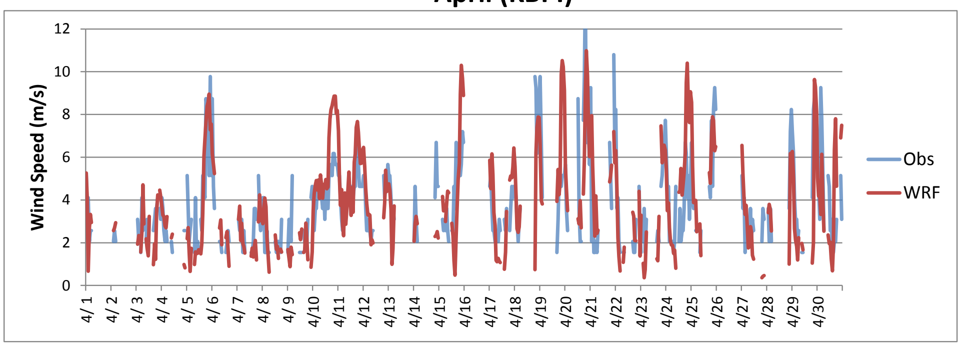
For all three sites, water vapor concentration is reasonably well represented in the WRF simulation. Of interest is the large increase in humidity that occurs around July 22nd. It is observed at all three sites and nicely captured by the model.

Figure 4-10. Average Observed (Obs) and Simulated (WRF) Surface Wind Speed (m/s) for the Big Piney Meteorological Monitoring Site (KBPI)

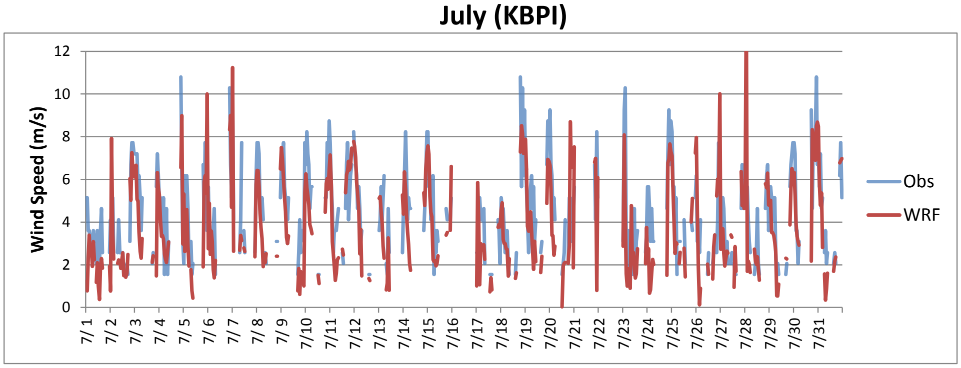
January (KBPI)



April (KBPI)



July (KBPI)



October (KBPI)

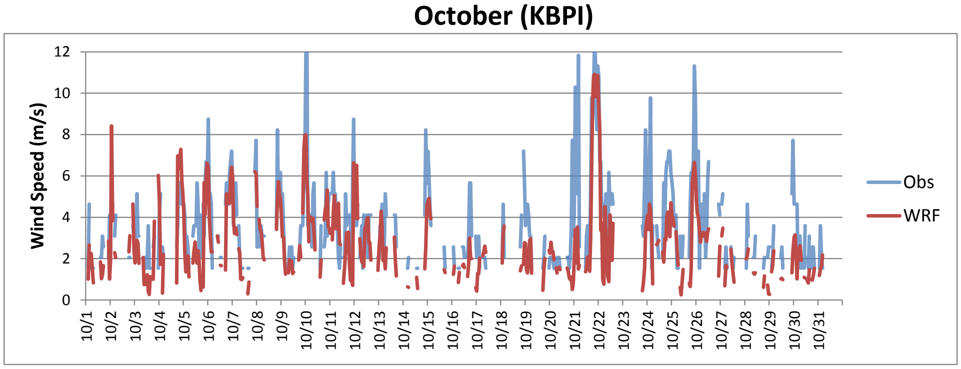


Figure 4-11. Average Observed (Obs) and Simulated (WRF) Surface Wind Direction (degrees) for the Big Piney Meteorological Monitoring Site (KBPI)

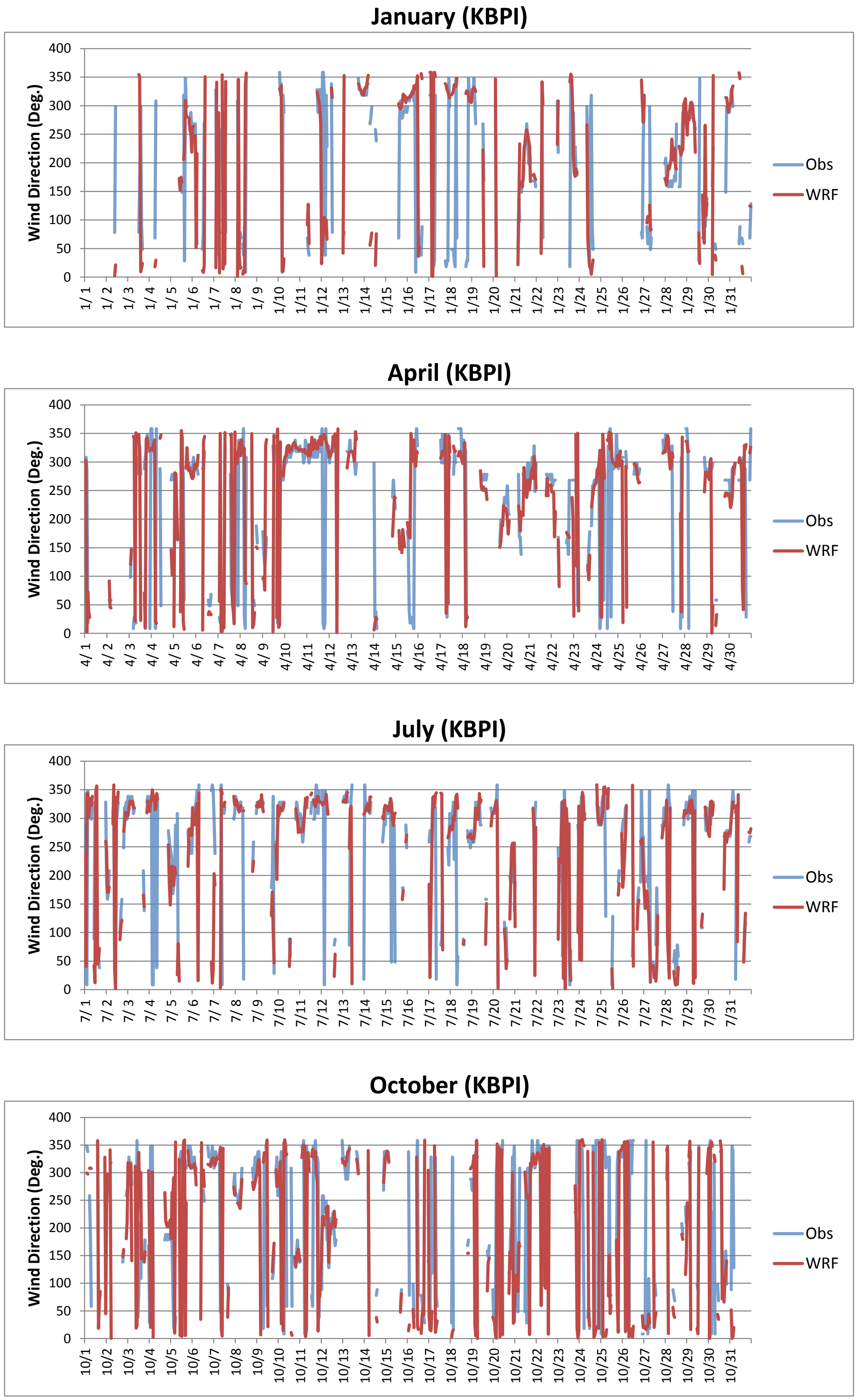
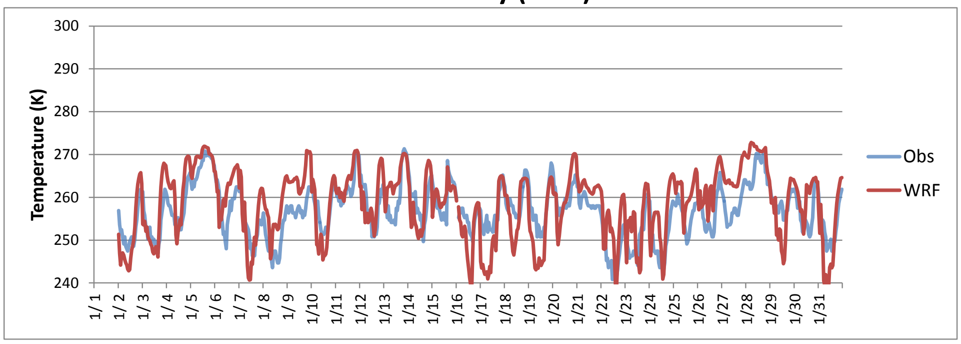
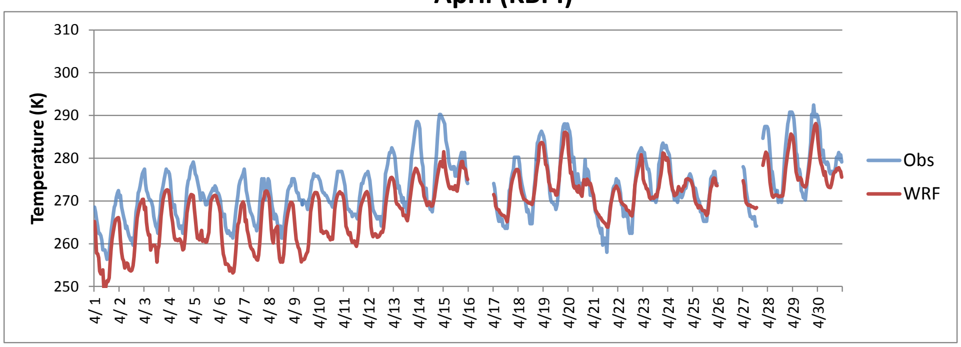


Figure 4-12. Average Observed (Obs) and Simulated (WRF) Surface Temperature (K) for the Big Piney Meteorological Monitoring Site (KBPI)

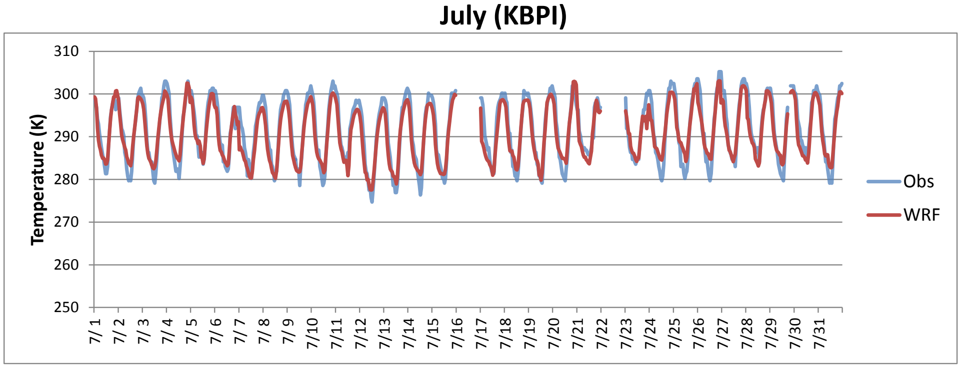
January (KBPI)



April (KBPI)



July (KBPI)



October (KBPI)

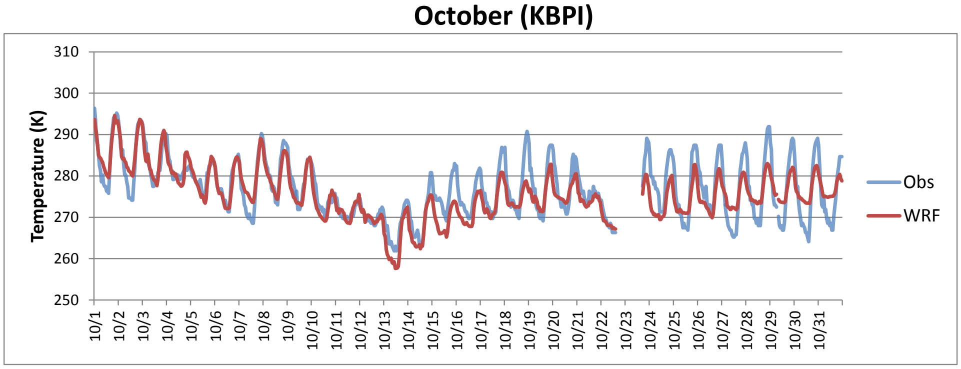


Figure 4-13. Average Observed (Obs) and Simulated (WRF) Surface Water Vapor Mixing Ratio (g/kg) for the Big Piney Meteorological Monitoring Site (KBPI)

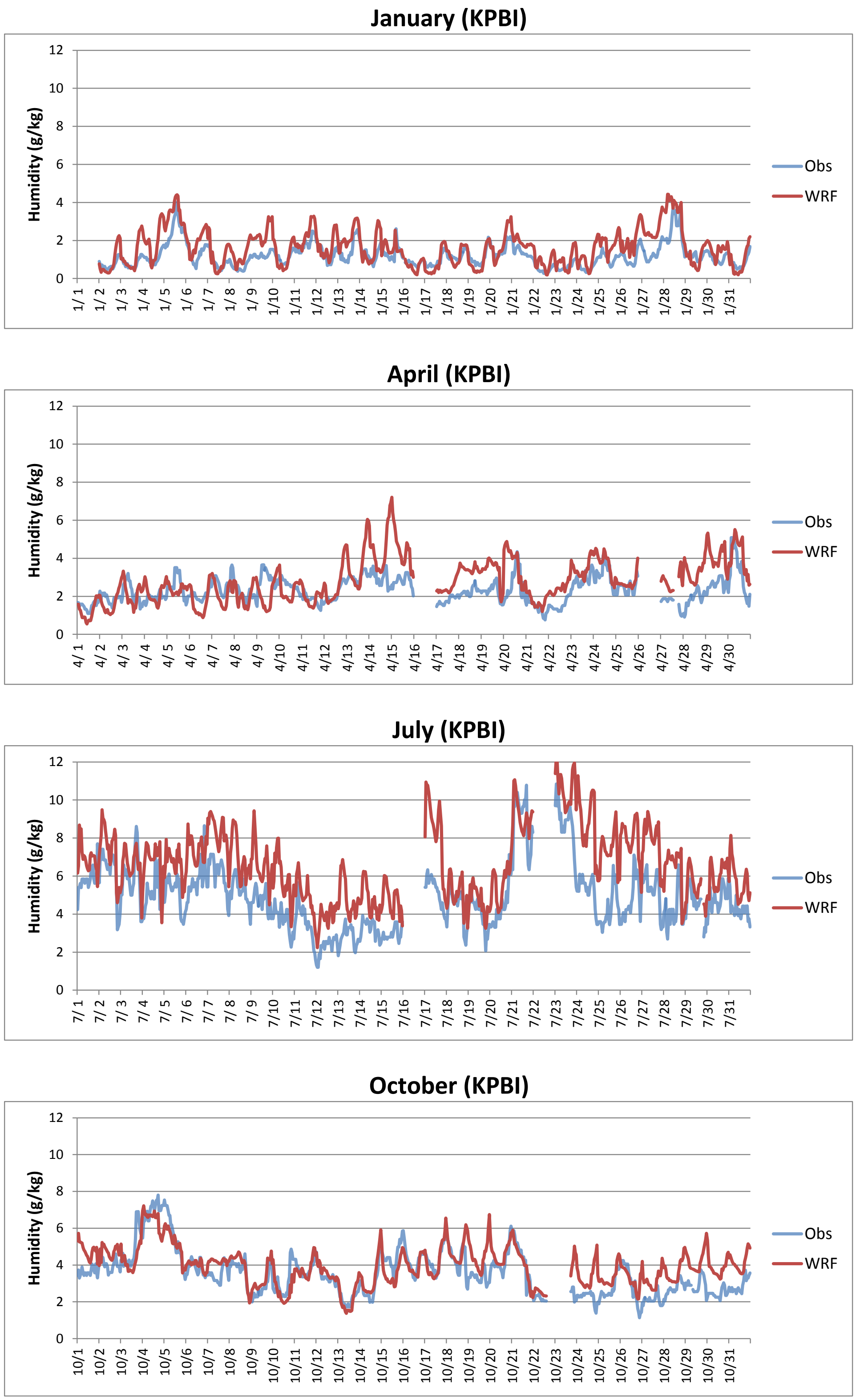


Figure 4-14. Average Observed (Obs) and Simulated (WRF) Surface Wind Speed (m/s) for the Pinedale Meteorological Monitoring Site (KPNA)

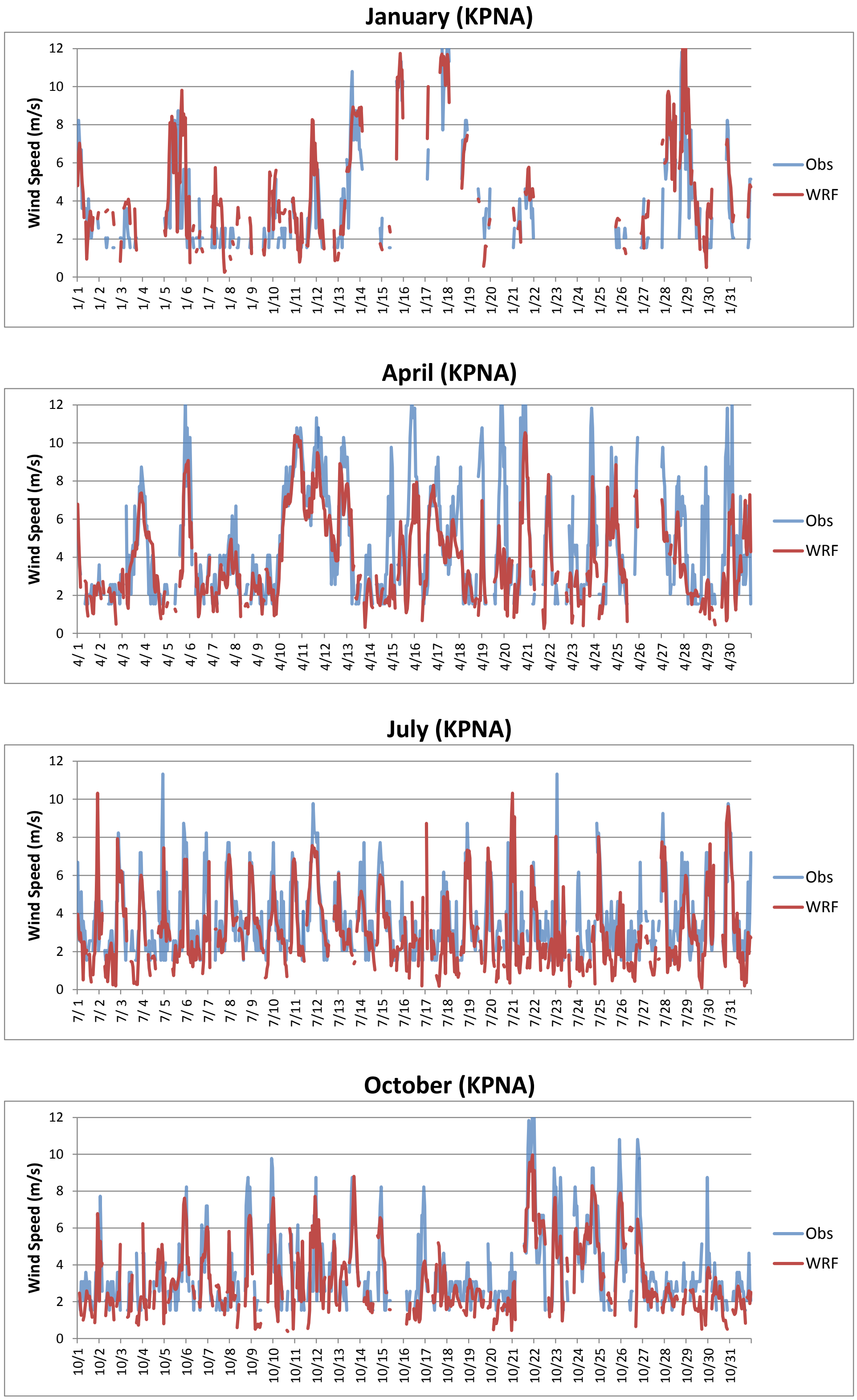


Figure 4-15. Average Observed (Obs) and Simulated (WRF) Surface Wind Direction (degrees) for the Pinedale Meteorological Monitoring Site (KPNA)

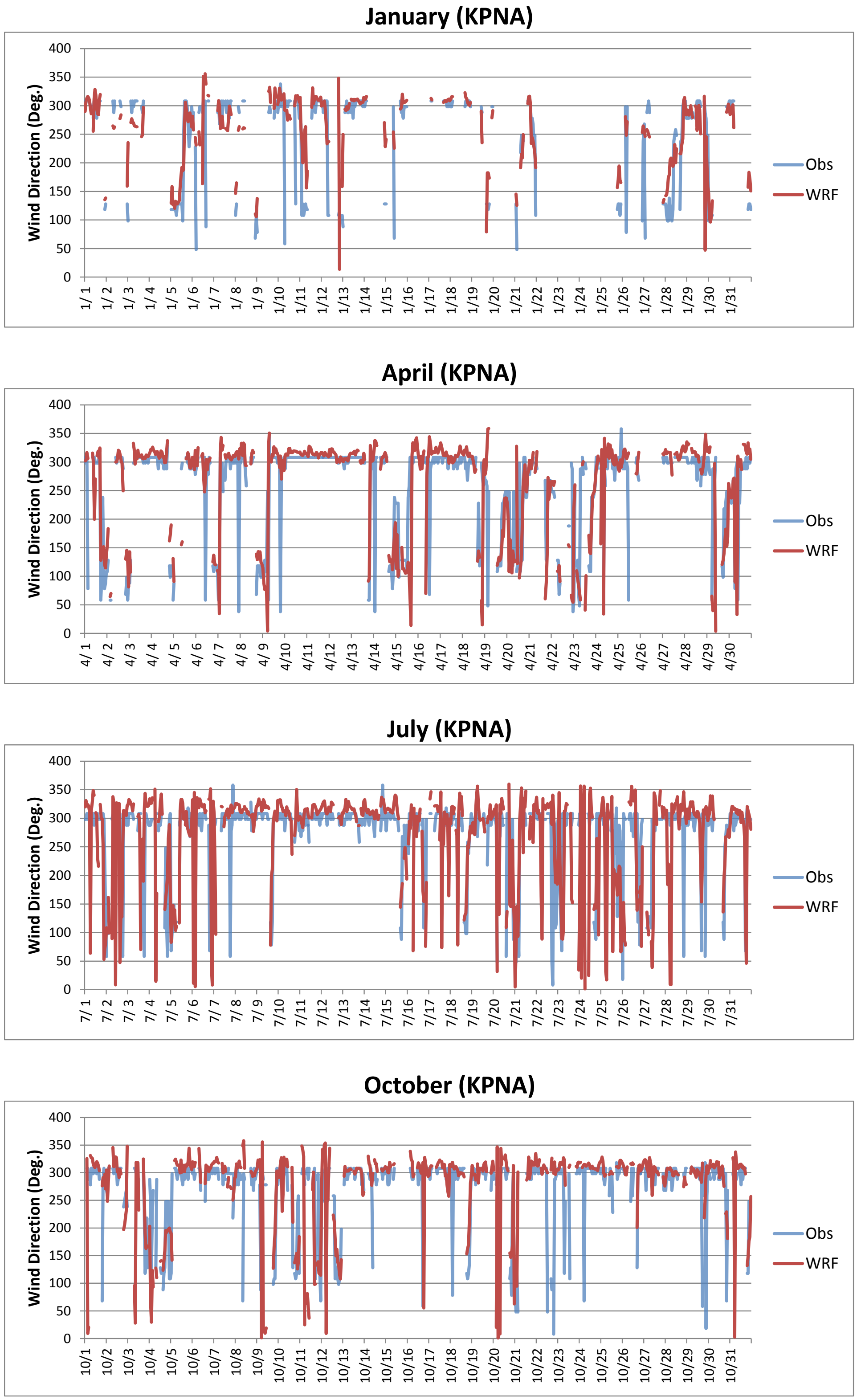
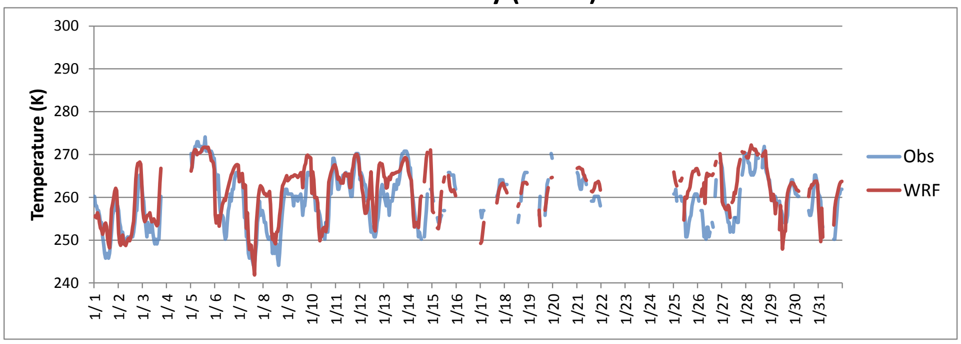
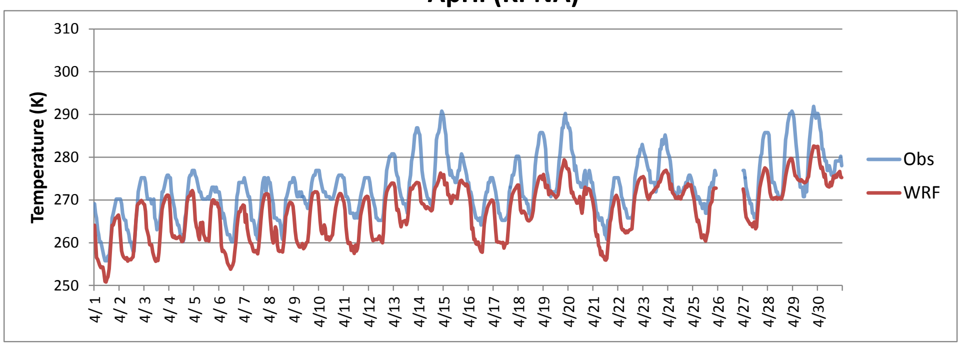


Figure 4-16. Average Observed (Obs) and Simulated (WRF) Surface Temperature (K) for the Pinedale Meteorological Monitoring Site (KPNA)

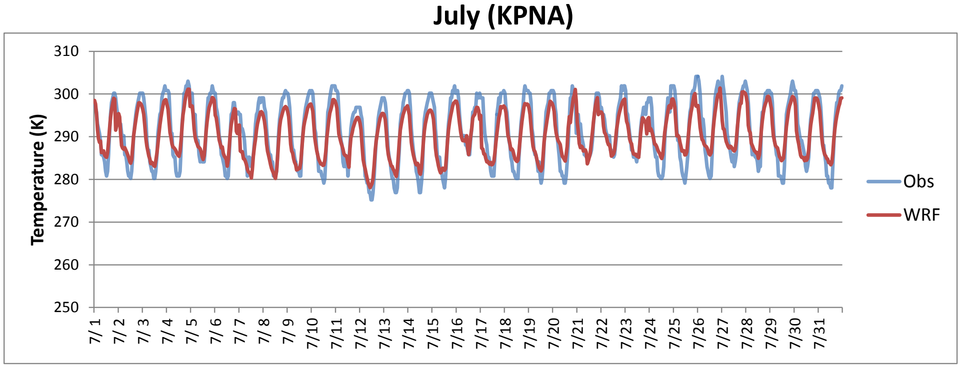
January (KPNA)



April (KPNA)



July (KPNA)



October (KPNA)

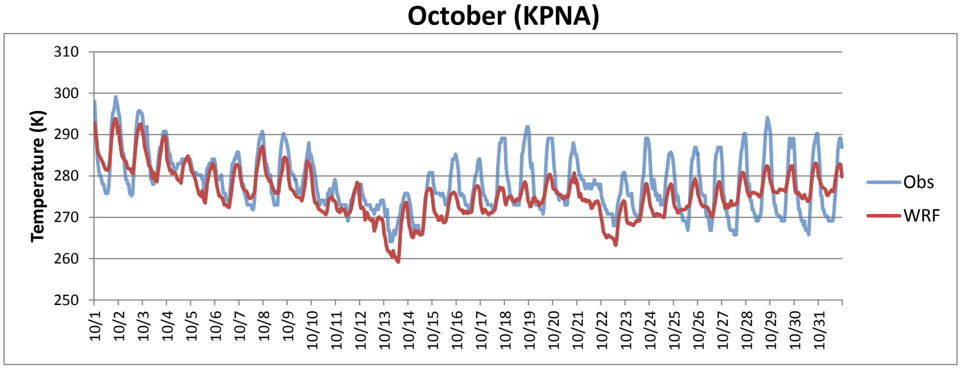


Figure 4-17. Average Observed (Obs) and Simulated (WRF) Surface Water Vapor Mixing Ratio (g/kg) for the Pinedale Meteorological Monitoring Site (KPNA)

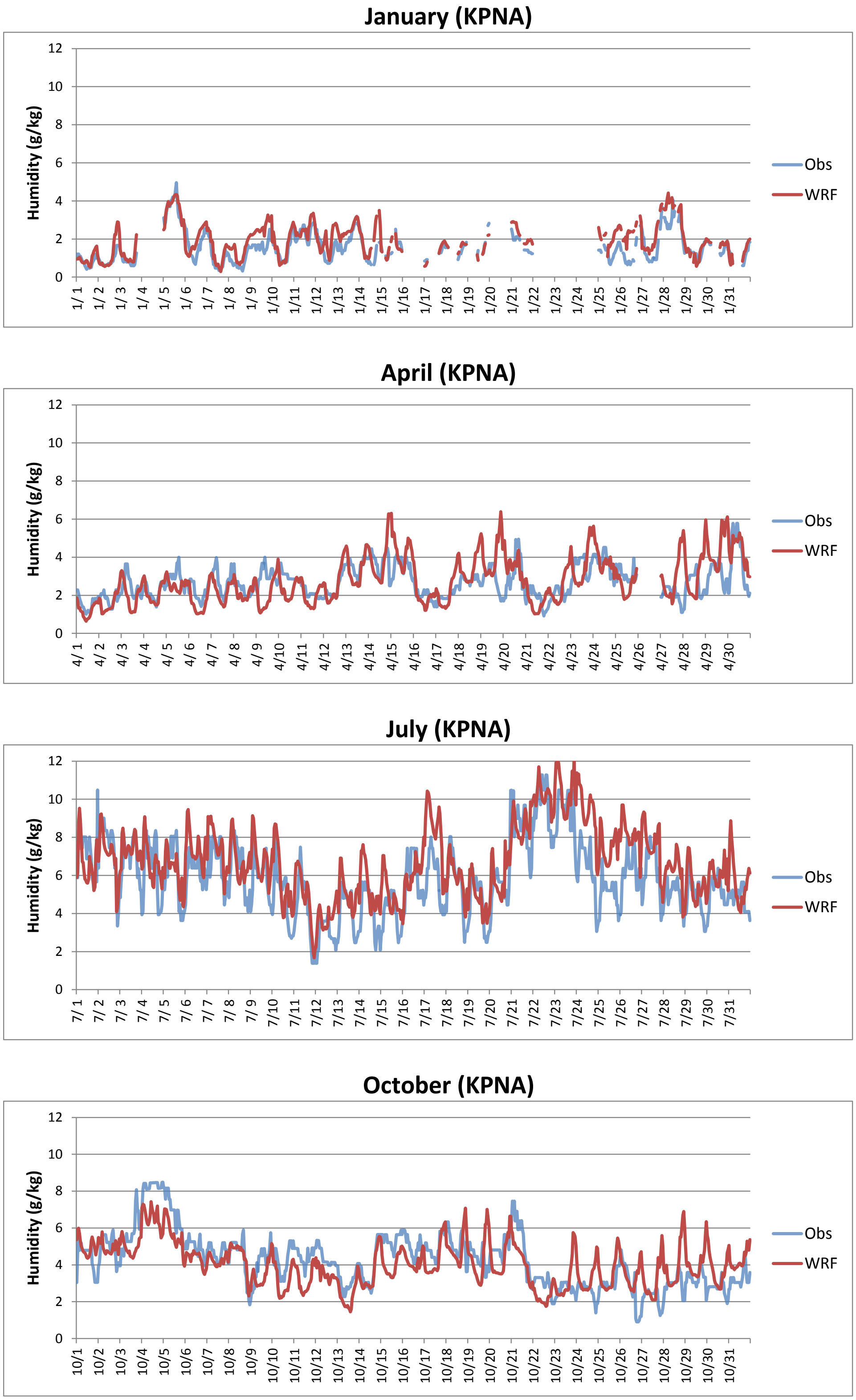
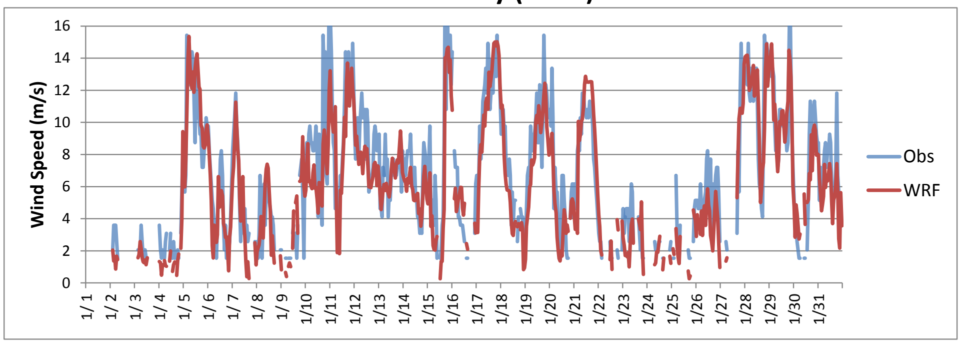
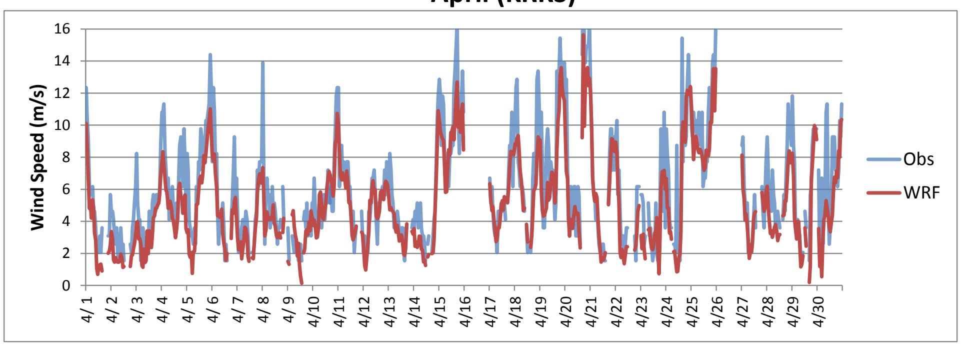


Figure 4-18. Average Observed (Obs) and Simulated (WRF) Surface Wind Speed (m/s) for the Rock Springs Meteorological Monitoring Site (KRKS)

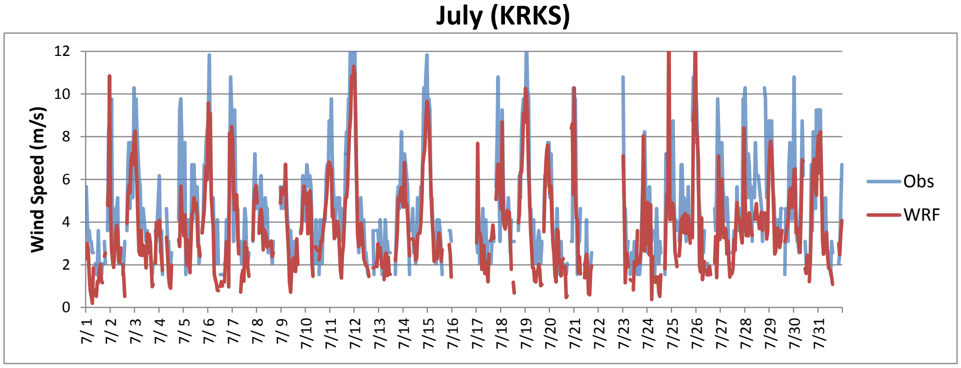
January (KRKS)



April (KRKS)



July (KRKS)



October (KRKS)

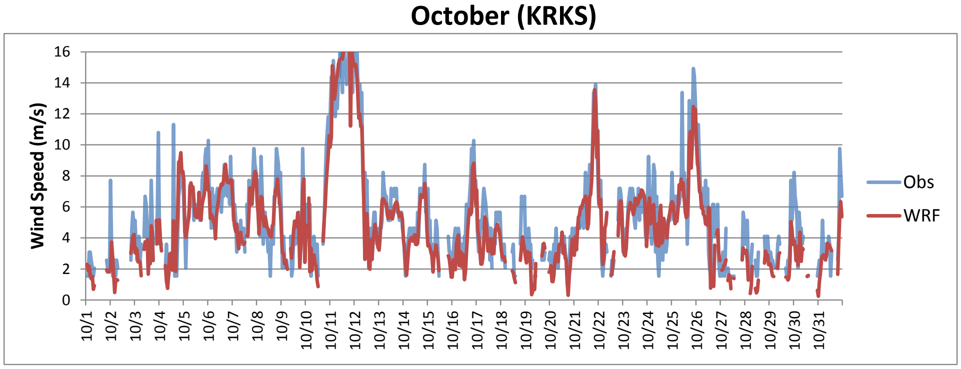


Figure 4-19. Average Observed (Obs) and Simulated (WRF) Surface Wind Direction (degrees) for the Rock Springs Meteorological Monitoring Site (KRKS)

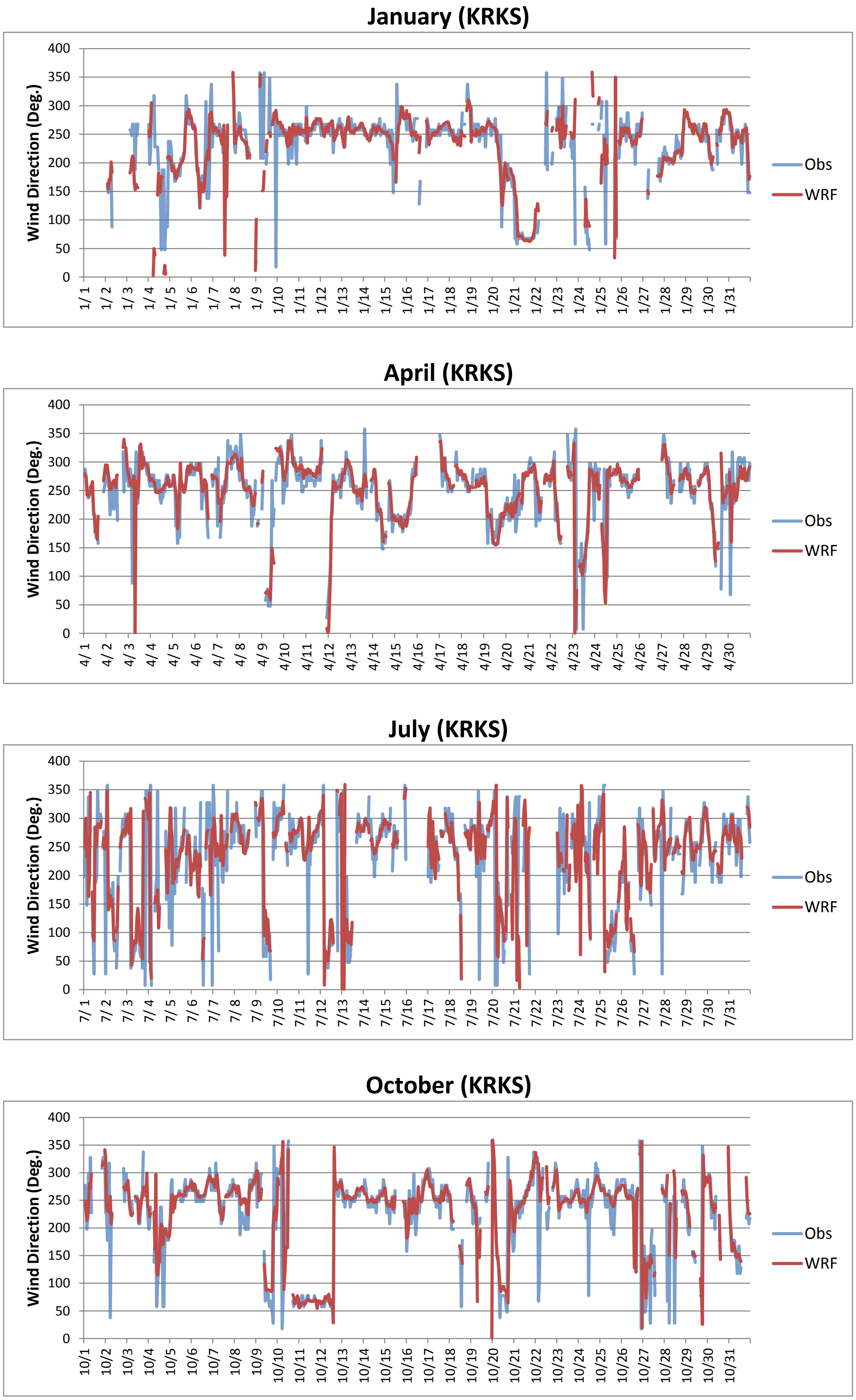
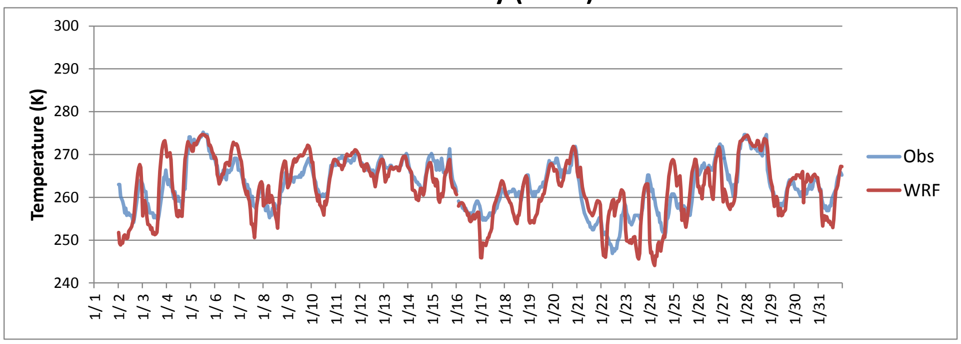
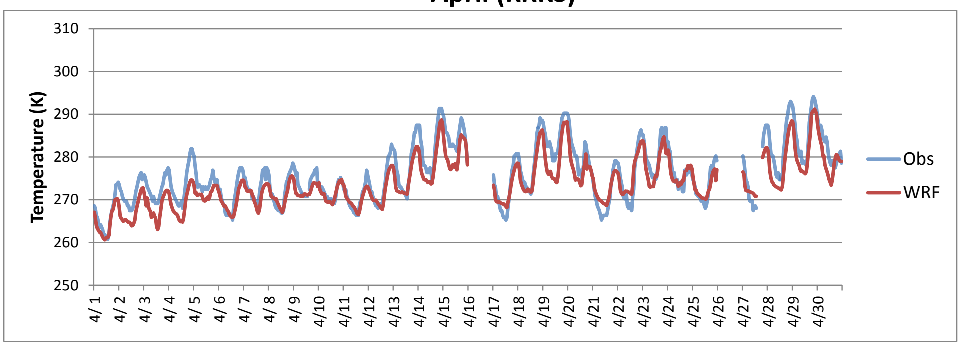


Figure 4-20. Average Observed (Obs) and Simulated (WRF) Surface Temperature (K) for the Rock Springs Meteorological Monitoring Site (KRKS)

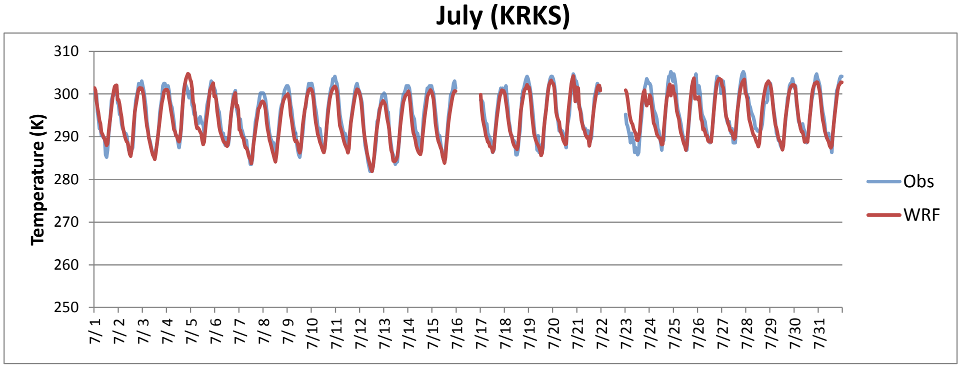
January (KRKS)



April (KRKS)



July (KRKS)



October (KRKS)

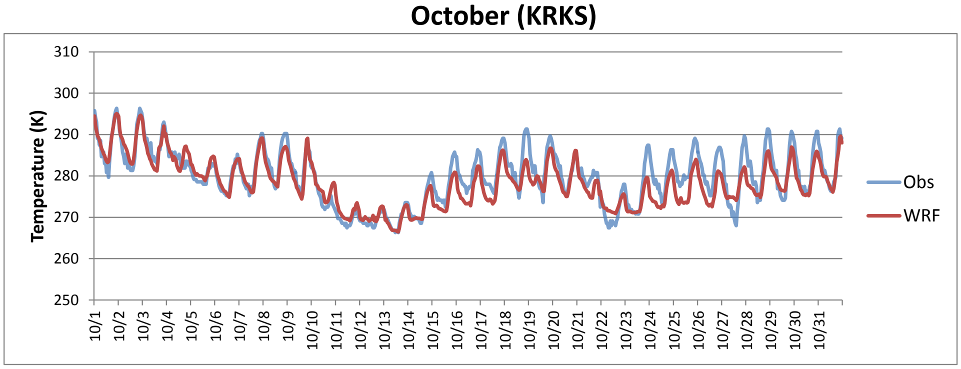
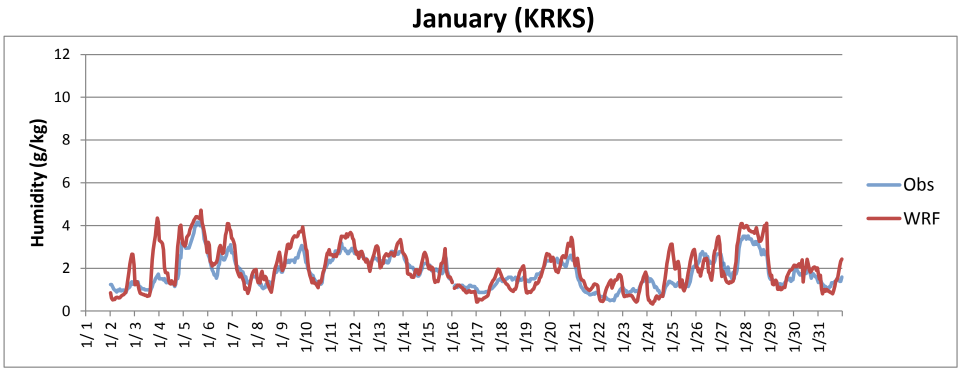
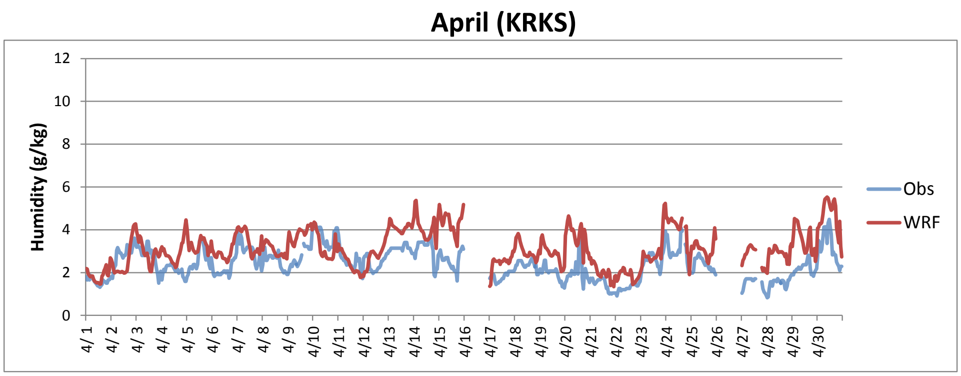
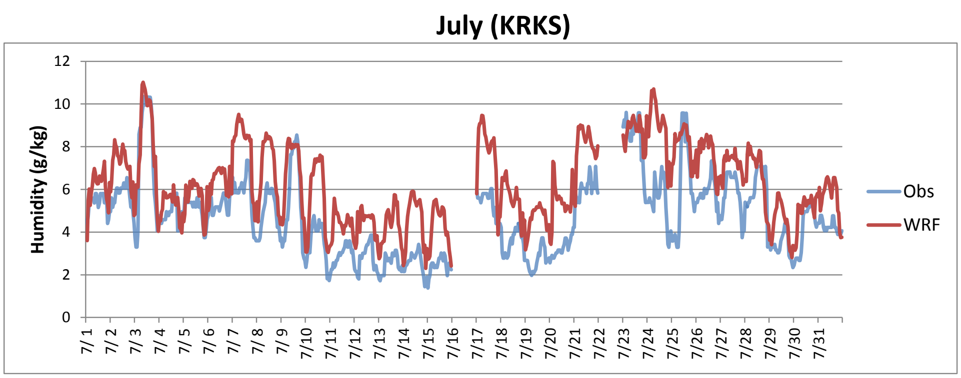
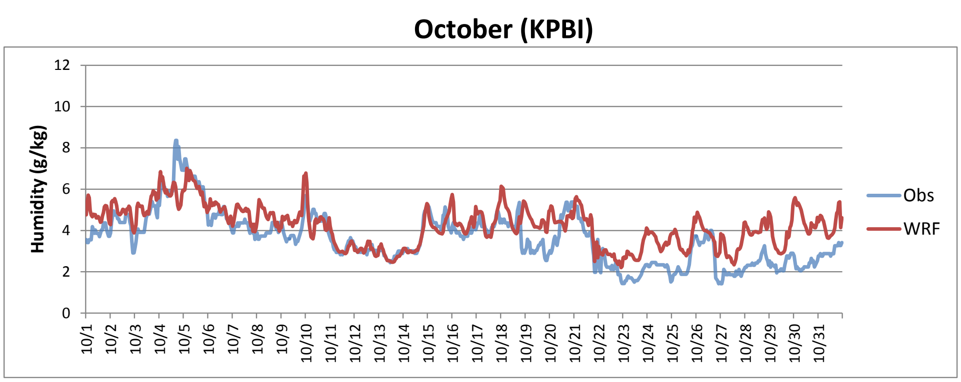


Figure 4-21. Average Observed (Obs) and Simulated (WRF) Surface Water Vapor Mixing Ratio (g/kg) for the Rock Springs Meteorological Monitoring Site (KRKS)









4.5 Wind Direction Frequency Distributions for Selected Monitoring Sites

Good representation of the near surface airflow patterns is an important factor when using the wind fields to drive an air quality model. Good representation of the magnitude, location, and timing of peak concentrations and episodic conditions (as well as a meaningful assessment of short-term impacts) requires an accurate representation of the wind flow parameters. Use of an air quality model to estimate seasonal and annual air quality and deposition (and especially seasonal and annual impacts on air quality and deposition) also requires that the distribution of wind speeds and directions is similar to observed for the period of interest. To examine how well the WRF simulation results capture the observed frequency of wind directions in the vicinity of the project area, the simulated frequency of surface wind direction was compared with that for the observed data for the Big Piney (KBPI), Pinedale (KPNA), and Rock Springs (KRKS) monitoring sites. The wind direction frequency plots are presented in the remainder of this section. For ease of reading, all plots are presented at the end of this section.

Figures 4-22 through 4-24 summarize the frequency of occurrence of winds from eight principal wind directions. Each wind direction represents the 45 degree sector centered on the direction (e.g., N winds range from 337.5 to 22.5 degrees, NE winds range from 22.5 to 67.5 degrees), where the wind direction is the direction from which the winds blow. This information is then graphically displayed in a radar diagram, such that each ring moving outward from the center represents a percent increase in the frequency of occurrence of the wind from a given direction.

Figure 4-22 compares simulated and observed hourly surface wind direction for KBPI. The figure consists of three parts that are based on data for (a) the full annual simulation period, (b) winter months only (Jan–Mar; Nov-Dec), and (c) non-winter months only (Apr-Oct).

Figure 4-23 compares simulated and observed hourly surface wind direction for KPNA for (a) the full annual simulation period, (b) winter months only, and (c) non-winter months only.

Figure 4-24 compares simulated and observed hourly surface wind direction for KRKS for (a) the full annual simulation period, (b) winter months only, and (c) non-winter months only.

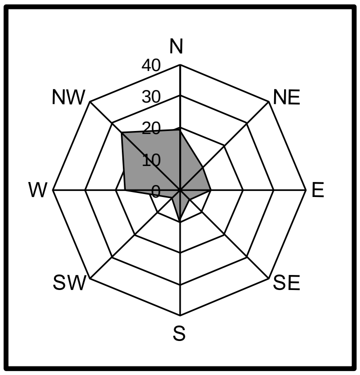
For all three sites, the observed predominant wind directions and the distributions of wind direction are well represented by the simulated surface winds. Some minor differences include the following. Northwesterly winds are more frequently simulated at KBPI than observed. Westerly winds are more frequent than observed at KPNA, but only for the winter months. Southwesterly winds are more frequent than observed at KRKS, but only during the summer months.

Figure 4-22. Comparison of Observed and Simulated Wind Direction Frequency for the Big Piney Monitoring Site (KBPI)

All Months (KBPI)

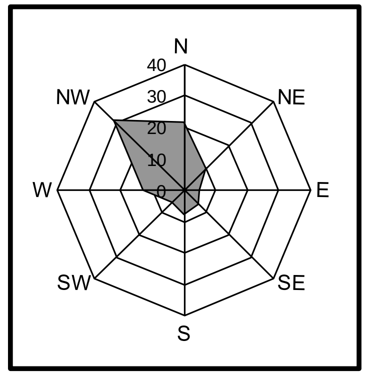
Observed

WD	%
N	19
NE	10
E	10
SE	4
S	10
SW	3
W	17
NW	26



Simulated

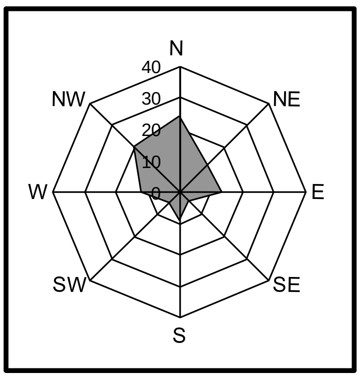
WD	%
N	22
NE	10
E	5
SE	6
S	8
SW	5
W	13
NW	31



Winter Months (Jan–Mar; Nov–Dec) (KBPI)

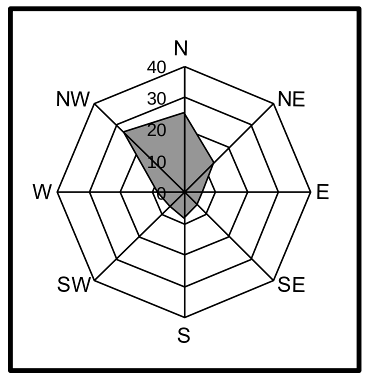
Observed

WD	%
N	24
NE	12
E	13
SE	4
S	9
SW	5
W	12
NW	20



Simulated

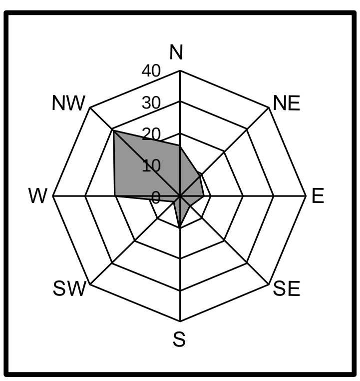
WD	%
N	25
NE	13
E	6
SE	6
S	8
SW	6
W	8
NW	27



Non-Winter Months (Apr–Oct) (KBPI)

Observed

WD	%
N	16
NE	9
E	8
SE	5
S	10
SW	3
W	20
NW	29



Simulated

WD	%
N	19
NE	7
E	4
SE	7
S	7
SW	5
W	16
NW	34

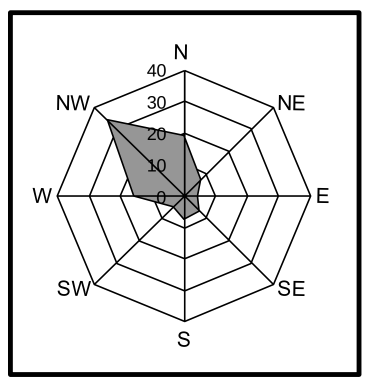
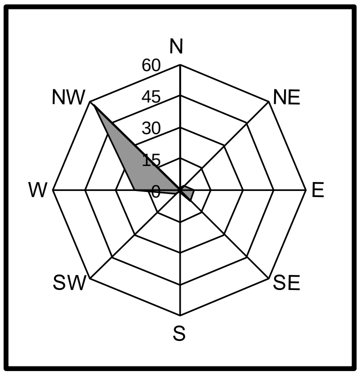


Figure 4-23. Comparison of Observed and Simulated Wind Direction Frequency for the Pinedale Monitoring Site (KPNA)

All Months (KPNA)

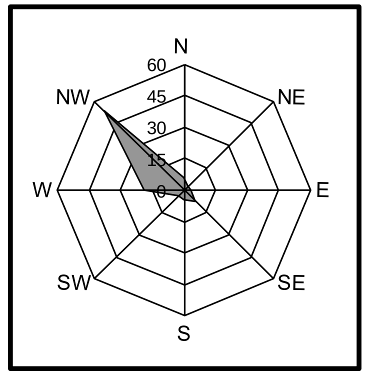
Observed

WD	%
N	1
NE	3
E	7
SE	7
S	1
SW	2
W	21
NW	57



Simulated

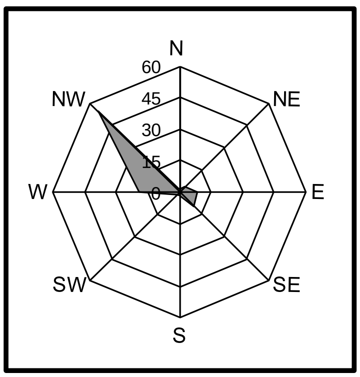
WD	%
N	6
NE	3
E	3
SE	8
S	5
SW	4
W	19
NW	53



Winter Months (Jan–Mar; Nov–Dec) (KPNA)

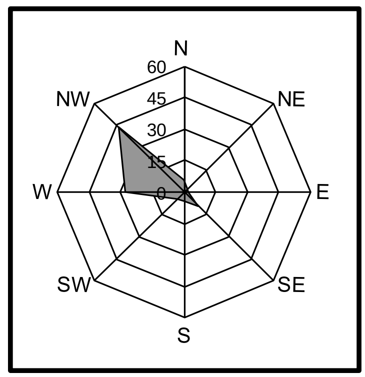
Observed

WD	%
N	1
NE	4
E	9
SE	10
S	2
SW	2
W	19
NW	54



Simulated

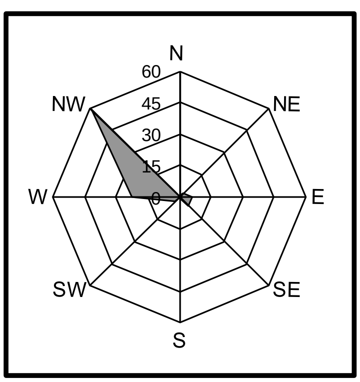
WD	%
N	6
NE	2
E	2
SE	10
S	4
SW	5
W	28
NW	44



Non-Winter Months (Apr–Oct) (KPNA)

Observed

WD	%
N	1
NE	3
E	6
SE	6
S	0
SW	3
W	22
NW	59



Simulated

WD	%
N	6
NE	3
E	4
SE	7
S	5
SW	3
W	14
NW	59

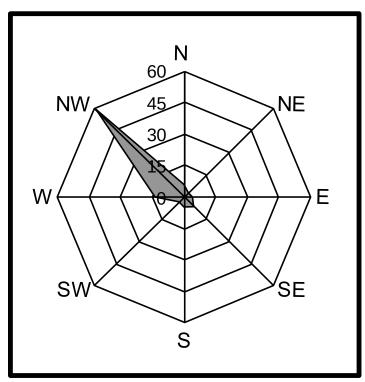
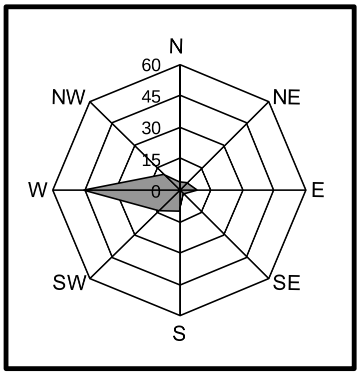


Figure 4-24. Comparison of Observed and Simulated Wind Direction Frequency for the Rock Springs Monitoring Site (KRKS)

All Months (KRKS)

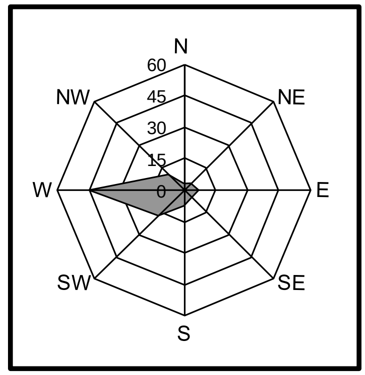
Observed

WD	%
N	4
NE	5
E	9
SE	3
S	10
SW	14
W	45
NW	11



Simulated

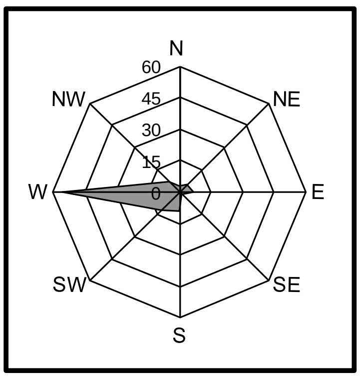
WD	%
N	3
NE	5
E	7
SE	5
S	7
SW	17
W	45
NW	11



Winter Months (Jan–Mar; Nov–Dec) (KRKS)

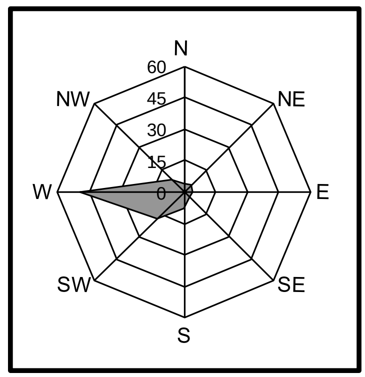
Observed

WD	%
N	3
NE	5
E	7
SE	2
S	9
SW	12
W	55
NW	7



Simulated

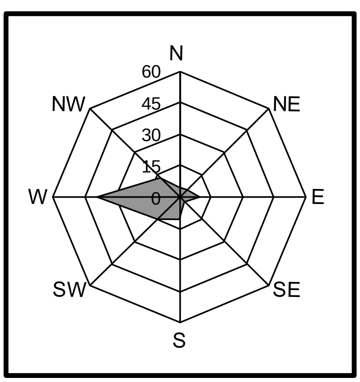
WD	%
N	4
NE	5
E	4
SE	4
S	8
SW	18
W	49
NW	8



Non-Winter Months (Apr–Oct) (KRKS)

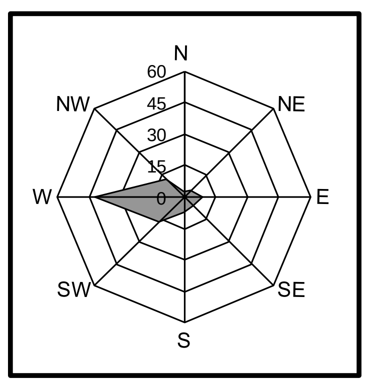
Observed

WD	%
N	5
NE	5
E	10
SE	3
S	11
SW	15
W	39
NW	13



Simulated

WD	%
N	3
NE	4
E	9
SE	6
S	7
SW	17
W	42
NW	12



4.6 Statistical Measures of Model Performance

Statistical measures were used to quantify model performance for the 12- and 4-km grids. METSTAT was applied for each grid, for each month, and for the following parameters: wind speed, wind direction, temperature, and mixing ratio. METSTAT uses surface data only. Monthly model performance statistics are presented in Tables 4-1a and b, for the 12- and 4-km grids respectively. For comparison purposes, the statistical benchmarks (goals) presented in Section 3 are included in the table, as appropriate. Similar statistical summaries for selected individual sites are presented in the Appendix.

Table 4-1a. Statistical Summary of WRF Model Performance for the 12-km Grid for the NPL Project

Metric/Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Goal
Wind Speed													
Mean Obs (m/s)	4.87	4.68	4.81	5.14	5.04	4.5	4.12	4.27	3.95	4.46	4.71	4.97	—
Mean Sim (m/s)	5.23	4.97	5.11	4.65	4.59	4.03	3.53	3.82	3.54	4.06	5.06	5.24	—
Bias (m/s)	0.36	0.29	0.3	-0.49	-0.45	-0.47	-0.59	-0.45	-0.42	-0.4	0.36	0.26	±0.5
Gross Error (m/s)	1.73	1.63	1.69	1.46	1.42	1.4	1.38	1.32	1.22	1.29	1.63	1.74	—
RMSE (m/s)	2.29	2.16	2.21	1.96	1.91	1.89	1.88	1.8	1.66	1.74	2.17	2.32	<2
IOA	0.82	0.83	0.82	0.83	0.83	0.77	0.73	0.78	0.79	0.83	0.82	0.83	≥0.6
Wind Direction													
Mean Obs (deg)	238.1	261.0	267.9	261.6	253.8	238.5	220.7	201.5	244.3	234.1	256.1	261.1	—
Mean Sim (deg)	242.0	263.2	271.2	257.7	250.3	242.9	228.1	204.2	230	233.1	254.8	264.4	—
Bias (deg)	5.74	4.51	5.63	2.48	1.82	1.74	2.71	2.95	1.82	1.52	4.09	5.38	±10
Gross Error (deg)	34.67	34.64	34.99	31.19	31.52	35.86	38.97	35.7	34.88	30.45	33.86	36.32	<30
Temperature													
Mean Obs (K)	265.8	269.3	273.5	277.8	284.1	289.2	294.7	293.5	287.0	280.6	275.7	266.5	—
Mean Sim (K)	266.7	269.1	273.0	277.1	283.8	289.0	294.9	293.6	287.5	280.5	275.8	267.7	—
Bias (K)	0.94	-0.16	-0.52	-0.69	-0.29	-0.18	0.23	0.16	0.53	-0.15	0.05	1.18	±0.5
Gross Error (K)	2.97	2.66	2.47	2.52	2.13	2.27	2.48	2.33	2.24	2.51	2.28	3.14	≤2
RMSE (K)	3.81	3.42	3.12	3.22	2.69	2.88	3.15	2.98	2.88	3.18	2.89	3.94	—
IOA	0.87	0.9	0.91	0.93	0.94	0.94	0.94	0.95	0.95	0.92	0.9	0.87	≥0.8
Mixing Ratio													
Mean Obs (g/kg)	1.94	2.51	2.72	2.97	5.05	6.26	7.54	7.4	5.61	4.08	3.55	2.16	—
Mean Sim (g/kg)	2.46	2.94	3.21	3.32	5.39	6.57	7.78	7.49	5.39	4.15	3.95	2.57	—
Bias (g/kg)	0.51	0.43	0.49	0.35	0.34	0.32	0.25	0.08	-0.22	0.06	0.41	0.4	±1.0
Gross Error (g/kg)	0.59	0.58	0.67	0.68	0.85	1.13	1.44	1.22	0.88	0.65	0.67	0.54	≤2
RMSE (g/kg)	0.73	0.74	0.83	0.88	1.1	1.46	1.85	1.58	1.14	0.86	0.84	0.68	—
IOA	0.77	0.8	0.74	0.75	0.81	0.85	0.82	0.87	0.83	0.8	0.77	0.82	≥0.6

Table 4-1b. Statistical Summary of WRF Model Performance for the 4-km Grid for the NPL Project

Metric/Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Goal
Wind Speed													
Mean Obs (m/s)	4.75	4.45	4.53	4.77	4.48	4.27	3.8	3.94	3.68	3.95	4.29	4.67	—
Mean Sim (m/s)	4.6	4.26	4.21	4.15	3.99	3.82	3.27	3.51	3.27	3.49	4.05	4.38	—
Bias (m/s)	-0.15	-0.19	-0.32	-0.62	-0.49	-0.45	-0.53	-0.43	-0.42	-0.46	-0.24	-0.3	±0.5
Gross Error (m/s)	1.62	1.54	1.57	1.45	1.38	1.38	1.31	1.31	1.2	1.22	1.48	1.66	—
RMSE (m/s)	2.15	2.03	2.07	1.89	1.82	1.84	1.76	1.76	1.61	1.62	1.97	2.21	<2
IOA	0.85	0.84	0.82	0.83	0.82	0.78	0.75	0.77	0.78	0.82	0.82	0.83	≥0.6
Wind Direction													
Mean Obs (deg)	234.7	242.9	258.9	266.6	266.0	251.8	242.3	210.7	221.8	247.5	245.1	253.8	—
Mean Sim (deg)	231.7	241.2	260.1	250.7	262.3	248.7	248.5	208.0	220.9	244.9	247.3	249.5	—
Bias (deg)	0.96	-0.25	1.91	2.49	2.24	2.97	2.69	3.35	2.63	1.49	-2.05	-0.42	±10
Gross Error (deg)	39.6	39.25	39.46	33.05	32.56	34.99	37.84	35.64	33.83	31.02	38.13	40.09	<30
Temperature													
Mean Obs (K)	264.6	268.9	272.3	276.8	283.1	288.6	294.4	293.1	286.2	280.0	275.7	267.1	—
Mean Sim (K	265.9	268.7	271.6	275.4	282.6	288.1	294.3	293.1	286.9	280.0	275.8	268.1	—
Bias (K)	1.33	-0.17	-0.69	-1.41	-0.49	-0.48	-0.12	-0.03	0.7	-0.03	0.06	0.92	±0.5
Gross Error (K)	3.25	2.77	2.44	2.68	2.01	2.11	2.31	2.24	2.23	2.6	2.25	3.07	≤2
RMSE (K)	4.21	3.63	3.16	3.37	2.53	2.69	2.97	2.89	2.88	3.32	2.87	3.97	—
IOA	0.83	0.83	0.89	0.9	0.93	0.94	0.95	0.95	0.94	0.9	0.89	0.83	≥0.8
Mixing Ratio													
Mean Obs (g/kg)	1.85	2.48	2.68	2.74	4.73	5.54	6.58	6.22	5.12	3.92	3.57	2.24	—
Mean Sim (g/kg)	2.4	2.96	3.25	3.18	5.12	5.9	7.01	6.59	4.89	4.02	4.13	2.75	—
Bias (g/kg)	0.55	0.48	0.57	0.44	0.39	0.36	0.42	0.37	-0.23	0.1	0.55	0.51	±1.0
Gross Error (g/kg)	0.63	0.64	0.71	0.74	0.84	1.11	1.39	1.24	0.92	0.69	0.74	0.62	≤2
RMSE (g/kg)	0.77	0.8	0.88	0.95	1.09	1.44	1.78	1.62	1.2	0.94	0.91	0.76	—
IOA	0.7	0.7	0.67	0.6	0.68	0.69	0.66	0.69	0.7	0.7	0.68	0.74	≥0.6

The statistical measures are similar for the 12- and 4-km grids. The statistics for wind speed are generally better for the 4-km grid, presumably because use of the higher resolution grid combined with “obs” nudging of the winds enables the WRF model to better resolve the local, surface-based airflow characteristics (including terrain and land-use effects) that are represented in the observations. The statistics for wind direction are slightly better for the 12-km grid. This may be due to the use of analysis nudging for winds for the 12-km grid, compared to only “obs” nudging for winds for the 4-km grid. The statistics for temperature and mixing ratio are not consistently better for either grid, but are overall slightly better for the 12-km grid.

4.6.1 Discussion of Statistical Model Performance for the 12-km Grid

For the 12-km grid, the wind speed bias is within ±1 m/s for all months and within ±0.5 m/s for all months except July. The bias is negative (winds are slower than observed) for the non-winter months (Apr–Oct) and positive for the winter months (Jan-Mar; Nov-Dec). The corresponding RMSE is less than 2 m/s for the non-winter months and slightly greater than 2 m/s for the winter months. The IOA is close to 0.8 for all months, with the exception of July for which it is 0.73. Overall, surface wind speeds within the 12-km grid are very well represented.

The wind direction bias is within ±10 degrees for all months and within ±3 degrees for the non-winter months. The gross error ranges from 31 to 39 degrees. Overall, surface wind directions within the 12-km grid are also very well represented.

The temperature bias is within ±0.5 K for most months and within ±1 K for all months, with the exception of December. The gross error is larger and ranges from 2.1 to 3.1 K, indicating that the error includes both over- and underestimation of the hourly temperatures (as confirmed by the time-series plots). Nevertheless, temperatures within the 12-km grid are well represented and the IOA is close to 0.9 or higher for all months.

The mixing ratio bias is within ±0.5 g/kg for all months, with the exception of December (0.51 g/kg). The bias is positive (indicating higher than observed humidity) for all months, except September. The gross error ranges from approximately 0.5 to 1.4 g/kg and the IOA ranges from 0.75 to 0.87 g/kg. Thus, on average, the mixing ratio is well represented for the 12-km grid.

4.6.2 Discussion of Statistical Model Performance for the 4-km Grid

For the 4-km grid, the wind speed bias is within ±1 m/s for all months and within ±0.5 m/s for all but two months (April and July, for which the values are -0.53 and -0.62, respectively). The bias is negative (winds are slower than observed) for all months. The corresponding RMSE is less than 2 m/s for the non-winter months and close to or slightly greater than 2 m/s for the winter months. The IOA is close to 0.8 for all months (the lowest value is 0.75 for July and the highest value is 0.85 for January). The corresponding benchmark values for wind speed are ±0.5 m/s for bias, ≤2 m/s for RMSE and ≥0.8 for IOA. Based on the statistical measures, surface wind speeds within the 4-km grid are very well represented.

The wind direction bias is within ±4 degrees for all months and within ±3 degrees for the non-winter months. The gross error is less than or equal to 40 degrees for all months. Although the bias is smaller, the error tends to be larger for the winter months. The corresponding benchmark values for wind direction are ±10 degrees for bias and ≤30 degrees for wind direction. Although the benchmarks are not fully met, the statistical measures indicate that, on average, surface wind directions within the 4-km grid are well represented.

The temperature bias is within ±0.5 K for most months and within ±1.5 K for all months. For most months, temperatures are underestimated. The gross error ranges from 2 to 3.25 K. The IOA indicates good correlation between the simulated and observed values and ranges from 0.83 to 0.95. The corresponding benchmark values for temperature are ±0.5 K for bias, ≤2 K for gross error, and ≥0.8 for IOA. Based on the statistical measures, temperatures within the 4-km grid are well represented.

The bias for mixing ratio is within ±0.55 g/kg for all months, and is positive for all months except September. The gross error ranges from 0.6 to 1.4 g/kg. The IOA indicates reasonably good correlation between the simulated and observed values and ranges from 0.6 to 0.74. The corresponding benchmark values for mixing ratio are ±1 g/kg for bias, ≤2 g/kg for gross error, and ≥0.6 for IOA. Based on the statistical measures, mixing ratios within the 4-km grid are well represented.

4.7 Comparison with Special Studies Data

To date, no comparisons with special studies data have been performed. It is expected that additional analysis of the meteorological fields will be conducted as the air quality assessment progresses in order to better quantify and/or understand any limitations associated with the WRF modeling results for the winter months. At that time, special studies data such as those collected as part of the UGWOS may be used as an independent check on WRF model performance for selected periods.

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APPENDIX A: STATISTICAL MEASURES OF MODEL PERFORMANCE FOR SPECIFIC MONITORING SITES

Statistical measures were used to quantify model performance for selected monitoring sites. METSTAT was applied for each site, for each month, and for the following parameters: wind speed, wind direction, temperature, and mixing ratio. Monthly model performance statistics are presented in Tables A-1 through A-3 for: Big Piney (KBPI), Pinedale (KPNA), and Rock Springs (KRKS). The statistical benchmarks (goals) presented in Section 3 of the main report are included in the table, as appropriate.

Table A-1. Statistical Summary of WRF Model Performance for KBPI for the NPL Project

Metric/Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Goal
Wind Speed													
Mean Obs (m/s)	2.56	2.52	3.00	3.62	3.31	3.91	4.31	3.90	3.60	3.57	4.09	3.59	—
Mean Sim (m/s)	2.88	2.41	3.14	3.62	3.70	3.75	3.65	3.29	2.86	2.55	2.99	2.71	—
Bias (m/s)	0.32	-0.10	0.14	0.00	0.40	-0.16	-0.66	-0.61	-0.74	-1.02	-1.10	-0.88	±0.5
Gross Error (m/s)	1.19	1.18	1.30	1.28	1.34	1.48	1.37	1.25	1.20	1.40	1.63	1.59	—
RMSE (m/s)	1.55	1.44	1.60	1.67	1.76	1.88	1.77	1.61	1.55	1.80	2.01	1.97	<2
IOA	0.19	0.35	0.59	0.70	0.66	0.73	0.77	0.75	0.75	0.62	0.63	0.58	≥0.6
Wind Direction													
Mean Obs (deg)	180.2	214.9	252.4	258.2	258.5	288.9	304.8	267.1	278.7	256.8	172.1	166.7	—
Mean Sim (deg)	205.8	219.9	232.6	259.1	284.0	278.8	304.2	265.5	275.7	216.9	193.1	169.3	—
Bias (deg)	-0.43	1.83	0.53	-2.13	-1.35	-5.00	-5.67	-9.95	-9.78	-3.61	-10.94	2.80	±10
Gross Error (deg)	52.03	55.85	42.92	31.98	31.46	32.00	33.50	37.97	37.72	35.51	44.65	54.65	<30
Temperature													
Mean Obs (K)	256.9	262.5	267.2	273.1	280.1	285.5	291.6	289.8	282.7	276.9	272.1	263.1	—
Mean Sim (K)	258.5	262.3	264.7	269.2	279.7	285.2	290.8	289.2	283.3	275.6	272.2	263.0	—
Bias (K)	1.62	-0.17	-2.52	-3.89	-0.39	-0.39	-0.80	-0.63	0.57	-1.28	0.10	-0.12	±0.5
Gross Error (K)	4.72	4.75	3.55	4.54	1.68	1.79	1.99	2.01	1.81	3.00	2.92	3.56	≤2
RMSE (K)	5.50	5.66	4.33	5.02	2.03	2.13	2.41	2.47	2.21	3.52	3.44	4.22	—
IOA	0.69	0.67	0.74	0.76	0.92	0.95	0.96	0.95	0.95	0.82	0.75	0.72	≥0.8
Mixing Ratio													
Mean Obs (g/kg)	1.19	1.82	2.31	2.32	3.97	4.43	4.88	4.79	4.31	3.52	2.93	1.77	—
Mean Sim (g/kg)	1.61	2.11	2.43	2.81	4.72	5.36	6.59	6.12	4.61	3.94	4.01	2.21	—
Bias (g/kg)	0.42	0.29	0.12	0.49	0.75	0.93	1.71	1.33	0.30	0.42	1.07	0.44	±1.0
Gross Error (g/kg)	0.56	0.67	0.51	0.83	0.88	1.12	1.78	1.41	0.73	0.72	1.09	0.55	≤2
RMSE (g/kg)	0.65	0.77	0.60	0.98	0.99	1.26	1.96	1.59	0.89	0.85	1.19	0.63	—
IOA	0.62	0.64	0.72	0.40	0.53	0.49	0.45	0.41	0.50	0.58	0.43	0.65	≥0.6

Table A-2. Statistical Summary of WRF Model Performance for KPNA for the NPL Project

Metric/Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Goal
Wind Speed													
Mean Obs (m/s)	3.90	3.57	3.99	4.66	4.26	3.96	3.62	3.59	3.32	3.61	4.55	3.86	—
Mean Sim (m/s)	4.33	3.82	4.06	3.80	3.67	3.68	3.02	3.15	2.79	3.15	4.22	4.13	—
Bias (m/s)	0.42	0.25	0.07	-0.86	-0.59	-0.27	-0.60	-0.44	-0.54	-0.46	-0.33	0.27	±0.5
Gross Error (m/s)	1.25	1.24	1.30	1.49	1.29	1.22	1.24	1.22	1.09	1.13	1.41	1.47	—
RMSE (m/s)	1.51	1.54	1.61	1.98	1.69	1.57	1.61	1.57	1.36	1.43	1.73	1.85	<2
IOA	0.65	0.63	0.71	0.71	0.76	0.78	0.74	0.71	0.73	0.70	0.65	0.58	≥0.6
Wind Direction													
Mean Obs (deg)	273.9	284.9	290.5	280.6	280.9	289.6	298.7	279.7	279.6	293.1	295.2	273.9	—
Mean Sim (deg)	270.5	279.4	279.9	270.8	287.4	290.0	305.4	289.0	280.0	292.9	287.9	262.8	—
Bias (deg)	4.11	-8.47	-2.93	6.49	4.81	10.37	9.35	11.46	8.47	8.13	-1.39	0.23	±10
Gross Error (deg)	35.92	40.29	33.46	25.96	28.12	32.04	34.37	32.30	33.34	28.54	24.43	35.33	<30
Temperature													
Mean Obs (K)	259.3	265.1	267.5	273.0	280.0	285.2	291.5	289.6	283.0	278.2	273.3	264.4	—
Mean Sim (K)	261.3	265.0	265.1	267.4	279.1	284.6	290.5	289.0	283.2	275.7	271.2	263.7	—
Bias (K)	1.95	-0.12	-2.38	-5.60	-0.91	-0.60	-0.92	-0.58	0.16	-2.56	-2.11	-0.71	±0.5
Gross Error (K)	3.76	3.69	3.16	5.66	2.10	2.10	2.65	2.93	2.47	4.13	3.13	3.27	≤2
RMSE (K)	4.46	4.46	3.89	6.27	2.42	2.51	3.10	3.42	2.84	4.77	3.63	3.81	—
IOA	0.71	0.70	0.73	0.66	0.89	0.92	0.93	0.91	0.90	0.70	0.67	0.73	≥0.8
Mixing Ratio													
Mean Obs (g/kg)	1.54	2.24	2.48	2.70	4.47	5.21	5.87	5.32	4.87	4.24	3.45	2.10	—
Mean Sim (g/kg)	1.87	2.46	2.49	2.77	4.69	5.28	6.72	6.20	4.71	4.04	3.91	2.27	—
Bias (g/kg)	0.34	0.22	0.01	0.08	0.22	0.07	0.85	0.89	-0.17	-0.21	0.45	0.17	±1.0
Gross Error (g/kg)	0.46	0.60	0.45	0.78	0.76	0.83	1.29	1.27	0.76	0.93	0.67	0.43	≤2
RMSE (g/kg)	0.54	0.71	0.55	0.97	0.90	1.01	1.55	1.54	0.90	1.14	0.84	0.52	—
IOA	0.72	0.67	0.75	0.42	0.52	0.58	0.57	0.43	0.50	0.45	0.50	0.69	≥0.6

Table A-3. Statistical Summary of WRF Model Performance for KRKS for the NPL Project

Metric/Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Goal
Wind Speed													
Mean Obs (m/s)	6.32	7.02	6.31	5.97	5.58	5.43	4.57	4.88	4.31	5.11	6.48	7.16	—
Mean Sim (m/s)	5.70	6.53	5.39	5.01	4.60	4.72	3.70	4.22	3.64	4.51	5.69	6.31	—
Bias (m/s)	-0.61	-0.49	-0.92	-0.96	-0.98	-0.71	-0.87	-0.66	-0.68	-0.60	-0.79	-0.84	±0.5
Gross Error (m/s)	1.43	1.59	1.62	1.32	1.43	1.29	1.29	1.31	1.18	1.11	1.38	1.86	—
RMSE (m/s)	1.76	2.00	1.99	1.67	1.86	1.70	1.67	1.71	1.53	1.44	1.73	2.28	<2
IOA	0.78	0.77	0.80	0.85	0.79	0.83	0.82	0.80	0.80	0.77	0.75	0.76	≥0.6
Wind Direction													
Mean Obs (deg)	232.5	249.8	250.4	264.6	223.6	236.4	253.6	211.7	217.5	221.2	239.7	237.2	—
Mean Sim (deg)	228.1	242.9	248.9	267.4	218.2	235.4	260.9	213.6	214.6	225.3	241.3	234.4	—
Bias (deg)	0.67	-2.89	-1.09	2.75	4.08	0.40	1.03	-0.36	3.47	1.70	0.76	-4.97	±10
Gross Error (deg)	25.62	19.87	22.51	16.93	18.49	21.76	27.20	22.23	21.84	19.71	17.49	21.19	<30
Temperature													
Mean Obs (K)	262.8	267.6	270.8	275.9	281.7	288.2	295.0	292.9	285.7	279.7	275.0	267.3	—
Mean Sim (K)	262.3	265.8	267.6	273.8	281.1	287.4	294.3	292.4	285.9	278.4	274.5	267.5	—
Bias (K)	-0.52	-1.77	-3.12	-2.06	-0.62	-0.74	-0.68	-0.53	0.19	-1.28	-0.51	0.18	±0.5
Gross Error (K)	3.07	2.95	3.39	2.62	1.77	1.61	1.43	1.58	1.55	2.30	2.17	3.04	≤2
RMSE (K)	3.63	3.59	3.93	2.95	2.10	1.96	1.69	1.89	1.84	2.66	2.58	3.53	—
IOA	0.70	0.71	0.66	0.83	0.93	0.93	0.97	0.95	0.94	0.84	0.75	0.69	≥0.8
Mixing Ratio													
Mean Obs (g/kg)	1.81	2.52	2.67	2.40	4.05	4.32	4.73	5.04	4.69	3.60	3.20	2.14	—
Mean Sim (g/kg)	2.00	2.55	2.88	3.14	4.79	5.48	6.25	6.22	5.41	4.22	4.26	2.78	—
Bias (g/kg)	0.19	0.02	0.20	0.74	0.74	1.16	1.52	1.18	0.73	0.62	1.06	0.64	±1.0
Gross Error (g/kg)	0.42	0.46	0.59	0.87	0.93	1.28	1.60	1.39	0.92	0.80	1.08	0.78	≤2
RMSE (g/kg)	0.50	0.54	0.71	0.96	1.07	1.43	1.81	1.57	1.04	0.90	1.16	0.84	—
IOA	0.62	0.71	0.53	0.42	0.54	0.46	0.46	0.44	0.52	0.49	0.39	0.50	≥0.6

As expected, averaging generally yields better overall statistics, and the statistical measures for the 4-km grid are generally better and more consistent from month-to-month than those for the individual sites. There are, however, some exceptions where the site-specific measures are better. For example, wind direction metrics for KPNA and KRKS indicate much better agreement with the observations than the average metrics for the 4-km grid. The temperature statistics indicate that WRF has some problems in simulating the site specific temperatures for KBPI and KPNA for April (this is also reflected in the grid-wide statistics, but to a lesser extent). The site-specific measures may be affected by a lack of complete data (resulting in somewhat of a random sampling of the hours); this is especially true for January, February, and March (as seen in the time-series plots for the individual sites presented in Section 4 of the main report). Overall, no major site specific performance issues are revealed by the individual site metrics.

ATTACHMENT C. CMAQ BASE-YEAR MODELING RESULTS AND MODEL PERFORMANCE EVALUATION

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NORMALLY PRESSURED LANCE (NPL)

NATURAL GAS DEVELOPMENT PROJECT

AIR QUALITY ASSESSMENT TECHNICAL SUPPORT DOCUMENT

Attachment C: CMAQ BASE-YEAR MODELING RESULTS AND MODEL PERFORMANCE EVALUATION

U.S. Department of the Interior
Bureau of Land Management

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Pinedale, Wyoming 82941

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The BLM manages more land – 253 million acres – than any other Federal agency. This land, known as the National System of Public Lands, is primarily located in 12 Western States, including Alaska. The Bureau, with a budget of about $1 billion, also administers 700 million acres of sub-surface mineral estate throughout the nation. The BLM's multiple-use mission is to sustain the health and productivity of the public lands for the use and enjoyment of present and future generations. The Bureau accomplishes this by managing such activities as outdoor recreation, livestock grazing, mineral development, and energy production, and by conserving natural, historical, cultural, and other resources on public lands.

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ACRONYMS AND ABBREVIATIONS

AMET	Atmospheric Model Evaluation Tool
ANC	Acid Neutralizing Capacity
AQRV	Air Quality Related Value
AQS	Air Quality System
ARW	Advanced Research WRF
BC	Black Carbon
BLM	Bureau of Land Management
CAIR	Clean Air Interstate Rule
CASTNet	Clean Air Status and Trends Network
CB	Carbon Bond
CM	Coarse Mass
CMAQ	Community Multiscale Air Quality
CO	Carbon monoxide
CONUS	Continental U.S.
EC	Elemental carbon
EGU	Electric Generating Unit
EIS	Environmental Impact Statement
EPA	U.S. Environmental Protection Agency
FDDA	Four-dimensional data assimilation
FINN	Fire Inventory
HAP	Hazardous Air Pollutant
HNO_3	Nitric acid
HONO	Formaldehyde
IC/BC	Initial and boundary conditions
IMPROVE	Interagency Monitoring of PROtected Visual Environments
IPM	Integrated Planning Model
kg/ha	Kilograms per hectare
LCC	Lambert Conformal Conic
$\mu g/m^3$	Micrograms per cubic meter
KBPI	Big Piney
KPNA	Pinedale
KRKS	Rock Springs
m	Meter(s)
mb	Millibars
MCIP	Meteorology-chemistry Interface Processor
MEGAN	Model of Emissions of Gases and Aerosols from Nature
MOVES	Motor Vehicle Emissions Simulator
N	Nitrogen
NAAQS	National Ambient Air Quality Standard
NH_4^+	Ammonium ion
NEPA	National Environmental Policy Act
NH_3	Ammonia
NMOC	Non-methane organic compound
NO	Nitrogen oxide
NADP	National Acid Deposition Program
NCAR	National Center for Atmospheric Research
NEI	National Emission Inventory
NO_2	Nitrogen dioxide
NO_3^-	Nitrate ion
NO_x	Oxides of nitrogen
NPL	Normally Pressured Lance
O_3	Ozone
PBL	Planetary boundary layer
PM	Particulate matter
$PM_{2.5}$	Fine particulate matter
PM_{10}	Coarse particulate matter
ppb	Parts per billion
PSD	Prevention of Significant Deterioration
RFD	Reasonably Foreseeable Development
RGF	Regional Gathering Facility
RMP	Resource Management Plan
ROD	Record of Decision
RPD	Rate per distance
RPP	Rate per profile
RPO	Regional Planning Organization
SMOKE	Sparse-Matrix Operator Kernel Emissions
S	Sulfur
SO_2	Sulfur dioxide
SO_4^{2-}	Sulfate ion
UCAR	University Center for Atmospheric Research
UGRB	Upper Green River Basin
U.S.	United States
WRAP	Western Regional Air Partnership
WRF	Weather Research and Forecasting
WY DEQ	Wyoming Department of Environmental Quality
WY	Wyoming

1.0 INTRODUCTION

This document summarizes the methods and results of the base-year application and performance evaluation of the Community Multiscale Air Quality (CMAQ) modeling system to support the assessment of impacts from emissions associated with the development of the Normally Pressured Lance (NPL) natural gas field on regional air quality. The NPL natural gas field is located northwest of Rock Springs, Wyoming, south of Pinedale, Wyoming, and adjacent to the existing Jonah Field; the project area comprises approximately 140,000 acres of land. A number of natural gas wells have already been drilled in the NPL. Jonah Energy proposes to drill an average of 350 wells per year over a 10-year period for a total of approximately 3,500 wells. Many outside factors, including economic, technological, and regulatory factors, may influence the rate of development as well as the total number of wells that will ultimately be drilled over the duration of the project.

The Bureau of Land Management (BLM) oversees and administers the public lands within the proposed NPL Project Area from the BLM Pinedale and Rock Springs field offices. Oil and gas development activities in the area are governed by the Pinedale Resource Management Plan (RMP) (BLM, 2008) and the Green River RMP (BLM, 1997). An Environmental Impact Statement (EIS) for the proposed project will be prepared by BLM in accordance with National Environmental Policy Act (NEPA) guidelines. Other NEPA analyses have been conducted for the area and management plans have been previously prepared for sections of the Project Area. These include the Green River RMP and Final EIS and Record of Decision (ROD), and the Pinedale RMP and Final EIS and ROD.

1.1 Project Description

The primary purpose of Jonah Energy's proposal to develop the NPL field is the recovery of natural gas and other hydrocarbon resources. Target formations for the development include the Lance Pool, and potentially the Unnamed Tertiary, Mesa Verde, and other possible productive formations evaluated during exploration and testing. Jonah Energy's planned development of the NPL field will include the building and/or installation of new access roads, well pads, pipelines, compressor stations, and other supporting facilities. At the present time, Jonah Energy proposes to use directional drilling from no more than four centralized surface locations per section. Drill pads are proposed to encompass up to approximately 19 acres per location for a total initial surface disturbance of approximately 6,340 acres of the NPL area. Upon completion of reclamation activities, approximately 1,890 acres would remain disturbed. Although the exact location of each well is not known at this time, the bottom-hole-location density is expected to be no less than a 10-acre spacing pattern to retrieve natural gas in the formations identified during exploration and testing.

To transport products (gas, condensate, and produced water), a three-phase pipeline gathering system is proposed to be installed from the well heads to designated Regional Gathering Facilities (RGF). For the development of the NPL, each RGF would be designed with facilities that support gas/liquid separation, gas compression and dehydration, liquid storage, and truck loading for condensate sales. Jonah Energy proposes to minimize emissions by employing natural-gas-powered drill rigs, and using electric compressors in place of diesel-powered compressors. Jonah Energy also proposes to undertake simultaneous completion operations whenever possible in an effort to minimize emissions associated with equipment use and movement. In addition, Jonah Energy proposes to limit emissions with the use of flare-less flow back technology for the completion operations.

1.2 Overview of the Air Quality Assessment

The overall NPL air quality analysis will include an assessment of expected future impacts of emissions from equipment and activities associated with the development of the NPL Project Area. Future-year air quality modeling will be conducted to assess impacts for criteria pollutants and other air quality related values (AQRVs). Near-field impacts will be evaluated using the Environmental Protection Agency (EPA) guideline model AERMOD, and far-field (or regional) impacts will be evaluated using Version 5.0 of EPA's Community Multiscale Air Quality (CMAQ) modeling system (Byun and Ching, 1999) as well as Version 5.8.4 of the CALPUFF modeling system (Scire et al., 2000).

1.2.1 Study Objectives

The objectives of this air quality assessment are to examine and quantify the potential air quality impacts from emissions associated with the development of the NPL natural gas field using the best available data and state-of-the-science data processing and modeling tools. This information will be used to support the development of an EIS for the NPL Project Area.

1.2.2 Modeling Analysis Components

The overall assessment will consider both near-field and far-field air quality impacts and will focus on:

- Criteria pollutants including ozone (O_3), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), carbon monoxide (CO), and particulate matter (PM), including both coarse (PM_{10}) and fine particulates ($PM_{2.5}$).
- Hazardous Air Pollutants (HAPs), including acetaldehyde, acrolein, benzene, ethyl benzene, formaldehyde, methanol, n-hexane, toluene, and xylene and;
- Air Quality Related Values (AQRVs) including visibility, acid neutralizing capacity (ANC) of sensitive water bodies, and atmospheric deposition to soils.

The HAPs assessment will focus only on the NPL Project Area, and the ANC analysis will be conducted for acid sensitive water bodies within nearby Class I and Class II areas identified in the analysis. The remaining air quality impacts will be evaluated for the NPL Project Area, nearby Class I areas, nearby sensitive Class II areas, and throughout the regional-scale air quality modeling domain.

For the near-field assessment, the modeling scenarios the modeling scenarios will be designed to capture the maximum impacts (based on emission rate) for each pollutant for each phase of the project.

The far-field or regional-scale CMAQ air quality modeling includes an assessment of "current" conditions for a recent historical period (2008). The assessment of current conditions is also referred to as the base-year modeling analysis. It includes a detailed model performance evaluation and is summarized in the remainder of this report.

Potential future impacts will then be evaluated for the selected future year (2024) by applying the modeling systems using the historical meteorological inputs and estimated future-year emissions for sources associated with the development of the field, as well as other regional sources. The regional modeling scenarios include:

- <u>2008 Base Case</u> – The current air quality conditions have been established using the base-year meteorological inputs and emissions data.

- No Action Alternative – This alternative will utilize reasonably foreseeable development (RFD) emissions for the selected future year (2024), excluding emissions from the NPL Project. This scenario will include local and regional emissions from all source categories, including emissions from nearby oil and gas development projects, as available.
- Proposed Action – This scenario will incorporate the project-specific emission inventory developed for the NPL Project and will be used to evaluate and quantify project-specific air quality impacts.
- Alternative Scenario – This scenario will represent a different development scenario for the NPL Project as an alternative to the proposed scenario.

The CMAQ base-year regional modeling analysis was conducted using emissions data available from BLM, the Wyoming Department of Environmental Quality (WY DEQ), the Western Regional Air Partnership (WRAP), and EPA. The future-year regional modeling analysis will utilize emissions from these same sources. The NPL impacts analysis modeling will be conducted using emissions specifically developed by Jonah Energy for the NPL Project development operations. Detailed information on the base-year emissions is provided in Section 2 of this document.

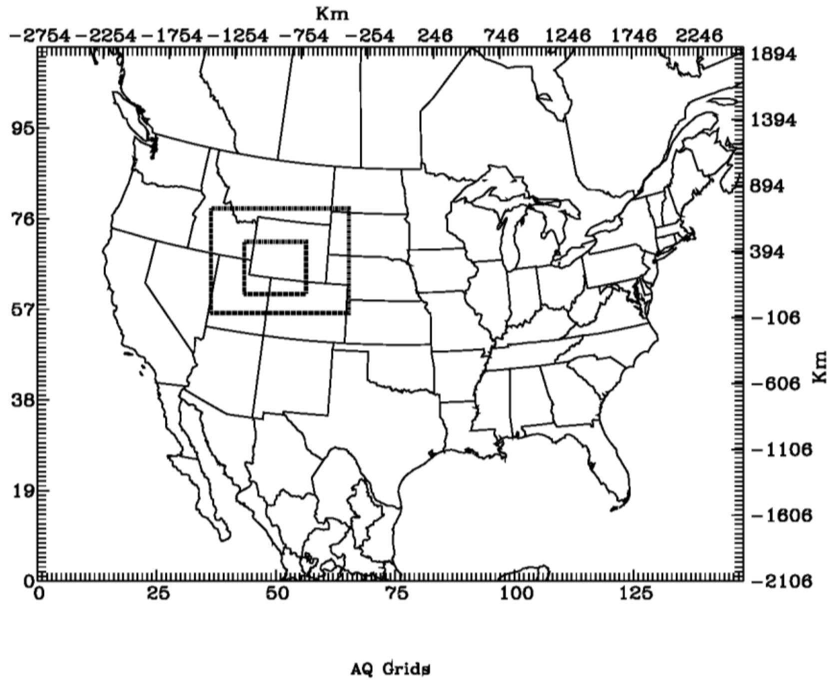
1.2.3 Modeling Tools

The primary air quality modeling tools used for this study include AERMOD, CALPUFF, the CMAQ model, the Weather Research and Forecasting (WRF) model, and the Sparse-Matrix Operator Kernel Emissions (SMOKE) modeling/processing tool. The application of SMOKE for the preparation of the base-year, regional-scale emission inventory and the application of CMAQ for the 2008 Base Case scenario are discussed in the remainder of this report.

1.3 Overview of the Base-Year Modeling and Performance Evaluation

For the base-year modeling effort, the CMAQ model (version 5.0) was applied for the calendar year 2008. The modeling domain consists of a 36-km resolution outer grid encompassing the U.S., a 12-km grid encompassing the State of Wyoming and portions of the surrounding states, and a 4-km grid encompassing the NPL Project Area and other nearby Prevention of Significant Deterioration (PSD) Class I and sensitive Class II areas. A one-way nesting approach was used for the horizontal grids. The modeling domain is illustrated in Figure 1-1.

Figure 1-1. CMAQ Modeling Domain for the NPL Air Quality Impact Assessment (36-, 12- and 4-km Grids)



In the vertical dimension, the modeling domain includes 34 layers for the months of April – October and 38 layers for January, February, March, November and December (the same layer structure that has been established for modeling studies of other, nearby project areas). The thickness of the layers increases with height above ground.

The base-year modeling effort included base-year model input preparation and model performance evaluation.

Meteorological inputs were prepared using the WRF model (version 3.3.1). The WRF application procedures and model performance evaluation are summarized in Section 3 of this report and presented in detail in a separate WRF model performance report (ICF, 2012).

Regional emissions data from BLM, WY DEQ, WRAP, and EPA were processed using the SMOKE and MEGAN tools. As part of the emissions processing, the emissions data were speciated into the Carbon Bond 2005 (CB05) chemical mechanism species, as required by CMAQ; temporally distributed to each hour of the simulation period; and spatially distributed to each grid cell within the modeling domain. The emissions for all source categories were merged to create CMAQ-ready input files.

Boundary conditions for the outermost domain were developed using output from the GEOS-Chem model for the model year 2008. Boundary conditions for the inner grids were generated as part of the CMAQ application and derived from the modeling results for the next largest outer grid within which the inner grid is nested.

Land use, photolysis rates, and other chemistry related inputs were prepared using standard CMAQ procedures and pre-processing programs. Additional details on the simulation parameters and options used for the CMAQ model application are presented in Section 3 of this report.

Output data files that include surface concentrations of all species and wet and dry deposition totals of all species were saved at hourly intervals and post-processed to obtain totals and average concentrations over different time periods.

The base-year CMAQ simulation results were evaluated using graphical and statistical analysis. Specifically, simulated ozone, PM_{10}, $PM_{2.5}$, SO_2, NO_x and CO concentrations and selected deposition species were compared with observed data, using a variety of graphical and statistical analysis products. A majority of the graphical analysis products and statistical measures were generated using the Atmospheric Model Evaluation Tool (AMET) (UNC, 2008). The model performance evaluation also included diagnostic and sensitivity testing, aimed at examining the sensitivity of the modeling system to changes in the inputs. An understanding of the strengths and weaknesses of the model obtained through the evaluation of model performance is critical to the appropriate use of the modeling system to assess the effects of changes in emissions on future air quality. The model performance methods are outlined in Section 4 of this report and the results of the model performance evaluation are discussed in detail in Section 5.

The results indicate that the CMAQ model is able to adequately replicate the air quality characteristics of the simulation period. This establishes the “base-case” simulation for the remainder of the NPL air quality assessment. The next steps are to establish a future-year baseline and conduct the future-year air quality assessment.

2.0 BASE-YEAR EMISSION INVENTORY

This section describes the data, methods, and procedures that were used to prepare the base-year, model-ready emissions inventory for application of CMAQ for the NPL air quality impact assessment. A detailed summary of the emission inventory is also provided.

2.1 Emissions Data and Processing Procedures

SMOKE, version 3.1, was used to process the emissions and prepare the base-year, CMAQ-ready modeling emission inventory based on the 2007 base case emissions in EPA's 2008-based modeling platform (known as 2007v5), which, in turn, is based on data from the 2008 National Emission Inventory (NEI) Version 2. For their national-scale rulemaking analyses, EPA chose to simulate the year 2007, but much of the emissions information contained in the 2007v5 platform was derived from the 2008 NEI Version 2 data (EPA, 2012a).

The emissions from the following source categories included in the base-year inventory were based on the EPA's NEI 2008-based platform:

- Electric Generating Unit (EGU) point sources (estimated using the Integrated Planning Model (IPM))
- Non-EGU point sources
- Agriculture
- Area fugitive dust
- Class 1 & 2 commercial marine vessel and non-rail maintenance locomotives
- Category 3 (c3) commercial marine vessels
- Non-point (area)
- Non-road
- On-road
- Point sources for Canada and Mexico
- Non-point and non-road for Canada and Mexico
- On-road for Canada and Mexico
- Oceanic gaseous chlorine emissions

In addition, the following files were recently updated by AECOM as part of the LaBarge EIS analysis (AECOM, 2013) and incorporated into the NPL base-year emission inventory:

- Oil and gas point source emissions for drilling and completion activities in five counties in southwestern Wyoming during 2008. The five counties include: Sublette, Lincoln, Sweetwater, Carbon and Uinta
- Oil and gas emissions for the State of Wyoming and states outside of Wyoming (Arizona, Colorado, Montana, Nevada, New Mexico, North Dakota, South Dakota, and Utah) that are modeled as area sources, available from either the WRAP Phase III or WRAP Phase II emissions inventories
- Ancillary files used to process oil and gas emissions: oil and gas spatial surrogates, oil and gas temporal profiles, VOC speciation profiles for oil and gas sources in southwest Wyoming.

The development of the model-ready inventory included processing and merging of all anthropogenic emissions using various SMOKE programs and inputs, calculation of biogenic and wildfire emissions, merging of all emissions, and review and quality assurance of the resulting emission inventory.

The general procedures followed in preparing the modeling inventories for CMAQ included:

- Chemical speciation of the criteria pollutant emissions into the Carbon Bond 2005 (CB05) chemical mechanism species, as required by CMAQ
- Temporal distribution of the input annual/monthly emissions into hourly emissions
- Spatial distribution of the emissions data to the 36-, 12- and 4-km resolution modeling grids
- Calculation of biogenic emissions using the 2008 base-year meteorological input files derived from the WRF model
- Extraction of the wildfire emissions for the 36-, 12- and 4-km resolution modeling grids from the University Center for Atmospheric Research (UCAR) database (UCAR, 2013)
- Merging of emissions from all source categories into CMAQ model-ready files
- Review and quality assurance of the processing steps and resulting emissions.

For most of the processing steps, including chemical speciation, temporal allocation, spatial distribution, and merging, standard SMOKE algorithms and utility programs were applied. Biogenic emissions were estimated using the Model of Emissions of Gases and Aerosols from Nature (MEGAN) software system (Guenther et al., 2006).

The base year (2008) coincides with scheduled updates for EPA's National Emission Inventory (NEI), which includes updates of criteria pollutant emissions from all source categories for all states, including Wyoming. Specific inventories of oil & gas sources developed for basins in Wyoming and neighboring states have been updated in recent years by the WRAP and were incorporated into the inventory. Some of these emissions have been used in recent years to support other air quality modeling activities associated with regional haze and $PM_{2.5}$ planning and management activities. Table 2-1 summarizes the various source components that comprise the 2008 base-year modeling emission inventory for the NPL analysis.

Table 2-1. Data Sources for the NPL 2008 Base Year Emissions Inventory

Component/Category	Sub-category/Description	Spatial area	Data source
Major and minor point	EGU and non-EGU point sources; oil and gas sources excluded	U.S.	2008 NEI v2
Area	Area sources; oil and gas sources excluded	U.S.	2008 NEI v2
	Ammonia	U.S.	2008 NEI v2
Oil and gas	Area and point sources	5 Southwest Wyoming Counties: Sublette, Lincoln, Sweetwater, Carbon, and Uinta	Updated by AECOM for LaBarge EIS
	Point sources	U.S. (excluding the SW WY 5-counties)	2008 NEI v2
	Area sources	States with WRAP data (Colorado, Montana, New Mexico, North	WRAP Phase II & III

Component/Category	Sub-category/Description	Spatial area	Data source
		Dakota, South Dakota, Utah, and Wyoming)	
	Area sources	Non-WRAP states (e.g., Oklahoma, Texas, etc.)	2008 NEI v2
Non-road	Non-road sources	U.S.	2008 NEI v2
On-road	On-road motor vehicle sources (MOVES)	U.S.	2008 NEI v2
Non U.S.	Point, area (non-point), and mobile sources	Portions of Canada and Mexico within the 36-km domain	2008 NEI v2
Offshore	Offshore sources	Portions of Pacific and Atlantic Oceans and Gulf of Mexico within 36-km domain	2008 NEI v2
Biogenic	Biogenic sources	U.S. and portions of Canada and Mexico within the 36-km domain	MEGAN
Wildfire	Point sources	U.S. and portions of Canada and Mexico within the 36-km domain	UCAR database

Additional details for each source category are provided in the following sections.

Major and Minor Point Sources

The emissions were obtained for the State of Wyoming (except for oil and gas point sources in the five counties of southwestern Wyoming) and all other states in the modeling domain from EPA's 2008-base platform (EPA, 2012a). The point source emissions were processed using SMOKE with the "in-line" point source option, and EPA-provided speciation/temporal profiles and associated cross reference files.

Area Sources

The emissions were obtained from EPA's 2008-base platform (EPA, 2012a) for all states in the modeling domain (except for the oil and gas sources in the State of Wyoming and WRAP states outside of Wyoming). Emissions for all major area source categories were obtained from EPA's data including industrial processes, miscellaneous area sources, mobile sources (marine vessels, aircraft, railroads, paved roads, etc.), solvent utilization, stationary source fuel combustion, storage and transport, and waste disposal, treatment, and recovery. The area source emissions were processed using SMOKE with EPA-provided speciation/temporal/surrogate profiles and associated cross reference files. The gridded surrogates used for spatially allocating area emissions for the 36-km domain were obtained from EPA's database for the continental U.S. (CONUS) grid, and the surrogates for the 12-km domain were extracted from EPA's corresponding 12-km database. The surrogate data required for the NPL 4-km grid were prepared using the EPA SRGTOOLS and associated data.

On-Road and Off-Road Mobile Sources

Estimates for on-road emissions were prepared by combining the emission factors generated using EPA's Motor Vehicle Emissions Simulator MOVES2010b, activity data, and 2008 meteorological data to produce gridded, hourly emissions. There are three sets of emission factors for the non-refueling part of on-road sources: 1) rate per distance (RPD) modeling of the on-network emissions, which includes the vehicle exhaust, evaporation, evaporative permeation, brake wear, and tire wear; 2) rate per vehicle

(RPV) modeling of the off-network emissions, including the vehicle exhaust, evaporative emissions, and evaporative permeation; and 3) rate per profile (RPP) modeling of the off-network emissions for parked vehicles, which includes the vehicle evaporative emissions (fuel vapor venting). There are two sets of emission factors for refueling part of on-road sources: RPD and RPV.

The emissions for non-road sources were estimated with the latest version of the NONROAD model (EPA, 2008).

Oil & Gas Sources – Southwestern Wyoming, Rest of Wyoming and All Other States

The 2008 oil and gas point source emissions for drilling and completion activities in five counties (Sublette, Lincoln, Sweetwater, Carbon and Uinta) in southwestern Wyoming were provided by AECOM (AECOM, 2013), following updates made to the inventory as part of the LaBarge natural gas development project EIS. These emissions were processed by SMOKE using the temporal profiles and VOC speciation profiles for oil and gas sources.

The 2008 area source oil and gas emissions for the State of Wyoming and the WRAP states outside of Wyoming were also provided by AECOM (AECOM, 2013). These emissions, which are also being used for the LaBarge EIS, are based on the available WRAP II or WRAP III database, and were processed using the oil and gas temporal profiles, VOC speciation profiles, and spatial surrogates.

The point and area emissions from oil and gas sources for other states were prepared based on EPA's 2008-based platform data.

Biogenic Emissions

The 2008 biogenic emissions were estimated using the MEGAN software system (Guenther et al., 2006). MEGAN is a global model for estimating the biogenic emissions used by air quality models. The base resolution is ~ 1 km. MEGAN uses land-cover data for emissions factors, leaf-area index, and plant functional types that are available in several formats. MEGAN produces emissions estimates of isoprene, monoterpenes, oxygenated compounds, sesquiterpenes, and nitrogen oxide. The biogenic emissions were estimated using the base-year 2008 meteorological inputs provided by the application of the WRF meteorological model.

Ammonia Emissions

Emission estimates for ammonia sources were obtained from EPA's 2008-based platform. The emissions processing incorporated a new EPA temporal allocation methodology for animal-related ammonia (NH_3) that allocates emissions down to the hourly level by taking into account temperature and wind speed.

Wildfire Emissions

Estimates of emissions from wildfires for 2008 were prepared using information obtained from the Fire INventory from NCAR (FINN) (Wiedinmyer et al., 2001; Wiedinmyer et al., 2006), which is affiliated with the University Center for Atmospheric Research (UCAR). FINN files covering the years 2002 through 2012 are currently available, and the emissions files for 2008 were downloaded from http://acd.ucar.edu/~christin/fire-emissions.

The fire emissions available from UCAR provide daily total fire emissions down to a resolution of about one kilometer. The inventory includes emissions estimates for all fires, not necessarily just prescribed burns and reported wildfires. Emissions of carbon dioxide (CO_2), CO, NO, NO_2, SO_2, NH_3, methane (CH_4), non-methane organic compounds (NMOC), formaldehyde (HONO), particulate organic carbon (OC), particulate black carbon (BC), $PM_{2.5}$, and PM_{10} are included in the files available from NCAR. The NMOC emissions are available speciated for either the MOZART-4 (Emmons et al., 2010) chemical mechanism or for the SAPRC99 (Carter, 2000) mechanism.

For the NPL modeling analysis, the fire emissions were aggregated for each grid cell of each grid (36-km, 12-km, and 4-km resolution) to get a daily fire emissions total in each grid cell. These emissions were then divided equally across all 24 hours of the day to obtain hourly emissions for each day of 2008.

As noted above, the NMOC fire emissions from UCAR have been speciated into SAPRC99 and MOZART-4 species. The CMAQ modeling for the NPL Project is utilizing the CB05 chemical mechanism. A number of species have a direct correspondence between the SAPRC99 and CB05 mechanisms, but other species were converted from the SAPRC99 species to appropriate species or collections of species in the CB05 system. Species conversion tables derived from (http://www.engr.ucr.edu/~carter/emitdb/#dbfiles) were used to guide the development of conversion factors for translating the SAPRC99 species into CB05 species.

2.2 Quality Assurance Procedures

Quality assurance of the emissions included the preparation and examination of tabular emissions summaries and graphical display products.

Tabular summaries were used to examine emissions totals for various steps of the emissions processing. Summaries of the input emissions were based on the input inventory data and include monthly emissions for the on-road and non-road sources, and annual emissions for other sources for criteria pollutants. Summaries for the emissions were based on the SMOKE output reports and include daily emissions for each CB05 species for each major source category. Following the emissions processing, summaries of the output emissions were also prepared. Daily emissions were summed over all days in the year and the CB05 species were summed for the criteria pollutants. Emissions summaries were prepared for each major source category and comparisons were made between the input and output emissions to ensure consistency.

In addition, tabular summaries of the resulting (model-ready) emissions were prepared that provide emissions totals by source category and pollutant for each of the three modeling grids (36-, 12- and 4-km grids). Graphical displays of the emissions were prepared for one day of each month to examine the spatial distribution and temporal variation for each major source category and the final merged model-ready) emission inventory. The spatial plots were prepared using the PAVE graphical plotting package.

2.3 Summary of the Base-Year Emission Inventory

Tables 2-2 through 2-4 summarize the base-year (2008) emissions used for the CMAQ modeling. These tables summarize anthropogenic emissions by major source category and pollutant for the 36-km grid, the 12-km grid, and the 4-km grid. The oil and gas emissions category includes emissions from area sources for states with WRAP data (Colorado, Montana, New Mexico, North Dakota, South Dakota, Utah, and Wyoming) and point sources for five southwest Wyoming counties (Sublette, Lincoln, Sweetwater, Carbon, and Uinta). Emissions totals are provided for the following species: volatile organic compounds (VOCs), oxides of nitrogen (NO_x), CO, SO_2, coarse particulate matter (PMC), fine particulate matter ($PM_{2.5}$), and NH_3. The units are tons per year (tpy).

Table 2-2. NPL 2008 Base Year Emissions Summary: 36-km Grid (U.S.)

Category	VOC (tpy)	NO_x (tpy)	CO (tpy)	SO_2 (tpy)	PMC (tpy)	$PM_{2.5}$ (tpy)	NH_3 (tpy)
EGU points	41,950	3,363,272	704,919	9,151,792	107,804	330,137	25,469
Non-EGU points	1,044,167	2,067,039	2,933,115	1,583,900	174,214	410,327	67,741
Area (non-point)	6,927,179	1,499,564	11,673,037	461,597	3,809,976	2,615,564	3,896,910
Non-road	2,493,949	3,349,093	18,046,297	255,776	13,201	231,994	2,481
On-road	3,042,122	7,429,653	37,278,146	39,188	82,164	283,274	139,009
Oil & gas	563,045	130,648	56,727	2,516	79	3,211	0
Total	**14,112,412**	**17,839,269**	**70,692,242**	**11,494,769**	**4,187,439**	**3,874,508**	**4,131,610**

Table 2-3. NPL 2008 Base Year Emissions Summary: 12-km Grid

Category	VOC (tpy)	NO_x (tpy)	CO (tpy)	SO_2 (tpy)	PMC (tpy)	$PM_{2.5}$ (tpy)	NH_3 (tpy)
EGU points	2,178	237,906	23,753	163,375	10,083	9,691	838
Non-EGU points	92,722	139,057	120,710	50,029	27,567	31,089	1,758
Area (non-point)	182,786	26,596	254,831	6,223	293,142	88,576	213,716
Non-road	86,863	152,920	611,688	5,534	567	9,687	112
On-road	91,215	231,232	1,190,232	1,665	2,151	8,447	3,973
Oil & gas	387,645	55,798	32,095	1,567	79	2,734	0
Total	**843,409**	**843,508**	**2,233,309**	**228,393**	**333,589**	**150,224**	**220,398**

Table 2-4. NPL 2008 Base Year Emissions Summary: 4-km Grid

Category	VOC (tpy)	NO_x (tpy)	CO (tpy)	SO_2 (tpy)	PMC (tpy)	$PM_{2.5}$ (tpy)	NH_3 (tpy)
EGU points	522	71,971	10,499	48,492	5,844	5,419	338
Non-EGU points	19,211	34,611	35,229	20,868	7,157	10,328	19
Area (non-point)	14,317	2,184	35,325	483	30,578	9,566	12,308
Non-road	19,186	22,887	108,921	836	96	1,615	18
On-road	6,553	21,833	92,715	125	156	820	293
Oil & gas	249,540	20,603	12,661	508	52	955	0
Total	**309,330**	**174,089**	**295,349**	**71,313**	**43,882**	**28,702**	**12,976**

Figure 2-1 (a) and (b) presents annual anthropogenic emission totals for VOC, NO_x, SO_2, and $PM_{2.5}$ for the 12-km and 4-km grids broken out by source category: electric generation units (EGU), point, area, non-road, and on-road sources. The figures show large contributions of area source VOCs which are associated with oil and natural gas development projects in the region. There are nearly equal contributions of NO_x emissions from these categories. The SO_2 emissions are predominantly from EGU emissions while the $PM_{2.5}$ emissions are predominantly from area sources.

Figure 2-1a. Annual Emissions for 2008 for the 12-km Grid

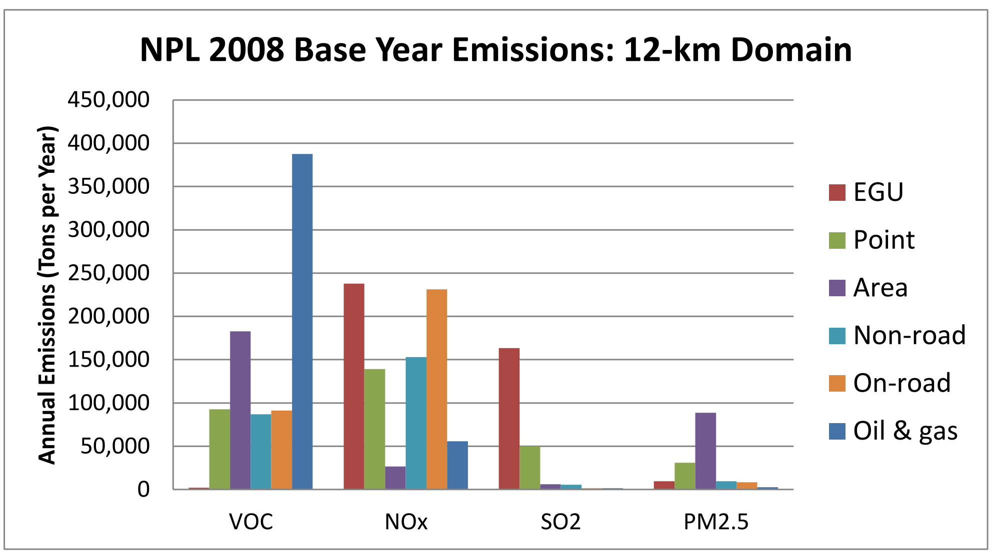
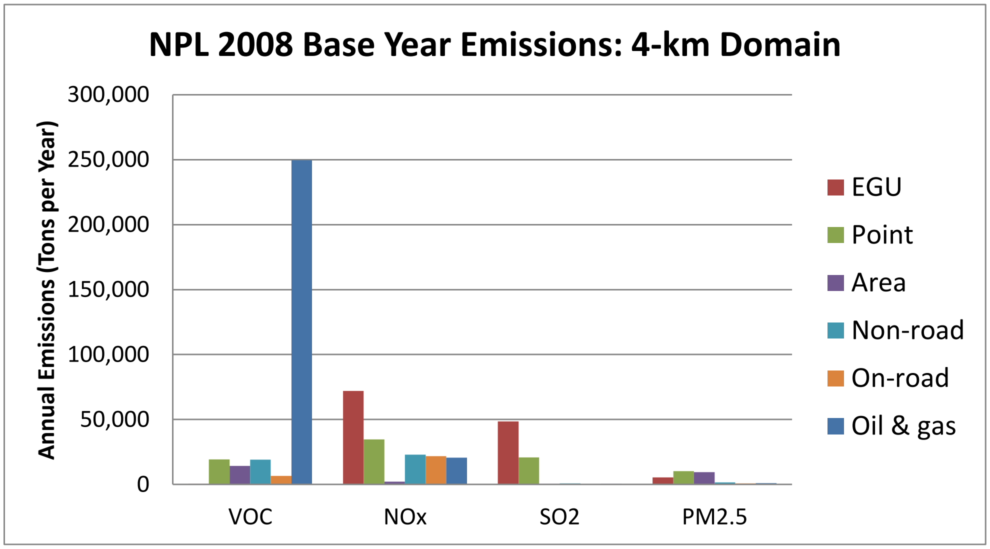


Figure 2-1b. Annual Emissions for 2008 for the 4-km Grid



To illustrate and check the reasonableness of the spatial distribution of emissions throughout the modeling domain, daily emission density plots for a selected day were prepared and examined. Figure 2-2 (a)-(f) presents daily anthropogenic emissions for the 2008 base-year inventory for July 15, 2008 for VOC, NO_x, CO, SO_2, $PM_{2.5}$, and NH_3, respectively, for the 12-km grid. The plots show that the highest emissions correspond to the locations of the major cities/population centers (Denver, Salt Lake City, Provo, etc.), major transportation corridors (I-70, I-80, I-25, etc.), as well as locations of existing energy development areas (Uintah Basin, Powder River Basin). Figure 2-3 presents biogenic VOC emissions for July 15, 2008 for the 12-km grid. The figure illustrates relatively low overall biogenic VOC emissions within the grid, but with some areas of higher emissions associated with the various forested areas of Wyoming, Colorado, Utah, Idaho, Montana, and western South Dakota.

Figure 2-2a. Daily Anthropogenic VOC Emissions (July 15, 2008) for the 12-km Grid

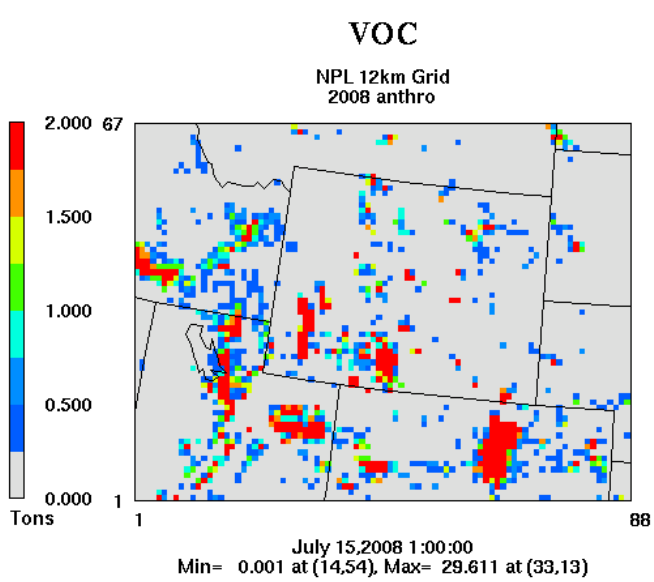


Figure 2-2b. Daily Anthropogenic NO_x Emissions (July 15, 2008) for the 12-km Grid.

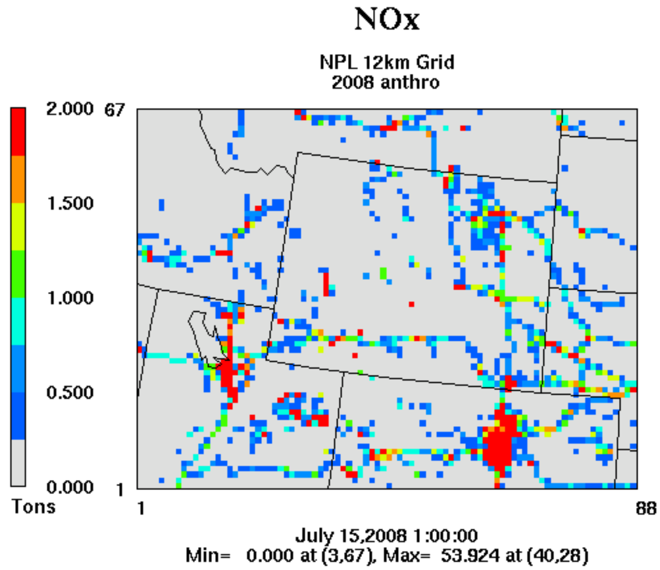


Figure 2-2c. Daily Anthropogenic CO Emissions (July 15, 2008) for the 12-km Grid

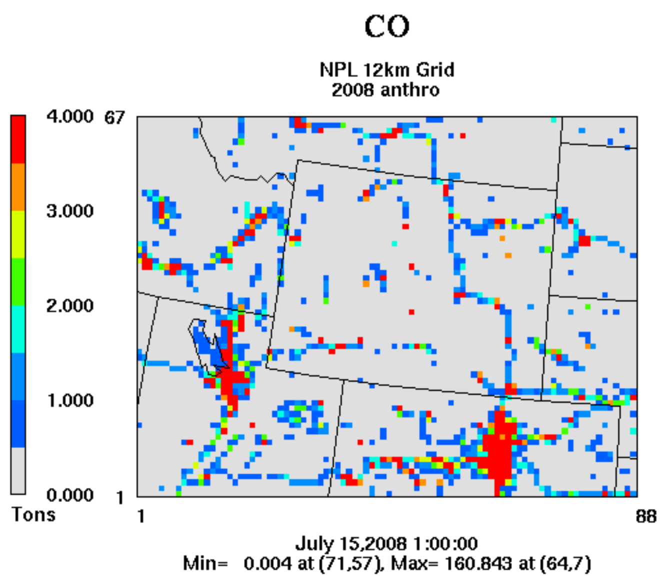


Figure 2-2d. Daily Anthropogenic SO_2 Emissions (July 15, 2008) for the 12-km Grid

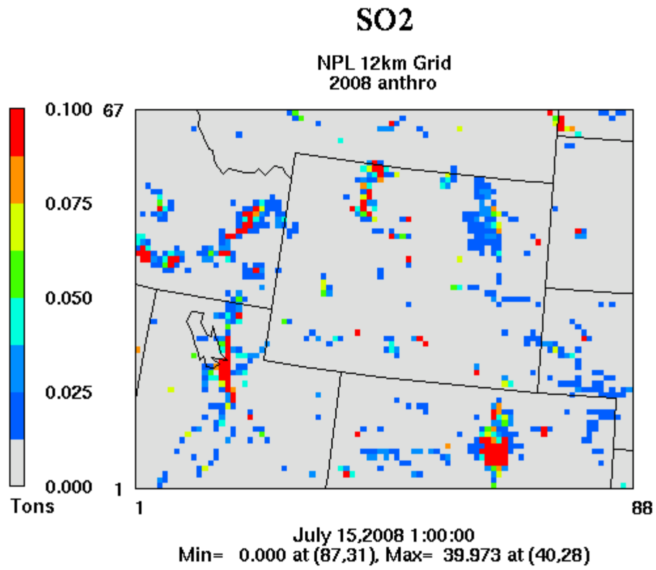


Figure 2-2e. Daily Anthropogenic $PM_{2.5}$ Emissions (July 15, 2008) for the 12-km Grid

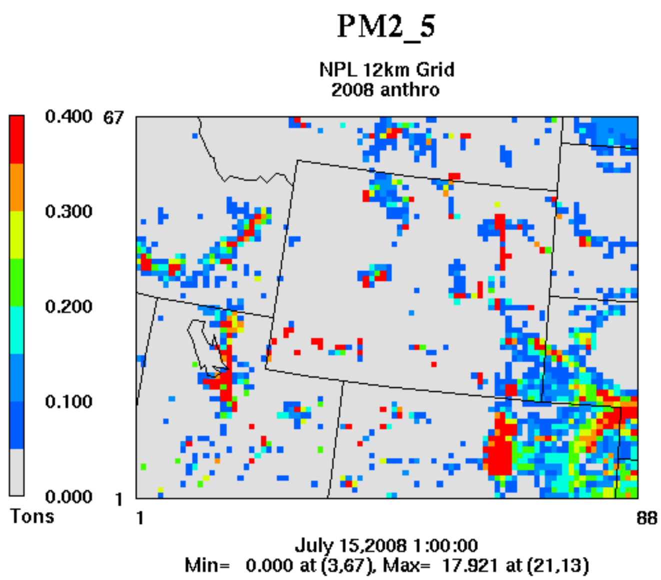


Figure 2-2f. Daily Anthropogenic NH_3 Emissions (July 15, 2008) for the 12-km Grid

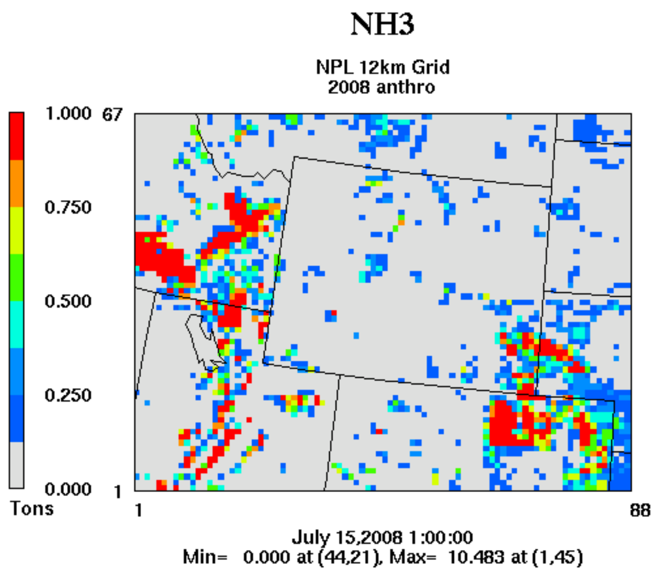
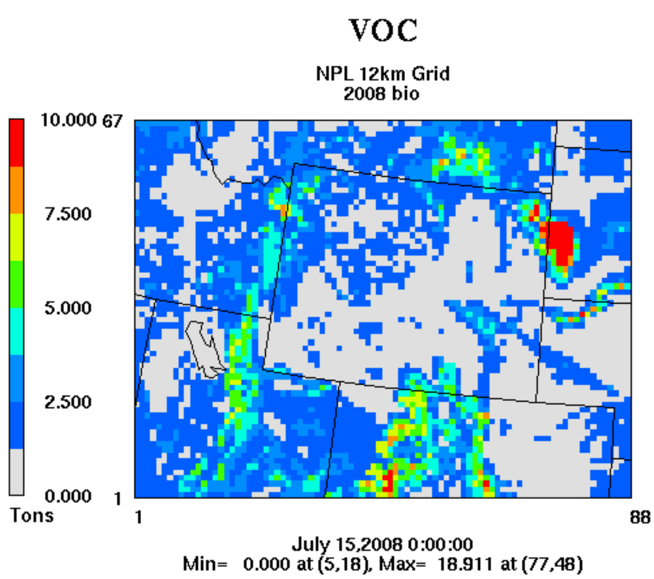


Figure 2-3. Daily Biogenic VOC Emissions (July 15, 2008) for the 12-km Grid



3.0 BASE-YEAR AIR QUALITY MODELING METHODOLOGY

The base-year modeling effort included base-year model input preparation, model performance evaluation, and establishment of a base-year (or base-case) simulation for use in the air quality assessment. For the base-year modeling effort, the CMAQ model (version 5.0) was applied for the calendar year 2008.

3.1 Description of the CMAQ Model

The CMAQ model is a state-of-the-science, regional air quality modeling system that can be used to simulate the physical and chemical processes that govern the formation, transport, and deposition of gaseous and particulate species in the atmosphere (Byun and Ching, 1999). The CMAQ tool was designed to improve the understanding of air quality issues (including the physical and chemical processes that influence air quality) and to support the development of effective emission control strategies on both the regional and local scales. The CMAQ model was designed as a “one-atmosphere” model. This concept refers to the ability of the model to dynamically simulate ozone, particulate matter, and other species (such as mercury) in a single simulation. In addition to addressing a variety of pollutants, CMAQ can be applied to a variety of regions (with varying geographical, land-use, and emissions characteristics) and for a range of space and time scales. The latest version of CMAQ includes state-of-the-science advection, dispersion and deposition algorithms, the latest version of the Carbon Bond (CB) chemical mechanism (CB05), and diagnostic tools for assessing source apportionment.

Numerous recent applications of the model, for both research and regulatory air quality planning purposes, have focused on the simulation of ozone and $PM_{2.5}$. The CMAQ model was used by EPA to support the development of the Clean Air Interstate Rule (CAIR) (EPA, 2005). It was also used by EPA to support the second prospective analysis of the costs and benefits of the Clean Air Act (CAA) (Douglas et al., 2008).

The CMAQ model numerically simulates the physical processes that determine the magnitude, temporal variation, and spatial distribution of the concentrations of ozone and particulate species in the atmosphere and the amount, timing, and distribution of their deposition to the earth’s surface. The simulation processes include advection, dispersion (or turbulent mixing), chemical transformation, cloud processes, and wet and dry deposition. The CMAQ science algorithms are described in detail by Byun and Ching (1999).

The CMAQ model requires several different types of input files. Gridded, hourly emission inventories characterize the release of anthropogenic, biogenic, and, in some cases, geogenic emissions from sources within the modeling domain. The emissions represent both low-level and elevated sources and a variety of source categories (including, for example, point, on-road mobile, non-road mobile, area, and biogenic). The amount and spatial and temporal distribution of each emitted pollutant or precursor species are key determinants to the resultant simulated air quality values.

The CMAQ model also requires hourly, gridded input fields of several meteorological parameters including wind, temperature, mixing ratio, pressure, solar radiation, fractional cloud cover, cloud depth, and precipitation. A full list of the meteorological input parameters is provided in Byun and Ching (1999). The meteorological input fields are typically prepared using a data-assimilating prognostic meteorological model, the output of which is processed for input to the CMAQ model using version 4.1 of the Meteorology-Chemistry Interface Processor (MCIP). The prescribed meteorological conditions influence the transport, vertical mixing, and resulting distribution of the simulated pollutant concentrations. Certain meteorological parameters, such as mixing ratio, can also influence the simulated chemical reaction rates. Rainfall and near-surface meteorological characteristics govern the wet and dry deposition, respectively, of the simulated atmospheric constituents.

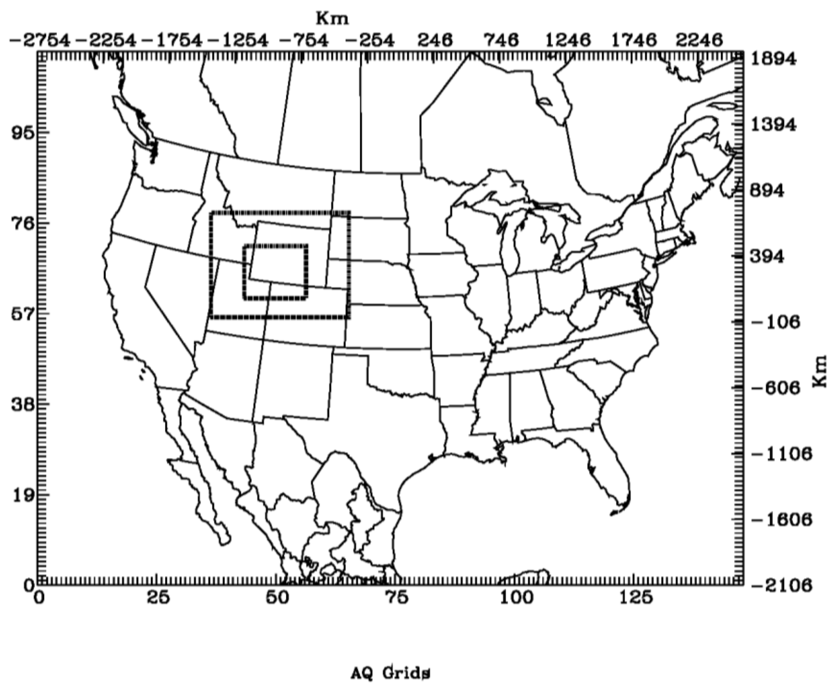
Initial and boundary condition (IC/BC) files provide information on pollutant concentrations throughout the domain for the first hour of the first day of the 10-day spin-up period for the simulation, and along the lateral boundaries of the domain for each hour of the simulation. Photolysis rates and other chemistry-related input files supply information needed by the gas-phase and particulate chemistry algorithms.

3.2 CMAQ Modeling Domain

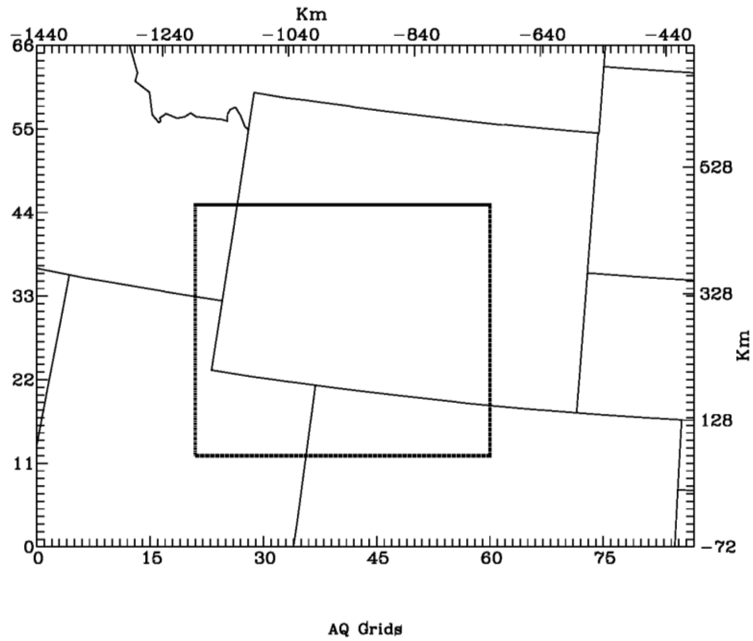
The CMAQ modeling domain was designed to accommodate both regional and subregional influences as well as to provide a detailed representation of the emissions, meteorological fields, and pollutant concentration patterns over the area of interest. The modeling domain is the same as that used for the LaBarge modeling study and is illustrated in Figure 3-1 (a)-(c).

Figure 3-1. CMAQ Modeling Domain for the NPL Air Quality Impact Assessment

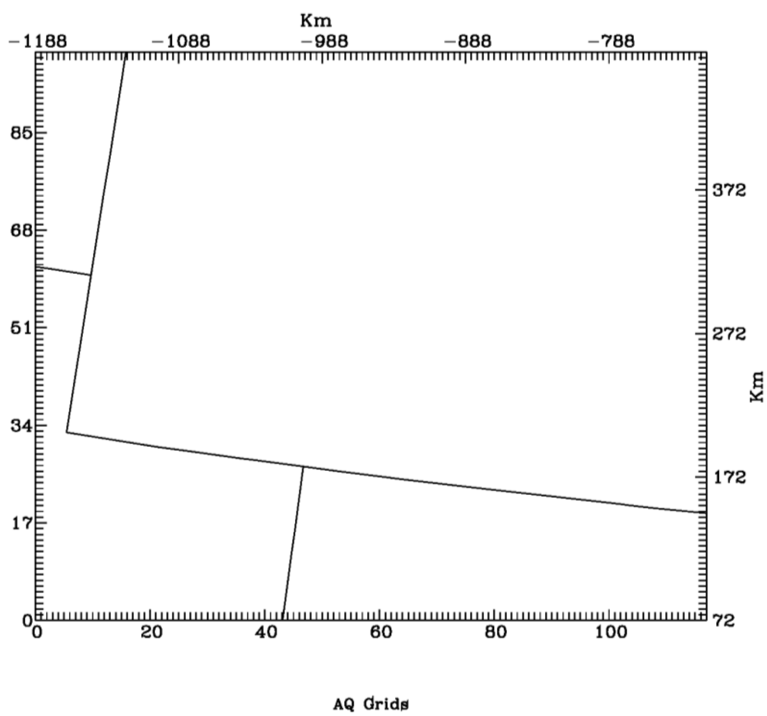
(a) 36-, 12- and 4-km Grids



(b) 12- and 4-km Grids



(c) 4-km Grid



The modeling domain includes a 36-km resolution outer grid encompassing the U.S. This domain is also referred to as the Continental U.S. or CONUS domain and has been used for numerous air quality applications conducted by EPA and Regional Planning Organizations (RPOs). The 36-km modeling grid is intended to provide model-based boundary conditions for the primary areas of interest and thus avoid some of the uncertainty introduced in the modeling results through the incomplete and sometimes arbitrary specification of boundary conditions. A one-way nesting approach was used. The 12-km grid is intended to represent the regional air quality conditions and to provide boundary conditions for the 4-km grid. The 4-km grid includes the NPL Project Area and other nearby PSD Class I and sensitive Class II areas.

The modeling grids are based on a Lambert Conformal Conic (LCC) map projection. The numbers of grid cells in the west-east and south-north directions are as follows: 36-km grid (148 x 112), 12-km grid (87 x 66), and 4-km grid (117 x 99).

In the vertical dimension, the modeling domain includes 34 layers for the months of April – October and 38 layers for January, February, March, November and December (the same layer structure that has been established for modeling studies of other, nearby project areas). The thickness of the layers increases with height above ground. The thinner layers near the surface are designed to provide enhanced resolution of the meteorological parameters and dispersion characteristics within the lowest part of the atmosphere (where they tend to be most variable) and to delineate the depth of the planetary boundary layer (PBL). Representation of the near surface meteorological characteristics and PBL depth is critical to accurate simulation of pollutant dispersion and transport. The vertical layers are presented in Tables 3-1a and b. For each layer, the table lists the sigma value (this corresponds to the internal sigma-based, or terrain-following, coordinate system), the approximate pressure at the top of the layer, the estimated height of the top of the layer (based on standard atmospheric conditions), and the estimated depth of the layer. Units are millibars (mb) for pressure and meters (m) for layer height and depth.

Table 3-1a. Vertical Layer Structure for the CMAQ Modeling Domain for the NPL Air Quality Impact Assessment (34 Layers)

Layer	Sigma	Pressure (mb)	Height (m)	Depth (m)
34	0.000	100	14,662	1,840
33	0.050	145	12,822	1,466
32	0.100	190	11,356	1,228
31	0.150	235	10,127	1,062
30	0.200	280	9,066	939
29	0.250	325	8,127	843
28	0.300	370	7,284	767
27	0.350	415	6,517	705
26	0.400	460	5,812	652
25	0.450	505	5,160	607
24	0.500	550	4,553	569
23	0.550	595	3,984	536
22	0.600	640	3,448	506
21	0.650	685	2,942	480
20	0.700	730	2,462	367
19	0.740	766	2,095	267

Table 3-1a. Vertical Layer Structure for the CMAQ Modeling Domain for the NPL Air Quality Impact Assessment (34 Layers)

Layer	Sigma	Pressure (mb)	Height (m)	Depth (m)
18	0.770	793	1,828	259
17	0.800	820	1,569	169
16	0.820	838	1,400	166
15	0.840	856	1,234	163
14	0.860	874	1,071	160
13	0.880	892	911	158
12	0.900	910	753	78
11	0.910	919	675	77
10	0.920	928	598	77
9	0.930	937	521	76
8	0.940	946	445	76
7	0.950	955	369	75
6	0.960	964	294	74
5	0.970	973	220	74
4	0.980	982.0	146	37
3	0.985	986.5	109	37
2	0.990	991.0	72	37
1	0.995	995.5	36	36
Ground	1.000	1000	0	0

Table 3-1b. Vertical Layer Structure for the CMAQ Modeling Domain for the NPL Air Quality Impact Assessment (Lowest 8 Layers of 38 Layers)

Layer	Sigma	Pressure (mb)	Height (m)	Depth (m)
8	0.9800	982.0	146	37
7	0.9850	986.5	109	36
6	0.9900	991.0	73	20
5	0.9930	993.7	53	17
4	0.9950	995.5	36	12
3	0.9968	997.1	24	10
2	0.9982	998.4	14	8
1	0.9992	999.3	6	6
Ground	1.0000	1000.0	0	0

3.3 Air Quality Assessment Areas

The criteria pollutant assessment was performed for all monitoring sites and unmonitored areas located within in the NPL CMAQ 4-km grid.

The AQRV assessment considered PSD Class I areas and sensitive Class II areas located within and near the 4-km grid. Within the 4-km grid, these include:

- Bridger Wilderness Area, Wyoming (Class I)
- Fitzpatrick Wilderness Area, Wyoming (Class I)
- Popo Agie Wilderness Area, Wyoming (Class II)
- Wind River Roadless Area, Wyoming (Class II)
- Savage Run Wilderness Area, Wyoming (Federal Class II, Wyoming Class I)
- Mount Zirkel Wilderness Area, Colorado (Class I)
- Rawah Wilderness Area, Colorado (Class I)
- Dinosaur National Monument, Colorado-Utah (Federal Class II, Colorado Class I (SO_2 only)

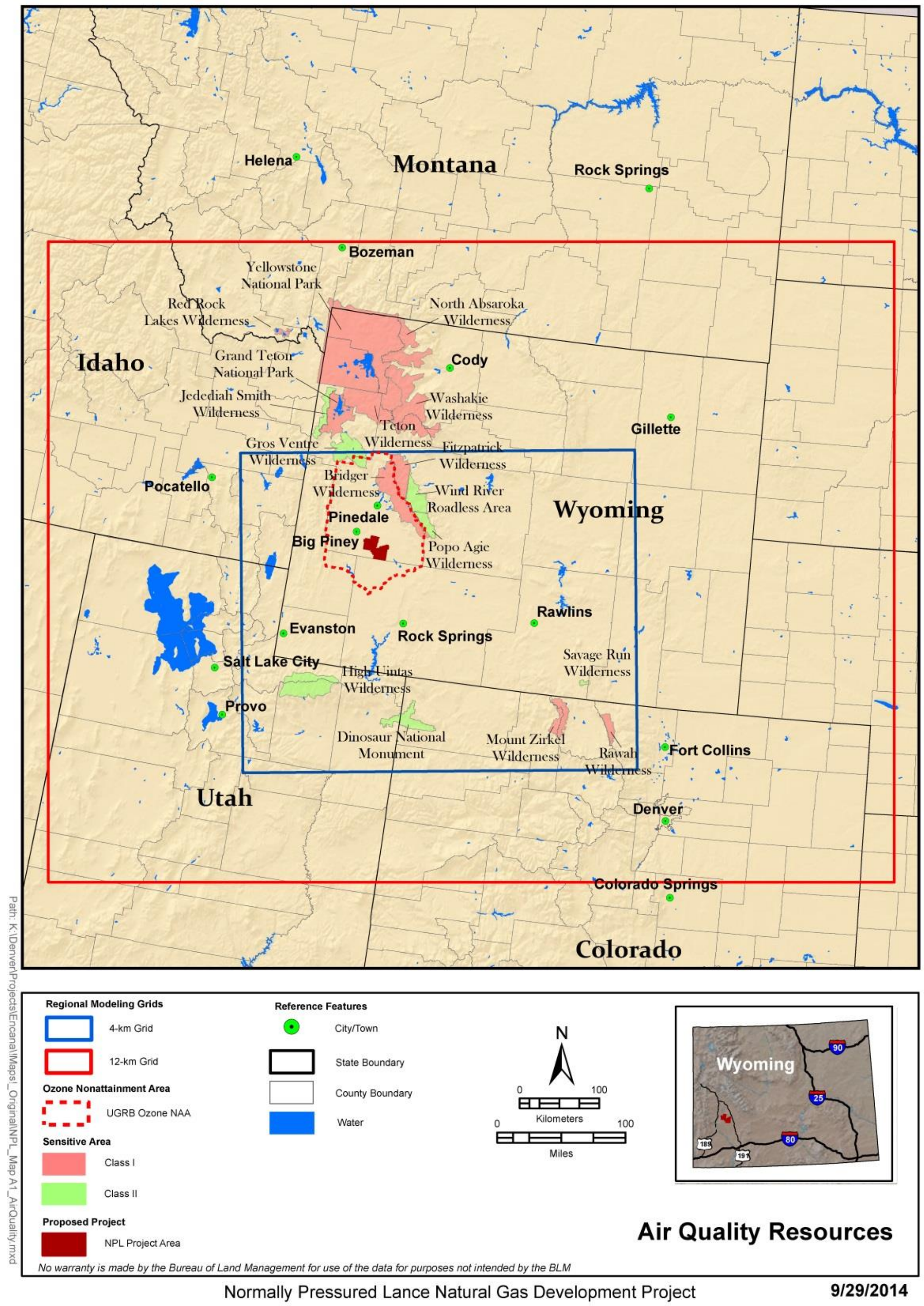
Additional areas located in the 12-km grid include:

- Yellowstone National Park, Wyoming (Class I)
- Grand Teton National Park, Wyoming (Class I)
- Teton Wilderness Area, Wyoming (Class I)
- Washakie Wilderness Area, Wyoming (Class I)
- Red Rock Lakes Wilderness Area, Montana (Class I)
- North Absaroka Wilderness Area, Wyoming (Class II)
- Gros Ventre Wilderness Area, Wyoming (Class II)
- Jedediah Smith Wilderness Area, Wyoming (Class II)
- High Uintas Wilderness Area, Utah (Class II)

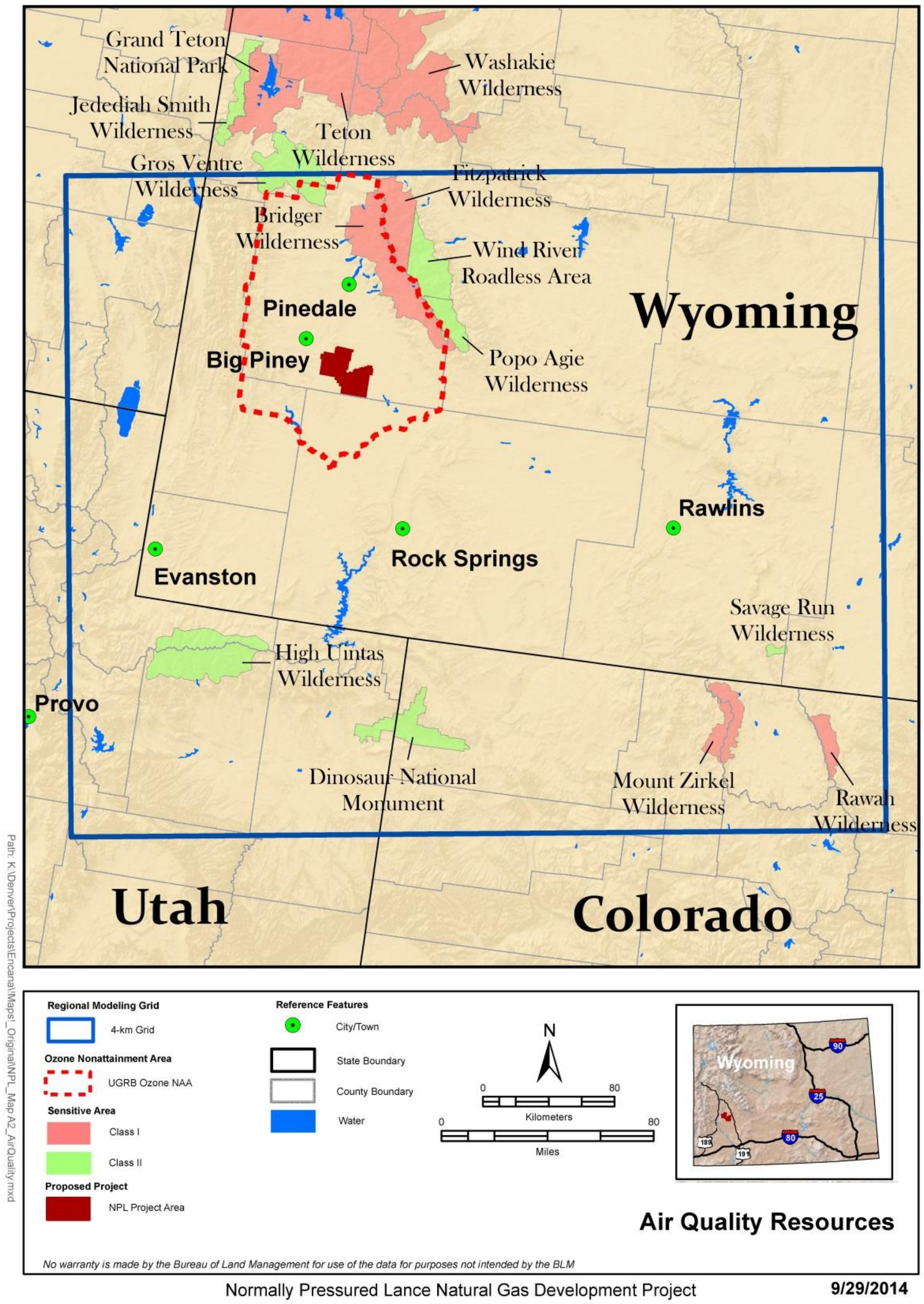
Figure 3-2 (a) and (b) illustrate the locations of these areas within the 12- and 4-km grids, respectively. The maps also depict the boundaries of the designated Upper Green River Basin (UGRB) ozone nonattainment area, which encompasses the NPL Project Area. In 2010, the Governor of Wyoming recommended to EPA that all of Sublette County and portions of adjacent Lincoln and Sweetwater Counties be designated a non-attainment area for ozone based on data collected during the winter periods of 2007, 2008, and 2009. On April 30, 2012, EPA issued final area designations for the 2008 8-hour average ozone standard and formalized the designation of this area as a Marginal ozone nonattainment area.

Figure 3-2. Location of National Parks and Wilderness Areas within the NPL CMAQ Modeling Domain

(a) 12- and 4-km Grids



(b) 4-km Grid

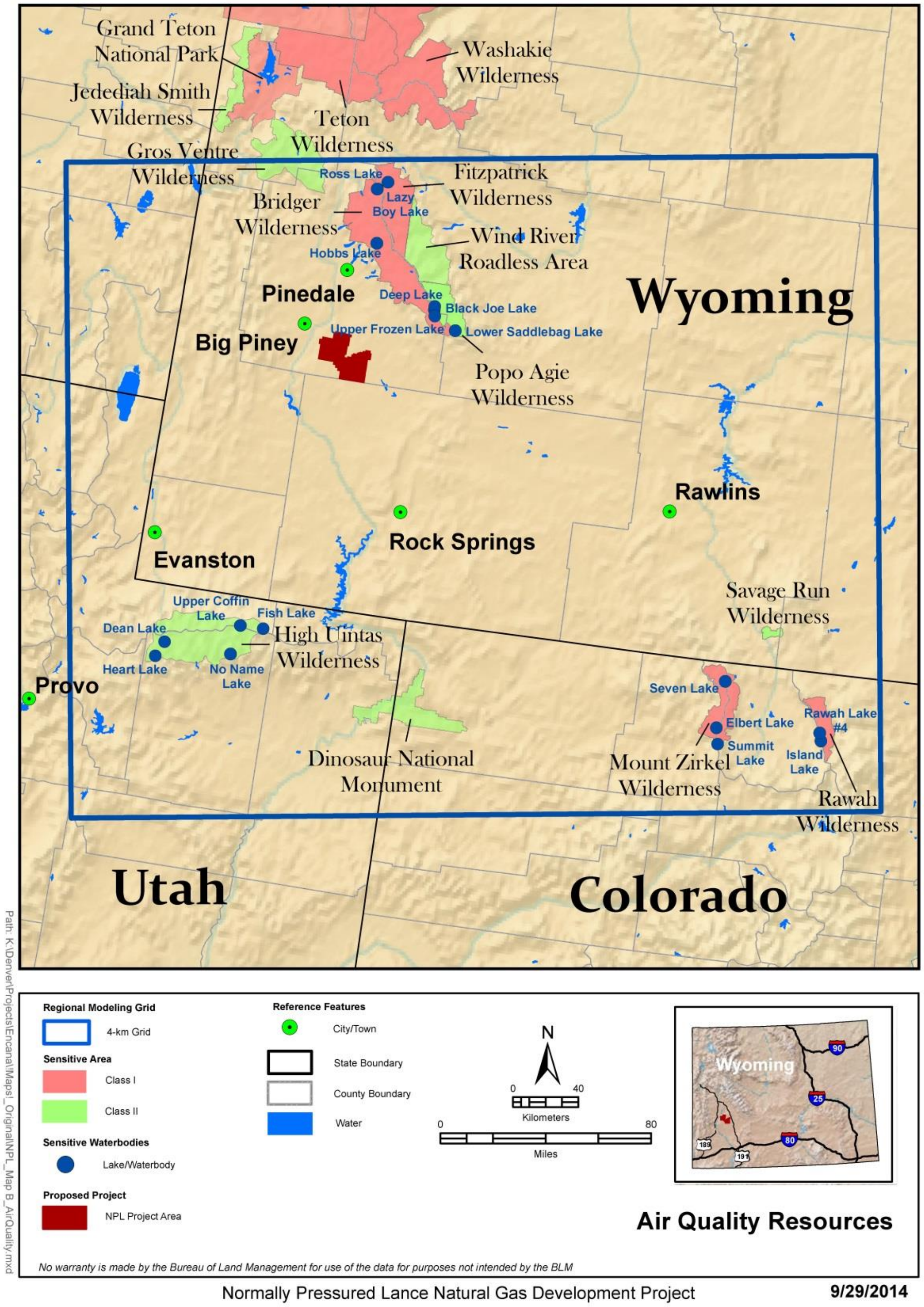

Grand Teton National Park
Washakie Wilderness
Jedediah Smith Wilderness
Teton Wilderness
Gros Ventre Wilderness
Fitzpatrick Wilderness
Bridger Wilderness
Wind River Roadless Area
Wyoming
Pinedale
Big Piney
Popo Agie Wilderness
Rawlins
Rock Springs
Evanston
Savage Run Wilderness
High Uintas Wilderness
Provo
Dinosaur National Monument
Mount Zirkel Wilderness
Rawah Wilderness
Utah
Colorado
Path: K:\Denver\Projects\Encana\Maps_Original\NPL_Map A2_AirQuality.mxd
Regional Modeling Grid
4-km Grid
Ozone Nonattainment Area
UGRB Ozone NAA
Sensitive Area
Class I
Class II
Proposed Project
NPL Project Area
Reference Features
City/Town
State Boundary
County Boundary
Water
N
0
80
Kilometers
0
80
Miles
Wyoming
Air Quality Resources
No warranty is made by the Bureau of Land Management for use of the data for purposes not intended by the BLM
Normally Pressured Lance Natural Gas Development Project
9/29/2014

In addition, 17 lakes within the sensitive PSD Class I and Class II Wilderness areas lakes are designated acid sensitive and the assessment examined potential lake acidification from atmospheric deposition impacts for these lakes including:

- Deep Lake in the Bridger Wilderness Area, Wyoming
- Black Joe Lake in the Bridger Wilderness Area, Wyoming
- Lazy Boy Lake in the Bridger Wilderness Area, Wyoming
- Upper Frozen Lake in the Bridger Wilderness Area, Wyoming
- Hobbs Lake in the Bridger Wilderness Area, Wyoming
- Ross Lake in the Fitzpatrick Wilderness Area, Wyoming
- Lower Saddlebag Lake in the Popo Agie Wilderness Area, Wyoming
- Dean Lake in the High Uintas Wilderness, Utah
- Heart Lake in the High Uintas Wilderness, Utah
- No Name (Duchesne – 4d2-039) Lake in the High Uintas Wilderness, Utah
- Fish Lake in the High Uintas Wilderness, Utah
- No Name (Duchesne – 4d1-044) Lake in the High Uintas Wilderness, Utah
- Lake Elbert in the Mt. Zirkel Wilderness, Colorado
- Seven Lakes in the Mt. Zirkel Wilderness, Colorado
- Summit Lake in the Mt. Zirkel Wilderness, Colorado
- Island Lake in the Rawah Wilderness, Colorado
- Rawah Lake #4 in the Rawah Wilderness, Colorado

Figure 3-3 illustrates the locations of these areas within the 4-km grid.

Figure 3-3. Location of Sensitive Lakes within the NPL CMAQ 4-km Modeling Grid



3.4 Air Quality, Meteorological, and Deposition Data

A variety of aerometric and deposition data were used to support the far-field modeling analysis and air quality assessment. The primary databases used in this analysis, including data sources, availability, and use are presented in this subsection.

3.4.1 Ambient Air Quality Monitoring Sites

Ambient air quality data were used in the evaluation of air quality model performance and will be used in the assessment of air quality impacts. Ozone, PM, NO_x, SO_2 and CO data were obtained from the EPA Air Quality System (AQS) dataset and, as needed, the WY DEQ data archives. Additional $PM_{2.5}$ data were obtained from the Interagency Monitoring of PROtected Visual Environments (IMPROVE) monitoring network datasets. Clean Air Status and Trends Network (CASTNet) data were also obtained.

There are nearly 175 criteria pollutant monitoring sites within the NPL CMAQ 12-km modeling grid and approximately 20 monitoring sites within the 4-km grid. A list of air quality monitoring sites for criteria pollutants within the 4-km modeling grid is provided in Table 3-2. The sites are organized by dataset and then alphabetically or numerically by site identifier (ID). Additional information in the table includes the county or site name, state, location (latitude and longitude), and measured species.

Table 3-2. Air Quality Monitoring Sites within the NPL CMAQ 4-km Modeling Grid

Site ID	County or Site Name	State	Latitude (Degrees)	Longitude (Degrees)	CO	NO_X	O_3	SO_2	$PM_{2.5}$	PM_{10}
AQS										
160290031	Caribou Co	ID	42.6950	-111.594				X		
490471002	Uintah Co	UT	40.4370	-109.305			X			
560070099	Carbon Co	WY	41.5356	-107.546		X	X			
560130099	Fremont Co	WY	42.3148	-108.431		X	X			X
560131003	Fremont Co	WY	42.8411	-108.736					X	
560250001	Natrona Co	WY	42.8510	-106.330						X
560350098	Sublette Co	WY	42.4294	-109.696		X	X			X
560350099	Sublette Co	WY	42.7206	-109.753		X	X			X
560350100	Sublette Co	WY	42.7926	-110.056		X	X			X
560350705	Sublette Co	WY	42.8705	-109.861					X	
560370007	Sweetwater Co	WY	41.5916	-109.221					X	
560370010	Sweetwater Co	WY	41.6458	-109.929						X
560370200	Sweetwater Co	WY	41.4066	-108.145		X	X	X		X
560410101	Uinta Co	WY	41.3731	-111.042	X	X	X	X		X

Table 3-2. Air Quality Monitoring Sites within the NPL CMAQ 4-km Modeling Grid

Site ID	County or Site Name	State	Latitude (Degrees)	Longitude (Degrees)	CO	NO_X	O_3	SO_2	$PM_{2.5}$	PM_{10}
CASTNET										
CENTNL	Centennial	WY	41.3722	-106.242			X			
PINEDL	Pinedale	WY	42.9288	-109.788			X			
IMPROVE										
Site ID	**Site Name**	**State**	**Latitude (Degrees)**	**Longitude (Degrees)**	**Speciated $PM_{2.5}$ Data**					
BRID	Bridger Wilderness	WY	42.9749	-109.758	X					
MOZI	Mount Zirkel Wilderness	CO	40.5383	-106.677	X					

The data sources for each dataset are as follows:

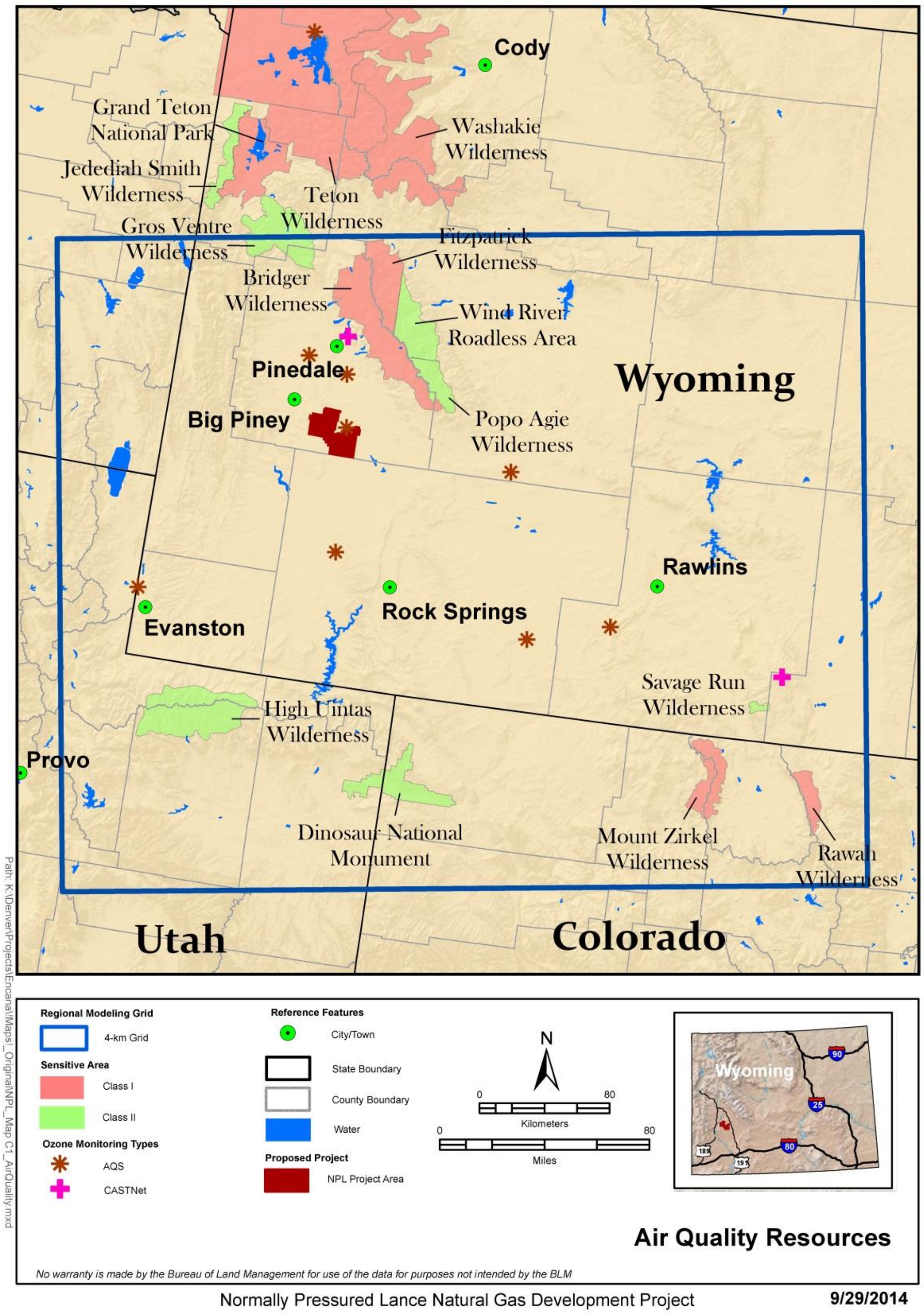
- AQS: http://www.epa.gov/ttn/airs/airsaqs/detaildata/downloadaqsdata.htm
- CASTNET: http://java.epa.gov/castnet/datatypepage.do?reportTypeLabel=Measurement%20(Raw%20Data)&reportTypeId=REP_001
- IMPROVE: http://views.cira.colostate.edu/web/
- Other: http://deq.state.wy.us/aqd/

Note that all WY DEQ sites (previously listed separately in the protocol document) are included in the EPA AQS database. Thus, these sites were listed twice in the similar table in the protocol document. In the remainder of the report, we refer to these sites as AQS sites and/or by name. Also note that the number of sites has been updated from the protocol to reflect actual data availability for 2008.

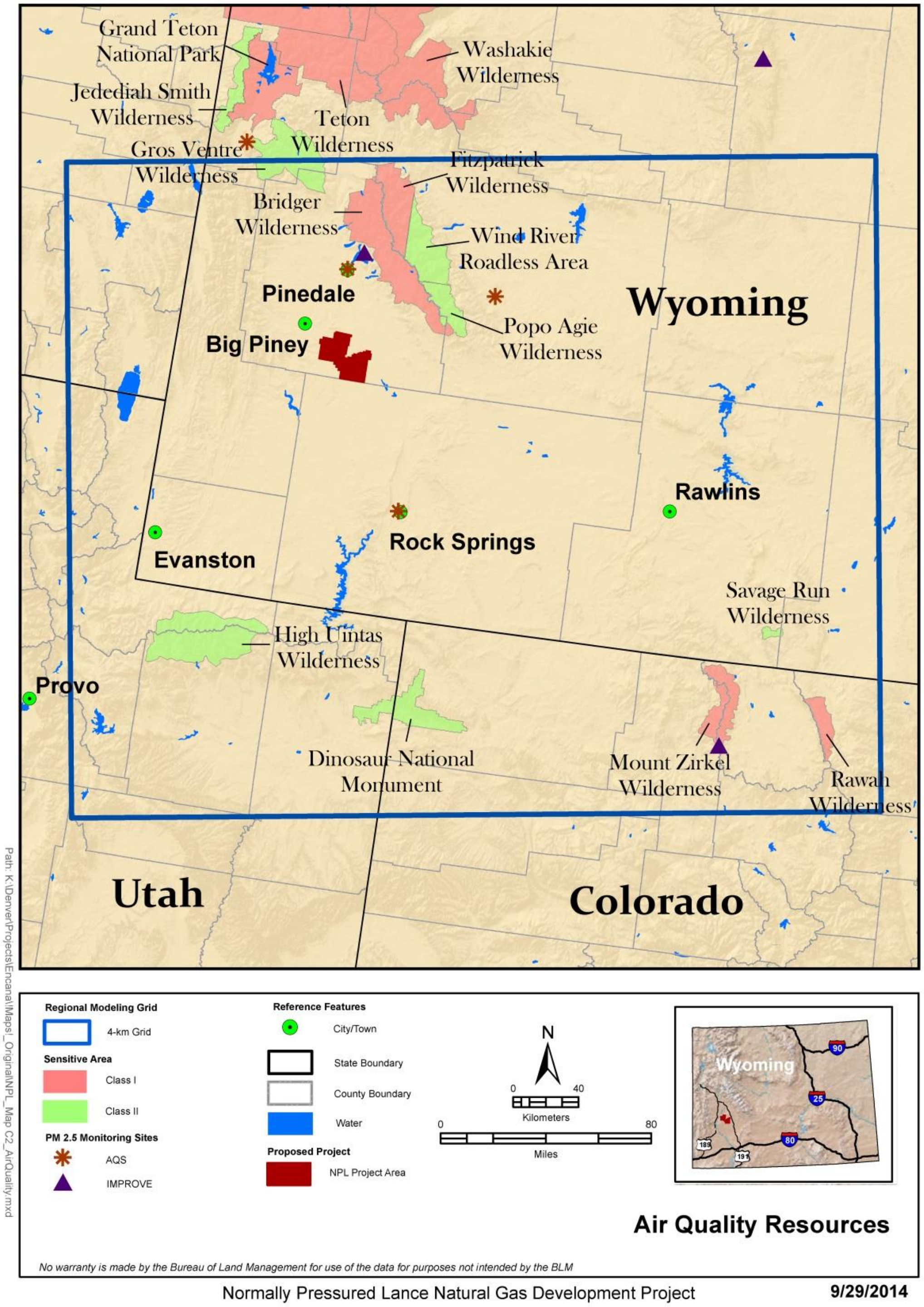
The locations of the ozone and $PM_{2.5}$ monitoring sites located within or near the NPL CMAQ 4-km grid are illustrated in Figures 3-4 (a) and (b). The monitoring sites are displayed using different symbols for each monitoring network.

Figure 3-4. Location of Criteria Pollutant Monitoring Sites within or in the Vicinity of the NPL CMAQ 4-km Modeling Grid

(a) Ozone



(b) $PM_{2.5}$


Grand Teton National Park
Washakie Wilderness
Jedediah Smith Wilderness
Teton Wilderness
Gros Ventre Wilderness
Fitzpatrick Wilderness
Bridger Wilderness
Wind River Roadless Area
Pinedale
Wyoming
Popo Agie Wilderness
Big Piney
Rawlins
Rock Springs
Evanston
Savage Run Wilderness
High Uintas Wilderness
Provo
Dinosaur National Monument
Mount Zirkel Wilderness
Rawah Wilderness
Utah
Colorado
Path: K:\Denver\Projects\Encana\Maps_Original\NPL_Map C2_AirQuality.mxd
Regional Modeling Grid
4-km Grid
Sensitive Area
Class I
Class II
PM 2.5 Monitoring Sites
AQS
IMPROVE
Reference Features
City/Town
State Boundary
County Boundary
Water
Proposed Project
NPL Project Area
N
0
40
Kilometers
0
80
Miles
Wyoming
90
25
80
189
191
Air Quality Resources
No warranty is made by the Bureau of Land Management for use of the data for purposes not intended by the BLM
Normally Pressured Lance Natural Gas Development Project
9/29/2014

3.4.2 Deposition Monitoring Sites

Deposition measurements from the CASTNet and National Acid Deposition Program (NADP) monitoring networks were used in the evaluation of deposition for selected species.

A list of deposition monitoring sites is given in Table 3-3. All sites located within the NPL CMAQ 4-km modeling grid are included in the list. The sites are organized by dataset and then alphabetically by site ID. The table also includes the site name and location (latitude and longitude).

Table 3-3. Deposition Monitoring Sites within the NPL CMAQ 4-km Modeling Grid

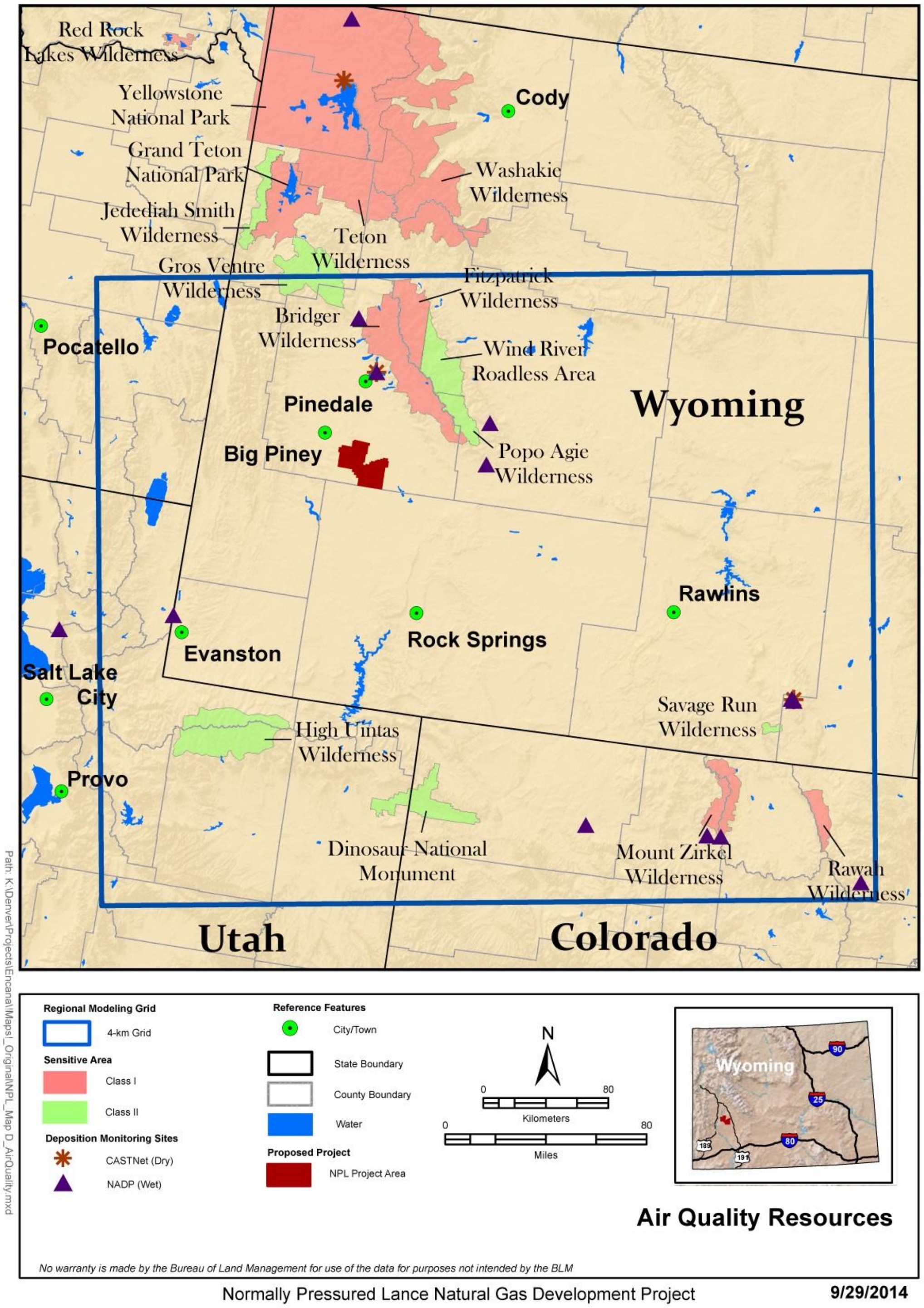
Site ID	County or Site Name	State	Latitude (Degrees)	Longitude (Degrees)
CASTNET				
CENTNL	Centennial	WY	41.3722	-106.242
PINEDL	Pinedale	WY	42.9288	-109.788
NADP				
CO15	Sand Spring	CO	40.5075	-107.702
CO19	Rocky Mountain National Park	CO	40.3642	-105.582
CO93	Buffalo Pass – Dry Lake	CO	40.5347	-106.780
CO95	Buffalo Pass – Summit Lake	CO	40.5378	-106.676
UT08	Murphy Ridge	UT	41.3575	-111.049
WY00	Snowy Ridge	WY	41.3761	-106.259
WY02	Sinks Canyon	WY	42.7339	-108.850
WY06	Pinedale	WY	42.9289	-109.787
WY95	Brooklyn Lake	WY	41.3647	-106.241
WY97	South Pass City	WY	42.4947	-108.829
WY98	Gypsum Creek	WY	43.2228	-109.991

The data sources for each dataset are as follows:

- CASTNET: http://java.epa.gov/castnet/datatypepage.do?reportTypeLabel=Measurement%20(Raw%20Data)&reportTypeId=REP_001
- NADP: http://nadp.sws.uiuc.edu/NTN/ntnData.aspx

The locations of the monitoring sites located within or near the CMAQ 4-km modeling grid are illustrated in Figure 3-5. The monitoring sites for each deposition species are displayed using different symbols for each monitoring network.

Figure 3-5. Location of Deposition Monitoring Sites within or in the Vicinity of the NPL CMAQ 4-km Modeling Grid



3.5 Input Preparation

3.5.1 Meteorological Input Preparation

The CMAQ model requires hourly, gridded input fields of several meteorological parameters including wind, temperature, mixing ratio, pressure, solar radiation, fractional cloud cover, cloud depth, and precipitation. A full list of the meteorological input parameters is given in Byun and Ching (1999). The meteorological input fields are typically prepared using a data-assimilating, prognostic meteorological model, the output of which is processed for input to the CMAQ model. The prescribed meteorological conditions influence the transport, vertical mixing, and resulting distribution of the simulated pollutant concentrations. Certain meteorological parameters, such as mixing ratio, can also influence the simulated chemical reaction rates. Precipitation and near-surface meteorological characteristics govern the wet and dry deposition, respectively, of the simulated atmospheric constituents.

For this analysis, the meteorological inputs were prepared using the Weather Research and Forecasting (WRF) model (NCAR, 2010). Version 3.3.1 of the Advanced Research WRF (ARW) model was used. WRF is a state-of-the-science atmospheric modeling system designed for use in simulating meteorological fields for a broad range of scales and applications. The ARW version of the WRF model contains data assimilation capabilities which are integral to the use of the model to prepare inputs for air quality modeling of historical simulation periods. This version of the model is currently maintained by the Mesoscale and Microscale Meteorology Division of the NCAR.

The WRF model application procedures and model configuration parameters are described in detail in the meteorological modeling report (ICF, 2012) and are the same as those used for the WRF application to support the air quality modeling for the LaBarge project (AECOM, 2012).

The WRF modeling results are also evaluated and described in the meteorological modeling report (ICF 2012). Key findings from the model performance evaluation include:

- Synoptic-scale weather patterns both near the surface and aloft for the simulation period are well represented by WRF.
- The WRF-derived regional-scale precipitation patterns are generally similar to the observed patterns, but overall the precipitation amounts are lower than observed, with the exception of over Wyoming, where simulated precipitation amounts are generally slightly higher than observed.
- Snow cover for Wyoming and the surrounding states is very well represented by WRF, based on a limited number of analysis days.
- Based on data for Riverton, Wyoming, the observed vertical temperature profile is well simulated, especially during the summer months. The more complex vertical variations in the humidity and wind speed profiles are generally not as well represented. Winds aloft (above the boundary layer), however, are generally very well represented in the WRF simulation.
- For all months, average surface wind speeds and the day-to-day variations in wind speed (averaged over all sites within the 4-km grid) are well represented by the WRF model, but there is a tendency for underestimation.

- Similarly, surface wind directions and especially the changes in wind direction over time (averaged over all sites within the 4-km grid) are very well represented by the WRF model. The largest differences between the simulated and observed wind directions occur during periods of light and variable winds.
- The average diurnal, day-to-day, multi-day, monthly, and seasonal variations in temperature are well represented by the WRF model. For all months there is a tendency for the model to underestimate the maximum observed temperatures and overestimate the minimum observed temperatures.
- For most months, average surface moisture is overestimated. The model has some difficulty simulating the diurnal and day-to-day variations in moisture, especially during the summer months. However, longer term (multi-day and monthly) variations are captured by the model.
- Based on a detailed analysis for three nearby monitoring sites, the observed predominant wind directions and the distributions of wind direction are well represented by the simulated surface winds.

Considering statistical measures of model performance for the 12-km grid:

- Wind speed bias is within ±1 m/s for all months and within ±0.5 m/s for all months except July.
- Wind direction bias is within ±10 degrees for all months and within ±3 degrees for the non-winter months.
- Temperature bias is within ±0.5 K for most months and within ±1 K for all months, with the exception of December.
- Mixing ratio bias is within ±0.5 g/kg for all months, with the exception of December (0.51 g/kg).
- On average, observed meteorological conditions are well represented for the 12-km grid.

Considering statistical measures of model performance for the 4-km grid:

- Wind speed bias is within ±1 m/s for all months and within ±0.5 m/s for all but two months (April and July, for which the values are -0.53 and -0.62, respectively). The bias is negative (winds are slower than observed) for all months.
- Wind direction bias is within ±4 degrees for all months and within ±3 degrees for the non-winter months. The gross error is less than or equal to 40 degrees for all months.
- Temperature bias is within ±0.5 K for most months and within ±1.5 K for all months. For most months, temperatures are underestimated.
- Mixing ratio bias is within ±0.55 g/kg for all months, and is positive for all months except September. The gross error ranges from 0.6 to 1.4 g/kg.
- Based on the statistical measures, observed meteorological conditions within the 4-km grid are well represented.

The WRF output was postprocessed to correspond to the CMAQ modeling domain and the units and formats required by the modeling system using version 4.1 of the MCIP postprocessing software.

The meteorological fields needed for emissions processing were also prepared using MCIP. These include:

- temperature, surface pressure, radiation/cloud cover, rainfall, soil temperature, soil moisture and soil type for the calculation of the biogenic emissions; and
- temperature and relative humidity for the calculation of motor vehicle emissions

3.5.2 Emission Inventory Input Preparation

Gridded, hourly emission inventories characterize the release of anthropogenic, biogenic and, in some cases, geogenic emissions from sources within the modeling domain. The anthropogenic emissions represent both low-level and elevated sources and a variety of source categories (including, for example, point-source, on-road mobile, non-road mobile, and area-source categories). The amount and spatial and temporal distribution of each emitted pollutant or precursor species are key determinants to the resultant simulated air quality values.

For the NPL base-year, far-field modeling analysis, the modeling inventory was processed and prepared for the CMAQ modeling system with EPA's SMOKE software (Version 3.1). Various raw SMOKE emissions source sector files for 2008, which were developed for the CAMx model application by AECOM for the LaBarge EIS, were obtained and used to prepare the anthropogenic emissions for the NPL application. Biogenic emissions were estimated using MEGAN, and wildfire emissions were obtained from NCAR (UCAR, 2013). The emissions data, processing methodologies, and resulting model-ready emission inventory is described in detail in Section 2 of this report.

3.5.3 Other Input Preparation

Initial and boundary conditions (IC/BC) files provide information on pollutant concentrations throughout the domain for the first hour of the first day of the simulation, and along the lateral boundaries of the domain (each grid) for each hour of the simulation. Gridded land-use information is required for the calculation of deposition and is used by other physical and numerical process algorithms. Photolysis rates and other chemistry related input files supply information needed by the gas-phase and particulate chemistry algorithms.

For this analysis, boundary conditions for the outermost domain were prepared using output from version 8-03-02 of the GEOS-Chem model for the model year 2008. The GEOS-Chem output files were obtained from EPA (EPA, 2012b). GEOS-Chem is a global model and the output from GEOS-Chem is routinely used by EPA to prepare boundary conditions for CMAQ. Boundary condition files for CMAQ were prepared using the "gc2cmaq" software, also obtained from EPA (EPA, 2012b). Boundary conditions for the inner grids were generated as part of the CMAQ application and derived from the modeling results for the next largest outer grid within which the inner grid is nested.

Land use, photolysis rates, and other chemistry related inputs were prepared using standard CMAQ procedures and pre-processing programs.

3.6 CMAQ Application Procedures

In applying the CMAQ model, the latest versions of the CB05 gas phase chemical mechanism, the AERO6 aerosol module, and the ISOROPIA2 aqueous partitioning routine (for the partitioning of sulfate and nitrate particulate matter) were used. CMAQ v5.0 does not include a functional plume-in-grid module, so no plume-in-grid treatment was used. Photolysis rates were calculated using the updated and improved algorithm included in CMAQ v5.0. Other options and inputs were set according to EPA recommendations for this version of CMAQ and for consistency with the emissions and meteorological data prepared in previous tasks.

The annual CMAQ simulation was divided into two parts: January – June and July – December. Each simulation part includes 10 spin-up days that were added in order to reduce the influence of the initial conditions on the simulation results.

4.0 MODEL PERFORMANCE EVALUATION METHODOLOGY

An integral component of all modeling studies is the evaluation of model performance for the base-year (or base-case) simulation. The CMAQ model performance evaluation methodology was designed to examine whether the CMAQ model is able to reproduce the observed air quality and deposition characteristics of the (historical) simulation period. Sensitivity testing was used to examine the response of modeling system to changes in the inputs. In addition, the CMAQ modeling results for ozone, PM_{10}, $PM_{2.5}$, SO_2, NO_x, CO, and NH_3 concentrations and selected deposition species were compared with observed data, using a variety of graphical and statistical analysis products. The model performance evaluation procedures are consistent with EPA guidance on the use of models for air quality assessment (EPA, 2007). Version 1.1 of the Atmospheric Model Evaluation Tool (AMET) (UNC, 2008) was used to support the evaluation of the CMAQ modeling results.

4.1 Overview of the CMAQ Model Performance Evaluation Methodology

The overall objective of a model performance evaluation is to establish that the modeling system can be used reliably to predict the effects of changes in emissions on future-year air quality. Specific objectives for the NPL study include: (1) ensuring that the regional-scale modeling results provide appropriate boundary conditions for the Project Area, (2) ensuring that the pollutant concentration and deposition patterns and levels and the temporal variations in these are well represented, and (3) ensuring that the modeling system exhibits a reasonable response to changes in the inputs (and that the inputs do not contain significant biases or compensating errors). This was primarily accomplished by comparing the modeling results with observed data, using a variety of graphical and statistical analysis products. EPA guidance (EPA, 2007b) stresses the need to evaluate the model relative to how it will be used in the air quality assessment; that is in simulating the response to changes in emissions. Thus the evaluation also included a sensitivity test that was designed to test the response of the model to changes in the inputs.

Previous model performance evaluation studies found that the CAMx regional-scale model performed acceptably for ozone during the traditional summer ozone season (April-October), but poorly for the colder months with especially poor performance during the winter months. For this study, CMAQ model performance for ozone was evaluated for all months, with emphasis on April through October.

The evaluation of model performance included both qualitative and quantitative components. A sensitivity test was conducted to examine the reasonableness of the GEOS-Chem derived boundary conditions. In addition, the ability of the model to simulate seasonal differences in concentration levels and patterns, simulate the frequency distribution of concentrations associated with different types of meteorological conditions, and perform consistently and reasonably across a range of different pollutants and species was also examined.

Analysis of results for the outer (36 and 12-km resolution) domains focused on representation of the regional-scale concentration levels and patterns, as well as seasonal variations in regional-scale air quality. A more detailed analysis of the results was performed for the innermost, high-resolution (4-km) grid. This included the analysis of the magnitude and timing of site-specific concentrations and a statistical evaluation. The graphical and statistical analysis products are listed and described in this section.

4.2 Methods and Tools

4.2.1 Species and Metrics

As summarized in Section 3, ozone, PM, NO_x, SO_2, and CO data were extracted from the EPA AQS and WY DEQ datasets. Statistics were calculated using hourly concentrations, daily maximum 1-hour concentrations, daily maximum 8-hour average concentrations (ozone only), and 24-hour average concentrations. For ozone, the evaluation focused on daily maximum 8-hour average ozone for the traditional ozone season months of April through October, but all months were considered.

The $PM_{2.5}$ dataset used for this analysis consists of data from the AQS and IMPROVE monitoring networks. Statistical measures were calculated using paired daily average values of $PM_{2.5}$ and selected species for the AQS and IMPROVE data. This evaluation focused on model performance for total $PM_{2.5}$.

Finally, deposition measurements from NADP were used in the evaluation of deposition and the weekly measurements were matched with the appropriate time intervals from the model output.

For extraction of the model output and matching with the station values, concentration and deposition information was taken from the grid cell in which the monitoring site is located.

4.2.2 Graphical Analysis to Support Model Performance Evaluation

Plots and graphics were used to assess the reasonableness of the results. For selected grids, subregions and time periods:

- Spatial plots of the simulation results were used to qualitatively assess the reasonableness of the simulated spatial concentration and deposition patterns.
- Concentration and deposition time-series plots for selected monitoring sites were used to determine whether the timing and magnitude of the simulated values match the observations.
- Scatter plots were used to graphically compare the simulated and observed deposition values.
- Bias and error time-series plots were used to graphically display statistical measures of model performance and to identify any temporal patterns or trends in the model performance statistics.
- Frequency distribution comparison plots were used to examine whether overall frequency distribution of the simulated values is consistent with the frequency distribution of observed values for selected time periods (including the annual simulation period).

4.2.3 Statistical Analysis to Support Model Performance Evaluation

AMET generates a wide variety of statistical measures and graphical analysis products to facilitate the evaluation of CMAQ model performance. Table 4-1 summarizes key statistical measures that were used to quantify model performance.

Table 4-1. Definition and Description of Measures/Metrics for CMAQ Model Performance Evaluation for the NPL Air Quality Impact Assessment

Metric	Definition
# of data pairs	The number of observation/simulation data pairs
Mean observation value	The average observed concentration
Mean simulation value	The average simulated concentration
Mean bias	$\left(\frac{1}{N}\right)\sum_{l=1}^{N}(S_l - O_l)$ Where N is the number of data pairs, and S_l and O_l are the simulated and observed values at site *l*, respectively, over a given time interval.
Normalized bias	$\left(\frac{1}{N}\right)\sum_{l=1}^{N}(S_l - O_l)/O_l \cdot 100\%$
Normalized mean bias	$\sum_{l=1}^{N}(S_l - O_l)/ \sum_{l=1}^{N}O_l \cdot 100\%$
Fractional bias	$\left(\frac{1}{N}\right)\sum_{l=1}^{N}(S_l - O_l)/0.5(S_l + O_l)\cdot 100\%$
Mean error	$\left(\frac{1}{N}\right)\sum_{l=1}^{N}\lvert S_l - O_l\rvert$
Normalized error	$\left(\frac{1}{N}\right)\sum_{l=1}^{N}\lvert S_l - O_l\rvert/O_l \cdot 100\%$
Normalized mean error	$\sum_{l=1}^{N}\lvert S_l - O_l\rvert \Big/ \sum_{l=1}^{N}O_l \cdot 100\%$
Fractional error	$\left(\frac{1}{N}\right)\sum_{l=1}^{N}\lvert S_l - O_l\rvert/0.5(S_l + O_l)\cdot 100\%$
Correlation	$\left(N\left(\sum SO\right)-\left(\sum S\right)\left(\sum O\right)\right)\Big/\sqrt{\left(N\sum S^2-\left(\sum S\right)^2\right)\left(N\sum O^2-\left(\sum O\right)^2\right)}$
Index of agreement	A measure of how well the model represents the pattern of perturbation about the mean value; ranges from 0 to 1.

In calculating the statistical measures, AMET pairs the CMAQ model output with the observed data for the appropriate locations and time intervals.

4.3 Statistical Benchmarks

Statistical measures for certain pollutants were compared with model performance goals and criteria used for prior studies, as suggested in EPA guidance (EPA, 2007). For ozone, these include recommended ranges for the normalized bias and normalized error from prior (ca. 1990) EPA guidance (these are still widely used for urban- and regional-scale model performance evaluation). For $PM_{2.5}$ and related species, these include goals presented by Boylan (2005).

In keeping with current EPA guidance on model performance evaluation for ozone and $PM_{2.5}$, a “weight-of-evidence” approach involving the integrated assessment of the above information was used to qualitatively and quantitatively determine that an acceptable base-case simulation was achieved.

5.0 CMAQ MODELING RESULTS

5.1 Summary of Model Performance for Ozone

CMAQ model performance for ozone is summarized in the remainder of this section. The detailed evaluation focused on the typical ozone season months of April through October, but statistics are provided for the full annual period.

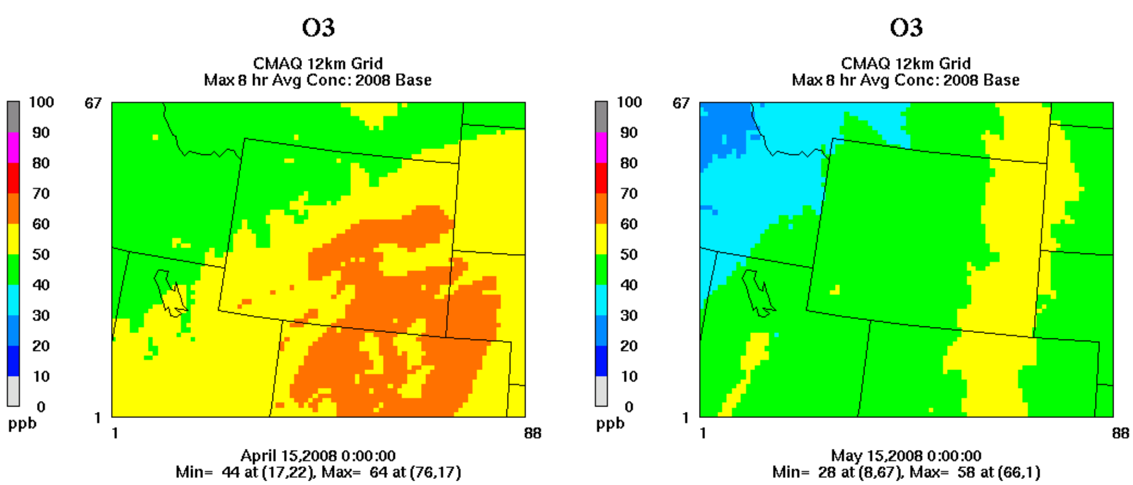
5.1.1 Regional-Scale Concentrations for the 12-km Grid

Spatial Concentration Patterns

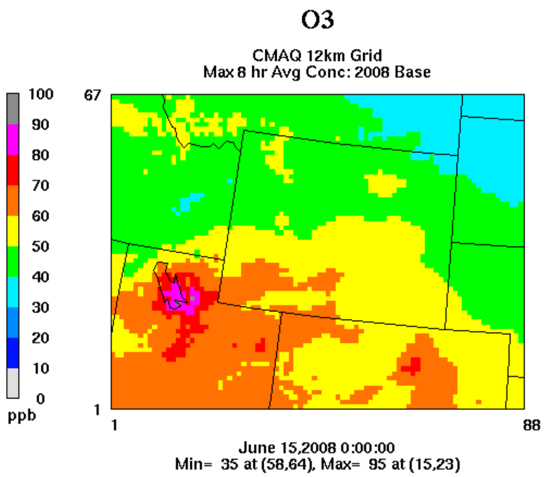
Spatial plots of the simulated ozone concentration patterns for the 12-km grid for selected days throughout the simulation period were plotted and examined. Figure 5-1 illustrates the simulated ozone concentration patterns for the 15th of each month (April – October). Consistent with the National Ambient Air Quality Standard (NAAQS) for ozone, daily maximum 8-hour average ozone concentration is displayed. The units are parts per billion (ppb).

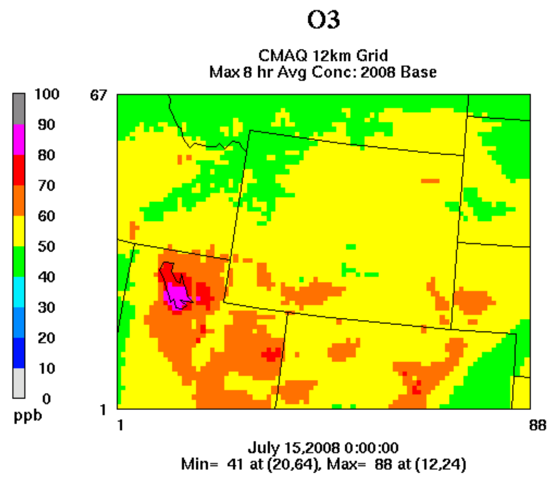
Figure 5-1. Simulated Daily Maximum 8-Hour Ozone Concentration (ppb) for Selected Days for the CMAQ 12-km Grid

April 15th/May 15th

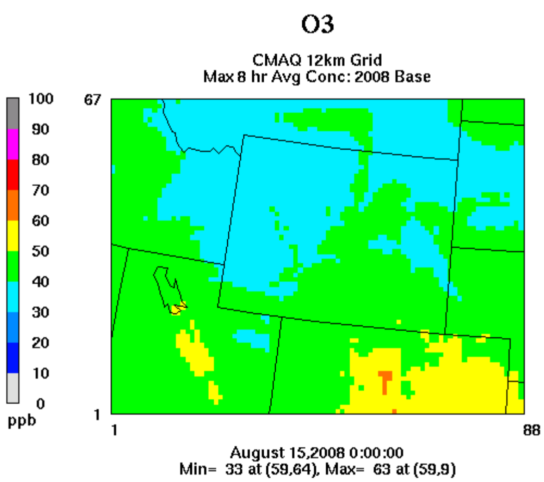


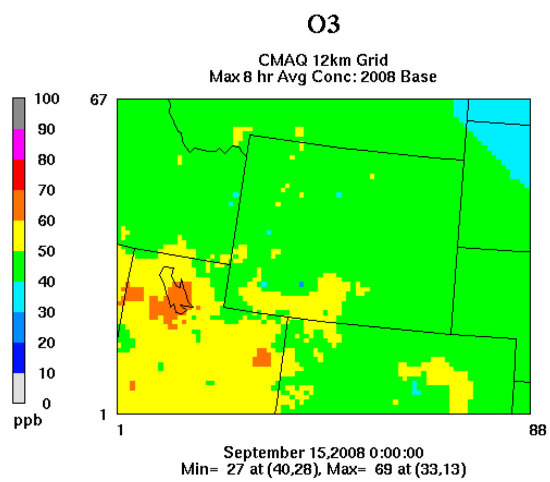
June 15th/July 15th



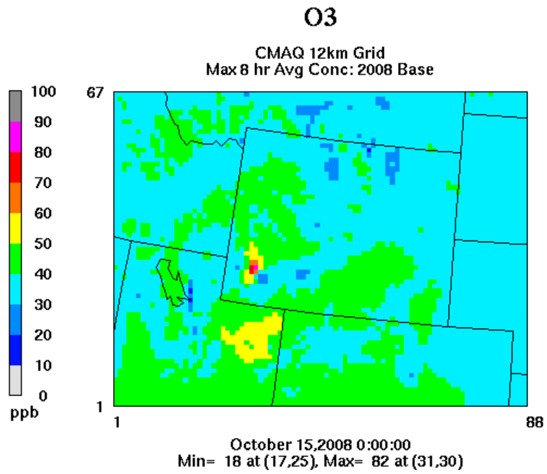


August 15th/September 15th





October 15th

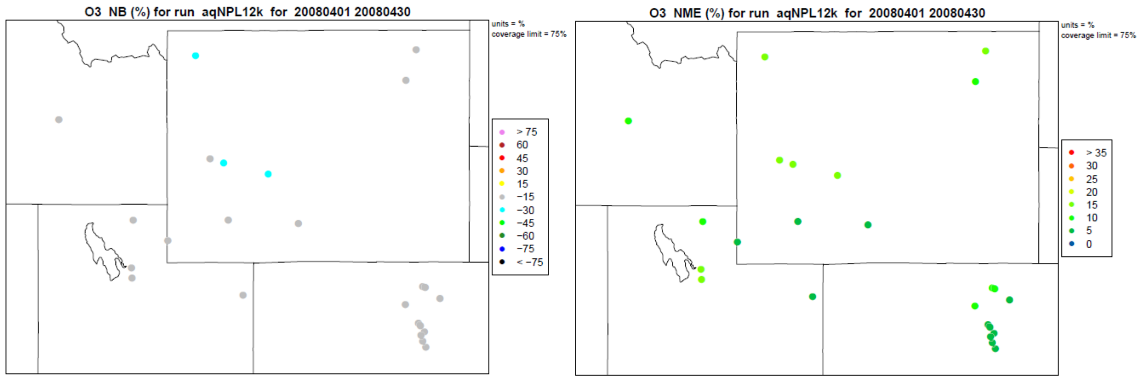


The simulated ozone concentration patterns show mostly low to moderate 8-hour average ozone concentrations over southwestern Wyoming on the selected days. Among the selected days, the highest simulated daily maximum 8-hour ozone concentration in southwestern Wyoming is 82 ppb on October 15^{th}. For several of the days (June 15^{th}, July 15^{th} and September 15^{th}) the overall maximum concentrations in the 12-km grid occur in northeastern Utah and are especially high over the Great Salt Lake.

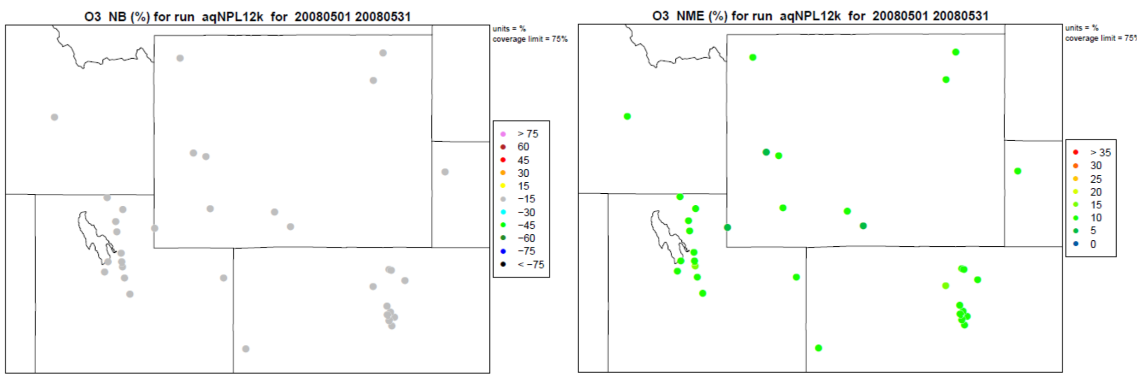
To illustrate the agreement between the simulated and observed values, Figure 5-2 depicts the monthly average bias and error for all sites in the 12-km modeling domain, based on daily maximum 8-hour ozone concentrations. Each monitoring site is represented by a circle and the shading of the circle provides information about how well the hourly observed ozone concentrations are represented by the simulation results, on average. A lower bound of 40 ppb is used in calculating the normalized bias and error statistics (that is, simulation-observation pairs are not included in the calculation if the observed value is less than 40 ppb). For the normalized bias, gray shaded circles indicate that the bias is within ± 15 percent and this corresponds to good model performance. Blue and green shading indicates underestimation of the observed concentrations and yellow, orange, and red shading indicates overestimation. For the normalized mean error, blue and green shading represent the smaller errors, while red indicates an error greater than 35 percent. Note that the number of monitoring sites varies slightly from month to month, based on data availability and that the program used to generate these plots approximates the 12-km grid, but does not represent it exactly.

Figure 5-2. Normalized Bias (%) and Normalized Mean Error (%) Based on Daily Maximum 8-Hour Average Simulated and Observed Ozone Concentrations for the CMAQ 12-km Grid

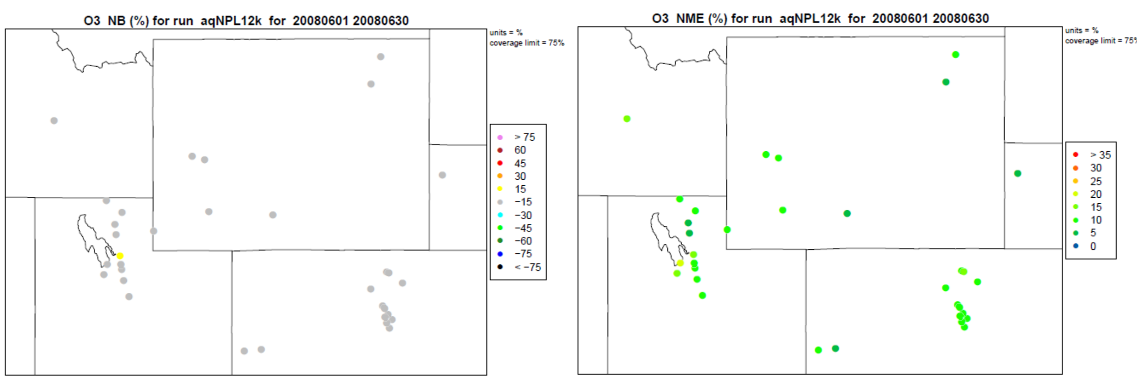
Normalized Bias (Left) and Normalized Mean Error (Right) for April



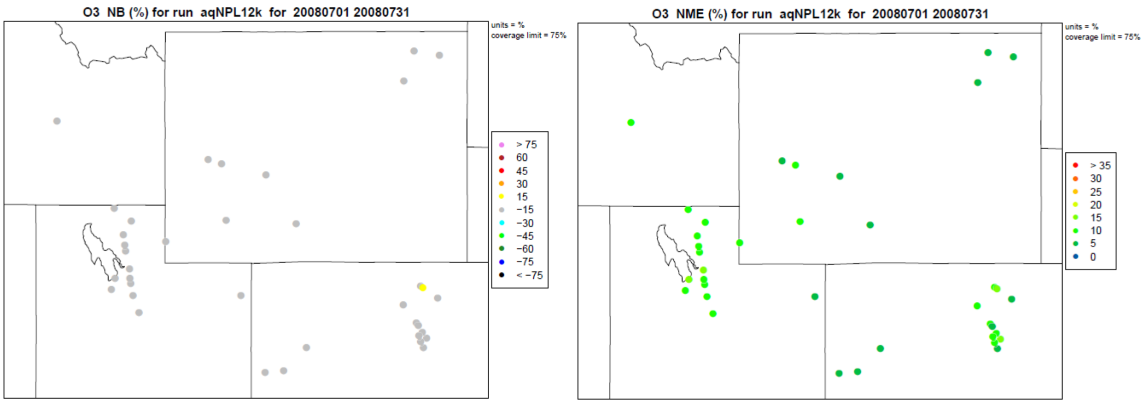
Normalized Bias (Left) and Normalized Mean Error (Right) for May



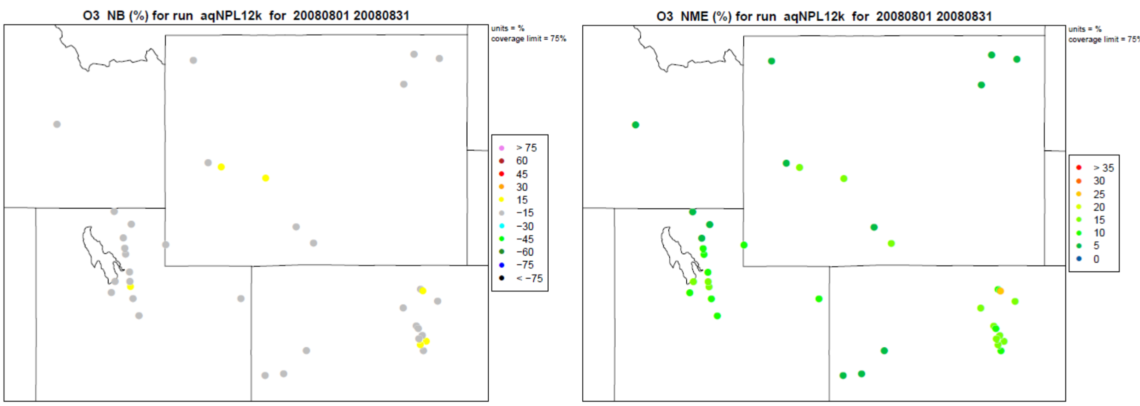
Normalized Bias (Left) and Normalized Mean Error (Right) for June



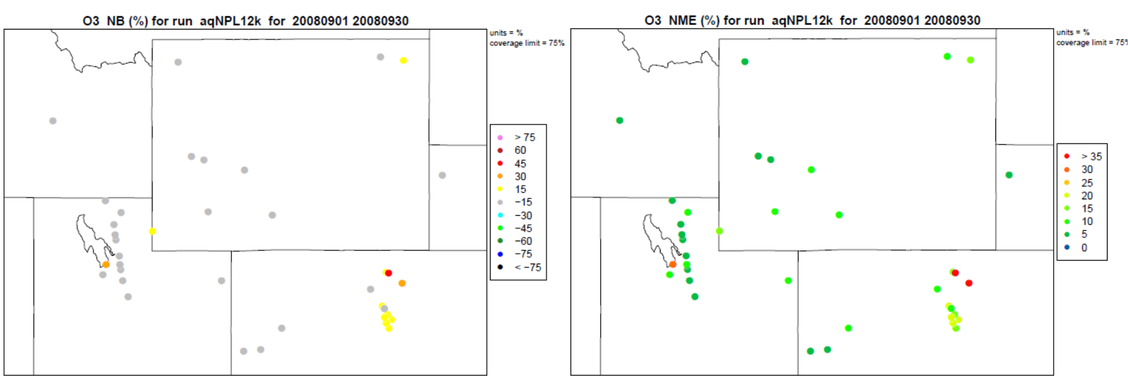
Normalized Bias (Left) and Normalized Mean Error (Right) for July



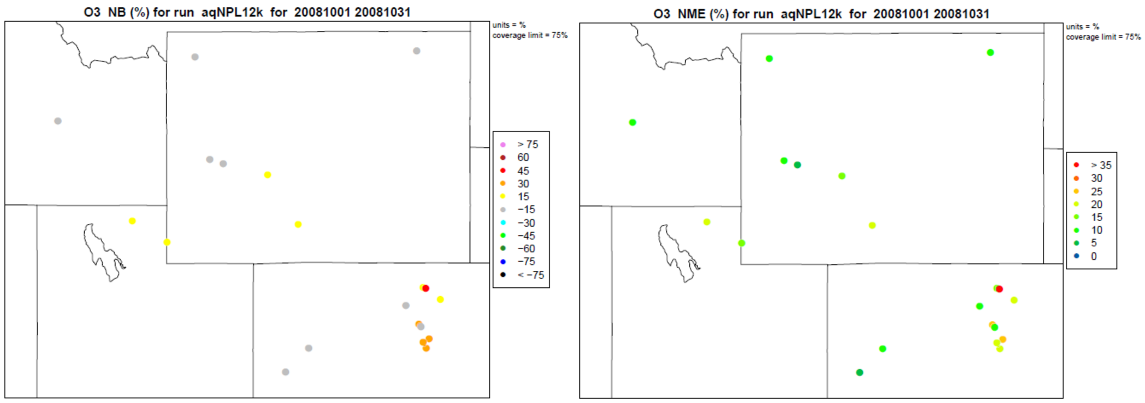
Normalized Bias (Left) and Normalized Mean Error (Right) for August



Normalized Bias (Left) and Normalized Mean Error (Right) for September



Normalized Bias (Left) and Normalized Mean Error (Right) for October



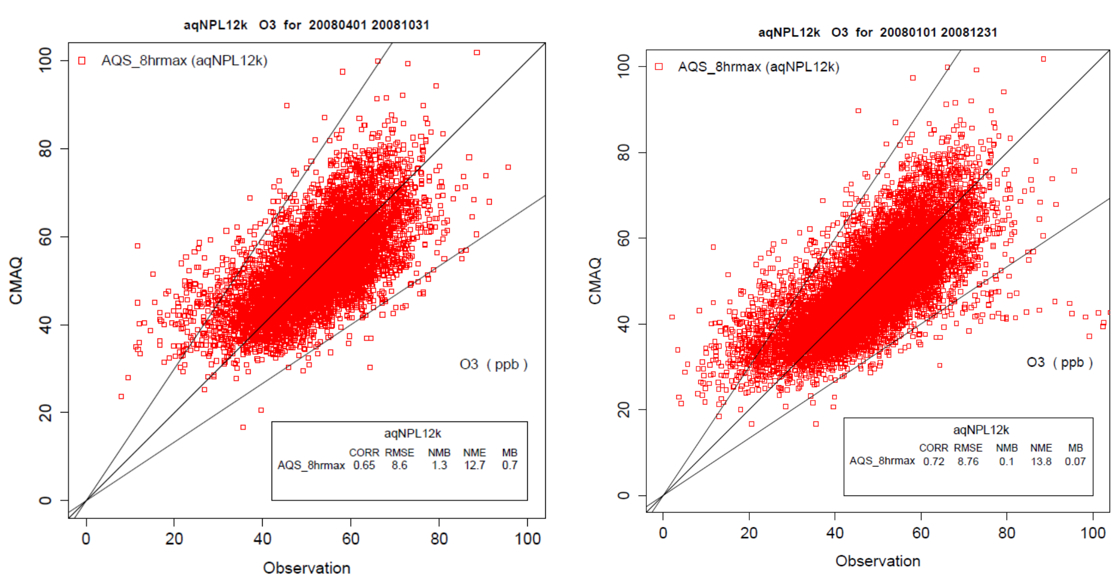
For most months and most monitoring sites, the normalized bias is within ± 15 percent (as indicated by the gray shading). There is some underestimation of ozone for April (for three Wyoming sites) and some overestimation of ozone for August, September, and October. With the exception of a few sites in Colorado in September and October, the normalized mean error is less than 35 percent for all sites and months.

Comparison of Simulated and Observed Concentrations

Scatter plots comparing simulated and observed daily maximum 8-hour ozone concentrations for the 12-km grid for April through October and the full annual simulation period are presented in Figure 5-3. The scatter plots provide a visual representation of how well the simulated values match the observations, and can reveal biases toward over- or underestimation of the observed values. Also included on the scatter plots is some statistical information further summarizing model performance. Note that these statistical measures are calculated using the 8-hour average ozone concentrations.

Figure 5-3. Comparison of Simulated and Observed Daily Maximum 8-Hour Average Ozone Concentration (ppb) for the 12-km Grid

April through October/All Months



For the ozone season, most of the data points fall within the ±25 percent range indicated by the solid lines on the plot. Some of the lower ozone concentrations are overestimated by more than this amount. There is a general tendency for CMAQ to overestimate the lower concentrations (especially those within the 20 to 40 ppb range). However, there is good correlation overall as indicated by a correlation coefficient of 0.65. For the full annual period, overall performance is similar to that for the ozone season except that the highest observed values, representing high wintertime ozone concentrations, are underestimated by a significant amount.

Statistical Measures of Model Performance

Finally, summary metrics and statistical measures calculated using hourly ozone concentrations for the 12-km grid are presented in Table 5-1 (a) and (b). Statistics were calculated for the individual months of the traditional ozone season (April through October), the traditional ozone season, and the full annual simulation period. The recommended ranges for the normalized bias and normalized error shown in this table are no longer a part of current EPA guidance but are still widely used for urban- and regional-scale model performance evaluation (EPA, 2007). The normalized bias and error statistics were calculated using a lower bound of 40 ppb (Table 5-1a) and a lower bound of 60 ppb (Table 5-1b). Statistics were also calculated using no lower bound but due to a large number of very low hourly concentrations, the normalized values are not meaningful.

Table 5-1a. Summary Model Performance Statistics for Ozone for the 12-km Modeling Grid: 40 ppb Lower Bound

Metric	Apr	May	Jun	Jul	Aug	Sep	Oct	Apr - Oct	All	Goal
Number of Data Pairs	14,950	15,599	16,295	19,379	14,468	10,104	3,896	94,691	126,590	
Mean Observed (ppb)	51.8	52.6	51.9	55.0	51.6	47.7	44.7	51.8	50.4	
Mean Simulated (ppb)	45.7	46.2	49.6	53.7	52.2	48.9	46.5	49.5	46.6	
Mean Bias (ppb)	-6.1	-6.4	-2.3	-1.2	0.6	1.1	1.8	-2.4	-4.1	
Normalized Bias (%)	-11.4	-11.3	-4.1	-1.4	1.8	2.7	4.1	-3.9	-7.6	± 15
Normalized Mean Bias (%)	-11.1	-12.2	-4.5	-2.3	1.2	2.4	4.0	-4.6	-8.0	
Fractional Bias (%)	-13.6	-13.5	-7.3	-3.2	-0.5	0.9	2.9	-6.2	-10.5	
Mean Error (ppb)	7.6	8.1	8.2	7.7	7.6	6.3	4.8	7.6	8.1	
Normalized Error (%)	14.8	15.1	15.9	14.1	15.1	13.5	10.9	14.6	16.0	≤ 35
Normalized Mean Error (%)	14.7	15.4	15.7	14.0	14.8	13.3	10.9	14.6	16.0	
Fractional Error (%)	16.8	17.0	17.9	14.7	15.5	13.7	10.8	15.8	18.0	
Correlation (unitless)	0.53	0.48	0.53	0.57	0.57	0.49	0.55	0.53	0.52	
Index of Agreement (unitless)	0.62	0.61	0.68	0.74	0.73	0.66	0.67	0.70	0.67	

Table 5-1b. Summary Model Performance Statistics for Ozone for the 12-km Modeling Grid: 60 ppb Lower Bound

Metric	Apr	May	Jun	Jul	Aug	Sep	Oct	Apr - Oct	All	Goal
Number of Data Pairs	2,051	3,211	3,015	5,629	2,728	444	44	17,122	18,182	
Mean Observed (ppb)	62.7	64.4	66.0	67.2	66.3	62.7	65.3	65.7	65.9	
Mean Simulated (ppb)	53.2	52.0	61.2	62.1	63.4	61.5	63.6	59.2	58.0	
Mean Bias (ppb)	-9.5	-12.4	-4.8	-5.1	-2.2	-1.2	-1.7	-6.5	-7.9	
Normalized Bias (%)	-15.1	-19.1	-7.0	-7.2	-3.9	-1.7	-2.4	-6.6	-11.6	± 15
Normalized Mean Bias (%)	-15.1	-19.3	-7.2	-7.6	-4.3	-2.0	-2.5	-9.7	-12.0	
Fractional Bias (%)	-16.8	-22.1	-9.6	-8.9	-5.6	-2.4	-3.4	-9.9	-14.6	
Mean Error (ppb)	9.7	12.7	9.4	9.3	6.4	5.6	5.9	9.8	11.0	
Normalized Error (%)	15.4	19.5	14.2	13.6	12.7	8.8	9.1	8.3	16.4	≤ 35
Normalized Mean Error (%)	15.5	19.7	14.3	13.9	12.8	9.0	9.1	14.8	16.7	
Fractional Error (%)	17.2	22.4	16.1	14.8	13.7	9.1	9.7	14.9	18.9	
Correlation (unitless)	0.22	0.21	0.28	0.34	0.27	0.30	0.30	0.34	0.19	
Index of Agreement (unitless)	0.28	0.30	0.42	0.53	0.50	0.32	0.46	0.47	0.40	

Using a lower bound of 40 ppb (Table 5-1a), the normalized bias is within ±15 percent and the normalized error is well within 35 percent for all months. Ozone is underestimated for April, May and the winter months, slightly underestimated for June and July, and slightly overestimated for the remaining traditional ozone season months. Only about 20 percent of the observed concentrations are greater than 60 ppb. The statistics calculated using a lower bound of 60 ppb (Table 5-1b), indicate that the higher ozone concentrations are underestimated, especially for April and May. The normalized bias is within ±15 percent for all other months/periods; the normalized error is well within 35 percent for all months.

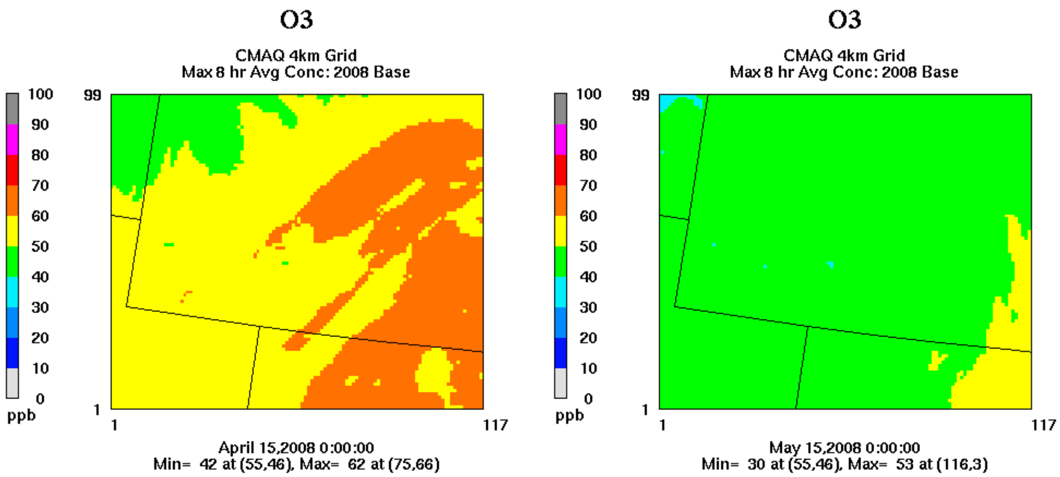
5.1.2 Regional-Scale Concentrations for the 4-km Grid

Spatial Concentration Patterns

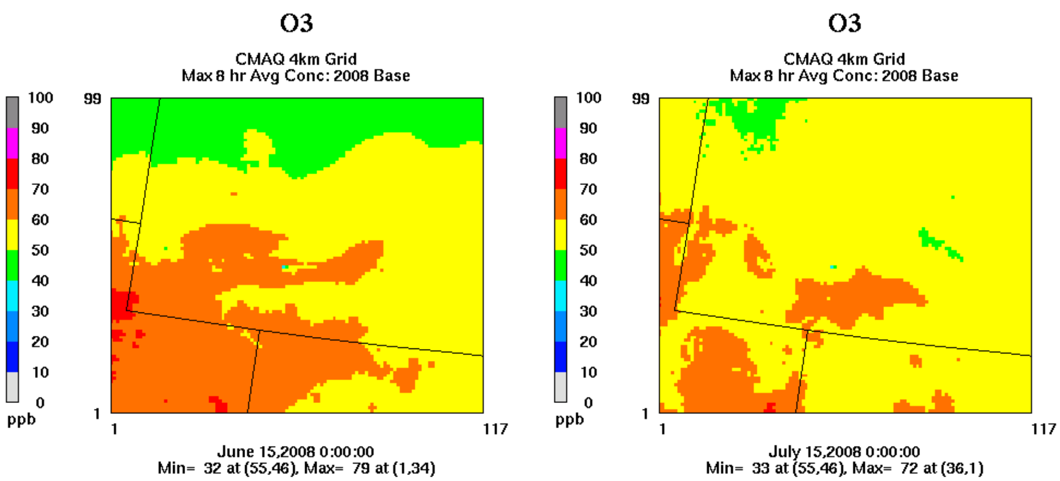
Spatial plots of the simulated ozone concentration patterns for the 4-km grid for selected days throughout the simulation period were plotted and examined. Figure 5-4 illustrates the daily maximum 8-hour average ozone concentration patterns for the 15th of each month (April – October). Units are parts per billion (ppb).

Figure 5-4. Simulated Daily Maximum 8-Hour Ozone Concentration (ppb) for Selected Days for the CMAQ 4-km Grid

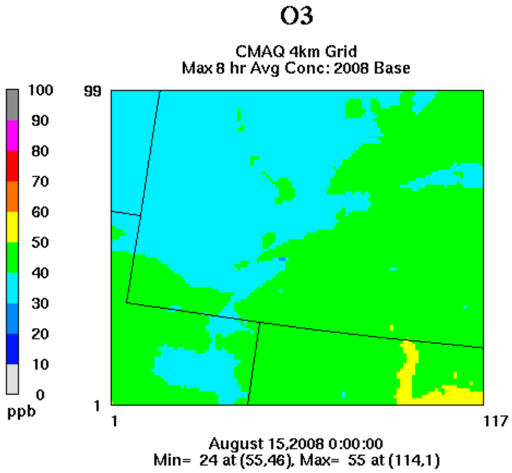
April 15th/May 15th

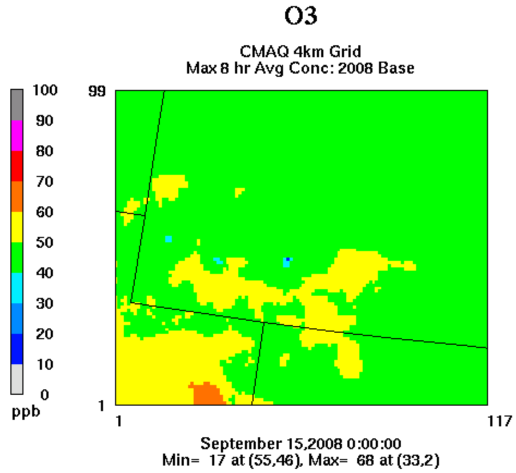


June 15th/July 15th

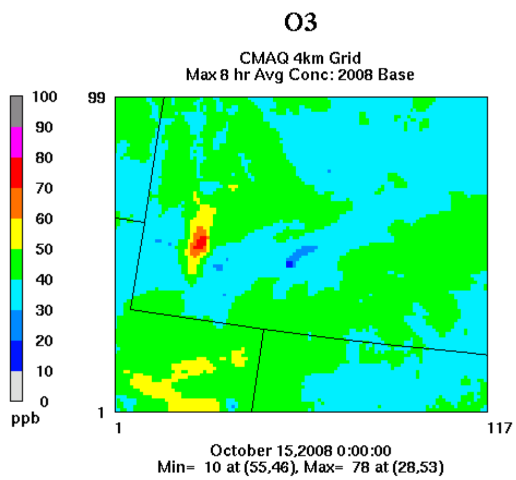


August 15th/September 15th





October 15th

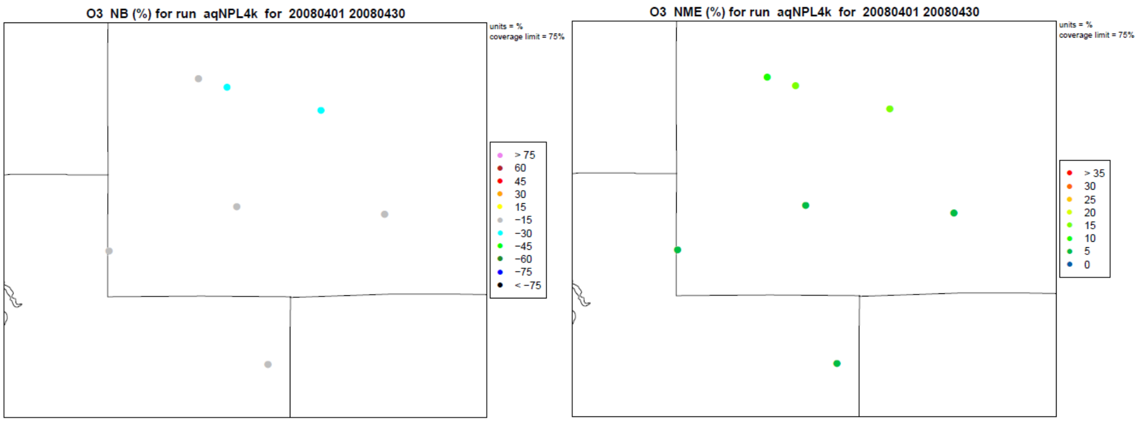


The simulated ozone concentration patterns for the selected days show mostly low to moderate 8-hour average ozone concentrations over southwestern Wyoming on the selected days with a maximum value of 78 ppb on October 15th. Daily maximum 8-hour ozone concentrations greater than 60 ppb are relatively widespread on April 15th, June 15th, and July 15th. In contrast, the high concentrations on October 15th are relatively localized.

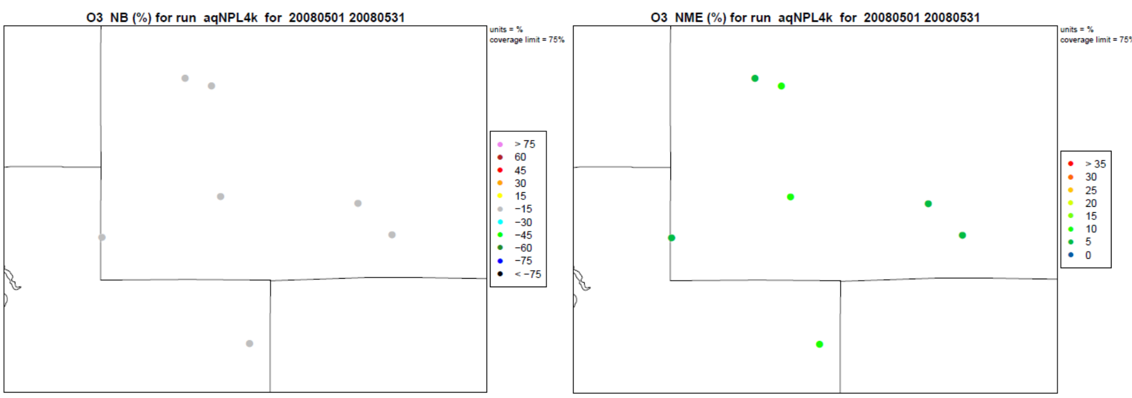
Figure 5-5 depicts the monthly average bias and error for all sites in the 4-km modeling domain, based on daily maximum 8-hour ozone concentrations. For the normalized bias, gray shaded circles indicate that the bias is within ± 15 percent; blue and green shading indicates underestimation of the observed concentrations and yellow, orange, and red shading indicates overestimation. For the normalized mean error, blue and green shading represent the smaller errors, while red indicates an error greater than 35 percent. A lower bound of 40 ppb was used in calculating the normalized bias and error statistics. Note that the number of monitoring sites varies slightly from month to month, based on data availability.

Figure 5-5. Normalized Bias (%) and Normalized Mean Error (%) Based on Daily Maximum 8-Hour Average Simulated and Observed Ozone Concentrations for the CMAQ 4-km Grid

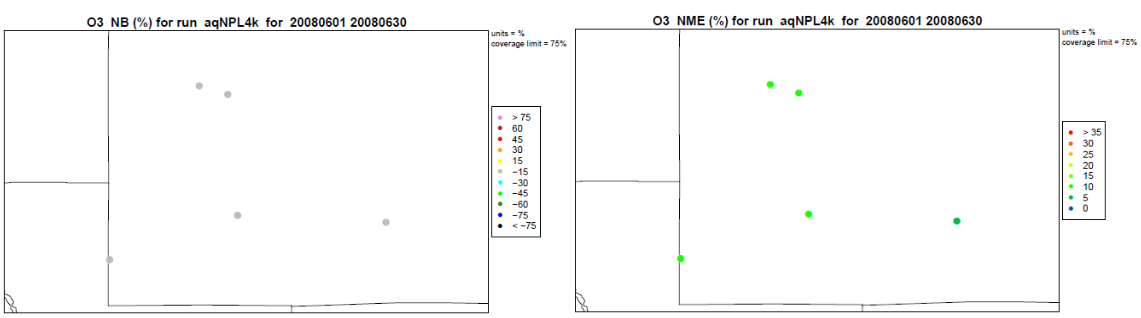
Normalized Bias (Left) and Normalized Mean Error (Right) for April



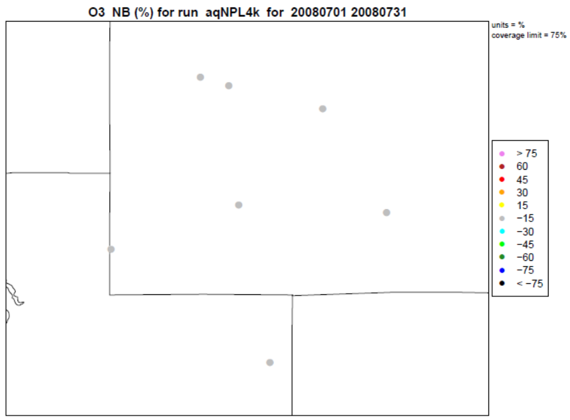
Normalized Bias (Left) and Normalized Mean Error (Right) for May

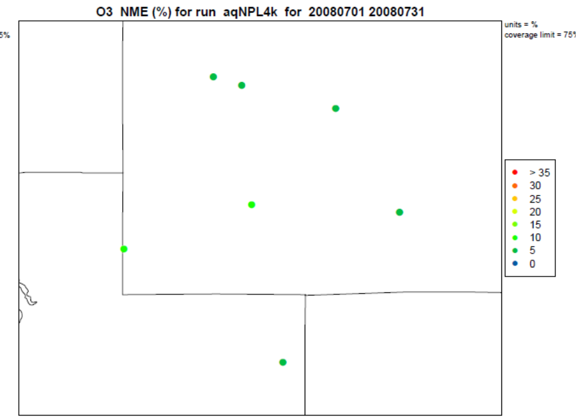


Normalized Bias (Left) and Normalized Mean Error (Right) for June

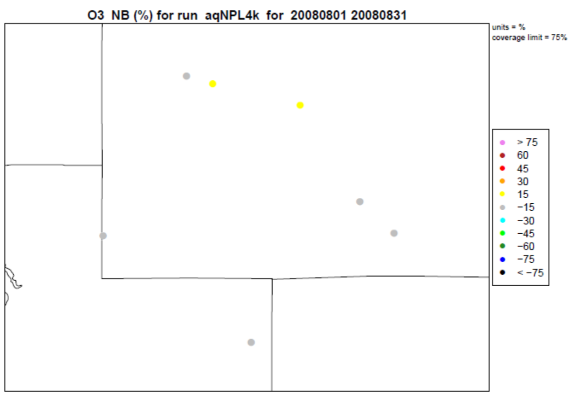


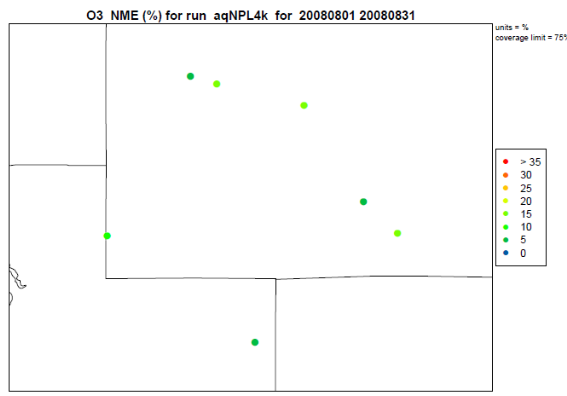
Normalized Bias (Left) and Normalized Mean Error (Right) for July



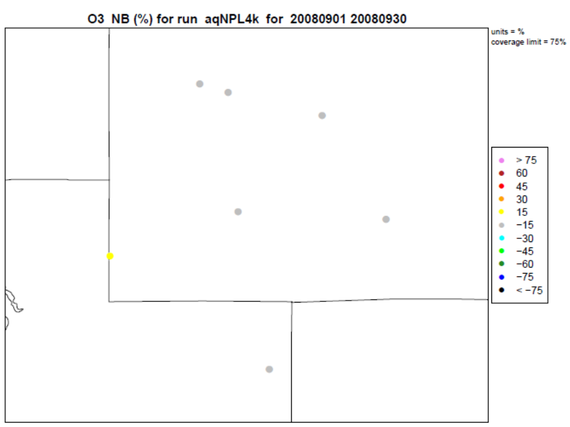


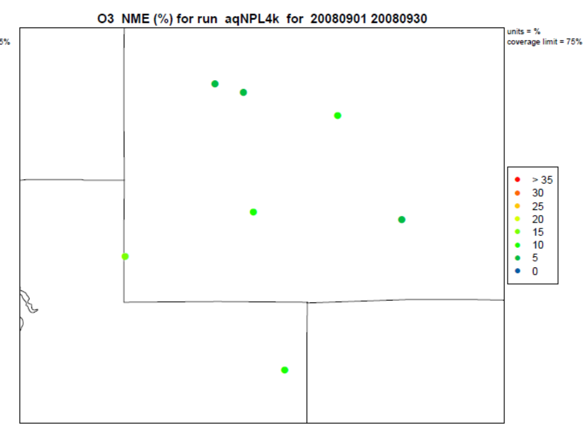
Normalized Bias (Left) and Normalized Mean Error (Right) for August



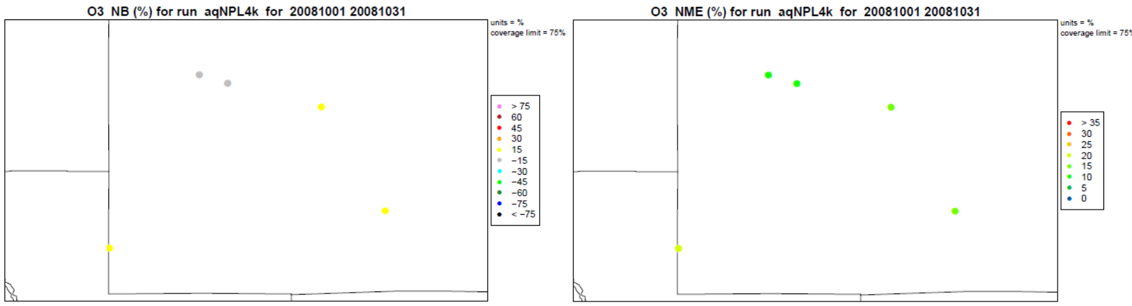


Normalized Bias (Left) and Normalized Mean Error (Right) for September





Normalized Bias (Left) and Normalized Mean Error (Right) for October



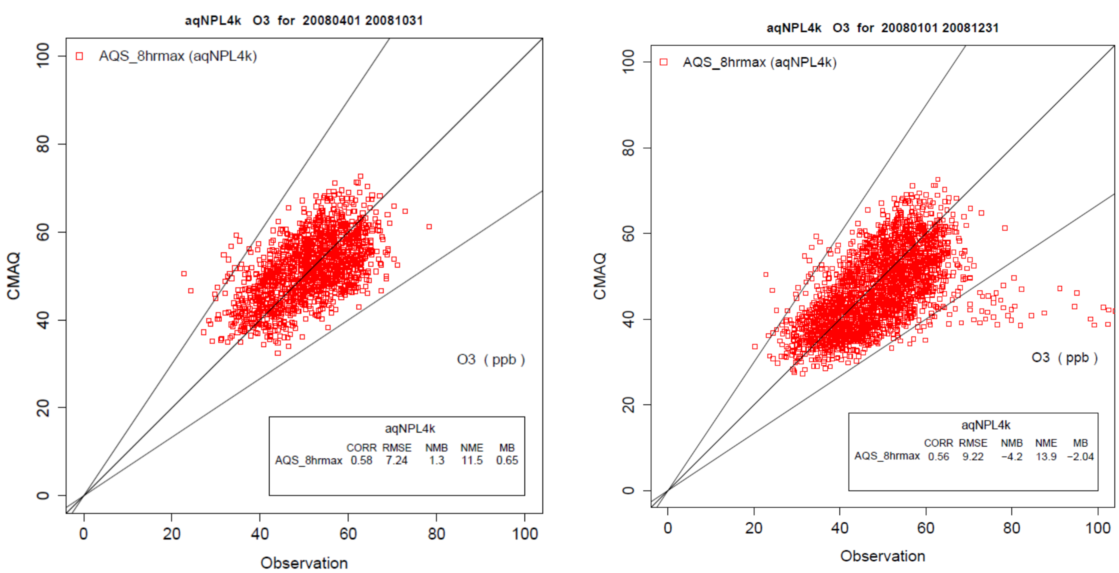
For most months and most monitoring sites, the normalized bias is within ± 15 percent (as indicated by the gray shading). There is some underestimation of ozone for April and some overestimation for September and October. The normalized mean error is less than 35 percent for all sites and months.

Comparison of Simulated and Observed Concentrations

Scatter plots comparing simulated and observed daily maximum 8-hour ozone concentrations for the 4-km grid for April through October and the full annual simulation period are presented in Figure 5-6. Again, note that the statistical measures given on the plots are calculated using the 8-hour average ozone concentrations.

Figure 5-6. Comparison of Simulated and Observed Daily Maximum 8-Hour Average Ozone Concentration (ppb) for the 4-km Grid

April through October/All Months



For both periods, a majority of the data points fall within the ±25 percent range indicated by the solid lines on the plot. Again, the higher wintertime ozone concentrations are underestimated.

Statistical Measures of Model Performance

Summary metrics and statistical measures calculated using hourly ozone concentrations for the 4-km grid are presented in Table 5-2 (a) and (b). Statistics were calculated for the individual months of the traditional ozone season (April through October), the traditional ozone season, and the full annual simulation period. The normalized bias and error statistics were calculated using a lower bound of 40 ppb (Table 5-2a) and a lower bound of 60 ppb (Table 5-2b). Statistics were also calculated using no lower bound but due to a number of very low hourly concentrations, the normalized values are not meaningful.

Table 5-2a. Summary Model Performance Statistics for Ozone for the 4-km Modeling Grid: 40 ppb Lower Bound

Metric	Apr	May	Jun	Jul	Aug	Sep	Oct	Apr - Oct	All	Goal
Number of Data Pairs	4,722	3,411	2,760	3,667	2,415	2,067	1,072	20,114	32,744	
Mean Observed (ppb)	52.1	51.9	49.9	52.6	49.1	47.4	43.9	50.6	49.8	
Mean Simulated (ppb)	45.9	48.2	48.7	53.0	52.6	50.8	47.8	49.4	44.6	
Mean Bias (ppb)	-6.2	-3.7	-1.2	0.4	3.4	3.4	3.9	-1.2	-5.2	
Normalized Bias (%)	-11.4	-6.2	-2.0	1.6	7.9	7.8	8.8	-1.5	-9.6	± 15
Normalized Mean Bias (%)	-11.8	-7.0	-2.2	0.6	7.0	7.3	8.9	-2.4	-10.4	
Fractional Bias (%)	-13.1	-7.2	-4.4	0.5	6.5	6.7	7.6	-2.9	-12.6	
Mean Error (ppb)	7.4	5.9	6.6	5.7	6.8	5.9	5.6	6.4	8.5	
Normalized Error (%)	14.1	11.1	13.5	11.1	14.2	12.7	12.7	12.8	16.8	≤ 35
Normalized Mean Error (%)	14.2	11.4	13.3	10.9	13.8	12.5	12.7	12.7	17.1	
Fractional Error (%)	15.6	11.8	14.8	11.0	13.4	12.0	11.9	13.2	19.1	
Correlation (unitless)	0.55	0.56	0.50	0.52	0.54	0.51	0.61	0.46	0.34	
Index of Agreement (unitless)	0.63	0.70	0.66	0.72	0.70	0.66	0.63	0.67	0.55	

Table 5-2b. Summary Model Performance Statistics for Ozone for the 4-km Modeling Grid: 60 ppb Lower Bound

Metric	Apr	May	Jun	Jul	Aug	Sep	Oct	Apr - Oct	All	Goal
Number of Data Pairs	632	584	246	665	242	53	0	2,423	3,388	
Mean Observed (ppb)	62.8	63.3	63.5	62.8	64.0	63.2	--	63.1	65.3	
Mean Simulated (ppb)	52.2	52.8	59.4	58.1	60.3	60.8	--	55.7	50.8	
Mean Bias (ppb)	-10.6	-10.5	-4.3	-4.7	-3.7	-2.4	--	-7.4	-14.5	
Normalized Bias (%)	-16.8	-16.5	-6.5	-7.4	-5.5	2.3	--	-11.6	-20.8	± 15
Normalized Mean Bias (%)	-16.9	-16.6	-6.5	-7.5	-5.9	-3.8	--	-11.8	-22.1	
Fractional Bias (%)	-18.8	-18.4	-7.2	-8.3	-6.4	-3.4	--	-13.0	-26.5	
Mean Error (ppb)	10.8	10.6	6.0	6.6	6.7	5.8	--	8.6	15.3	
Normalized Error (%)	17.1	16.6	9.5	10.4	10.3	7.8	--	13.5	22.0	≤ 35
Normalized Mean Error (%)	17.2	16.7	9.5	10.5	10.5	9.1	--	13.6	23.4	
Fractional Error (%)	19.1	18.5	10.1	11.1	10.4	8.7	--	14.8	27.7	
Correlation (unitless)	0.29	0.30	0.37	0.34	0.36	0.35	--	0.33	0.30	
Index of Agreement (unitless)	0.37	0.37	0.44	0.34	0.37	0.33	--	0.30	0.22	

Using a lower bound of 40 ppb (Table 5-2a), the normalized bias is within ±15 percent and the normalized error is well within 35 percent for all months. The greatest differences occur for April, and ozone is underestimated for this month, on average. The bias becomes increasingly positive throughout the remaining months. Only about 10 percent of the observed concentrations are greater than 60 ppb. The statistics calculated using a lower bound of 60 ppb (Table 5-2b), indicate that the higher ozone concentrations are underestimated, especially for April, May and the winter months. The normalized bias is within ±15 percent for all other months/periods; the normalized error is well within 35 percent for all months.

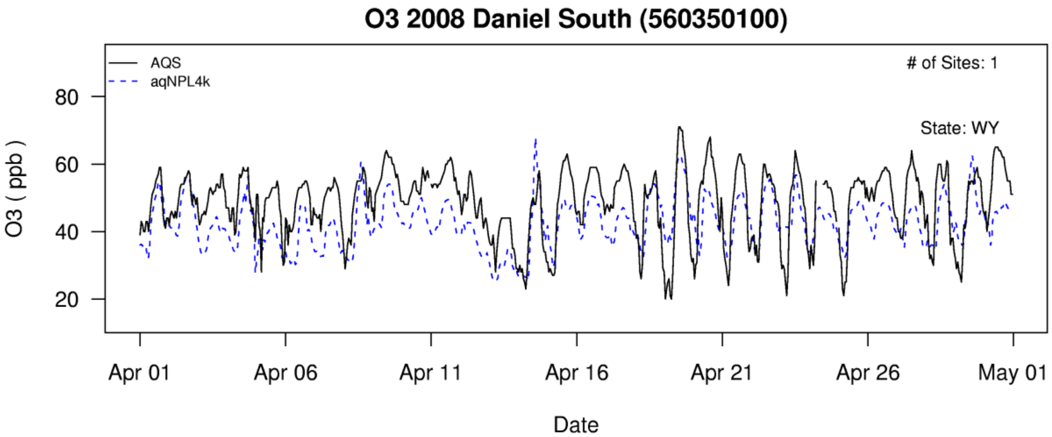
5.1.3 Site-Specific Concentrations for the 4-km Grid

Time-series plots comparing the hourly simulated and observed values at the monitoring sites demonstrate how well the timing and magnitude of the simulation concentrations compare to the observations. The time-series plots in Figure 5-7 through 5-11 compare hourly simulated and observed ozone concentrations for selected monitoring sites located within the 4-km grid. As indicated by the scatter plots and statistics, model performance for ozone is poor for the winter months and the time-series plots for those months are not included here. The analysis focuses on the ozone season months of April through October. The sites include: Daniel South, Boulder, South Pass, Wamsutter, and Murphy

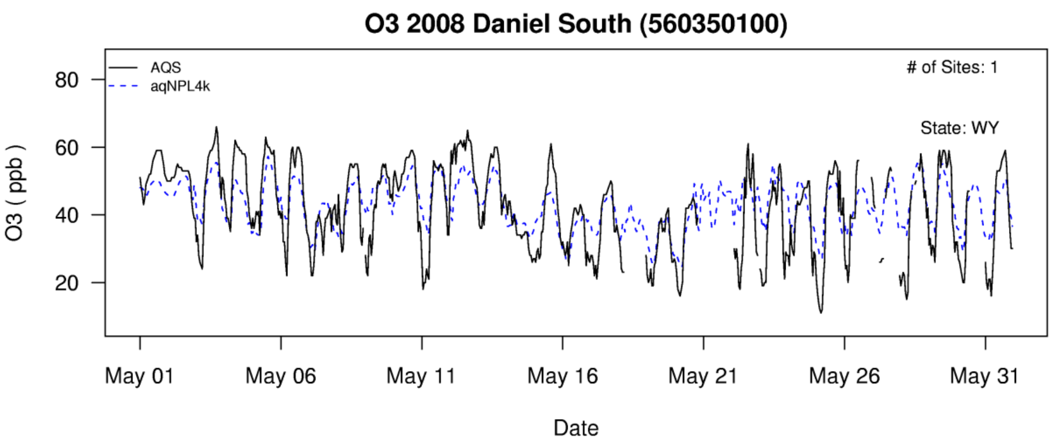
Ridge. In these plots, the solid black lines represent the observed values and the dashed blue lines represent the simulated values (taken from the grid cell in which the monitor is located).

Figure 5-7. Time-Series Plots Comparing Simulated and Observed Ozone Concentration (ppb): Daniel South

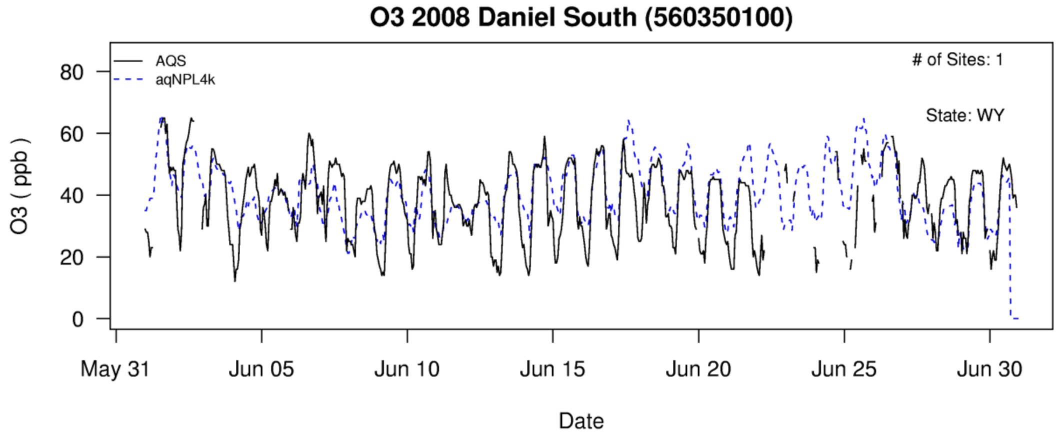
April



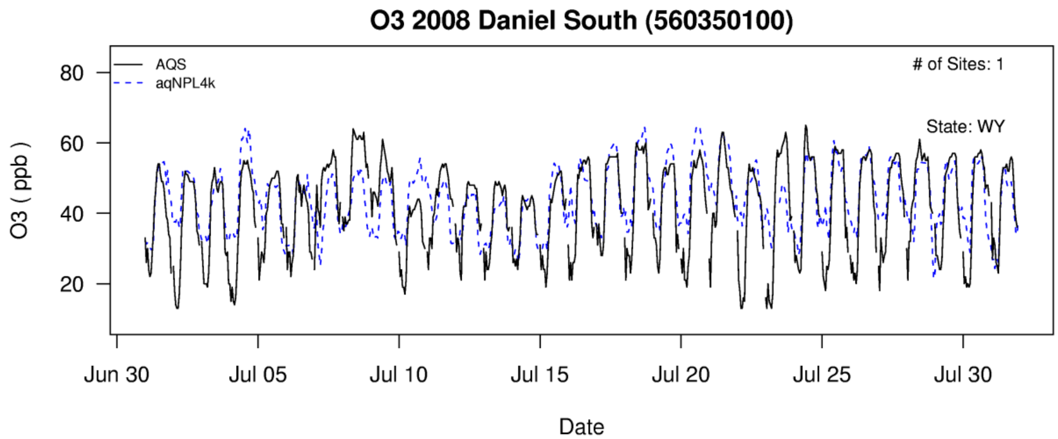
May



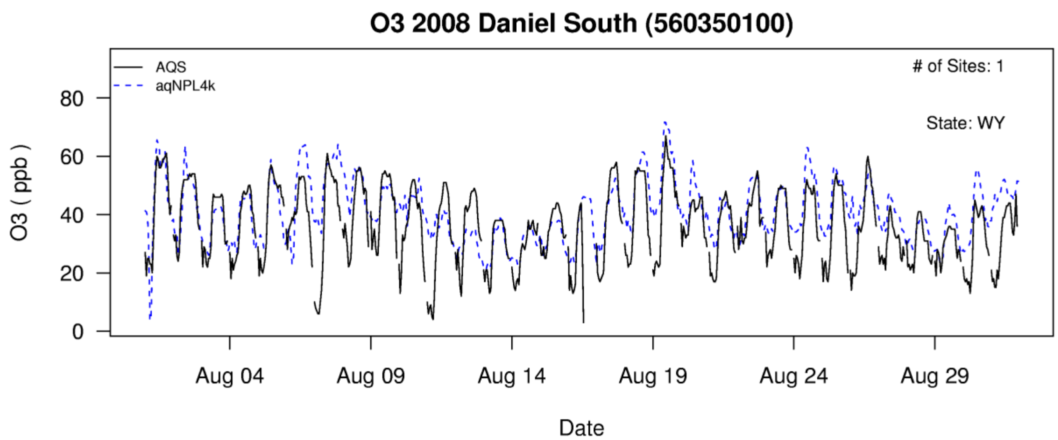
June



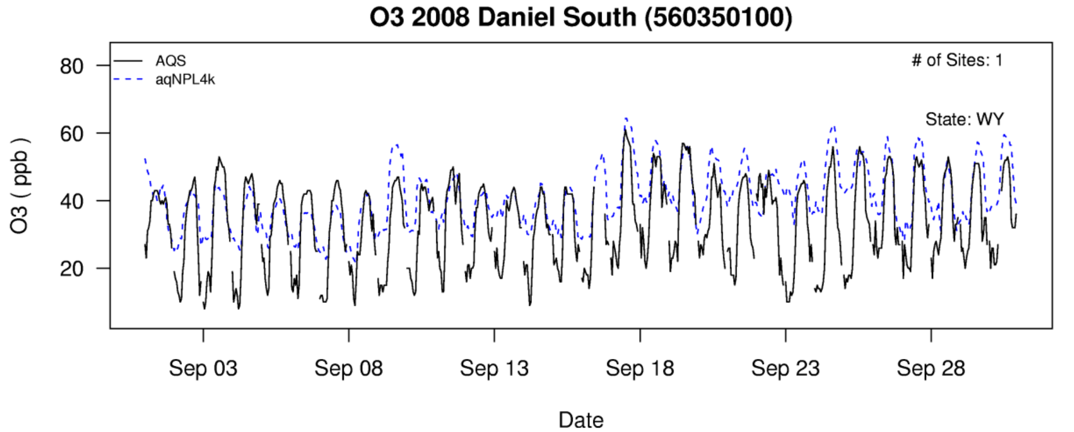
July



August



September



October

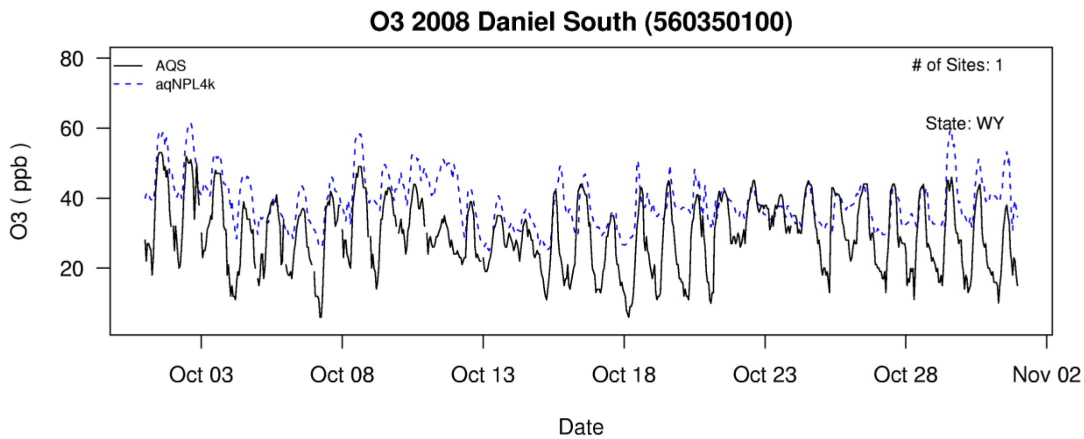
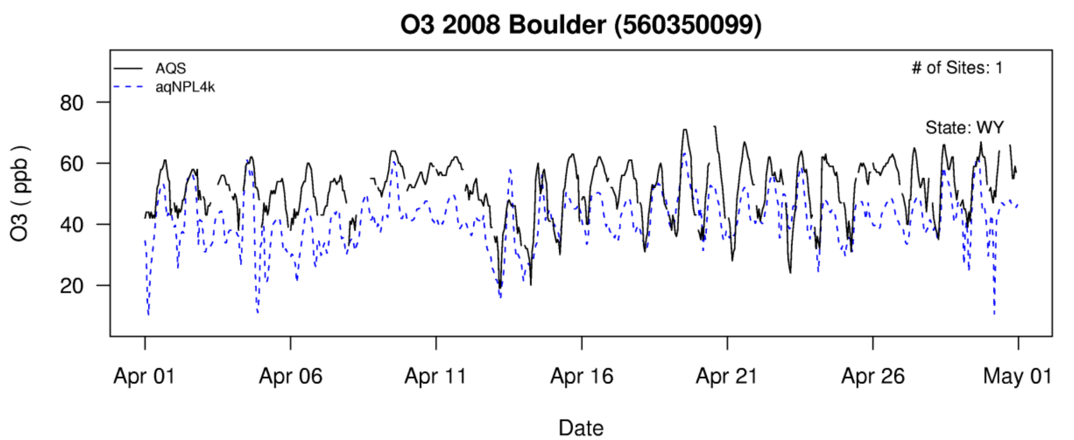
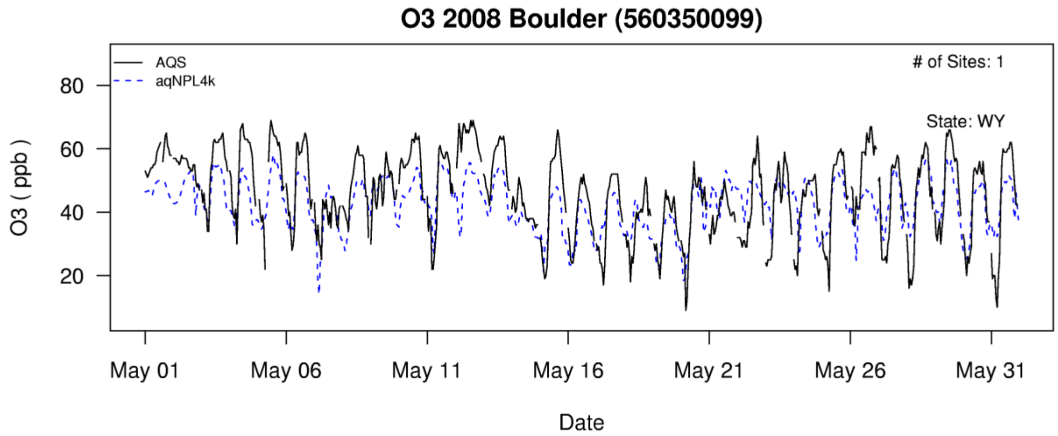


Figure 5-8. Time-Series Plots Comparing Simulated and Observed Ozone Concentration (ppb): Boulder

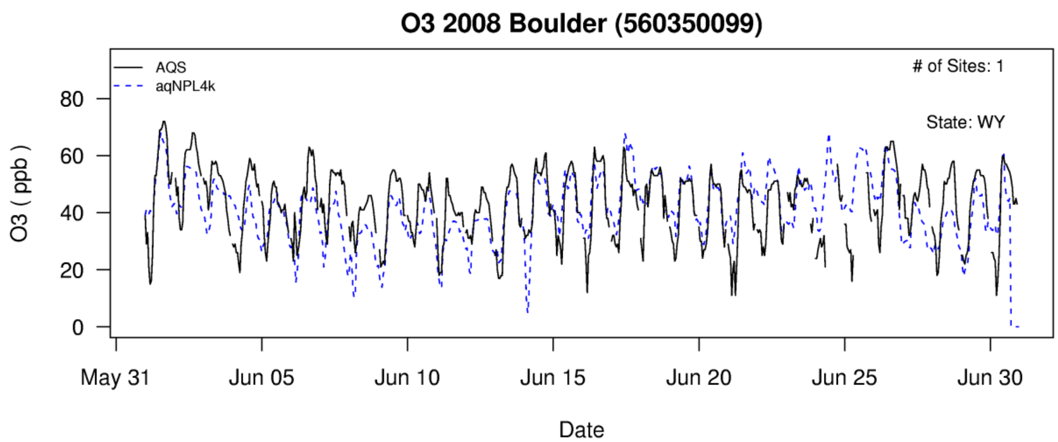
April



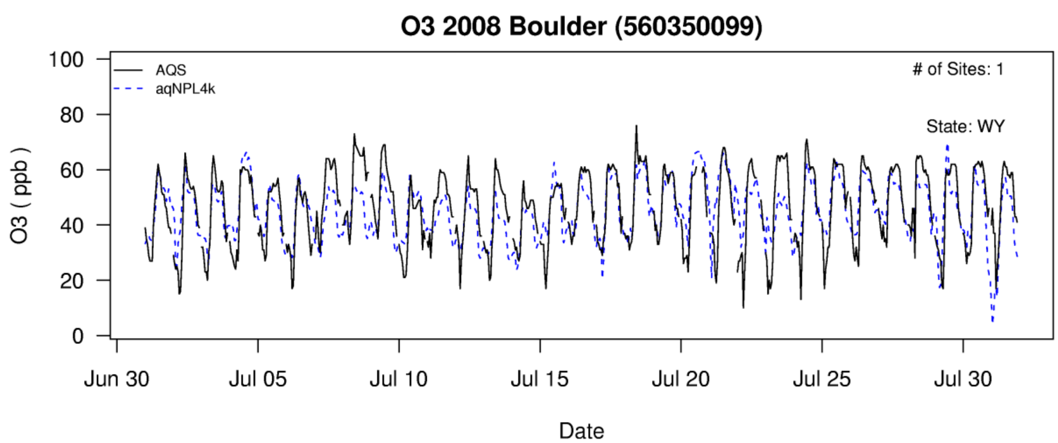
May



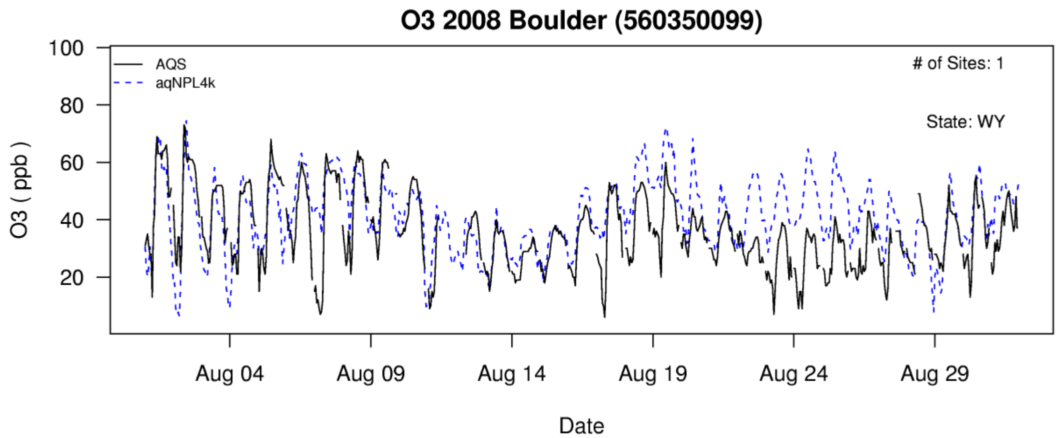
June



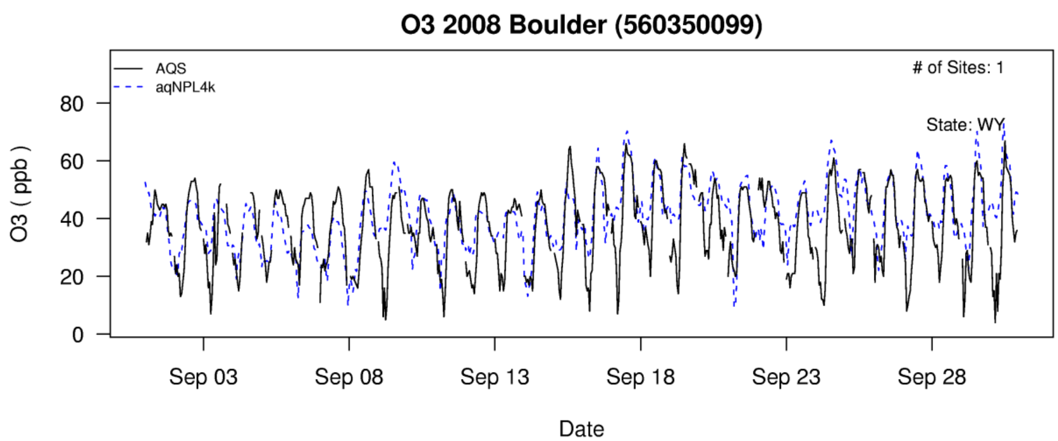
July



August



September



October

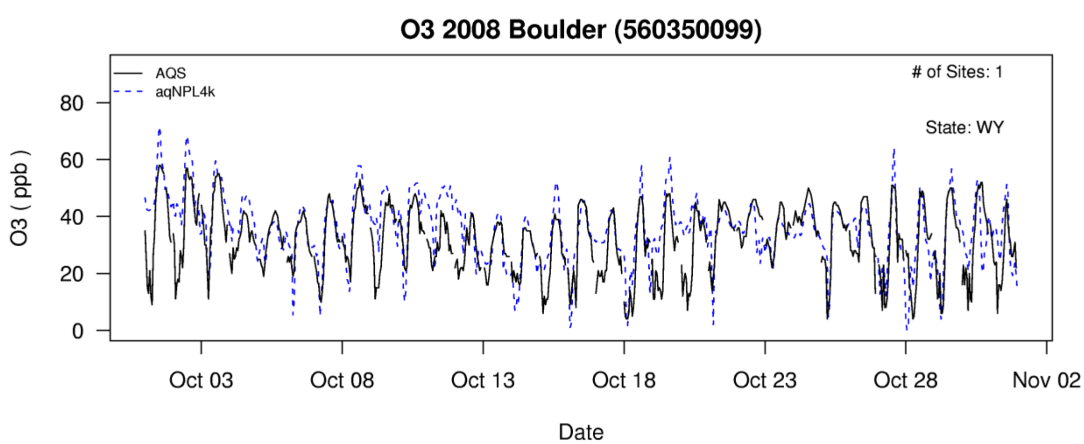
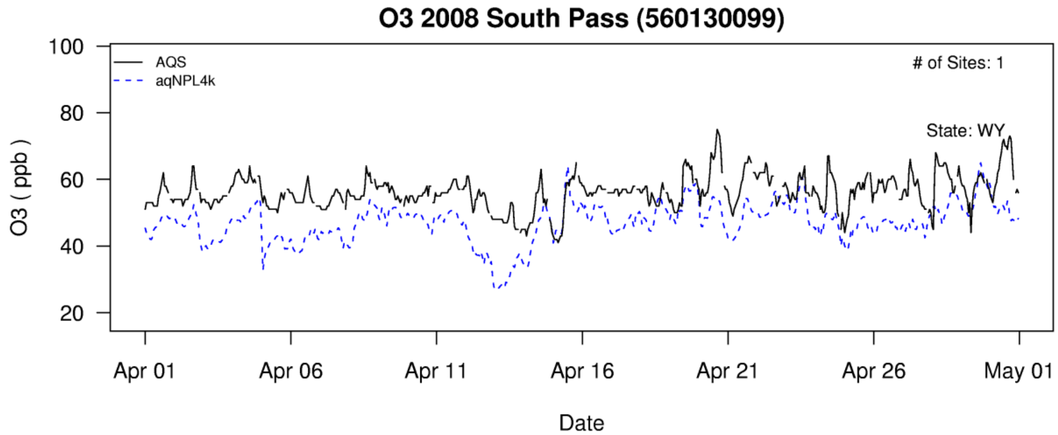
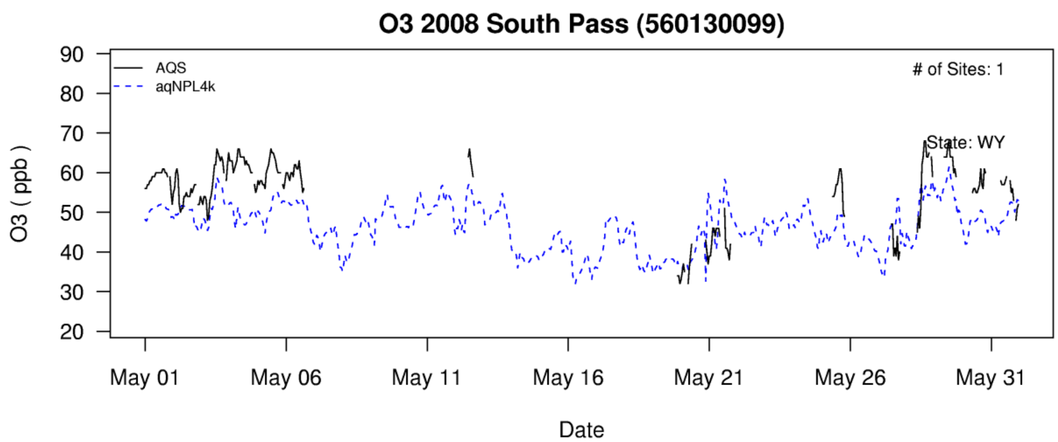


Figure 5-9. Time-Series Plots Comparing Simulated and Observed Ozone Concentration (ppb): South Pass

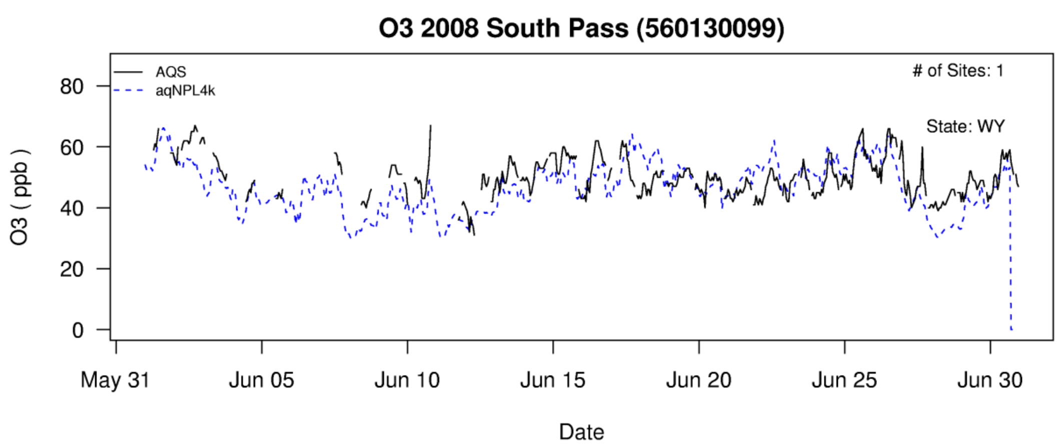
April



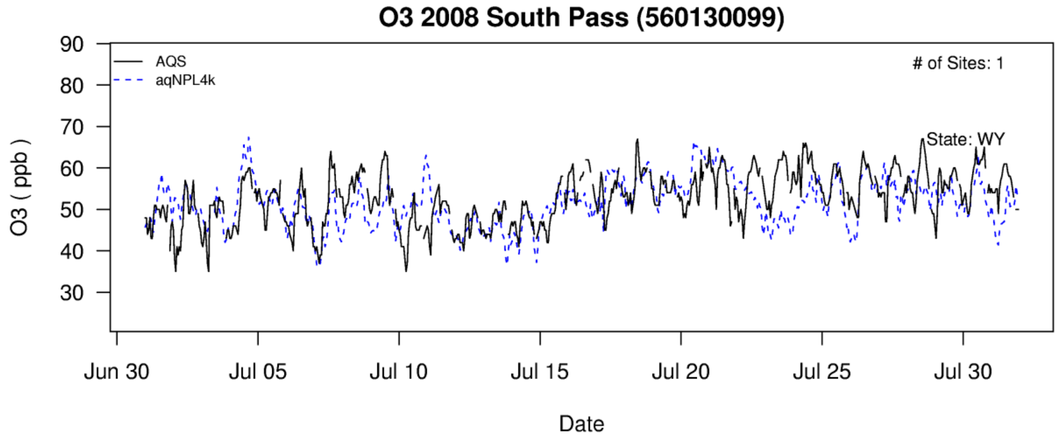
May



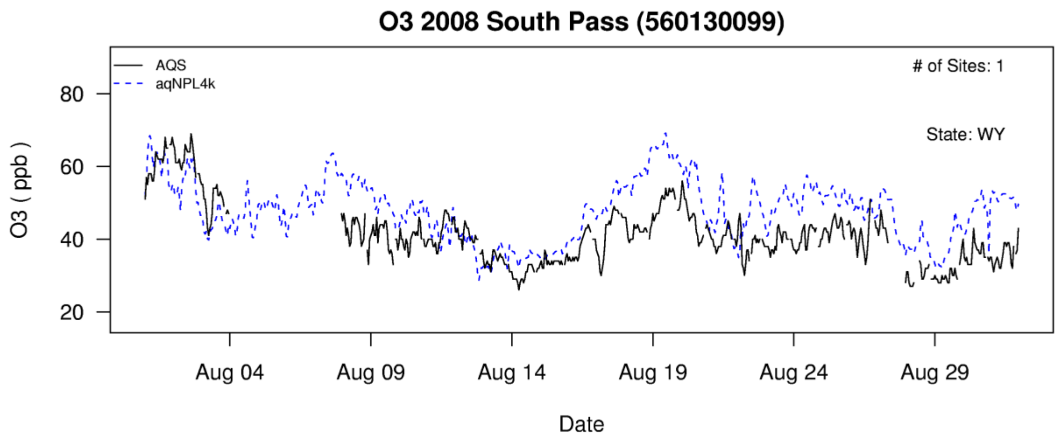
June



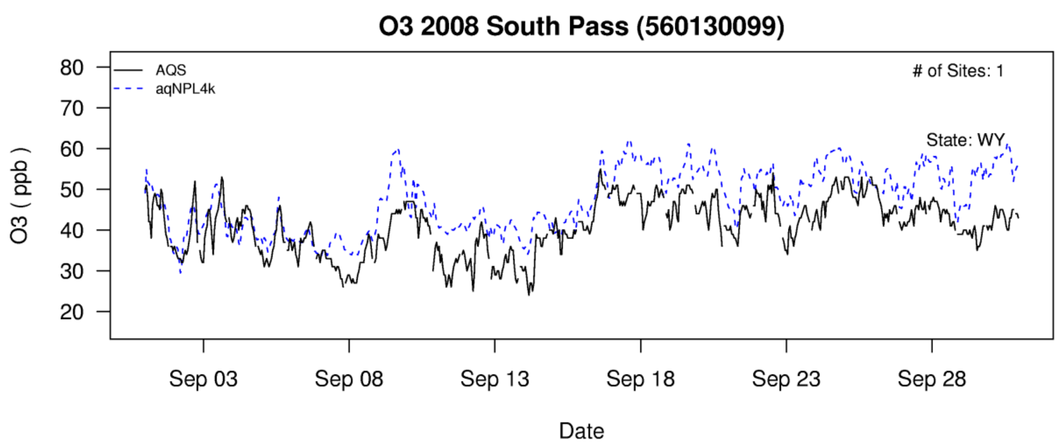
July



August



September



October

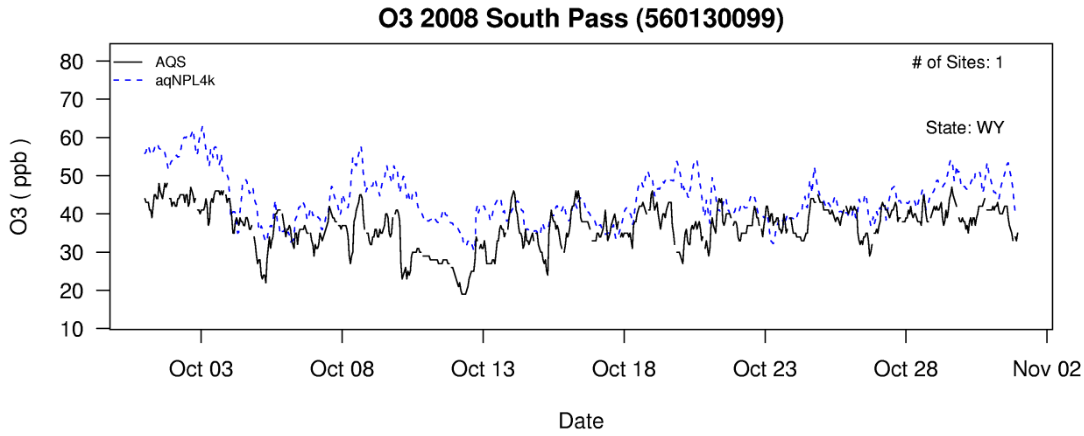
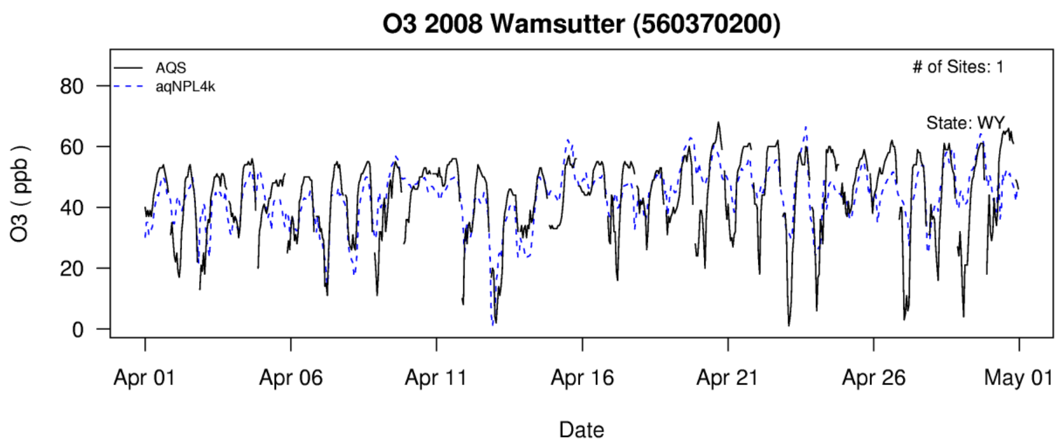
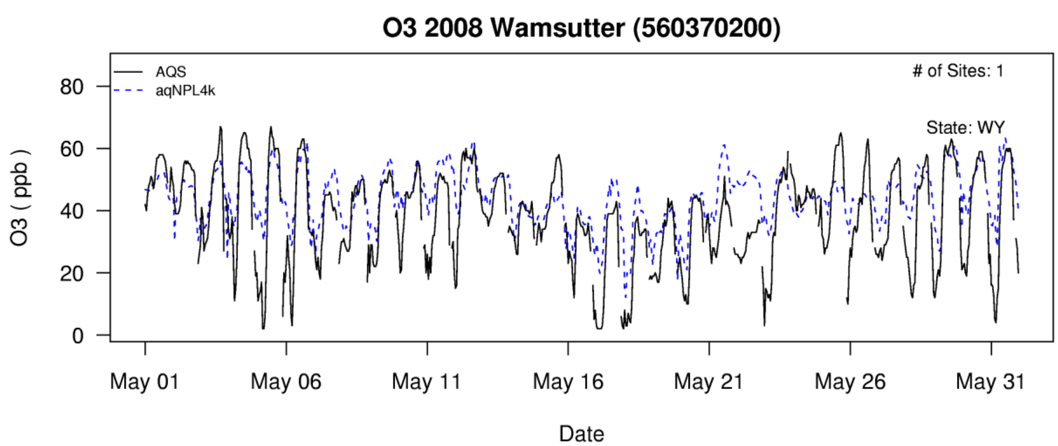


Figure 5-10. Time-Series Plots Comparing Simulated and Observed Ozone Concentration (ppb): Wamsutter

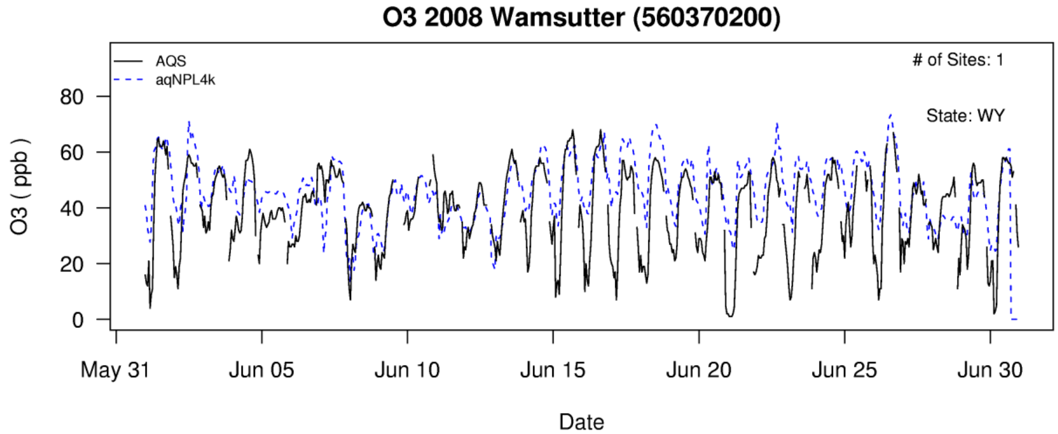
April



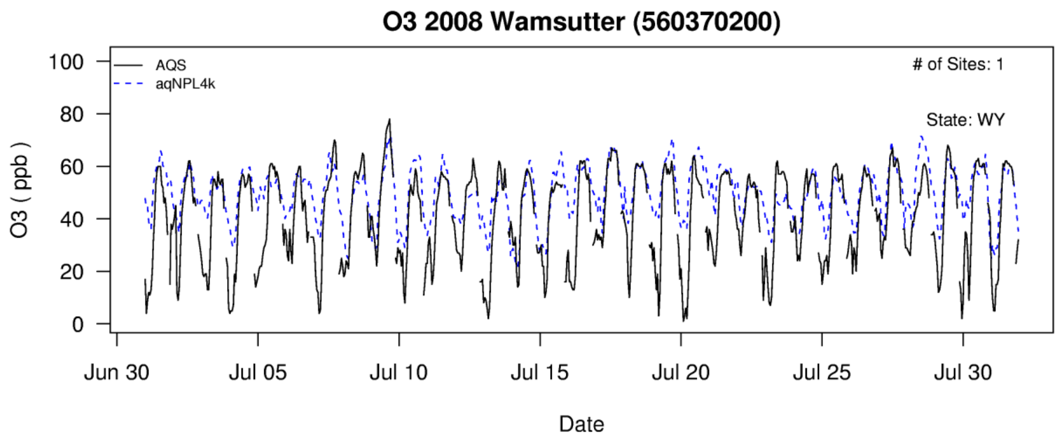
May



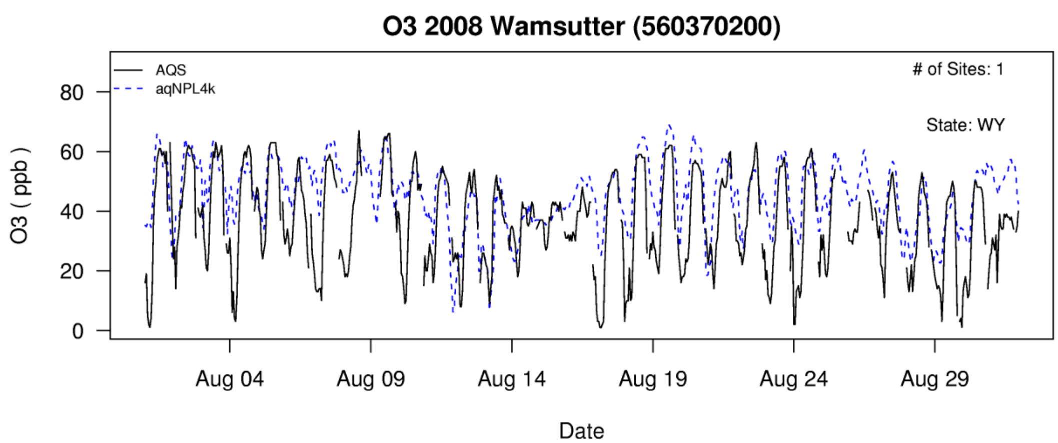
June



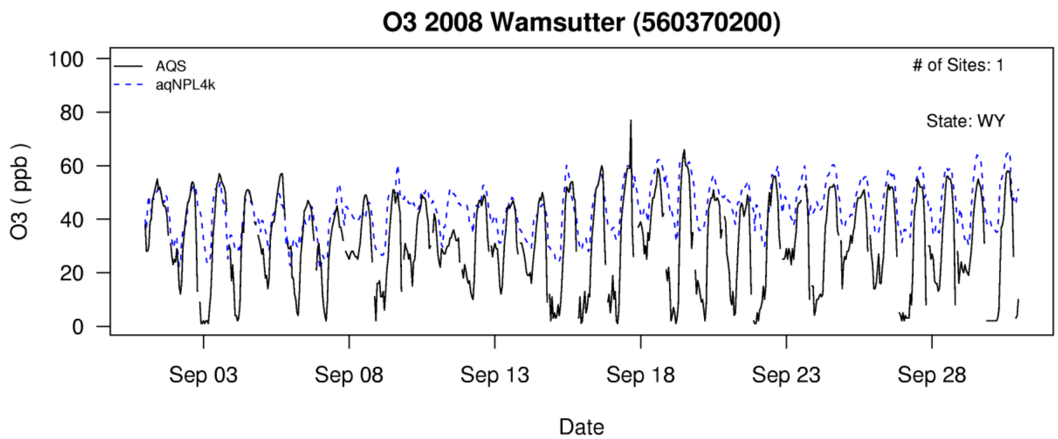
July



August



September



October

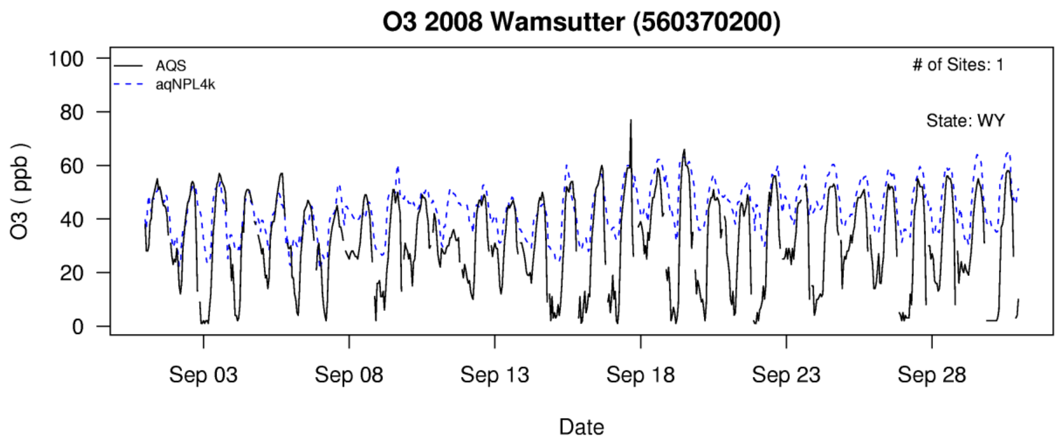
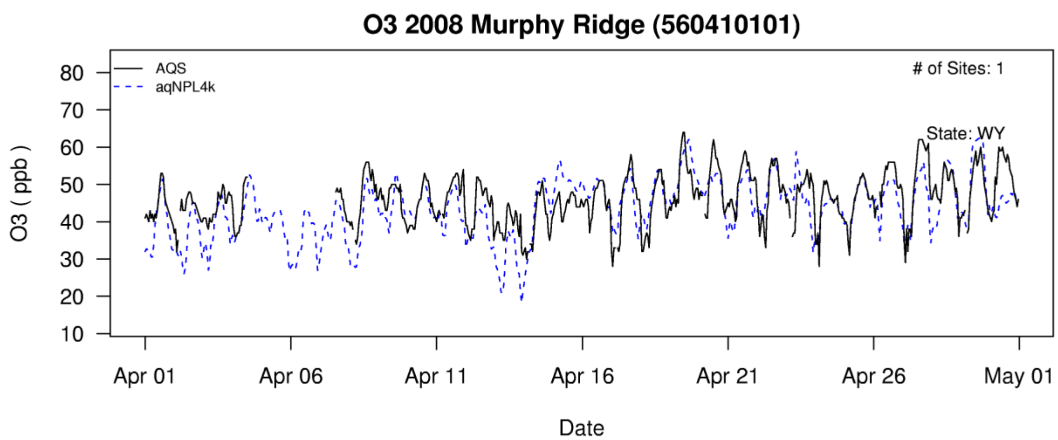
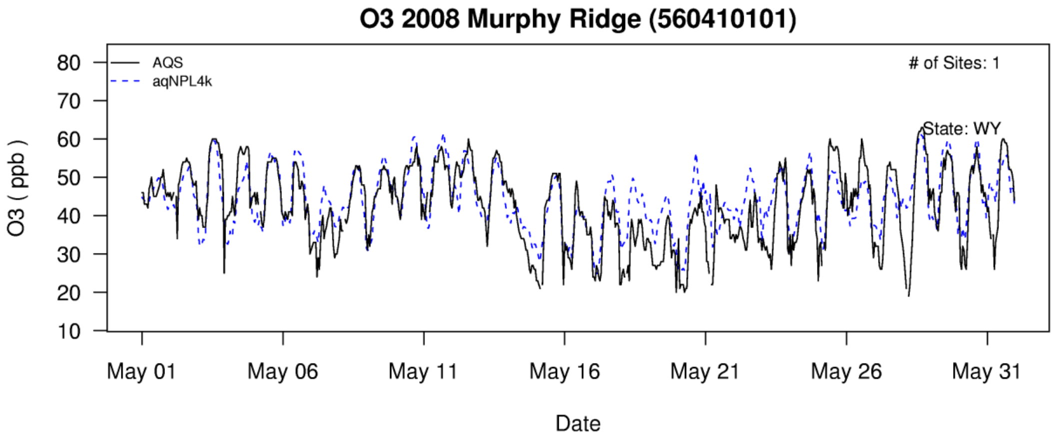


Figure 5-11. Time-Series Plots Comparing Simulated and Observed Ozone Concentration (ppb): Murphy Ridge

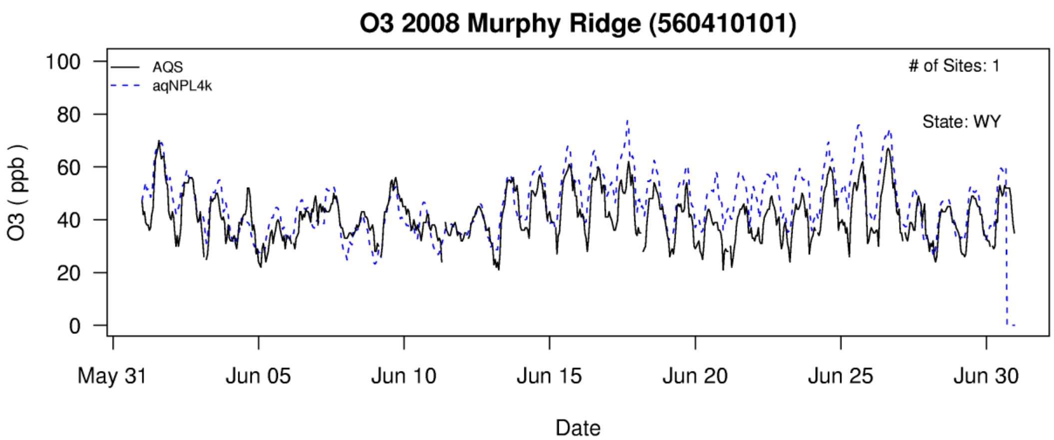
April



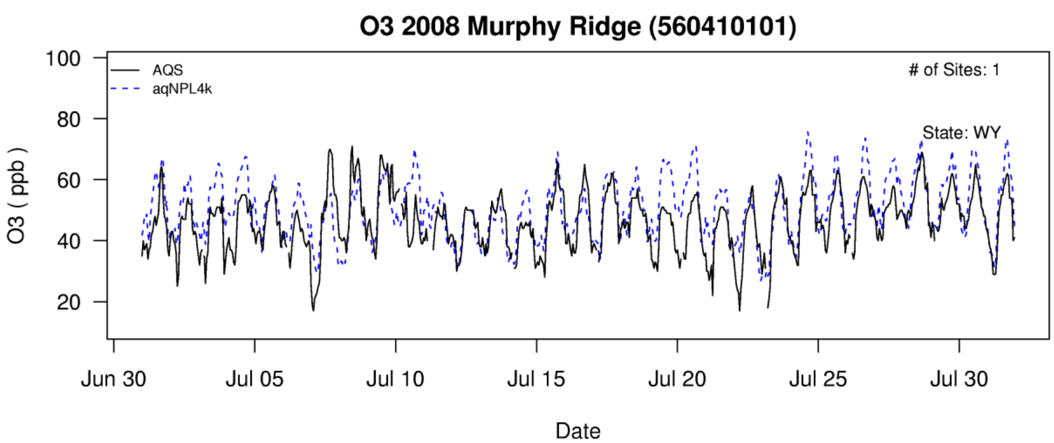
May



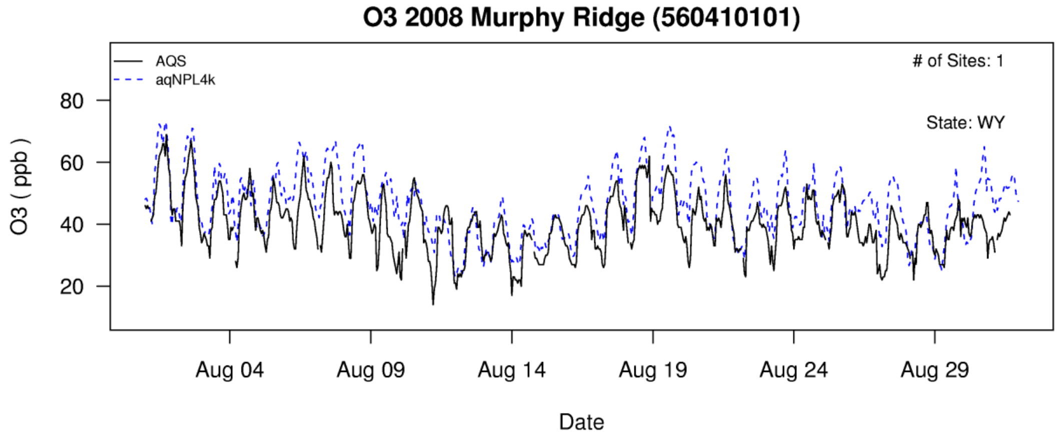
June



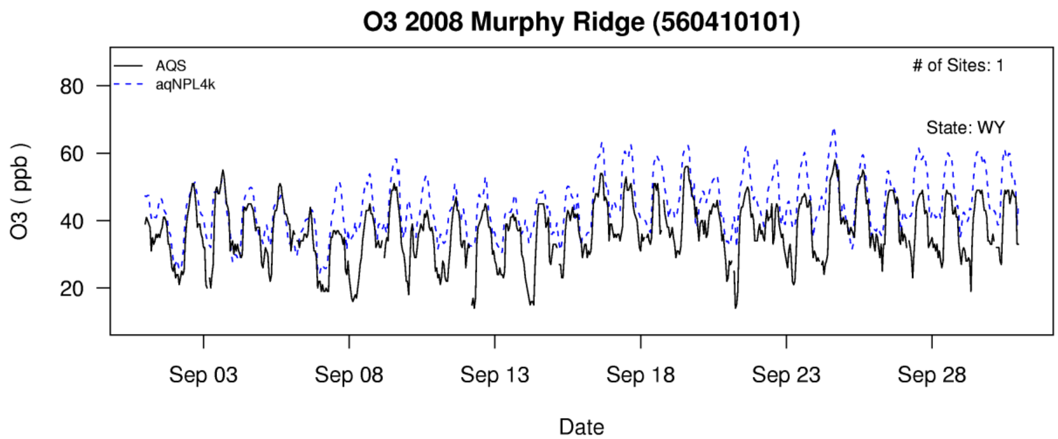
July



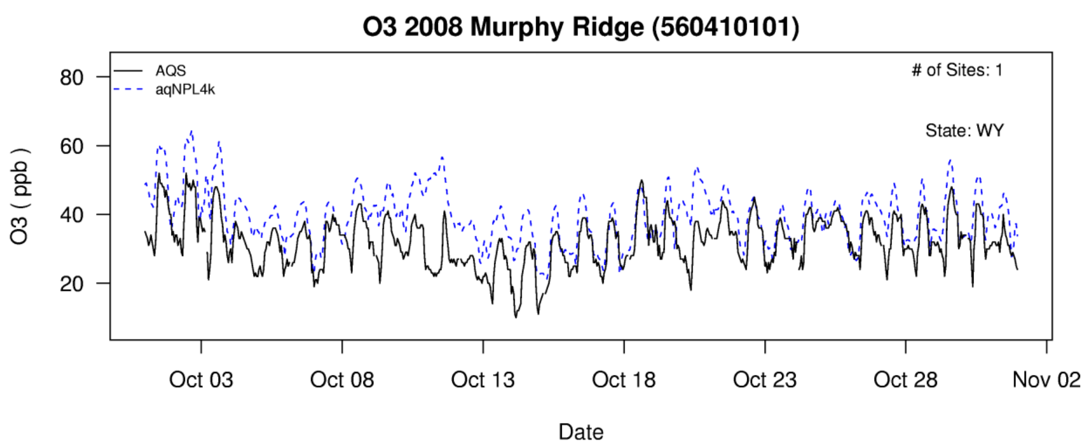
August



September



October



Overall, multiday ozone events, day-to-day variations in ozone concentration, and diurnal profiles are reasonably well represented with some exceptions. For the Daniel South monitoring site, peak concentrations are underestimated for May, overestimated for October, and reasonably well represented for the remaining months. A key model performance issue for this site is that the simulated nighttime ozone concentrations are consistently higher than observed. For the Boulder monitoring site, there is a mix of under- and overestimation of the peak concentrations as well as the lower nighttime concentrations. Overall, the model shows greater skill in simulating the diurnal profiles for this site, compared to Daniel South. For the South Pass monitoring site, the overall tendencies for higher and lower ozone (across multi-day periods) are fairly well simulated. Both the simulated and observed diurnal profiles for this higher elevation site are much less pronounced than for Daniel South and Boulder. Ozone concentrations are underestimated for April and overestimated for September and October. For Wamsutter, peak concentrations are reasonably well represented for all months. Diurnal profiles are also generally well represented for April and May and parts of June and August, but less so for the remaining months. Nighttime ozone concentrations are particularly overestimated for this site for September and October. For Murphy Ridge, ozone concentrations are overestimated from mid-September through mid-October. Otherwise, model performance is quite good and both the peak concentrations and diurnal profiles are well represented. For these same sites, as noted earlier, model performance is poor for the winter months and the time-series plots (not shown) indicate that the high concentrations that occur on several days in February and March are not simulated by the model.

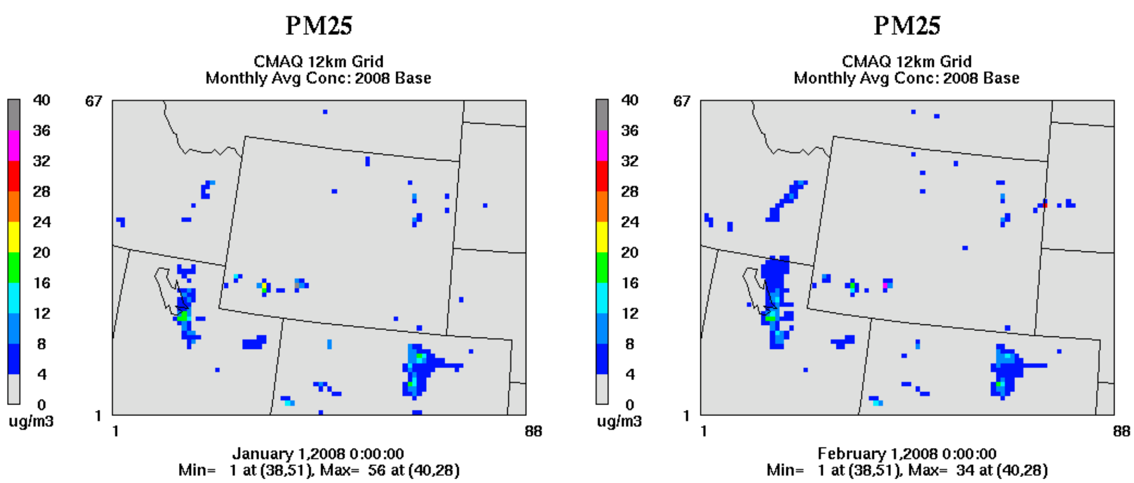
5.2 Summary of Model Performance for PM2.5

5.2.1 Regional-Scale Concentrations for the 12-km Grid

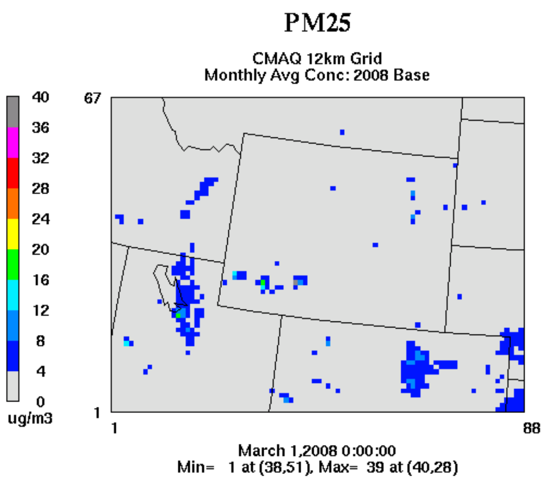
Spatial plots of the monthly average simulated $PM_{2.5}$ concentration patterns for the 12-km grid are illustrated in Figure 5-12. The units are micrograms per cubic meter (µg/m^3).

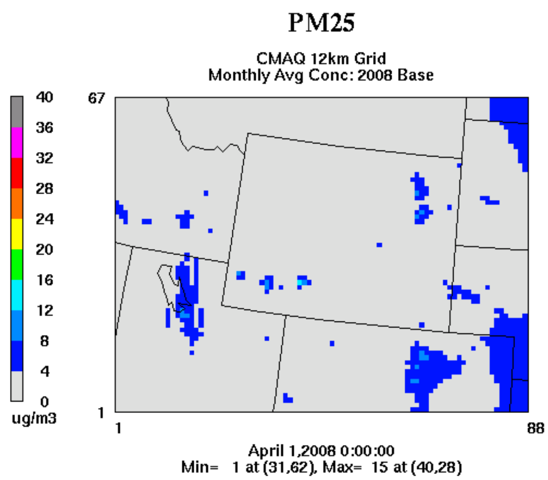
Figure 5-12. Simulated Monthly Average $PM_{2.5}$ Concentration (µg/m^3) for the CMAQ 12-km Grid

January/February

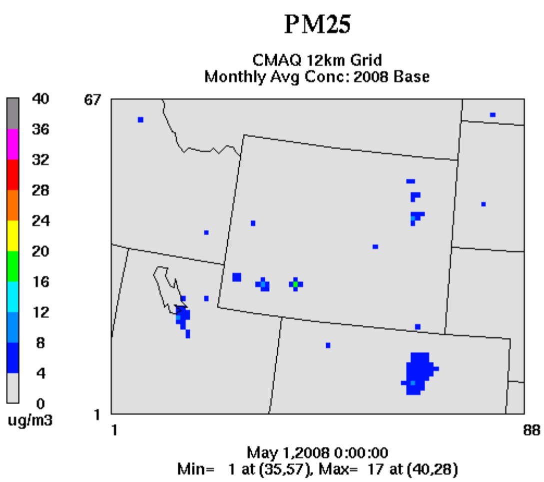


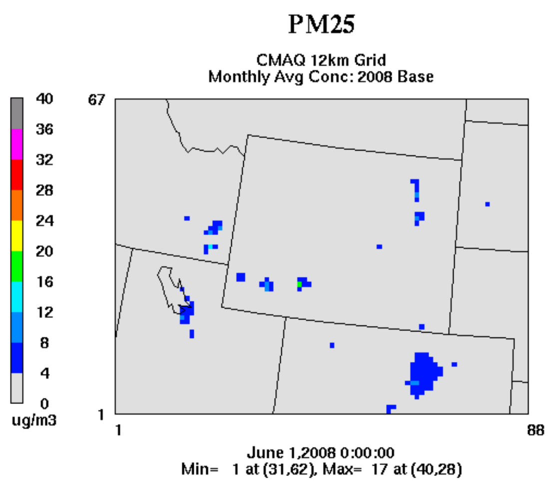
March/April



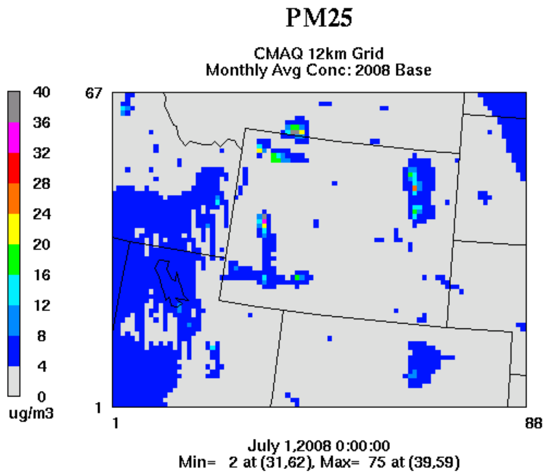


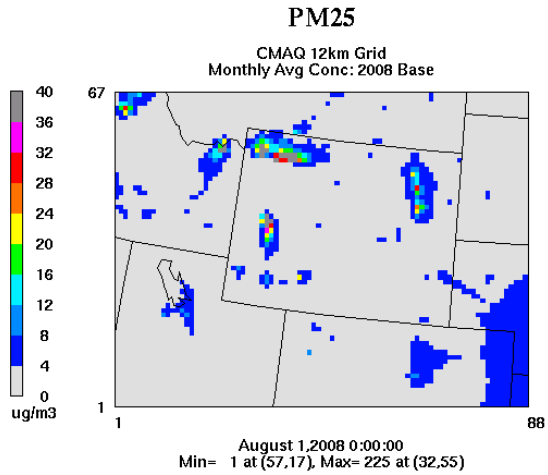
May/June



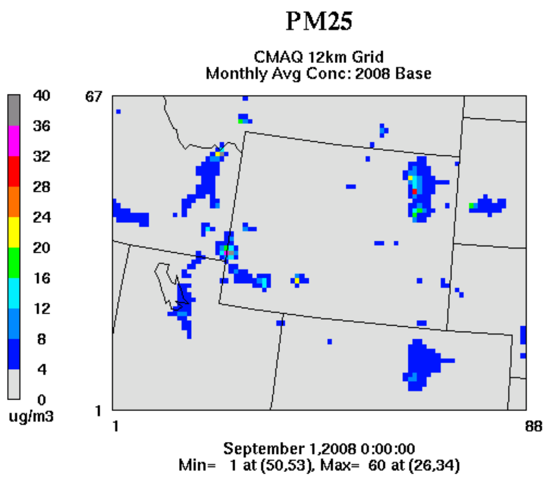


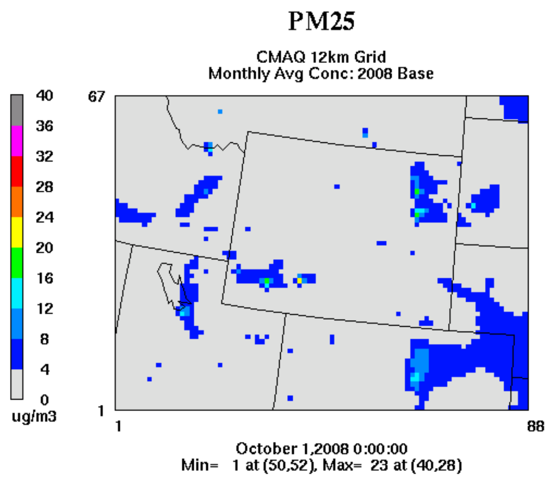
July/August



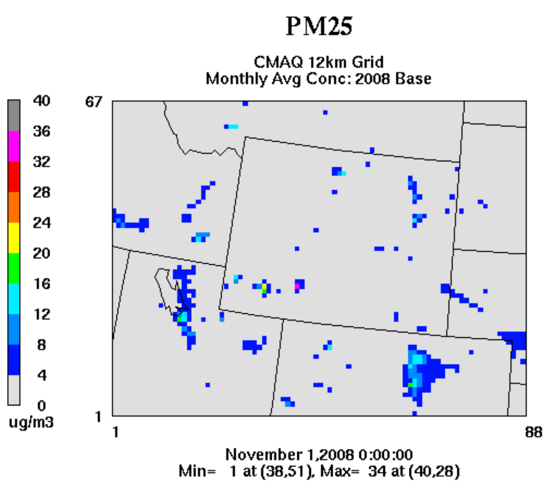


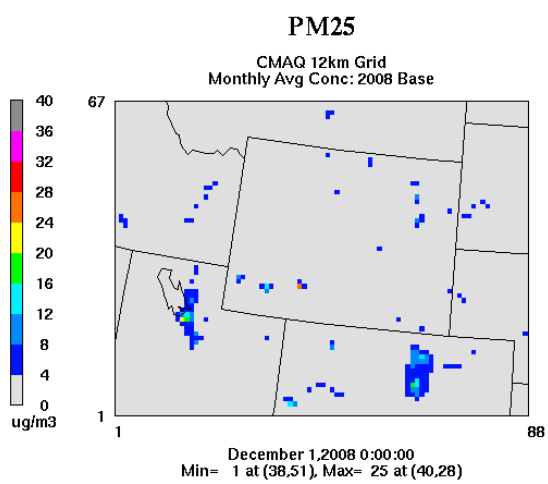
September/October





November/December

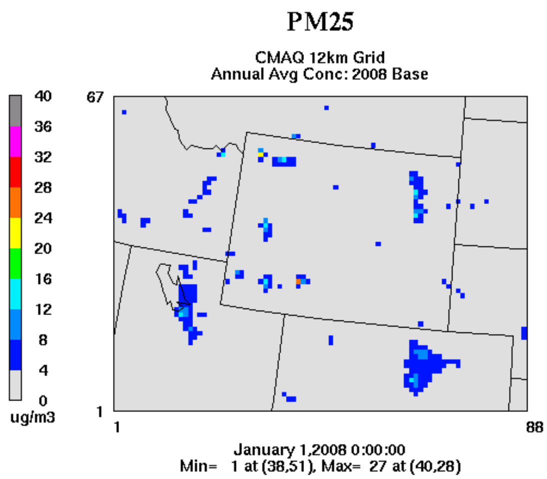




The simulated monthly average $PM_{2.5}$ concentrations are generally lower than 12 µg/m^3. The concentration patterns reveal localized areas of higher $PM_{2.5}$. These are located near the major urban areas of Salt Lake City and Denver, as well as near some existing oil and gas development areas in Wyoming. The very high $PM_{2.5}$ concentrations for August in the northwest corner of Wyoming are attributable to a wildfire near Yellowstone National Park (note that the fire began on July 30, so the concentrations for July are also relatively high in this area).

Figure 5-13 displays the annual average simulated $PM_{2.5}$ concentration pattern for the 12-km grid.

Figure 5-13. Simulated Annual Average $PM_{2.5}$ Concentration (µg/m^3) for the CMAQ 12-km Grid



The concentration patterns reveal localized areas of $PM_{2.5}$ concentrations greater than 4 µg/m^3. The maximum simulated annual average $PM_{2.5}$ concentration is 27 µg/m^3, and is located in southwestern Wyoming.

There are two primary sources of $PM_{2.5}$ concentration data: AQS and IMPROVE. Because the measurement techniques and therefore the concentration data are different, comparisons of simulated and observed concentrations are performed separately for the datasets. In addition, because the observed concentrations can be quite small and there is no accepted minimum threshold, fractional bias and error are better suited to characterizing model performance for $PM_{2.5}$. To illustrate the agreement between the simulated and observed values, Figures 5-14 and 5-15 depict the fractional bias and fractional error statistics for the AQS and IMPROVE sites, respectively, for the 12-km modeling domain. The statistics are calculated using 24-hour average $PM_{2.5}$ concentrations and are calculated using data for the annual simulation period. Again, each monitoring site is represented by a circle and the shading of the circle provides information about how well the 24-hour observed $PM_{2.5}$ concentrations are represented by the simulation results, on average. For the fractional bias, gray shaded circles indicate that the fraction bias is within ± 20 percent and, in general, values within ±60 percent (lighter colors) correspond to acceptable model performance. Blue and green shading indicates underestimation of the observed concentrations and yellow, orange, and red shading indicates overestimation. For the fractional error, blue and green shading represent the smaller errors, while red indicates an error greater than 100 percent. Values less than 75 percent are considered to represent reasonable model performance for $PM_{2.5}$.

Figure 5-14. Fractional Bias (%) and Fractional Error (%) Based on 24-Hour Average Simulated and Observed $PM_{2.5}$ Concentrations for the CMAQ 12-km Grid and the Annual Simulation Period: AQS

Normalized Bias (Left) and Normalized Mean Error (Right)

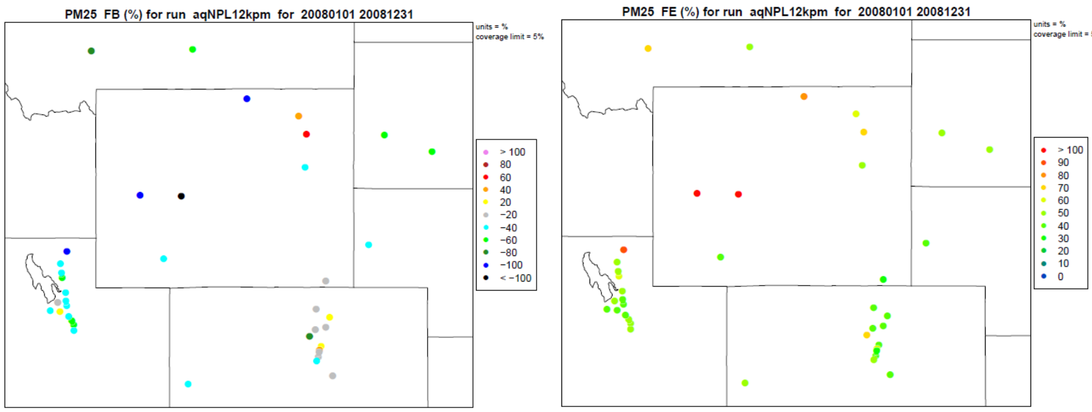
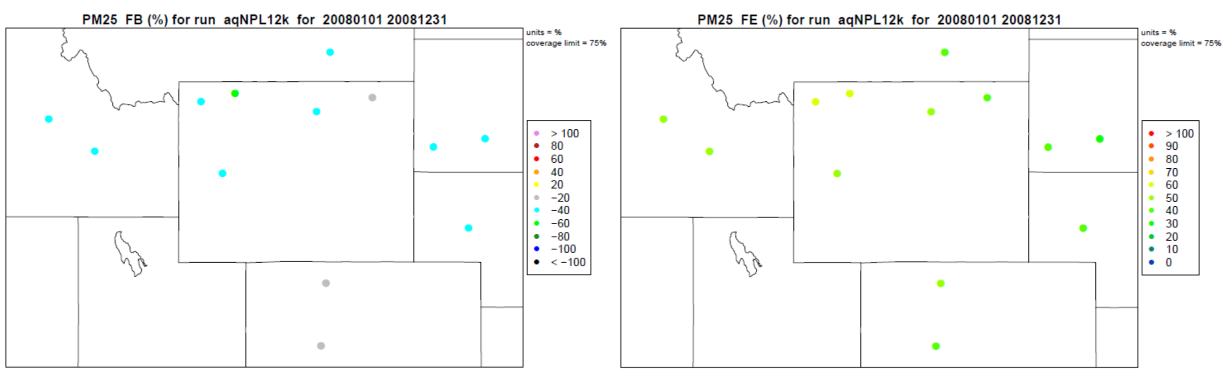


Figure 5-15. Fractional Bias (%) and Fractional Error (%) Based on 24-Hour Average Simulated and Observed $PM_{2.5}$ Concentrations for the CMAQ 12-km Grid and the Annual Simulation Period: IMPROVE

Normalized Bias (Left) and Normalized Mean Error (Right)



Model performance is quite mixed for the AQS sites; the fractional bias indicates a mix of under- and overestimation of the PM concentrations. For most sites, the fractional error is less than 75 percent.

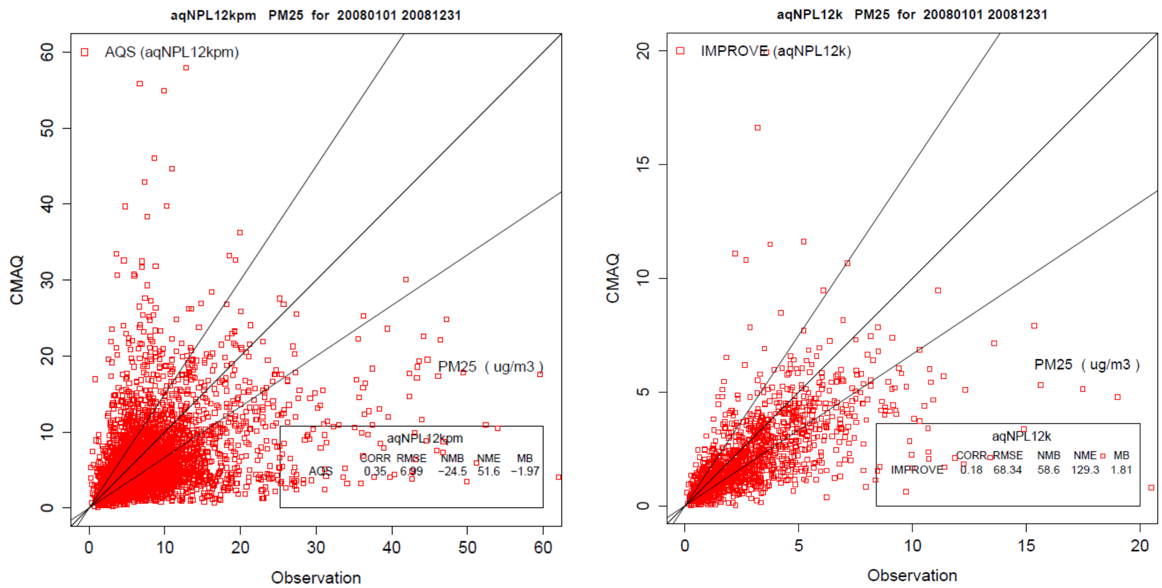
For the IMPROVE sites, the fractional bias values indicate that $PM_{2.5}$ concentrations are generally underestimated. All but one value is within the -40 to +20 percent range. The corresponding errors range from approximately 30 to 60 percent, and are largest for sites in northwestern Wyoming.

Comparison of Simulated and Observed Concentrations

Scatter plots comparing simulated and observed 24-hour $PM_{2.5}$ concentrations for AQS sites and IMPROVE sites within the 12-km grid for the annual simulation period are presented in Figure 5-16.

Figure 5-16. Comparison of Simulated and Observed 24-Hour Average $PM_{2.5}$ Concentration ($\mu g/m^3$) for the 12-km Grid (All Months)

AQS/IMPROVE



Both plots show a good deal of under- and overestimation of the observed $PM_{2.5}$ concentrations. The results indicate that the model is better able to reproduce the concentrations at the more regional-scale IMPROVE monitors, compared to the more urban-scale AQS monitors. Note that a few of the highest simulated values are off the chart, and that the scales were set to optimize viewing of a majority of the data.

Statistical Measures of Model Performance

Total PM2.5

Summary metrics and statistical measures calculated using 24-hr $PM_{2.5}$ concentrations for the 12-km grid are presented in Tables 5-3a and b, for the AQS and IMPROVE datasets, respectively. The recommended ranges for the fractional bias and fractional error are based on Boylan (2005) and are widely used for regional-scale model performance evaluation for $PM_{2.5}$. No lower bound was applied in calculating the statistics.

Table 5-3a. Comparison of Simulated and Observed $PM_{2.5}$ Concentrations for the 12-km Grid: AQS

Metric	Jan – Mar	Apr – Jun	Jul – Sep	Oct – Dec	Annual	Goal
Number of Data Pairs	1,257	1,229	1,211	1,183	4,880	
Mean Observed (µg/m^3)	9.2	6.9	8.4	7.6	8.0	
Mean Simulated (µg/m^3)	7.3	4.5	6.0	6.4	6.1	
Mean Bias (µg/m^3)	-1.9	-2.5	-2.3	-1.1	-2.0	
Fractional Bias (%)	-14.4	-42.4	-43.3	-18.5	-29.6	± 60
Mean Error (µg/m^3)	4.7	3.4	4.8	3.6	4.1	
Fractional Error (%)	52.6	56.3	58.8	50.6	54.6	≤ 75
Correlation (unitless)	0.48	0.23	0.19	0.42	0.35	
Index of Agreement (unitless)	0.64	0.49	0.39	0.64	0.56	

Table 5-3b. Comparison of Simulated and Observed $PM_{2.5}$ Concentrations for the 12-km Grid: IMPROVE

Metric	Jan – Mar	Apr – Jun	Jul – Sep	Oct – Dec	Annual	Goal
Number of Data Pairs	369	352	357	260	1,438	
Mean Observed (µg/m^3)	1.6	3.5	5.2	2.1	3.0	
Mean Simulated (µg/m^3)	1.6	2.3	14.0	1.8	4.9	
Mean Bias (µg/m^3)	-0.1	-1.1	8.8	-0.3	1.8	
Fractional Bias (%)	-0.9	-45.4	-43.5	-14.8	-25.8	± 60
Mean Error (µg/m^3)	0.6	1.3	13.1	0.9	4.0	
Fractional Error (%)	41.7	52.8	59.0	45.1	49.5	≤ 75
Correlation (unitless)	0.67	0.67	0.21	0.49	0.39	
Index of Agreement (unitless)	0.81	0.72	0.03	0.66	0.51	

On an annual basis, the statistical measures indicate that model performance is reasonable for both datasets, and slightly better for the IMPROVE dataset. On average, $PM_{2.5}$ concentrations at the AQS monitors (Table 5-3a) are underestimated throughout the year. The lowest bias and error values and thus the best model performance are achieved for the first and fourth quarters, when $PM_{2.5}$ concentrations are relatively low.

The results using the IMPROVE data (Table 5-3b) show that concentrations are overestimated for the July through September period. The model simulates higher than observed $PM_{2.5}$ concentrations at the Yellowstone NP monitor due to wildfire emissions in the area. Although a wildfire did occur near Yellowstone NP during that period, the effects of the fire on $PM_{2.5}$ concentrations at the monitoring site are not well represented by the model. Possible reasons for the overestimation include overestimation of the emissions, insufficient plume rise for the wildfire emissions, and errors in the wind directions or other meteorological parameters. The best model performance is achieved for the first and fourth quarters.

PM2.5 Species

The model results were also compared to the speciated IMPROVE data. Key metrics and statistics are presented in Table 5-4 for sulfate (SO_4^{2-}), nitrate (NO_3-), organic carbon (OC), elemental carbon (EC), ammonium (NH_4^+), and soil (SOIL). Coarse mass (CM) is a calculated value and was not included here. The number of data pairs is the same as for total $PM_{2.5}$, as given in Table 5-3b.

Table 5-4. Comparison of Simulated and Observed $PM_{2.5}$ Concentrations for the 12-km Grid: IMPROVE Species

Metric	Jan – Mar	Apr – Jun	Jul – Sep	Oct – Dec	Annual	Goal
SO_4^{2-}						
Mean Observed (µg/m^3)	0.4	0.7	0.7	0.4	0.5	
Mean Simulated (µg/m^3)	0.5	0.5	0.6	0.4	0.5	
Fractional Bias (%)	37.1	-25.8	-17.1	5.1	0.3	± 60
Fractional Error (%)	57.9	43.4	32.8	50.2	46.2	≤ 75
NO_3^-						
Mean Observed (µg/m^3)	0.0	0.0	0.0	0.0	0.0	
Mean Simulated (µg/m^3)	0.2	0.2	0.1	0.3	0.2	
Fractional Bias (%)	141.5	119.9	105.7	112.0	118.8	± 60
Fractional Error (%)	162.7	146.4	132.2	153.1	150.5	≤ 75
OC						
Mean Observed (µg/m^3)	0.3	0.7	1.7	0.5	0.8	
Mean Simulated (µg/m^3)	0.2	0.3	3.4	0.3	1.0	
Fractional Bias (%)	-26.8	-74.1	-69.5	-34.2	-50.8	± 60
Fractional Error (%)	65.9	82.0	81.5	67.1	74.0	≤ 75
EC						
Mean Observed (µg/m^3)	0.1	0.1	0.2	0.1	0.1	
Mean Simulated (µg/m^3)	0.0	0.1	0.2	0.1	0.1	
Fractional Bias (%)	-13.0	-30.5	-32.9	-13.7	-22.4	± 60
Fractional Error (%)	64.1	63.3	62.4	64.1	63.5	≤ 75
NH_4^+						
Mean Observed (µg/m^3)	0.2	0.3	0.2	0.2	0.2	
Mean Simulated (µg/m^3)	0.2	0.1	0.2	0.2	0.2	
Fractional Bias (%)	15.5	-32.9	-19.0	-0.8	-0.1	± 60
Fractional Error (%)	28.5	38.0	25.4	25.3	29.2	≤ 75
SOIL						
Mean Observed (µg/m^3)	0.3	0.9	0.7	0.3	0.5	
Mean Simulated (µg/m^3)	0.1	0.5	0.1	0.1	0.2	
Fractional Bias (%)	-50.5	-27.4	-66.6	-55.9	-50.2	± 60
Fractional Error (%)	56.9	38.6	67.8	60.7	56.1	≤ 75

The results for SO_4^{2-} indicate a mix of under and overestimation, depending upon the period. SO_4^{2-} is overestimated during the colder months and underestimated during the warmer months. The fractional bias and error values are within the goals for all periods.

The results for NO_3^- indicate consistent overestimation but both the observed and simulated values are very small. The fractional bias and error values are large (in part due to the very small values used in the calculations) and do not meet the goals for any period.

The results for OC indicate a mix of under and overestimation, depending upon the period and the measure. OC is overestimated during the colder months and underestimated during the warmer months. The fractional bias and error values are within the goals for two of the quarters and for the full period.

The results for EC indicate underestimation of the observed values for all periods. Both the observed and simulated values are very small. The fractional bias and error values are within the goals for all periods.

The results for NH_4^+ indicate a mix of under and overestimation, depending upon the period. NH_4^+ is overestimated during the colder months. The fractional bias and error values are within the goals for all periods.

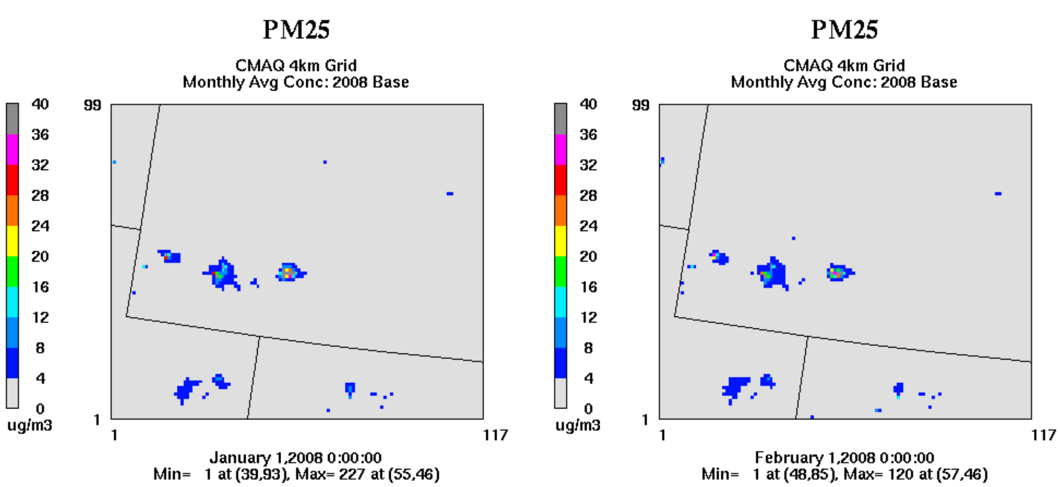
The results for SOIL indicate underestimation of this species, especially during the third quarter. The fractional bias and error values are within the goals for all but one period.

5.2.2 Regional-Scale Concentrations for the 4-km Grid

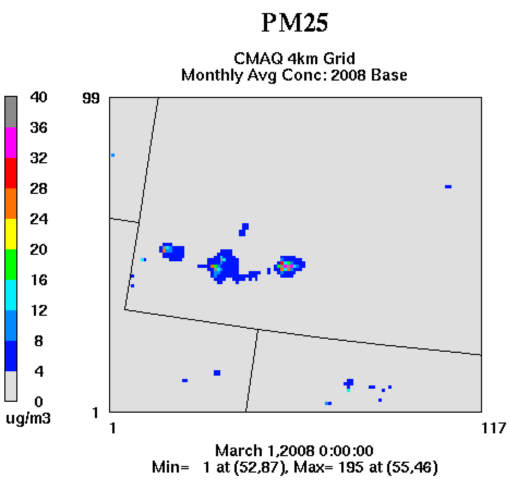
Spatial plots of the monthly average simulated $PM_{2.5}$ concentration patterns for the 4-km grid are illustrated in Figure 5-17. The units are micrograms per cubic meter (µg/m³).

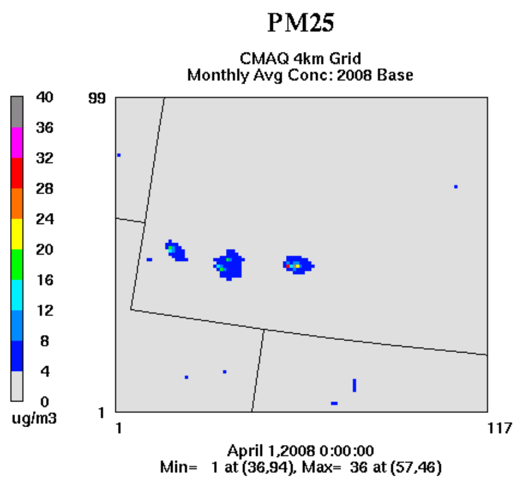
Figure 5-17. Simulated Monthly Average $PM_{2.5}$ Concentration (µg/m³) for the CMAQ 4-km Grid

January/February

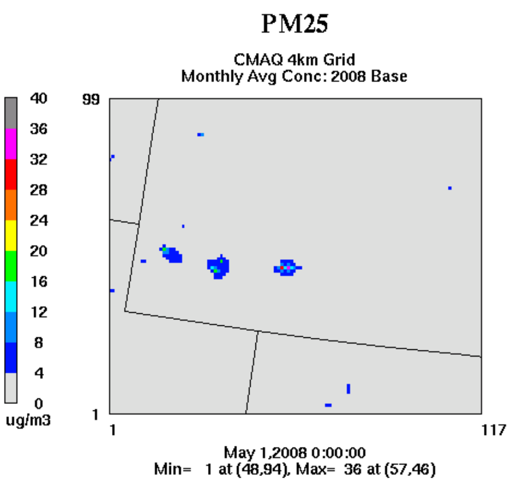


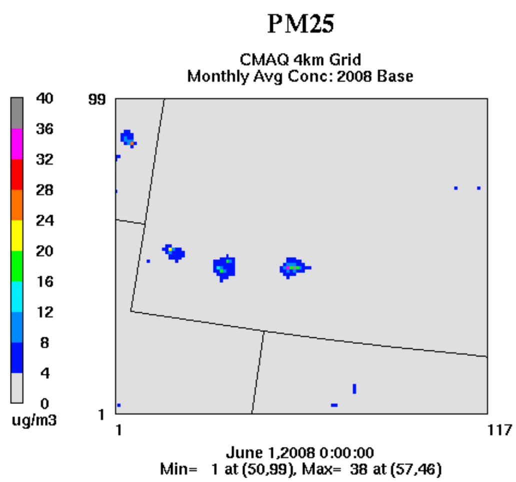
March/April



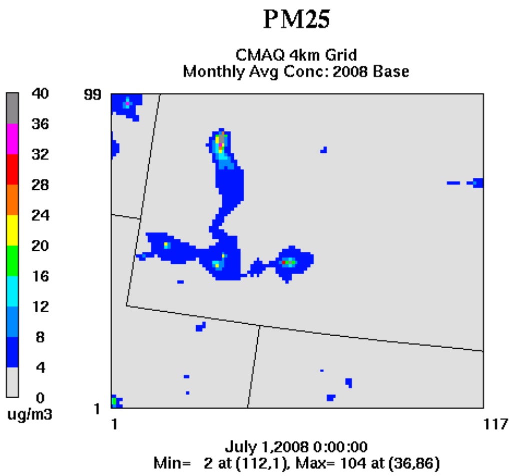


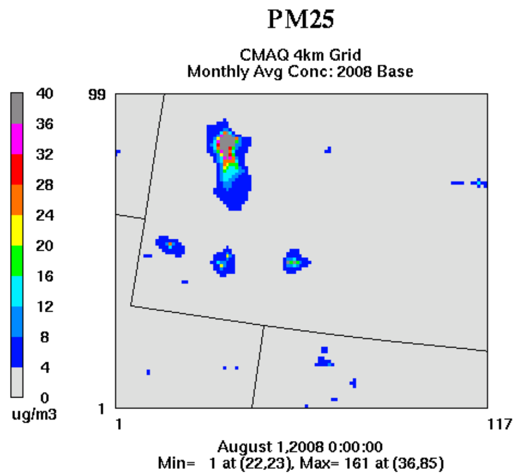
May/June



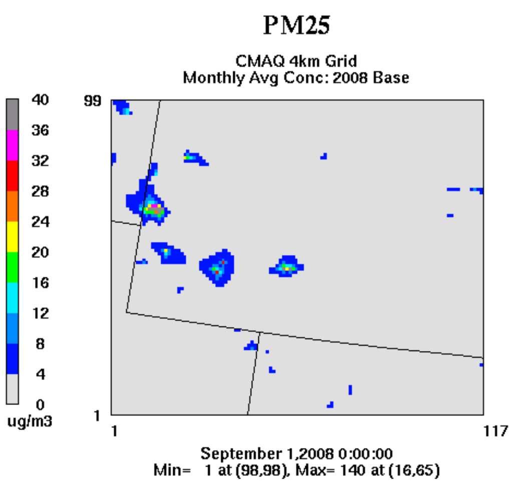


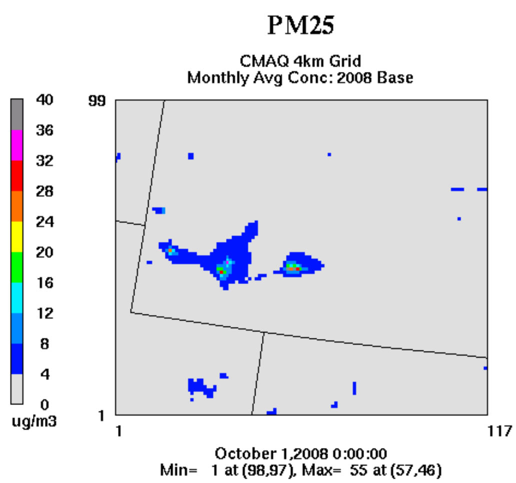
July/August



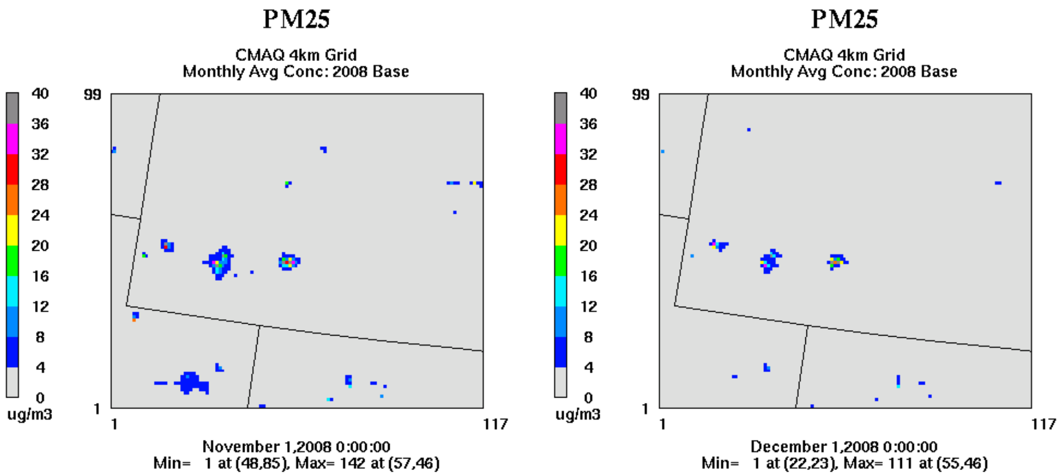


September/October





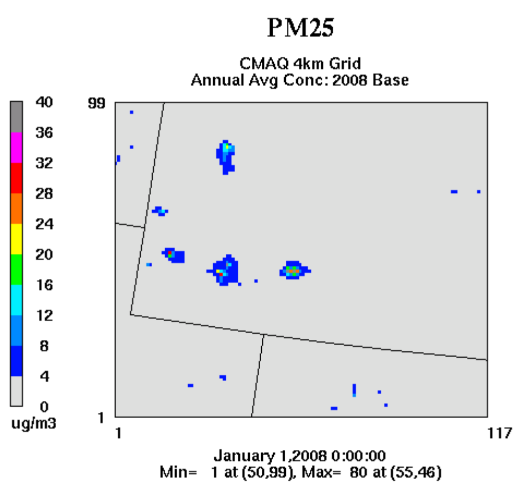
November/December



Although for most of the 4-km grid, the monthly average simulated $PM_{2.5}$ concentrations are generally less than 4 µg/m^3, there are localized areas of higher $PM_{2.5}$, most consistently in southwestern Wyoming. The maximum monthly average simulated $PM_{2.5}$ concentrations for these areas range from approximately 30 to 200 µg/m^3. The effects of the emissions from wildfires in northwestern Wyoming (as included in the emissions inventory) are apparent in the monthly average concentrations for July and August and affect a broad area in the west-central portion of the state.

Figure 5-18 displays the annual average simulated $PM_{2.5}$ concentration pattern for the 4-km grid.

Figure 5-18. Simulated Annual Average $PM_{2.5}$ Concentration (µg/m^3) for the CMAQ 4-km Grid



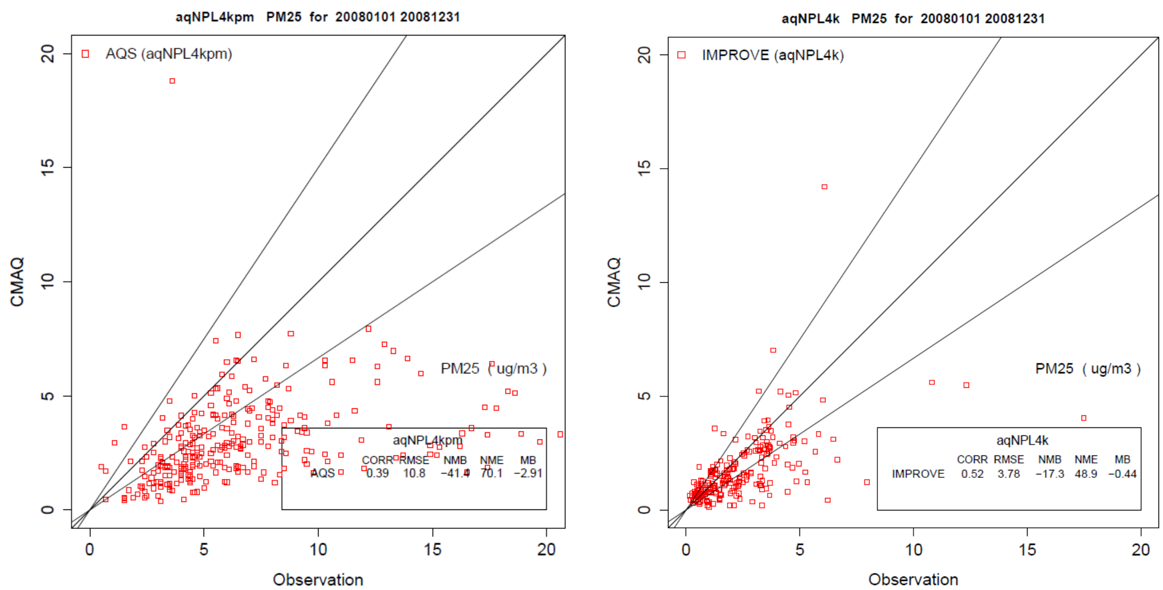
The annual average concentration patterns reveal localized areas of $PM_{2.5}$ concentrations greater than 4 µg/m^3. The maximum simulated annual average $PM_{2.5}$ concentration is 80 µg/m^3, and is located in southwestern Wyoming (near the center of the 4-km grid).

Comparison of Simulated and Observed Concentrations

Scatter plots comparing simulated and observed 24-hour $PM_{2.5}$ concentrations for AQS and IMPROVE sites within the 4-km grid for the annual simulation period are presented in Figure 5-19.

Figure 5-19. Comparison of Simulated and Observed 24-Hour Average $PM_{2.5}$ Concentration ($\mu g/m^3$) for the 4-km Grid (All Months)

AQS/IMPROVE



For both datasets, the higher concentrations are underestimated. There is much better agreement between the simulated and observed values for the IMPROVE sites. Correlation coefficients are 0.39 for the AQS sites and 0.52 for the IMPROVE sites. Note that a few of the highest simulated values are off the chart, and that the scales were set to optimize viewing of a majority of the data.

Statistical Measures of Model Performance

<u>Total PM2.5</u>

Summary metrics and statistical measures calculated using 24-hour average $PM_{2.5}$ concentrations for the 4-km grid are presented in Tables 5-5a and b, for the AQS and IMPROVE datasets, respectively. Note that for the 4-km grid, the AQS dataset includes three sites and the IMPROVE dataset includes two sites. Recommended ranges for fractional bias and fractional error are based on Boylan (2005). No lower bound was applied in calculating the statistics.

Table 5-5a. Comparison of Simulated and Observed $PM_{2.5}$ Concentrations for the 4-km Grid: AQS

Metric	Jan – Mar	Apr – Jun	Jul – Sep	Oct – Dec	Annual	Goal
Number of Data Pairs	59	81	81	69	300	
Mean Observed (µg/m^3)	10.0	4.9	7.3	6.6	7.0	
Mean Simulated (µg/m^3)	3.3	2.4	7.6	2.9	4.1	
Mean Bias (µg/m^3)	-6.8	-2.5	0.2	-3.7	-2.9	
Fractional Bias (%)	-83.3	-69.1	-60.9	-69.5	-69.8	± 60
Mean Error (µg/m^3)	6.9	2.6	6.9	3.8	4.9	
Fractional Error (%)	87.3	76.3	75.3	72.2	77.1	≤ 75
Correlation (unitless)	0.22	0.68	0.64	0.27	0.39	
Index of Agreement (unitless)	0.48	0.62	0.48	0.47	0.49	

Table 5-5b. Comparison of Simulated and Observed $PM_{2.5}$ Concentrations for the 4-km Grid: IMPROVE

Metric	Jan – Mar	Apr – Jun	Jul – Sep	Oct – Dec	Annual	Goal
Number of Data Pairs	60	57	57	54	228	
Mean Observed (µg/m^3)	1.2	3.4	4.4	1.3	2.6	
Mean Simulated (µg/m^3)	1.3	1.9	4.0	1.2	2.1	
Mean Bias (µg/m^3)	0.2	-1.5	-0.4	-0.1	-0.4	
Fractional Bias (%)	14.4	-54.3	-48.5	-7.3	-23.7	± 60
Mean Error (µg/m^3)	0.4	1.6	2.6	0.4	1.2	
Fractional Error (%)	38.5	57.9	60.4	38.0	48.7	≤ 75
Correlation (unitless)	0.75	0.55	0.51	0.82	0.52	
Index of Agreement (unitless)	0.85	0.58	0.57	0.9	0.64	

The results are similar to those for the 12-km grid and show better agreement between the simulated and observed values for the IMPROVE sites. For the AQS sites, the statistical measures indicate better agreement between the simulated and observed values for the second and third quarters, but overall the statistical measures suggest relatively poor model performance. For the IMPROVE sites, the measures indicate better agreement between the simulated and observed values for the first and fourth quarters, and overall reasonable model performance. The results indicate that the model is better able to reproduce the concentrations at the more regional-scale IMPROVE monitors, compared to the more urban-scale AQS monitors. Concentrations at AQS monitors are more likely to be influenced by local emissions and these results indicate that the model is able to simulate the overall regional-scale concentrations but not the details of the variations in concentration near emission sources. Note that there are very few monitors in the 4-km grid, and neither the background nor the urban concentrations are adequately sampled by the monitoring data.

PM2.5 Species

The model results were also compared to the speciated IMPROVE data. Key metrics and statistics are presented in Table 5-6 for sulfate (SO_4^{2-}), nitrate (NO_3-), organic carbon (OC), elemental carbon (EC), ammonium (NH_4^+), and soil (SOIL). The number of data pairs is the same as for total $PM_{2.5}$, as given in Table 5-5b.

Table 5-6. Comparison of Simulated and Observed $PM_{2.5}$ Concentrations for the 4-km Grid: IMPROVE Species

Metric	Jan – Mar	Apr – Jun	Jul – Sep	Oct – Dec	Annual	Goal
SO_4^{2-}						
Mean Observed (µg/m^3)	0.3	0.6	0.5	0.3	0.4	
Mean Simulated (µg/m^3)	0.5	0.4	0.5	0.4	0.5	
Fractional Bias (%)	48.8	-30.5	-9.2	19.1	7.5	± 60
Fractional Error (%)	64.1	46.3	33.6	51.2	49.0	≤ 75
NO_3^-						
Mean Observed (µg/m^3)	0.0	0.0	0.0	0.0	0.0	
Mean Simulated (µg/m^3)	0.1	0.1	0.0	0.1	0.1	
Fractional Bias (%)	125.9	118.8	116.5	80.4	105.4	± 60
Fractional Error (%)	151.3	143.4	149.3	147.3	148.1	≤ 75
OC						
Mean Observed (µg/m^3)	0.2	0.5	1.6	0.3	0.6	
Mean Simulated (µg/m^3)	0.2	0.2	1.0	0.2	0.4	
Fractional Bias (%)	3.5	-77.6	-75.1	-20.4	-41.6	± 60
Fractional Error (%)	55.3	80.8	83.7	53.7	68.2	≤ 75
EC						
Mean Observed (µg/m^3)	0.0	0.1	0.1	0.0	0.1	
Mean Simulated (µg/m^3)	0.0	0.0	0.1	0.0	0.0	
Fractional Bias (%)	3.6	-35.5	-43.3	-8.6	-21.3	± 60
Fractional Error (%)	51.2	63.8	58.6	57.4	57.8	≤ 75
NH_4^+						
Mean Observed (µg/m^3)	0.1	0.2	0.2	0.1	0.2	
Mean Simulated (µg/m^3)	0.2	0.1	0.2	0.1	0.1	
Fractional Bias (%)	15.8	-34.5	-13.2	0.5	-7.6	± 60
Fractional Error (%)	30.6	39.0	20.1	23.8	28.4	≤ 75
SOIL						
Mean Observed (µg/m^3)	0.2	1.2	0.5	0.2	0.5	
Mean Simulated (µg/m^3)	0.0	0.0	0.0	0.0	0.0	
Fractional Bias (%)	-66.1	-85.7	-91.5	-61.4	-78.2	± 60
Fractional Error (%)	70.8	87.7	91.5	69.5	79.9	≤ 75

As for the 12-km grid, the results for SO_4^{2-} indicate a mix of under and overestimation, depending upon the period. SO_4^{2-} is overestimated during the colder months and underestimated during the warmer months. The fractional bias and error values are within the goals for all periods.

The results for NO_3^- indicate consistent overestimation, but both the observed and simulated values are very small. The fractional bias and error values are large (in part due to the very small values used in the calculations) and do not meet the goals for any period.

The results for OC indicate a mix of under and overestimation, depending upon the period. OC is overestimated during the first quarter and underestimated during the remaining periods, but especially during the warmer months. The fractional bias and error values are not within the goals for the second and third quarters.

EC is slightly overestimated for the first quarter and underestimated for the remaining periods. Both the observed and simulated values are very small. The fractional bias and error values are within the goals for all periods.

The results for NH_4^+ indicate a mix of under and overestimation. NH_4^+ is slightly overestimated during the colder months and underestimated during the warmer months. The fractional bias and error values are within the goals for all periods.

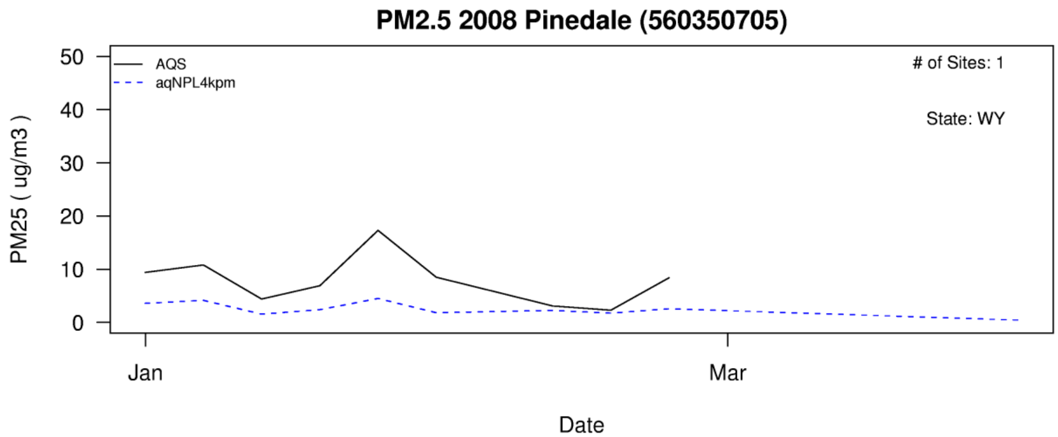
SOIL is consistently underestimated for the sites within the 4-km grid. None of the fractional bias and error values are within the goals.

5.2.3 Site-Specific Concentrations for the 4-km Grid

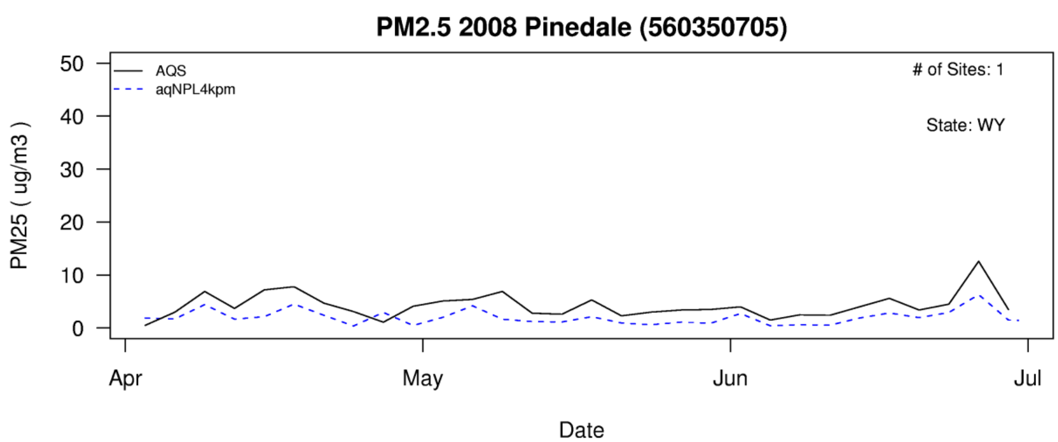
Time-series plots in Figure 5-20 and 5-21 compare daily (24-hour average) simulated and observed $PM_{2.5}$ concentrations for one AQS monitoring site (Pinedale) and one IMPROVE monitoring site (Bridger Wilderness Area) located within the 4-km grid. In these plots, the solid black lines represent the observed values and the dashed blue lines represent the simulated values (taken from the grid cell in which the monitoring site is located). The observed PM data and thus the simulation-observation pairs are available every three days.

Figure 5-20. Time-Series Plots Comparing Simulated and Observed $PM_{2.5}$ Concentration (ppb): Pinedale (AQS)

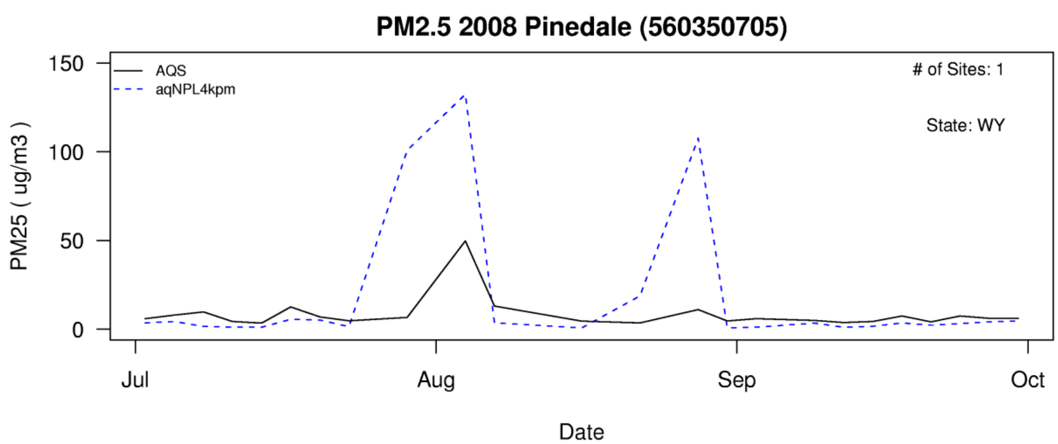
January - March



April - June



July - September



October - December

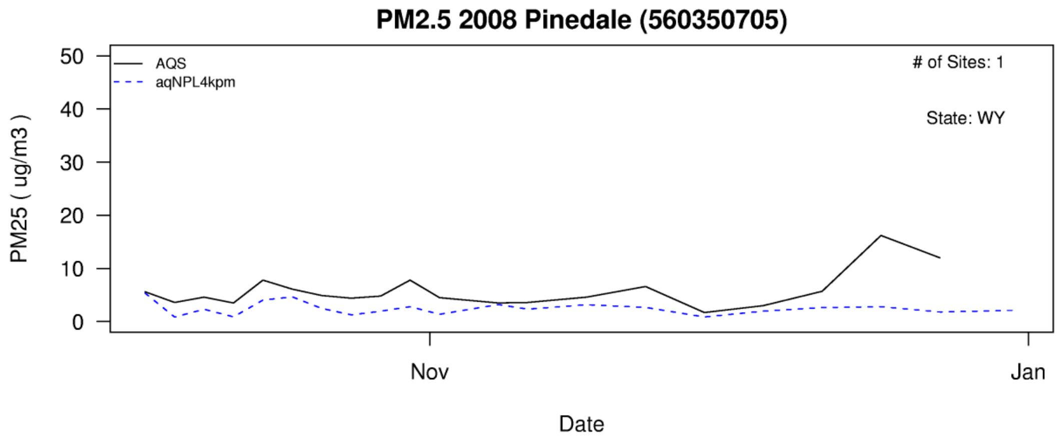
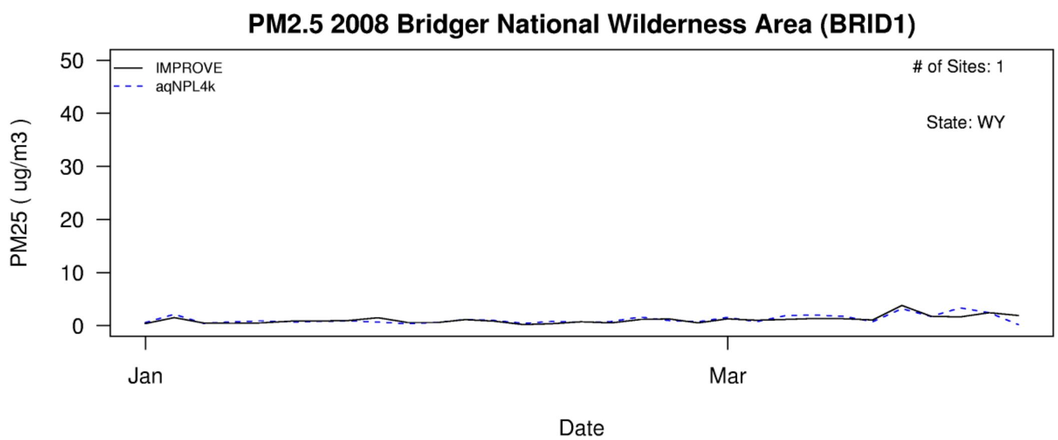
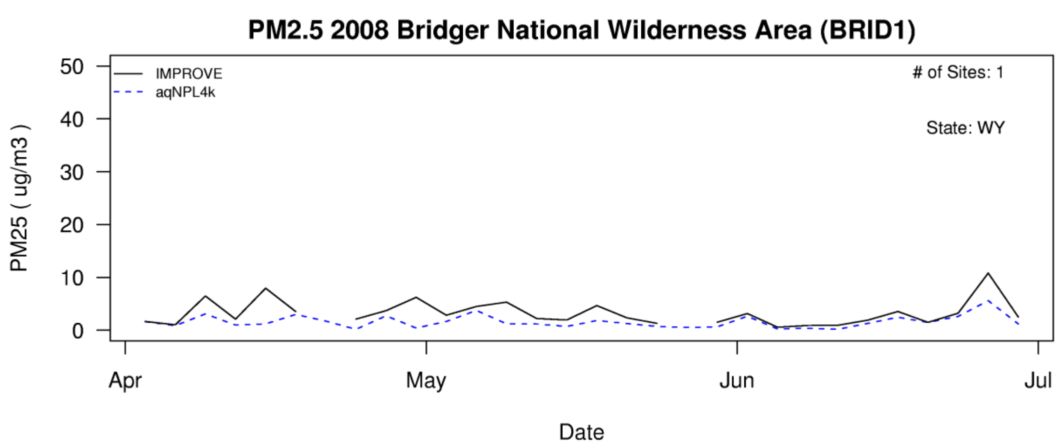


Figure 5-21. Time-Series Plots Comparing Simulated and Observed $PM_{2.5}$ Concentration (ppb): Bridger Wilderness Area (IMPROVE)

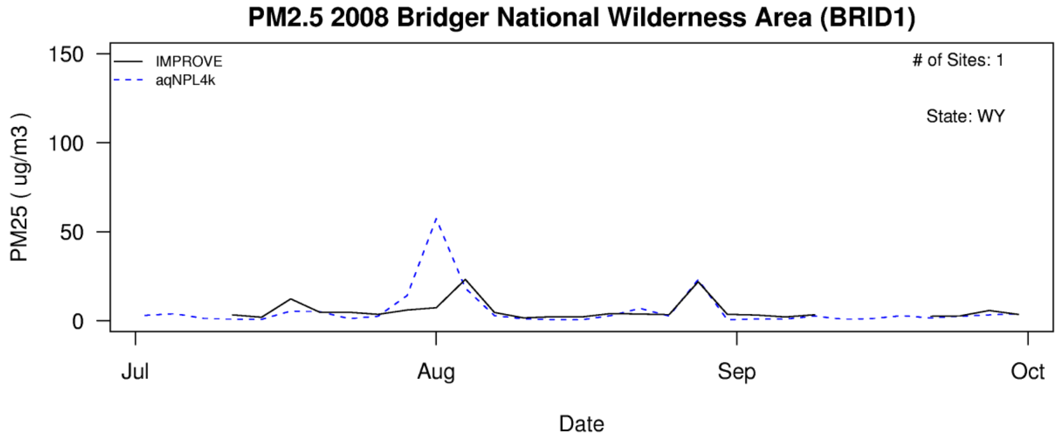
January - March



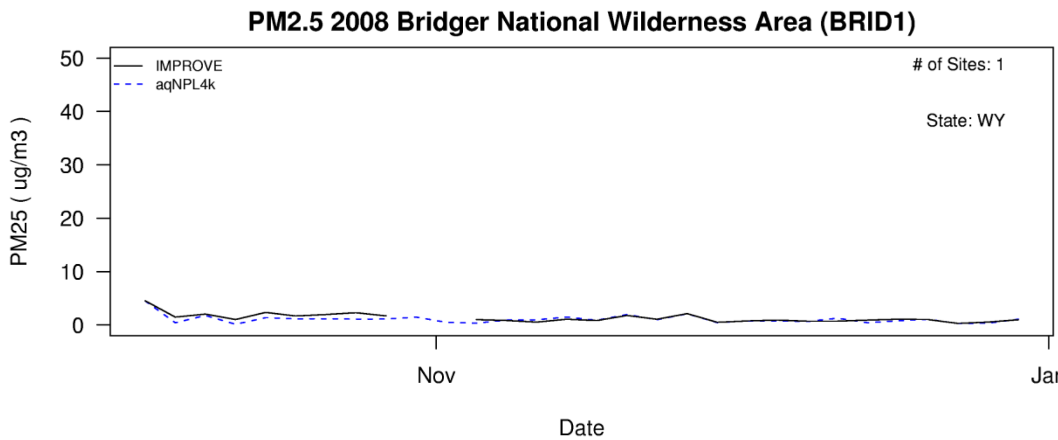
April - June



July - September



October - December



For both sites, the overall tendencies in the $PM_{2.5}$ concentrations are generally represented and the model shows skill in distinguishing periods of higher PM. For both sites, the timing seems to be off by a few days for some, but not all, cases. For Bridger Wilderness, for example, the higher $PM_{2.5}$ concentrations that occur in early August are simulated too early and are overestimated, while the higher $PM_{2.5}$ concentrations in late August are nearly perfectly simulated. For Pinedale, concentrations are consistently lower than observed, with the exception of the few days in August with very high simulated PM.

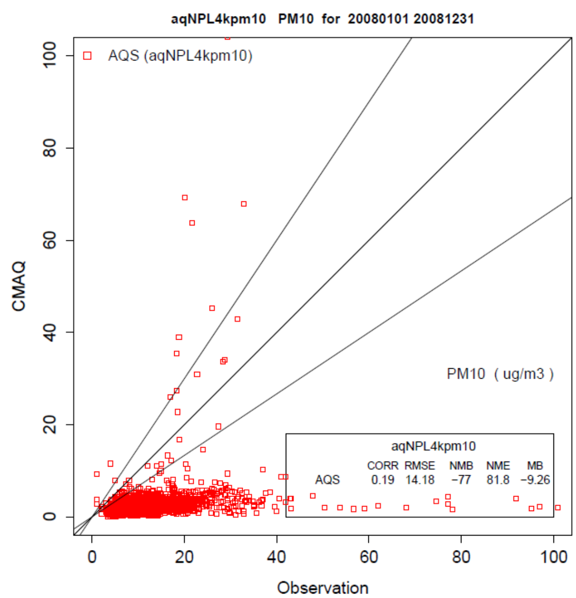
5.3 Summary of Model Performance for PM_{10}, NO_x, SO_2 and CO

Observed concentrations of these criteria pollutants are generally expected to represent local rather than regional scale concentrations. This is due to the fact that these pollutants are directly emitted into the atmosphere and also because the monitoring sites are typically located in urban areas and near roadways. Thus, for most sites, a grid-based model like CMAQ is not likely to capture the sub grid-scale variations in concentration reflected in the data that are due to local emissions sources. In other words, the observed data may not be representative of the 4-km square grid cell and, therefore, not directly comparable to the simulated values. Nevertheless, assessment of model performance for these pollutants may provide important insight into overall model performance. NO_x is a precursor to ozone and both NO_x and SO_2 are precursors to $PM_{2.5}$. A large bias in the precursor pollutants may indicate model performance issues for the secondary pollutants (ozone and $PM_{2.5}$). CO is often assumed to be a tracer for vehicle emissions or other combustion sources and can help in the interpretation of model performance for other pollutants originating from these sources. With this in mind, model performance for these species was examined, with emphasis on quarterly and annual average concentrations. Note that for CO, there is only one monitoring site (Murphy Ridge) located within the 4-km grid and the data for this site are sporadic (mostly missing or zero).

Comparison of Simulated and Observed Concentrations

Scatter plots comparing simulated and observed 24-hour PM_{10} concentrations for AQS sites within the 4-km grid for the annual simulation period are presented in Figure 5-22. Note that only those PM_{10} sites that are also WY DEQ sites were used in the comparison. Units for PM_{10} are µg/m^3.

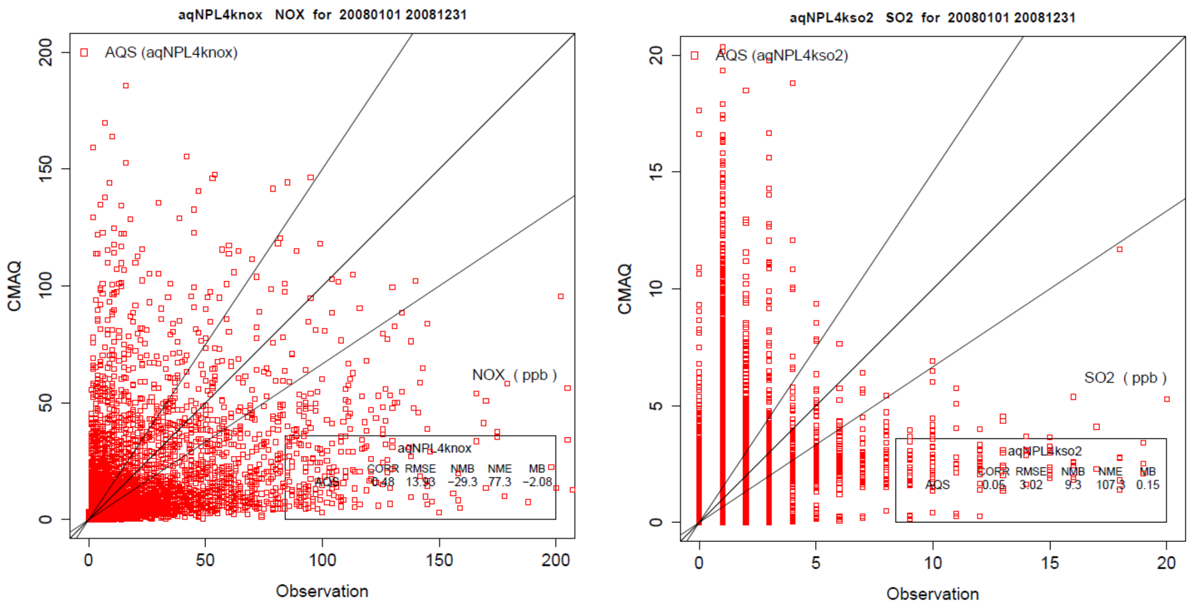
Figure 5-22. Comparison of Simulated and Observed 24-Hour Average PM_{10} Concentration (µg/m^3) for the 4-km Grid (All Months)



Scatter plots comparing simulated and observed hourly NO_2 and SO_2 concentrations for AQS sites within the 4-km grid for the annual simulation period are presented in Figure 5-23. Units for the gaseous species are ppb. Note that the observed SO_2 data are rounded to the nearest ppb.

Figure 5-23. Comparison of Simulated and Observed Hourly Average NOx and SO_2 Concentrations (ppb) for the 4-km Grid (All Months)

NO_x/SO_2



As expected, agreement between the simulated and observed values is not good. PM_{10} concentrations are mostly underestimated. Model performance for 1-hour NO_x and SO_2 concentrations is characterized by a good deal of scatter about the 1:1 line and a tendency for underestimation of the higher observed values and overestimation of the low values.

Statistical Measures of Model Performance

Summary metrics and statistical measures for PM_{10}, NO_x, SO_2, and CO for the 4-km grid are presented in Tables 5-5 through 5-8. The AQS dataset includes data for eight PM_{10}, seven NO_x, and three SO_2 monitoring sites and one CO monitoring site. No lower bound was applied in calculating the statistics; fractional bias and error are emphasized.

Table 5-5. Comparison of Simulated and Observed PM_{10} Concentrations for the 4-km Grid Using AQS Data

Metric	Jan – Mar	Apr – Jun	Jul – Sep	Oct – Dec	Annual
Number of Data Pairs	545	432	411	412	1,800
Mean Observed (μg/m^3)	7.6	15.7	17.3	8.8	12.0
Mean Simulated (μg/m^3)	2.0	2.3	5.2	1.9	2.8
Mean Bias (μg/m^3)	-5.6	-13.4	-12.1	-6.9	-9.2
Fractional Bias (%)	-113.6	-141.7	-130.2	-127.4	-127.3
Mean Error (μg/m^3)	5.6	13.4	14.6	7.0	9.8
Fractional Error (%)	114.9	141.7	135.3	128.1	129

Table 5-6. Comparison of Simulated and Observed NO_x Concentrations for the 4-km Grid Using AQS Data

Metric	Jan – Mar	Apr – Jun	Jul – Sep	Oct – Dec	Annual
Number of Data Pairs	7,558	5,785	6,619	6,406	26,368
Mean Observed (ppb)	12.8	5.4	4.1	4.9	7.1
Mean Simulated (ppb)	9.0	3.3	2.6	4.3	5.0
Mean Bias (ppb)	-3.9	-2.0	-1.5	-0.6	-2.1
Fractional Bias (%)	-42.2	-56.7	-52.8	-18.5	-42.3
Mean Error (ppb)	9.8	4.0	3.3	4.0	5.5
Fractional Error (%)	80.5	93.2	88.8	76.4	84.4

Table 5-7. Comparison of Simulated and Observed SO_2 Concentrations for the 4-km Grid Using AQS Data

Metric	Jan – Mar	Apr – Jun	Jul – Sep	Oct – Dec	Annual
Number of Data Pairs	4,464	1,064	2,674	3,744	11,946
Mean Observed (ppb)	1.6	1.3	1.8	1.5	1.6
Mean Simulated (ppb)	1.4	1.4	2.2	1.9	1.7
Mean Bias (ppb)	-0.2	0.1	0.4	0.4	0.1
Fractional Bias (%)	-71.4	-37.1	13.8	-29.8	-36.2
Mean Error (ppb)	1.7	1.2	1.8	1.7	1.7
Fractional Error (%)	123.4	98.6	86.6	105.6	107.4

Table 5-8. Comparison of Simulated and Observed CO Concentrations for the 4-km Grid Using AQS Data

Metric	Jan – Mar	Apr – Jun	Jul – Sep	Oct – Dec	Annual
Number of Data Pairs	553	964	1,532	494	3,197
Mean Observed (ppb)	143.1	123.5	168.2	93.1	146.7
Mean Simulated (ppb)	130.7	115.0	91.5	94.5	105.2
Mean Bias (ppb)	-12.5	-8.5	-76.6	1.4	-41.5
Fractional Bias (%)	19.6	19.6	-18.7	23.4	1.3
Mean Error (ppb)	85.8	71.9	111.8	52.9	92.4
Fractional Error (%)	65.3	62.2	75.3	60.9	69.0

A fractional bias within ±67 percent indicates that the simulated values are, on average, within a factor of two of the observed values. This is achieved for NO_x, SO_2, and CO, but not for PM_{10}.

5.4 Summary of Model Performance for Deposition

5.4.1 Wet Deposition

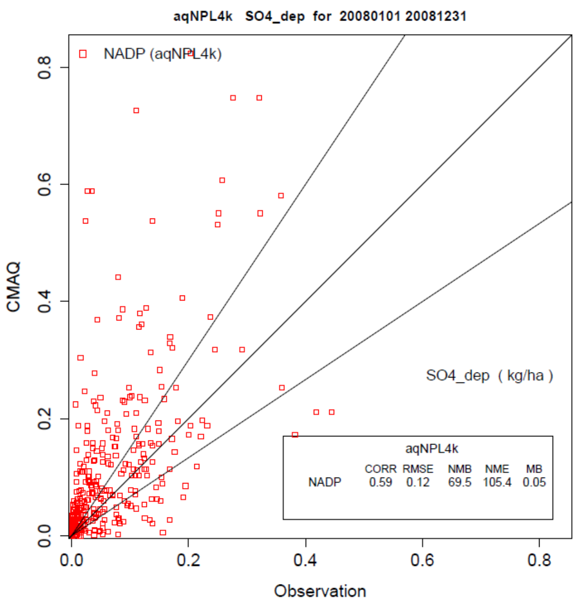
The assessment of model performance for wet deposition focused on the following ions/species: sulfate (SO_4^{2-}), nitrate (NO_3^-), and ammonium (NH_4^+).

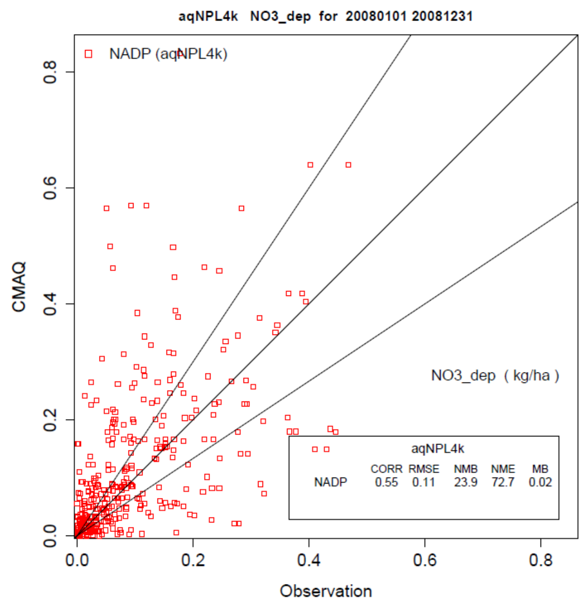
Comparison of Simulated and Observed Deposited Mass

Scatter plots comparing simulated and observed weekly wet deposition values for NADP sites within the 4-km grid for the annual simulation period are presented in Figure 5-24. Units for deposition are kilograms per hectare (kg/ha).

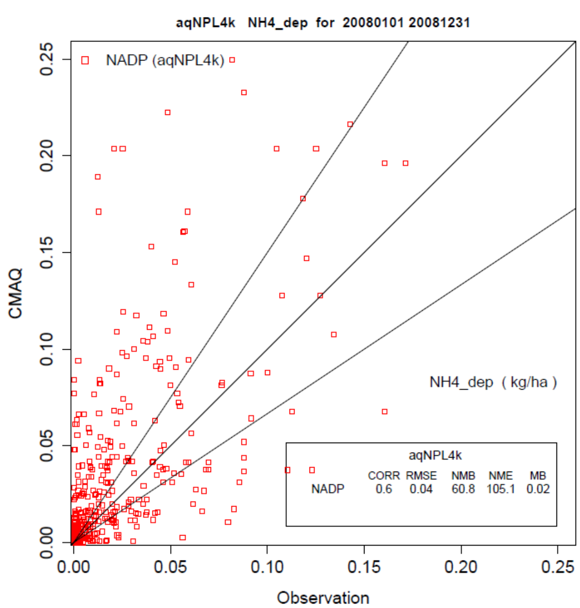
Figure 5-24. Comparison of Simulated and Observed Total Weekly Wet Deposition (kg/ha) for the 4-km Grid (All Weeks)

SO_4^{2-}/NO_3^-





NH_4^+



Agreement between the simulated and observed values is reasonably good, with a slight tendency for overestimation, for all three species.

Statistical Measures of Model Performance

Summary metrics and statistical measures for wet deposition for the 4-km grid are presented in Table 5-9. The NADP dataset includes data for 11 monitoring sites that are located in this grid. Data are available approximately weekly. The corresponding annual values would be approximately 52 times the mean values given in the table. No lower bound was applied in calculating the statistics; fractional bias and error are emphasized.

Table 5-9. Comparison of Simulated and Observed SO_4^{2-} NO_3^- and NH_4^+ Total Weekly Wet Deposition for the 4-km Grid (All Weeks)

Metric	SO_4^{2-}	NO_3^-	NH_4^+
Number of Data Pairs	345	345	345
Mean Observed (kg/ha)	0.07	0.10	0.02
Mean Simulated (kg/ha)	0.11	0.12	0.04
Mean Bias (kg/ha)	0.05	0.02	0.02
Fractional Bias (%)	40.1	11.7	40.1
Mean Error (kg/ha)	0.07	0.07	0.03
Fractional Error (%)	85.2	75.4	95.3

The fractional bias is well within ±67 percent for all three species which indicates that the simulated values are, on average, within a factor of two of the observed values.

5.4.2 Dry Deposition

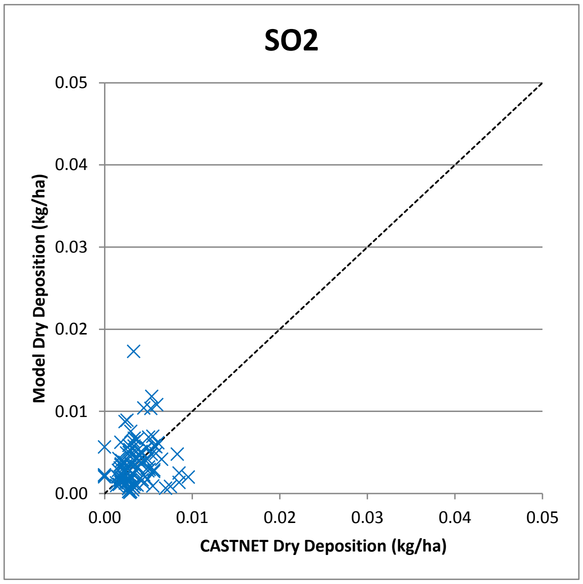
The assessment of model performance for dry deposition focused on the following ions/species: sulfur dioxide (SO_2), sulfate (SO_4^{2-}), total sulfur (S), nitrate (NO_3^-), nitric acid (HNO_3), ammonium (NH_4^+) and total nitrogen (N).

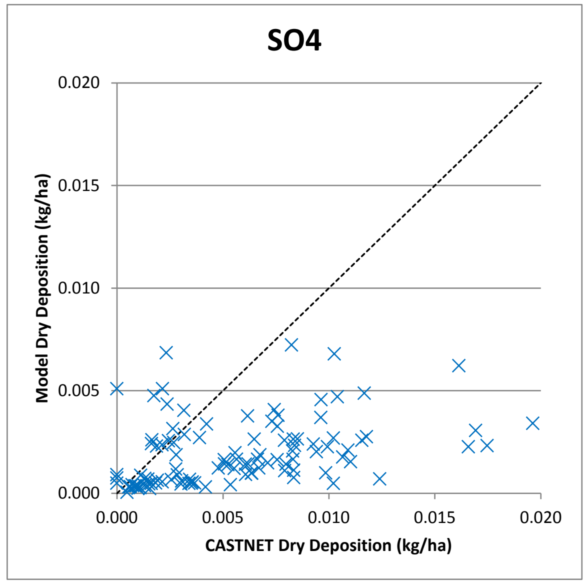
Comparison of Simulated and Observed Deposited Mass

Scatter plots comparing simulated and observed weekly dry deposition values for the two CASTNet sites within the 4-km grid for the annual simulation period are presented in Figures 5-25 and 5-26, for sulfur and nitrogen species, respectively. Units for deposition are kilograms per hectare (kg/ha).

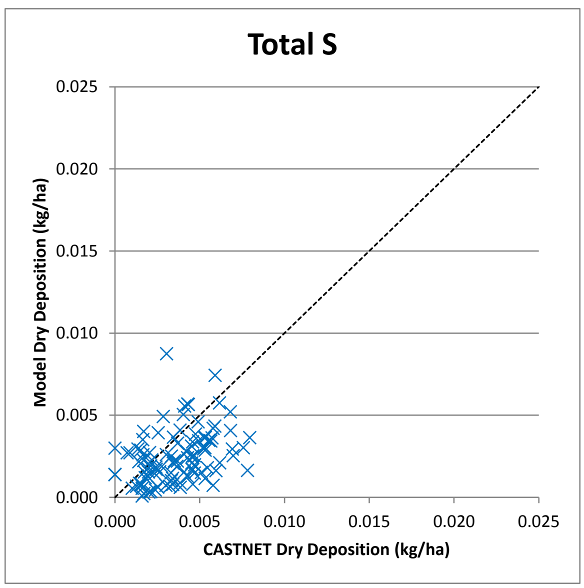
Figure 5-25. Comparison of Simulated and Observed Total Weekly Dry Deposition (kg/ha) of Sulfur Species for the 4-km Grid (All Weeks)

SO_2/ SO_4^{2-}





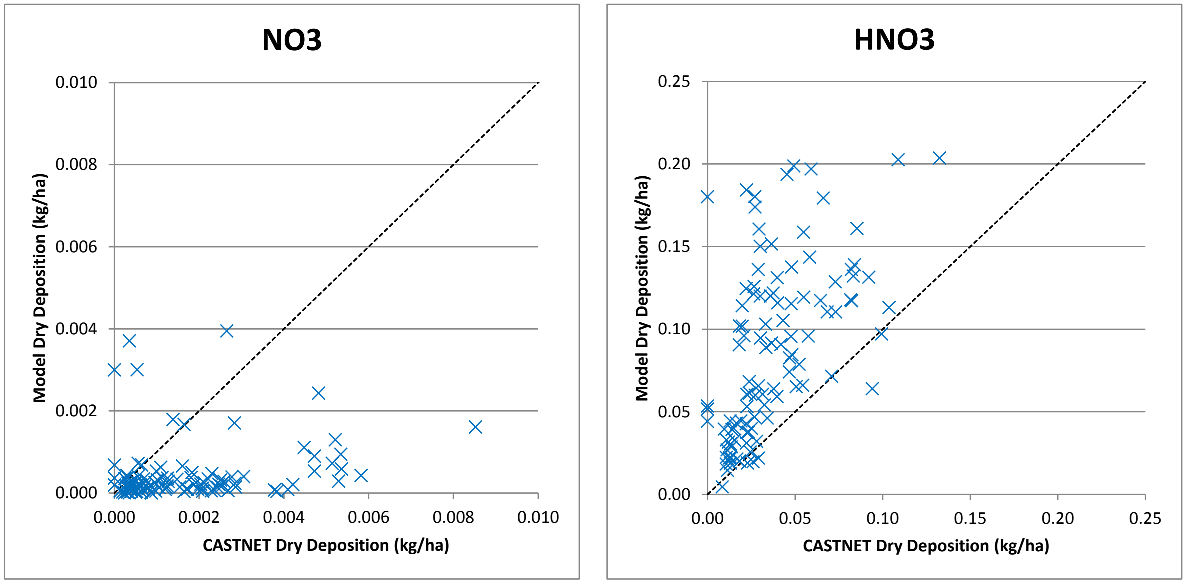
Total S



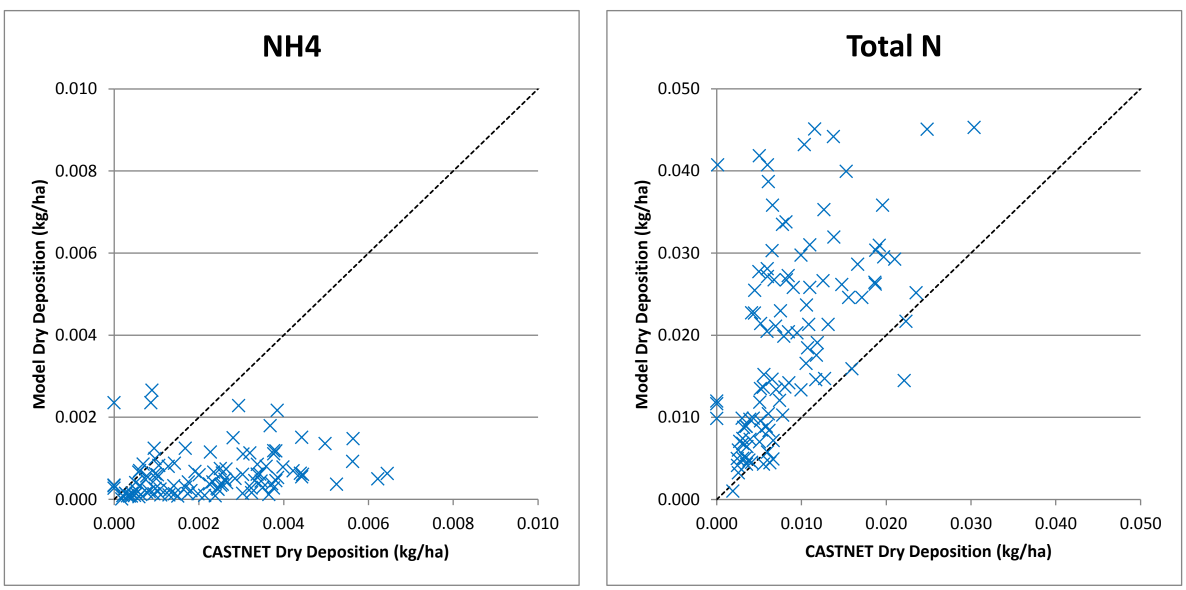
For sulfate there is a tendency for overestimation. Agreement between the simulated and observed values for SO_2 and total sulfur is reasonably good, with a slight tendency for overestimation of total sulfur.

Figure 5-26. Comparison of Simulated and Observed Total Weekly Dry Deposition (kg/ha) of Nitrogen Species for the 4-km Grid (All Weeks)

NO_3^-/ HNO_3



NH_4^+/ Total N



Based on comparison with the CASTNet data, dry deposition of nitrate and ammonium is underestimated while dry deposition of nitric acid and total nitrogen are overestimated by the CMAQ model.

Statistical Measures of Model Performance

Summary metrics and statistical measures for dry deposition for the 4-km grid are presented in Tables 5-9 and 5-10, for sulfur and nitrogen species, respectively. The CASTNet dataset includes data for two monitoring sites that are located in this grid. Data are available approximately weekly. The corresponding annual values would be approximately 52 times the mean values given in the table. No lower bound was applied in calculating the statistics; fractional bias and error are emphasized.

Table 5-9. Comparison of Simulated and Observed SO_4^{2-}, NO_3^- and NH_4^+ Total Weekly Dry Deposition of Sulfur Species for the 4-km Grid (All Weeks)

Metric	SO_2	SO_4^{-2}	Total S
Number of Data Pairs	106	106	106
Mean Observed (kg/ha)	0.004	0.006	0.002
Mean Simulated (kg/ha)	0.004	0.002	0.002
Mean Bias (kg/ha)	0.0	-0.004	-0.001
Fractional Bias (%)	-9.8	-83.3	-40.8
Mean Error (kg/ha)	0.0	0.004	0.002
Fractional Error (%)	66.3	107.4	70.3

The fractional bias is well within ±67 percent for SO_2 and total sulfur. As indicated in the scatter plot, dry deposition of sulfate is underestimated by quite a lot.

Table 5-10. Comparison of Simulated and Observed SO_4^{2-}, NO_3^- and NH_4^+ Total Weekly Dry Deposition of Nitrogen Species for the 4-km Grid (All Weeks)

Metric	NO_3^-	HNO_3	NH_4^+	Total N
Number of Data Pairs	106	106	106	106
Mean Observed (kg/ha)	0.002	0.04	0.002	0.001
Mean Simulated (kg/ha)	0.0	0.09	0.001	0.002
Mean Bias (kg/ha)	-0.001	0.05	-0.002	0.01
Fractional Bias (%)	-107.7	75.4	-100.2	71.3
Mean Error (kg/ha)	0.001	0.05	0.002	0.01
Fractional Error (%)	131.7	78.7	120.1	75.2

Dry deposition of nitrate and ammonium is underestimated while that for nitric acid is overestimated. This results in an overestimation of total nitrogen.

5.5 Sensitivity Testing

Throughout this section, the ability of the model to simulate seasonal, monthly, and diurnal differences in concentration levels and patterns was examined and this provides some insight into the ability of the model to respond to changes in the inputs (e.g., variations in meteorological conditions and emissions). Key findings include:

- Although reasonable performance is achieved for all ozone season months, model performance for ozone varies by month and is characterized by underestimation of ozone for April followed by an increasingly positive bias throughout the remaining months.
- Overall, multiday ozone events, day-to-day variations in ozone concentration, and diurnal profiles are reasonably well represented but there are some exceptions. For example simulated nighttime ozone concentrations are consistently higher than observed at the Daniel South monitoring site. Site-specific model performance for ozone also varies from month to month.
- For $PM_{2.5}$, the CMAQ model is better able to reproduce the concentrations at the more regional-scale IMPROVE monitors, compared to the more urban-scale AQS monitors.
- For the AQS sites, the statistical measures indicate better agreement between the simulated and observed for $PM_{2.5}$ concentrations for the second and third quarters, while for the IMPROVE sites, the measures indicate better agreement between the simulated and observed values for the first and fourth quarters.
- Comparison of simulated and observed concentrations of PM_{10}, NO_x, SO_2 and CO indicates that CMAQ is not able to capture the variations in concentration reflected in the data, especially those that are due to local emissions sources. CMAQ performs much better for secondary (formed in the atmosphere) than primary (emitted into the atmosphere) pollutants because secondary pollutants are much more likely to be representative of concentrations with a 4-km square area (or grid cell).
- Model performance for wet deposition is roughly consistent among the species.

In addition, one sensitivity test was conducted to examine the influence of the GEOS-Chem derived boundary conditions. CMAQ was rerun for a two-month period (July and August) with zero emissions. Monthly average daily maximum 8-hour ozone concentrations for the zero-emissions simulation are compared with the monthly average difference between the base and zero-emissions simulations (base minus zero-emissions) in Figures 5-27 and 5-28. These represent (approximately) the contributions from boundary conditions and emissions, respectively. These are only approximate contributions because nonlinear interactions between the boundary conditions and the emissions contribute to the overall simulated base concentrations.

Figure 5-27. Monthly Average Daily Maximum 8-Hour Ozone Concentrations (ppb) for July 2008.
Zero Emissions/Base Minus Zero Emissions

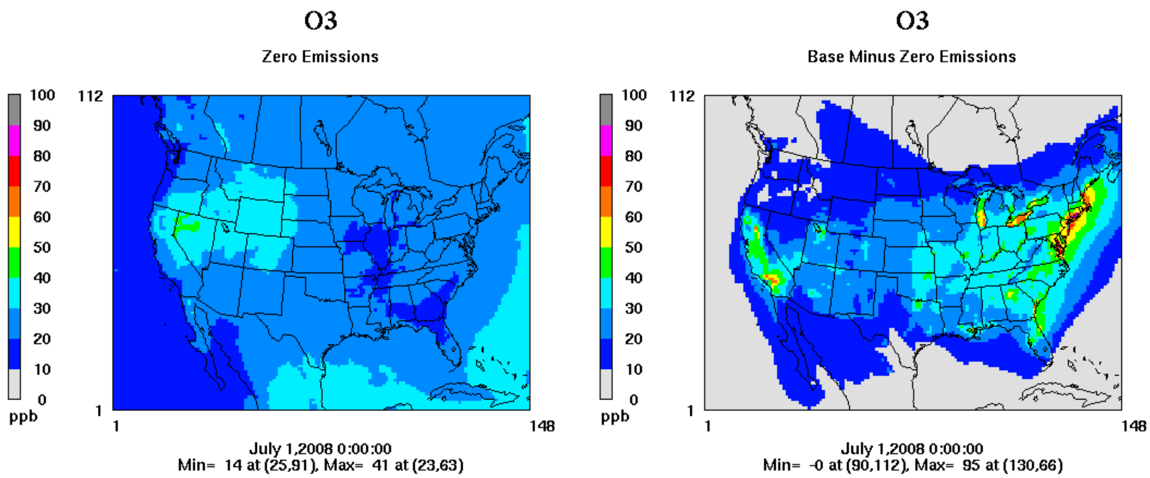
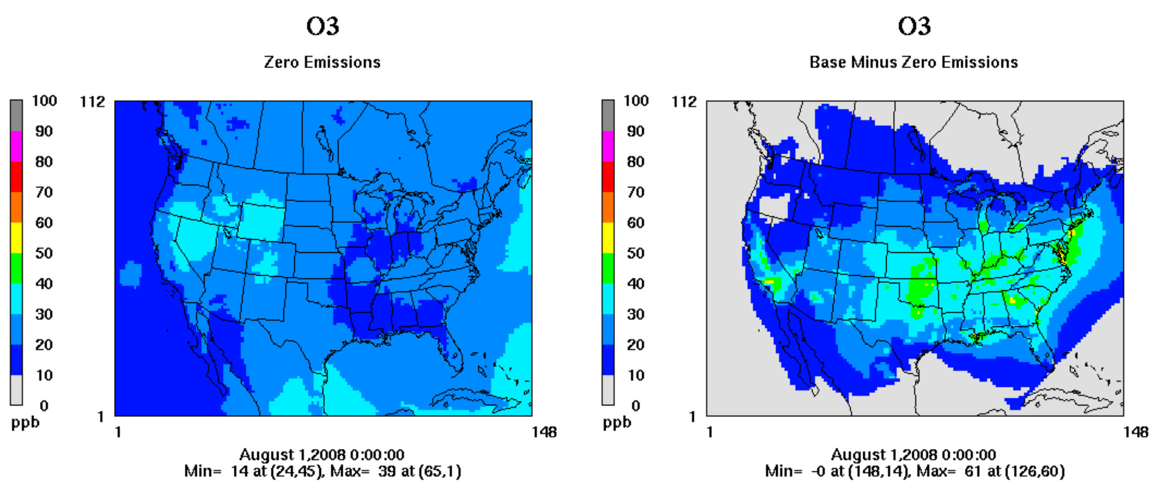


Figure 5-28. Monthly Average Daily Maximum 8-Hour Ozone Concentrations (ppb) for August 2008.
Zero Emissions/Base Minus Zero Emissions

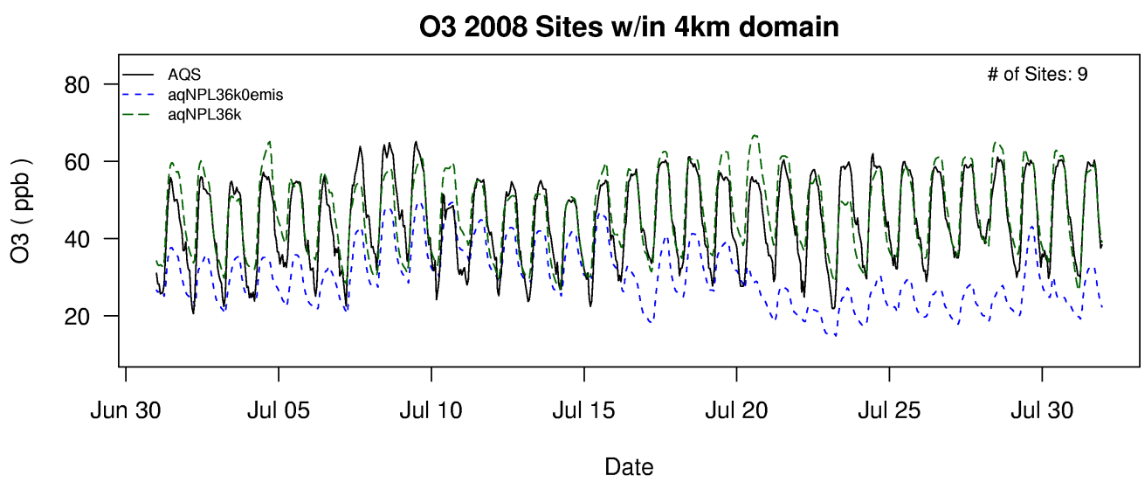


The plots indicate that the boundary conditions account for approximately 30 to 40 ppb of the monthly average daily maximum 8-hour ozone concentrations over Wyoming for the summer months of July and August. The emissions contribute on the order of 10 to 30 ppb to the monthly average 8-hour concentrations. Compared to many other regions of the U.S., the boundary conditions represent a greater percentage of the monthly average (and potentially background) concentration.

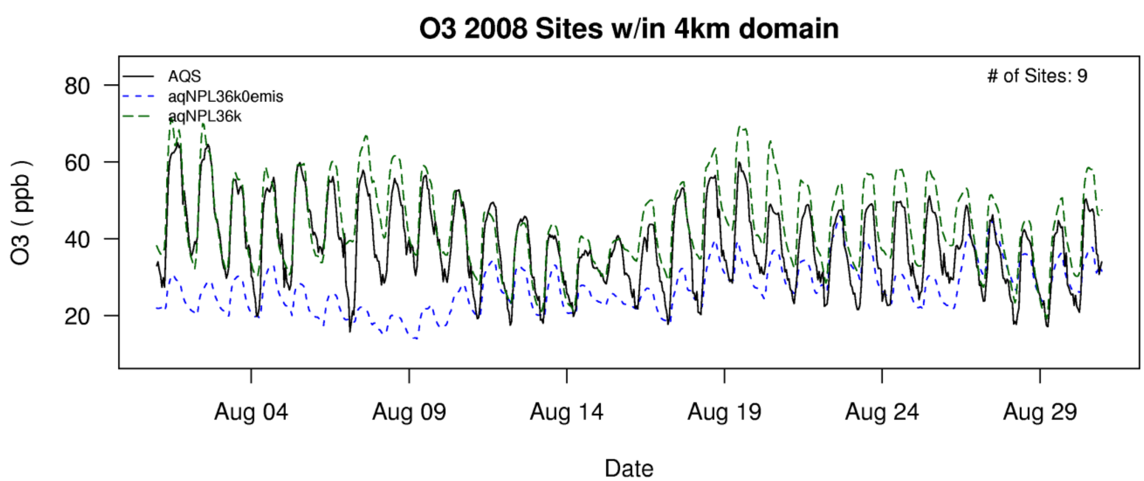
The boundary conditions contributions vary from day to day and are compared with the base simulation results for the 36-km grid and with the observed data in Figure 5-29. The simulated (base and zero-emissions) and observed values are averaged over all ozone monitoring sites located within the CMAQ 4-km grid. These plots clearly illustrate that, for most days, the emissions account for the pronounced diurnal profile and are the predominant contributor to the peak concentration (with a contribution on the order of 10 to 40 ppb). For most of the two month period, there is no indication that the contribution from the boundary conditions (whether higher or lower than average) is correlated with over or underestimation of ozone. Beginning around August 19th, relatively high boundary conditions are associated with overestimation of ozone. However, this is only the case for some of the days for which ozone is overestimated, so again there does not appear to be a strong correlation between the boundary contribution and ozone model performance. Note that these results are for the 36-km resolution grid only. At higher spatial and temporal resolution, regional and local emissions will further influence the daily concentration levels and patterns.

Figure 5-29. Time-Series Plots Comparing 36-km Base (Dashed Green), Zero-Emissions (Dashed Blue), and Observed (Solid Black) Ozone Concentrations (ppb)

July



August



Monthly average $PM_{2.5}$ concentrations for the zero-emissions simulation are compared with the monthly average difference between the base and zero-emissions simulations (base minus zero-emissions) in

Figures 5-30 and 5-31. Again these represent (approximately) the contributions from boundary conditions and emissions, respectively.

Figure 5-30. Monthly Average Daily $PM_{2.5}$ Concentrations (µg/m^3) for July 2008.
Zero Emissions/Base Minus Zero Emissions

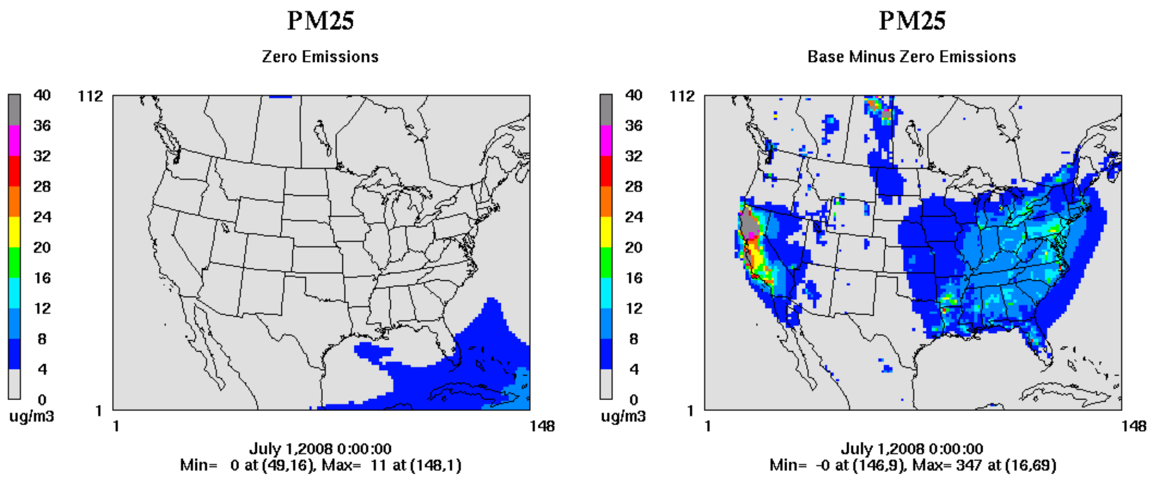
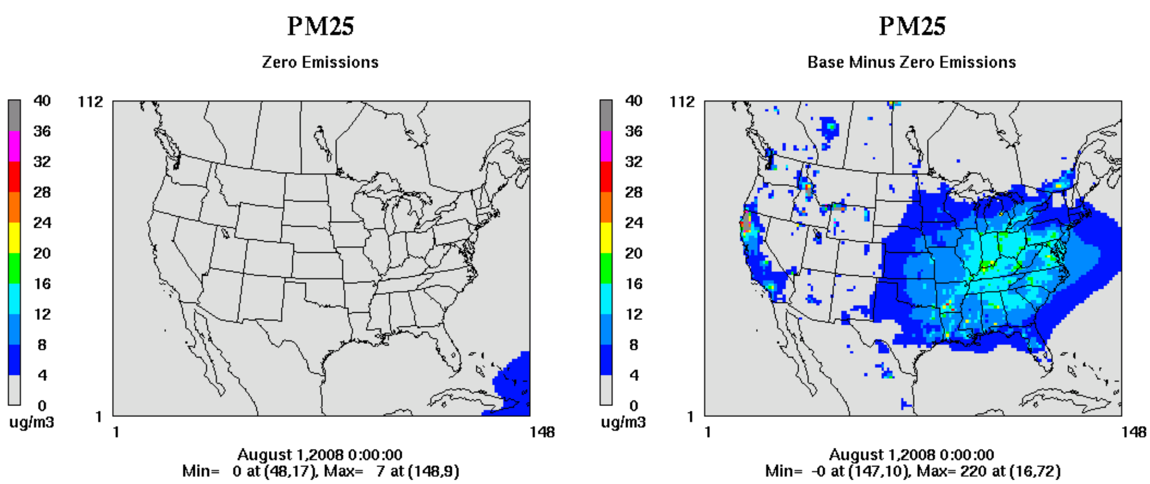


Figure 5-31. Monthly Average Daily $PM_{2.5}$ Concentrations (µg/m^3) for August 2008.
Zero Emissions/Base Minus Zero Emissions



The plots indicate that, the emissions account for practically all of the monthly average $PM_{2.5}$ concentrations over Wyoming for the summer months of July and August. The contribution from the boundary conditions is negligible.

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ATTACHMENT D. FUTURE YEAR MODELING AND ASSESSMENT

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NORMALLY PRESSURED LANCE (NPL)

NATURAL GAS DEVELOPMENT PROJECT

Air Quality Assessment Technical Support Document

Attachment D: Future-Year Modeling and Assessment

U.S. Department of the Interior
Bureau of Land Management

BLM Pinedale Field Office
P.O. Box 768
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San Rafael, California 94903

The BLM manages more land – 253 million acres – than any other Federal agency. This land, known as the National System of Public Lands, is primarily located in 12 Western States, including Alaska. The Bureau, with a budget of about $1 billion, also administers 700 million acres of sub-surface mineral estate throughout the nation. The BLM's multiple-use mission is to sustain the health and productivity of the public lands for the use and enjoyment of present and future generations. The Bureau accomplishes this by managing such activities as outdoor recreation, livestock grazing, mineral development, and energy production, and by conserving natural, historical, cultural, and other resources on public lands.

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ACRONYMS AND ABBREVIATIONS

ANC	Acid Neutralizing Capacity
AQRV	Air Quality Related Value
AQS	Air Quality System
ASOS	Automated Surface Observation System
b_{ext}	Beta extinction (extinction coefficient)
BLM	Bureau of Land Management
CASTNet	Clean Air Status and Trends Network
CB	Carbon bond
CH_4	Methane
CMAQ	Community Multiscale Air Quality
CNG	Compressed natural gas
CO	Carbon monoxide
CO_2	Carbon dioxide
DA	Development area
DAT	Deposition Analysis Threshold
DEM	Digital Elevation Model
dv	Deciview
EGU	Electric generating unit
EIS	Environmental Impact Statement
EPA	U.S. Environmental Protection Agency
FDV	Future design value
FLAG	Federal Land Manager's Air Quality Related Values Work Group
GHG	Greenhouse gas
ha	Hectare
HAP	Hazardous Air Pollutant
HNO_3	Nitric acid
IC/BC	Initial conditions/boundary conditions
IDLH	Immediately Dangerous to Life or Health
IMPROVE	Interagency Monitoring of PROtected Visual Environments
IUR	Inhalation Unit Risk
kg	Kilogram
LCC	Lambert Conformal Conic
m	Meter(s)
µeq/L	Micro equivalents per liter
$\mu g/m^3$	Microgram per cubic meter
MATS	Modeled Attainment Test Software
MCIP	Meteorology-Chemistry Interface Processor
mg/m^3	Milligram per cubic meter
Mm^{-1}	Inverse megameters
MMIF	Meteorological Model Interface Program
MOVES	Motor Vehicle Emission Simulator
N	Nitrogen
N_2O	Nitrous oxide
NAAQS	National Ambient Air Quality Standards
NADP	National Acid Deposition Program
NCAR	National Center for Atmospheric Research
NEI	National Emission Inventory
NEPA	National Environmental Policy Act
NH_3	Ammonia
NO	Nitrogen oxide
NO_2	Nitrogen dioxide
NO_3	Nitrate
NO_x	Oxides of nitrogen
NP	National Park
NPL	Normally Pressured Lance
NPS	National Park Service
NWS	National Weather Service
O_3	Ozone
OLM	Ozone Limiting Method
PBL	Planetary boundary layer
PG	Pasquill-Gifford
PM	Particulate matter
$PM_{2.5}$	Fine particulate matter
PM_{10}	Coarse particulate matter
PMC	Coarse particulate matter
PMF	Fine particulate matter
ppb	Parts per billion
PSD	Prevention of Significant Deterioration
PVMRM	Plume Volume Molar Reaction Model
QA	Quality Assurance
RA	Roadless Area
REL	Reference Exposure Level
RfC	Reference Concentration
RFD	Reasonably Foreseeable Development
RFFA	Reasonably Foreseeable Future Actions
RGF	Regional Gathering Facility
rh	Relative humidity
RHR	Regional Haze Rule
RMP	Resource Management Plan
ROD	Record of Decision
RPO	Regional Planning Organization
RRF	Relative response factor

SMOKE	Sparse-Matrix Operator Kernel Emissions
S	Sulfur
SO_2	Sulfur dioxide
SO_4	Sulfate
TSP	Total suspended particulate
UGRB	Upper Green River Basin
U.S.	United States
USFS	U.S. Forest Service
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geologic Survey
VOC	Volatile organic compound
VRU	Vapor recovery unit
WA	Wilderness Area
WAAQS	Wyoming Ambient Air Quality Standards
WRAP	Western Regional Air Partnership
WRF	Weather Research and Forecasting
WY DEQ	Wyoming Department of Environmental Quality
yr	Year

1.0 INTRODUCTION

This document summarizes the methods and results of the future-year application of air quality modeling tools to support the assessment of impacts from emissions associated with the development of the Normally Pressured Lance (NPL) natural gas field on local and regional air quality. The NPL natural gas field is located northwest of Rock Springs, Wyoming, south of Pinedale, Wyoming, and adjacent to the existing Jonah Field; the project area comprises approximately 140,000 acres of land. A number of natural gas wells have already been drilled in the NPL. Jonah Energy proposes to drill an average of 350 wells per year over a 10-year period for a total of approximately 3,500 wells. Many outside factors, including economic, technological, and regulatory factors, may influence the rate of development as well as the total number of wells that will ultimately be drilled over the duration of the project.

The Bureau of Land Management (BLM) oversees and administers the public lands within the proposed NPL project from the BLM Pinedale and Rock Springs field offices. Oil and gas development activities in the area are governed by the Pinedale Resource Management Plan (RMP) (2008) and the Green River RMP (1997). An Environmental Impact Statement (EIS) for the proposed project will be prepared by BLM in accordance with National Environmental Policy Act (NEPA) guidelines. Other NEPA analyses have been conducted for the area and management plans have been previously prepared for sections of the project area. These include the Green River RMP and Final EIS and Record of Decision (ROD) (1997), and the Pinedale RMP and Final EIS and ROD (2008).

1.1 Project Description

The primary purpose of Jonah Energy's proposal to develop the NPL field is the recovery of natural gas and other hydrocarbon resources. Target formations for the development include the Lance Pool, and potentially the Unnamed Tertiary, Mesa Verde, and other possible productive formations evaluated during exploration and testing. Jonah Energy's planned development of the NPL field will include the building and/or installation of new access roads, well pads, pipelines, compressor stations, and other supporting facilities. At the present time, Jonah Energy proposes to use directional drilling from no more than four centralized surface locations per section. Drill pads are proposed to encompass up to approximately 18 acres per location for a total initial surface disturbance of approximately 6,854 acres of the NPL area. Upon completion of reclamation activities, approximately 2,348 acres would remain disturbed. Although the exact location of each well is not known at this time, the bottom-hole-location density is expected to be no less than a 10-acre spacing pattern to retrieve natural gas in the formations identified during exploration and testing.

To transport products (gas, condensate, and produced water), a three-phase pipeline gathering system is proposed to be installed from the well heads to designated Regional Gathering Facilities (RGF). For the development of the NPL, each RGF would be designed with facilities that support gas/liquid separation, gas compression and dehydration, liquid storage, and truck loading for condensate sales. Jonah Energy proposes to minimize emissions by employing natural-gas-powered drill rigs, and using electric compressors in place of diesel-powered compressors. Jonah Energy also proposes to undertake simultaneous completion operations whenever possible in an effort to minimize emissions associated with equipment use and movement. In addition, Jonah Energy proposes to limit emissions with the use of flare-less flow back technology for the completion operations.

1.2 Overview of the Air Quality Assessment

The NPL air quality assessment was designed to examine and quantify the expected future impacts of emissions from equipment and activities associated with the development of the NPL field. It includes both base-year and future-year air quality modeling. The base-year modeling was summarized in a companion report by ICF (ICF, 2014). The future-year air quality modeling was conducted to assess impacts for criteria pollutants and other air quality related values (AQRVs). Near-field impacts were evaluated using the Environmental Protection Agency (EPA) guideline model AERMOD, and far-field (or regional) impacts were evaluated using Version 5.0 of EPA's Community Multiscale Air Quality (CMAQ) modeling system and Version 5.8.4 of the CALPUFF model.

1.2.1 Study Objectives

The objectives of this air quality assessment were to examine and quantify the potential air quality impacts from emissions associated with the development of the NPL natural gas field using the best available data and state-of-the-science data processing and modeling tools. This information will be used to support the development of an EIS for the NPL project area.

1.2.2 Modeling Analysis Components

The air quality modeling analysis included an assessment of "current" conditions for a recent historical period (2008). Potential future impacts were then evaluated for a selected future year by applying the modeling systems using the historical meteorological inputs and estimated emissions for sources associated with the development of the field, as well as other regional sources. The assessment considered both near-field and far-field air quality impacts and focused on:

- Criteria pollutants including ozone (O_3), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), carbon monoxide (CO), and particulate matter (PM), including both coarse (PM_{10}) and fine particulates ($PM_{2.5}$).
- Hazardous Air Pollutants (HAPs), including acetaldehyde; acrolein; benzene; ethyl benzene; formaldehyde; methanol; n-hexane; toluene; and xylene, and;
- AQRV's including visibility, atmospheric deposition to soils, and acid neutralizing capacity (ANC) of sensitive water bodies.

The HAPs assessment focused only on the NPL project area, and the ANC analysis was conducted for acid sensitive water bodies within nearby Class I and Class II areas identified in the analysis. The remaining air quality impacts were evaluated for the NPL project area, nearby Class I areas, nearby sensitive Class II areas, and throughout the regional-scale air quality modeling domain.

The current- and future-year regional modeling analyses were conducted using emissions data available from BLM, the Wyoming Department of Environmental Quality (WY DEQ), the Western Regional Air Partnership (WRAP), and EPA. The NPL impacts analysis modeling was conducted using emissions specifically developed by Jonah Energy for the NPL field development operations. Detailed information on the base-year emissions is presented in detail in a separate base-year modeling report (ICF, 2014). Detailed information on the future-year emissions is provided in Section 2 of this document.

For the near-field assessment, the modeling scenarios were designed to capture the reasonable maximum emissions year impacts for each pollutant for each phase of the project.

The CMAQ model was used for the far-field or regional-scale assessment of impacts on criteria pollutants and AQRVs. The CMAQ modeling included a detailed model performance evaluation; the CMAQ model performance evaluation is presented in a separate base-year modeling report (ICF, 2014).

The CMAQ modeling scenarios include:

- 2008 Base Case – The current air quality conditions were established using the base-year meteorological inputs and emissions data.
- No Action Alternative – This scenario includes future-year local and regional emissions from all source categories, including emissions from nearby oil and gas development projects, as available. This alternative utilizes reasonably foreseeable development (RFD) emissions for the selected future year, excluding emissions from NPL.
- Proposed Action – This scenario includes future-year local and regional emissions from all source categories, including emissions from nearby oil and gas development projects, as available. This alternative utilizes RFD emissions for the future year, including emissions from NPL. This scenario was used to evaluate and quantify project-specific air quality impacts.

The CALPUFF modeling was conducted to assess impacts for AQRVs. The CALPUFF modeling scenarios included:

- Project-specific Emissions Scenario – The project-specific emissions were used to evaluate and quantify project-specific air quality impacts.
- Cumulative Emissions Scenario – A cumulative modeling assessment was conducted that included project specific emissions as well as future-year emissions from other sources, including Reasonably Foreseeable Development (RFD) projects in the region.

1.2.3 Modeling Tools

The primary air quality modeling tools that were used for this study include AERMOD, the CMAQ model, CALPUFF, the Weather Research and Forecasting (WRF) model, and the Sparse-Matrix Operator Kernel Emissions (SMOKE) modeling/processing tool.

1.3 Overview of the Future-Year Modeling and Assessment

Near-field ambient air quality impacts within the NPL project area resulting from project-related emissions were quantified using AERMOD (version 12060). AERMOD was applied for a five-year simulation period spanning 2006 to 2010. The modeling scenarios were designed to capture the reasonable maximum emissions year impacts for each pollutant for each of the major development phases of the project, namely, construction, drilling, and production. The modeling scenarios focused on the emissions within one section of the NPL field which is equivalent to one square mile. AERMOD was used to examine the impacts of emissions of the following criteria pollutants: PM_{10}, $PM_{2.5}$, NO_2, SO_2 and CO. For each criteria pollutant, the averaging period(s) was based on the relevant National Ambient Air Quality Standards (NAAQS). AERMOD was also used to examine the impacts of emissions of the following HAPs: acetaldehyde; acrolein; benzene; ethyl benzene; formaldehyde; methanol; n-hexane; toluene; and xylene. For the HAPs, the modeled concentrations were used to establish inhalation unit risk (IUR) factors for carcinogens and reference concentrations (RfCs) or reference exposure levels (RELs) for non-carcinogens. Both short-term and long-term exposures were considered. The project-specific emissions are presented in Section 2 of this report, and the near-field modeling methods and results are discussed in detail in Section 3.

Far-field ambient air quality impacts from project-related emissions were examined and quantified using regional-scale modeling and both the CMAQ and CALPUFF models.

CMAQ modeling was used to support the analysis of impacts from the NPL emissions on ambient air concentrations and AQRVs throughout the region, including within any nearby Class I and Class II areas. It should be noted that the future year 2024 was originally selected based on available projections for the planned ten-year development of the NPL field provided by Jonah Energy, which, at the time of the analysis, was expected to commence in 2015. Given that development will now likely not begin until 2018 or later, the future year for the regional modeling analysis of NPL impacts was based on the availability of future-year modeling emissions from EPA (2020) and the maximum emissions year for the project. The emissions for the NPL project for the impact analysis were from Year 10 of the development, since NOx and VOC emissions are expected to be greatest during this year.

The CMAQ-based future-year air quality impact assessment included the projection and modification of the emission inputs to reflect the future year and the application of CMAQ to assess the impacts of the project emissions on future air quality and AQRVs throughout the region of interest.

Two future-year CMAQ scenarios were considered: the future year No Action scenario and the future-year Proposed Action scenario. The future-year assessment examined air concentrations for ozone, PM_{10}, $PM_{2.5}$, NO_x, SO_2, CO, and NH_3; visibility; and sulfur and nitrogen deposition and included the following components:

- Assessment of the change in air concentrations and AQRVs resulting from the addition of the project emissions
- Assessment of the NPL impacts on air quality metrics and compliance relative to the NAAQS and Wyoming AAQS
- Comparison of modeled air quality impacts with applicable Prevention of Significant Deterioration (PSD) increments for Class I and sensitive Class II areas (Note that all NEPA analysis comparisons to the PSD increments are intended to evaluate a threshold of concern and do not represent a regulatory PSD Increment Consumption Analysis).

The CMAQ modeling methods and results are presented in detail in Section 4 of this report.

CALPUFF modeling was used to support the analysis of impacts from the NPL emissions on AQRVs within nearby Class I and Class II areas. The CALPUFF model (version 5.8.4) was applied using project-specific emissions corresponding to the NPL Proposed Action scenario as well as using project-specific and regional emissions (in order to assess the cumulative impacts of emissions from all other projects and sources). The cumulative emissions were based on the regional-scale Proposed Action emissions, as developed for the CMAQ modeling.

Two future-year CALPUFF scenarios were considered: the project-specific emissions scenario and the cumulative emissions scenario. The CALPUFF modeling focused on estimating the impacts on AQRVs, including visibility, atmospheric deposition, and the impact of modeled deposition on soils and the ANC of sensitive water bodies.

The CALPUFF modeling methods and results are presented in detail in Section 5 of this report.

2.0 EMISSION INVENTORIES

This section describes the data, methods, and procedures that were used to prepare the model-ready emission inventories for the NPL future-year regional impacts analysis. These include the NPL project-specific emission inventory reflecting the Proposed Action and the regional inventory that includes all other anthropogenic and biogenic sources within the air quality modeling domain

2.1 Project-Specific Emissions for NPL

The project-specific emission inventory for the Proposed Action was developed using a spreadsheet tool and information provided by Jonah Energy. The tool includes the types of equipment that are expected to be used along with estimates of their activity levels for the various phases of development of the NPL field, including construction, drilling/completion, and production. The equipment and activity information was used along with appropriate emission factors to estimate emissions for the following pollutants: volatile organic compounds (VOC), oxides of nitrogen (NO_x), carbon monoxide (CO), sulfur dioxide (SO_2), fine particulates ($PM_{2.5}$), coarse particulates (PM_{10}), and ammonia (NH_3). Emissions for hazardous air pollutants (HAPs) were estimated for the following species: acetaldehyde; acrolein; benzene, ethylbenzene, formaldehyde, n-hexane, toluene, and xylene. In addition, the inventory includes estimates of the following greenhouse gases: carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O).

After a three-year initial ramp-up period, the Proposed Action for the development of the NPL field reflects a planned drilling rate of an average of 350 wells per year for a 10-year period. The spreadsheet includes information for the Proposed Action that specifies assumptions regarding drilling activities including the number of pads per year (22), number of pads per section (4), pad spacing (160 acres), acreage per pad (18), and number of wells per pad (16). Assumptions regarding activities and equipment that will be used in the 10-year development period associated with the construction (roads, pads, and pipelines), drilling, completion, and production phases are also included in the spreadsheet tool. The NPL emissions tool was used as the basis for preparing project-specific emission estimates for the selected future year for the near-field and far-field modeling analyses. Additional detail regarding the calculation of project specific emissions for each development phase is provided in the following subsections.

2.1.1 Construction Emissions

Emissions of particulates and criteria pollutants will result from equipment used in the construction of new well pads, expansion of existing well pads, as well as construction of access roads, pipelines and power lines. Fugitive particulate emissions (PM, PM_{10}, and $PM_{2.5}$) will result from the disturbance of the soil during grading, as well as from wind erosion and vehicle traffic. The estimation of fugitive particulate emissions from the disturbed soil during construction activities took into consideration emissions from the construction of the well pads, local and resource roads, the pipeline and other miscellaneous activities. Emission estimates were based on the area disturbed (expansion area in acres, road or pipeline length in miles), construction activity total suspended particulate (TSP) emission factors from WRAP's fugitive dust handbook (WRAP, 2006), duration of activity, and control efficiency.

Fugitive particulate emissions due to wind erosion for the same activities were estimated based on the same disturbed areas and durations, and employed wind erosion calculations outlined in Chapter 13 of

AP-42 (EPA, 2006). Meteorological data from the Big Piney National Weather Service (NWS) site for 2008-2010 were used. Fugitive particulate emissions due to traffic during pad, road, and pipeline construction were also estimated. The road type (local or resource), size and type of vehicle/equipment, silt and moisture content of road, dust control methods, emission control efficiency, speed, distance and frequency travelled, as well as fugitive emission factors from AP-42 were used.

Tailpipe emissions from heavy equipment, as well as vehicular traffic were computed based on the type of equipment (backhoes, dozers, scrapers, graders, etc.), size (horsepower), load factors, duration of operation, as well as emission factors based age distribution of the equipment operating in the field. Emission factors for heavy equipment were obtained from the NONROAD 2008 model (EPA, 2008a) and those for vehicular traffic from the MOVES (MOVES2010a) model (EPA, 2010), which was the latest version available at the time.

2.1.2 Drilling and Completion Emissions

The operation of drill rigs as well as transport and servicing of the rigs by heavy and light duty vehicles will also generate emissions. For the proposed NPL development, natural gas fired drill rigs will be utilized. Tier 3 equivalent emission factors were assumed in the computation of emissions from drill rig equipment. Completion/fracking rig emissions were computed based on Tier 2 factors for diesel engines. Fugitive particulate emissions as well as tailpipe emissions for drilling rigs and support vehicles were computed for the drilling phases, in the manner similar to that used for the construction phase activities. In addition, during cold weather periods, boilers may be required to provide heat and steam for the drilling rigs. However, the boilers to be used in the development of the NPL field will be electrical and will not produce any on-site emissions.

2.1.3 Production Emission

During the operation of a production well, criteria pollutants and HAPs will be emitted by equipment during the various stages of production. The movement of material and equipment in the field by haul trucks and tanker trucks will produce tailpipe and road dust emissions. All pumps, miscellaneous engines, and heaters expected to be used in the NPL field will be electrified and will not produce any emissions. Dehydrator flashing operations will utilize electric engines with a vapor recovery unit (VRU) for controlling and minimizing VOC emissions as well as a combustor backup system. Some emissions are expected when the combustor unit is in operation. Pneumatic pumps and compressors will also be electrified and produce no emissions. Fugitive VOC emissions will be produced at the well head as well as from condensate storage and loading operations. Fugitive emission factors were taken from the WY DEQ (2010a) "Oil and Gas Production Facilities Chapter 6, Section 2 Permitting Guidance". During all phases of development, emissions will be produced from passenger vehicles commuting to and from the NPL field from housing centers and well as from vehicles service various pads and facilities within the field. The truck fleet for contractors was assumed to be distributed as 50% gas and 50% diesel powered. By the start of development, Jonah Energy plans to have their entire (employee operated) truck fleet switch to compressed natural gas (CNG) vehicles

2.1.4 Greenhouse Gas Emissions

Although not used in the air quality impact modeling analysis summarized in this report, emissions of greenhouse gases (GHGs) have been estimated for all sources and activities expected to be operating in the NPL field during the construction, drilling, and production phases of development. Emissions have been estimated for carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O).

The methods for estimating GHG emissions are based on Subpart W of EPA's Greenhouse Gas Reporting Program (GHGRP). Subpart W GHG emission estimation methodologies are in part supplemented by the 1996 GRI study, the 2009 API Compendium, and EPA AP-42[1, 2, 3].

Equation 1 is the basis for quantification methods presented throughout this methodology. Wherein, data on activities are presented as an Activity Factor (AF). These data are multiplied by an emission factor (EF) to obtain an emission estimate for emission sources.

Equation 1. General Estimation Approach for GHGs

Activity Factor (AF) x Emission Factor (EF) = GHG Emissions

For most equations, the emissions units are thousand standard cubic feet (Mscf). For CH_4, the emissions have been converted into metric tonnes of CH_4 using Equation 2. CH_4 emissions have been converted from metric tonnes to metric tonnes of CO_2 equivalent ($MTCO_2E$) by multiplying by the global warming potential (GWP) of 21 taken from the IPCC Second Assessment Report (SAR)[4].

Equation 2. Thousand standard cubic feet (Mscf) CH_4 to metric tonnes CH_4 conversion

CH_4 Emissions (Mscf) = 1 [Mscf CH_4] x 1000 [scf CH_4/Mscf CH_4] x 19.26 [g CH_4/scf CH_4] x 1 [kg CH_4/1000g CH_4] x 1 [metric tonne CH_4/1000kg CH_4] = 0.01926 metric tonnes CH_4

For CO_2, emissions have been converted from Mscf to metric tonnes CO_2 using Equation 3. CO_2 emissions have been converted from metric tonnes to $MTCO_2E$ by multiplying by the GWP of 1 taken from the IPCC SAR.

Equation 3. Thousand standard cubic feet (Mscf) CO_2 to metric tonnes CO_2 conversion

CO_2 Emissions (Mscf) = 1 [Mscf CO_2] x 1000 [scf CO_2/Mscf CO_2] x 51.89 [g CO_2/scf CO_2] x 1 [kg CO_2/1000g CO_2] x 1 [metric tonne CO_2/1000kg CO_2] = 0.0519 metric tonnes CO_2

Similar to criteria pollutants, the equipment and activity included in the spreadsheet were used to estimate GHG emissions using appropriate source-specific emission factors.

2.1.5 Emission Summaries

Summaries of the criteria pollutants and greenhouse gas emissions follow.

[1] *All volumes available at: www.epa.gov/gasstar/tools/related.html*

[2] *Available at: www.api.org/ehs/climate/new/upload/2009_GHG_COMPENDIUM.pdf*

[3] *Available at: http://www.epa.gov/ttnchie1/ap42/*

[4] *Available at: http://www.ipcc.ch/publications_and_data/publications_and_data_reports.shtml*

Criteria Pollutant Emissions

Table 2-1 (a) and (b) presents a summary of criteria pollutant emissions by year for the Proposed Action for each major phase of the 10-year development period of the NPL field as well as a table of total emissions. Figure 2-1 (a) and (b) provides a graphical depiction of these emissions for VOC, NO_x, CO, SO_2, PM_{10}, and $PM_{2.5}$. The tables and figures indicate that the emissions are largest for all pollutants (except VOC) during the drilling phase of development, which requires a variety of engines and other supporting equipment for each of the wells. The largest VOC emissions are associated with the production phase of the development and these emissions peak out by the 10th year of development when the planned maximum numbers of wells are expected to be in full production mode. As noted earlier, emissions peak in Year 10 when the field is fully developed.

Table 2-1a. Annual Criteria Pollutant Emissions (tons) During Construction Activities for the NPL Field

Year	VOC	NO_x	CO	SO_2	PM_{10}	$PM_{2.5}$
1	1.9	15.9	8.6	0.4	30.6	5.8
2	1.9	15.8	8.6	0.4	30.1	5.7
3	1.9	15.7	8.6	0.4	29.6	5.7
4	1.9	15.8	8.6	0.4	30.1	5.7
5	1.9	15.6	8.5	0.4	29.1	5.6
6	1.9	15.7	8.6	0.4	29.6	5.7
7	1.9	15.7	8.6	0.4	29.6	5.7
8	1.9	15.6	8.5	0.4	29.1	5.6
9	1.9	15.7	8.6	0.4	29.6	5.7
10	1.9	15.6	8.5	0.4	29.1	5.6

Table 2-1b. Annual Criteria Pollutant Emissions (tons) During Drilling Activities of the NPL Field

Year	VOC	NO_x	CO	SO_2	PM_{10}	$PM_{2.5}$
1	7.2	80	125	1.6	147	21
2	21.1	231	318	4.8	441	63
3	28.0	307	414	6.4	588	84
4	40.7	445	591	9.4	857	122
5	40.7	445	589	9.4	857	122
6	40.7	445	588	9.4	857	122
7	40.7	445	587	9.4	857	122
8	40.7	445	587	9.4	857	122
9	40.7	445	586	9.4	857	122
10	40.7	445	585	9.4	857	122

Table 2-1c. Annual Criteria Pollutant Emissions (tons) During Production Activities of the NPL Field

Year	VOC	NO_x	CO	SO_2	PM_{10}	$PM_{2.5}$
1	83	2.7	1.8	0.0	100	13.2
2	162	4.4	2.8	0.0	185	24.7
3	239	5.2	3.4	0.0	254	34.4
4	318	6.9	4.3	0.0	338	45.8
5	392	6.9	4.3	0.0	391	53.7
6	468	7.8	4.8	0.0	460	63.4
7	545	8.6	5.2	0.0	529	73.1
8	618	8.6	5.2	0.0	581	81.0
9	695	9.4	5.5	0.0	650	90.7
10	768	9.4	5.5	0.0	703	98.6

Table 2-1d. Total Annual Criteria Pollutant Emissions (tons) from all Activities for the NPL Field

Year	VOC	NO_x	CO	SO_2	PM_{10}	$PM_{2.5}$
1	91	98	136	2.0	278	40
2	184	251	329	5.2	656	93
3	268	328	426	6.8	871	124
4	360	468	604	9.8	1226	174
5	433	468	602	9.8	1278	182
6	509	469	602	9.8	1347	191
7	585	469	601	9.8	1416	201
8	658	469	600	9.8	1468	209
9	735	470	600	9.8	1537	219
10	808	470	599	9.8	1589	226

Figure 2-1a. Annual Emissions of VOC (tons) for the Development of the NPL Field

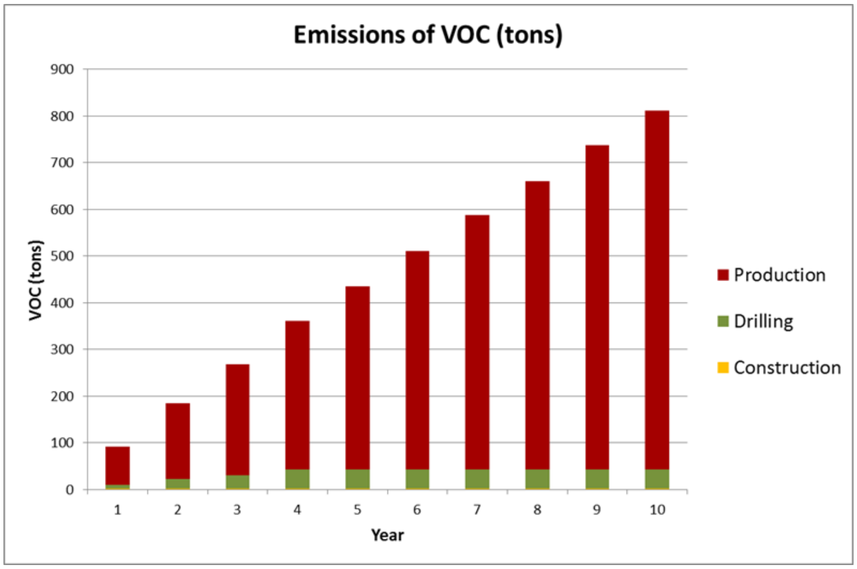


Figure 2-1b. Annual Emissions of NO_x (tons) for the Development of the NPL Field

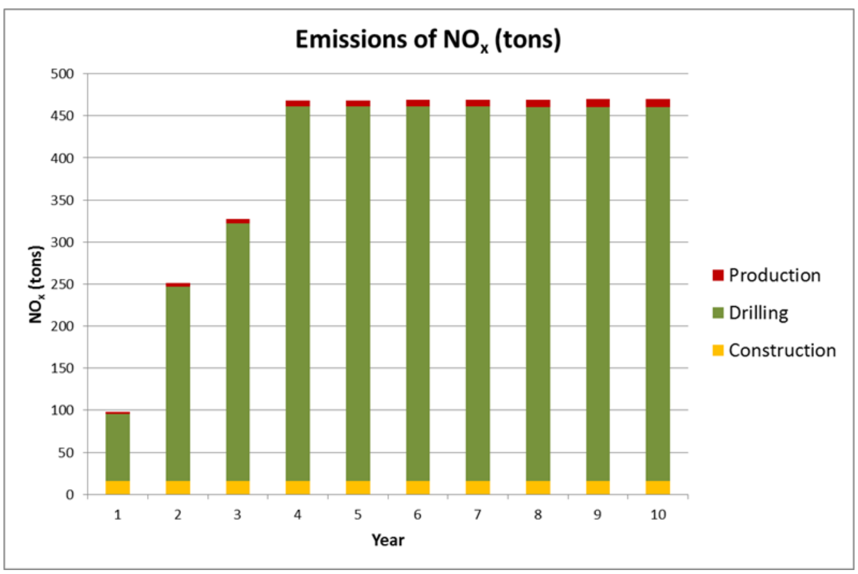


Figure 2-1c. Annual Emissions of CO (tons) for the Development of the NPL Field

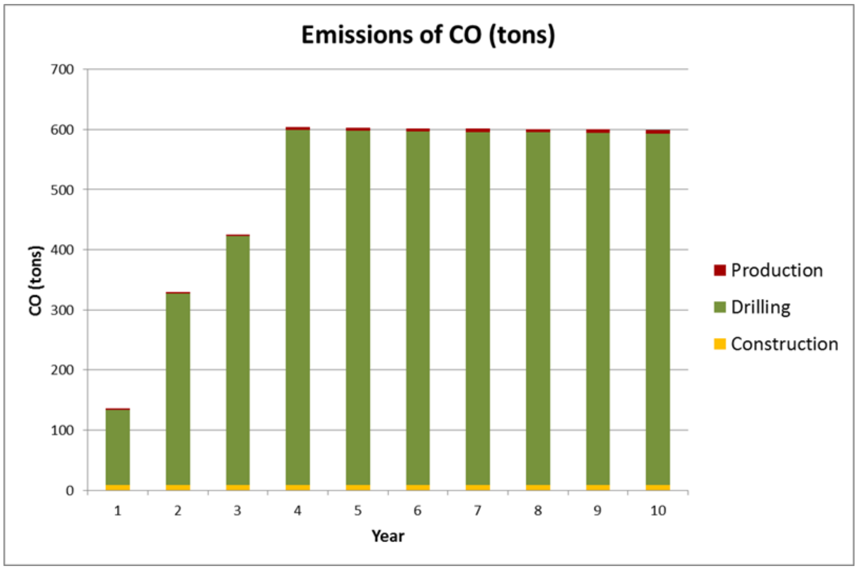


Figure 2-1d. Annual Emissions of SO_2 (tons) for the Development of the NPL Field

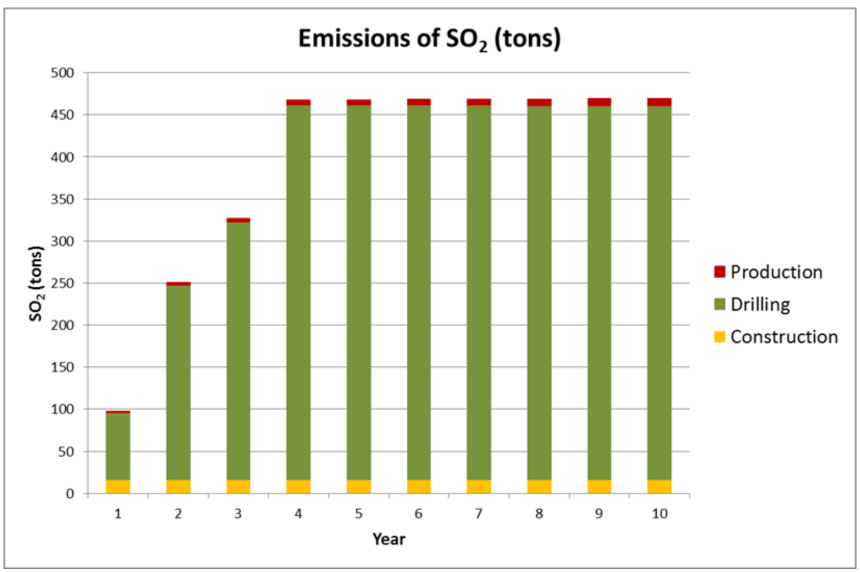


Figure 2-1e. Annual Emissions of PM_{10} (tons) for the Development of the NPL Field

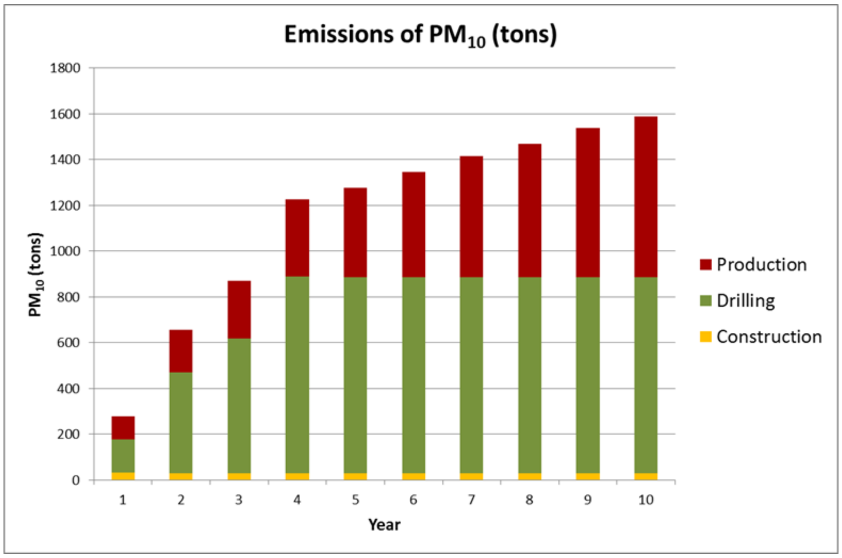
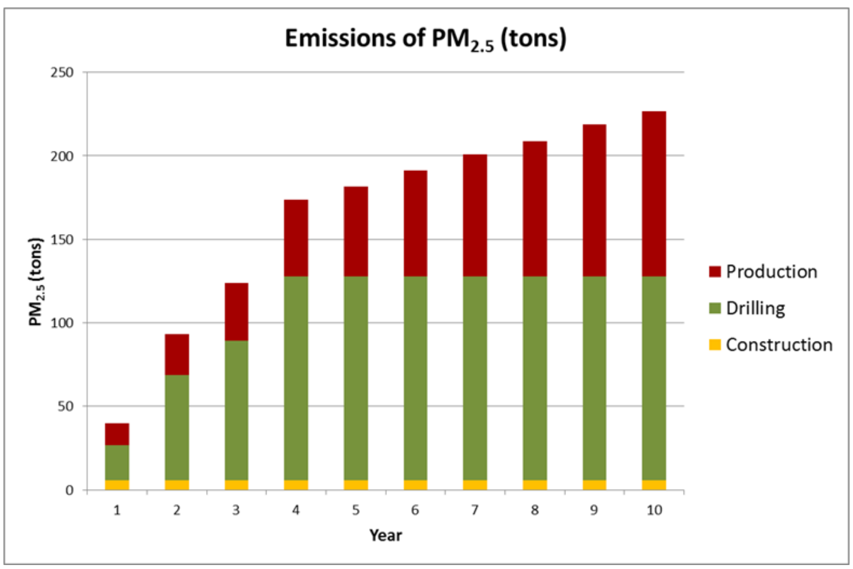


Figure 2-1f. Annual Emissions of $PM_{2.5}$ (tons) for the Development of the NPL Field



HAPS Emissions

Table 2-2 presents annual HAPs emission totals for acetaldehyde, acrolein, benzene, ethyl benzene, formaldehyde, methanol, n-hexane, toluene, and xylene for the Proposed Action for the development period. Similar to the magnitudes of overall VOC emissions, the HAPs emissions are associated with the operation of drilling, completion, and production equipment and reach their peak levels by the 10^{th} year of the development period.

Table 2-2. Total Annual HAPs Emissions (tons) from all Activities for the NPL Field

Year	Acetal-dehyde	Acrolein	Benzene	Ethyl Benzene	Formal-dehyde	Meth-anol	n-Hexane	Toluene	Xylene
1	0.3	0.2	0.5	0.0	6.3	0.5	1.8	0.7	0.3
2	1.0	0.6	1.0	0.1	18.8	1.0	3.6	1.3	0.6
3	1.3	0.8	1.4	0.1	25.1	1.4	5.2	1.9	0.8
4	1.9	1.1	1.9	0.1	36.6	1.9	7.0	2.5	1.1
5	1.9	1.1	2.2	0.1	36.6	2.2	8.5	3.0	1.2
6	1.9	1.1	2.6	0.2	36.6	2.6	10.0	3.5	1.4
7	1.9	1.1	2.9	0.2	36.6	2.9	11.5	4.1	1.6
8	1.9	1.1	3.2	0.2	36.6	3.2	12.0	4.6	1.8
9	1.9	1.1	3.6	0.2	36.6	3.6	14.6	5.1	2.0
10	1.9	1.1	3.9	0.2	36.6	3.9	16.1	5.5	2.2

Greenhouse Gas Emissions

Table 2-3 presents annual greenhouse gas emission totals for CO_2, CH_4, N_2O, and CO_2-equivalents for the Proposed Action for the 10-year development period. The emissions for CO_2 and N_2O are highest in drilling phase of development, while the highest emissions for CH_4 are associated with the production phase of development. Similar to VOC emissions, the emissions of all GHG's are expected to reach their peak by the 10^{th} year of development when the field is in full production. Figure 2-2 (a) – (d) provides a graphical depiction of these emissions.

Table 2-3. Total Annual GHG Emissions (tons) from all Activities for the NPL Field

Year	CO_2	CH_4	N_2O	CO_{2eq}
1	19,634	691	0.1	36,955
2	51,209	1,495	0.2	88,648
3	67,019	2,149	0.3	120,823
4	96,019	2,930	0.4	169,391
5	95,991	3,434	0.4	181,959
6	96,269	3,956	0.4	195,294
7	96,514	4,478	0.4	208,588
8	96,502	4,982	0.4	221,172
9	96,744	5,504	0.4	234,462
10	96,733	6,008	0.4	247,047

Figure 2-2a. Annual Emissions of CO_2 (tons) for the Development of the NPL Field

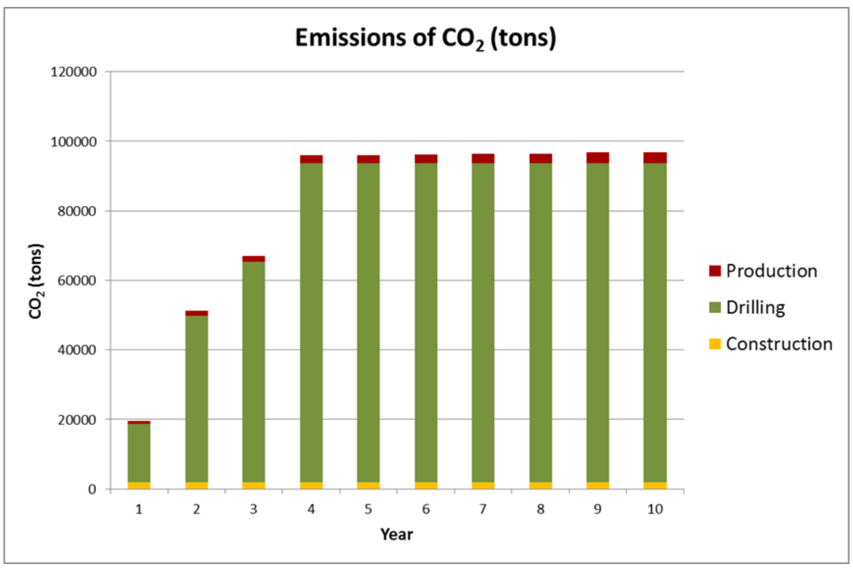


Figure 2-2b. Annual Emissions of CH_4 (tons) for the Development of the NPL Field

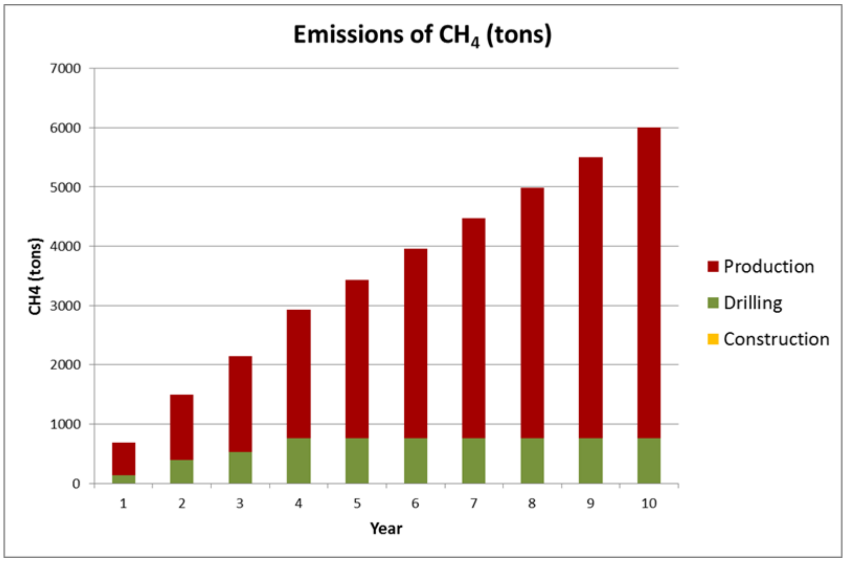


Figure 2-2c. Annual Emissions of N_2O (tons) for the Development of the NPL Field

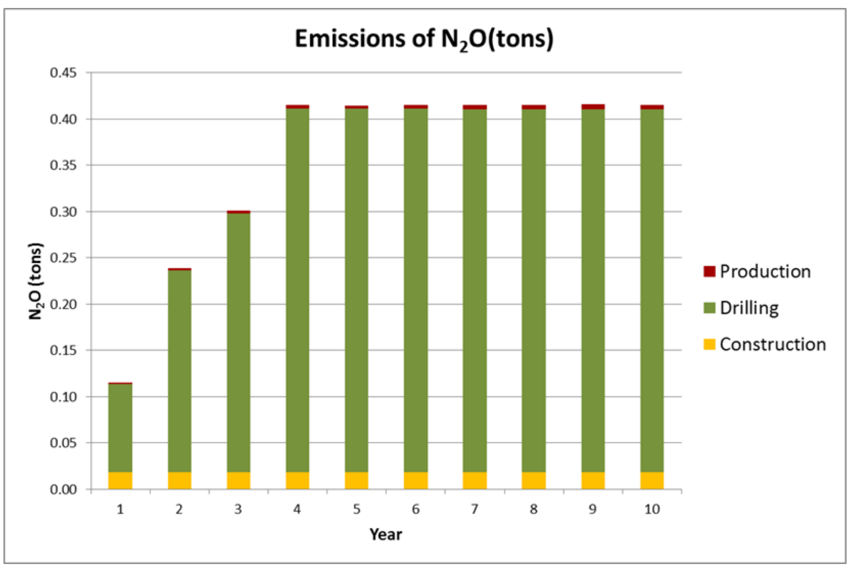
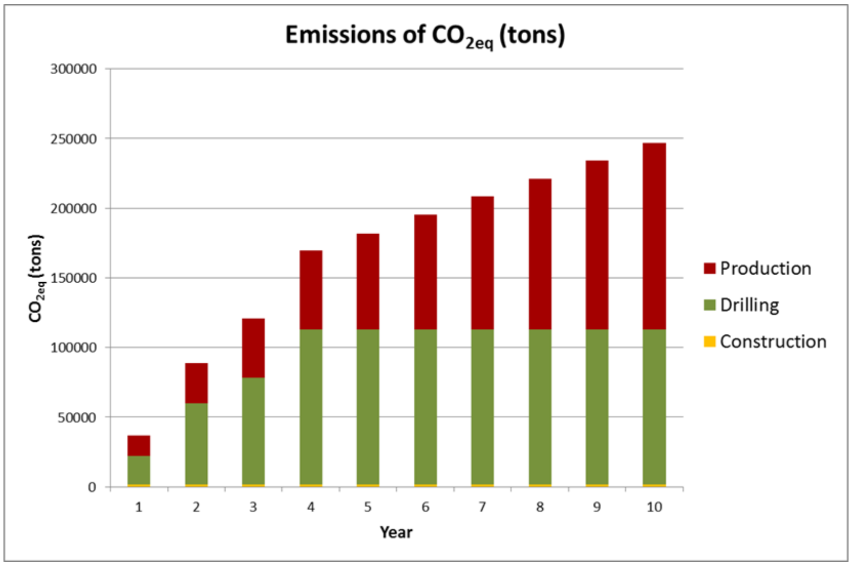


Figure 2-2d. Annual Emissions of CO_2-equivalent (tons) for the Development of the NPL Field



Emissions for the Alternatives

In addition to the Proposed Action, the NPL EIS also examined two Alternatives (A and B) that differ in a number of ways, including the total number of wells, the pace of development, the assumed density of wells, and the planned sequencing of activities, etc. The major differences of these alternatives, compared to the Proposed Action, are summarized in the following:

Alternative A:

- This alternative specifies fewer new wells be developed per year during the development period (332 wells pear year compared to 350) and a slightly longer development period (10.5 years compared to 10 years).
- Development would be conducted sequentially by phase. Development would be completed in each phase prior to starting development within designated development areas (DAs) in the next phase.
- The distance between clusters of development would be greater than the more uniformly distributed clusters of development for the Proposed Action.
- In contrast to the Proposed Action and Alternative B, which would rely on trucking produced water and condensate from regional gathering facilities (RGFs) to offsite facilities, Alternative A would utilize two separate buried pipelines to transport produced water and condensate from RGFs to existing water treatment plants or condensate sales points (i.e., heavy vehicle truck trips reduced by 121 per day, compared to Proposed Action).
- RGFs, compressor facilities, and power lines would be prohibited within Sage-Grouse Winter Concentration Areas in DA 1, all delineated mountain plover habitat, within raptor nest buffers in DA 1, DA 3, and DA 5, and within burrowing owl nest buffers in DA 6. In addition, power lines in Sage-Grouse Core Habitat would be buried (overhead power lines would be prohibited in Core Habitat).

Alternative B:

- This alternative assumes fewer new wells developed per year during the development period (336 wells pear year compared to 350) and a slightly longer development period (10.4 years compared to 10 years).
- The distance between clusters of development would be greater than the more uniformly distributed clusters of development for the Proposed Action.
- Similar to the Proposed Action, RGFs would be allowed in Sage-Grouse Core Habitat and Sage-Grouse Winter Concentration Areas in DA 1. However, power lines connecting to RGFs would be buried in Sage-Grouse Core Habitat and Sage-Grouse Winter Concentration Areas in DA 1 (overhead power lines would be prohibited in these areas).
- Due to a more distributed pattern of development, Alternative B includes more miles of roads, pipelines, and power lines, compared to the Proposed Action.

In summary, the differences in assumed number of wells, activity, density, and sequencing components between the Proposed Action and Alternatives A and B are quite small and would result in minor net reductions in overall emissions (less than 5%). Because of these small differences, the emission totals were not explicitly quantified and the air quality impacts were only assessed for the Proposed Action scenario in the modeling analyses summarized in Sections 3 and 4 of this report.

2.2 Regional-Scale Emissions

This section presents a summary of the preparation of the future-year regional emissions inventory for the CMAQ model including sources of information, emissions processing procedures, quality assurance, and summaries of the No Action and Proposed Action emission inventories.

2.2.1 Data Sources

Similar to the approach being followed in other similar air quality analyses being conducted for BLM to support EIS's for natural gas development in Wyoming, modeling emission files for 2020, available from the EPA's 2008-based platform were used as the basis for the future-year No Action regional modeling inventory. Table 2-4 presents a summary of the source of information for each component of the NPL future year regional emission inventory.

Table 2-4. Sources of Future-Year Emissions for the No Action Emission Inventory for the NPL Air Quality Assessment

Source Category	Source of Information/Explanation
Major and Minor Point Sources	2020 Inventory from the EPA's 2008-based platform
Area Sources	2020 Inventory from the EPA's 2008-based platform
On-Road Mobile Sources	2020 Inventory from the EPA's 2008-based platform and the EF are prepared using MOVES 2010a
Non-Road Mobile Sources	2020 Inventory from the EPA's 2008-based platform and modeled with NONROAD
Oil & Gas Sources (WRAP States)	WRAP Phase III oil and gas Inventory, and RFD oil and gas emissions for various projects provided by BLM

Source Category	Source of Information/Explanation
Oil & Gas Sources (non-WRAP States)	2020 Inventory from the EPA's 2008-based platform
Biogenics	Same as 2008
Ammonia	2020 Inventory from the EPA's 2008-based platform
Wildfires	Same as 2008

The biogenic and wildfire emissions for the future year are the same for the 2008 base year.

For all non-oil and gas sectors, 2020 emissions from the EPA's 2008-based platform database were used.

For oil and gas sources, the WRAP Phase III oil and gas emission estimates included in the EPA's 2008-based platform database were used. In addition, the Reasonably Foreseeable Development (RFD) oil and gas emissions and associated ancillary files provided by BLM were incorporated into the emissions inventory.

Emissions for Reasonably Foreseeable Development (RFD)

Because there currently are a number of other similar studies being conducted to support the development of EIS's for oil and natural gas development projects in Wyoming and neighboring states, it was important to include emissions from these other development areas into the future-year regional emission inventory prepared for the NPL analysis. Although it is difficult to accurately estimate the pace of development in these other areas because of economic, technological, and regulatory factors that may influence the development, the latest information available (February 2014) was obtained. Table 2-5 provides a summary of the projects for which updated RFD emissions were available and incorporated into the regional No Action emission inventory for the NPL analysis.

Table 2-5. List of Projects for which RFD Emissions were Received (Alphabetical Order)

Project	Project
Bird Canyon Infill Development Project - Wyoming	Little Snake, Colorado RMP
Continental Divide-Creston Natural Gas Project (Wyoming)	Monell-Arch Oil and Gas Development Project (Wyoming)
Colorado River Valley, Colorado RMP	Moneta Divide Natural Gas Development Project (Wyoming)
Grand Junction, Colorado RMP	Moxa Arch Gas Development Project (Wyoming)
Hiawatha Regional Energy Development (Wyoming)	Pinedale Anticline Oil and Gas Exploration and Development Project (Wyoming)
Jonah Infill Drilling Project (Wyoming)	Rock Springs, Wyoming RMP
Kremmling, Colorado RMP	Uncompahgre, Colorado RMP
LaBarge Platform Infill Oil and Gas Project (Wyoming)	White River, Colorado RMP

2.2.2 Emissions Processing and Quality Assurance Procedures

SMOKE, version 3.1 was utilized to process the emissions with the “in-line” point-source emissions feature to prepare CMAQ-ready inputs for the future-year scenarios. Emission files were prepared for the NPL 36-, 12- and 4-km resolution CMAQ grids, and included processing of all source sectors using various SMOKE programs and inputs, and review and quality assurance checks.

The general procedures followed in preparing the modeling inventories, using various programs included with SMOKE, are the following:

- Perform chemical speciation to transform input criteria pollutants into the Carbon Bond (CB05) chemical mechanism species, as required by CMAQ. The speciation of $PM_{2.5}$ includes the CMAQ required additional species generated using the EPA provided speciation profiles, which are based on the updated speciation profiles in SPECIATE 4.3.
- Perform temporal distribution to convert annual/monthly emissions into hourly emissions.
- Perform spatial distribution of the emissions to the 36-, 12- and 4-km resolution modeling grids.
- Merge emissions from all source categories into the CMAQ model-ready files.
- Review and quality assurance of the processing steps and resulting emissions

The emissions inventory processing quality assurance (QA) procedures included the preparation and examination of tabular emissions summaries and graphical display products.

Tabular summaries were used to examine emissions totals for various steps of the emissions processing. Summaries for input emissions are based on the input inventory data: monthly emissions for the on-road and non-road sectors, and annual emissions for other sectors for criteria pollutants. Summaries for the emissions are based on the SMOKE output reports which include daily emissions for each CB05 species for each sector. The output daily emissions are summed over all days in the year and the CB05 species are summed for the criteria pollutants. The emissions summaries were made for each scenario by state and sector, and comparisons were made between the input emissions and output emissions for each sector to ensure consistency.

In addition to the tabular summaries, various graphical displays were prepared for one day of each month to examine the spatial distribution and temporal variation for each sector and the final merged emissions using a graphical plotting package.

2.2.3 Summary of the Future-Year No Action Emission Inventory

The future-year emissions are used to establish the future no action/no-build conditions within the regional-scale modeling domain and the area of interest. For this assessment, the selected year for the No Action inventory is supposed to represent the future year with the greatest amount of emissions from NPL development sources. Based on project-specific emissions totals for the development of the NPL field, emissions from development activities for most criteria pollutants are comparable during the last seven years of the development, although VOC emissions are expected to be highest in the last five years of the project when the field is in full production. As such, the emissions files for 2020 obtained from EPA are appropriate to represent estimates of emissions from all other anthropogenic sources that potentially influence air quality in the region surrounding the NPL field.

Tables 2-6 through 2-8 summarize the future-year (2020) No Action emissions used for the CMAQ modeling. These tables summarize anthropogenic emissions by major source category and pollutant for the 36-, 12-, and 4-km resolution grids. The oil and gas category includes emissions from states with WRAP Phase III data (Colorado, Montana, New Mexico, Utah, and Wyoming) and emissions obtained from the RFD estimates provided by the BLM for various projects in the region. Emissions totals are provided for the following species: volatile organic compounds (VOCs), oxides of nitrogen (NO_x), carbon monoxide (CO), sulfur dioxide (SO_2), coarse particulate matter (PMC), fine particulate matter ($PM_{2.5}$), and ammonia (NH_3). The units are tons per year (tpy).

Table 2-6. NPL Future-Year (2020) Emissions Summary: 36-km Grid (U.S.)

Category	VOC (tpy)	NO_x (tpy)	CO (tpy)	SO_2 (tpy)	PMC (tpy)	$PM_{2.5}$ (tpy)	NH_3 (tpy)
EGU points	47,641	1,885,941	865,243	2,106,199	62,725	234,227	40,561
Non-EGU points	1,020,032	2,041,141	2,647,651	995,674	170,044	372,668	67,794
Area (non-point)	6,664,511	1,625,005	12,010,201	382,329	3,801,899	2,663,973	4,069,065
Non-road	1,339,240	2,047,497	13,032,657	15,875	6,629	113,693	2,924
On-road	1,167,815	2,183,094	18,130,895	27,093	82,009	101,569	78,608
Oil & gas	465,676	113,667	92,667	2,481	11,126	6,626	0
Total	**10,704,915**	**9,896,346**	**46,779,315**	**3,529,652**	**4,134,433**	**3,492,757**	**4,258,951**

Table 2-7. NPL Future-Year (2020) Emissions Summary: 12-km Grid

Category	VOC (tpy)	NO_x (tpy)	CO (tpy)	SO_2 (tpy)	PMC (tpy)	$PM_{2.5}$ (tpy)	NH_3 (tpy)
EGU points	2,508	190,103	22,231	66,150	4,369	14,065	1,180
Non-EGU points	91,235	147,331	121,489	39,984	26,994	30,246	1,772
Area (non-point)	116,256	27,099	262,981	6,160	288,773	89,313	217,118
Non-road	49,389	98,007	444,278	143	336	5,085	130
On-road	51,800	67,767	688,431	876	2,248	3,217	2,397
Oil & gas	238,155	52,397	55,426	1,557	10,694	4,011	0
Total	**549,342**	**582,702**	**1,594,835**	**114,870**	**333,413**	**145,937**	**222,598**

Table 2-8. NPL Future-Year (2020) Emissions Summary: 4-km Grid

Category	VOC (tpy)	NO_x (tpy)	CO (tpy)	SO_2 (tpy)	PMC (tpy)	$PM_{2.5}$ (tpy)	NH_3 (tpy)
EGU points	742	63,015	6,020	16,254	422	3,687	312
Non-EGU points	19,186	44,358	39,629	16,170	6,760	9,914	20
Area (non-point)	14,187	2,200	35,848	483	29,914	9,571	12,461
Non-road	10,736	14,653	78,947	22	56	844	22
On-road	3,228	5,372	46,253	62	142	251	167
Oil & gas	261,163	37,856	36,535	997	6,999	2,746	0
Total	**309,242**	**167,454**	**243,232**	**33,988**	**44,294**	**27,012**	**12,980**

Figure 2-3 presents annual anthropogenic emission totals for VOC, NO_x, SO_2, and $PM_{2.5}$ for the No Action emission inventory for the 12- and 4-km grids, broken out by major source category: electric generating units (EGU), non-EGU point, area, non-road, and on-road sources. The figures show large contributions of area source VOCs, which are associated with oil and natural gas development projects in the region. The combination of EGU and other industrial point sources contribute about 60 percent of total NO_x emissions. The SO_2 emissions are predominantly from EGU and industrial point sources while the $PM_{2.5}$ emissions are predominantly from area sources.

Figure 2-3a. Annual Emissions for the NPL No Action Alternative for the 12-km Grid

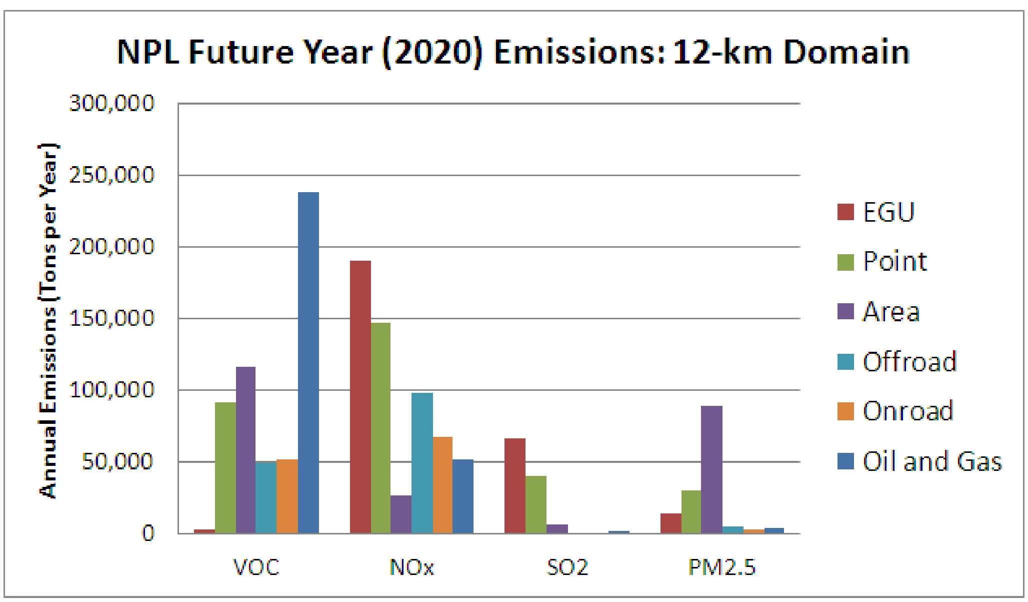
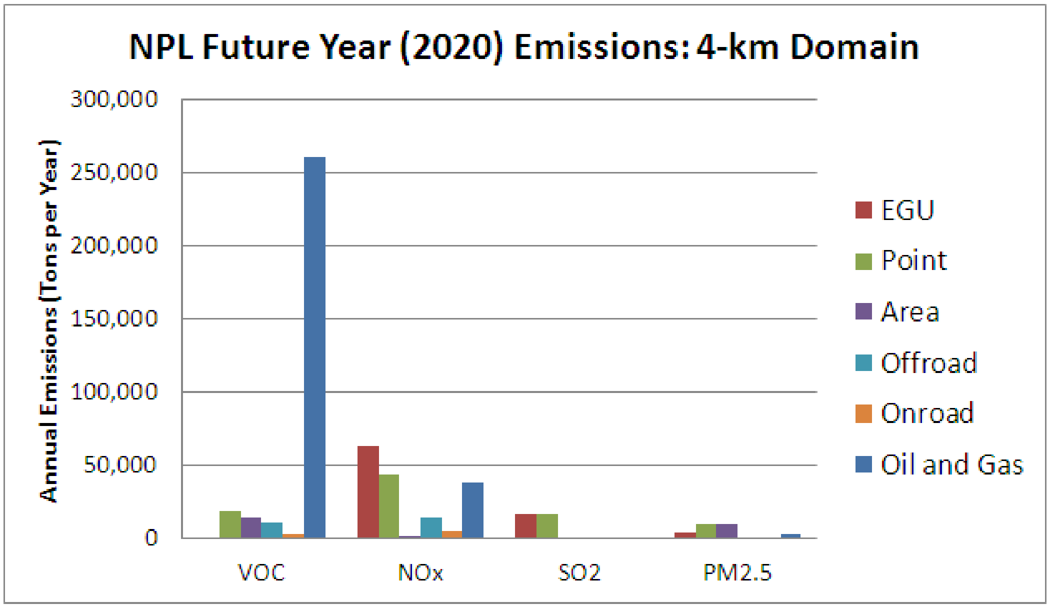


Figure 2-3b. Annual Emissions for NPL No Action Alternative for the 4-km Grid



To illustrate and check the reasonableness of the spatial distribution of emissions throughout the modeling domain, daily emission density plots for a selected day were prepared and examined. Figure 2-4 presents daily anthropogenic emissions for the future year No Action Alternative inventory for July 15 for VOC, NO_x, CO, SO_2, $PM_{2.5}$, and NH_3, respectively, for the 12-km grid. The plots show that the highest emissions correspond to the locations of the major cities/population centers (Denver, Salt Lake City, Provo, etc.), major transportation corridors (I-70, I-80, I-25, etc.), as well as locations of existing energy development areas (e.g., the Uintah Basin in Utah, Powder River Basin in Wyoming). Figure 2-5 presents biogenic VOC emissions for July 15, 2008 for the 12-km grid. The figure illustrates relatively low overall biogenic VOC emissions within the grid, but with some areas of higher emissions associated with the various forested areas of Wyoming, Colorado, Utah, Idaho, Montana, and western South Dakota.

Figure 2-4a. Daily Anthropogenic VOC Emissions (July 15) for the 12-km Grid

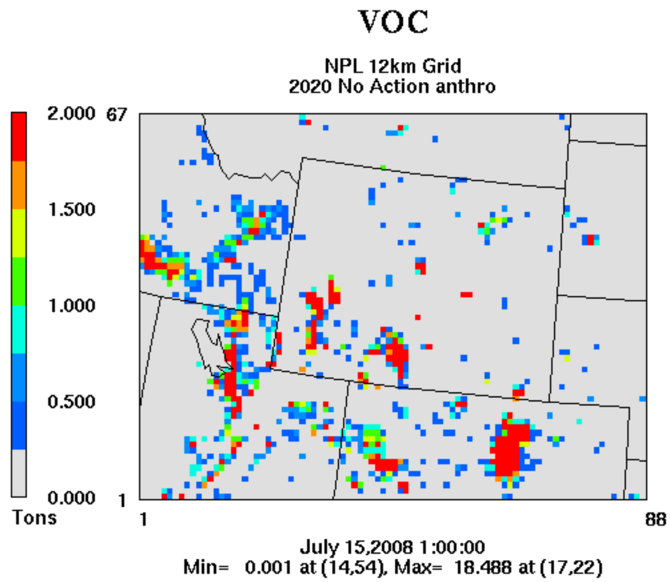


Figure 2-4b. Daily Anthropogenic NO_x Emissions (July 15) for the 12-km Grid

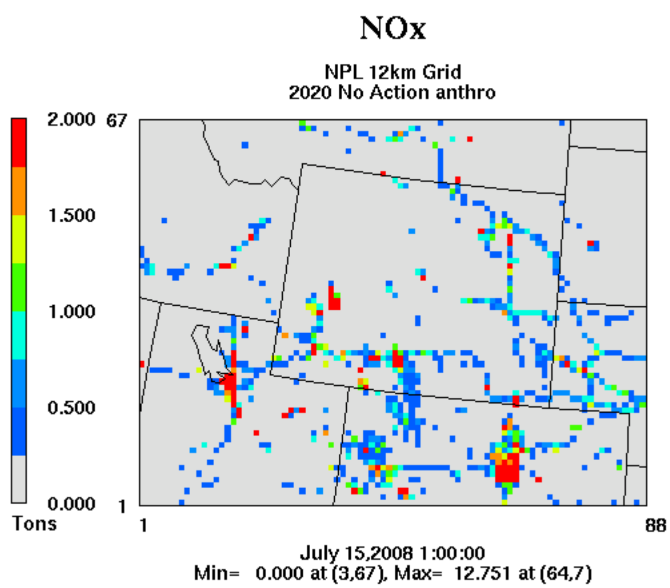


Figure 2-4c. Daily Anthropogenic CO Emissions (July 15) for the 12-km Grid

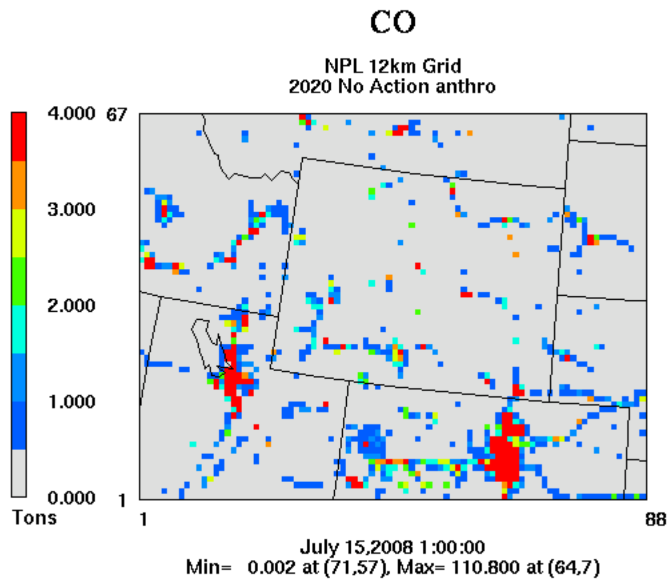


Figure 2-4d. Daily Anthropogenic SO_2 Emissions (July 15) for the 12-km Grid

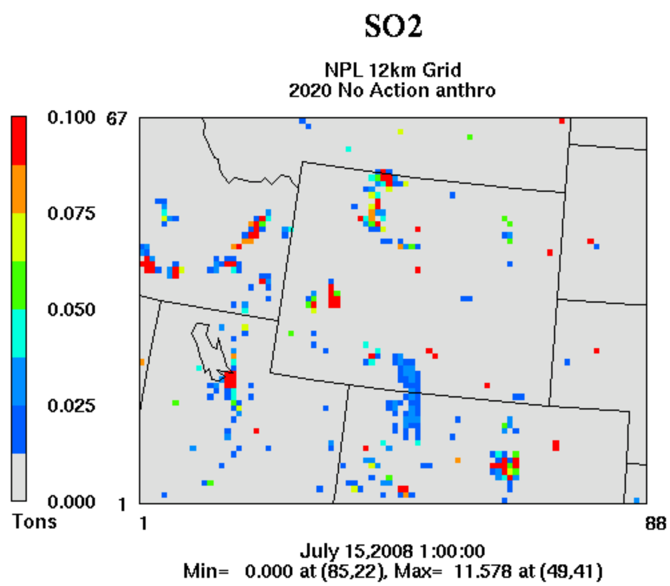


Figure 2-4e. Daily Anthropogenic $PM_{2.5}$ Emissions (July 15) for the 12-km Grid

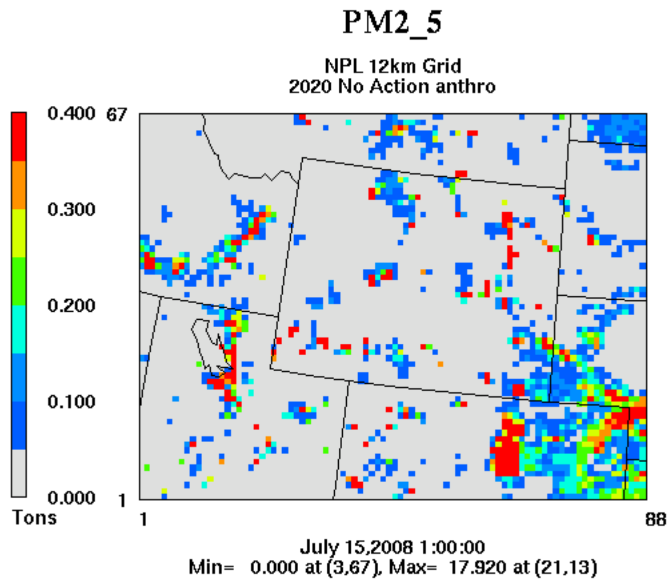


Figure 2-4f. Daily Anthropogenic NH_3 Emissions (July 15) for the 12-km Grid

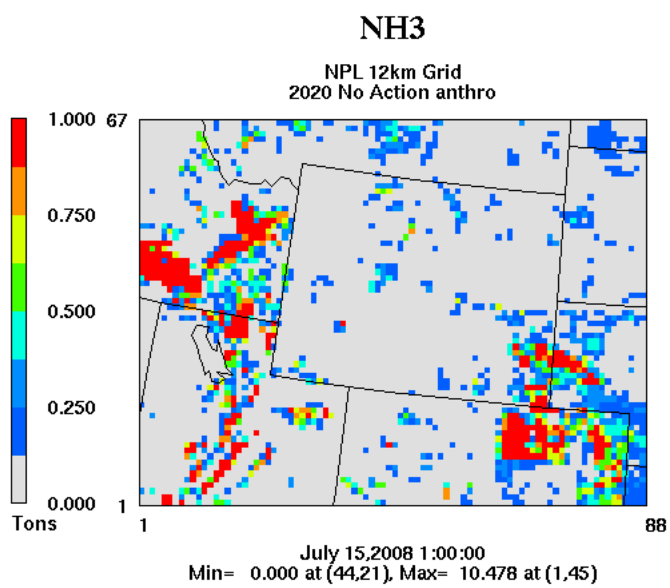
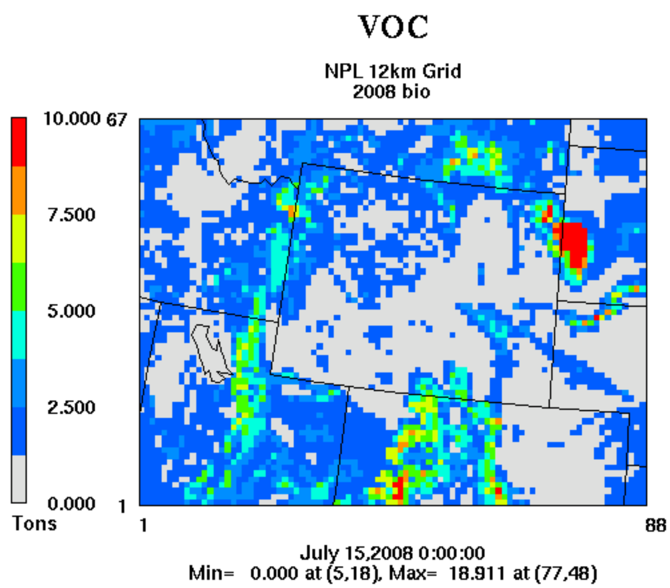


Figure 2-5. Daily Biogenic VOC Emissions (July 15, 2008) for the 12-km Grid



2.2.4 Future-Year Proposed Action Emission Inventory

The future year Proposed Action regional emission inventory was prepared by adding the NPL project-specific emissions for Year 10 of the development into the future year No Action regional emissions inventory. All of the NPL project-specified emissions are non-point sources and the emissions were processed following the steps as specified in Section 2.2.2. Table 2-9 provides a summary of the Year 10 NPL project-specific emissions by source category that were added to the No Action regional emissions to prepare the Proposed Action regional inventory for the CMAQ analysis. Because these emissions are relatively small compared to the total emissions for the 12- and 4-km resolution grids, emission totals for those grids are not presented here for the Proposed Action inventory.

Table 2-9. NPL Project-Specific Emissions (tpy) for Year 10 by Source Category

Phase	Category	VOC (tpy)	NO_x (tpy)	CO (tpy)	SO_2 (tpy)	PMC (tpy)	$PM_{2.5}$ (tpy)
All	Passenger vehicle	0.09	3.29	18.95	0.01	0.04	0.05
Construction	Traffic dust					6.29	5.62
Construction	Construction Dust, Fugitive					12.74	1.42
Construction	Wind erosion construction					1.34	0.24
Construction	Wind erosion production					462.05	81.54
Construction	Construction heavy equipment	1.87	15.56	8.53	0.40	0.03	1.45
Drilling and Completion	Drilling unpaved road dust					172.28	19.14
Drilling and Completion	Completion unpaved road dust					611.36	96.85
Drilling and Completion	Completion/workover equipment	9.81	172.07	37.47	7.72	0.13	6.37
Drilling and Completion	Drilling equipment combustion	31.02	272.28	529.33	1.69	3.15	2.49
Production	Production traffic combustion	0.01	0.14	0.06	2.78E-04	0.00	0.01
Production	Tanker traffic combustion	0.58	5.75	2.26	0.01	0.08	0.30
Production	Production + tanker traffic dust					93.63	10.36
Production	Dehy flashing	0.76	0.77	2.02		0.00	0.04
Production	Blowdown	235.45					
Production	Fugitive VOCs - Facility	28.58					
Production	Fugitive VOCs - Well	497.42					
Production	Compressor engines	1.05					
Production	Condensate loading	0.09	1.89E-03	5.00E-03		0.00	9.46E-05
Production	Condensate tank storage	1.05	0.04	0.11		0.00	0.01
Total		**807.78**	**469.90**	**598.73**	**9.82**	**1363.12**	**225.88**

3.0 NEAR-FIELD MODELING ANALYSES

Near-field ambient air quality impacts resulting from project-related emissions were quantified using AERMOD (EPA, 2004a and 2012a). AERMOD is a steady-state Gaussian dispersion model designed to simulate the local-scale dispersion of pollutants from low-level or elevated sources in simple or complex terrain. It is an EPA "preferred" model (40 CFR Part 51, Appendix W, Guideline on Air Quality Models). AERMOD version 12345 was used for this application.

The selection of AERMOD for this study was based on the technical formulation and capabilities of the model as well as its extensive use for other source-specific model applications. The dispersion algorithms are based on the fundamental concepts of planetary boundary layer meteorology. The airflow and stability characteristics (e.g., convective versus stable) as well as the vertical structure of the boundary layer are accounted for in simulating dispersion. Numerous features and options accommodate a variety of source types, pollutants, and land-use and topographical features.

The methodologies and results of the application of AERMOD are presented in the remainder of this section.

3.1 Modeling Approach

AERMOD was applied for a five-year simulation period spanning 2006 through 2010. The modeling scenarios were designed to examine the impacts of emissions from both the development and production phases of the NPL project.

3.1.1 Model Options

For this application, AERMOD was run using regulatory default options for the simulation parameters. For NO_2, both the Plume Volume Molar Reaction Model (PVMRM) and Ozone Limiting Method (OLM) modules were tested. Considering the conditions under which some of the highest NO_2 concentration occurred (stable conditions with high NO_x and low to moderate ozone concentrations) the OLM option was selected as better suited to simulating the ground-level NO_2 concentrations. For a given NO_x emission rate and ambient ozone concentration, the conversion of NO to NO_2 for PVMRM is relatively instantaneous (controlled somewhat by the volume of the plume), while that for OLM is more gradual and is controlled by the ground level NO_x and ozone concentrations. Sensitivity tests (Brode, 2004) have demonstrated that OLM tends to be more conservative than PVMRM. For this application, the OLMGROUP ALL option was used to combine plumes and ensure that all sources will potentially compete for the available ozone.

In applying the OLM module, hourly ozone data for the period 2006-2010 for the nearby Boulder monitoring site were used to approximate the rate of conversion of NO to NO_2. The Boulder monitoring site is the nearest site to the Project Area with ozone data for this period. Interpolation methods were used to fill in any missing data. In addition, the following assumptions were used: ambient NO_2/NO_X ratio of 90 percent and in-stack NO_2/NO_X ratio of 10 percent by mass. Data from Wyoming DEQ stack testing reports (WY DEQ, 2010b) support the use of a 10 percent or lower NO_2/NO_X ratio for diesel engines of the type used for rigs. In addition, the San Joaquin Valley Air Pollution Control District (SJVAPCD) recommends values on the order of 10 percent for a range of different sources (SJVAPCD, 2010).

3.1.2 Pollutants and Averaging Periods

AERMOD was used to examine the impacts of emissions of the following criteria pollutants: PM_{10}, $PM_{2.5}$, NO_2, SO_2 and CO. For each criteria pollutant, the averaging period(s) were based on the relevant National and State of Wyoming Ambient Air Quality Standards (NAAQS and WAAQS). The averaging periods are as follows:

- PM_{10}: 24-hour and annual averaging periods
- $PM_{2.5}$: 24-hour and annual averaging periods
- NO_2: 1-hour and annual averaging periods
- SO_2: 1-hour averaging period
- CO: 1-hour and 8-hour averaging periods

The latest EPA guidance (Fox, 2011) was used to guide the analysis of 1-hour NO_2.

AERMOD was also used to examine the impacts of emissions of the following HAPs: acetaldehyde; acrolein; benzene; ethyl benzene; formaldehyde; methanol; n-hexane; toluene; and xylene. For the HAPs, the modeled concentrations were compared to inhalation unit risk (IUR) factors for carcinogens and reference concentrations (RfCs) or reference exposure levels (RELs) for non-carcinogens. Both short-term and long-term exposures were considered.

3.1.3 Input Preparation

AERMOD requires several input files. The simulation control file specifies which options and features of AERMOD are to be applied, and contains information about the emissions sources (location, emissions rate, stack parameters, etc.) as well as the receptor locations (elevation, topography, and land use). Two meteorological input files provide detailed information about 1) the characteristics of the boundary layer (wind, temperature, stability parameters) and 2) the vertical structure of temperature and wind near the source location.

Topographical Data

The terrain in this area consists of rolling hills and is interspersed with buttes. Digital topographical data (in the form of 7.5 minute Digital Elevation Model (DEM) files) for the analysis region were obtained from the U.S. Geological Survey (through Micropath Corporation) and processed for use in AERMOD using the AERMAP preprocessor program (version 11103) (EPA, 2004b and 2011a).

Meteorological and Land-Use Data

Meteorological inputs for AERMOD for the years 2006-2010 were developed using observed data from nearby monitoring sites. Specifically, this analysis utilized surface meteorological data from the Big Piney monitoring site and twice-daily upper-air data from Riverton, WY. The data for Big Piney are one-minute-resolution Automated Surface Observing System (ASOS) data and were processed using the AERMINUTE program (version 11325).

The meteorological inputs for AERMOD were then generated using the AERMOD Meteorological Processor (AERMET) program (EPA, 2004c and 2011b). AERMET requires additional information about the land-use characteristics of the area in which the surface meteorological monitoring site is located. This information was obtained using the AERSURFACE preprocessor program (EPA, 2008b). The remaining steps in the preparation of the meteorological inputs included processing of the of hourly surface and twice-daily upper-air data, quality assurance of the data, merging of the surface and upper-air data, and application of AERMET to calculate the planetary boundary layer parameters required by AERMOD. In applying AERMET, the methods and reference levels for standard NWS data were employed (EPA, 2004c). Version 11059 of AERMET and version 08009 of AERSURFACE were used for this application. In applying AERMET, the methods and reference levels for standard NWS data were employed (EPA, 2004c). Note that a newer version of the AERMET code was released subsequent to the preparation of the meteorological inputs for the NPL modeling exercise, but, based on the release notes, the changes are not expected to affect the modeling results.

The resulting meteorological inputs consist of two files. The first file includes surface wind, temperature, pressure, relative humidity, and stability information as well as cloud cover and precipitation values. The second file contains information on the vertical structure of temperature and wind near the source location.

3.1.4 Assessment Area and Receptor Grids

The source areas for the near-field modeling include both individual well pads and one-square-mile sections that contain four well pads. The receptor grid for each source area consists of 100 x 100 meter (m) receptor cells starting at 100 m from the source area; these increase to 250 x 250 m and cover a 2500 x 2500 m (2.5 x 2.5 km) area surrounding the source(s). The breakpoints in meters from the well pad are 1000 m for the 100 x 100 m receptor cells and 2500 m for the 250 x 250 m receptor cells. A receptor-exclusion zone that is located 100 meters from the defined edge of the well or well pad area was employed to capture near source modeled impacts. All compressors will be electric with zero emissions so additional receptors with 25 m spacing are not needed. Pollutant impacts were assessed throughout the receptor grid. The HAPs analysis was based on the maximum modeled value within the area covered by to the receptor grid.

The receptor grids are illustrated in Figure 3-1 (a) and (b).

Figure 3-1a. AERMOD Receptor Grid for a Single Well Pad

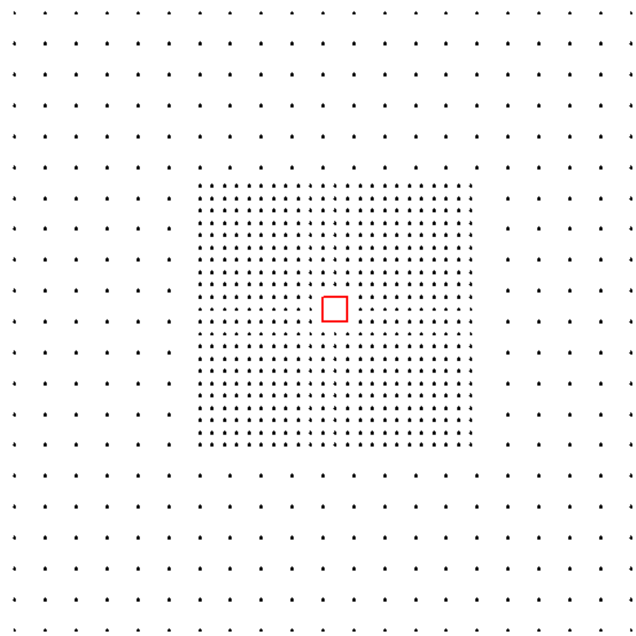
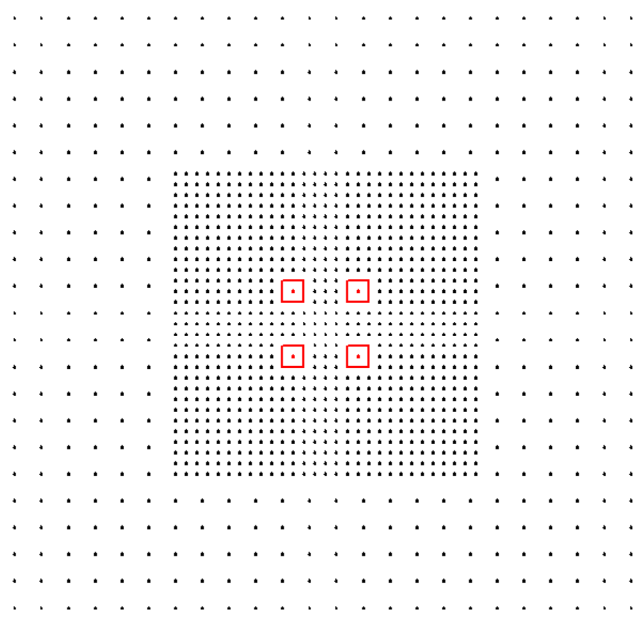


Figure 3-1b. AERMOD Receptor Grid for a Four-Well-Pad Section



3.1.5 Background Air Quality Data

Overall air quality is the sum of the AERMOD-derived impacts plus background pollutant concentrations for the region. The background concentrations were calculated based on EPA guidance (Fox, 2011). Background concentrations were calculated for each pollutant and averaging period listed in Table 3-1, using data from nearby monitoring sites (as specified in the table). The units are micrograms per cubic meter (μg/m^3).

Table 3-1. Averaging Periods and Background Concentrations for Use with the AERMOD Modeling Results

Pollutant	Averaging Period	Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec	Annual
PM_{10}[1]	24-Hour (μg/m^3)	--	--	--	--	32.7
	Annual (μg/m^3)	--	--	--	--	7.8
$PM_{2.5}$[2]	24-Hour (μg/m^3)	10.6	7.6	9.5	10.3	10.2
	Annual (μg/m^3)	--	--	--	--	4.1
NO_2[1]	1-Hour (μg/m^3)	16.3	5.0	6.9	11.3	11.9
	Annual (μg/m^3)	--	--	--	--	0.5
SO_2[3]	1-Hour (μg/m^3)	25.6	14.3	23.6	19.6	22.5
CO[4]	1-Hour (μg/m^3)	--	--	--	--	996
	8-Hour (μg/m^3)	--	--	--	--	790

[1] Background values are based on data collected at the Daniel South, Wyoming monitoring site.

[2] Background values are based on data collected at the Pinedale, Wyoming monitoring site.

[3] Background values are based on data collected at the Wamsutter, Wyoming monitoring site.

[4] Background values are based on data collected at the Murphy Ridge, Wyoming monitoring site.

Note that CO data were available for 2008 only for Murphy Ridge, Wyoming. The values were obtained from WY DEQ annual summary report (MSI, 2009).

Per EPA guidance, the most recent three years of available data were used. Background concentrations were calculated to be consistent with the form of the standard for each pollutant and averaging time. However, in accordance with EPA guidance, the background values for $PM_{2.5}$, NO_2 and SO_2 may vary by season (in this case, by quarter) and data used to calculate the quarterly averages were selected to approximate the overall form of the standard. For example, the background values for 1-hour NO_2 were based on the 3rd highest value for each quarter, averaged over the three-year period. This is expected to be the quarterly equivalent of the use of the 98th percentile daily maximum 1-hour NO_2, as used for the annual standard. The calculation of background values for $PM_{2.5}$ and SO_2 followed similar procedures.

For this analysis, the quarterly values were used only for NO_2, since the annual results NO_2 were close to or greater than the NAAQS and the background values showed significant variation among the quarters. The quarterly values, therefore, give additional information about what time of year a concentration greater than the NAAQS is most likely to occur. According to EPA (Fox, 2011), the use of seasonal background concentrations calculated using this technique should ensure that the monitored contribution to the cumulative impact assessment accounts for meteorological variability, and also reflects worst-case conditions in a manner that is consistent with the probabilistic form of the NO_2 standard.

3.1.6 AERMOD Modeling Scenarios

The modeling platform established for the near-field analysis was used to simulate future-year air quality impacts resulting from project-related emissions. The modeling scenarios were designed to capture the reasonable maximum emissions year impacts for each pollutant for each of the major development phases of the project, namely, construction, drilling/completion, and production. The emissions for each AERMOD modeling scenario were based on the NPL Proposed Action scenario. The modeling scenarios focus on the emissions for one well pad (construction) or for one 640-acre section of the NPL field (drilling and production). For the NPL Proposed Action, it is expected that there would be an average of four multi-well pads per section outside of designated sage-grouse core habitat.

Construction Scenarios

Starting in the first year of development (currently planned for 2015), the construction of roads and well pads would take place throughout the expected ten-year development period. Five construction related-scenarios were developed and modeled based on information provided by the operators that on any given day there would be at most one construction crew per section and this crew would perform construction activities related to one of five construction areas: well pad, access road, resource road, pipeline, or other construction. Emissions associated with each of these areas are as follows:

Construction-related emissions associated with well pad construction include:

- Fugitive particulate emissions from well pad construction
- Fugitive particulate emissions from traffic on unpaved roads related to well pad construction
- Wind erosion from well pad construction
- Diesel combustion/tailpipe emissions from heavy equipment related to well pad construction

Construction-related emissions associated with access road construction include:

- Fugitive particulate emissions from access road construction
- Fugitive particulate emissions from traffic on unpaved roads related to access road construction
- Wind erosion from access road construction
- Diesel combustion/tailpipe emissions from heavy equipment related to access road construction

Construction-related emissions associated with resource road construction include:

- Fugitive particulate emissions from resource road construction
- Fugitive particulate emissions from traffic on unpaved roads related to resource road construction
- Wind erosion from resource road construction
- Diesel combustion/tailpipe emissions from heavy equipment related to resource road construction

Construction-related emissions associated with pipeline construction include:

- Fugitive particulate emissions from pipeline construction
- Fugitive particulate emissions from traffic on unpaved roads related to pipeline construction
- Wind erosion from pipeline construction
- Diesel combustion/tailpipe emissions from heavy equipment related to pipeline construction

Construction-related emissions associated with other construction include:

- Fugitive particulate emissions from other (e.g., central facility/compressor station) construction
- Fugitive particulate emissions from traffic on unpaved roads related to other (e.g. central facility/compressor station) construction
- Wind erosion from other (e.g., central facility/compressor station) construction
- Diesel combustion/tailpipe emissions from heavy equipment related to other (e.g. central facility/compressor station) construction

Five reasonable worst-case scenarios were examined. Each scenario included the emissions from each of the emission categories listed above (i.e., fugitive emissions from construction, fugitive emissions from unpaved roads, wind erosion, and diesel combustion/tailpipe emissions from heavy equipment). The emissions levels are consistent with new well pad construction. It was assumed that the worst-case emissions for a given day would be the same for all years during the construction period.

Consistent with the assumption that on any given day there would be at most one construction crew in a section, the construction scenarios were modeled for an individual well pad. The well pad was located in the center of the NPL Project Area, and terrain information for that area was used as input to the AERMOD model. The dimensions of the well pad are 200 x 200 meters and the nearest receptors were located 100 m from the edge of the well pad. The construction sources were treated as area sources, distributed throughout the well pad. Tailpipe emissions from haul vehicles and other large trucks were assigned a release height of 3.5 meters, which is the average height of a haul truck. Based on a recent analysis by the haul road workgroup (EPA, 2012b), fugitive particulate matter emissions from construction traffic were assigned an estimated plume top of 6 meters (1.7 times the height of the truck), a release height of 3 meters (the estimated plume top divided by 2), and an initial vertical plume width of 2.8 meters (the estimated plume top divided by 2.15) in order to account for mechanical turbulence. Since all of the construction activities have an elapsed time of 12 hours per day or less, total emissions were calculated for a reasonable worst-case day and distributed across the daytime hours (7 am to 7 pm).

Criteria pollutant emissions for the construction scenarios are summarized in Table 3-2. The total emissions for each scenario include worst-case emissions for one day for each of the activities listed above under the scenario.

Table 3-2. AERMOD Construction Scenario Emissions

Scenario	Pollutant	Emissions (lbs/hour)	Emissions (tons/year)*
Well Pad Construction	PM_{10}	3.0	13.2
	$PM_{2.5}$	0.6	2.5
	NO_2	4.2	18.3
	SO_2	0.1	0.5
	CO	1.7	7.3
Pipeline Construction	PM_{10}	1.5	6.6
	$PM_{2.5}$	0.7	3.2
	NO_2	6.4	27.9
	SO_2	0.2	0.7
	CO	4.0	17.4
Resource Road Construction	PM_{10}	3.3	14.3
	$PM_{2.5}$	0.6	2.6
	NO_2	4.1	18.0
	SO_2	0.1	0.5
	CO	1.6	7.0
Access Road Construction	PM_{10}	0.3	1.3
	$PM_{2.5}$	0.0	0.1
	NO_2	0.0	0.0
	SO_2	0.0	0.0
	CO	0.2	0.7
Other Construction	PM_{10}	1.2	5.4
	$PM_{2.5}$	0.4	1.7
	NO_2	4.1	18.2
	SO_2	0.1	0.5
	CO	1.6	7.2

*Tons per year equivalent; most construction activities last for 2-10 days.

Note that emissions for several source types were assigned to the resource road construction category and not to access road construction, the emissions for resource roads are overstated while those for access road construction are understated, but together they provide the range of impacts associated with road construction.

Assessment of the modeling results for the construction scenarios focused on short-term air quality impacts, ranging from one to 24 hours, and for the following criteria pollutants: PM_{10}, $PM_{2.5}$, NO_2, SO_2

and CO. Annual impacts (estimated using worst-case emissions for all calendar days for a full year) were also considered, but these are overestimates since most of the construction activities were limited to 10 or fewer days per well.

Well Drilling Activities

Starting in the first year of development well drilling activities would ramp up during the first four years of the ten-year development period, and then remain constant until the final two years of the period. Emissions associated well-drilling activities are as follows:

- Fugitive particulate emissions from traffic on unpaved roads related to drilling
- Fugitive particulate emissions from traffic on unpaved roads related to rig moving
- Diesel combustion/tailpipe emissions from heavy equipment related to drilling
- Diesel combustion/tailpipe emissions from haul trucks related to rig moving
- Combustion emissions from drilling engines
- Diesel combustion emissions from hydraulic fracturing/other completion engines
- Well completion emissions
- Fugitive particulate emissions from traffic on unpaved roads related to completion/testing
- Diesel combustion/tailpipe emissions from heavy equipment related to completion/testing

A reasonable worst-case scenario was examined in which it was assumed that a maximum of two wells would be drilled and two other wells would be completed at one time within a given section. For this scenario, based on guidance provided by the operators, drilling emissions were allocated to two of the well pads and completion emissions were allocated to the other two well pads within the section. The drilling scenarios were modeled for a four-well-pad section. The section was located in the center of the NPL Project Area, and terrain information for that area was used as input to the AERMOD model. The nearest receptors were located 100 m from the edge of the each well pad.

Drilling emissions included emissions from the first five categories listed above, and completion emissions included emissions from the remaining four categories. Drill rigs and well-site combustion equipment were treated as point sources, and the remaining sources were treated as area sources, distributed throughout the well pad. Tailpipe emissions from haul vehicles and other large trucks were assigned a release height of 3.5 meters, which is the average height of a haul truck. Similarly, in accordance with AERMOD modeling guidance, particulate matter emissions from drilling traffic were assigned a release height of 3 meters and an initial vertical plume width of 2.8 meters (the plume height divided by 2.15) in order to account for mechanical turbulence. For those activities (including most drilling activities) that occur 24 hours per day the total emissions were calculated for the worst day and distributed across all hours of the days. For those activities that have an elapsed time of less than 24 hours per day, total emissions were calculated for the worst-case day and distributed across the daytime hours (7 am to 7 pm).

The emissions levels are consistent with drilling on a new well pad. The worst-case emissions for a given day are the same for the third through the thirteenth year of development during which drilling at a planned average rate of 350 wells per year is occurring.

Criteria pollutant and HAPs emissions for the drilling and completion scenario are summarized in Table 3-3. The emissions are provided separately for drilling and completion activities and are both for one well on a day during which these activities occur. As discussed earlier in this section, the AERMOD scenario included drilling of two wells and completion of two wells – so the input emissions are double those given in the table.

Table 3-3. AERMOD Drilling and Completion Scenario Emissions

Activity	Pollutant	Emissions (per well)	
		(lbs/hour)	(tons/year)*
Drilling	PM_{10}	0.4	2.0
	$PM_{2.5}$	0.1	0.6
	NO_2	6.2	27.4
	SO_2	0.0	0.2
	CO	12.7	55.7
	VOC	0.7	3.1
	Acetaldehyde	0.042	0.183
	Acrolein	0.025	0.111
	Benzene	0.006	0.025
	Ethyl benzene	0.000	0.002
	Formaldehyde	0.823	3.606
	Methanol	0.013	0.057
	n-Hexane	0.013	0.057
	Toluene	0.005	0.022
	Xylene	0.002	0.010
Completion	PM_{10}	7.8	34.0
	$PM_{2.5}$	1.5	6.7
	NO_2	21.0	91.9
	SO_2	1.0	4.3
	CO	4.6	20.2
	VOC	1.0	4.5
	Acetaldehyde	0.012	0.055
	Acrolein	0.002	0.007
	Benzene	0.014	0.063
	Ethyl benzene	0.000	0.000
	Formaldehyde	0.018	0.080
	Methanol	0.000	0.000
	n-Hexane	0.000	0.001
	Toluene	0.006	0.028
	Xylene	0.004	0.019

*Tons per year equivalent; most drilling and completion activities last for approximately 5 to 20 days.

Assessment of the modeling results for the drilling and completion scenario focused on both short-term air quality impacts, ranging from one to 24 hours, and annual impacts. Both criteria pollutants (PM_{10}, $PM_{2.5}$, NO_2, SO_2 and CO) and HAPs were considered.

Sample AERMOD input files (for PM_{10} and NO_2) and emission summaries (for all pollutants) for the drilling and completion scenario are included as Appendix A.

Production Operations

Starting in the first year of development, and similar to well drilling activities, production activities would ramp up during the first several years of the ten-year development period, and then would increase moderately and peak out during the final four years of the period, when the field has been fully developed. AERMOD was applied using the worst-case emissions for a given year during which production is occurring. For the criteria pollutants, the emissions are greatest for the last year of the ten-year development period, although several reach the maximum value earlier and stay the same for the remainder of the period. For VOCs and HAPs, the production emissions are greatest for the last year of development. Production related emissions include:

- Fugitive particulate emissions from traffic on unpaved roads related to production (not including tanker trucks)
- Fugitive particulate emissions from traffic on unpaved roads related to tanker trucks
- Diesel combustion/tailpipe emissions from heavy equipment related to production (not including tanker trucks)
- Diesel combustion/tailpipe emissions from heavy equipment related to tanker trucks
- Wind erosion emissions related to production
- Combustion emissions from compressor engines related to production
- Natural gas combustion emissions from miscellaneous engines related to production
- Dehydrator emissions related to production
- Pneumatic emissions related to production
- Fugitive VOC/HAPs emissions related to production
- Condensate storage tank emissions related to production
- Condensate loading emissions related to production
- Passenger vehicle emissions related to production

A reasonable worst-case scenario was examined in which the emissions were based on four (4) well pads (the maximum number to fit within one square mile based on a well-pad spacing of 160 acres (or 0.25 square miles) and 16 wells per pad (the maximum number of wells per pad). Thus the total number of wells included in the modeling is 64. The wells were evenly distributed across the well pads and the well pads were evenly distributed within the section, according to the well pad spacing criteria.

The production scenario was modeled for a four-well pad section. The section was located in the center of the NPL Project Area, and terrain information for that area was used as input to the AERMOD model. The nearest receptors were located 100 m from the edge of the each well pad. A majority of the engines used for production will be electric and will have zero emissions; the remaining sources included in the production scenario were treated as area sources, distributed throughout the four well pads. Tailpipe emissions from tanker trucks were assigned a release height of 3.5 meters particulate matter emissions from tanker truck traffic were assigned a release height of 3 meters and an initial vertical plume width of 2.8 meters. Production activities occur 24 hours per day and the daily total emissions were distributed accordingly.

Criteria pollutant and HAPs emissions for the production scenario are summarized in Table 3-4. The total emissions are for 64 wells distributed across four well pads as well as a portion of the emissions from one of the regional gathering facilities (RGFs). Eleven RGFs would be constructed in densely drilled portions of the NPL Project Area to separate and store liquids from the natural gas stream. Each fully operational RGF would include liquids separation and gas dehydration equipment, gas compression facilities, water injection wells and pumps, water and condensate storage tank batteries, liquids handling and offloading facilities, as well as electrical transformers, and power control facilities. To minimize air emissions, electric compression would be used at each RGF, powered by high-voltage distribution lines. Based on information provided by the operators, each facility is expected to service 20 well pads, so one-fifth of the emissions from the facility were included in the production emissions for the four-well-pad area. No larger centralized facilities are planned. Note that no emissions were available for acetaldehyde, acrolein or methanol and these emissions were assumed to be zero for the production scenario.

Table 3-4. AERMOD Production Scenario Emissions

Activity	Pollutant	Emissions (per 4-well pad section)	
		(lbs/hour)	(tons/year)*
Production	PM_{10}	0.4	1.6
	$PM_{2.5}$	0.0	0.2
	NO_2	0.0	0.0
	SO_2	0.0	0.0
	CO	0.0	0.1
	VOC	0.1	0.6
	Benzene	0.001	0.004
	Ethyl benzene	0.000	0.000
	Formaldehyde	0.000	0.000
	n-Hexane	0.003	0.011
	Toluene	0.002	0.007
	Xylene	0.001	0.004

Assessment of the modeling results for the production scenario focused both short-term air quality impacts, ranging from one to 24 hours, and annual impacts. Both criteria pollutants (PM_{10}, $PM_{2.5}$, NO_2, SO_2 and CO) and HAPs were considered.

Combination Scenario

A combination scenario was examined in which the timing of the various activities was accounted for. This scenario assumed:

- Construction activity (well pad construction; one well pad at a time) during the first year
- Drilling and completion (drilling of one well on two well pads; completion of one well on two well pads) during the second year
- Production occurring on all four well pads (64 wells total) during the third through fifth years

For this scenario, the AERMOD results for each year/activity were combined and used to calculate the air quality metrics (e.g., three-year averages). All simultaneous activities were modeled together. The results overestimate the potential impacts, since the maximum values for each scenario were used in calculating the multi-year averages and were assumed to be collocated. In fact, the maximum values occur at different locations for the different scenarios. This combination scenario focused on both short-term and annual air quality impacts for criteria pollutants.

Since the impacts for any combination scenario involving concurrent activities on the individual well pads are expected to be less than those of the drilling and completion scenario (i.e., they do not represent a worst case) they were not modeled.

3.2 Criteria Pollutant Modeling and Impact Assessment

The AERMOD-derived impacts were added to representative background air quality concentrations (presented in Section 3.4) and compared to both the NAAQS and applicable WAAQS. These standards are summarized in Table 3-5. Units are µg/m3 and parts per billion (ppb)

Table 3-5. Summary of Ambient Air Quality Standards

Pollutant (Units)	Averaging Period	NAAQS	WAAQS
PM_{10} (µg/m^3)	24-hour[1]	150	150
	Annual[2]	--	50
$PM_{2.5}$ (µg/m^3)	24-hour[3]	35	35
	Annual[4]	12	12
Ozone (ppb)	8-hour[5]	75	75
NO_2 (µg/m^3)	1-hour[6]	188	188
	Annual[2]	100	100
SO_2 (µg/m^3)	1-hour[7]	196	196
CO (µg/m^3)	1-hour[8]	40,000	40,000
	8-hour[8]	10,000	10,000

[1] Not to be exceeded more than once per year on average over 3 years.
[2] Not to be exceeded.
[3] The three-year average of the 98th percentile 24-hour average concentration must not exceed this standard.
[4] The three-year average of the annual average concentration must not exceed this standard.
[5] To attain this standard, the 3-year average of the fourth-highest daily maximum 8-hour average O3 concentration measured at each monitor within an area over each year must not exceed 70 ppb.
[6] The 3-year average of the 98th percentile of the daily maximum 1-hour average is not to exceed this standard.
[7] The 3-year average of the 99th percentile of the daily maximum 1-hour average must not exceed this standard.
[8] Not to be exceeded more than once per year.

The AERMOD-derived impacts for the production scenario were also compared with applicable PSD increments for designated Class I and Class II areas. All comparisons to the PSD increments are intended to evaluate a threshold of concern and do not represent a regulatory PSD Increment Consumption Analysis.

The concentrations presented in the remainder of this section represent the maximum values for the receptor grid consistent with the form of each standard, paired in space and averaged, as appropriate, over multiple years in accordance with the form of the NAAQS/WAAQS. In most cases, the maximum value occurs at the first row of receptors (100 m from the source). If the modeled value results in a concentration greater than an applicable standard, the distance at which concentration is lower than the standard is also presented.

Simulated values of 24-hour $PM_{10,}$ 24-hour $PM_{2.5}$ and 1-hour NO_2 for each year of the five year simulation period are presented in Appendix B.

3.2.1 Construction Scenario Results

Results for the criteria pollutants for the construction scenarios are compared with the NAAQS and WAAQS in Tables 3-6 through 3-10. The AERMOD-derived concentrations presented in these tables have been paired in space and averaged, as appropriate, over multiple years in accordance with the form of the NAAQS/WAAQS. Concentrations that are greater than either the NAAQS or the WAAQS are highlighted in bold. Concentration units for all pollutants are µg/m^3. As noted earlier in this section, both annual and quarterly background values were used for the analysis of 1-hour NO_2. Annual results are presented in the first part of each table and quarterly results are presented in the second part of each table.

Table 3-6a. AERMOD-Derived Criteria Pollutant Impacts Calculated Using Annual Background Concentrations: Well-Pad Construction Scenario

Pollutant (Units)	Averaging Period	AERMOD-Derived Concentration (µg/m^3)	Background Concentration (µg/m^3)	Total AERMOD-Derived + Background Concentration (µg/m^3)	NAAQS	WAAQS
PM_{10} (µg/m^3)	24-hour	88.4	32.7	121.1	150	150
	Annual	6.8	7.8	14.6	--	50
$PM_{2.5}$ (µg/m^3)	24-hour	6.6	10.2	16.8	35	35
	Annual	0.8	4.1	4.9	12	12
NO_2 (µg/m^3)	1-hour	98.9	11.9	110.8	188	188
	Annual	4.4	0.5	4.9	100	100
SO_2 (µg/m^3)	1-hour	13.0	22.5	35.5	196	196
CO (µg/m^3)	1-hour	281	996	1,277	40,000	40,000
	8-hour	78	790	868	10,000	10,000

Table 3-6b. AERMOD-Derived 1-Hour NO_2 Impacts Calculated Using Quarterly Background Concentrations: Well-Pad Construction Scenario

Pollutant (Units)	Averaging Period	AERMOD-Derived Concentration (µg/m^3)	Background Concentration (µg/m^3)	Total AERMOD-Derived + Background Concentration (µg/m^3)*
1-hour NO_2 (µg/m^3)	Jan-Mar	129.4	16.3	145.7
	Apr-Jun	68.2	5.0	73.2
	Jul-Sep	78.2	6.9	85.1
	Oct-Dec	91.5	11.3	102.8

*Note that the NAAQS (and WAAQS) for 1-hour NO_2 is 188 µg/m^3.

Table 3-7a. AERMOD-Derived Criteria Pollutant Impacts Calculated Using Annual Background Concentrations: Pipeline Construction Scenario

Pollutant (Units)	Averaging Period	AERMOD-Derived Concentration (µg/m³)	Background Concentration (µg/m³)	Total AERMOD-Derived + Background Concentration (µg/m³)	NAAQS	WAAQS
PM_{10} (µg/m³)	24-hour	41.1	32.7	73.8	150	150
	Annual	3.2	7.8	11.0	--	50
$PM_{2.5}$ (µg/m³)	24-hour	8.0	10.2	18.2	35	35
	Annual	1.9	4.1	6.0	12	12
NO_2 (µg/m³)	1-hour	120.0	11.9	131.9	188	188
	Annual	5.7	0.5	6.2	100	100
SO_2 (µg/m³)	1-hour	16.3	22.5	38.8	196	196
CO (µg/m³)	1-hour	668	996	1,664	40,000	40,000
	8-hour	185	790	975	10,000	10,000

Table 3-7b. AERMOD-Derived NO_2 Impacts Calculated Using Quarterly Background Concentrations: Pipeline Construction Scenario

Pollutant (Units)	Averaging Period	AERMOD-Derived Concentration (µg/m³)	Background Concentration (µg/m³)	Total AERMOD-Derived + Background Concentration (µg/m³)*
1-hour NO_2 (µg/m³)	Jan-Mar	145.3	16.3	161.6
	Apr-Jun	76.7	5.0	81.7
	Jul-Sep	92.9	6.9	99.8
	Oct-Dec	110.7	11.3	122.0

*Note that the NAAQS (and WAAQS) for 1-hour NO_2 is 188 µg/m³.

Table 3-8a. AERMOD-Derived Criteria Pollutant Impacts Calculated Using Annual Background Concentrations: Resource Road Construction Scenario

Pollutant (Units)	Averaging Period	AERMOD-Derived Concentration (µg/m³)	Background Concentration (µg/m³)	Total AERMOD-Derived + Background Concentration (µg/m³)	NAAQS	WAAQS
PM_{10} (µg/m³)	24-hour	97.6	32.7	130.3	150	150
	Annual	7.4	7.8	15.2	--	50
$PM_{2.5}$ (µg/m³)	24-hour	6.9	10.2	17.1	35	35
	Annual	0.9	4.1	5.0	12	12
NO_2 (µg/m³)	1-hour	98.2	11.9	110.1	188	188
	Annual	4.4	0.5	4.9	100	100
SO_2 (µg/m³)	1-hour	12.9	22.5	35.4	196	196
CO (µg/m³)	1-hour	270	996	1,266	40,000	40,000
	8-hour	75	790	865	10,000	10,000

Table 3-8b. AERMOD-Derived NO_2 Impacts Calculated Using Quarterly Background Concentrations: Resource Road Construction Scenario

Pollutant (Units)	Averaging Period	AERMOD-Derived Concentration (µg/m³)	Background Concentration (µg/m³)	Total AERMOD-Derived + Background Concentration (µg/m³)*
1-hour NO_2 (µg/m³)	Jan-Mar	128.9	16.3	145.2
	Apr-Jun	67.9	5.0	72.9
	Jul-Sep	77.7	6.9	84.6
	Oct-Dec	90.8	11.3	102.1

*Note that the NAAQS (and WAAQS) for 1-hour NO_2 is 188 µg/m³.

Table 3-9a. AERMOD-Derived Criteria Pollutant Impacts Calculated Using Annual Background Concentrations: Access Road Construction Scenario

Pollutant (Units)	Averaging Period	AERMOD-Derived Concentration (μg/m^3)	Background Concentration (μg/m^3)	Total AERMOD-Derived + Background Concentration (μg/m^3)	NAAQS	WAAQS
PM_{10} (μg/m^3)	24-hour	9.8	32.7	42.5	150	150
	Annual	0.7	7.8	8.5	--	50
$PM_{2.5}$ (μg/m^3)	24-hour	0.4	10.2	10.6	35	35
	Annual	0.1	4.1	4.2	12	12
NO_2 (μg/m^3)	1-hour	0.1	11.9	12.0	188	188
	Annual	0.0	0.5	0.5	100	100
SO_2 (μg/m^3)	1-hour	0.0	22.5	22.5	196	196
CO (μg/m^3)	1-hour	35	996	1,031	40,000	40,000
	8-hour	9	790	799	10,000	10,000

Table 3-9b. AERMOD-Derived NO_2 Impacts Calculated Using Quarterly Background Concentrations: Access Road Construction Scenario

Pollutant (Units)	Averaging Period	AERMOD-Derived Concentration (μg/m^3)	Background Concentration (μg/m^3)	Total AERMOD-Derived + Background Concentration (μg/m^3)*
1-hour NO_2 (μg/m^3)	Jan-Mar	0.1	16.3	16.4
	Apr-Jun	0.1	5.0	5.2
	Jul-Sep	0.1	6.9	7.0
	Oct-Dec	0.1	11.3	11.4

*Note that the NAAQS (and WAAQS) for 1-hour NO_2 is 188 μg/m^3.

Table 3-10a. AERMOD-Derived Criteria Pollutant Impacts Calculated Using Annual Background Concentrations: Other Construction Scenario

Pollutant (Units)	Averaging Period	AERMOD-Derived Concentration (μg/m^3)	Background Concentration (μg/m^3)	Total AERMOD-Derived + Background Concentration (μg/m^3)	NAAQS	WAAQS
PM_{10} (μg/m^3)	24-hour	37.1	32.7	69.8	150	150
	Annual	2.8	7.8	10.6	--	50
$PM_{2.5}$ (μg/m^3)	24-hour	4.5	10.2	14.7	35	35
	Annual	0.6	4.1	4.7	12	12
NO_2 (μg/m^3)	1-hour	98.5	11.9	110.4	188	188
	Annual	4.4	0.5	4.9	100	100
SO_2 (μg/m^3)	1-hour	12.9	22.5	35.4	196	196
CO (μg/m^3)	1-hour	276	996	1,272	40,000	40,000
	8-hour	77	790	867	10,000	10,000

Table 3-10b. AERMOD-Derived NO_2 Impacts Calculated Using Quarterly Background Concentrations: Other Construction Scenario

Pollutant (Units)	Averaging Period	AERMOD-Derived Concentration (μg/m^3)	Background Concentration (μg/m^3)	Total AERMOD-Derived + Background Concentration (μg/m^3)
1-hour NO_2 (μg/m^3)	Jan-Mar	129.1	16.3	145.4
	Apr-Jun	68.1	5.0	73.1
	Jul-Sep	77.9	6.9	84.8
	Oct-Dec	91.1	11.3	102.4

*Note that the NAAQS (and WAAQS) for 1-hour NO_2 is 188 μg/m^3.

In applying AERMOD, it was assumed that construction activities occur every day of the year. This is necessary to capture the worst-case impacts, but, as a result, the annual average impacts are likely overstated. Similarly, calculation of the multi-year average air quality metrics assumed that all construction on a given well pad would be completed within a two-year period. If construction is completed within one year (this is likely), these metrics are also likely to be overestimated.

Using the annual background concentrations, the modeled plus background values for all criteria pollutants and time periods are less than the NAAQS and WAAQS thresholds. Using the quarterly background concentrations the 1-hour daily maximum NO_2 concentrations are also less than the NAAQS.

The values for the first quarter of the year (January through March) are about 35 to 60 percent higher than the overall annual values, indicating that many of the high 1-hour NO_2 values occur during this period.

3.2.2 Drilling Scenario Results

Results for the criteria pollutants for the drilling and completion scenario are compared with the NAAQS and WAAQS in Table 3-11 (a) and (b). The AERMOD-derived concentrations presented in this table have been paired in space and averaged, as appropriate, over multiple years in accordance with the form of the NAAQS/WAAQS. Concentrations that are greater than either the NAAQS or the WAAQS are highlighted in bold. Concentration units for all pollutants are μg/m^3.

Table 3-11a. AERMOD-Derived Criteria Pollutant Impacts Calculated Using Annual Background Concentrations: Drilling and Completion Scenario

Pollutant (Units)	Averaging Period	AERMOD-Derived Concentration (μg/m^3)	Background Concentration (μg/m^3)	Total AERMOD-Derived + Background Concentration (μg/m^3)	NAAQS	WAAQS
PM_{10} (μg/m^3)	24-hour	477.1	32.7	**509.8**	150	150
	Annual	75.1	7.8	**82.9**	--	50
$PM_{2.5}$ (μg/m^3)	24-hour	21.4	10.2	31.6	35	35
	Annual	5.4	4.1	9.5	12	12
NO_2 (μg/m^3)	1-hour	104.5	11.9	116.4	188	188
	Annual	24.0	0.5	24.5	100	100
SO_2 (μg/m^3)	1-hour	25.0	22.5	47.5	196	196
CO (μg/m^3)	1-hour	344	996	1340	40,000	40,000
	8-hour	153	790	943	10,000	10,000

Table 3-11b. AERMOD-Derived NO_2 Impacts Calculated Using Quarterly Background Concentrations: Drilling and Completion Scenario

Pollutant (Units)	Averaging Period	AERMOD-Derived Concentration (μg/m^3)	Background Concentration (μg/m^3)	Total AERMOD-Derived + Background Concentration (μg/m^3)*
1-hour NO_2 (μg/m^3)	Jan-Mar	113.5	16.3	129.8
	Apr-Jun	100.9	5.0	105.9
	Jul-Sep	97.4	6.9	104.3
	Oct-Dec	102.4	11.3	113.7

*Note that the NAAQS (and WAAQS) for 1-hour NO_2 is 188 μg/m^3.

Calculation of the multi-year average air quality metrics assumed that all drilling and completion activities on a given section would be completed within a two-year period. If drilling and completion are completed within one year, these metrics are likely to be overestimated.

The resultant 24-hour PM_{10} concentration is greater than both the NAAQS and WAAQS thresholds. The maximum modeled value occurs 100 meters to the west of the center portion of the northeastern well pad – in between two well pads. There are several other receptors in between well pads for which the concentrations are greater than 150 µg/m^3. Outside of the four-well-pad area the maximum modeled concentration is 222 µg/m^3 and occurs 100 meters to the southwest of the southwestern corner of the southeastern well pad. At a distance of 200 m the modeled value falls to 118 µg/m^3 which when added to the background value of 32.7 µg/m^3 results in an overall value of 150.7 µg/m^3. Thus the resultant value is at the NAAQS and WAAQS at a distance of 200 m from the source, and below the NAAQS at 300 m from the source.

The modeled plus background values for all other criteria pollutants and time periods are less than the NAAQS and WAAQS thresholds. The quarterly NO_2 values show that the highest NO_2 concentrations occur during the first quarter (January through March).

3.2.3 Production Scenario Results

Results for the criteria pollutants for the production scenario are compared with the NAAQS and WAAQS in Table 3-12. Again, the AERMOD-derived concentrations presented in this table have been paired in space and averaged, as appropriate, over multiple years in accordance with the form of the NAAQS/WAAQS. Concentrations that are greater than either the NAAQS or the WAAQS are highlighted in bold. Concentration units for all pollutants are µg/m^3.

Table 3-12. AERMOD-Derived Criteria Pollutant Impacts Calculated Using Annual Background Concentrations: Production Scenario

Pollutant (Units)	Averaging Period	AERMOD-Derived Concentration (µg/m^3)	Background Concentration (µg/m^3)	Total AERMOD-Derived + Background Concentration (µg/m^3)	NAAQS	WAAQS
PM_{10} (µg/m^3)	24-hour	7.5	32.7	40.2	150	150
	Annual	1.2	7.8	9.0	--	50
$PM_{2.5}$ (µg/m^3)	24-hour	0.5	10.2	10.7	35	65
	Annual	0.1	4.1	4.2	12	12
NO_2 (µg/m^3)	1-hour	0.5	11.9	12.4	188	188
	Annual	0.0	0.5	0.5	100	100
SO_2 (µg/m^3)	1-hour	0.0	22.5	22.5	196	196
CO (µg/m^3)	1-hour	1	996	997	40,000	40,000
	8-hour	1	790	791	10,000	10,000

The modeled plus background values for all criteria pollutants and time periods are less than the NAAQS and WAAQS thresholds. Most of the engines used in production are electric and this accounts for the low criteria pollutant emissions of NO_x, SO_2, and CO.

Results for the production scenario are compared with applicable PSD consumption increments in Table 3-13. No concentrations are greater than the PSD increments.

Table 3-13. Comparison of AERMOD-Derived Criteria Pollutant Impacts with Applicable PSD Consumption Increments: Production Scenario

Pollutant (Units)	Averaging Period	AERMOD-Derived Concentration (µg/m^3)	PSD Class II Increment
PM_{10} (µg/m^3)	24-hour	7.5	30
	Annual	1.2	17
$PM_{2.5}$ (µg/m^3)	24-hour	0.5	8
	Annual	0.1	4
NO_2 (µg/m^3)	1-hour	0.5	--
	Annual	0.0	25
SO_2 (µg/m^3)	1-hour	0.0	--
CO (µg/m^3)	1-hour	1	--
	8-hour	1	--

3.2.4 Combination Scenario Results

As noted earlier, the impacts for any combination scenario involving concurrent activities on the individual well pads are expected to be less than those of the drilling and completion scenario. Thus, the drilling and completion scenario represents the overall worst case.

For the combination scenario, the timing of the activities was examined and the AERMOD results for each year/activity were combined and used to calculate the air quality metrics. Note that the maximum values for each scenario were used in calculating the multi-year averages, and that these are not necessarily paired in space. The simulated values for each scenario and year used in calculating the combination scenario impacts are presented in Appendix C. Contour plots for each pollutant for each scenario and year used in the combination scenario are also presented in the appendix.

Results for the criteria pollutants for the combination scenario are compared with the NAAQS and WAAQS in Table 3-14 (a) and (b). Concentrations that are greater than either the NAAQS or the WAAQS are highlighted in bold. Concentration units for all pollutants are µg/m^3.

Table 3-14a. AERMOD-Derived Criteria Pollutant Impacts Calculated Using Annual Background Concentrations: Combination Scenario

Pollutant (Units)	Averaging Period	AERMOD-Derived Concentration (µg/m^3)	Background Concentration (µg/m^3)	Total AERMOD-Derived + Background Concentration (µg/m^3)	NAAQS	WAAQS
PM_{10} (µg/m^3)	24-hour	287.6	32.7	**320.3**	150	150
	Annual	75.1	7.8	**82.9**	--	50
$PM_{2.5}$ (µg/m^3)	24-hour	12.5	10.2	22.7	35	35
	Annual	3.2	4.1	7.3	12	12
NO_2 (µg/m^3)	1-hour	93.1	11.9	105.0	188	188
	Annual	18.7	0.5	19.2	100	100
SO_2 (µg/m^3)	1-hour	17.0	22.5	39.5	196	196
CO (µg/m^3)	1-hour	345	996	1,341	40,000	40,000
	8-hour	145	790	935	10,000	10,000

Table 3-14b. AERMOD-Derived NO_2 Impacts Calculated Using Quarterly Background Concentrations: Drilling and Combination Scenario

Pollutant (Units)	Averaging Period	AERMOD-Derived Concentration (µg/m^3)	Background Concentration (µg/m^3)	Total AERMOD-Derived + Background Concentration (µg/m^3)*
1-hour NO_2 (µg/m^3)	Jan-Mar	102.2	16.3	118.5
	Apr-Jun	78.5	5.0	83.5
	Jul-Sep	82.7	6.9	89.6
	Oct-Dec	93.8	11.3	105.1

*Note that the NAAQS (and WAAQS) for 1-hour NO_2 is 188 µg/m^3.

The modeled 24-hour and annual PM_{10} concentrations are greater than both the NAAQS and WAAQS thresholds, due primarily to the emissions associated with drilling and completion that is assumed to occur for one year of the three-year averaging period.

3.3 HAP Modeling and Impact Assessment

AERMOD was also used to simulate airborne concentrations of HAPs, and the resulting concentrations were used to assess the risks associated with both short-term and long-term exposures to the various hazardous and toxic air pollutants. Based on the available emissions data, the following HAPs were considered: benzene; ethyl benzene; formaldehyde; n-hexane; toluene; and xylene. Acetaldehyde, acrolein, and methanol are also considered for the drilling scenario only.

For modeling purposes, HAP emissions were represented in AERMOD using a unit emission rate (i.e., 1 gram per second) for each modeled source. The impacts were then scaled by the maximum emission rates for each source to estimate the concentrations of each pollutant. The resulting concentrations were compared to established IUR factors for carcinogens and RfCs or RELs for non-carcinogens. Both short-term and long-term exposures were considered. The HAPs analysis considered the maximum modeled values within the area covered by the receptor grid.

Short-term (1-hour) air toxic impacts calculated by AERMOD were compared to the acute RELs shown in Table 3-15. Acute RELs are defined as concentrations at or below which no adverse health effects are expected. Since there are no established RELs for ethyl benzene or n-hexane, Immediately Dangerous to Life or Health (IDLH) values (IDLH/10) will be used. These IDLH values are determined by the National Institute for Occupational Safety and Health and were obtained from EPA's Air Toxics Database (EPA, 2007a). Units are milligrams per cubic meter (mg/m^3).

Table 3-15. Acute Reference Exposure Levels (REL) or Immediately Dangerous to Life or Health (IDLH) for Selected Hazardous Air Pollutants (HAPs)

HAP	REL or IDLH/10 (mg/m^3)
Acetaldehyde	0.47
Acrolein	0.0025
Benzene	1.3
Ethyl benzene	350*
Formaldehyde	0.055
Methanol	28
n-Hexane	390*
Toluene	37
Xylene	22

* IDLH/10

Source: EPA 2010 (http://www.epa.gov/ttn/atw/toxsource/table2.pdf)

Long-term inhalation exposure to non-carcinogenic air toxics (based on annual average pollutant concentrations) was calculated using the AERMOD results and compared to RfCs for chronic inhalation of non-carcinogenic hazardous air pollutants, as listed in Table 3-16 (EPA, 2007a). The RfC for a given pollutant is defined as the threshold at or below which no long-term adverse health effects are expected. Units are mg/m^3.

Table 3-16. Non-Carcinogenic Chronic Reference Concentration (RfC) for Selected Hazardous Air Pollutants

HAP	RfC (mg/m^3)
Acetaldehyde	0.009
Acrolein	0.00002
Benzene	.03
Ethyl benzene	1
Formaldehyde	.01
Methanol	4
n-Hexane	0.7
Toluene	5
Xylene	0.1

Source: EPA, 2010 (http://www.epa.gov/ttn/atw/toxsource/table1.pdf)

Finally, the AERMOD results were also used to estimate the cancer risk associated with exposure to carcinogenic hazardous air pollutants. To estimate the incremental inhalation cancer risk for each toxic pollutant, annual modeled concentrations were multiplied by the EPA's IUR factors presented in Table 3-17. These are estimates of the cancer risk (on a per unit concentration unit basis) based on 70-year exposure to the carcinogenic toxic air pollutants. For example, an IUR of 7.8E-6 for benzene is equivalent to a cancer risk of 7.8 per million per $\mu g/m^3$. Each IUR is based on continuous exposure for 70 years. Although it is standard practice to adjust the IUR to reflect exposure time for specific receptor types, this was not done as part of this study since no clear receptors were identified. Thus the results represent the maximum risk, and depending upon receptor type the results would be lower.

Table 3-17. Carcinogenic Inhalation Unit Risk (IUR) Factors Selected Hazardous Air Pollutants

HAP	IUR $1/(\mu g/m^3)$
Benzene	7. 8E-6
Ethyl benzene	2.5E-6
Formaldehyde	1.3E-5

Source: EPA, 2010 (http://www.epa.gov/ttn/atw/toxsource/table1.pdf)

3.3.1 Drilling Scenario Results (HAPs)

Short-Term Impacts

AERMOD-derived maximum 1-hour air toxic impacts for the drilling scenario are compared to acute RELs and IDLH/10 values in Table 3-18. The maximum value occurs 100 meters north from the center portion of the northeast well pad. No concentrations are greater than the RELs or IDLH/10 values. Units are milligrams per cubic meter (mg/m^3).

Table 3-18. Comparison of Short-Term AERMOD-Derived HAPs Impacts with RELs and IDLH/10 Values: Drilling Scenario

Pollutant (Units)	AERMOD-Derived Concentration (mg/m^3)	REL or IDLH/10 (mg/m^3)
Acetaldehyde	9.73E-05	0.47
Acrolein	1.18E-05	0.0025
Benzene	1.26E-04	1.3
Ethyl benzene	3.83E-07	350
Formaldehyde	1.59E-04	0.055
Methanol	5.07E-08	28
n-Hexane	2.86E-05	390
Toluene	6.12E-05	37
Xylene	3.96E-05	22

Long-term impacts were not calculated for the drilling scenario.

3.3.2 Production Scenario Results (HAPs)

Short-Term Impacts

AERMOD-derived maximum 1-hour air toxic impacts for the production scenario are compared to acute RELs and IDLH values in Table 3-19. The maximum value occurs 100 meters west of the center portion of the southwestern well pad. No concentrations are greater than the RELs or IDLH/10 values. Units are milligrams per cubic meter (mg/m^3).

Table 3-19. Comparison of Short-Term AERMOD-Derived HAPs Impacts with RELs and IDLH/10 Values: Production Scenario

Pollutant (Units)	AERMOD-Derived Concentration (mg/m^3)	REL or IDLH/10 (mg/m^3)
Benzene	3.82E-04	1.3
Ethyl benzene	3.65E-05	350
Formaldehyde	6.05E-06	0.055
n-Hexane	1.11E-03	390
Toluene	7.02E-04	37
Xylene	4.42E-04	22

Long-Term Impacts (Non-Carcinogenic)

AERMOD-derived annual average air toxic impacts for the production scenario are compared to RfCs for chronic inhalation of non-carcinogenic hazardous air pollutants in Table 3-20. The maximum value, as reported in the table, occurs 100 meters west of the southwest corner of the southeastern well pad. No concentrations are greater than the RfC values. Units are milligrams per cubic meter (mg/m^3).

Table 3-20. Comparison of Long-Term AERMOD-Derived Non-Carcinogenic HAPs Impacts with RfC Values: Production Scenario

Pollutant (Units)	AERMOD-Derived Concentration (mg/m^3)	RfC (mg/m^3)
Benzene	1.922E-05	0.03
Ethyl benzene	1.836E-06	1
Formaldehyde	3.272E-07	0.01
n-Hexane	5.590E-05	0.7
Toluene	3.531E-05	5
Xylene	2.226E-05	0.1

Long-Term Impacts (Cancer Risks)

AERMOD-derived incremental inhalation cancer risk base on maximum annual-average modeled concentrations are presented in Table 3-21. These are estimates of cancer are based on 70-year exposure to the carcinogenic toxic air pollutants.

Table 3-21. AERMOD-Derived Cancer Risk: Production Scenario

Pollutant (Units)	AERMOD-Derived Concentration (µg/m^3)	IUR (1/(µg/m^3))	Cancer Risk (per million)
Benzene	1.92E-02	7.80E-06	1.50E-01
Ethyl benzene	1.84E-03	2.50E-06	4.59E-03
Formaldehyde	3.27E-04	1.30E-05	4.25E-03

The total overall cancer risk is 0.16 per million for this production scenario. This value could be further adjusted for exposure but given the location of the peak concentrations within the Project Area and considering that the overall risk is estimated to be <1 per million, no exposure adjustment was applicable. Note, however, that the additive effects of multiple chemicals are not fully understood.

4.0 FAR-FIELD FUTURE-YEAR AIR QUALITY IMPACT ASSESSMENT: CMAQ MODELING

4.1 CMAQ Modeling Approach

Far-field (or regional) impacts were evaluated using Version 5.0 of EPA's Community Multiscale Air Quality (CMAQ) modeling system.

The CMAQ model is a state-of-the-science, regional air quality modeling system that can be used to simulate the physical and chemical processes that govern the formation, transport, and deposition of gaseous and particulate species in the atmosphere (Byun and Ching, 1999). The CMAQ tool was designed to improve the understanding of air quality issues (including the physical and chemical processes that influence air quality) and to support the development of effective emission control strategies on both the regional and local scales. The CMAQ model was designed as a "one-atmosphere" model. This concept refers to the ability of the model to dynamically simulate ozone, particulate matter, and other species (such as mercury) in a single simulation. In addition to addressing a variety of pollutants, CMAQ can be applied to a variety of regions (with varying geographical, land-use, and emissions characteristics) and for a range of space and time scales. CMAQ includes state-of-the-science advection, dispersion and deposition algorithms, the latest version of the Carbon Bond (CB) chemical mechanism (CB05), and diagnostic tools for assessing source apportionment.

The CMAQ model numerically simulates the physical processes that determine the magnitude, temporal variation, and spatial distribution of the concentrations of ozone and particulate species in the atmosphere and the amount, timing, and distribution of their deposition to the earth's surface. The simulation processes include advection, dispersion (or turbulent mixing), chemical transformation, cloud processes, and wet and dry deposition. The CMAQ science algorithms are described in detail by Byun and Ching (1999).

The CMAQ model requires several different types of input files. Gridded, hourly emission inventories characterize the release of anthropogenic, biogenic, and, in some cases, geogenic emissions from sources within the modeling domain. The emissions represent both low-level and elevated sources and a variety of source categories (including, for example, point, on-road mobile, non-road mobile, area, and biogenic). The amount and spatial and temporal distribution of each emitted pollutant or precursor species are key determinants to the resultant simulated air quality values.

The CMAQ model also requires hourly, gridded input fields of several meteorological parameters including wind, temperature, mixing ratio, pressure, solar radiation, fractional cloud cover, cloud depth, and precipitation. A full list of the meteorological input parameters is provided in Byun and Ching (1999). The meteorological input fields are typically prepared using a data-assimilating prognostic meteorological model, the output of which is processed for input to the CMAQ model using the Meteorology-Chemistry Interface Processor (MCIP). The prescribed meteorological conditions influence the transport, vertical mixing, and resulting distribution of the simulated pollutant concentrations. Certain meteorological parameters, such as mixing ratio, can also influence the simulated chemical reaction rates. Rainfall and near-surface meteorological characteristics govern the wet and dry deposition, respectively, of the simulated atmospheric constituents.

Initial and boundary condition (IC/BC) files provide information on pollutant concentrations throughout the domain for the first hour of the first day of the 10-day spin-up period for the simulation, and along the lateral boundaries of the domain for each hour of the simulation. Photolysis rates and other chemistry-related input files supply information needed by the gas-phase and particulate chemistry algorithms.

For the NPL air quality assessment, the meteorological inputs were prepared using the Weather Research and Forecasting (WRF) model (NCAR, 2010). The WRF model application procedures and model configuration parameters are described in detail in the meteorological modeling report (ICF, 2012). A detailed discussion of the input preparation and application procedures is provided in a companion report on CMAQ model performance evaluation (ICF, 2014).

In applying the CMAQ model for the NPL air quality assessment, the latest versions of the CB05 gas phase chemical mechanism, the AERO6 aerosol module, and the ISOROPIA2 aqueous partitioning routine (for the partitioning of sulfate and nitrate particulate matter) were used. CMAQ v5.0 does not include a functional plume-in-grid module, so no plume-in-grid treatment was used. Photolysis rates were calculated using the updated and improved algorithm included in CMAQ v5.0. Other options and inputs were set according to EPA recommendations for this version of CMAQ and for consistency with the emissions and meteorological inputs.

CMAQ was applied for 2008 in order to establish current air quality conditions. The 2008 base case was summarized in the CMAQ model performance evaluation report (ICF, 2014).

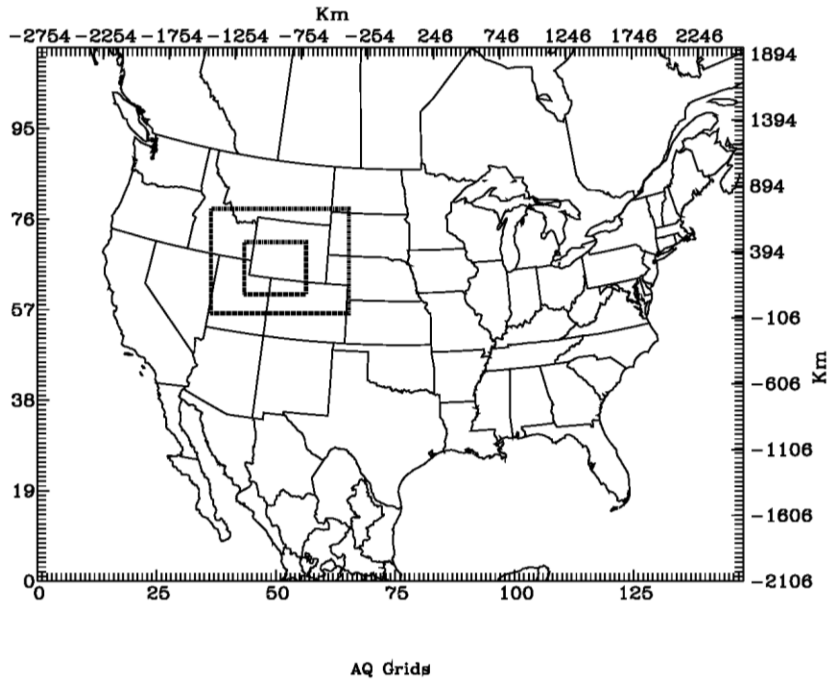
The annual CMAQ simulation was divided into two parts: January through June and July through December. Each simulation part includes 10 spin-up days that were added in order to reduce the influence of the initial conditions on the simulation results.

4.1.1 Air Quality Modeling Domain

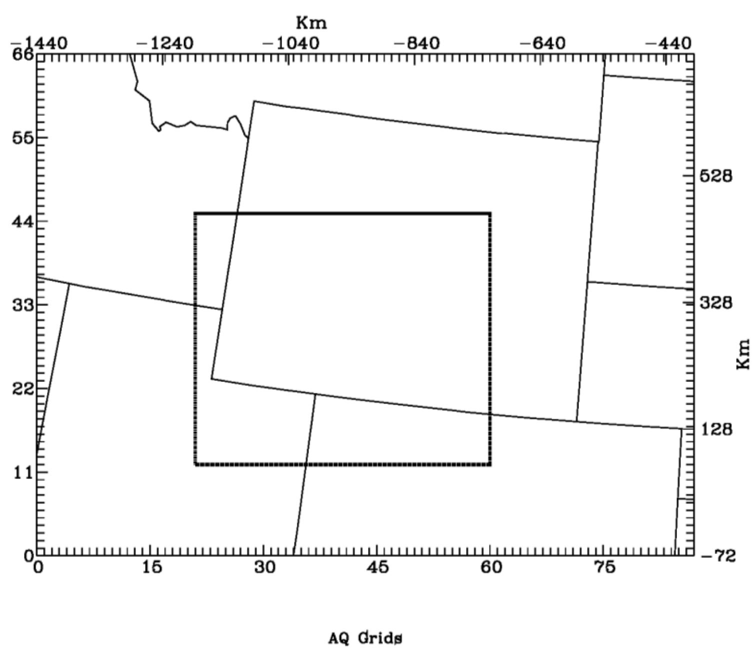
The CMAQ modeling domain was designed to accommodate both regional and subregional influences as well as to provide a detailed representation of the emissions, meteorological fields, and pollutant concentration patterns over the area of interest. The modeling domain is illustrated in Figure 4-1 (a)-(c).

Figure 4-1. CMAQ Modeling Domain for the NPL Air Quality Impact Assessment

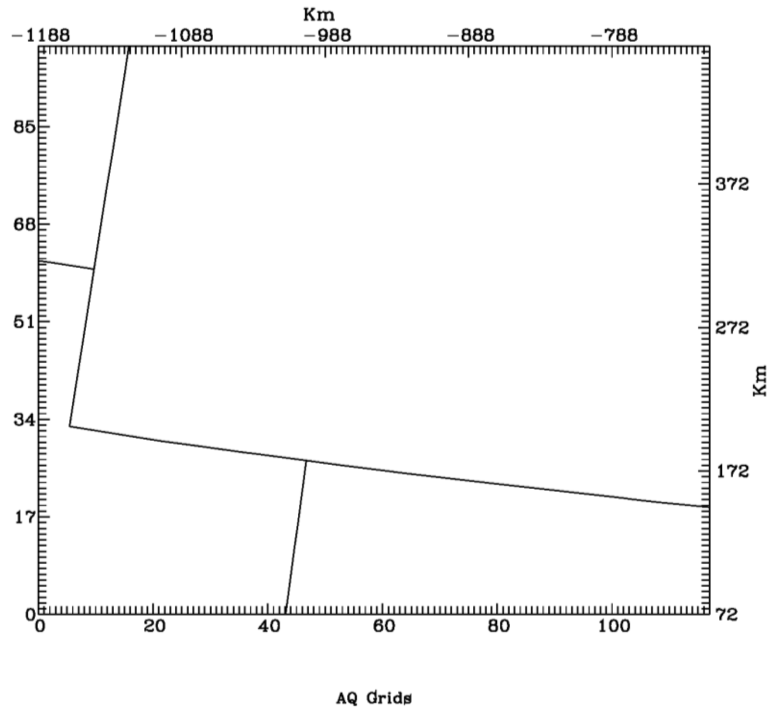
(a) 36-, 12- and 4-km Grids



(b) 12- and 4-km Grids



(c) 4-km Grid



The modeling domain includes a 36-km resolution outer grid encompassing the U.S. This domain is also referred to as the Continental U.S. or CONUS domain and has been used for numerous air quality applications conducted by EPA and Regional Planning Organizations (RPOs). The 36-km modeling grid is intended to provide model-based boundary conditions for the primary areas of interest and thus avoid some of the uncertainty introduced in the modeling results through the incomplete and sometimes arbitrary specification of boundary conditions. A one-way nesting approach was used. The 12-km grid is intended to represent the regional air quality conditions and to provide boundary conditions for the 4-km grid. The 4-km grid includes the NPL Project Area and other nearby PSD Class I and sensitive Class II areas.

The modeling grids are based on a Lambert Conformal Conic (LCC) map projection. The numbers of grid cells in the west-east and south-north directions are as follows: 36-km grid (148 x 112), 12-km grid (87 x 66), and 4-km grid (117 x 99).

In the vertical dimension, the modeling domain includes 34 layers for the months of April through October and 38 layers for January, February, March, November and December. The layer structure is summarized in detail in the companion model performance evaluation report (ICF, 2014).

4.1.2 Air Quality Assessment Areas

The criteria pollutant assessment was performed for all monitoring sites and unmonitored areas located within in the NPL CMAQ 4-km grid. The AQRV assessment considered PSD Class I areas and sensitive Class II areas located within and near the 4-km grid. Within the 4-km grid, these include:

- Bridger Wilderness Area, Wyoming (Class I)

- Fitzpatrick Wilderness Area, Wyoming (Class I)
- Popo Agie Wilderness Area, Wyoming (Class II)
- Savage Run Wilderness Area, Wyoming (Federal Class II, Wyoming Class I)
- Wind River Roadless Area, Wyoming (Class II)
- Mount Zirkel Wilderness Area, Colorado (Class I)
- Rawah Wilderness Area, Colorado (Class I)
- Dinosaur National Monument, Colorado-Utah (Federal Class II, Colorado Class I (SO_2 only)

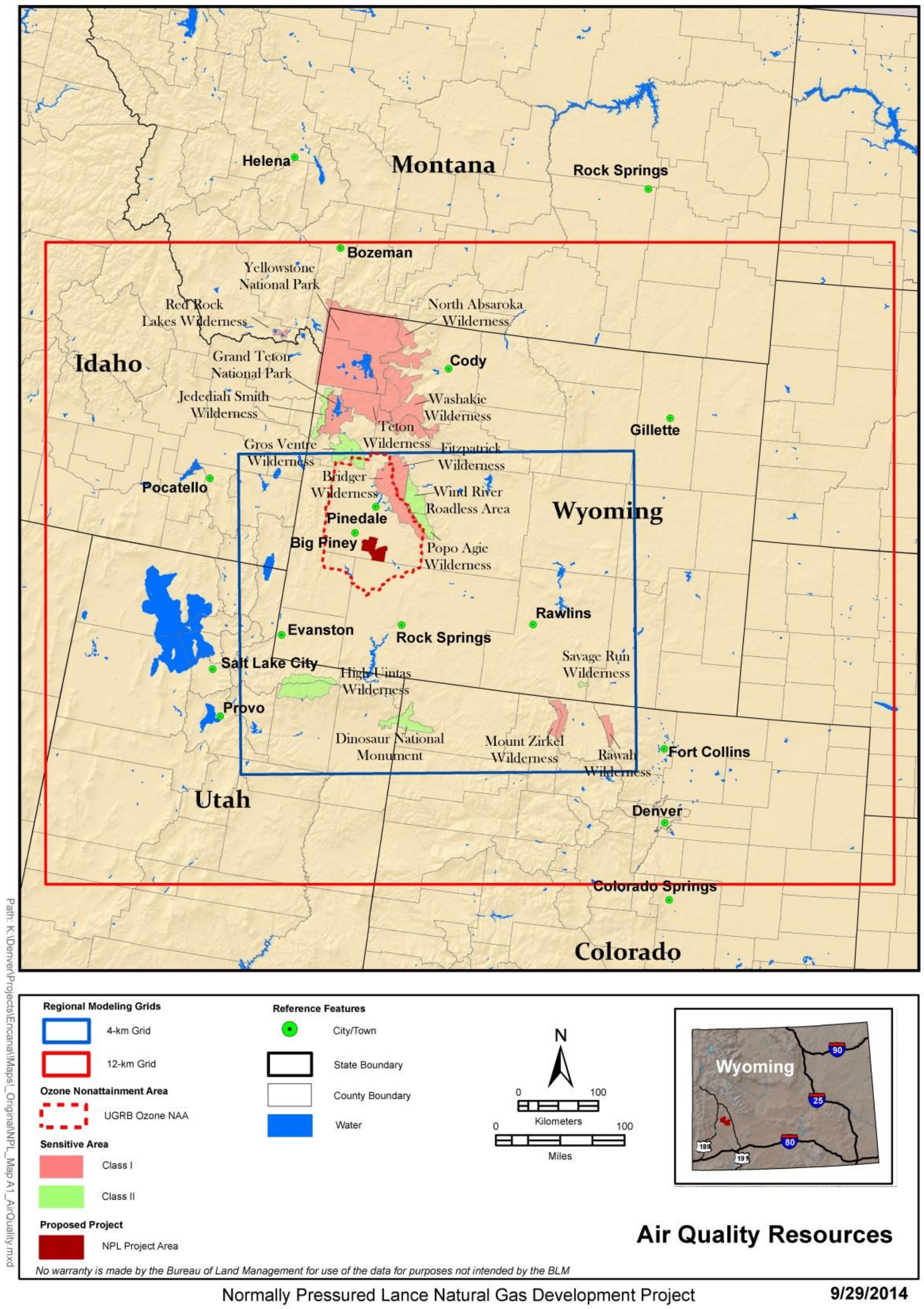
Additional areas located in the 12-km grid include:

- Grand Teton National Park, Wyoming (Class I)
- Teton Wilderness Area, Wyoming (Class I)
- Washakie Wilderness Area, Wyoming (Class I)
- Yellowstone National Park, Wyoming (Class I)
- North Absaroka Wilderness Area, Wyoming (Class II)
- Gros Ventre Wilderness Area, Wyoming (Class II)
- Jedediah Smith Wilderness Area, Wyoming (Class II)
- High Uintas Wilderness Area, Utah (Class II)
- Red Rock Lakes Wilderness Area, Montana (Class I)

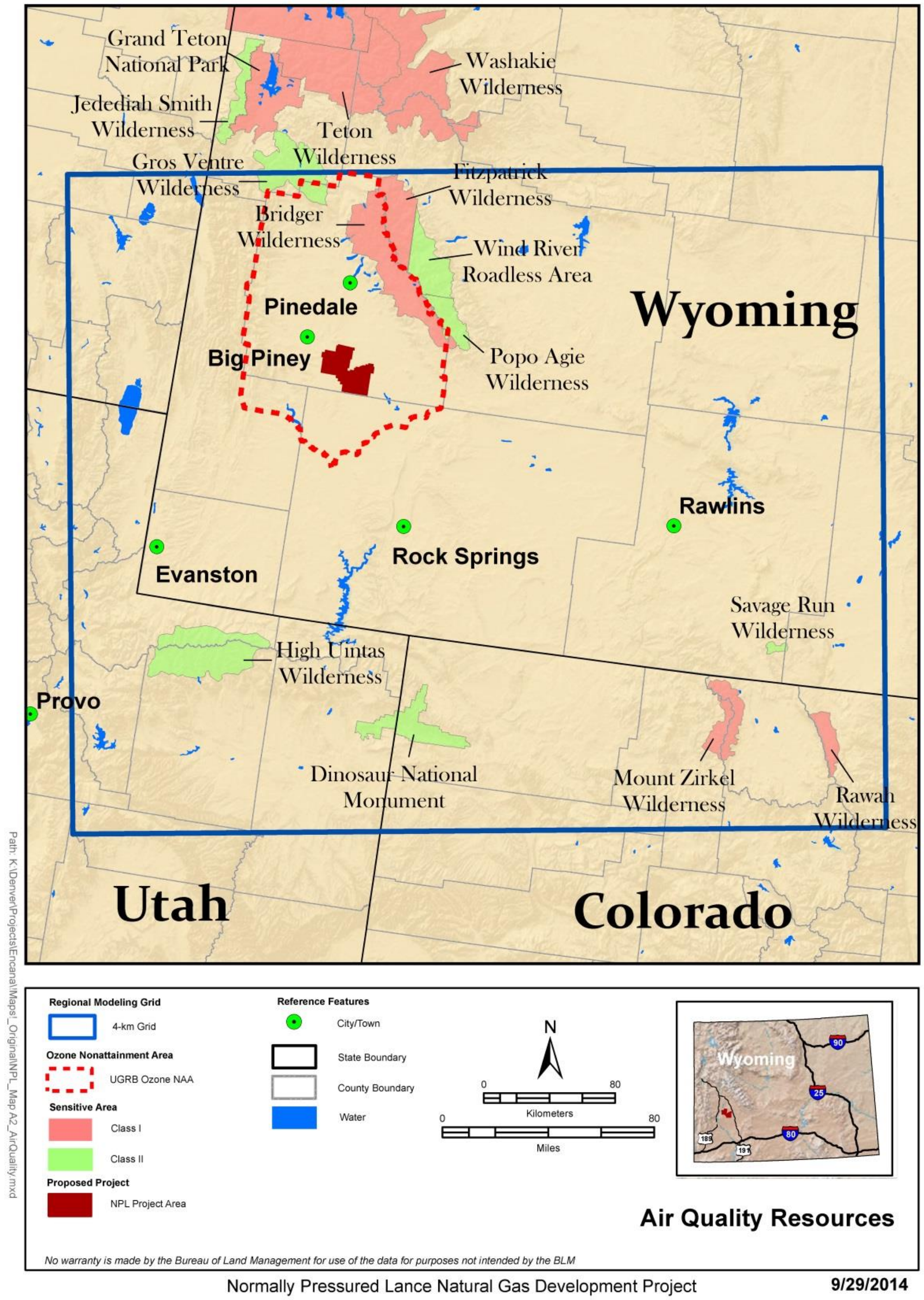
Figure 4-2 (a) and (b) illustrate the locations of these areas within the 12- and 4-km grids, respectively. The maps also depict the boundaries of the designated Upper Green River Basin (UGRB) ozone nonattainment area, which encompasses the NPL Project Area.

Figure 4-2. Location of National Parks and Wilderness Areas within the NPL CMAQ Modeling Domain

(a) 12- and 4-km Grids



(b) 4-km Grid

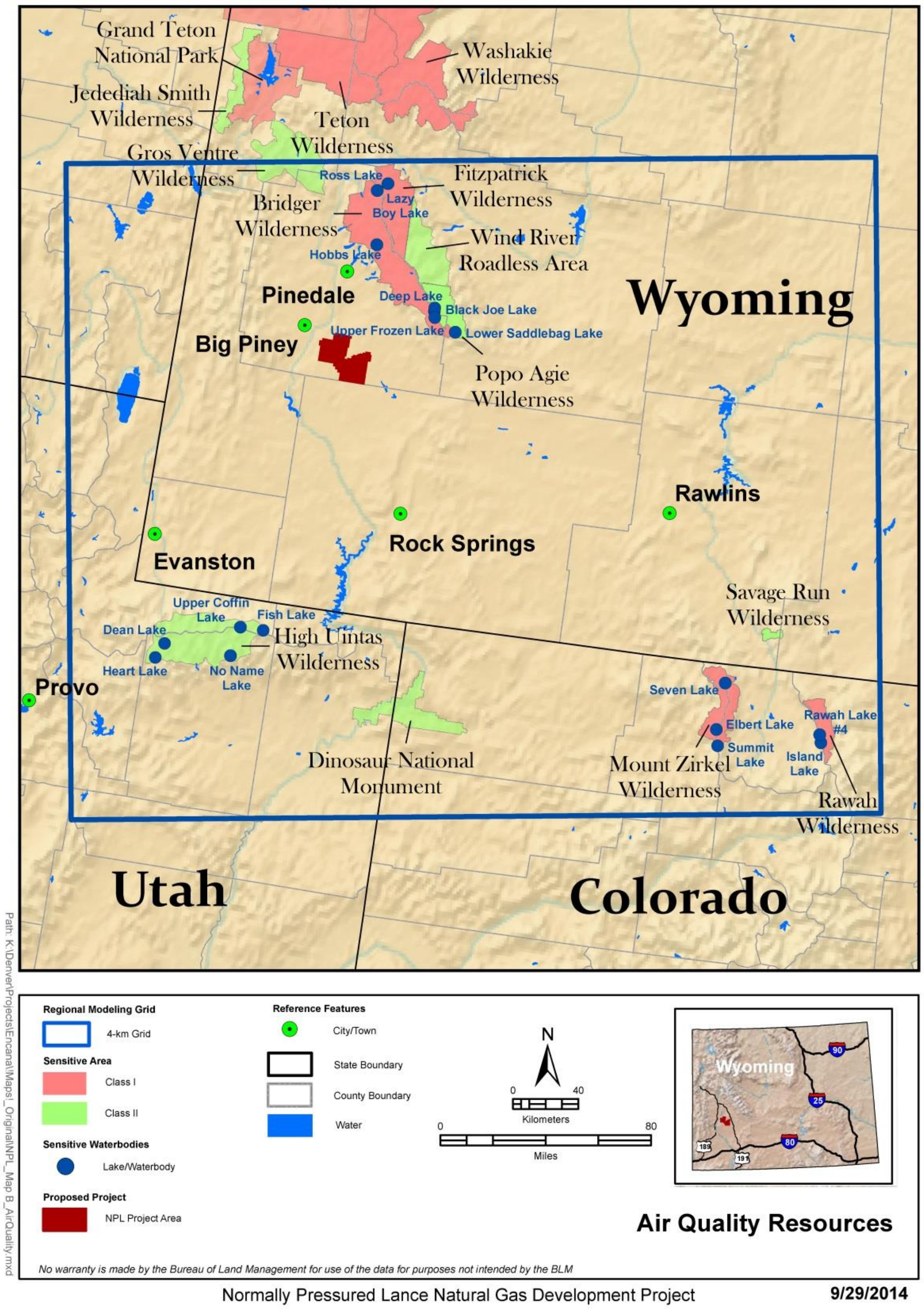

Grand Teton National Park
Washakie Wilderness
Jedediah Smith Wilderness
Teton Wilderness
Gros Ventre Wilderness
Fitzpatrick Wilderness
Bridger Wilderness
Wind River Roadless Area
Pinedale
Wyoming
Big Piney
Popo Agie Wilderness
Rawlins
Rock Springs
Evanston
Savage Run Wilderness
High Uintas Wilderness
Provo
Dinosaur National Monument
Mount Zirkel Wilderness
Rawah Wilderness
Utah
Colorado
Regional Modeling Grid
4-km Grid
Ozone Nonattainment Area
UGRB Ozone NAA
Sensitive Area
Class I
Class II
Proposed Project
NPL Project Area
Reference Features
City/Town
State Boundary
County Boundary
Water
N
0 80 Kilometers
0 80 Miles
Air Quality Resources
No warranty is made by the Bureau of Land Management for use of the data for purposes not intended by the BLM
Normally Pressured Lance Natural Gas Development Project
9/29/2014

In addition, 17 lakes within the PSD Class I and sensitive Class II Wilderness areas are designated acid sensitive and the assessment also examined potential lake acidification from atmospheric deposition impacts for these lakes including:

- Deep Lake in the Bridger Wilderness Area, Wyoming
- Black Joe Lake in the Bridger Wilderness Area, Wyoming
- Lazy Boy Lake in the Bridger Wilderness Area, Wyoming
- Upper Frozen Lake in the Bridger Wilderness Area, Wyoming
- Hobbs Lake in the Bridger Wilderness Area, Wyoming
- Ross Lake in the Fitzpatrick Wilderness Area, Wyoming
- Lower Saddlebag Lake in the Popo Agie Wilderness Area, Wyoming
- Dean Lake in the High Uintas Wilderness, Utah
- Heart Lake in the High Uintas Wilderness, Utah
- No Name (Duchesne – 4d2-039) Lake in the High Uintas Wilderness, Utah
- Fish Lake in the High Uintas Wilderness, Utah
- No Name (Duchesne – 4d1-044) Lake in the High Uintas Wilderness, Utah
- Lake Elbert in the Mt. Zirkel Wilderness, Colorado
- Seven Lakes in the Mt. Zirkel Wilderness, Colorado
- Summit Lake in the Mt. Zirkel Wilderness, Colorado
- Island Lake in the Rawah Wilderness, Colorado
- Rawah Lake #4 in the Rawah Wilderness, Colorado

Figure 4-3 illustrates the locations of these areas within the 4-km grid.

Figure 4-3. Location of Sensitive Lakes within the NPL CMAQ 4-km Modeling Grid



4.1.3 Ambient Air Quality Data

A variety of aerometric and deposition data were used to support the far-field modeling analysis and air quality assessment. Ozone, PM, NO_x, SO_2 and CO data were obtained from the EPA Air Quality System (AQS) dataset and, as needed, the WY DEQ data archives. Additional $PM_{2.5}$ data were obtained from the Interagency Monitoring of PROtected Visual Environments (IMPROVE) monitoring network datasets. Clean Air Status and Trends Network (CASTNet) data were also obtained. Deposition measurements from the CASTNet and National Acid Deposition Program (NADP) monitoring networks were used in the evaluation and assessment of deposition for selected species. The databases used in this analysis, including data sources, availability, and use are presented in the companion report on the base case modeling and performance evaluation (ICF, 2014).

4.1.4 Future-Year Scenarios

The future-year CMAQ modeling scenarios for the NPL air quality assessment include:

- No Action Alternative – This scenario includes future-year local and regional emissions from all source categories. It includes reasonably foreseeable development (RFD) emissions from nearby oil and gas development projects, but does not include emissions for the NPL project.
- Proposed Action – This scenario incorporates the NPL project emissions and was used to evaluate and quantify project-specific air quality impacts.

The future-year modeling results for the No Action and Proposed Action scenarios are presented in the remainder of this section.

4.2 Criteria Pollutant Impact Assessment

The criteria pollutant assessment results are presented in this section. The results are based on the modeling results for the 4-km grid and focus on differences in pollutant concentrations between the Proposed Action and No Action simulations throughout the State of Wyoming and design values and design-value-related metrics at monitoring sites and selected unmonitored areas throughout the state. Throughout this section pollutant concentrations that exceed either the NAAQS or the WAAQS are highlighted in bold.

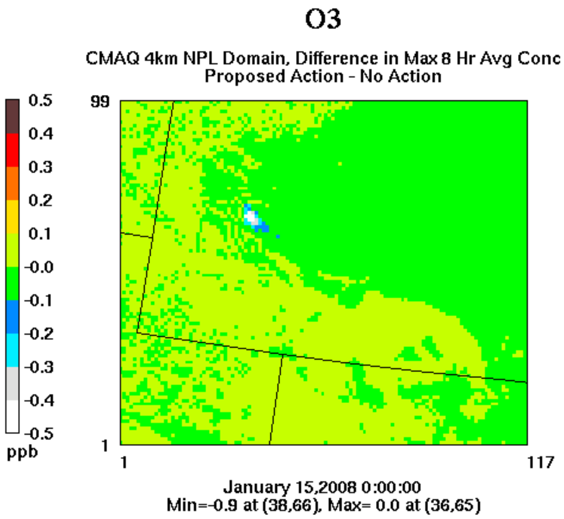
4.2.1 Ambient Air Quality Concentrations

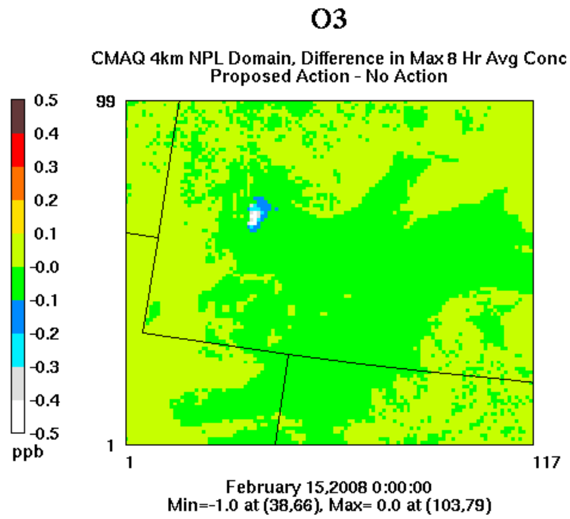
Ozone

Figure 4-4 illustrates the difference in daily maximum 8-hour average ozone concentration for the 4-km grid and the 15^{th} of each month between the Proposed Action and No Action simulations. The differences are calculated as Proposed Action minus No Action. The units are ppb. The date and time given on these and all subsequent difference plots refer to the meteorological base year and start hour for the selected day or averaging period. The minimum and maximum difference values for any location within the domain are also provided, along with their grid cell (x,y) locations. These plots are intended to provide perspective to the summary results that follow and to illustrate the varying spatial extent and magnitude of the differences for sample days and different times of the year.

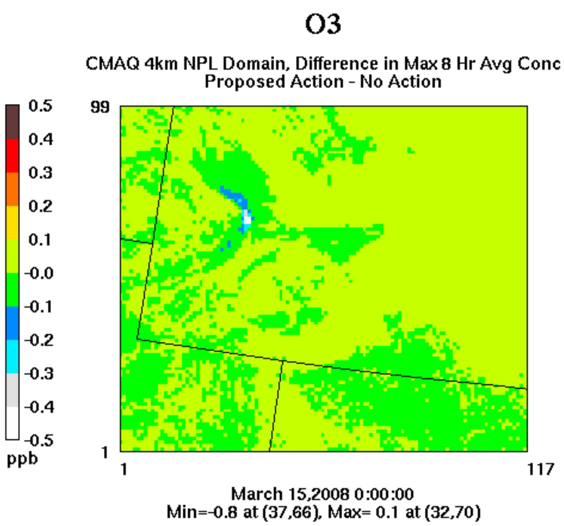
Figure 4-4. Difference in Simulated Daily Maximum 8-Hour Ozone Concentration (ppb) for Selected Days for the CMAQ 4-km Grid: Proposed Action – No Action

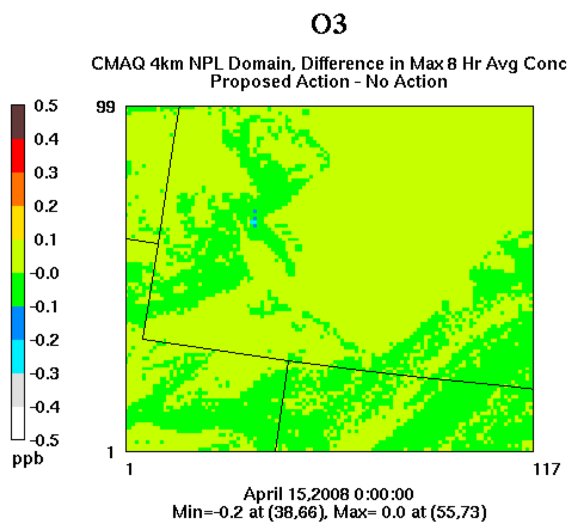
January/February



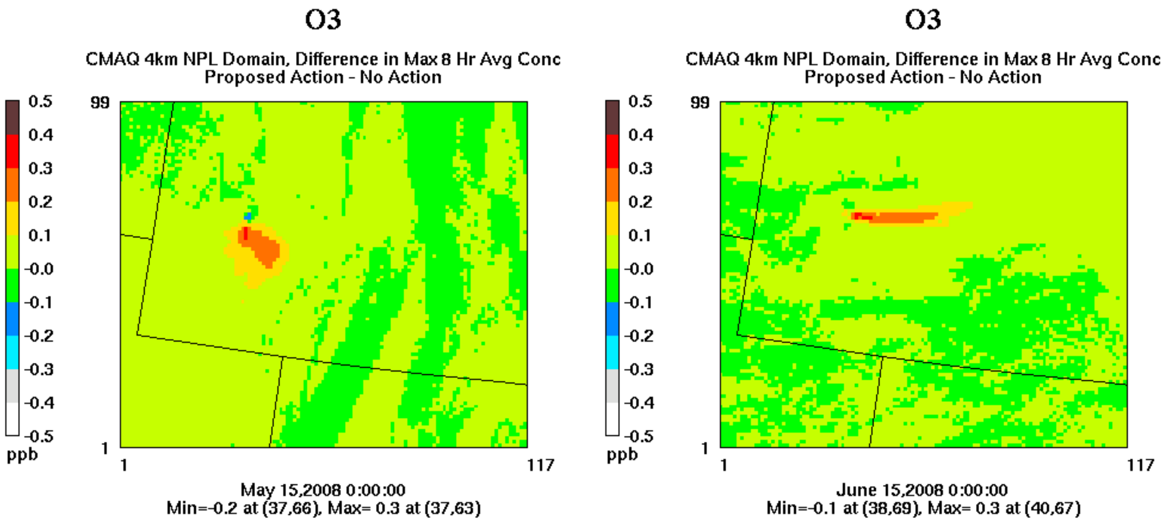


March/April

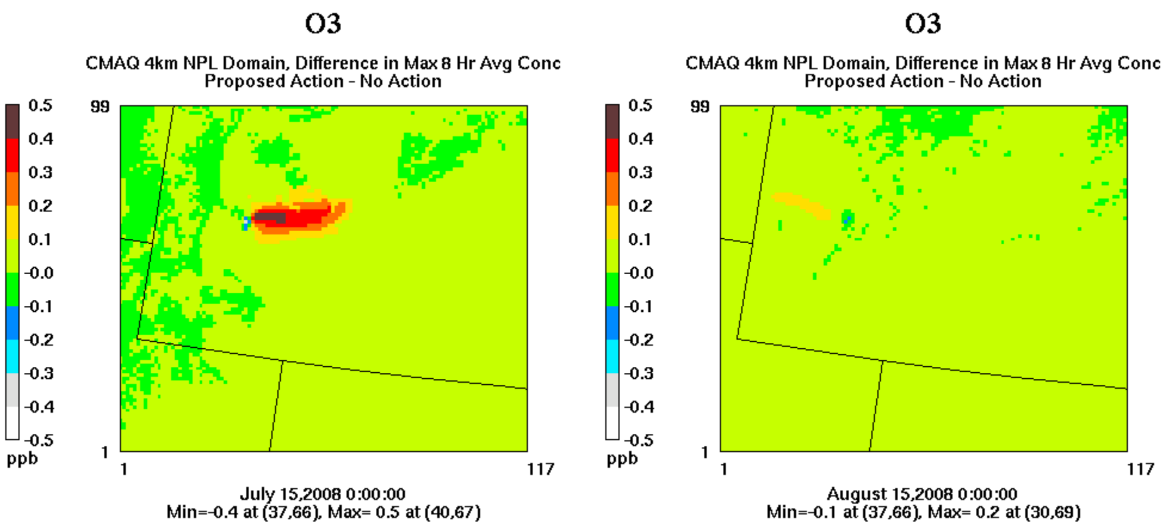




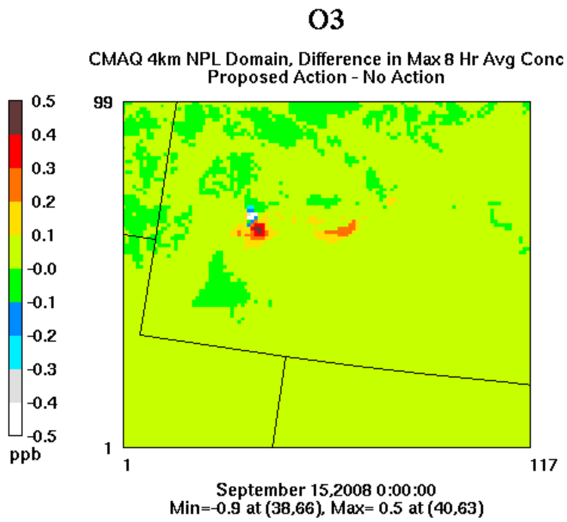
May/June

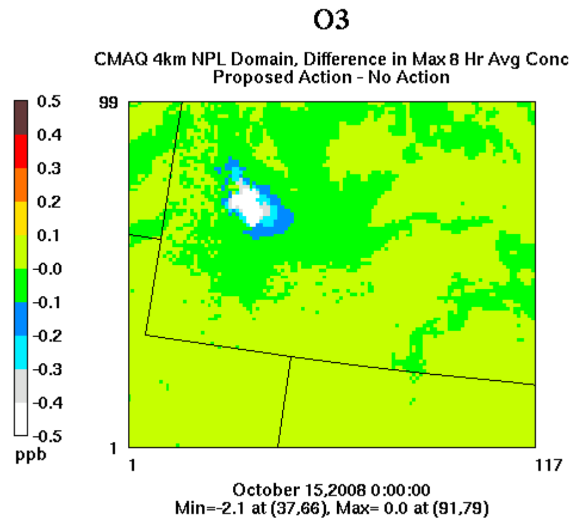


July/August

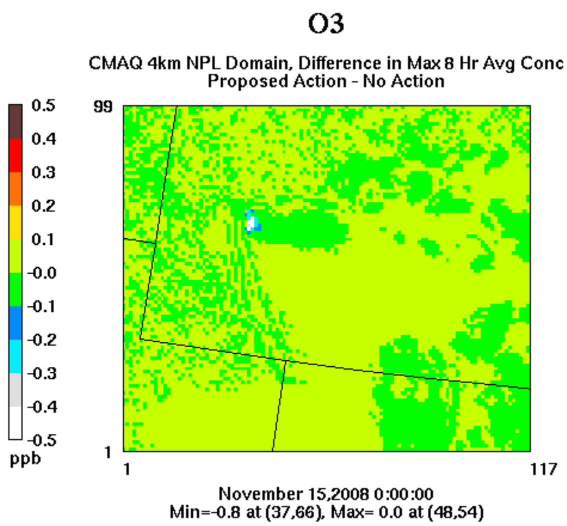


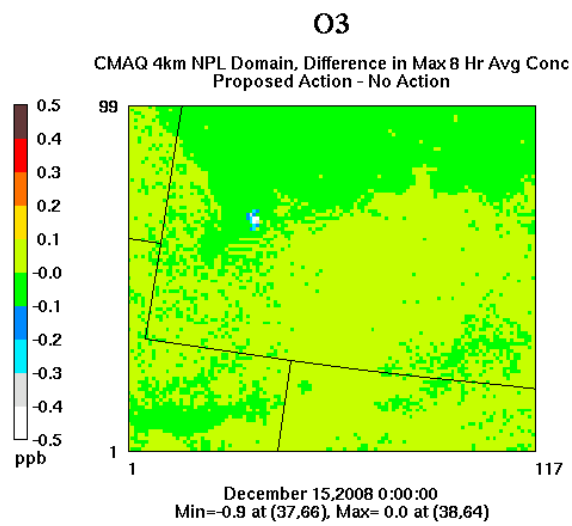
September/October





November/December





The plots show a mix of small increases and decreases in daily maximum 8-hour ozone concentrations for the selected days. The increases range from 0 to 0.5 and are greatest for the warmer months. The decreases range from -0.1 to -2.1 ppb and are greatest for the cooler (fall and winter) months. Decreases in ozone are likely due to the increase in NO_x emissions in the Project Area. The response of the CMAQ model to the changes in emissions is influenced by the complex photochemistry represented by the model. Under certain conditions increases in NO_x emissions can lead to decreases in ozone. This occurs when the conversion of NO to NO_2 is inhibited (due to either relatively low VOC concentrations or limited photolysis conditions – as might be expected to occur during the nighttime hours, on cloudy days, or during the winter). Since the CMAQ model was not able to simulate the observed high wintertime ozone concentrations (as discussed in the base-case modeling report), the accuracy of the model response under wintertime conditions is also somewhat uncertain.

Based on the CMAQ results, Table 4-1 summarizes the 4th high 8-hour ozone concentration (a key NAAQS related metric) for the base- and future-year simulations. Included in the table are the simulated concentrations for ozone monitoring sites operating for one or more years during the period 2006 – 2010. These sites were selected to represent air quality conditions for the 2008 base year (later in this section "current-year" design values for 2008 are calculated using data for the 2006 – 2010 period). The difference in concentration between the Proposed Action and No Action scenarios is also provided.

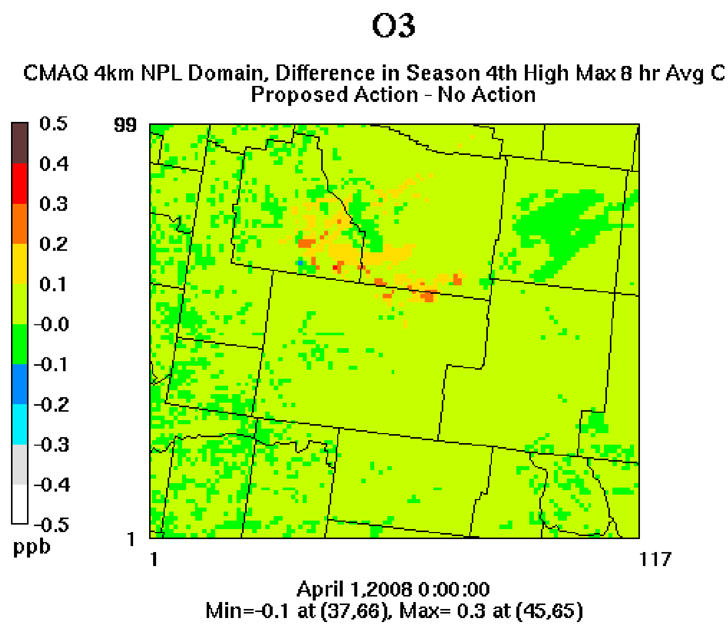
Table 4-1. Simulated 4th High Daily Maximum 8-Hour Ozone Concentration (ppb) for Monitoring Sites within the NPL 4-km Grid (Wyoming)

Site ID	Site Name	County	4th High Daily Maximum 8-Hour Ozone Concentration (ppb)			Change in Concentration due to Proposed Action (ppb)
			2008 Base Year	Future Year No Action	Future Year Proposed Action	
56-007-0100	Atlantic Rim	Carbon	63.3	62.6	62.6	0.0
56-013-0099	South Pass	Fremont	64.5	59.6	59.8	0.2
56-013-0232	Spring Creek	Fremont	62.5	58.4	58.4	0.0
56-035-0098	Jonah	Sublette	65.4	58.7	58.9	0.2
56-035-0099	Boulder	Sublette	64.4	60.1	60.2	0.1
56-035-0100	Daniel South	Sublette	62.3	58.5	58.5	0.0
56-035-0101	Pinedale	Sublette	63.5	57.2	57.3	0.1
56-035-1002	Juel Spring	Sublette	64.2	60.3	60.4	0.1
56-037-0200	Wamsutter	Sweetwater	66.6	62.7	62.7	0.0
56-037-0300	Moxa Arch	Sweetwater	66.7	61.5	61.5	0.0
56-037-0898	OCI #4	Sweetwater	67.7	61.9	61.9	0.0
56-041-0101	Murphy Ridge	Uinta	69.5	60.7	60.7	0.0

The simulated fourth highest 8-hour average ozone concentrations for all of the monitoring sites listed in Table 4-1 are all less than 70 ppb. Concentrations are projected to be lower for the future year, compared to the base year. The average decrease in this metric between the base year and the future-year No Action scenario is approximately 5 ppb. Compared to the No Action scenario, simulated concentrations for the Proposed Action scenario are 0.1 to 0.2 ppb higher for five of the ozone monitoring sites including South Pass, Jonah, Boulder, Pinedale, and Juel Spring.

The difference in simulated fourth highest daily maximum 8-hour average ozone concentration for each grid cell within the 4-km grid (for the typical ozone season months of April through October) is displayed in Figure 4-5.

Figure 4-5. Difference in Simulated 4th High Daily Maximum 8-Hour Ozone Concentration (ppb) for the CMAQ 4-km Grid: Proposed Action – No Action



The maximum difference (maximum impact on the fourth highest 8-hour ozone concentration) is 0.3 ppb. The greatest impacts occur near and to the southeast, east, and northeast of the Project Area.

To complete the ozone assessment, EPA's Modeled Attainment Test Software (MATS) (Abt, 2012) was applied using the base- and future-year modeling results and was used to estimate future-year design values for monitoring sites throughout the 4-km grid. This methodology is outlined in EPA guidance on the use of models for attainment demonstration purposes (EPA, 2007b) and is based on relative (rather than absolute) use of the modeling results. It relies on the ability of the air quality modeling system to simulate the change in concentration due to changes in emissions, but not necessarily its ability to simulate exact values for future-year concentrations. A future-year estimated design value (FDV) is calculated using the "current-year" design value and the future-year and base-year modeling results. The current-year design value for each site is multiplied by a relative response factor (RRF), which is defined as ratio of the future-year to base-year simulated concentration in the vicinity of the monitoring site. The resulting value is referred to as the future-year design value or FDV. The MATS input parameters were set to the EPA-recommended default values. This methodology was applied for both the No Action and Proposed Action scenarios.

Table 4-2 summarizes the modeled attainment test results for 8-hour ozone. The current-year design values used for this summary were calculated as the weighted average of the design values for the three overlapping three-year periods that include the modeled year (2006-2008, 2007-2009, and 2008-2010). This is the default for the application of MATS for 8-hour ozone. The current-year design values are based on the "official" data contained with the MATS database and are calculated within MATS. The current-year ozone design values are based on one to five years of monitoring data as follows: Juel Spring (1 year), Spring Creek and Pinedale (2 years), Jonah and OCI #4 (3 years), Atlantic Rim and South Pass (4 years) and all remaining sites (5 years).

Table 4-2. Estimated Future-Year 8-Hour Ozone Design Values (ppb) for Monitoring Sites within the NPL 4-km Grid (Wyoming)

Site ID	Site Name	County	8-Hour Ozone Design Value (ppb)			Change in Design Value due to Proposed Action (ppb)
			Current Year	Future Year No Action	Future Year Proposed Action	
56-007-0100	Atlantic Rim	Carbon	50.5	47.4	47.4	0.0
56-013-0099	South Pass	Fremont	70.3	64.3	64.3	0.0
56-013-0232	Spring Creek	Fremont	59.5	54.7	54.7	0.0
56-035-0098	Jonah	Sublette	**76.7**	67.5	67.6	0.1
56-035-0099	Boulder	Sublette	**78.7**	**71.9**	**72**	0.1
56-035-0100	Daniel South	Sublette	68	62.2	62.3	0.1
56-035-0101	Pinedale	Sublette	57.5	52.3	52.3	0.0
56-035-1002	Juel Spring	Sublette	64	58.4	58.5	0.1
56-037-0200	Wamsutter	Sweetwater	64	59.1	59.1	0.0
56-037-0898	OCI #4	Sweetwater	67	59.8	59.8	0.0
56-041-0101	Murphy Ridge	Uinta	64.7	55.4	55.4	0.0

Note: The NAAQS for 8-hour average ozone concentration is 70 ppb.

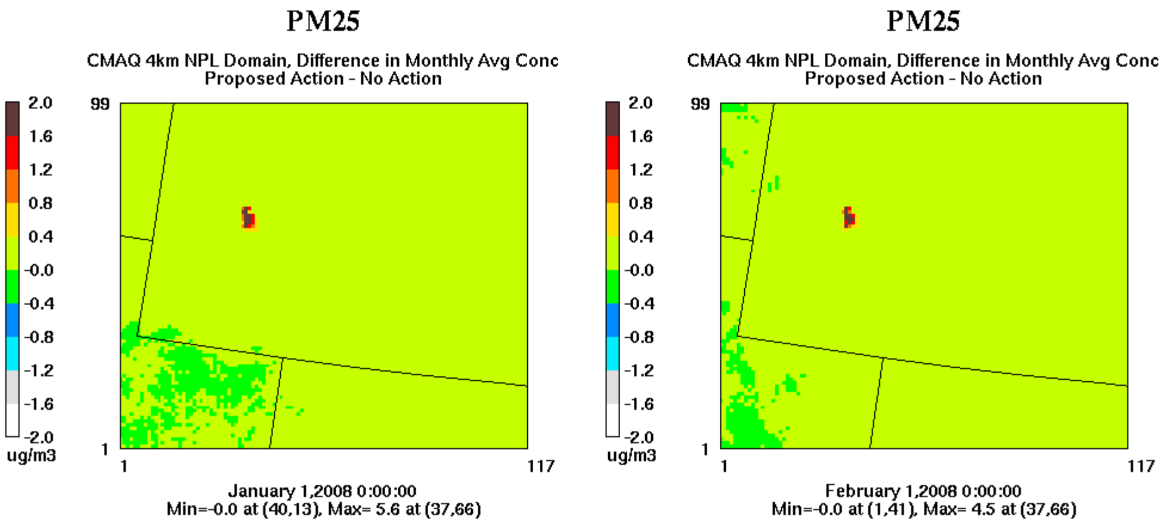
Ozone design values for the future-year No Action scenario are estimated to be approximately 3 to 9 ppb lower than the current-year values. The average reduction in this metric is 5.9 ppb. Design values for four sites (Jonah, Boulder, Daniel South, and Juel Spring) are 0.1 ppb higher for the Proposed Action scenario, compared to the No Action scenario. The estimated future-year design values for all sites except the Boulder site are below the NAAQS for both scenarios.

$PM_{2.5}$

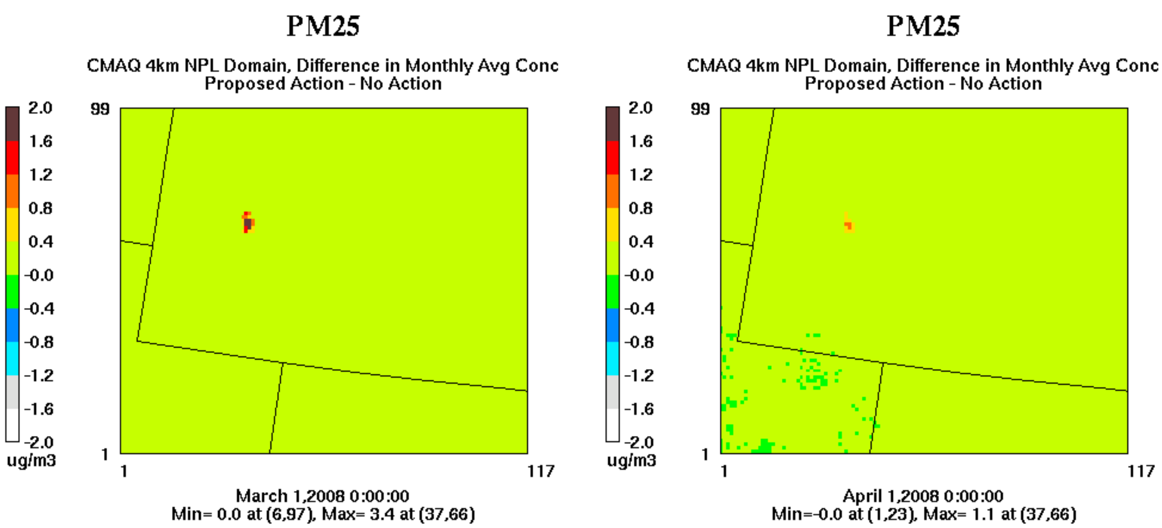
Figure 4-6 illustrates the difference in monthly average $PM_{2.5}$ concentration for the 4-km grid for each month between the Proposed Action and No Action simulations. The differences are calculated as Proposed Action minus No Action. The units are $\mu g/m^3$. Again, the date and time given on these and all subsequent difference plots refer to the meteorological base year and start hour for the selected day or averaging period. The minimum and maximum difference values for any location within the domain are also provided, along with their grid cell (x,y) locations. These plots are intended to provide perspective to the summary results that follow and to illustrate the varying spatial extent and magnitude of the differences for different times of the year.

Figure 4-6. Difference in Monthly Average $PM_{2.5}$ Concentration (µg/m^3) for the CMAQ 4-km Grid: Proposed Action – No Action

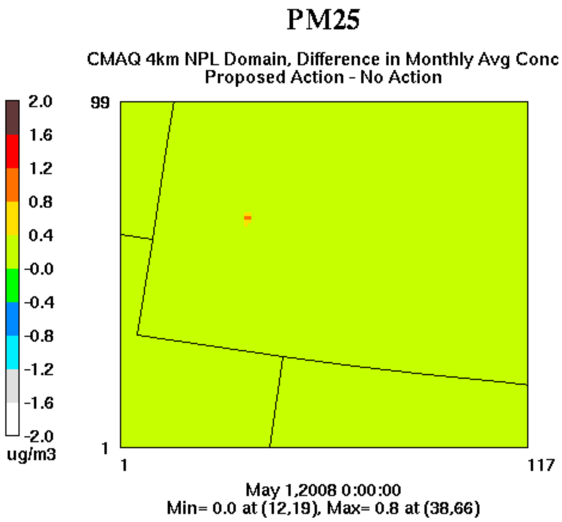
January/February

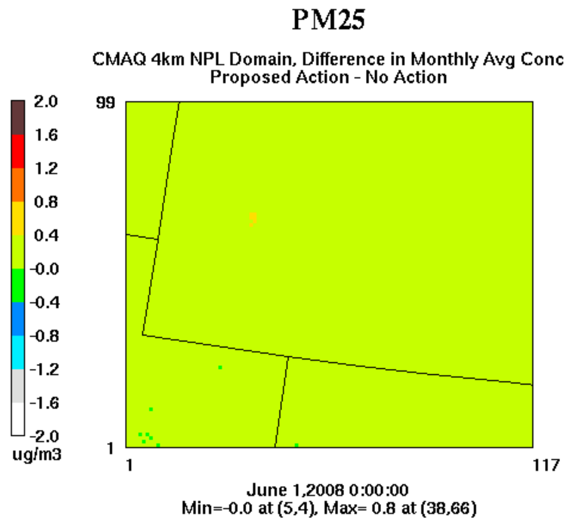


March/April

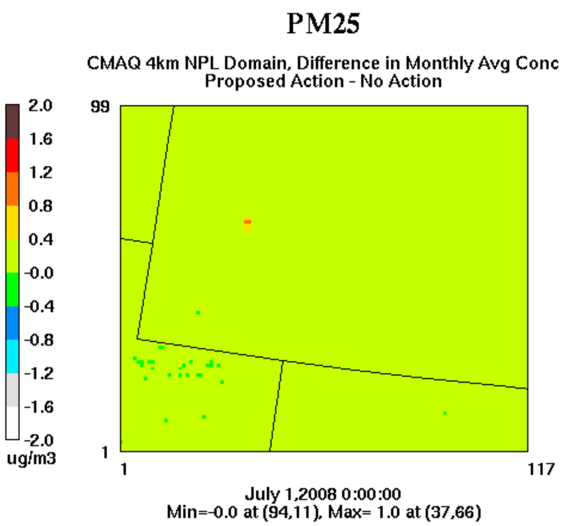


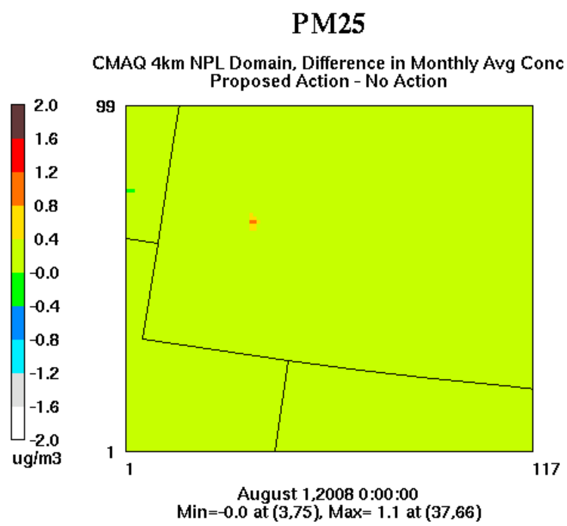
May/June



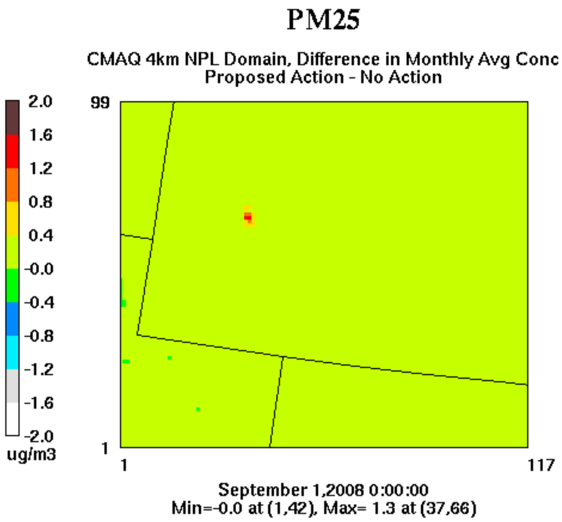


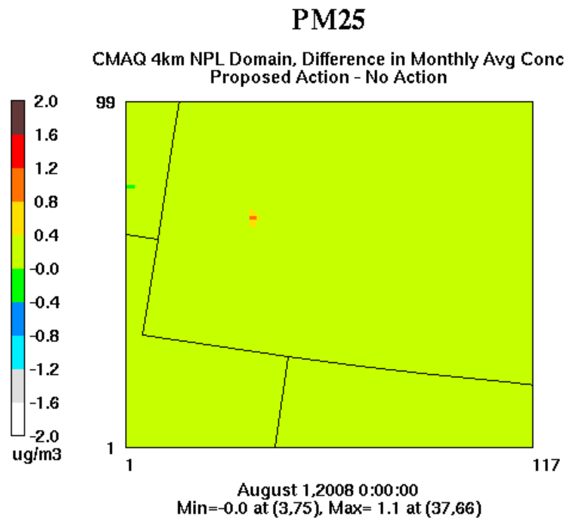
July/August



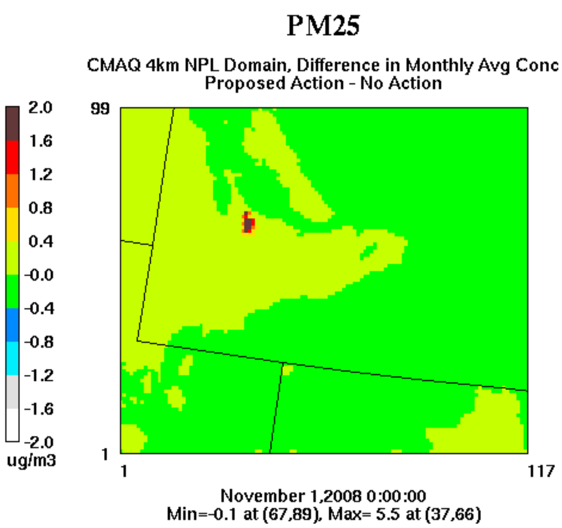


September/October





November/December



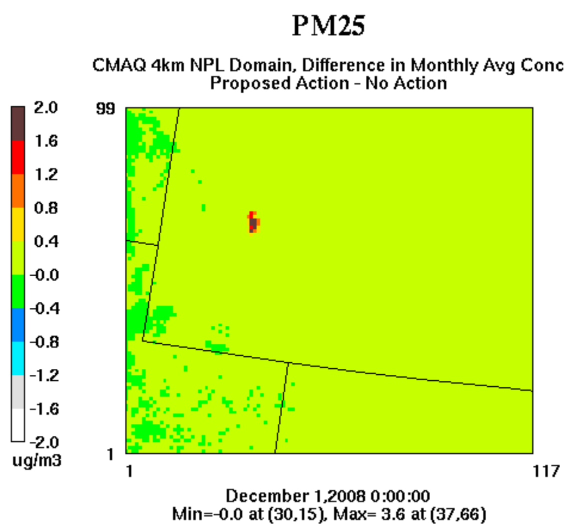
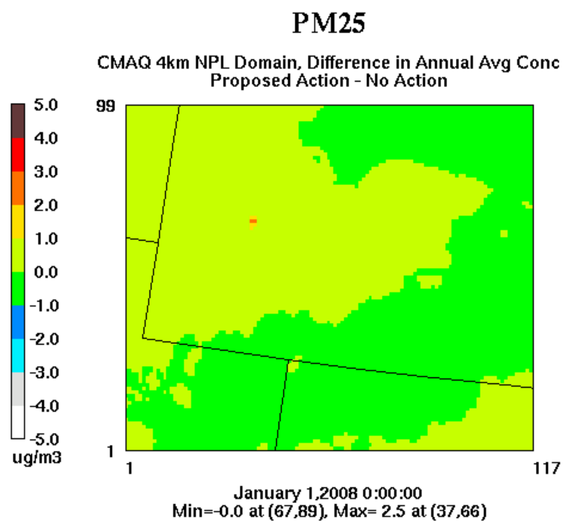


Figure 4-7 illustrates the difference in annual average $PM_{2.5}$ concentration between the Proposed Action and No Action simulations for the 4-km grid.

Figure 4-7. Difference in Annual Average $PM_{2.5}$ Concentration (µg/m³) for Selected Days for the CMAQ 4-km Grid: Proposed Action – No Action



The plots show localized increases in $PM_{2.5}$ concentrations for each month and for the annual period. The monthly increases range from 0.8 to 5.6 µg/m³and are greatest for the winter months. The maximum increase in annual average $PM_{2.5}$ concentration is 2.5 µg/m³.

Focusing in on key NAAQS metrics, Table 4-3 summarizes simulated the 98th percentile 24-hour average $PM_{2.5}$ concentration (a key NAAQS related metric) for the base- and future-year simulations. Included in the table are the simulated concentrations for $PM_{2.5}$ monitoring sites operating for one or more years during the period 2006 – 2010. These sites were selected to represent air quality conditions for the 2008 base year (later in this section "current-year" design values for 2008 are calculated using data for the 2006 – 2010 period).

Table 4-3. Simulated 98th Percentile 24-Hour Average $PM_{2.5}$ Concentration (µg/m³) for Monitoring Sites within the NPL 4-km Grid (Wyoming)

Site ID	Site Name	County	98th Percentile 24-Hour $PM_{2.5}$ Concentration (µg/m³)			Change in Concentration due to Proposed Action (µg/m³)
			2008 Base Year	Future Year No Action	Future Year Proposed Action	
56-013-1003	Lander	Fremont	6.0	5.7	5.7	0.0
56-035-0101	Pinedale	Sublette	**48.3**	**48.1**	**48.1**	0.0
56-037-0007	Rock Springs	Sweetwater	9.2	6.9	6.9	0.0
56-039-1006	Jackson	Teton	5.3	5.0	5.0	0.0

The simulated 24-hour average $PM_{2.5}$ concentrations range from approximately 5 to 48 µg/m³. Concentrations are projected to be slightly lower for the future year, compared to the base year. The average decrease in this metric between the base year and the future-year scenarios is approximately 0.8 µg/m^3. Simulated concentrations for the No Action and Proposed Action scenarios for the $PM_{2.5}$ monitoring sites are the same.

Table 4-4 summarizes the annual average $PM_{2.5}$ concentration for these same sites for the base- and future-year simulations.

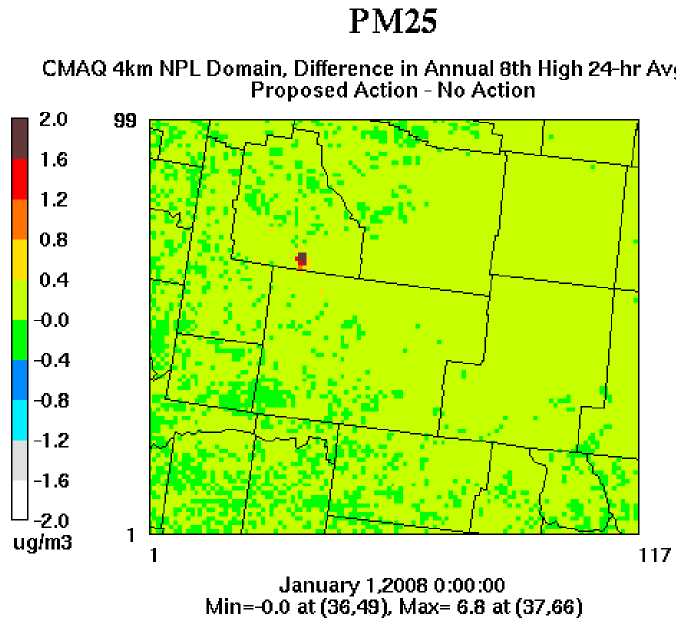
Table 4-4. Simulated Annual Average $PM_{2.5}$ Concentration (µg/m^3) for Monitoring Sites within the NPL 4-km Grid (Wyoming)

Site ID	Site Name	County	Annual Average $PM_{2.5}$ Concentration (µg/m^3)			Change in Concentration due to Proposed Action (µg/m^3)
			2008 Base Year	Future Year No Action	Future Year Proposed Action	
56-013-1003	Lander	Fremont	2.6	2.3	2.3	0.0
56-035-0705	Pinedale	Sublette	5.7	5.6	5.6	0.0
56-037-0007	Rock Springs	Sweetwater	4.0	3.2	3.2	0.0
56-039-1006	Jackson	Teton	1.9	1.7	1.7	0.0

The simulated annual average $PM_{2.5}$ concentrations for the future-year scenarios are lower than the base-year values, by an average of 0.4 µg/m^3. Simulated concentrations for the No Action and Proposed Action scenarios are the same.

The difference in simulated 98th percentile 24-hour average $PM_{2.5}$ concentration for each grid cell within the 4-km grid (for the annual simulation period) is displayed in Figure 4-8.

Figure 4-8. Difference in Simulated 98th Percentile 24-Hour $PM_{2.5}$ Concentration (µg/m³) for the CMAQ 4-km Grid: Proposed Action – No Action



The maximum difference (maximum impact on the 98th percentile 24-hour $PM_{2.5}$ concentration) is 6.8 µg/m³. The impacts are localized and occur within the Project Area.

The difference in simulated annual average $PM_{2.5}$ concentration for each grid cell within the 4-km grid is displayed in Figure 4-7. The maximum impact on annual average $PM_{2.5}$ concentration is 2.5 µg/m³. The impacts are localized and occur within the Project Area.

EPA's MATS software was applied using the base- and future-year modeling results and was used to estimate future-year design values for monitoring sites throughout the 4-km grid. The MATS input parameters were set to the EPA-recommended default values for $PM_{2.5}$ related analyses. This methodology was applied for both the No Action and Proposed Action scenarios.

Table 4-5 summarizes the modeled attainment test results for 24-hour $PM_{2.5}$. The current-year design values used for this summary were calculated based on data for 2006-2010. This is the default period for the application of MATS for 24-hour $PM_{2.5}$. The current-year design values are based on the "official" data contained within the MATS database and are calculated within MATS. The current-year $PM_{2.5}$ design values are based on three years of monitoring data for Rock Springs and five years of monitoring data for all other sites.

Table 4-5. Estimated Future-Year 24-Hour $PM_{2.5}$ Design Values (ppb) for Monitoring Sites within the NPL 4-km Grid (Wyoming)

Site ID	Site Name	County	24-Hour $PM_{2.5}$ Design Value (µg/m³)			Change in Design Value due to Proposed Action (µg/m³)
			Current Year	Future Year No Action	Future Year Proposed Action	
56-013-1003	Lander	Fremont	27.3	25.2	25.2	0.0
56-035-0705	Pinedale	Sublette	15.1	15	15	0.0
56-037-0007	Rock Springs	Sweetwater	14.5	12.3	12.3	0.0
56-039-1006	Jackson	Teton	11	10.4	10.4	0.0

Note: The NAAQS for 24-hour average $PM_{2,5}$ concentration is 35 µg/m³.

Daily 24-hour $PM_{2.5}$ design values for the future-year scenarios are estimated to be approximately 0.1 to 2.2 µg/m³ lower than the current-year values. The average reduction is 1.3 µg/m³. Design values are unchanged for the Proposed Action scenario, compared to the No Action scenario. The estimated future-year design values for all sites are below the NAAQS for both scenarios.

Table 4-6 summarizes the modeled attainment test results for annual average $PM_{2.5}$. The current-year design values used for this summary were calculated based on data 2006-2010. This is the default period for the application of MATS for annual average $PM_{2.5}$.

Table 4-6. Estimated Future-Year Annual Average $PM_{2.5}$ Design Values (µg/m³) for Monitoring Sites within the NPL 4-km Grid (Wyoming)

Site ID	Site Name	County	Annual Average $PM_{2.5}$ Design Value (µg/m³)			Change in Design Value due to Proposed Action (µg/m³)
			Current Year	Future Year No Action	Future Year Proposed Action	
56-013-1003	Lander	Fremont	8.0	7.6	7.6	0.0
56-035-0101	Pinedale	Sublette	6.5	6.4	6.4	0.0
56-037-0007	Rock Springs	Sweetwater	6.2	5.3	5.3	0.0
56-039-1006	Jackson	Teton	4.7	4.5	4.5	0.0

Note: The NAAQS for annual average $PM_{2,5}$ concentration is 12 µg/m³.

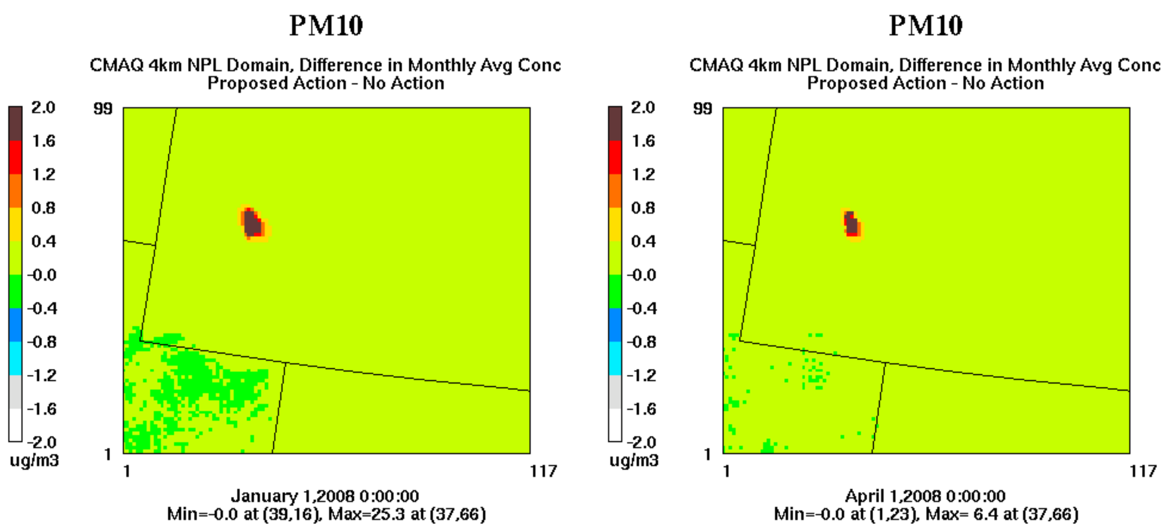
Annual $PM_{2.5}$ design values for the future-year scenarios are estimated to be approximately 0.1 to 0.9 µg/m³ lower than the current-year values. The average reduction is 0.4 µg/m³. Design values are unchanged for the Proposed Action scenario, compared to the No Action scenario. The estimated future-year design values for all sites are below the NAAQS for both scenarios.

PM_{10}

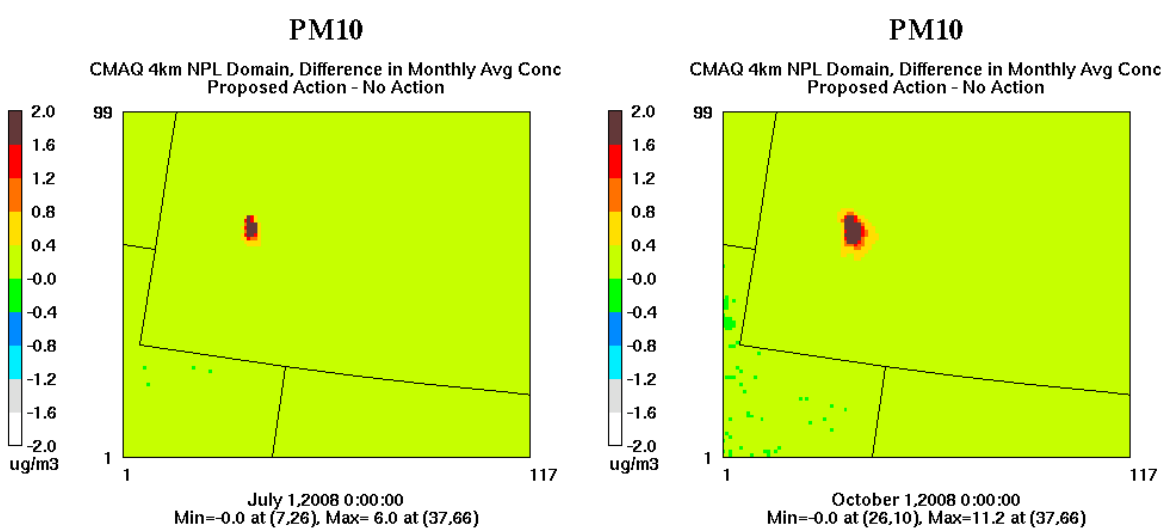
Figure 4-9 illustrates the simulated differences in monthly average PM_{10} concentration for January, April, July, and October (every third month) for the 4-km grid. These plots are intended to provide perspective to the summary results that follow and to illustrate the varying spatial extent and magnitude of the differences for different times of the year.

Figure 4-9. Difference in Monthly Average PM_{10} Concentration (µg/m^3) for the CMAQ 4-km Grid: Proposed Action – No Action

January/April



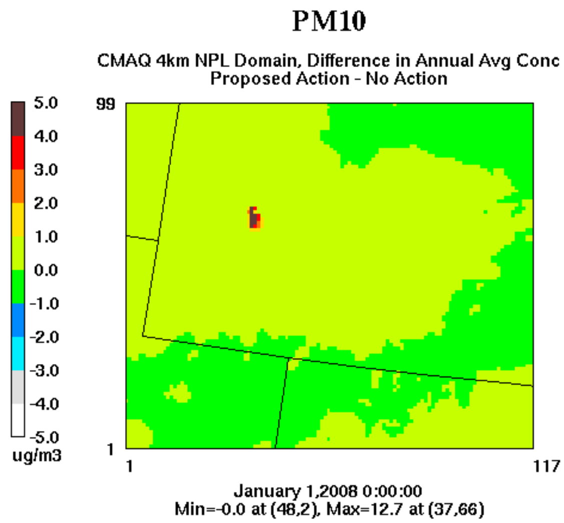
July/October



Results for the remaining months (not shown) are similar.

Figure 4-10 illustrates the difference in annual average PM_{10} concentration between the Proposed Action and No Action simulations for the 4-km grid.

Figure 4-10. Difference in Annual Average PM_{10} Concentration (µg/m³) for the CMAQ 4-km Grid: Proposed Action – No Action



The plots show localized increases in PM_{10} concentrations for each month and for the annual period. The maximum increase in annual average PM_{10} concentration is 12.7 µg/m³.

Based on the CMAQ results, Table 4-7 summarizes the simulated maximum 24-hour average PM_{10} concentration (a key NAAQS related metric) for the base- and future-year simulations. Included in the table are PM_{10} monitoring sites operating for one or more years during the period 2006 through 2010. These sites were selected to represent air quality conditions for the 2008 base year (later in this section "current-year" design values for 2008 are calculated using data for the 2007 – 2009 period).

Table 4-7. Simulated Maximum 24-Hour Average PM_{10} Concentration (µg/m3) for Monitoring Sites within the NPL 4-km Grid (Wyoming)

Site ID	Site Name	County	Maximum 24-Hour PM_{10} Concentration (µg/m³)			Change in Concentration due to Proposed Action (µg/m³)
			2008 Base Year	Future Year No Action	Future Year Proposed Action	
56-013-0099	South Pass	Fremont	20.9	20.8	20.8	0.0
56-013-0232	Spring Creek	Fremont	7.5	7.7	7.7	0.0
56-035-0098	Jonah	Sublette	43.6	43.6	44.2	0.6
56-035-0099	Boulder	Sublette	135.0	134.0	134.0	0.0
56-035-0100	Daniel South	Sublette	108.0	107.0	107.0	0.0

Table 4-7. Simulated Maximum 24-Hour Average PM_{10} Concentration (µg/m3) for Monitoring Sites within the NPL 4-km Grid (Wyoming)

Site ID	Site Name	County	Maximum 24-Hour PM_{10} Concentration ($\mu g/m^3$)			Change in Concentration due to Proposed Action ($\mu g/m^3$)
			2008 Base Year	Future Year No Action	Future Year Proposed Action	
56-037-0200	Wamsutter	Sweetwater	9.4	10.3	10.3	0.0
56-037-0300	Moxa Arch	Sweetwater	21.9	20.0	20.2	0.2
56-041-0101	Murphy Ridge	Uinta	15.2	14.1	14.1	0.0

The simulated maximum 24-hour average PM_{10} concentrations are not consistently higher or lower for the No Action scenario, compared to the base year. On average, concentrations are projected to be slightly lower for the future year. The average decrease in this metric between the base year and the future-year scenarios is approximately 0.5 $\mu g/m^3$. The maximum simulated concentration for the Proposed Action scenario is higher by 0.2 $\mu g/m^3$ for the Moxa Arch monitoring site and by 0.6 $\mu g/m^3$ for the Jonah monitoring site, compared to the No Action scenario. The values for the remaining sites are the same for the No Action and Proposed Action scenarios.

Table 4-8 summarizes the annual average PM_{10} concentration for these same sites for the base- and future-year simulations.

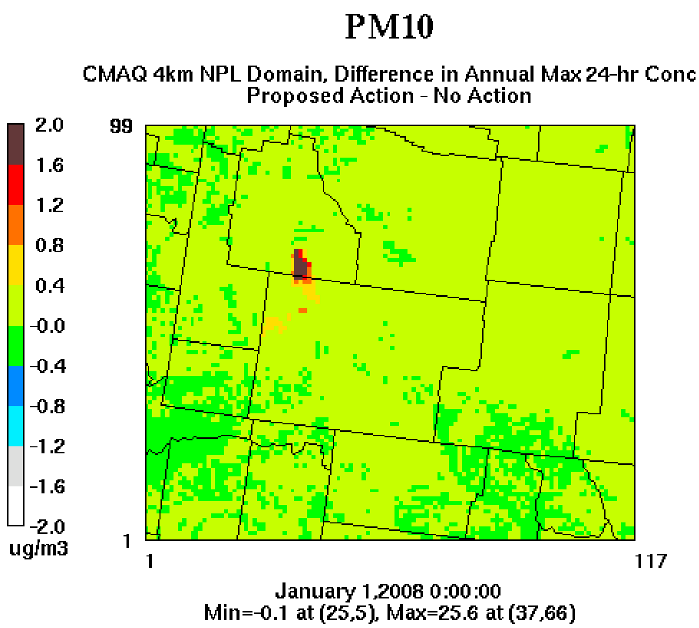
Table 4-8. Simulated Annual Average PM_{10} Concentration (µg/m3) for Monitoring Sites within the NPL 4-km Grid (Wyoming)

Site ID	Site Name	County	Annual Average PM_{10} Concentration ($\mu g/m^3$)			Change in Concentration due to Proposed Action ($\mu g/m^3$)
			2008 Base Year	Future Year No Action	Future Year Proposed Action	
56-013-0099	South Pass	Fremont	2.0	1.9	1.9	0.0
56-013-0232	Spring Creek	Fremont	2.2	2.1	2.1	0.0
56-035-0098	Jonah	Sublette	2.9	3.7	4.6	0.9
56-035-0099	Boulder	Sublette	4.1	4.1	4.2	0.1
56-035-0100	Daniel South	Sublette	3.1	2.9	2.9	0.0
56-037-0200	Wamsutter	Sweetwater	2.9	3.8	3.8	0.0
56-037-0300	Moxa Arch	Sweetwater	5.5	4.6	4.7	0.1
56-041-0101	Murphy Ridge	Uinta	3.9	3.6	3.6	0.0

Similarly, the simulated annual average PM_{10} concentrations are not consistently higher or lower for the No Action scenario, compared to the base year. On average, there is no change in concentration between the base year and the future-year No Action scenario. The maximum simulated concentration for the Proposed Action scenario is higher by 0.1 µg/m^3 for the Moxa Arch and Boulder monitoring sites and by 0.9 µg/m^3 for the Jonah monitoring site, compared to the No Action scenario. The values for the remaining sites are the same for the No Action and Proposed Action scenarios.

The difference in simulated daily maximum 24-hour average PM_{10} concentration for each grid cell within the 4-km grid is displayed in Figure 4-11.

Figure 4-11. Difference in Simulated Maximum 24-Hour PM_{10} Concentration (µg/m^3) for the CMAQ 4-km Grid: Proposed Action – No Action



The maximum impact on daily maximum 24-hour PM_{10} concentration anywhere in the grid is 25.6 µg/m^3. The greatest impacts occur within and to the south of the Project Area.

The difference in simulated annual average PM_{10} concentration for each grid cell within the 4-km grid is displayed in Figure 4-10. The maximum impact on annual average PM_{10} concentration is 12.7 µg/m^3. The impacts are localized to the Project Area.

MATS does not accommodate PM_{10}. The results presented in the remainder of this section were calculated using the MATS procedures, but in this case the procedures were applied manually within spreadsheets containing the model output for PM_{10}.

Table 4-9 summarizes the modeled attainment test results for 24-hour PM_{10}. The current-year design values used for this summary were calculated based on data for 2007-2009 and are equal to the maximum 2nd highest PM_{10} concentration during the three-year period. Only sites with data for one or more years during the three-year period were included. The current-year PM_{10} design values are based on one year of monitoring data for Spring Creek, two years of monitoring data for Jonah, and three years of monitoring data for all other sites.

Table 4-9. Estimated Future-Year 24-Hour PM_{10} Design Values (ppb) for Monitoring Sites within the NPL 4-km Grid (Wyoming)

Site ID	Site Name	County	24-Hour PM_{10} Design Value ($\mu g/m^3$)			Change in Design Value due to Proposed Action ($\mu g/m^3$)
			Current Year	Future Year No Action	Future Year Proposed Action	
56-013-0099	South Pass	Fremont	68.0	65.8	66.0	0.2
56-013-0232	Spring Creek	Fremont	22.0	21.2	21.2	0.0
56-035-0098	Jonah	Sublette	95.0	96.8	99.0	2.2
56-035-0099	Boulder	Sublette	76.0	75.6	75.6	0.0
56-035-0100	Daniel South	Sublette	43.0	42.4	42.4	0.0
56-037-0200	Wamsutter	Sweetwater	**199.0**	**209.3**	**209.6**	0.3
56-041-0101	Murphy Ridge	Uinta	100.0	96.6	96.7	0.1

Note: The NAAQS for maximum 24-hour average PM_{10} concentration is 150 $\mu g/m^3$.

Differences between the estimated future-year design values for the No Action scenario and the base year design values range from approximately -3 to 10 $\mu g/m^3$ and are characterized by a mix of increases and decreases. On average, the design values are 0.7 $\mu g/m^3$ higher for the No Action scenario. For several sites, the design values are also higher for the Proposed Action scenario compared to the No Action scenario, with an average increase of 0.3 $\mu g/m^3$. Both the base and future-year design values for Wamsutter are above the NAAQS. The design values for all other sites are below the NAAQS.

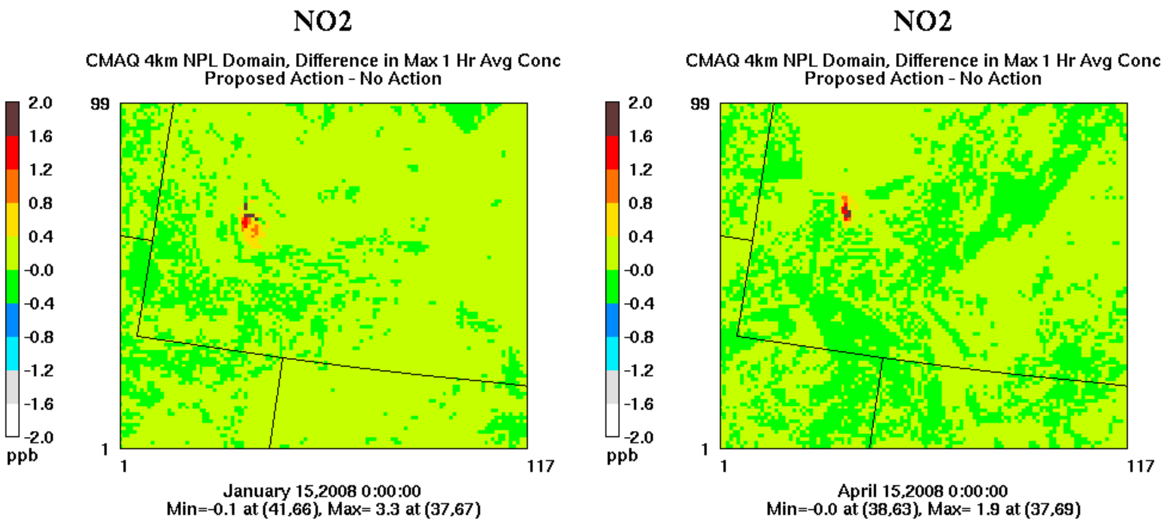
Similar relative response factors (ranging from 0.96 to 1.05) would be applied to the annual WAAQS design values. Since the PM_{10} design values for all sites are well below the annual WAAQS, the calculations were not performed.

NO_2

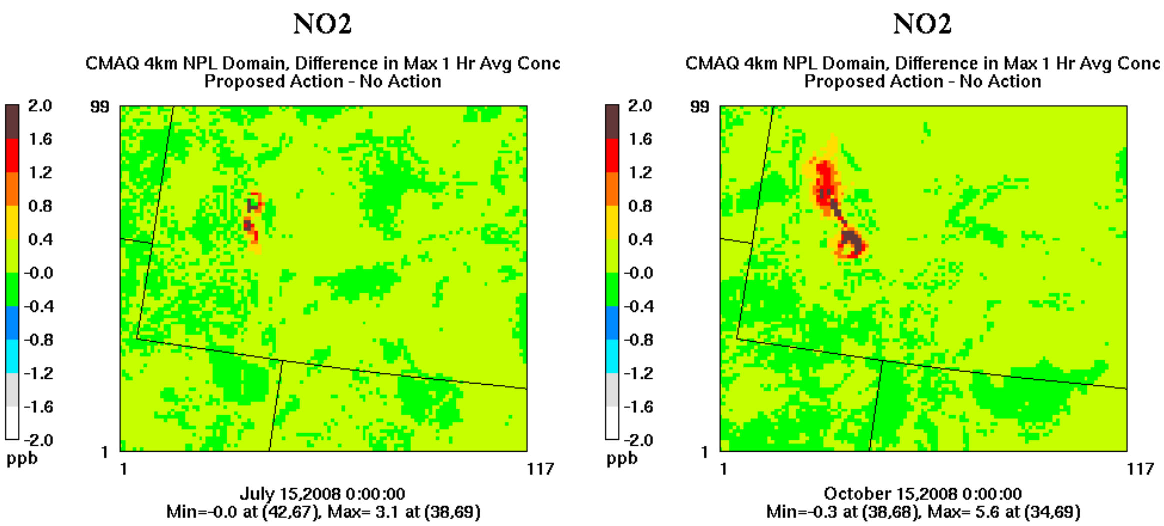
Figure 4-12 illustrates the simulated differences in daily maximum 1-hour NO_2 concentration for the 15th of each month for January, April, July, and October (every third month) for the 4-km grid.

Figure 4-12. Difference in Daily Maximum 1-Hour NO_2 Concentration (ppb) for Selected Days for the CMAQ 4-km Grid: Proposed Action – No Action

January/April



July/October



Results for the remaining months (not shown) are similar.

Based on the CMAQ results, Table 4-10 summarizes the 98th percentile daily maximum 1-hour average NO_2 concentration (a key NAAQS related metric) for the base- and future-year simulations. Included in the table are NO_2 monitoring sites operating for one or more years during the period 2006 through 2010. These sites were selected to represent air quality conditions for the 2008 base year (later in this section "current-year" design values for 2008 are calculated using data for the 2007 – 2009 period).

Table 4-10. Simulated 98th Percentile Daily Maximum 1-Hour Average NO_2 Concentration (ppb) for Monitoring Sites within the NPL 4-km Grid (Wyoming)

Site ID	Site Name	County	98th Percentile 1-Hour NO_2 Concentration (ppb)			Change in Concentration due to Proposed Action (ppb)
			2008 Base Year	Future Year No Action	Future Year Proposed Action	
56-007-0100	Atlantic Rim	Carbon	12.8	22.5	22.5	0.0
56-013-0099	South Pass	Fremont	4.8	3.7	3.7	0.0
56-013-0232	Spring Creek	Fremont	5.4	9.3	9.3	0.0
56-035-0098	Jonah	Sublette	72.0	72.0	72.1	0.1
56-035-0099	Boulder	Sublette	46.9	42.3	42.3	0.0
56-035-0100	Daniel South	Sublette	15.3	19.3	19.7	0.4
56-035-0101	Pinedale	Sublette	50.4	49.9	49.9	0.0
56-035-1002	Juel Spring	Sublette	32.4	43.7	43.9	0.2
56-037-0200	Wamsutter	Sweetwater	34.8	37.0	37.0	0.0
56-037-0300	Moxa Arch	Sweetwater	32.1	31.9	31.9	0.0
56-037-0898	OCI #4	Sweetwater	27.8	28.5	28.5	0.0
56-041-0101	Murphy Ridge	Uinta	13.8	8.8	8.8	0.0

The simulated 98th percentile 1-hour NO_2 concentrations are all less than 100 ppb. The simulated concentrations are not consistently higher or lower for the No Action scenario, compared to the base year. On average, concentrations are projected to be slightly higher (1.7 ppb) for the future year. Compared to the No Action scenario, simulated concentrations for the Proposed Action scenario are 0.1 to 0.4 ppb higher for the Jonah, Juel Spring and Daniel South monitoring sites.

Table 4-11 summarizes the annual average NO_2 concentration for these same sites for the base- and future-year simulations.

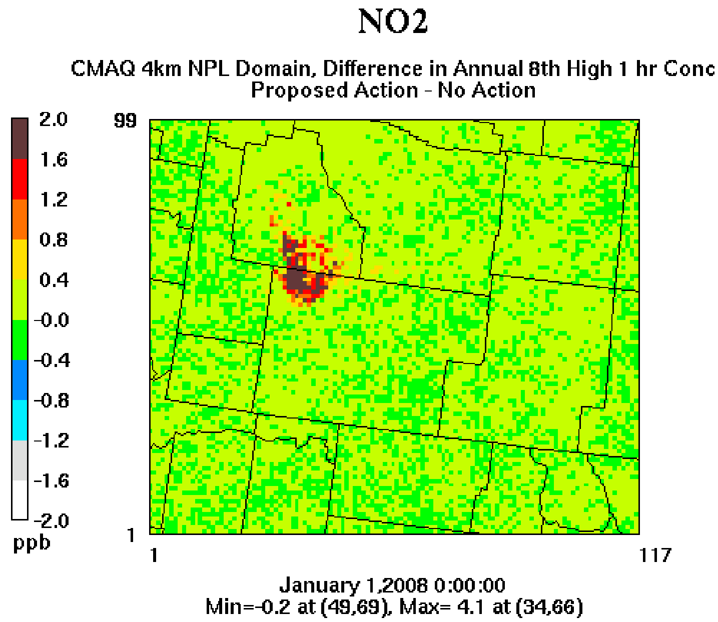
Table 4-11. Simulated Annual Average NO_2 Concentration (ppb) for Monitoring Sites within the NPL 4-km Grid (Wyoming)

Site ID	Site Name	County	Annual Average NO_2 Concentration (ppb)			Change in Concentration due to Proposed Action (ppb)
			2008 Base Year	Future Year No Action	Future Year Proposed Action	
56-007-0100	Atlantic Rim	Carbon	1.3	2.1	2.1	0.0
56-013-0099	South Pass	Fremont	0.3	0.3	0.3	0.0
56-013-0232	Spring Creek	Fremont	0.5	0.5	0.5	0.0
56-035-0098	Jonah	Sublette	12.4	18.3	18.4	0.1
56-035-0099	Boulder	Sublette	5.2	5.2	5.2	0.0
56-035-0100	Daniel South	Sublette	1.0	0.8	0.8	0.0
56-035-0101	Pinedale	Sublette	2.2	2.2	2.2	0.0
56-035-1002	Juel Spring	Sublette	3.1	5.0	5.2	0.2
56-037-0200	Wamsutter	Sweetwater	3.2	6.1	6.1	0.0
56-037-0300	Moxa Arch	Sweetwater	3.2	3.4	3.4	0.0
56-037-0898	OCI #4	Sweetwater	3.4	3.4	3.4	0.0
56-041-0101	Murphy Ridge	Uinta	1.9	1.4	1.4	0.0

The simulated annual average NO_2 concentrations are all less than 53 ppb. The simulated concentrations are not consistently higher or lower for the No Action scenario, compared to the base year. On average, concentrations are projected to be slightly higher (0.9 ppb) for the future year. Compared to the No Action scenario, simulated concentrations for the Proposed Action scenario are 0.1 higher for the Jonah monitoring site and 0.2 ppb higher for the Juel Spring. There is no change for the remaining sites.

The difference in simulated 98th percentile 1-hour average NO_2 concentration for each grid cell within the 4-km grid (for the annual simulation period) is displayed in Figure 4-13.

Figure 4-13. Difference in Simulated 98th Percentile 1-Hour NO_2 Concentration (ppb) for the CMAQ 4-km Grid: Proposed Action – No Action



The maximum difference (maximum impact on the 98th percentile 1-hour NO_2 concentration) is 4.1 ppb. The greatest impacts on this metric occur within and to the south of the Project Area.

MATS also does not accommodate NO_2. The results presented in the remainder of this section were calculated using the MATS procedures, but in this case the procedures were applied manually within spreadsheets containing the model output for NO_2.

Table 4-12 summarizes the modeled attainment test results for 1-hour NO_2. The current-year design values used for this summary were calculated based on data for 2007-2009. Only sites with data for one or more years during the three-year period were included. The current-year NO_2 design values are based on one year of monitoring data for Spring Creek and Pinedale, two years of monitoring data for Jonah, and three years of monitoring data for all other sites.

Table 4-12. Estimated Future-Year 1-Hour NO_2 Design Values (ppb) for Monitoring Sites within the NPL 4-km Grid (Wyoming)

Site ID	Site Name	County	1-Hour NO_2 Design Value (ppb)			Change in Design Value due to Proposed Action (ppb)
			Current Year	Future Year No Action	Future Year Proposed Action	
56-013-0099	South Pass	Fremont	11.3	18.1	18.1	0.0
56-013-0232	Spring Creek	Fremont	5.3	2.5	2.5	0.0
56-035-0098	Jonah	Sublette	6.0	9.4	9.4	0.0
56-035-0099	Boulder	Sublette	92.0	84.6	84.9	0.3
56-035-0100	Daniel South	Sublette	33.3	31.8	31.8	0.0
56-035-0101	Pinedale	Sublette	8.0	8.3	8.3	0.0
56-037-0200	Wamsutter	Sweetwater	27.0	26.7	26.7	0.0
56-041-0101	Murphy Ridge	Uinta	41.0	29.4	29.4	0.0

Note: The NAAQS for 1-hour average NO_2 concentration is 100 ppb.

Differences between the estimated future-year design values for the No Action scenario and the base year design values range from approximately -12 to 7 ppb and are a mix of increases and decreases. On average, the design values are 2.3 ppb lower for the No Action scenario. Compared to the No Action scenario, the estimated future-year design values for the Proposed Action scenario are the same as those for the No Action scenario, with one exception. There is a 0.3 ppb increase in the estimated design value for the Boulder monitoring site.

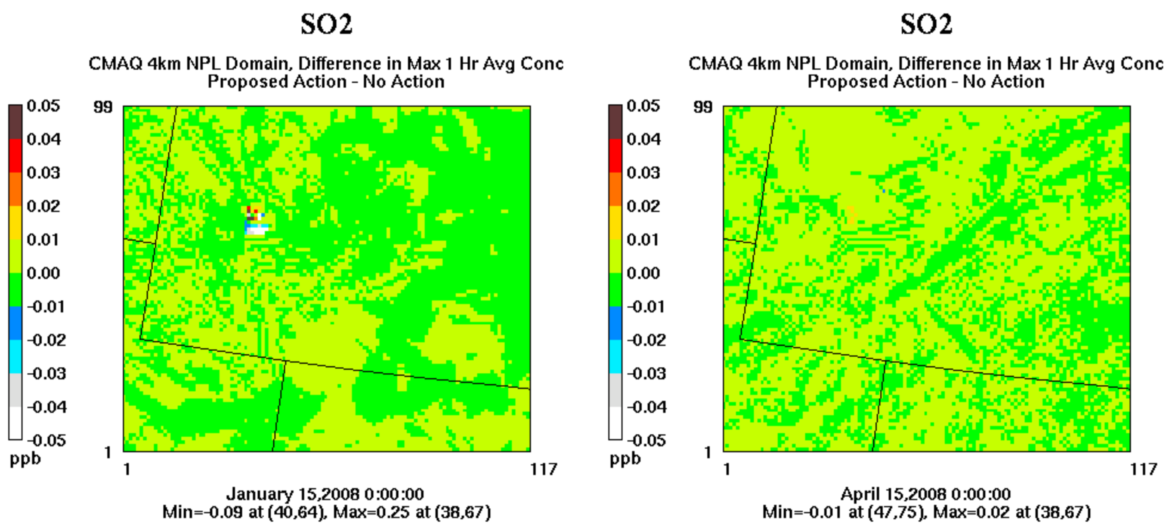
Similar relative response factors (ranging from 0.6 to 1.6) would be applied to the annual design values. Since the NO_2 design values for all sites are well below the annual NAAQS, the detailed calculations were not performed.

SO_2

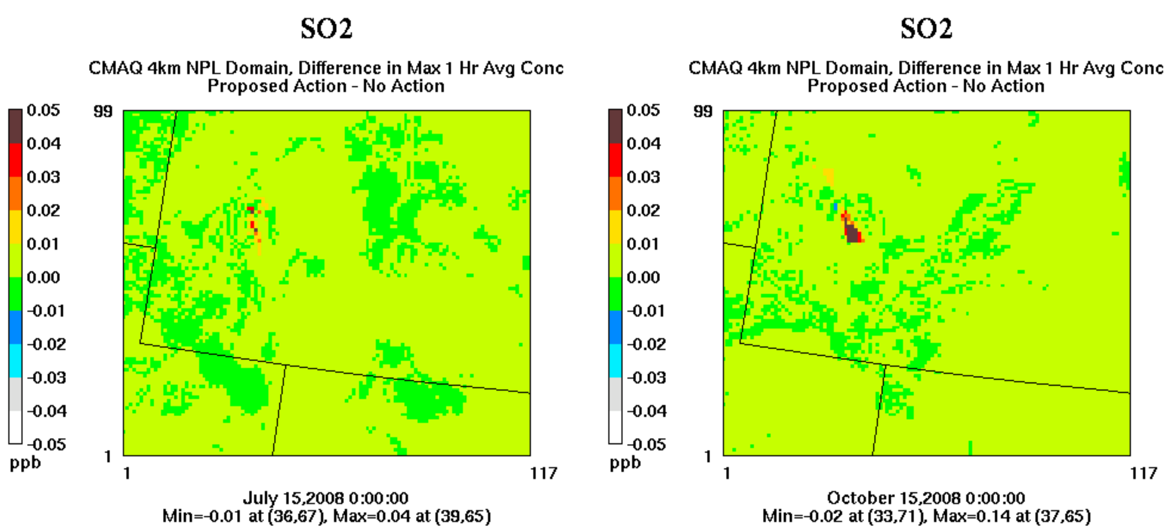
Figure 4-14 illustrates the simulated differences in daily maximum 1-hour SO_2 concentration for the 15th of each month for January, April, July, and October (every third month) for the 4-km grid. Note that the scale ranges from only -0.05 to 0.05 ppb.

Figure 4-14. Difference in Daily Maximum 1-Hour SO_2 Concentration (ppb) for Selected Days for the CMAQ 4-km Grid: Proposed Action – No Action

January/April



July/October



Results for the remaining months (not shown) are similar.

Based on the CMAQ results, Table 4-13 summarizes the 99th percentile daily maximum 1-hour SO_2 concentration (a key NAAQS related metric) for the base- and future-year simulations. Included in the table are SO_2 monitoring sites operating for one or more years during the period 2006 – 2010. These sites were selected to represent air quality conditions for the 2008 base year. In addition, Pinedale was included as a pseudo monitor for SO_2 to allow the review of the simulation results for Sublette County.

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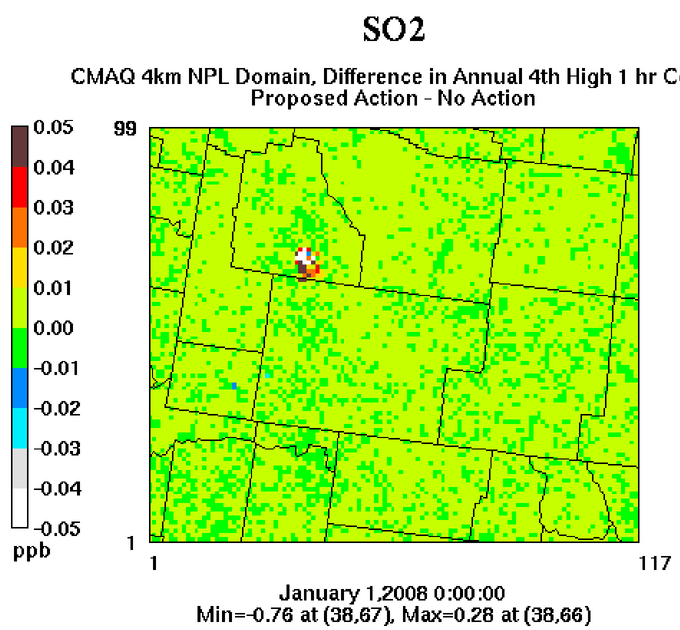
Table 4-13. Simulated 99th Percentile Daily Maximum 1-Hour SO_2 Concentration (ppb) for Monitoring Sites within the NPL 4-km Grid (Wyoming)

Site ID	Site Name	County	99th Percentile 1-Hour SO_2 Concentration (ppb)			Change in Concentration due to Proposed Action (ppb)
			2008 Base Year	Future Year No Action	Future Year Proposed Action	
56-013-0099	South Pass	Fremont	4.2	1.8	1.8	0.0
56-035-0101	Pinedale	Sublette	10.8	10.8	10.8	0.0
56-037-0200	Wamsutter	Sweetwater	15.5	2.1	2.1	0.0
56-037-0300	Moxa Arch	Sweetwater	28.3	8.4	8.4	0.0
56-041-0101	Murphy Ridge	Uinta	6.8	6.9	6.9	0.0

Concentrations are projected to be lower for the future year, compared to the base year for three of the sites (South Pass, Wamsutter and Moxa Arch) and higher or the same for the other two sites (Pinedale and Murphy Ridge). The average change in this metric between the base year and the future-year scenarios is approximately -7 ppb. Simulated concentrations for the No Action and Proposed Action scenarios for the SO_2 monitoring sites are the same.

The difference in simulated 99th percentile 1-hour average SO_2 concentration for each grid cell within the 4-km grid (for the annual simulation period) is displayed in Figure 4-15.

Figure 4-15. Difference in Simulated 99th Percentile 1-Hour SO_2 Concentration (ppb) for the CMAQ 4-km Grid: Proposed Action – No Action



The maximum impact on the 99th percentile 1-hour SO_2 concentration is 0.3 ppb. The greatest impacts on this metric occur within the Project Area.

MATS does not accommodate SO_2. The results presented in the remainder of this section were calculated using the MATS procedures, but in this case the procedures were applied manually within spreadsheets containing the model output for SO_2.

Table 4-14 summarizes the modeled attainment test results for 1-hour SO_2. The current-year design values used for this summary were calculated based on data for 2007-2009. Only sites with data for one or more years during the three-year period were included. The current-year SO_2 design values are based three years of monitoring data for all three sites.

Table 4-14. Estimated Future-Year 1-Hour SO_2 Design Values (ppb) for Monitoring Sites within the NPL 4-km Grid (Wyoming)

Site ID	Site Name	County	1-Hour SO_2 Design Value (ppb)			Change in Design Value due to Proposed Action (ppb)
			Current Year	Future Year No Action	Future Year Proposed Action	
56-013-0099	South Pass	Fremont	6.3	1.0	1.0	0.0
56-037-0200	Wamsutter	Sweetwater	9.0	0.7	0.7	0.0
56-041-0101	Murphy Ridge	Uinta	5.3	2.7	2.7	0.0

Note: The NAAQS for 1-hour average SO_2 concentration is 75 ppb.

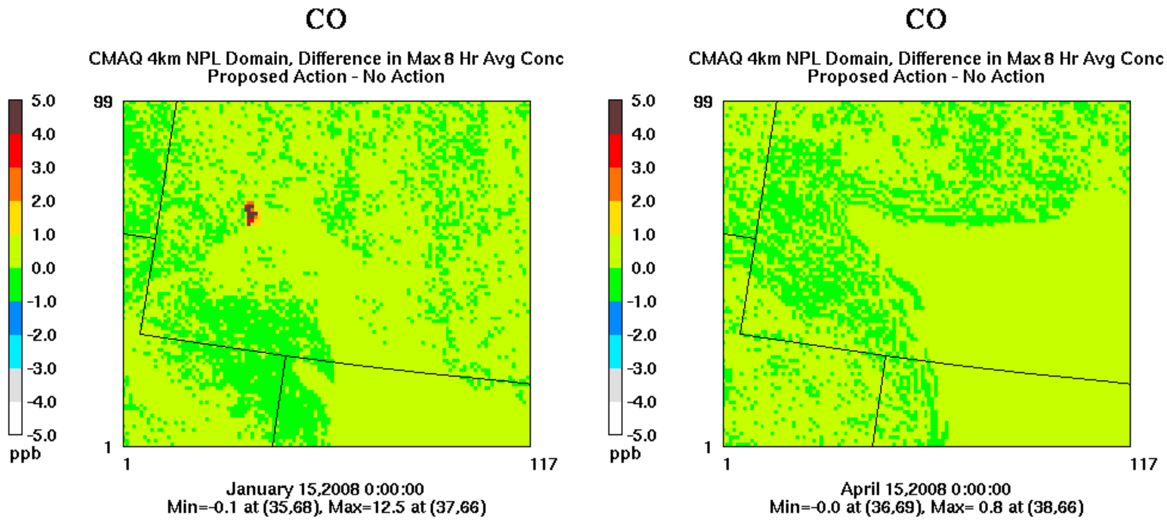
For all three sites the estimated future-year design values are much lower than the current year values. This is due in part to differences in emissions between the base and future year for a power plant located along the southern boundary of the 4-km grid (and what appears to be an error in the 2008 National Emission Inventory (NEI) that was corrected by EPA in the future-year emissions). Compared to the No Action scenario, the estimated future-year design values for the Proposed Action scenario are the same as those for the No Action scenario.

CO

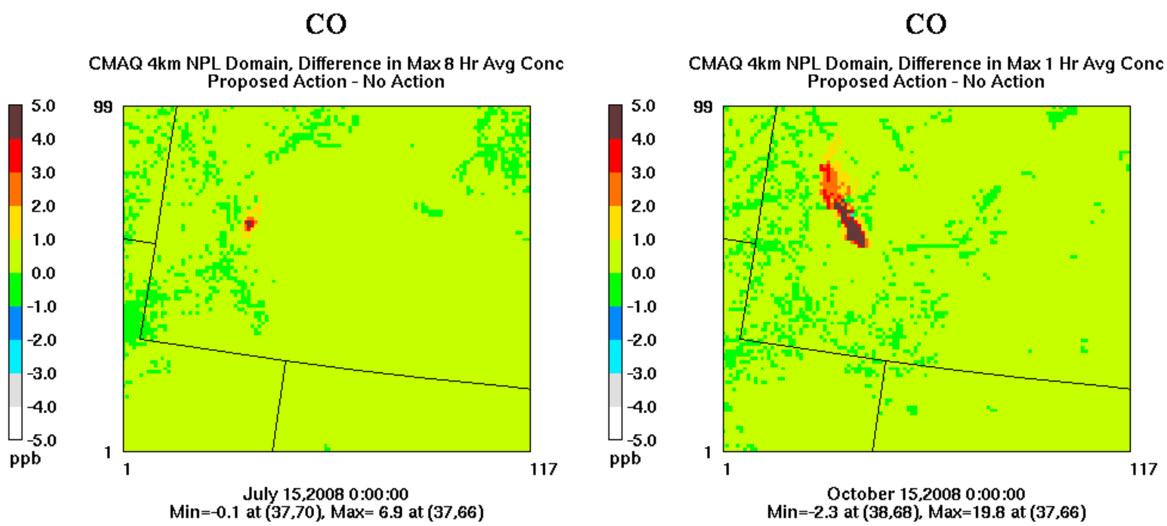
Figure 4-16 illustrates the simulated differences in 8-hour average CO concentration for the 15th of each month for January, April, July, and October (every third month) for the 4-km grid.

Figure 4-16. Difference in 8-Hour Average CO Concentration (ppb) for Selected Days for the CMAQ 4-km Grid: Proposed Action – No Action

January/April



July/October



Results for the remaining months (not shown) are similar.

Based on the CMAQ results, Table 4-15 summarizes the highest daily maximum 1-hour CO concentration (a key NAAQS related metric) for the base- and future-year simulations. Since CO was monitored for one year (2008) at one site (Murphy Ridge), the actual and pseudo SO_2 monitoring sites were used as surrogate sites for CO for the purposes of sampling the simulation results for multiple locations.

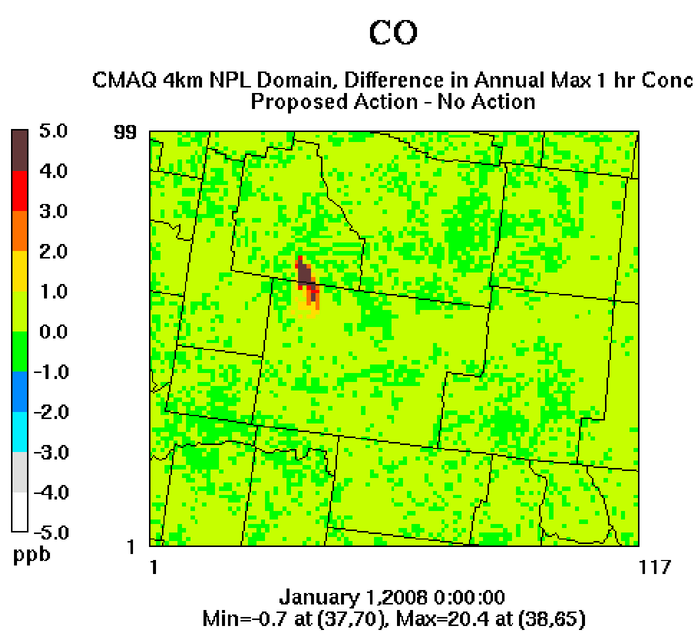
Table 4-15. Simulated Highest Daily Maximum 1-Hour CO Concentration (ppb) for Monitoring Sites within the NPL 4-km Grid (Wyoming)

Site ID	Site Name	County	Maximum 1-Hour CO Concentration (ppb)			Change in Concentration due to Proposed Action (ppb)
			2008 Base Year	Future Year No Action	Future Year Proposed Action	
56-035-0101	Pinedale	Sublette	5450	5450	5450	0
56-037-0200	Wamsutter	Sweetwater	178	303	303	0
56-037-0300	Moxa Arch	Sweetwater	267	256	256	0
56-041-0101	Murphy Ridge	Uinta	272	261	261	0

The simulated CO concentrations corresponding to the peak 1-hour concentration are not consistently higher or lower for the No Action scenario, compared to the base year. The differences vary by site. The values for all sites are the same for the No Action and Proposed Action scenarios.

The difference in simulated maximum 1-hour average CO concentration for each grid cell within the 4-km grid (for the annual simulation period) is displayed in Figure 4-17.

Figure 4-17. Difference in Simulated Maximum 1-Hour CO Concentration (ppb) for the CMAQ 4-km Grid: Proposed Action – No Action



The maximum impact on daily maximum 1-hour CO concentration is 20.4 ppb. The greatest impacts occur within and to the south of the Project Area.

There is one site with partial data during the 2007-2009 current year period, so estimated design values were not calculated. However, the relative response factors were calculated and range from 0.8 to 1 for both future-year scenarios.

4.2.2 Prevention of Significant Deterioration

The incremental increases in concentration for the Proposed Action scenario relative to the No Action scenario are compared with applicable PSD consumption increments in Table 4-16 (a) and (b). These were calculated for the grid cell with the maximum impact within each of the Class I and Class II areas listed in Section 3. For those areas within the 4-km grid, the 4-km resolution modeling results were used. For those areas located outside of the 4-km grid, the 12-km resolution modeling results were used. No increases in concentration exceed the PSD increments; all calculated increments are very small compared to the allowable increments.

Table 4-16a. Comparison of CMAQ-Derived Criteria Pollutant Impacts Based on the Proposed Action and No Action Scenarios with PSD Consumption Increments: Class I Areas

Class I Area	State	PM_{10} Increment (µg/m^3)		$PM_{2.5}$ Increment (µg/m^3)		Annual NO_2 Increment (µg/m^3)	Annual SO_2 Increment (µg/m^3)
		24-Hour	Annual	24-Hour	Annual		
Bridger WA	WY	0.097	0.012	0.022	0.003	0.005	0.0
Fitzpatrick WA	WY	0.063	0.004	0.018	0.002	0.002	0.0
Grand Teton NP	WY	0.044	0.002	0.0	0.001	0.001	0.0
North Absaroka WA	WY	0.007	0.0	0.003	0.0	0.0	0.0
Teton WA	WY	0.013	0.002	0.0	0.001	0.001	0.0
Washakie WA	WY	0.008	0.002	0.004	0.001	0.001	0.0
Yellowstone NP	WY	0.013	0.001	0.002	0.0	0.001	0.0
Mt. Zirkel NP	CO	0.003	0.001	0.002	0.0	0.001	0.0
Rawah WA	CO	0.0	0.002	0.001	0.001	0.002	0.0
Red Rock Lakes WA	MT	0.007	0.0	0.002	0.0	0.0	0.0
Allowable PSD Class I Increment		**8**	**4**	**2**	**1**	**2.5**	**--**

Table 4-16b. Comparison of CMAQ-Derived Criteria Pollutant Impacts Based on the Proposed Action and No Action Scenarios with PSD Consumption Increments: Sensitive Class II Areas

Sensitive Class II Area	State	PM_{10} Increment (µg/m^3)		$PM_{2.5}$ Increment (µg/m^3)		Annual NO_2 Increment (µg/m^3)	Annual SO_2 Increment (µg/m^3)
		24-Hour	Annual	24-Hour	Annual		
Cloud Peak WA	WY	0.0	0.001	0.0	0.0	0.0	0.0
Gros Ventre WA	WY	0.031	0.006	0.0	0.001	0.002	0.0
Jedediah Smith WA	WY	0.079	0.001	0.0	0.0	0.0	0.0
Popo Agie WA	WY	0.010	0.008	0.006	0.003	0.003	0.0
Savage Run WA	WY	0.001	0.0	0.001	0.0	0.001	0.0
Wind River RA	WY	0.055	0.005	0.017	0.002	0.002	0.0
Dinosaur NP	CO	0.010	0.0	0.003	0.0	0.0	0.0
High Uintas WA	UT	0.0	0.0	0.0	0.0	0.0	0.0
Allowable PSD Class II Increment		**30**	**17**	**8**	**4**	**25**	**--**

4.3 Air Quality Related Values Impact Assessment

4.3.1 Visibility

The visibility assessment focused on all grid cells that overlap a Class I or sensitive Class II area within the study region. For each modeled scenario, estimated visibility degradation was calculated for each Class I and sensitive Class II area within the 4- and 12-km grids. Two methodologies were used to evaluate visibility impacts.

The first method is described in the Federal Land Managers' Air Quality Related Values Work Group (FLAG) Phase I Report—Revised 2010 and is hereafter referred to as the FLAG 2010 method (FLAG, 2010). Changes in visibility due to project-related emissions were calculated from the difference between the modeled concentrations for the Proposed Action and No Action scenarios.

For each scenario, visibility was calculated using the latest IMPROVE algorithm (Hand and Malm, 2006), modeled species concentrations, and site-specific monthly relative humidity factors (FLAG, 2010). The IMPROVE algorithm characterizes visibility in terms of an extinction coefficient (b_{ext}). For each Class I and sensitive Class II area the grid cell with the maximum impact was identified and the maximum and 98th percentile change in b_{ext} at the location of maximum impact was calculated. The percent change that these impacts represent relative to natural background was calculated. The b_{ext} values were also converted to deciview haze index, defined as equal to 10 ln(b_{ext}/10), and the change in deciviews (dv) associated with the maximum and 98th percentile impacts was calculated.

A 5 percent change in light extinction (approximately equal to 0.5 deciview [dv]) is the threshold recommended in FLAG 2010 and is considered to contribute to regional haze visibility impairment. A 10 percent change in light extinction (approximately equal to 1.0 dv) is considered to cause visibility impairment when compared to background conditions. Thus the number of days that exceed the 5 and 10 percent thresholds was also obtained.

Background values were obtained from the FLAG 2010 report (Table 5 – 20% Best Natural Conditions – Concentrations and Rayleigh Scattering by Class I Area and Table 6 – Annual Average Natural Conditions – Concentrations and Rayleigh Scattering by Class I Area). These were used along with monthly average f(RH) values, also obtained from the FLAG 2010 report (Table 7 - Monthly f(RH) – Large $(NH_4)^2$ SO_4 and NH_4NO_3 Relative Humidity Adjustment Factor), to estimate background light extinction for all Class I areas (IMPROVE data sites). Natural conditions for all Class I areas are provided in the FLAG tables. The natural condition values are based on IMPROVE data. These values for Class I areas with IMPROVE monitoring sites are also used to represent nearby Class I areas that do not have monitoring sites, in accordance with EPA guidance for tracking progress under the Regional Haze Rule (RHR) (EPA, 2003). For sensitive Class II areas, values from the closest or most climatically similar Class I area were used.

Tables 4-17 and 4-18 summarize visibility change for the Class I and Class II areas within the 12- and 4-km grids. In Table 4-17 (a) and (b), the results are presented relative to annual average natural background. In Table 4-18 (a) and (b), the results are presented relative to natural background for the 20 percent best visibility days. In these tables, WA is Wilderness Area, RA is Roadless Area, and NP is National Park. The units for b_{ext} are inverse megameters (Mm^{-1}).

Table 4-17a. Visibility Impacts for the Proposed Action Based on Annual Average Natural Background: Class I Areas

Class I Area	State	Natural Visibility b_{ext} (Mm^{-1})	98th Percentile Impact			Maximum Impact			# Days >5% Change	# Days >10% Change
			Δ b_{ext} (Mm^{-1})	% Change in b_{ext}	Δ dv	Δ b_{ext} (Mm^{-1})	% Change in b_{ext}	Δ dv		
Bridger WA	WY	15.02	0.02	0.14	0.01	1.05	6.98	0.67	1	0
Fitzpatrick WA	WY	15.02	0.02	0.12	0.01	0.97	6.43	0.62	1	0
Grand Teton NP	WY	15.03	0.02	0.16	0.02	0.09	0.59	0.06	0	0
North Absaroka WA	WY	15.02	0.01	0.04	0.00	0.01	0.09	0.01	0	0
Teton WA	WY	15.03	0.02	0.15	0.01	0.04	0.26	0.03	0	0
Washakie WA	WY	15.02	0.02	0.13	0.01	0.03	0.21	0.02	0	0
Yellowstone NP	WY	15.03	0.00	0.03	0.00	0.03	0.18	0.02	0	0
Mt. Zirkel NP	CO	15.01	0.01	0.06	0.01	0.03	0.18	0.02	0	0
Rawah WA	CO	15.01	0.01	0.06	0.01	0.27	1.79	0.18	0	0
Red Rock Lakes WA	MT	15.09	0.00	0.01	0.01	0.07	0.04	0.00	0	0

Table 4-17b. Visibility Impacts for the Proposed Action Based on Annual Average Natural Background: Sensitive Class II Areas

Sensitive Class II Area	State	Natural Visibility b_{ext} (Mm^{-1})	98th Percentile Impact			Maximum Impact			# Days >5% Change	# Days >10% Change
			Δ b_{ext} (Mm^{-1})	% Change in b_{ext}	Δ dv	Δ b_{ext} (Mm^{-1})	% Change in b_{ext}	Δ dv		
Cloud Peak WA	WY	15.02	0.01	0.04	0.00	0.01	0.08	0.01	0	0
Gros Ventre WA	WY	15.03	0.05	0.31	0.03	0.17	1.15	0.11	0	0
Jedediah Smith WA	WY	15.03	0.02	0.12	0.01	0.11	0.72	0.07	0	0
Popo Agie WA	WY	15.02	0.05	0.33	0.03	1.23	8.17	0.79	1	0
Savage Run WA	WY	15.01	0.01	0.08	0.01	0.03	0.18	0.02	0	0
Wind River RA	WY	15.02	0.04	0.24	0.02	0.86	5.71	0.56	1	0
Dinosaur NP	CO	15.01	0.01	0.07	0.01	0.02	0.10	0.01	0	0
High Uintas WA	UT	15.01	0.00	0.02	0.00	0.24	1.60	0.16	0	0

Table 4-18a. Visibility Impacts for the Proposed Action Based on 20% Best Days Natural Background: Class I Areas

Class I Area	State	Natural Visibility b_{ext} (Mm^{-1})	98th Percentile Impact			Maximum Impact			# Days >5% Change	# Days >10% Change
			Δ b_{ext} (Mm^{-1})	% Change in b_{ext}	Δ dv	Δ b_{ext} (Mm^{-1})	% Change in b_{ext}	Δ dv		
Bridger WA	WY	11.63	0.02	0.18	0.02	1.05	9.01	0.86	1	0
Fitzpatrick WA	WY	11.63	0.02	0.16	0.02	0.97	8.30	0.80	1	0
Grand Teton NP	WY	11.64	0.02	0.21	0.02	0.09	0.77	0.08	0	0
North Absaroka WA	WY	11.63	0.01	0.06	0.01	0.01	0.12	0.01	0	0
Teton WA	WY	11.64	0.02	0.19	0.02	0.04	0.33	0.03	0	0
Washakie WA	WY	11.63	0.02	0.17	0.02	0.03	0.27	0.03	0	0
Yellowstone NP	WY	11.64	0.00	0.04	0.00	0.03	0.24	0.02	0	0
Mt. Zirkel NP	CO	11.62	0.01	0.08	0.01	0.03	0.23	0.02	0	0
Rawah WA	CO	11.62	0.01	0.07	0.01	0.27	2.31	0.23	0	0
Red Rock Lakes WA	MT	11.68	0.0	0.01	0.0	0.01	0.06	0.01	0	0

Table 4-18b. Visibility Impacts for the Proposed Action Based on 20% Best Days Natural Background: Sensitive Class II Areas

Sensitive Class II Area	State	Natural Visibility b_{ext} (Mm^{-1})	98th Percentile Impact			Maximum Impact			# Days >5% Change	# Days >10% Change
			Δ b_{ext} (Mm^{-1})	% Change in b_{ext}	Δ dv	Δ b_{ext} (Mm^{-1})	% Change in b_{ext}	Δ dv		
Cloud Peak WA	WY	11.63	0.01	0.06	0.01	0.01	0.10	0.01	0	0
Gros Ventre WA	WY	11.64	0.05	0.40	0.04	0.17	1.49	0.15	0	0
Jedediah Smith WA	WY	11.64	0.02	0.15	0.02	0.11	0.92	0.09	0	0
Popo Agie WA	WY	11.63	0.05	0.43	0.04	1.23	10.55	1.00	1	1
Savage Run WA	WY	11.62	0.01	0.11	0.01	0.03	0.23	0.02	0	0
Wind River RA	WY	11.63	0.04	0.31	0.03	0.86	7.38	0.71	1	0
Dinosaur NP	CO	11.62	0.01	0.09	0.01	0.02	0.13	0.01	0	0
High Uintas WA	UT	11.62	0.00	0.02	0.00	0.24	2.06	0.20	0	0

Relative to annual average natural background (Table 4-17), the largest 98th percentile impact is 0.03 dv, for both the Gros Ventre and Popo Agie Wilderness Areas. Maximum impacts are larger and there is one day for each of Bridger, Fitzpatrick, and Popo Agie Wilderness Areas and Wind River Roadless Area for which a greater than 5 percent change in light extinction (a greater than 0.5 dv impact) is modeled.

Relative to natural background for the 20% best visibility days (Table 4-18), the largest 98^{th} percentile impact is 0.04 dv, for both the Gros Ventre and Popo Agie Wilderness Areas. Maximum impacts indicate that there is one day for each of Bridger, Fitzpatrick, and Popo Agie Wilderness Areas and Wind River Roadless Area for which a greater than 5 percent change in light extinction (a greater than 0.5 dv impact) is modeled. There is also one day for the Popo Agie Wilderness Area for which a greater than 10 percent change in light extinction (a greater than 1.0 dv impact) is modeled.

The second method used to examine visibility focused on cumulative impacts and made use of the EPA MATS software to calculate future-year mean visibility for the 20 percent best and worst visibility days. The steps involved in the MATS approach can be summarized as follows:

Step 1: Calculate the average baseline visibility for each Class I and Class II area based on five years of monitoring data for the 20 percent best and 20 percent worst days.

Step 2: Estimate site-specific RRFs for each visibility component (as specified in the new IMPROVE equation) based on the future-year and base-year modeling results. As noted earlier in the section, the RRF is defined as the ratio of the future-year to base-year simulated concentration in the vicinity of a monitoring site.

Step 3: Apply the RRFs to the monitoring data to estimate future-year concentrations corresponding to the 20 percent best and 20 percent worst visibility days.

Step 4: Use the concentration estimates from Step 3 to calculate future-year visibility for the best and worst days.

Step 5: Using the information from Step 4, calculate the future-year mean visibility for the 20 percent best and worst days.

MATS was applied for the No Action and Proposed Action scenarios. The difference in estimated future-year mean visibility between the Proposed Action and No Action scenarios was calculated and used to quantify the change in cumulative visibility resulting from project-specific emissions.

Typically MATS would only be applied for Class I areas with IMPROVE monitoring sites, since the application of MATS relies on baseline visibility data. For this analysis, additional locations were added so that all Class I and sensitive Class II areas within the 12- and 4-km grids were included. Similar to the FLAG analysis, the additional locations (or pseudo sites) were assigned to the grid cell with the maximum visibility impact from the Proposed Action emissions. The average baseline visibility data for Class I areas with IMPROVE monitoring sites (Bridger Wilderness and Mount Zirkel Wilderness) were used to represent nearby Class I and sensitive Class II areas without monitoring sites. Average baseline visibility was calculated using data for the best and worst visibility days for the five-year period 2006-2010.

Tables 4-19 and 4-20 summarize the MATS results for visibility – first for the 20 percent best visibility days and then for the 20 percent worst visibility days. The units are deciviews (dv).

Table 4-19a. Estimated Future-Year Visibility (dv) for the 20 Percent Best Days: Class I Areas

Class I Area	State	Baseline Visibility (dv)	Estimated Future-Year Visibility (dv)		Change in Visibility due to Proposed Action (Δ dv)
			No Action Scenario	Proposed Action Scenario	
Bridger WA	WY	1.39	1.25	1.25	0
Fitzpatrick WA	WY	1.39	1.28	1.28	0
Grand Teton NP	WY	1.85	1.57	1.57	0
North Absaroka WA	WY	1.42	1.21	1.21	0
Teton WA	WY	1.85	1.58	1.58	0
Washakie WA	WY	1.42	1.22	1.22	0
Yellowstone NP	WY	1.85	1.58	1.58	0
Mt. Zirkel NP	CO	0.95	0.77	0.77	0
Rawah WA	CO	0.95	0.87	0.87	0
Red Rock Lakes WA	MT	1.85	1.60	1.60	0

Table 4-19b. Estimated Future-Year Visibility (dv) for the 20 Percent Best Days: Sensitive Class II Areas

Sensitive Class II Area	State	Baseline Visibility (dv)	Estimated Future-Year Visibility (dv)		Change in Visibility due to Proposed Action (Δ dv)
			No Action Scenario	Proposed Action Scenario	
Cloud Peak WA	WY	1.42	1.22	1.22	0
Gros Ventre WA	WY	1.85	1.57	1.59	0.02
Jedediah Smith WA	WY	1.85	1.56	1.56	0
Popo Agie WA	WY	1.39	1.25	1.25	0
Savage Run WA	WY	0.95	0.76	0.77	0.01
Wind River RA	WY	1.39	1.25	1.25	0
Dinosaur NP	CO	0.95	0.6	0.6	0
High Uintas WA	UT	0.95	0.75	0.75	0

Table 4-20a. Estimated Future-Year Visibility (dv) for the 20 Percent Worst Days: Class I Areas

Class I Area	State	Baseline Visibility (dv)	Estimated Future-Year Visibility (dv)		Change in Visibility due to Proposed Action (Δ dv)
			No Action Scenario	Proposed Action Scenario	
Bridger WA	WY	10.58	9.92	9.93	0.01
Fitzpatrick WA	WY	10.58	9.89	9.89	0
Grand Teton NP	WY	11.57	10.8	10.8	0
North Absaroka WA	WY	11.72	11.28	11.28	0
Teton WA	WY	11.57	10.79	10.80	0.01
Washakie WA	WY	11.72	11	11.01	0.01
Yellowstone NP	WY	11.57	11.19	11.19	0
Mt. Zirkel NP	CO	9.36	8.73	8.73	0
Rawah WA	CO	9.36	8.75	8.75	0
Red Rock Lakes WA	MT	11.57	10.97	10.98	0.01

Table 4-20b. Estimated Future-Year Visibility (dv) for the 20 Percent Worst Days: Sensitive Class II Areas

Sensitive Class II Area	State	Baseline Visibility (dv)	Estimated Future-Year Visibility (dv)		Change in Visibility due to Proposed Action (Δ dv)
			No Action Scenario	Proposed Action Scenario	
Cloud Peak WA	WY	11.72	11.05	11.06	0.01
Gros Ventre WA	WY	11.57	10.83	10.84	0.01
Jedediah Smith WA	WY	11.57	10.81	10.81	0
Popo Agie WA	WY	10.58	9.90	9.91	0.01
Savage Run WA	WY	9.36	8.79	8.80	0.01
Wind River RA	WY	10.58	9.91	9.91	0
Dinosaur NP	CO	9.36	8.58	8.58	0
High Uintas WA	UT	9.36	8.62	8.62	0

Using the MATS approach, the calculated impact on future-year visibility from the Proposed Action for the 20 percent best days is greater than zero for two areas: the Gros Ventre Wilderness Area (0.02 dv) and the Savage Run Wilderness Area (0.01 dv). The calculated impact on future-year visibility from the

Proposed Action for the 20 percent worst days is 0.01 dv for seven areas including the Bridger, Teton, Washakie, Cloud Peak, Gros Ventre, Popo Agie, and Savage Run Wilderness Areas.

4.3.2 Atmospheric Deposition

The effects of atmospheric deposition of nitrogen and sulfur compounds on terrestrial and aquatic ecosystems are well documented and have been shown to cause leaching of nutrients from soils, acidification of surface waters, injury to high elevation vegetation, and changes in nutrient cycling and species composition. Project-specific and cumulative nitrogen and sulfur deposition impacts were examined for Class I areas and identified sensitive Class II areas within the project study area.

CMAQ-derived annual wet, dry, and total (wet plus dry) deposition fluxes of total S and N compounds were used to estimate the total S and N deposition fluxes at the Class I and sensitive Class II areas within the 4- and 12-km grids and are presented in Table 4-21 (a) and (b). Deposition was calculated for the No Action and Proposed Action scenarios. The difference in deposition for each species (attributable to the Proposed Action) is compared with the deposition analysis threshold (DAT) developed by the National Park Service (NPS) and the U.S. Fish and Wildlife Service (USFWS). The DATs represent values for nitrogen and sulfur deposition from project-specific emission sources below which estimated impacts are considered negligible. The DAT established for both nitrogen and sulfur in western Class I areas is 0.005 kilograms per hectare per year (kg/ha/yr).

Cumulative modeled deposition amounts are also compared to critical load thresholds to assess total deposition impacts. In this study, deposition results are compared to critical load thresholds established for the Rocky Mountain region. Critical loads vary by sensitive resource. For this analysis, the critical load for the most sensitive resource (high elevation surface waters was used). The critical load thresholds are: 3 kg/ha/yr for total S deposition and 2.2 kg/ha/yr for total N deposition. Deposition amounts that exceed the critical load values are highlighted in bold.

Table 4-21a. CMAQ-Derived Total Sulfur and Nitrogen Deposition (kg/ha/yr): Class I Areas

Class I Area	State	Total S Deposition (kg/ha/yr)			Total N Deposition (kg/ha/yr)		
		No Action Scenario	Proposed Action Scenario	∆S Deposition due to Proposed Action	No Action Scenario	Proposed Action Scenario	∆N Deposition due to Proposed Action
Bridger WA	WY	2.11	2.11	0.000	**2.11**	**2.12**	0.004
Fitzpatrick WA	WY	1.57	1.57	0.000	1.70	1.70	0.002
Grand Teton NP	WY	1.80	1.80	0.000	1.39	1.39	0.001
North Absaroka WA	WY	0.86	0.86	0.000	1.03	1.03	0.000
Teton WA	WY	1.52	1.52	0.000	1.33	1.33	0.001
Washakie WA	WY	0.92	0.92	0.000	0.99	0.99	0.001
Yellowstone NP	WY	1.44	1.44	0.000	1.23	1.23	0.000
Mt. Zirkel NP	CO	2.73	2.73	0.000	**3.36**	**3.36**	0.001
Rawah WA	CO	1.74	1.74	0.000	**2.45**	**2.45**	0.001
Red Rock Lakes WA	MT	1.02	1.02	0.000	1.0	1.0	0.000
DAT				**0.005**			**0.005**
Critical Load Threshold		**3.0**	**3.0**		**2.2**	**2.2**	

Table 4-21b. CMAQ-Derived Total Sulfur and Nitrogen Deposition (kg/ha/yr): Sensitive Class II Areas

Sensitive Class II Area	State	Total S Deposition (kg/ha/yr)			Total N Deposition (kg/ha/yr)		
		No Action Scenario	Proposed Action Scenario	ΔS Deposition due to Proposed Action	No Action Scenario	Proposed Action Scenario	ΔN Deposition due to Proposed Action
Cloud Peak WA	WY	1.83	1.83	0.000	1.69	1.69	0.001
Gros Ventre WA	WY	1.93	1.93	0.000	1.89	1.89	0.003
Jedediah Smith WA	WY	2.06	2.06	0.000	1.59	1.59	0.000
Popo Agie WA	WY	2.07	2.07	0.000	**2.34**	**2.35**	0.006
Savage Run WA	WY	1.46	1.46	0.000	**2.07**	**2.07**	0.002
Wind River RA	WY	1.38	1.38	0.000	1.74	1.74	0.003
Dinosaur NP	CO	0.66	0.66	0.000	1.31	1.31	0.000
High Uintas WA	UT	1.72	1.72	0.000	1.96	1.96	0.000
DAT				**0.005**			**0.005**
Critical Load Threshold		**3.0**	**3.0**		**2.2**	**2.2**	

For sulfur, the simulated change in deposition due to the Proposed Action does not exceed the DAT of 0.005 kg/ha/yr for any area. In addition, the simulated cumulative deposition amount is less than the critical load threshold of 3.0 kg/ha/yr for all areas.

For nitrogen, the simulated change in deposition due to the Proposed Action exceeds the DAT of 0.005 kg/ha/yr for the Popo Agie Wilderness Area. The simulated cumulative deposition amount is greater than the critical load threshold of 2.2 kg/ha/yr for five of the 17 areas.

Note that the cumulative simulated deposition amounts for both sulfur and nitrogen are quite a bit larger than those calculated by CALPUFF using the same emissions information. The CALPUFF results are presented in Section 5. It is expected that CMAQ has higher deposition rates than CALPUFF due to a number of factors including a more detailed wet deposition algorithm and direct simulation of the chemical transformation of NO_2 to nitric acid (HNO_3) which results in a much higher deposition rate for both wet and dry deposition, compared to CALPUFF.

4.3.3 Lake Chemistry

The change in water chemistry associated with atmospheric deposition from project sources was also calculated for 17 acid sensitive lakes located within the 4-km CMAQ grid. An estimation of potential changes in ANC was made using a procedure developed by the USFS Rocky Mountain Region (USFS, 2000).

The equation is as follows:

% ANC change = [Hdep/ANC(o)] x 100

where:

ANC(o) = baseline ANC for entire lake catchment in eq = W x P x (1-Et) x A x (10,000m^2/ha) x (eq/106 µeq) x (103 liters/m^3)

A = baseline lake sample alkalinity in µeq/l

Hdep = acid deposition in eq = [H(s) + H(n)] x W x 10,000m^2/ha

Hs = sulfur deposition in eq/m2/yr = Ds (kg/ha/yr) x (ha/10,000m^2) x (1000g/kg) x (eq/16g S)

Hn = nitrogen deposition in eq/m2/yr = Dn (kg/ha/yr) x ha/10,000m^2) x (1000g/kg) x (eq/14g N)

W = watershed area in ha

P = average annual precipitation in meters

Et = fraction of the annual precipitation lost to evaporation and transpiration (assume Et = .33)

Ds = sulfur deposition in kg/ha/yr from all sulfur species

Dn = nitrogen deposition in kg/ha/yr from all nitrogen species

The CMAQ-derived changes in ANC due to the Proposed Action, along with several of the key terms in the calculation, are presented in Table 4-22. Background ANC data for this analysis were provided by the USFS (USFS, 2011 and 2014). The 10^{th} percentile ANC values and the number of samples used in the calculation of the 10^{th} percentile lowest ANC values are also provided in the table. Note that the very small negative numbers for sulfur deposition are likely the result of numerical errors in the CMAQ advection or chemistry routines and are effectively zero.

Table 4-22. CMAQ-Derived Change in ANC for Sensitive Lakes

Class I/ Class II Area	Lake	Lat (deg)	Lon (deg)	10th Percentile Lowest ANC Value (µeq/l) (A)	No. of Samples	Precip-itation (m) (P)	ΔS Deposition (eq/m2/yr) (Hs)	ΔN Deposition (eq/m2/yr) (Hn)	Total S + N Dep (eq) (Hdep)	ANC(o) (eq)	% Change in ANC	Delta ANC (µeq/l)
Bridger	Deep	42.719	-109.171	61.1	62	0.28	1.65E-06	7.21E-05	0.74	112.61	0.65	0.40
Bridger	Black Joe	42.739	-109.171	70.6	72	0.28	1.65E-06	7.21E-05	0.74	130.12	0.57	0.40
Bridger	Lazy Boy	43.333	-109.73	27.8	1	0.28	4.05E-07	1.51E-05	0.15	51.24	0.30	0.08
Bridger	Upper Frozen	42.687	-109.161	13.2	3	0.28	2.28E-06	5.78E-05	0.60	24.33	2.47	0.33
Bridger	Hobbs	43.036	-109.672	69.8	76	0.28	-3.36E-06	2.24E-05	0.19	128.64	0.15	0.10
Fitzpatrick	Ross	43.378	-109.658	54	55	0.23	3.41E-07	8.16E-06	0.09	81.97	0.10	0.06
Popo Agie	Lower Saddlebag	42.623	-108.994	55.5	54	0.34	6.03E-07	2.14E-05	0.22	126.00	0.17	0.10
High Uintas	Dean	40.679	-110.761	51.4	7	0.45	-1.07E-07	1.69E-06	0.02	154.30	0.01	0.01
High Uintas	Heart	40.594	-110.811	54.6	1	0.45	-1.07E-07	1.69E-06	0.02	163.91	0.01	0.01
High Uintas	No Name (Duchesne – 4d2-039)	40.671	-110.275	65.2	3	0.45	-2.73E-07	1.79E-06	0.02	195.73	0.01	0.01
High Uintas	Fish	40.837	-110.069	104.5	6	0.45	-3.96E-08	3.24E-06	0.03	313.71	0.01	0.01
High Uintas	Upper Coffin (Duchesne – 4d1-044)	40.834	-110.237	65	2	0.60	-3.96E-08	3.24E-06	0.03	262.38	0.01	0.01

Class I/ Class II Area	Lake	Lat (deg)	Lon (deg)	10th Percentile Lowest ANC Value (µeq/l) (A)	No. of Samples	Precip-itation (m) (P)	ΔS Deposition (eq/m2/yr) (Hs)	ΔN Deposition (eq/m2/yr) (Hn)	Total S + N Dep (eq) (Hdep)	ANC(o) (eq)	% Change in ANC	Delta ANC (µeq/l)
Mt. Zirkel	Elbert	40.634	-106.707	53.8	68	0.60	-1.01E-07	4.13E-06	0.04	217.17	0.02	0.01
Mt. Zirkel	Seven (Lakes)	40.896	-106.682	36.4	67	0.60	-3.55E-07	3.92E-06	0.04	146.93	0.02	0.01
Mt. Zirkel	Summit	40.545	-106.683	48	110	0.60	4.61E-08	3.64E-06	0.04	193.35	0.02	0.01
Rawah	Island	40.627	-105.942	71.9	25	0.60	3.93E-07	8.86E-06	0.09	289.62	0.03	0.02
Rawah	Rawah Lake #4	40.671	-105.958	41.5	24	0.60	3.93E-07	8.86E-06	0.09	167.17	0.06	0.02

Deposition is greatest for the lakes in the Bridger Wilderness Area. Simulated changes in ANC were compared with the applicable threshold for each identified lake: 10 percent change in ANC for lakes with background ANC values greater than 25 micro equivalents per liter [μeq/L], and less than a 1 μeq/L change in ANC for lakes with background ANC values equal to or less than 25 μeq/L. Of the 17 lakes listed in Table 4-22, only Upper Frozen Lake is considered to be extremely sensitive to atmospheric deposition by the USFS since the background ANC is less than 25 μeq/L. The percent change in ANC is less than 10 percent for all lakes considered. The change in ANC for Upper Frozen Lake is 0.33 μeq/L, less than the 1 μeq/L threshold.

5.0 FAR-FIELD FUTURE-YEAR AIR QUALITY IMPACT ASSESSMENT: CALPUFF MODELING

5.1 CALPUFF Modeling Approach

Version 5.8.4 of the CALPUFF model was used in this study to assess impacts for air quality related values (AQRVs). CALPUFF (Scire et al., 2000) is an air quality modeling system designed for the assessment of long-range transport of pollutants and their impacts on Federal Class I areas. It is well suited for applications involving complex airflow patterns, as characterized by spatially and temporally varying wind fields that are associated with complex terrain and/or other meteorological factors. CALPUFF requires hourly, gridded fields of several meteorological parameters including temperature, humidity, wind speed, wind direction, and a variety of boundary layer and dispersion parameters. The CALPUFF modeling system consists of three main components and a set of preprocessing and postprocessing programs. The main components of the modeling system are: CALMET (a diagnostic meteorological model), CALPUFF (the air quality dispersion model), and CALPOST (a postprocessing package that is used to support the analysis of impacts on criteria pollutant concentrations and visibility). Although CALPUFF includes an algorithm to calculate secondary aerosol formation, the model does not include algorithms for simulating the photochemistry of ozone formation.

CALPUFF was used to assess the impacts of project-related emissions at Class I and sensitive Class II areas and to model cumulative impacts from the project-related sources and other major emission sources within the modeling domain, including RFD/RFFA sources. The assessment considered visibility as well as sulfur and nitrogen deposition. The CALPUFF modeling results were post-processed using the POSTUTIL and CALPOST utility programs.

5.1.1 Air Quality Modeling Domain

An expanded version of the NPL CMAQ 4-km resolution modeling grid was used for the CALPUFF modeling. The grid was expanded to the north such that the NPL Project Area is positioned approximately 200 km away from the north, east, and south boundaries of the modeling domain. The boundaries of the domain are approximately 50 km from the nearest edge of applicable assessment areas to allow for puff recirculation. The CALPUFF modeling domain is illustrated in Section 5.1.2 (see Figure 5-1). The domain includes the NPL Project Area and nearby PSD Class I and sensitive Class II areas.

5.1.2 Air Quality Assessment Areas and Receptors

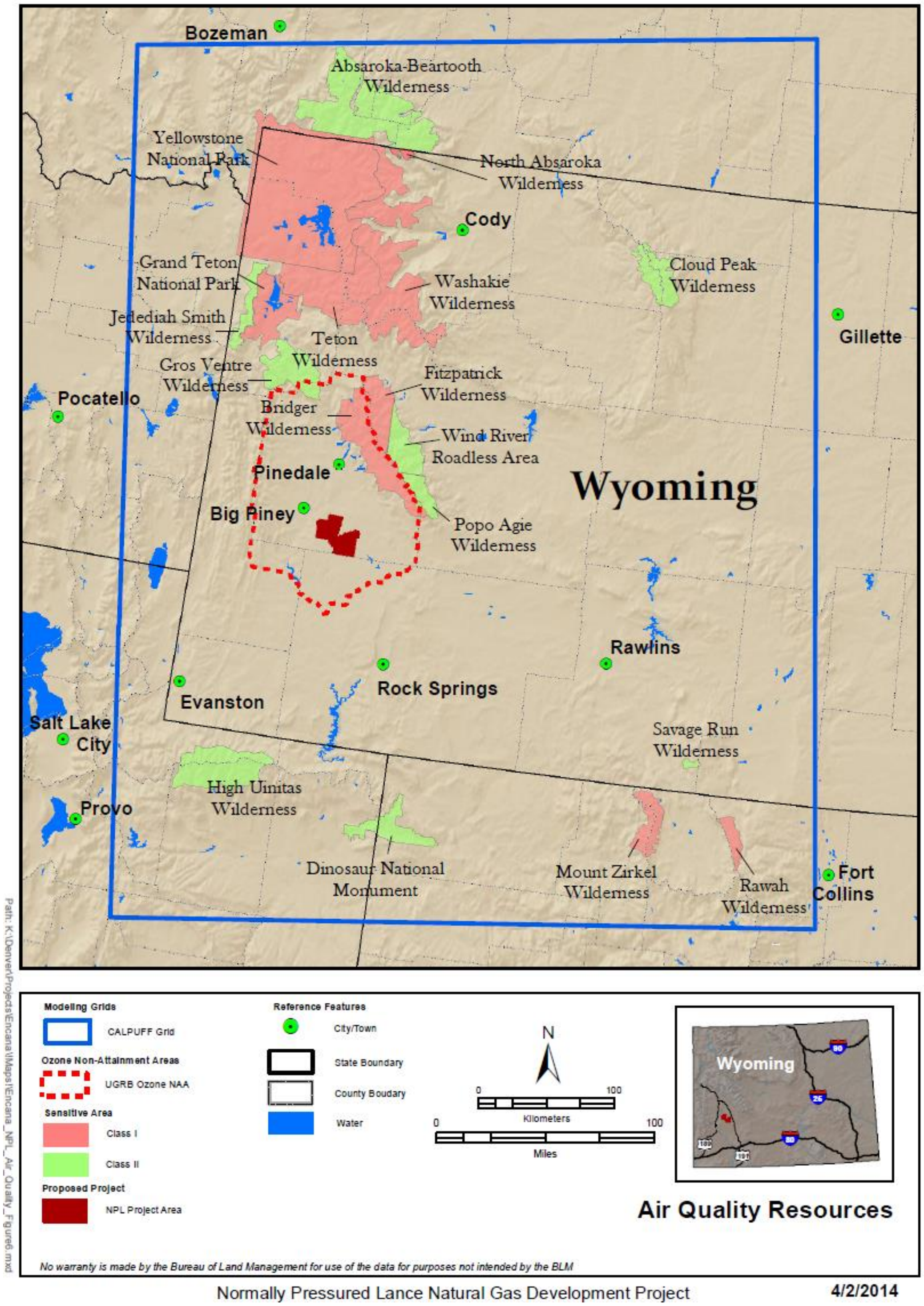
The AQRV assessment considered Class I areas and sensitive Class II areas located within the modeling domain. Key areas include:

- Bridger Wilderness Area, Wyoming (Class I)
- Fitzpatrick Wilderness Area, Wyoming (Class I)
- Yellowstone National Park, Wyoming (Class I)
- Grand Teton National Park, Wyoming (Class I)
- Teton Wilderness Area, Wyoming (Class I)
- Washakie Wilderness Area, Wyoming (Class I)

- North Absaroka Wilderness Area, Wyoming (Class I)
- Popo Agie Wilderness Area, Wyoming (Class II)
- Wind River Roadless Area, Wyoming (Class II)
- Gros Ventre Wilderness, Wyoming (Class II)
- Jedediah Smith Wilderness Area, Wyoming (Class II)
- Cloud Peak Wilderness Area, Wyoming (Class II)
- Savage Run Wilderness Area, Wyoming (Federal Class II, Wyoming Class I)
- Mount Zirkel Wilderness Area, Colorado (Class I)
- Rawah Wilderness Area, Colorado (Class I)
- Dinosaur National Monument, Colorado-Utah (Federal Class II, Colorado Class I (SO_2 only)
- High Uintas Wilderness Area, Utah (Class II)

Figure 5-1 illustrates the locations of these areas within the CALPUFF modeling domain. The map also depicts the boundaries of the designated Upper Green River Basin (UGRB) ozone nonattainment area, which encompasses the NPL Project Area. Note that the Red Rock Lakes Wilderness Area was not included in the CALPUFF modeling analysis.

Figure 5-1. Location of National Parks and Wilderness Areas within the NPL CALPUFF Modeling Domain



In addition, 17 lakes within the PSD Class I and sensitive Class II Wilderness areas are designated acid sensitive and the assessment also examined potential lake acidification from atmospheric deposition impacts for these lakes including:

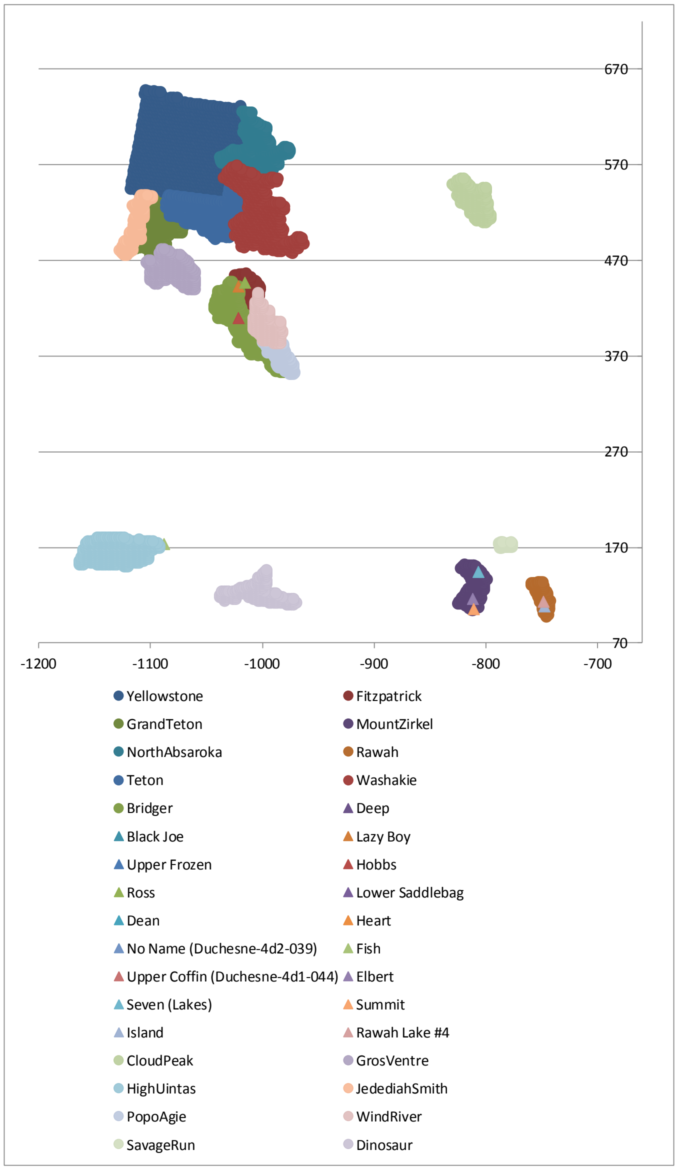
- Deep Lake in the Bridger Wilderness Area, Wyoming
- Black Joe Lake in the Bridger Wilderness Area, Wyoming
- Lazy Boy Lake in the Bridger Wilderness Area, Wyoming
- Upper Frozen Lake in the Bridger Wilderness Area, Wyoming
- Hobbs Lake in the Bridger Wilderness Area, Wyoming
- Ross Lake in the Fitzpatrick Wilderness Area, Wyoming
- Lower Saddlebag Lake in the Popo Agie Wilderness Area, Wyoming
- Dean Lake in the High Uintas Wilderness, Utah
- Heart Lake in the High Uintas Wilderness, Utah
- No Name (Duchesne – 4d2-039) Lake in the High Uintas Wilderness, Utah
- Fish Lake in the High Uintas Wilderness, Utah
- No Name (Duchesne – 4d1-044) Lake in the High Uintas Wilderness, Utah
- Lake Elbert in the Mt. Zirkel Wilderness, Colorado
- Seven Lakes in the Mt. Zirkel Wilderness, Colorado
- Summit Lake in the Mt. Zirkel Wilderness, Colorado
- Island Lake in the Rawah Wilderness, Colorado
- Rawah Lake #4 in the Rawah Wilderness, Colorado

Receptors were placed over the PSD Class I and sensitive Class II areas located within the modeling domain as listed earlier in this section. AQRV impacts were calculated for these receptors. Receptor sets available from the NPS were used as a basis for determining modeling receptors for PSD Class I areas. The complete NPS receptor set was used. For the sensitive Class II areas, receptors were placed along the boundaries and inside the sensitive area boundaries using a 1 to 2-km resolution, with a maximum of 500 receptors per area. Receptor resolution was adjusted based on the size of the area to stay within a 500 receptor maximum. Receptor elevations were estimated using U.S. Geologic Survey (USGS) Digital Elevation Model (DEM) data.

Discrete receptors were placed at the seven lakes identified as sensitive to acid deposition. Elevations for the sensitive lake receptors were derived from USGS DEM data.

The resulting total number of receptors including Class I area, sensitive Class II areas and sensitive lakes is 7,095. The receptor locations are diagramed in Figure 5-2.

Figure 5-2. Receptor Locations for Class I Areas, Sensitive Class II Areas and Sensitive Lakes within the NPL CALPUFF Modeling Domain



No of Receptors

Class I Area	*No. Rec*	
Rawah	116	
MountZirkel	253	
Fitzpatrick	316	
GrandTeton	506	
Washakie	509	
NorthAbsaroka	567	
Bridger	684	
Yellowstone	915	
Teton	940	
Total Class I	***4,806***	
Lakes Receptors	***17***	
Class II Area	***No. Rec***	***Spacing***
CloudPeak	209	2km
Dinosaur	208	2km
GrosVentre	282	2km
HighUintas	421	2km
JedediahSmith	478	1km
PopoAgie	416	1km
SavageRun	65	1km
WindRiver	193	2km
Total Class II	***2,272***	
Grand Total	**7,095**	

5.1.3 Input Preparation

Meteorological Inputs

For this study, version 3.0 of the Mesoscale Model Interface (MMIF) program (Brashers and Emery, 2013) was used to convert the WRF-derived inputs prepared for the CMAQ modeling component of the NPL air quality assessment into the meteorological input fields required by CALPUFF. MMIF is an alternative to CALMET for generating three-dimensional meteorological input fields for long-range transport assessments and air quality impact analyses. The MMIF program converts prognostic meteorological model output fields (such as those generated using the WRF model) to the parameters and formats required for direct input into the CALPUFF model.

Key parameter settings for MMIF are as follows:

- Ten model layers were employed, such that the tops of the layers are 20, 40, 80, 160, 320, 640, 1200, 2000, 3000, and 4000 meters (m) above ground level (agl). This is the default for CALPUFF.
- Stability parameters were calculated using the Golder method, in which Pasquill-Gifford stability class is based upon relationships among Monin-Obukhov lengths and surface roughness. The method is consistent with that used in AERMOD and is the default for MMIF.
- The option to recalculate planetary boundary layer (PBL) heights was not used. This is the default for MMIF.

Emission Inputs

Project-Specific Emissions

Project-specific emissions described in Section 2 were input to CALPUFF to simulate the air quality impacts from the Project. For this assessment, the modeled year coincided with the tenth year of development, which is the future year with the greatest amount of emissions from NPL sources.

Seasonal adjustment factors were applied to compensate for increased gas well-heater use in the winter months. Project emissions were modeled as area sources, allocated to the Project Area with a spatial resolution of 4 km x 4 km. The NPL emissions were represented by 56 source locations. The project-specific emissions are the same as those used for the CMAQ application and represent construction, drilling, and production emissions. The emissions were input to the model based on parameters and source types as used for CMAQ.

Regional Source Emissions

For the cumulative impacts assessment, regional sources that are expected to be operational in the future year, including permitted sources, and RFD and RFFA sources listed in Section 2, were also input to the CALPUFF model. These sources were added to the model ready emission inventory for the assessment of cumulative impacts, since they are not represented by background data.

The regional-source background emission inventory for the cumulative impacts assessment was extracted from the CMAQ emissions input data and was designed to be as similar as possible to that used for the CMAQ modeling. Source location and stack parameter data were obtained from the future-year Proposed Action CMAQ emission inventory. The emission inventory was developed using the output of SMOKE, and consisted of both point sources and area sources.

The point sources were grouped on a facility level for the larger points (i.e. more than 250 tons per year of SO_2, NO_2, and PM combined) and on a grid level for the smaller point sources. Multiple stacks within single facilities were combined into a single, representative stack. Combined stack parameters were based on the potential for the greatest long-range impacts (i.e., greater stack height, greater exhaust flow rate). After grouping of the smaller sources, the total number of point sources is 454.

Emissions from area sources including some of the oil and gas sources, all other area sources, on-road mobile sources, non-road sources, and windblown dust were allocated spatially throughout the CALPUFF domain in a similar manner to the emission inputs for CMAQ. The spatial resolution of the

CALPUFF area source groupings is 12 km x 12 km, consistent with the intermediate CMAQ modeling grid. The total number of area sources is 2,388. Further spatial grouping was not done, since total the number of sources was readily accepted by CALPUFF.

5.1.4 Background Air Quality

Ozone

Background ozone concentrations were based on hourly ozone data for the period 2008, for all EPA Air Quality System (AQS) and Clean Air Status and Trends Network (CASTNet) monitoring sites that are located within the CALPUFF modeling domain. This includes 12 AQS sites and approximately six CASTNet sites. Most of these are located in Wyoming, but there are also a few sites in both Colorado and Utah. Several of the CASTNet sites are located within the receptor areas. CALPUFF is able to utilize hourly ozone data from multiple monitoring sites. The spatial variability represented by the ozone data accommodates spatially varying ozone daytime chemical transformation rates. Only those sites with valid, hourly ozone data and sufficient data capture were used. Data for 2008 were used for consistency with the meteorological conditions.

Ammonia

Background ammonia concentrations were based on data for the Boulder monitoring site. The ammonia data consist of weekly average measurement of both gaseous (ammonia) and particulate (ammonium) and are available for the period 2007-2012. Since CALPUFF accepts a single monthly ammonia value, the weekly average measured values were used to calculate monthly averages. To avoid reliance on a single year of data, monthly averages were calculated using data for 2007-2012.

The monthly background ammonia concentrations for input to CALPUFF were based on monthly average total available ammonia, calculated using combined ammonia and ammonium measurements. Total available ammonia was defined as gaseous ammonia plus any particulate ammonium bonded with nitrate. The formation of particulate ammonium nitrate is a reversible reaction while the formation of ammonium sulfate is not a reversible reaction. Therefore, ammonium bonded to sulfate is not available for reaction with the modeled emissions and the ammonium sulfate was not included in the calculation of “total available ammonia” to be input into CALPUFF.

Table 5-1 summarizes the total available ammonia for 2007-2012 for the Boulder monitoring site. The monthly average value from this table was input to CALPUFF.

Table 5-1. Monthly Average Total Available Ammonia for the Boulder Monitoring Site, Based on Data for 2007-2012.

Calendar Month	Monthly Average Total Available Ammonia (ppb)						Recommended Monthly Average Available Ammonia (ppb)
	2007	2008	2009	2010	2011	2012	
1	0.32	0.23	0.20	0.42	0.38	0.11	0.28
2	0.24	0.22	0.30	0.25	0.22	0.26	0.25
3	0.27	0.34	0.34	0.28	0.32	0.28	0.30
4	0.29	0.12	0.44	0.24	0.18	0.32	0.26
5	0.32	0.15	0.39	0.30	0.21	0.34	0.28
6	0.24	0.40	0.62	0.50	0.35	0.54	0.44
7	0.86	1.06	0.97	0.87	0.84	1.61	1.03
8	0.98	1.34	0.94	0.60	0.57	1.25	0.95
9	0.42	0.70	0.75	0.41	0.44	0.95	0.61
10	0.17	0.33	0.26	0.28	0.18	0.39	0.27
11	0.12	0.15	0.13	0.08	0.15	0.22	0.14
12	0.23	0.13	0.31	0.25	0.24	0.12	0.21

Visibility

CALPOST (Version 6.221) was used to estimate changes in light extinction from CALPUFF model concentration results. The visibility calculation utilized CALPOST visibility Method 8 (Mode 5) for computing light extinction change in combination with Interagency Monitoring of PROtected Visual Environments (IMPROVE) data. MVISCHECK was set equal to one to ensure that the visibility parameter settings conform to recommendations of the Federal Land Managers' Air Quality Related Values Work Group (FLAG) Phase I Report—Revised 2010 (FLAG, 2010).

Method 8 uses the FLAG 2010 visibility assumptions and revised IMPROVE equation. Background extinction coefficients for each of the component visibility species were based on 1) annual average conditions and 2) 20 percent best days conditions. Results for both are reported later in this section.

Lake Chemistry

Background ANC values were based on the latest available data from the USFS. The 10^{th} percentile lowest ANC values were used to represent the background.

5.1.5 Modeling Options and Application Procedures

The application of CALPUFF followed the methods outlined in the Federal Land Manager's CALPUFF review guide (Anderson, 2011), which recommends the use of standard default values, where applicable. Chemical transformations were modeled based on the MESOPUFF II chemistry mechanism for conversion of SO_2 to sulfate (SO_4) and NO_x to nitric acid (HNO_3) and nitrate (NO_3).

Modeled pollutant species included the following gaseous and particulate species: SO_2, NO_x, and HNO_3 (gaseous species) and SO_4, NO_3, PM_{10}, and $PM_{2.5}$ (particulate species). The PM_{10} emission rate input to CALPUFF included only that portion of the PM_{10} emission rate greater than the $PM_{2.5}$ emission rate, since

$PM_{2.5}$ is modeled as a separate species. In this manner, PM_{10} was considered as coarse particulate (PMC) and $PM_{2.5}$ was considered fine particulate (PMF). Consideration of these as separate species allows the user to specify separate mass mean diameters (for deposition modeling) in CALPUFF. A mass mean diameter of 5.0 microns was used for PM_{10} and mass mean diameter of 0.48 microns was used for $PM_{2.5}$. In both cases, the standard deviation was 2.0 microns. Total PM_{10} impacts were determined in the post-processing of modeled impacts.

Additional model options included:

- Both wet and dry deposition were included (MWET = 1 and MDRY = 1).
- Dispersion was calculated using the standard Pasquill-Gifford (PG) dispersion coefficients (MDISP = 3).
- To ensure that the CALPUFF control parameters are set to current regulatory recommendations, the default override option was invoked (MREG = 1).
- For consistency with the WRF outputs, a Lambert Conformal (LCC) map projection was used.

5.1.6 Future-Year Scenarios

The CALPUFF modeling scenarios included:

- <u>Project-specific Emissions Scenario</u> – The project-specific emissions were used to evaluate and quantify project-specific air quality impacts.

- <u>Cumulative Emissions Scenario</u> – A cumulative modeling assessment was conducted that included project specific emissions as well as emissions from other sources, including Reasonably Foreseeable Development (RFD) projects in the region.

The CALPUFF input file for the project-specific emissions scenario is included as Appendix D.

5.2 Air Quality Related Values Impact Assessment

5.2.1 Visibility

CALPOST (Version 6.221) was used to estimate change in light extinction from the CALPUFF model concentration results. The visibility calculation utilized CALPOST visibility Method 8 (Mode 5) for computing light extinction change in combination with IMPROVE data. MVISCHECK was set equal to one to ensure that the visibility parameter settings conform to recommendations contained in the FLAG 2010 report.

Method 8 uses the FLAG 2010 visibility assumptions and revised IMPROVE equation. Background extinction coefficients for each of the component visibility species were based on 1) 20 percent best conditions and 2) annual average conditions.

Background values were obtained from the FLAG 2010 report (Table 5 – 20% Best Natural Conditions – Concentrations and Rayleigh Scattering by Class I Area and Table 6 – Annual Average Natural Conditions – Concentrations and Rayleigh Scattering by Class I Area). These were used along with monthly average f(RH) values, also obtained from the FLAG 2010 report (Table 7 - Monthly f(RH) – Large $(NH_4)^2$ SO_4 and

NH_4NO_3 Relative Humidity Adjustment Factor), to estimate background light extinction for all Class I areas (IMPROVE data sites).

Natural conditions for all Class I areas are provided in the FLAG tables. The natural condition values are based on IMPROVE data, which are used directly for Class I areas with IMPROVE monitoring sites (Bridger Wilderness and Mount Zirkel Wilderness) as well as for nearby Class I areas that do not have monitoring sites, in accordance with EPA guidance for tracking progress under the Regional Haze Rule (RHR) (EPA, 2003). For sensitive Class II areas, values from the closest or most climatically similar Class I area were used.

The visibility assessment focused on all receptors in a Class I or sensitive Class II area within the study region. Estimated visibility degradation was calculated for each Class I and sensitive Class II area within the CALPUFF modeling domain. For each receptor within each Class I and sensitive Class II area the maximum and 98th percentile change in extinction coefficient (b_{ext}) was identified. The overall maximum for each area and each metric was then used to quantify visibility impacts, in terms of the percent change that these impacts represent relative to natural background. Using an estimated annual natural background value (since f(rh) values vary by month, natural background also varies by month), the b_{ext} values were also converted to deciview haze index, defined as equal to 10 $\ln(b_{ext}/10)$, and the change in deciviews (dv) associated with the maximum and 98th percentile impacts was also calculated.

A 5 percent change in light extinction (approximately equal to 0.5 dv) is the threshold recommended in FLAG 2010 and is considered to contribute to regional haze visibility impairment. A 10 percent change in light extinction (approximately equal to 1.0 dv) is considered to cause visibility impairment when compared to background conditions. Thus the number of days that exceed the 5 and 10 percent thresholds was also obtained.

Project-Specific Emissions Scenario

Tables 5-2 and 5-3 summarize visibility change for the Class I and Class II areas within the CALPUFF modeling domain for the NPL-only or project-specific emissions scenario. In Table 5-2 (a) and (b), the results are presented relative to annual average natural background. In Table 5-3 (a) and (b), the results are presented relative to natural background for the 20 percent best visibility days.

Table 5-2a. CALPUFF-Derived Visibility Impacts for the Proposed Action Based on Annual Average Natural Background: Class I Areas

Class I Area	State	Natural Visibility b_{ext} (Mm^{-1})*	98th Percentile Impact		Maximum Impact		# Days >5% Change	# Days >10% Change
			% Change in b_{ext}	Δ dv	% Change in b_{ext}	Δ dv		
Bridger WA	WY	15.02	4.09	0.40	4.80	0.47	0	0
Fitzpatrick WA	WY	15.02	2.77	0.27	3.62	0.36	0	0
Grand Teton NP	WY	15.03	0.37	0.04	0.40	0.04	0	0
North Absaroka WA	WY	15.02	0.30	0.03	0.32	0.03	0	0
Teton WA	WY	15.03	3.97	0.39	4.54	0.44	0	0
Washakie WA	WY	15.02	2.48	0.24	2.87	0.28	0	0
Yellowstone NP	WY	15.03	0.26	0.03	0.32	0.03	0	0
Mt. Zirkel NP	CO	15.01	1.93	0.19	2.18	0.22	0	0
Rawah WA	CO	15.01	0.18	0.02	0.20	0.02	0	0

*Estimated using EPA (2003) method and annual average f(RH) values.

Table 5-2b. CALPUFF-Derived Visibility Impacts for the Proposed Action Based on Annual Average Natural Background: Sensitive Class II Areas

Sensitive Class II Area	State	Natural Visibility b_{ext} (Mm^{-1})	98th Percentile Impact		Maximum Impact		# Days >5% Change	# Days >10% Change
			% Change in b_{ext}	Δ dv	% Change in b_{ext}	Δ dv		
Cloud Peak WA	WY	15.02	0.16	0.02	0.16	0.02	0	0
Gros Ventre WA	WY	15.03	3.23	0.32	4.75	0.46	0	0
Jedediah Smith WA	WY	15.03	0.36	0.04	0.37	0.04	0	0
Popo Agie WA	WY	15.02	3.56	0.35	4.68	0.46	0	0
Savage Run WA	WY	15.01	0.36	0.04	0.39	0.04	0	0
Wind River RA	WY	15.02	1.16	0.11	1.17	0.12	0	0
Dinosaur NP	CO	15.01	0.29	0.03	0.29	0.03	0	0
High Uintas WA	UT	15.01	0.38	0.04	0.40	0.04	0	0

*Estimated using EPA (2003) method and annual average f(RH) values.

Table 5-3a. CALPUFF-Derived Visibility Impacts for the Proposed Action Based on 20 Percent Best Days Natural Background: Class I Areas

Class I Area	State	Natural Visibility b_{ext} (Mm^{-1})*	98th Percentile Impact		Maximum Impact		# Days >5% Change	# Days >10% Change
			% Change in b_{ext}	Δ dv	% Change in b_{ext}	Δ dv		
Bridger WA	WY	11.63	5.47	0.53	6.41	0.62	3	0
Fitzpatrick WA	WY	11.63	3.66	0.36	4.78	0.47	0	0
Grand Teton NP	WY	11.64	0.61	0.06	0.66	0.07	0	0
North Absaroka WA	WY	11.63	0.40	0.04	0.42	0.04	0	0
Teton WA	WY	11.64	6.51	0.63	7.44	0.72	1	0
Washakie WA	WY	11.63	3.29	0.32	3.81	0.37	0	0
Yellowstone NP	WY	11.64	0.26	0.03	0.53	0.05	0	0
Mt. Zirkel NP	CO	11.62	2.66	0.26	3.01	0.30	0	0
Rawah WA	CO	11.62	0.26	0.03	0.27	0.03	0	0

*Estimated using EPA (2003) method and annual average f(RH) values.

Table 5-3b. CALPUFF-Derived Visibility Impacts for the Proposed Action Based on 20 Percent Best Days Natural Background: Sensitive Class II Areas

Sensitive Class II Area	State	Natural Visibility b_{ext} (Mm^{-1})	98th Percentile Impact		Maximum Impact		# Days >5% Change	# Days >10% Change
			% Change in b_{ext}	Δ dv	% Change in b_{ext}	Δ dv		
Cloud Peak WA	WY	11.63	0.21	0.02	0.22	0.02	0	0
Gros Ventre WA	WY	11.64	5.30	0.52	7.79	0.75	1	0
Jedediah Smith WA	WY	11.64	0.59	0.06	0.61	0.06	0	0
Popo Agie WA	WY	11.63	4.76	0.46	6.25	0.61	1	0
Savage Run WA	WY	11.62	0.50	0.05	0.53	0.05	0	0
Wind River RA	WY	11.63	1.54	0.15	1.57	0.16	0	0
Dinosaur NP	CO	11.62	0.40	0.04	0.40	0.04	0	0
High Uintas WA	UT	11.62	0.53	0.05	0.55	0.05	0	0

*Estimated using EPA (2003) method and annual average f(RH) values.

Relative to annual average natural background (Table 5-2), the largest 98th percentile impact is 0.4 dv, for the Bridger Wilderness Area. Maximum impacts are slightly larger, but there are no days for any of the areas for which a greater than 5 percent change in light extinction (a greater than 0.5 dv impact) is modeled.

Relative to natural background for the 20% best visibility days (Table 5-3), the largest 98th percentile impact is 0.63 dv, for the Teton Wilderness Area. This is followed by 0.53 and 0.52 for Bridger and Gros Ventre Wilderness Areas, respectively. Maximum impacts indicate that there are three days for Bridger and one day each for the Teton, Gros Ventre, and Popo Agie Wilderness Areas for which a greater than 5 percent change in light extinction (a greater than 0.5 dv impact) is modeled. There are no days/receptors for which a greater than 10 percent change in light extinction is modeled.

Cumulative Emissions Scenario

Tables 5-4 and 5-5 summarize visibility change for the Class I and Class II areas within the CALPUFF modeling domain for the cumulative emissions scenario. In Table 5-4 (a) and (b), the results are presented relative to annual average natural background. In Table 5-5 (a) and (b), the results are presented relative to natural background for the 20 percent best visibility days.

Table 5-4a. CALPUFF-Derived Visibility Impacts for the Cumulative Emissions Scenario Based on Annual Average Natural Background: Class I Areas

Class I Area	State	Natural Visibility b_{ext} (Mm^{-1})*	98th Percentile Cumulative Impact		Maximum Cumulative Impact	
			% Change in b_{ext}	Δ dv	% Change in b_{ext}	Δ dv
Bridger WA	WY	15.02	109	7.36	117	7.78
Fitzpatrick WA	WY	15.02	51.4	4.15	56.5	4.48
Grand Teton NP	WY	15.03	32.7	2.83	36.1	3.08
North Absaroka WA	WY	15.02	31.5	2.74	32.4	2.81
Teton WA	WY	15.03	26.6	2.36	27.1	2.40
Washakie WA	WY	15.02	54.1	4.33	57.2	4.52
Yellowstone NP	WY	15.03	23.2	2.09	26.8	2.37
Mt. Zirkel NP	CO	15.01	109	7.38	123.2	8.03
Rawah WA	CO	15.01	587	19.3	727.8	21.1

*Estimated using EPA (2003) method and annual average f(RH) values.

Table 5-4b. CALPUFF-Derived Visibility Impacts for the Cumulative Emissions Scenario Based on Annual Average Natural Background: Sensitive Class II Areas

Sensitive Class II Area	State	Natural Visibility b_{ext} (Mm^{-1})	98th Percentile Cumulative Impact		Maximum Cumulative Impact	
			% Change in b_{ext}	Δ dv	% Change in b_{ext}	Δ dv
Cloud Peak WA	WY	15.02	36.9	3.14	37.6	3.19
Gros Ventre WA	WY	15.03	59.4	4.66	71.5	5.39
Jedediah Smith WA	WY	15.03	71.5	5.39	77.7	5.75
Popo Agie WA	WY	15.02	68.4	5.21	69.8	5.30
Savage Run WA	WY	15.01	46.9	3.84	47.3	3.87
Wind River RA	WY	15.02	46.7	3.83	47.9	3.92
Dinosaur NP	CO	15.01	98.3	6.85	114	7.61
High Uintas WA	UT	15.01	37.5	3.19	39.4	3.32

*Estimated using EPA (2003) method and annual average f(RH) values.

Table 5-5a. CALPUFF-Derived Visibility Impacts for the Cumulative Emissions Scenario Based on 20 Percent Best Days Natural Background: Class I Areas

Class I Area	State	Natural Visibility b_{ext} (Mm^{-1})*	98th Percentile Cumulative Impact		Maximum Cumulative Impact	
			% Change in b_{ext}	Δ dv	% Change in b_{ext}	Δ dv
Bridger WA	WY	11.63	146	9.02	158	9.49
Fitzpatrick WA	WY	11.63	69.3	5.26	76.1	5.66
Grand Teton NP	WY	11.64	53.8	4.31	59.4	4.66
North Absaroka WA	WY	11.63	42.4	3.54	43.7	3.63
Teton WA	WY	11.64	43.7	3.62	44.6	3.68
Washakie WA	WY	11.63	72.9	5.48	77.1	5.71
Yellowstone NP	WY	11.64	38.3	3.24	44.1	3.65
Mt. Zirkel NP	CO	11.62	151	9.19	170	149
Rawah WA	CO	11.62	812	22.1	1007	810

*Estimated using EPA (2003) method and annual average f(RH) values.

Table 5-5b. CALPUFF-Derived Visibility Impacts for the Cumulative Emissions Scenario Based on 20 Percent Best Days Natural Background: Sensitive Class II Areas

Sensitive Class II Area	State	Natural Visibility b_{ext} (Mm^{-1})	98th Percentile Cumulative Impact		Maximum Cumulative Impact	
			% Change in b_{ext}	Δ dv	% Change in b_{ext}	Δ dv
Cloud Peak WA	WY	11.63	49.4	4.02	50.3	4.07
Gros Ventre WA	WY	11.64	97.9	6.83	118	7.78
Jedediah Smith WA	WY	11.64	117.8	7.78	128	8.24
Popo Agie WA	WY	11.63	91.8	6.51	93.7	6.61
Savage Run WA	WY	11.62	64.6	4.98	65.2	63.1
Wind River RA	WY	11.63	62.9	4.88	64.5	4.98
Dinosaur NP	CO	11.62	135	8.56	157	134
High Uintas WA	UT	11.62	51.7	4.17	54.3	50.2

*Estimated using EPA (2003) method and annual average f(RH) values.

As expected, the cumulative contribution from all sources to visibility at the Class I and Class II areas is significant. Relative to annual average natural background (Table 5-4), the largest 98th percentile impacts range from 2.1 (Yellowstone National Park) to approximately 7.4 dv (Mt. Zirkel and Bridger Wilderness Areas), with one exception. The impact from all sources for the Rawah Wilderness Area is 19 dv. The results for Rawah do not seem plausible. One possible explanation is that the area is impacted by a nearby source. However, this same result does not occur with CMAQ.

Relative to natural background for the 20 percent best visibility days (Table 5-5), the largest 98^{th} percentile impacts range from 3.2 dv (Yellowstone National Park) to around 9 dv (Bridger and Mt. Zirkel Wilderness Area and Dinosaur National Monument). Again the results for Rawah are extremely large and seemingly questionable.

One of the purposes of the cumulative emissions simulation is to put the project specific impacts into some perspective, relative to that from all sources. The CALPUFF-derived project-specific impacts are greatest for the Bridger and Teton Wilderness areas. For the Bridger Wilderness Area, using annual average natural background, the 98^{th} percentile project-specific impact is 0.4 dv compared to the cumulative source impact of 7.4 dv. Using the 20% best days natural background, the project-specific impact is 0.5 dv compared to the cumulative source impact of 9 dv. For the Teton Wilderness Area, using annual average natural background, the 98^{th} percentile project specific impact is 0.4 dv compared to the cumulative source impact of 2.3 dv. Using the 20% best days natural background, the project specific impact is 0.6 dv compared to the cumulative source impact of 3.6 dv.

5.2.2 Atmospheric Deposition

Project-specific and cumulative nitrogen and sulfur deposition impacts were examined for Class I areas and identified sensitive Class II areas within the project study area. CALPUFF-derived annual wet, dry, and total (wet plus dry) deposition fluxes of total S and N compounds were used to estimate the total S and N deposition fluxes over the Class I and sensitive Class II areas within the CALPUFF modeling domain Both average (averaged over all receptors that comprise the area) and maximum (at any receptor in the area) fluxes were calculated.

POSTUTIL was used to process the CALPUFF deposition output. The following species and scaling factors based on Anderson (2011) were applied in POSTUTIL to calculate total sulfur and total nitrogen deposition.

Sulfur: SO_2 (0.5), SO_4 (0.33)

Nitrogen: SO_4 (0.29167), NO_x (0.30435), HNO_3 (0.22222), NO_3 (0.45161)

The scaling factors are based on the molecular weight of sulfur or nitrogen to the molecular weight of the compound modeled by CALPUFF.

Project-Specific Emissions Scenario

The CALPUFF-derived project-specific deposition amounts are presented in Table 5-6 (a) and (b). The project specific impacts for each species are compared with the corresponding deposition analysis threshold (DAT) developed by the National Park Service and the Fish and Wildlife Service. The DATs represent values for nitrogen and sulfur deposition from project-specific emission sources below which estimated impacts are considered negligible. The DAT established for both nitrogen and sulfur in western Class I areas is 0.005 kilograms per hectare per year (kg/ha/yr).

Table 5-6a. CALPUFF-Derived Project Specific Sulfur and Nitrogen Deposition Impacts (kg/ha/yr): Class I Areas

Class I Area	State	Average Deposition due to Proposed Action (kg/ha/yr)		Maximum Deposition due to Proposed Action (kg/ha/yr)	
		Sulfur	Nitrogen	Sulfur	Nitrogen
Bridger WA	WY	0.000	0.001	0.000	0.002
Fitzpatrick WA	WY	0.000	0.001	0.000	0.001
Grand Teton NP	WY	0.000	0.000	0.000	0.000
North Absaroka WA	WY	0.000	0.000	0.000	0.000
Teton WA	WY	0.000	0.000	0.000	0.000
Washakie WA	WY	0.000	0.000	0.000	0.000
Yellowstone NP	WY	0.000	0.000	0.000	0.000
Mt. Zirkel NP	CO	0.000	0.000	0.000	0.000
Rawah WA	CO	0.000	0.000	0.000	0.000
DAT		**0.005**	**0.005**	**0.005**	**0.005**

Table 5-6b. CALPUFF-Derived Project Specific Sulfur and Nitrogen Deposition Impacts (kg/ha/yr): Sensitive Class II Areas

Sensitive Class II Area	State	Average Deposition due to Proposed Action (kg/ha/yr)		Maximum Deposition due to Proposed Action (kg/ha/yr)	
		Sulfur	Nitrogen	Sulfur	Nitrogen
Cloud Peak WA	WY	0.000	0.000	0.000	0.000
Gros Ventre WA	WY	0.000	0.000	0.000	0.001
Jedediah Smith WA	WY	0.000	0.000	0.000	0.000
Popo Agie WA	WY	0.000	0.001	0.000	0.002
Savage Run WA	WY	0.000	0.000	0.000	0.000
Wind River RA	WY	0.000	0.001	0.000	0.001
Dinosaur NP	WY	0.000	0.000	0.000	0.000
High Uintas WA	CO	0.000	0.000	0.000	0.000
DAT		**0.005**	**0.005**	**0.005**	**0.005**

For both sulfur and nitrogen, the simulated change in deposition due to the Proposed Action does not exceed the DAT of 0.005 kg/ha/yr for any area. Average impacts of 0.001 kg/ha/yr and maximum impacts on the order of 0.001 to 0.002 kg/ha/yr are simulated for nitrogen for several areas including the Bridger, Fitzpatrick and Popo Agie Wilderness Areas and the Wind River Roadless Area.

Cumulative Emissions Scenario

The CALPUFF-derived cumulative deposition amounts are presented in Table 5-7 (a) and (b). Cumulative modeled deposition amounts are also compared to critical load thresholds to assess total deposition impacts. In this study, deposition results are compared to critical load thresholds established for the Rocky Mountain region. The critical load thresholds are: 3 kg/ha/yr for total S deposition and 2.2 kg/ha/yr for total N deposition. Deposition amounts that exceed the critical load values are highlighted in bold.

Table 5-7a. CALPUFF-Derived Cumulative Sulfur and Nitrogen Deposition Impacts (kg/ha/yr): Class I Areas

Class I Area	State	Average Cumulative Deposition (kg/ha/yr)		Maximum Cumulative Deposition (kg/ha/yr)	
		Sulfur	Nitrogen	Sulfur	Nitrogen
Bridger WA	WY	0.039	0.107	0.059	0.211
Fitzpatrick WA	WY	0.033	0.080	0.038	0.103
Grand Teton NP	WY	0.034	0.091	0.137	0.687
North Absaroka WA	WY	0.018	0.044	0.035	0.134
Teton WA	WY	0.022	0.053	0.031	0.262
Washakie WA	WY	0.028	0.048	0.508	0.151
Yellowstone NP	WY	0.016	0.041	0.031	0.394
Mt. Zirkel NP	CO	0.095	0.341	0.181	1.060
Rawah WA	CO	0.059	0.451	0.090	**3.942**
Critical Load Threshold		**3.0**	**2.2**	**3.0**	**2.2**

Table 5-7b. CALPUFF-Derived Project Specific Sulfur and Nitrogen Deposition Impacts (kg/ha/yr): Sensitive Class II Areas

Sensitive Class II Area	State	Average Cumulative Deposition (kg/ha/yr)		Maximum Cumulative Deposition (kg/ha/yr)	
		Sulfur	Nitrogen	Sulfur	Nitrogen
Cloud Peak WA	WY	0.049	0.085	0.061	0.128
Gros Ventre WA	WY	0.032	0.115	0.060	0.691
Jedediah Smith WA	WY	0.052	0.113	0.382	0.732
Popo Agie WA	WY	0.056	0.132	0.065	0.157
Savage Run WA	WY	0.073	0.203	0.076	0.215
Wind River RA	WY	0.044	0.108	0.057	0.274
Dinosaur NP	WY	0.038	0.106	0.045	0.287
High Uintas WA	CO	0.010	0.049	0.018	0.902
Critical Load Threshold		**3.0**	**2.2**	**3.0**	**2.2**

For sulfur, both the average and maximum simulated cumulative deposition amounts are less than the critical load threshold of 3.0 kg/ha/yr for all areas.

For nitrogen, the maximum simulated cumulative deposition amount is greater than the critical load threshold of 2.2 kg/ha/yr for one area (Rawah Wilderness).

5.2.3 Lake Chemistry

POSTUTIL was also used to process the CALPUFF deposition output for use in the ANC calculations. The following species and scaling factors were applied in POSTUTIL to calculate total sulfur and total nitrogen deposition as used in the ANC calculations.

Sulfur: SO_2 (0.5), SO_4 (0.33)

Nitrogen: NO_x (0.30435), HNO_3 (0.22222), NO_3 (0.22581)

The scaling factors used for the ANC calculations for some species differ from those used for the deposition calculations in Sec. 5.2.2 because the nitrogen mass from ammonium is not included in the nitrogen total for the ANC calculations. Ammonium acts to neutralize acid, so inclusion of the ammonium mass in the ANC calculations would overstate the potential for acidification due to deposition. The above factors used for the ANC calculations are consistent with those recommended in the IWAQM-Phase2 report (IWAQM, 1998). The USFS recommendations (USFS, 2000) refer the reader to the factors in the IWAQM-Phase2 report for use in the ANC calculations.

CALPUFF-derived impacts to lake chemistry were also calculated using the USFS procedure for estimated potential changes in ANC (as presented in Section 4.3.3). Background ANC data for this analysis was provided by the NPS.

Project-Specific Emissions Scenario

The change in water chemistry associated with atmospheric deposition from project sources was calculated for 17 acid sensitive lakes located within CALPUFF domain. The CALPUFF-derived changes in ANC due to the Proposed Action, along with several of the key terms in the calculation, are presented in Table 5-8. The 10th percentile ANC values and the number of samples used in the calculation of the 10th percentile lowest ANC values are also provided in the table. Values that exceed ANC change thresholds are highlighted in bold.

Table 5-8. CALPUFF-Derived Change in ANC for Sensitive Lakes: Project-Specific Emissions

Class I/ Class II Area	Lake	Lat (deg)	Lon (deg)	10th Percentile Lowest ANC Value (μeq/l) (A)	No. of Samples	Precip-itation (m) (P)	ΔS Deposition (eq/m2/yr) (Hs)	ΔN Deposition (eq/m2/yr) (Hn)	Total S + N Dep (eq) (Hdep)	ANC(o) (eq)	% Change in ANC	Delta ANC (μeq/l)
Bridger	Deep	42.719	-109.171	61.1	62	0.28	4.52E-07	7.30E-06	0.08	112.61	0.07	0.04
Bridger	Black Joe	42.739	-109.171	70.6	72	0.28	4.44E-07	7.14E-06	0.08	130.12	0.06	0.04
Bridger	Lazy Boy	43.333	-109.73	27.8	1	0.28	1.12E-07	1.88E-06	0.02	51.24	0.04	0.01
Bridger	Upper Frozen	42.687	-109.161	13.2	3	0.28	4.25E-07	6.65E-06	0.07	24.33	0.29	0.04
Bridger	Hobbs	43.036	-109.672	69.8	76	0.28	2.02E-07	3.34E-06	0.04	128.64	0.03	0.02
Fitzpatrick	Ross	43.378	-109.658	54	55	0.23	1.06E-07	1.75E-06	0.02	81.97	0.02	0.01
Popo Agie	Lower Saddlebag	42.623	-108.994	55.5	54	0.34	3.90E-07	5.96E-06	0.06	126.00	0.05	0.03
High Uintas	Dean	40.679	-110.761	51.4	7	0.45	8.12E-09	1.67E-07	0.00	154.30	0.00	0.00
High Uintas	Heart	40.594	-110.811	54.6	1	0.45	6.58E-09	1.27E-07	0.00	163.91	0.00	0.00
High Uintas	No Name (Duchesne – 4d2-039)	40.671	-110.275	65.2	3	0.45	1.30E-08	2.37E-07	0.00	195.73	0.00	0.00
High Uintas	Fish	40.837	-110.069	104.5	6	0.45	2.20E-08	4.08E-07	0.00	313.71	0.00	0.00
High Uintas	Upper Coffin (Duchesne – 4d1-044)	40.834	-110.237	65	2	0.60	1.87E-08	3.69E-07	0.00	262.38	0.00	0.00

Class I/ Class II Area	Lake	Lat (deg)	Lon (deg)	10th Percentile Lowest ANC Value (µeq/l) (A)	No. of Samples	Precip-itation (m) (P)	ΔS Deposition (eq/m2/yr) (Hs)	ΔN Deposition (eq/m2/yr) (Hn)	Total S + N Dep (eq) (Hdep)	ANC(o) (eq)	% Change in ANC	Delta ANC (µeq/l)
Mt. Zirkel	Elbert	40.634	-106.707	53.8	68	0.60	5.69E-08	1.11E-06	0.01	217.17	0.01	0.00
Mt. Zirkel	Seven (Lakes)	40.896	-106.682	36.4	67	0.60	8.85E-08	1.54E-06	0.02	146.93	0.01	0.00
Mt. Zirkel	Summit	40.545	-106.683	48	110	0.60	4.94E-08	9.96E-07	0.01	193.35	0.01	0.00
Rawah	Island	40.627	-105.942	71.9	25	0.60	6.32E-08	9.67E-07	0.01	289.62	0.00	0.00
Rawah	Rawah Lake #4	40.671	-105.958	41.5	24	0.60	6.76E-08	1.02E-06	0.01	167.17	0.01	0.00

Deposition is greatest for the lakes in the Bridger Wilderness Area. Simulated changes in ANC were compared with the applicable threshold for each identified lake: 10 percent change in ANC for lakes with background ANC values greater than 25 micro equivalents per liter [μeq/L], and less than a 1 μeq/L change in ANC for lakes with background ANC values equal to or less than 25 μeq/L. Of the 17 lakes listed in Table 5-8, only Upper Frozen Lake is considered to be extremely sensitive to atmospheric deposition by the USFS since the background ANC is less than 25 μeq/L. The percent change in ANC is less than 10 percent for all lakes considered. The change in ANC for Upper Frozen Lake is 0.04 μeq/L and is less than the 1 μeq/L threshold.

Cumulative Emissions Scenario

The CALPUFF-derived change in ANC due to cumulative emissions is presented in Table 5-9. Values that exceed ANC change thresholds are highlighted in bold.

Table 5-9. CALPUFF-Derived Change in ANC for Sensitive Lakes: Cumulative Emissions

Class I/ Class II Area	Lake	Lat (deg)	Lon (deg)	10th Percentile Lowest ANC Value (µeq/l) (A)	No. of Samples	Precip-itation (m) (P)	Total S Deposition (eq/m2/yr) (Hs)	N Deposition (eq/m2/yr) (Hn)	Total S + N Dep (eq) (Hdep)	ANC(o) (eq)	% Change in ANC	Delta ANC (µeq/l)
Bridger	Deep	42.719	-109.171	61.1	62	0.28	3.45E-04	5.62E-04	9.08	112.61	8.06	4.93
Bridger	Black Joe	42.739	-109.171	70.6	72	0.28	3.45E-04	5.51E-04	8.96	130.12	6.89	4.86
Bridger	Lazy Boy	43.333	-109.73	27.8	1	0.28	1.84E-04	2.66E-04	4.50	51.24	8.78	2.44
Bridger	Upper Frozen	42.687	-109.161	13.2	3	0.28	3.49E-04	5.79E-04	9.28	24.33	**38.14**	**5.03**
Bridger	Hobbs	43.036	-109.672	69.8	76	0.28	2.08E-04	3.56E-04	5.64	128.64	4.38	3.06
Fitzpatrick	Ross	43.378	-109.658	54	55	0.23	1.94E-04	2.65E-04	4.59	81.97	5.60	3.02
Popo Agie	Lower Saddlebag	42.623	-108.994	55.5	54	0.34	3.81E-04	5.59E-04	9.39	126.00	7.45	4.14
High Uintas	Dean	40.679	-110.761	51.4	7	0.45	4.03E-05	1.03E-04	1.43	154.30	0.93	0.48
High Uintas	Heart	40.594	-110.811	54.6	1	0.45	3.97E-05	9.84E-05	1.38	163.91	0.84	0.46
High Uintas	No Name (Duchesne – 4d2-039)	40.671	-110.275	65.2	3	0.45	7.60E-05	2.41E-04	3.17	195.73	1.62	1.05
High Uintas	Fish	40.837	-110.069	104.5	6	0.45	1.21E-04	3.02E-04	4.24	313.71	1.35	1.41
High Uintas	Upper Coffin (Duchesne – 4d1-044)	40.834	-110.237	65	2	0.60	9.18E-05	2.34E-04	3.26	262.38	1.24	0.81

Class I/ Class II Area	Lake	Lat (deg)	Lon (deg)	10th Percentile Lowest ANC Value (µeq/l) (A)	No. of Samples	Precip-itation (m) (P)	Total S Deposition (eq/m2/yr) (Hs)	N Deposition (eq/m2/yr) (Hn)	Total S + N Dep (eq) (Hdep)	ANC(o) (eq)	% Change in ANC	Delta ANC (µeq/l)
Mt. Zirkel	Elbert	40.634	-106.707	53.8	68	0.60	4.89E-04	1.01E-03	14.98	217.17	6.90	3.71
Mt. Zirkel	Seven (Lakes)	40.896	-106.682	36.4	67	0.60	5.11E-04	1.05E-03	15.65	146.93	**10.65**	3.88
Mt. ZIrkel	Summit	40.545	-106.683	48	110	0.60	5.16E-04	1.07E-03	15.90	193.35	8.22	3.95
Rawah	Island	40.627	-105.942	71.9	25	0.60	3.19E-04	6.61E-04	9.80	289.62	3.38	2.43
Rawah	Rawah Lake #4	40.671	-105.958	41.5	24	0.60	3.34E-04	6.91E-04	10.25	167.17	6.13	2.55

For the cumulative emissions scenario, the percent change in ANC ranges from less than one to 38 percent. For two of the lakes (Seven Lakes and Upper Frozen Lake), the change is greater than 10 percent. The greatest percentage change is for Upper Frozen Lake and represents a change in ANC of 5.0 μeq/L. Thus, the contribution from regional emissions to ANC is significant.

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APPENDIX A: SAMPLE AERMOD INPUT FILES AND EMISSION SUMMARIES

Example AERMOD Input File for the Drilling Scenario (PM10)

```
**BEE-Line Software: BEEST for Windows (Version 10.06) data input file
**  Model: AERMOD.EXE     Input File Creation Date: 7/31/2013  Time: 11:19:31 AM
NO ECHO

CO STARTING
CO TITLEONE NPL Drilling and Completion Scenario PM10 Concentrations
CO TITLETWO 200 x 200m Well Pads
CO MODELOPT DFAULT CONC
CO AVERTIME 24 ANNUAL
CO POLLUTID PM10
CO RUNORNOT RUN
CO FINISHED

SO STARTING
SO ELEVUNIT METERS
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SO SRCPARAM P1_21_3516G 0.0085221 4.34 628.71 10.82 0.24
SO LOCATION P1_21_C27 POINT 594797. 4691890. 2160.12
SO SRCPARAM P1_21_C27 0.0066663 4.34 723.15 10.82 0.24
SO LOCATION P1_21_BOILER POINT 594797. 4691890. 2160.12
SO SRCPARAM P1_21_BOILER 0.0018123 2.23 447.04 2.25 0.39
SO LOCATION P3_21_3516G POINT 594797. 4691290. 2155.2
SO SRCPARAM P3_21_3516G 0.0085221 4.34 628.71 10.82 0.24
SO LOCATION P3_21_C27 POINT 594797. 4691290. 2155.2
SO SRCPARAM P3_21_C27 0.0066663 4.34 723.15 10.82 0.24
SO LOCATION P3_21_BOILER POINT 594797. 4691290. 2155.2
SO SRCPARAM P3_21_BOILER 0.0018123 2.23 447.04 2.25 0.39
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SO SRCPARAM P2_22_OTHER 0.064787 3.89 547.59 10.34 0.2
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SO SRCPARAM P2_22_CUM 0.0065801 3.89 547.59 73.5 0.08
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SO SRCPARAM P2_22_WIREL 0.0032848 2.59 838.71 9.24 0.2
SO LOCATION P2_22_CRANE POINT 595397. 4691890. 2159.22
SO SRCPARAM P2_22_CRANE 9.4141E-05 2.59 838.71 9.24 0.2
SO LOCATION P2_22_HEATER POINT 595397. 4691890. 2159.22
SO SRCPARAM P2_22_HEATER 0.024198 2.59 866.48 2.85 0.2
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SO LOCATION P4_22_CUM POINT 595397. 4691290. 2158.01
SO SRCPARAM P4_22_CUM 0.0065801 3.89 547.59 73.5 0.08
SO LOCATION P4_22_WIREL POINT 595397. 4691290. 2158.01
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RE DISCCART 597197.0 4694440.0 2163. 2163.

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RE DISCCART 597697.0 4694440.0 2150.36 2150.36
RE DISCCART 597947.0 4694440.0 2148.38 2148.38
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ME PROFFILE "C:\Project_files\npl\aermod\metdata\NPL_2006_11325_1MIN-ASOS_ADJ.PFL"
ME SURFDATA  24164 2006
ME UAIRDATA  24061 2006
ME PROFBASE 2124. METERS
ME FINISHED

OU STARTING
OU RECTABLE 24 SECOND
OU PLOTFILE 24 ALL SECOND "C:\Project_files\npl\aermod\drill\PM10\npl_200m_driling_PM10_2006.GRF" 31
OU PLOTFILE ANNUAL ALL "C:\Project_files\npl\aermod\drill\PM10\npl_200m_driling_PM10_2006.GRF" 31
OU SUMMFILE "C:\Project_files\npl\aermod\drill\PM10\npl_200m_driling_PM10_2006.SUM"
OU FINISHED
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Example AERMOD Input File for the Drilling Scenario (NO2)

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**BEE-Line Software: BEEST for Windows (Version 10.06) data input file
**  Model: AERMOD.EXE     Input File Creation Date: 9/11/2014  Time: 7:38:41 PM
NO ECHO

CO STARTING
CO TITLEONE NPL Drilling and Completion Scenario NO2 Concentrations - 1 Hour and Annual with OLM GROUPALL
CO TITLETWO 200 x 200m Well Pad
CO MODELOPT CONC OLM
CO AVERTIME 1 ANNUAL
CO POLLUTID NO2
CO RUNORNOT RUN
CO OZONEFIL "C:\Project_files\npl\aermod\ozone_data\boulder_ozone_hourly_2006.txt" PPB
CO NO2STACK 0.1
CO NO2EQUIL 0.9
CO FINISHED

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SO LOCATION P1_21_C27 POINT 594797. 4691890. 2160.12
SO SRCPARAM P1_21_C27 0.13147 4.34 723.15 10.82 0.24
SO LOCATION P1_21_BOILER POINT 594797. 4691890. 2160.12
SO SRCPARAM P1_21_BOILER 0.024466 2.23 447.04 2.25 0.39
SO LOCATION P3_21_3516G POINT 594797. 4691290. 2155.2
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SO LOCATION P3_21_C27 POINT 594797. 4691290. 2155.2
SO SRCPARAM P3_21_C27 0.13147 4.34 723.15 10.82 0.24
SO LOCATION P3_21_BOILER POINT 594797. 4691290. 2155.2
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SO LOCATION P2_22_CUM POINT 595397. 4691890. 2159.22
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SO LOCATION P2_22_CRANE POINT 595397. 4691890. 2159.22
SO SRCPARAM P2_22_CRANE 0.0013133 2.59 838.71 9.24 0.2
SO LOCATION P2_22_HEATER POINT 595397. 4691890. 2159.22
SO SRCPARAM P2_22_HEATER 0.28643 2.59 866.48 2.85 0.2
SO LOCATION P4_22_OTHER POINT 595397. 4691290. 2158.01
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SO LOCATION P4_22_CUM POINT 595397. 4691290. 2158.01
SO SRCPARAM P4_22_CUM 0.21676 3.89 547.59 73.5 0.08
SO LOCATION P4_22_WIREL POINT 595397. 4691290. 2158.01
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SO LOCATION P4_22_HEATER POINT 595397. 4691290. 2158.01
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SO LOCATION P1_MV_DIRTRD AREA 594697. 4691790. 2159.98
SO SRCPARAM P1_MV_DIRTRD 2.495425E-09 0.0 200. 200. 0
SO LOCATION P3_18_19 AREA 594697. 4691190. 2155.25
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SO LOCATION P4_25 AREA 595297. 4691190. 2156.78
SO SRCPARAM P4_25 5.8075E-08 3.5 200. 200. 0
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SO EMISFACT P2_22_CRANE HROFDY 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 1 0 0 0 0 0 0
SO EMISFACT P2_22_HEATER HROFDY 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 1 0 0 0 0 0 0
SO EMISFACT P4_22_WIREL HROFDY 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 1 0 0 0 0 0 0
SO EMISFACT P4_22_CRANE HROFDY 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 1 0 0 0 0 0 0
SO EMISFACT P4_22_HEATER HROFDY 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 1 0 0 0 0 0 0
SO EMISFACT P1_MV_DIRTRD HROFDY 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 1 0 0 0 0 0 0
SO EMISFACT P3_MV_DIRTRD HROFDY 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 1 0 0 0 0 0 0
SO EMISFACT P2_22_BB HROFDY 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 1 0 0 0 0 0 0
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SO EMISFACT P4_MV_DIRTRD HROFDY 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 1 0 0 0 0 0 0
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SO OLMGROUP ALL P1_21_C27
SO OLMGROUP ALL P1_21_BOILER
SO OLMGROUP ALL P3_21_3516G
SO OLMGROUP ALL P3_21_C27
SO OLMGROUP ALL P3_21_BOILER
SO OLMGROUP ALL P2_22_OTHER
SO OLMGROUP ALL P2_22_CUM
SO OLMGROUP ALL P2_22_WIREL
SO OLMGROUP ALL P2_22_CRANE
SO OLMGROUP ALL P2_22_HEATER
SO OLMGROUP ALL P4_22_OTHER
SO OLMGROUP ALL P4_22_CUM
SO OLMGROUP ALL P4_22_WIREL
SO OLMGROUP ALL P4_22_CRANE
SO OLMGROUP ALL P4_22_HEATER
SO OLMGROUP ALL P1_18_19
SO OLMGROUP ALL P1_MV_DRILL
SO OLMGROUP ALL P1_MV_DIRTRD
SO OLMGROUP ALL P3_18_19
SO OLMGROUP ALL P3_MV_DRILL
SO OLMGROUP ALL P3_MV_DIRTRD
SO OLMGROUP ALL P2_23
SO OLMGROUP ALL P2_25
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SO OLMGROUP ALL P4_25
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SO OLMGROUP ALL P4_MV_DIRTRD
SO SRCGROUP ALL
SO FINISHED

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RE DISCCART 593697.0 4694190.0 2169.83 2169.83
RE DISCCART 593947.0 4694190.0 2163.21 2163.21
RE DISCCART 594197.0 4694190.0 2161.74 2161.74
RE DISCCART 594447.0 4694190.0 2155.57 2160.33
RE DISCCART 594697.0 4694190.0 2153.34 2159.24
RE DISCCART 594947.0 4694190.0 2151.28 2151.28
RE DISCCART 595197.0 4694190.0 2160.13 2160.13
RE DISCCART 595447.0 4694190.0 2157.16 2157.16
RE DISCCART 595697.0 4694190.0 2151.3 2151.3
RE DISCCART 595947.0 4694190.0 2150.07 2150.07
RE DISCCART 596197.0 4694190.0 2153.41 2153.41
RE DISCCART 596447.0 4694190.0 2159.51 2159.51
RE DISCCART 596697.0 4694190.0 2159.6 2159.6
RE DISCCART 596947.0 4694190.0 2156.4 2156.4
RE DISCCART 597197.0 4694190.0 2154.62 2154.62

```
RE DISCCART 597447.0 4694190.0 2152.8 2152.8
RE DISCCART 597697.0 4694190.0 2151.98 2151.98
RE DISCCART 597947.0 4694190.0 2152.86 2152.86
RE DISCCART 592197.0 4694440.0 2182.95 2182.95
RE DISCCART 592447.0 4694440.0 2180.84 2180.84
RE DISCCART 592697.0 4694440.0 2179.49 2179.49
RE DISCCART 592947.0 4694440.0 2179.47 2179.47
RE DISCCART 593197.0 4694440.0 2180.25 2180.25
RE DISCCART 593447.0 4694440.0 2174.51 2174.51
RE DISCCART 593697.0 4694440.0 2170.35 2170.35
RE DISCCART 593947.0 4694440.0 2165.87 2169.15
RE DISCCART 594197.0 4694440.0 2166.64 2166.64
RE DISCCART 594447.0 4694440.0 2163.06 2163.06
RE DISCCART 594697.0 4694440.0 2160.66 2160.66
RE DISCCART 594947.0 4694440.0 2159.97 2159.97
RE DISCCART 595197.0 4694440.0 2144.98 2144.98
RE DISCCART 595447.0 4694440.0 2144.54 2144.54
RE DISCCART 595697.0 4694440.0 2151.02 2151.02
RE DISCCART 595947.0 4694440.0 2155.55 2155.55
RE DISCCART 596197.0 4694440.0 2158.75 2158.75
RE DISCCART 596447.0 4694440.0 2159.47 2159.47
RE DISCCART 596697.0 4694440.0 2163.23 2163.23
RE DISCCART 596947.0 4694440.0 2158.71 2158.71
RE DISCCART 597197.0 4694440.0 2163. 2163.
RE DISCCART 597447.0 4694440.0 2155.68 2155.68
RE DISCCART 597697.0 4694440.0 2150.36 2150.36
RE DISCCART 597947.0 4694440.0 2148.38 2148.38
RE FINISHED

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ME PROFFILE "C:\Project_files\npl\aermod\metdata\NPL_2006_11325_1MIN-ASOS_ADJ.PFL"
ME SURFDATA  24164 2006
ME UAIRDATA  24061 2006
ME PROFBASE 2124. METERS
ME FINISHED

OU STARTING
OU RECTABLE 1 EIGHTH
OU PLOTFILE 1 ALL EIGHTH
"C:\Project_files\npl\aermod\drill\NO2\run_by_year\npl_200m_drilling_OLMGRP_NO2_2006.NO2.GRF" 31
OU PLOTFILE ANNUAL ALL
"C:\Project_files\npl\aermod\drill\NO2\run_by_year\npl_200m_drilling_OLMGRP_NO2_2006.NO2.GRF" 31
OU SUMMFILE "C:\Project_files\npl\aermod\drill\NO2\run_by_year\npl_200m_drilling_OLMGRP_NO2_2006.NO2.SUM"
OU FINISHED
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Example AERMOD Input Emissions for the Drilling Scenario

Pollutant: PM10

*** POINT SOURCE DATA ***

SOURCE ID	NUMBER PART. CATS.	EMISSION RATE (GRAMS/SEC)	X (METERS)	Y (METERS)	BASE ELEV. (METERS)	STACK HEIGHT (METERS)	STACK TEMP. (DEG.K)	STACK EXIT VEL. (M/SEC)	STACK DIAMETER (METERS)	BLDG EXISTS	URBAN SOURCE	CAP/ HOR	EMIS RATE SCALAR VARY BY
P1_21_3516G	0	0.85221E-02	594797.0	4691890.0	2160.1	4.34	628.71	10.82	0.24	NO	NO	NO	
P1_21_C27	0	0.66663E-02	594797.0	4691890.0	2160.1	4.34	723.15	10.82	0.24	NO	NO	NO	
P1_21_BOILER	0	0.18123E-02	594797.0	4691890.0	2160.1	2.23	447.04	2.25	0.39	NO	NO	NO	
P3_21_3516G	0	0.85221E-02	594797.0	4691290.0	2155.2	4.34	628.71	10.82	0.24	NO	NO	NO	
P3_21_C27	0	0.66663E-02	594797.0	4691290.0	2155.2	4.34	723.15	10.82	0.24	NO	NO	NO	
P3_21_BOILER	0	0.18123E-02	594797.0	4691290.0	2155.2	2.23	447.04	2.25	0.39	NO	NO	NO	
P2_22_OTHER	0	0.64787E-01	595397.0	4691890.0	2159.2	3.89	547.59	10.34	0.20	NO	NO	NO	
P2_22_CUM	0	0.65801E-02	595397.0	4691890.0	2159.2	3.89	547.59	73.50	0.08	NO	NO	NO	
P2_22_WIREL	0	0.32848E-02	595397.0	4691890.0	2159.2	2.59	838.71	9.24	0.20	NO	NO	NO	HROFDY
P2_22_CRANE	0	0.94141E-04	595397.0	4691890.0	2159.2	2.59	838.71	9.24	0.20	NO	NO	NO	HROFDY
P2_22_HEATER	0	0.24198E-01	595397.0	4691890.0	2159.2	2.59	866.48	2.85	0.20	NO	NO	NO	HROFDY
P4_22_OTHER	0	0.64787E-01	595397.0	4691290.0	2158.0	3.89	547.59	10.34	0.20	NO	NO	NO	
P4_22_CUM	0	0.65801E-02	595397.0	4691290.0	2158.0	3.89	547.59	73.50	0.08	NO	NO	NO	
P4_22_WIREL	0	0.32848E-02	595397.0	4691290.0	2158.0	2.59	838.71	9.24	0.20	NO	NO	NO	HROFDY
P4_22_CRANE	0	0.94141E-04	595397.0	4691290.0	2158.0	2.59	838.71	9.24	0.20	NO	NO	NO	HROFDY
P4_22_HEATER	0	0.24198E-01	595397.0	4691290.0	2158.0	2.59	866.48	2.85	0.20	NO	NO	NO	HROFDY

*** AREA SOURCE DATA ***

SOURCE ID	NUMBER PART. CATS.	EMISSION RATE (GRAMS/SEC /METER**2)	COORD (SW CORNER) X (METERS)	COORD (SW CORNER) Y (METERS)	BASE ELEV. (METERS)	RELEASE HEIGHT (METERS)	X-DIM OF AREA (METERS)	Y-DIM OF AREA (METERS)	ORIENT. OF AREA (DEG.)	INIT. SZ (METERS)	URBAN SOURCE	EMISSION RATE SCALAR VARY BY
P1_16_17	0	0.98890E-06	594697.0	4691790.0	2160.0	3.00	200.00	200.00	0.00	2.80	NO	
P1_18_19	0	0.68873E-09	594697.0	4691790.0	2160.0	3.50	200.00	200.00	0.00	0.00	NO	
P1_MV_DRILL	0	0.22439E-09	594697.0	4691790.0	2160.0	0.00	200.00	200.00	0.00	0.00	NO	
P1_MV_DIRTRD	0	0.15290E-09	594697.0	4691790.0	2160.0	0.00	200.00	200.00	0.00	0.00	NO	HROFDY
P3_16_17	0	0.98890E-06	594697.0	4691190.0	2155.2	3.00	200.00	200.00	0.00	2.80	NO	
P3_18_19	0	0.68873E-09	594697.0	4691190.0	2155.2	3.50	200.00	200.00	0.00	0.00	NO	
P3_MV_DRILL	0	0.22439E-09	594697.0	4691190.0	2155.2	0.00	200.00	200.00	0.00	0.00	NO	
P3_MV_DIRTRD	0	0.15290E-09	594697.0	4691190.0	2155.2	0.00	200.00	200.00	0.00	0.00	NO	HROFDY
P2_23	0	0.10602E-09	595297.0	4691790.0	2156.4	0.00	200.00	200.00	0.00	0.00	NO	
P2_24	0	0.21828E-04	595297.0	4691790.0	2156.4	3.00	200.00	200.00	0.00	2.80	NO	
P2_25	0	0.38340E-08	595297.0	4691790.0	2156.4	3.50	200.00	200.00	0.00	0.00	NO	
P2_MV	0	0.30927E-09	595297.0	4691790.0	2156.4	0.00	200.00	200.00	0.00	0.00	NO	
P2_22_BB	0	0.13573E-06	595297.0	4691790.0	2156.4	3.50	200.00	200.00	0.00	0.00	NO	HROFDY
P2_MV_DIRTRD	0	0.15290E-09	595297.0	4691790.0	2156.4	0.00	200.00	200.00	0.00	0.00	NO	HROFDY
P4_23	0	0.10602E-09	595297.0	4691190.0	2156.8	0.00	200.00	200.00	0.00	0.00	NO	
P4_24	0	0.21828E-04	595297.0	4691190.0	2156.8	3.00	200.00	200.00	0.00	2.80	NO	
P4_25	0	0.38340E-08	595297.0	4691190.0	2156.8	3.50	200.00	200.00	0.00	0.00	NO	
P4_MV	0	0.30927E-09	595297.0	4691190.0	2156.8	0.00	200.00	200.00	0.00	0.00	NO	
P4_22_BB	0	0.13573E-06	595297.0	4691190.0	2156.8	3.50	200.00	200.00	0.00	0.00	NO	HROFDY
P4_MV_DIRTRD	0	0.15290E-09	595297.0	4691190.0	2156.8	0.00	200.00	200.00	0.00	0.00	NO	HROFDY

Pollutant: PM2.5

*** POINT SOURCE DATA ***

SOURCE ID	NUMBER PART. CATS.	EMISSION RATE (GRAMS/SEC)	X (METERS)	Y (METERS)	BASE ELEV. (METERS)	STACK HEIGHT (METERS)	STACK TEMP. (DEG.K)	STACK EXIT VEL. (M/SEC)	STACK DIAMETER (METERS)	BLDG EXISTS	URBAN SOURCE	CAP/ HOR	EMIS RATE SCALAR VARY BY
P1_21_3516G	0	0.10951E-03	594797.0	4691890.0	2160.1	4.34	628.71	10.82	0.24	NO	NO	NO	
P1_21_C27	0	0.66663E-02	594797.0	4691890.0	2160.1	4.34	723.15	10.82	0.24	NO	NO	NO	
P1_21_BOILER	0	0.46577E-05	594797.0	4691890.0	2160.1	2.23	447.04	2.25	0.39	NO	NO	NO	
P3_21_3516G	0	0.10951E-03	594797.0	4691290.0	2155.2	4.34	628.71	10.82	0.24	NO	NO	NO	
P3_21_C27	0	0.66663E-02	594797.0	4691290.0	2155.2	4.34	723.15	10.82	0.24	NO	NO	NO	
P3_21_BOILER	0	0.46577E-05	594797.0	4691290.0	2155.2	2.23	447.04	2.25	0.39	NO	NO	NO	
P2_22_OTHER	0	0.64787E-01	595397.0	4691890.0	2159.2	3.89	547.59	10.34	0.20	NO	NO	NO	
P2_22_CUM	0	0.65801E-02	595397.0	4691890.0	2159.2	3.89	547.59	73.50	0.08	NO	NO	NO	
P2_22_WIREL	0	0.32848E-02	595397.0	4691890.0	2159.2	2.59	838.71	9.24	0.20	NO	NO	NO	HROFDY
P2_22_CRANE	0	0.94141E-04	595397.0	4691890.0	2159.2	2.59	838.71	9.24	0.20	NO	NO	NO	HROFDY
P2_22_HEATER	0	0.24198E-01	595397.0	4691890.0	2159.2	2.59	866.48	2.85	0.20	NO	NO	NO	HROFDY
P4_22_OTHER	0	0.64787E-01	595397.0	4691290.0	2158.0	3.89	547.59	10.34	0.20	NO	NO	NO	
P4_22_CUM	0	0.65801E-02	595397.0	4691290.0	2158.0	3.89	547.59	73.50	0.08	NO	NO	NO	
P4_22_WIREL	0	0.32848E-02	595397.0	4691290.0	2158.0	2.59	838.71	9.24	0.20	NO	NO	NO	HROFDY
P4_22_CRANE	0	0.94141E-04	595397.0	4691290.0	2158.0	2.59	838.71	9.24	0.20	NO	NO	NO	HROFDY
P4_22_HEATER	0	0.24198E-01	595397.0	4691290.0	2158.0	2.59	866.48	2.85	0.20	NO	NO	NO	HROFDY

*** AREA SOURCE DATA ***

SOURCE ID	NUMBER PART. CATS.	EMISSION RATE (GRAMS/SEC /METER**2)	COORD (SW CORNER) X (METERS)	Y (METERS)	BASE ELEV. (METERS)	RELEASE HEIGHT (METERS)	X-DIM OF AREA (METERS)	Y-DIM OF AREA (METERS)	ORIENT. OF AREA (DEG.)	INIT. SZ (METERS)	URBAN SOURCE	EMISSION RATE SCALAR VARY BY
P1_16_17	0	0.23591E-06	594697.0	4691790.0	2160.0	3.00	200.00	200.00	0.00	2.80	NO	
P1_18_19	0	0.54348E-09	594697.0	4691790.0	2160.0	3.50	200.00	200.00	0.00	0.00	NO	
P1_MV_DRILL	0	0.18445E-09	594697.0	4691790.0	2160.0	0.00	200.00	200.00	0.00	0.00	NO	
P1_MV_DIRTRD	0	0.11807E-09	594697.0	4691790.0	2160.0	0.00	200.00	200.00	0.00	0.00	NO	HROFDY
P3_16_17	0	0.23591E-06	594697.0	4691190.0	2155.2	3.00	200.00	200.00	0.00	2.80	NO	
P3_18_19	0	0.54348E-09	594697.0	4691190.0	2155.2	3.50	200.00	200.00	0.00	0.00	NO	
P3_MV_DRILL	0	0.18445E-09	594697.0	4691190.0	2155.2	0.00	200.00	200.00	0.00	0.00	NO	
P3_MV_DIRTRD	0	0.11807E-09	594697.0	4691190.0	2155.2	0.00	200.00	200.00	0.00	0.00	NO	HROFDY
P2_23	0	0.10602E-09	595297.0	4691790.0	2156.4	0.00	200.00	200.00	0.00	0.00	NO	
P2_24	0	0.21797E-05	595297.0	4691790.0	2156.4	3.00	200.00	200.00	0.00	2.80	NO	
P2_25	0	0.30255E-08	595297.0	4691790.0	2156.4	3.50	200.00	200.00	0.00	0.00	NO	
P2_MV	0	0.25425E-09	595297.0	4691790.0	2156.4	0.00	200.00	200.00	0.00	0.00	NO	
P2_22_BB	0	0.13573E-06	595297.0	4691790.0	2156.4	3.50	200.00	200.00	0.00	0.00	NO	HROFDY
P2_MV_DIRTRD	0	0.11807E-09	595297.0	4691790.0	2156.4	0.00	200.00	200.00	0.00	0.00	NO	HROFDY
P4_23	0	0.10602E-09	595297.0	4691190.0	2156.8	0.00	200.00	200.00	0.00	0.00	NO	
P4_24	0	0.21797E-05	595297.0	4691190.0	2156.8	3.00	200.00	200.00	0.00	2.80	NO	
P4_25	0	0.30255E-08	595297.0	4691190.0	2156.8	3.50	200.00	200.00	0.00	0.00	NO	
P4_MV	0	0.25425E-09	595297.0	4691190.0	2156.8	0.00	200.00	200.00	0.00	0.00	NO	
P4_22_BB	0	0.13573E-06	595297.0	4691190.0	2156.8	3.50	200.00	200.00	0.00	0.00	NO	HROFDY
P4_MV_DIRTRD	0	0.11807E-09	595297.0	4691190.0	2156.8	0.00	200.00	200.00	0.00	0.00	NO	HROFDY

Pollutant: NO2

*** POINT SOURCE DATA ***

SOURCE ID	NUMBER PART. CATS.	EMISSION RATE (GRAMS/SEC)	X (METERS)	Y (METERS)	BASE ELEV. (METERS)	STACK HEIGHT (METERS)	STACK TEMP. (DEG.K)	STACK EXIT VEL. (M/SEC)	STACK DIAMETER (METERS)	BLDG EXISTS	URBAN SOURCE	CAP/ HOR	EMIS RATE SCALAR VARY BY
P1_21_3516G	0	0.63064E+00	594797.0	4691890.0	2160.1	4.34	628.71	10.82	0.24	NO	NO	NO	
P1_21_C27	0	0.13147E+00	594797.0	4691890.0	2160.1	4.34	723.15	10.82	0.24	NO	NO	NO	
P1_21_BOILER	0	0.24466E-01	594797.0	4691890.0	2160.1	2.23	447.04	2.25	0.39	NO	NO	NO	
P3_21_3516G	0	0.63064E+00	594797.0	4691290.0	2155.2	4.34	628.71	10.82	0.24	NO	NO	NO	
P3_21_C27	0	0.13147E+00	594797.0	4691290.0	2155.2	4.34	723.15	10.82	0.24	NO	NO	NO	
P3_21_BOILER	0	0.24466E-01	594797.0	4691290.0	2155.2	2.23	447.04	2.25	0.39	NO	NO	NO	
P2_22_OTHER	0	0.20054E+01	595397.0	4691890.0	2159.2	3.89	547.59	10.34	0.20	NO	NO	NO	
P2_22_CUM	0	0.21676E+00	595397.0	4691890.0	2159.2	3.89	547.59	73.50	0.08	NO	NO	NO	
P2_22_WIREL	0	0.38881E-01	595397.0	4691890.0	2159.2	2.59	838.71	9.24	0.20	NO	NO	NO	HROFDY
P2_22_CRANE	0	0.13133E-02	595397.0	4691890.0	2159.2	2.59	838.71	9.24	0.20	NO	NO	NO	HROFDY
P2_22_HEATER	0	0.28643E+00	595397.0	4691890.0	2159.2	2.59	866.48	2.85	0.20	NO	NO	NO	HROFDY
P4_22_OTHER	0	0.20054E+01	595397.0	4691290.0	2158.0	3.89	547.59	10.34	0.20	NO	NO	NO	
P4_22_CUM	0	0.21676E+00	595397.0	4691290.0	2158.0	3.89	547.59	73.50	0.08	NO	NO	NO	
P4_22_WIREL	0	0.38881E-01	595397.0	4691290.0	2158.0	2.59	838.71	9.24	0.20	NO	NO	NO	HROFDY
P4_22_CRANE	0	0.13133E-02	595397.0	4691290.0	2158.0	2.59	838.71	9.24	0.20	NO	NO	NO	HROFDY
P4_22_HEATER	0	0.28643E+00	595397.0	4691290.0	2158.0	2.59	866.48	2.85	0.20	NO	NO	NO	HROFDY

```
 *** AREA SOURCE DATA ***

          NUMBER EMISSION RATE  COORD (SW CORNER)  BASE     RELEASE  X-DIM     Y-DIM    ORIENT.   INIT.   URBAN  EMISSION RATE
 SOURCE      PART.  (GRAMS/SEC      X       Y      ELEV.    HEIGHT  OF AREA   OF AREA   OF AREA    SZ     SOURCE  SCALAR VARY
   ID       CATS.   /METER**2)   (METERS) (METERS) (METERS) (METERS) (METERS)  (METERS)   (DEG.)  (METERS)           BY
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

P1_18_19        0  0.10432E-07  594697.0 4691790.0  2160.0    3.50   200.00   200.00     0.00    0.00    NO
P1_MV_DRILL     0  0.38747E-08  594697.0 4691790.0  2160.0    0.00   200.00   200.00     0.00    0.00    NO
P1_MV_DIRTRD    0  0.24954E-08  594697.0 4691790.0  2160.0    0.00   200.00   200.00     0.00    0.00    NO    HROFDY
P3_18_19        0  0.10432E-07  594697.0 4691190.0  2155.2    3.50   200.00   200.00     0.00    0.00    NO
P3_MV_DRILL     0  0.38747E-08  594697.0 4691190.0  2155.2    0.00   200.00   200.00     0.00    0.00    NO
P3_MV_DIRTRD    0  0.24954E-08  594697.0 4691190.0  2155.2    0.00   200.00   200.00     0.00    0.00    NO    HROFDY
P2_23           0  0.21204E-08  595297.0 4691790.0  2156.4    0.00   200.00   200.00     0.00    0.00    NO
P2_25           0  0.58075E-07  595297.0 4691790.0  2156.4    3.50   200.00   200.00     0.00    0.00    NO
P2_MV           0  0.53408E-08  595297.0 4691790.0  2156.4    0.00   200.00   200.00     0.00    0.00    NO
P2_22_BB        0  0.23269E-05  595297.0 4691790.0  2156.4    3.50   200.00   200.00     0.00    0.00    NO    HROFDY
P2_MV_DIRTRD    0  0.24954E-08  595297.0 4691790.0  2156.4    0.00   200.00   200.00     0.00    0.00    NO    HROFDY
P4_23           0  0.21204E-08  595297.0 4691190.0  2156.8    0.00   200.00   200.00     0.00    0.00    NO
P4_25           0  0.58075E-07  595297.0 4691190.0  2156.8    3.50   200.00   200.00     0.00    0.00    NO
P4_MV           0  0.53408E-08  595297.0 4691190.0  2156.8    0.00   200.00   200.00     0.00    0.00    NO
P4_22_BB        0  0.23269E-05  595297.0 4691190.0  2156.8    3.50   200.00   200.00     0.00    0.00    NO    HROFDY
P4_MV_DIRTRD    0  0.24954E-08  595297.0 4691190.0  2156.8    0.00   200.00   200.00     0.00    0.00    NO    HROFDY
```

Pollutant: SO2

*** POINT SOURCE DATA ***

SOURCE ID	NUMBER PART. CATS.	EMISSION RATE (GRAMS/SEC)	X (METERS)	Y (METERS)	BASE ELEV. (METERS)	STACK HEIGHT (METERS)	STACK TEMP. (DEG.K)	STACK EXIT VEL. (M/SEC)	STACK DIAMETER (METERS)	BLDG EXISTS	URBAN SOURCE	CAP/ HOR	EMIS RATE SCALAR VARY BY
P1_21_C27	0	0.46664E-02	594797.0	4691890.0	2160.1	4.34	723.15	10.82	0.24	NO	NO	NO	
P1_21_BOILER	0	0.18123E-03	594797.0	4691890.0	2160.1	2.23	447.04	2.25	0.39	NO	NO	NO	
P3_21_C27	0	0.46664E-02	594797.0	4691290.0	2155.2	4.34	723.15	10.82	0.24	NO	NO	NO	
P3_21_BOILER	0	0.18123E-03	594797.0	4691290.0	2155.2	2.23	447.04	2.25	0.39	NO	NO	NO	
P2_22_OTHER	0	0.97419E-01	595397.0	4691890.0	2159.2	3.89	547.59	10.34	0.20	NO	NO	NO	
P2_22_CUM	0	0.10000E-01	595397.0	4691890.0	2159.2	3.89	547.59	73.50	0.08	NO	NO	NO	
P2_22_WIREL	0	0.13889E-02	595397.0	4691890.0	2159.2	2.59	838.71	9.24	0.20	NO	NO	NO	HROFDY
P2_22_CRANE	0	0.55557E-04	595397.0	4691890.0	2159.2	2.59	838.71	9.24	0.20	NO	NO	NO	HROFDY
P2_22_HEATER	0	0.10232E-01	595397.0	4691890.0	2159.2	2.59	866.48	2.85	0.20	NO	NO	NO	HROFDY
P4_22_OTHER	0	0.97419E-01	595397.0	4691290.0	2158.0	3.89	547.59	10.34	0.20	NO	NO	NO	
P4_22_CUM	0	0.10000E-01	595397.0	4691290.0	2158.0	3.89	547.59	73.50	0.08	NO	NO	NO	
P4_22_WIREL	0	0.13889E-02	595397.0	4691290.0	2158.0	2.59	838.71	9.24	0.20	NO	NO	NO	HROFDY
P4_22_CRANE	0	0.55557E-04	595397.0	4691290.0	2158.0	2.59	838.71	9.24	0.20	NO	NO	NO	HROFDY
P4_22_HEATER	0	0.10232E-01	595397.0	4691290.0	2158.0	2.59	866.48	2.85	0.20	NO	NO	NO	HROFDY

```
*** AREA SOURCE DATA ***

        NUMBER EMISSION RATE  COORD (SW CORNER)  BASE     RELEASE  X-DIM     Y-DIM    ORIENT.    INIT.   URBAN  EMISSION RATE
 SOURCE      PART.  (GRAMS/SEC      X       Y      ELEV.    HEIGHT  OF AREA   OF AREA   OF AREA     SZ     SOURCE  SCALAR VARY
   ID       CATS.   /METER**2)   (METERS) (METERS) (METERS) (METERS) (METERS)  (METERS)   (DEG.)  (METERS)            BY
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

P1_18_19        0  0.20640E-10  594697.0 4691790.0  2160.0     3.50   200.00   200.00     0.00    0.00    NO
P1_MV_DRILL     0  0.15695E-10  594697.0 4691790.0  2160.0     0.00   200.00   200.00     0.00    0.00    NO
P1_MV_DIRTRD    0  0.48133E-11  594697.0 4691790.0  2160.0     0.00   200.00   200.00     0.00    0.00    NO    HROFDY
P3_18_19        0  0.20640E-10  594697.0 4691190.0  2155.2     3.50   200.00   200.00     0.00    0.00    NO
P3_MV_DRILL     0  0.15695E-10  594697.0 4691190.0  2155.2     0.00   200.00   200.00     0.00    0.00    NO
P3_MV_DIRTRD    0  0.48133E-11  594697.0 4691190.0  2155.2     0.00   200.00   200.00     0.00    0.00    NO    HROFDY
P2_25           0  0.11490E-09  595297.0 4691790.0  2156.4     3.50   200.00   200.00     0.00    0.00    NO
P2_MV           0  0.21633E-10  595297.0 4691790.0  2156.4     0.00   200.00   200.00     0.00    0.00    NO
P2_22_BB        0  0.83335E-07  595297.0 4691790.0  2156.4     3.50   200.00   200.00     0.00    0.00    NO    HROFDY
P2_MV_DIRTRD    0  0.48133E-11  595297.0 4691790.0  2156.4     0.00   200.00   200.00     0.00    0.00    NO    HROFDY
P4_25           0  0.11490E-09  595297.0 4691190.0  2156.8     3.50   200.00   200.00     0.00    0.00    NO
P4_MV           0  0.21633E-10  595297.0 4691190.0  2156.8     0.00   200.00   200.00     0.00    0.00    NO
P4_22_BB        0  0.83335E-07  595297.0 4691190.0  2156.8     3.50   200.00   200.00     0.00    0.00    NO    HROFDY
P4_MV_DIRTRD    0  0.48133E-11  595297.0 4691190.0  2156.8     0.00   200.00   200.00     0.00    0.00    NO    HROFDY
```

Pollutant: CO

*** POINT SOURCE DATA ***

SOURCE ID	NUMBER PART. CATS.	EMISSION RATE (GRAMS/SEC)	X (METERS)	Y (METERS)	BASE ELEV. (METERS)	STACK HEIGHT (METERS)	STACK TEMP. (DEG.K)	STACK EXIT VEL. (M/SEC)	STACK DIAMETER (METERS)	BLDG EXISTS	URBAN SOURCE	CAP/ HOR	EMIS RATE SCALAR VARY BY
P1_21_3516G	0	0.14828E+01	594797.0	4691990.0	2160.0	4.34	628.71	10.82	0.24	NO	NO	NO	
P1_21_C27	0	0.25184E-01	594797.0	4691990.0	2160.0	4.34	723.15	10.82	0.24	NO	NO	NO	
P1_21_BOILER	0	0.94241E-01	594797.0	4691990.0	2160.0	2.23	447.04	2.25	0.39	NO	NO	NO	
P3_21_3516G	0	0.14828E+01	594797.0	4691390.0	2155.3	4.34	628.71	10.82	0.24	NO	NO	NO	
P3_21_C27	0	0.25184E-01	594797.0	4691390.0	2155.3	4.34	723.15	10.82	0.24	NO	NO	NO	
P3_21_BOILER	0	0.94241E-01	594797.0	4691390.0	2155.3	2.23	447.04	2.25	0.39	NO	NO	NO	
P2_22_OTHER	0	0.37646E+00	595397.0	4691990.0	2160.7	3.89	547.59	10.34	0.20	NO	NO	NO	
P2_22_CUM	0	0.42126E-01	595397.0	4691990.0	2160.7	3.89	547.59	73.50	0.08	NO	NO	NO	
P2_22_WIREL	0	0.16427E-01	595397.0	4691990.0	2160.7	2.59	838.71	9.24	0.20	NO	NO	NO	HROFDY
P2_22_CRANE	0	0.42565E-03	595397.0	4691990.0	2160.7	2.59	838.71	9.24	0.20	NO	NO	NO	HROFDY
P2_22_HEATER	0	0.12102E+00	595397.0	4691990.0	2160.7	2.59	866.48	2.85	0.20	NO	NO	NO	HROFDY
P4_22_OTHER	0	0.37646E+00	595397.0	4691390.0	2156.2	3.89	547.59	10.34	0.20	NO	NO	NO	
P4_22_CUM	0	0.42126E-01	595397.0	4691390.0	2156.2	3.89	547.59	73.50	0.08	NO	NO	NO	
P4_22_WIREL	0	0.16427E-01	595397.0	4691390.0	2156.2	2.59	838.71	9.24	0.20	NO	NO	NO	HROFDY
P4_22_CRANE	0	0.42565E-03	595397.0	4691390.0	2156.2	2.59	838.71	9.24	0.20	NO	NO	NO	HROFDY
P4_22_HEATER	0	0.12102E+00	595397.0	4691390.0	2156.2	2.59	866.48	2.85	0.20	NO	NO	NO	HROFDY

*** AREA SOURCE DATA ***

SOURCE ID	NUMBER PART. CATS.	EMISSION RATE (GRAMS/SEC /METER**2)	COORD (SW CORNER) X (METERS)	COORD (SW CORNER) Y (METERS)	BASE ELEV. (METERS)	RELEASE HEIGHT (METERS)	X-DIM OF AREA (METERS)	Y-DIM OF AREA (METERS)	ORIENT. OF AREA (DEG.)	INIT. SZ (METERS)	URBAN SOURCE	EMISSION RATE SCALAR VARY BY
P1_18_19	0	0.18196E-08	594647.0	4691840.0	2161.0	3.50	300.00	300.00	0.00	0.00	NO	
P1_MV_DRILL	0	0.35447E-08	594647.0	4691840.0	2161.0	0.00	300.00	300.00	0.00	0.00	NO	
P1_MV_DIRTRD	0	0.10796E-07	594647.0	4691840.0	2161.0	0.00	300.00	300.00	0.00	0.00	NO	HROFDY
P3_18_19	0	0.18196E-08	594647.0	4691240.0	2155.4	3.50	300.00	300.00	0.00	0.00	NO	
P3_MV_DRILL	0	0.35447E-08	594647.0	4691240.0	2155.4	0.00	300.00	300.00	0.00	0.00	NO	
P3_MV_DIRTRD	0	0.10796E-07	594647.0	4691240.0	2155.4	0.00	300.00	300.00	0.00	0.00	NO	HROFDY
P2_23	0	0.24907E-08	595247.0	4691840.0	2156.6	0.00	300.00	300.00	0.00	0.00	NO	
P2_25	0	0.10129E-07	595247.0	4691840.0	2156.6	3.50	300.00	300.00	0.00	0.00	NO	
P2_MV	0	0.48859E-08	595247.0	4691840.0	2156.6	0.00	300.00	300.00	0.00	0.00	NO	
P2_22_BB	0	0.23831E-06	595247.0	4691840.0	2156.6	3.50	300.00	300.00	0.00	0.00	NO	HROFDY
P2_MV_DIRTRD	0	0.10796E-07	595247.0	4691840.0	2156.6	0.00	300.00	300.00	0.00	0.00	NO	HROFDY
P4_23	0	0.24907E-08	595247.0	4691240.0	2155.7	0.00	300.00	300.00	0.00	0.00	NO	
P4_25	0	0.10129E-07	595247.0	4691240.0	2155.7	3.50	300.00	300.00	0.00	0.00	NO	
P4_MV	0	0.48859E-08	595247.0	4691240.0	2155.7	0.00	300.00	300.00	0.00	0.00	NO	
P4_22_BB	0	0.23831E-06	595247.0	4691240.0	2155.7	3.50	300.00	300.00	0.00	0.00	NO	HROFDY
P4_MV_DIRTRD	0	0.10796E-07	595247.0	4691240.0	2155.7	0.00	300.00	300.00	0.00	0.00	NO	HROFDY

APPENDIX B: YEAR-BY-YEAR PM_{10}, $PM_{2.5}$ AND NO_2 AERMOD RESULTS

Year-by-year 2nd highest 24-hour PM_{10}, 98th percentile 24-hour $PM_{2.5}$ and 98th percentile 1-hour NO_2 concentrations for each scenario are provided in this appendix. The maximum 2nd highest simulated values of 24-hour PM_{10} over all receptors for each year of the five year simulation period are presented in Tables B-1 through B-3 for the construction, drilling and completion, and production scenarios, both without and with background concentrations. For this analysis, the background concentration for PM_{10} is estimated to be 32.7 µg/m^3. Values that exceed the NAAQS or WAAQS are highlighted in bold.

Table B-1a. Maximum AERMOD-Derived 2nd Highest 24-Hour PM_{10} Concentration for Each Simulation Year for the Construction Scenarios (No Background)

Year	AERMOD-Derived 24-Hour PM_{10} Concentration (µg/m^3)				
	Well-Pad Construction	Pipeline Construction	Resource Road Construction	Access Road Construction	Other Construction
2006	68.4	31.7	75.5	7.5	28.7
2007	56.5	26.7	62.1	6.2	23.6
2008	88.4	41.1	97.6	9.8	37.1
2009	57.8	27.2	63.7	6.4	24.2
2010	81.3	36.8	90.2	9.2	34.3

Table B-1b. Maximum AERMOD-Derived 2nd Highest 24-Hour PM_{10} Concentration for Each Simulation Year for the Construction Scenarios (With Background)

Year	AERMOD-Derived 24-Hour PM_{10} Concentration (µg/m^3)				
	Well-Pad Construction	Pipeline Construction	Resource Road Construction	Access Road Construction	Other Construction
2006	101.1	64.4	108.2	40.2	61.4
2007	89.2	59.4	94.8	38.9	47.2
2008	121.1	73.8	130.3	42.5	69.8
2009	90.5	59.9	96.4	39.1	56.9
2010	114.0	69.5	122.9	41.9	67.0

Calculation of the multi-year average quality metrics presented in Section 3 assumed that all construction activities on a given well pad would be completed within a two-year period. For comparison with the NAAQS and WAAQS, the maximum second highest value for any year was selected.

Table B-2a. Maximum AERMOD-Derived 2nd Highest 24-Hour PM_{10} Concentration for Each Simulation Year for the Drilling and Completion Scenario (No Background)

Year	AERMOD-Derived 24-Hour PM_{10} Concentration ($\mu g/m^3$)
2006	**316.3**
2007	**304.0**
2008	**477.1**
2009	**288.2**
2010	**272.8**

Table B-2b. Maximum AERMOD-Derived 2nd Highest (8th High) 24-Hour PM_{10} Concentration for Each Simulation Year for the Drilling and Completion Scenario (With Background)

Year	AERMOD-Derived 24-Hour PM_{10} Concentration ($\mu g/m^3$)
2006	**349.0**
2007	**336.7**
2008	**509.8**
2009	**320.9**
2010	**305.5**

Calculation of the multi-year average quality metrics presented in Section 3 assumed that all drilling and completion activities for a given section would be conducted over a two-year period. For comparison with the NAAQS and WAAQS, the maximum second highest value for any year was selected.

Table B-3a. Maximum AERMOD-Derived 2nd Highest 24-Hour PM_{10} Concentration for Each Simulation Year for the Production Scenario (No Background)

Year	AERMOD-Derived 24-Hour PM_{10} Concentration (µg/m³)
2006	5.1
2007	5.1
2008	7.5
2009	4.7
2010	4.4

Table B-3b. Maximum AERMOD-Derived 2nd Highest 24-Hour PM_{10} Concentration for Each Simulation Year for the Production Scenario (With Background)

Year	AERMOD-Derived 24-Hour PM_{10} Concentration (µg/m³)
2006	37.8
2007	37.8
2008	40.2
2009	37.4
2010	37.1

Calculation of the multi-year average quality metrics presented in Section 3 assumed that all production would occur for five or more years. For comparison with the NAAQS and WAAQS, the maximum second highest value for any year was selected.

The maximum 98th percentile (or 8th highest) simulated values of 24-hour $PM_{2.5}$ over all receptors and for each year of the five year simulation period are presented in Tables B-4 through B-6 for the construction, drilling and completion, and production scenarios, both without and with background concentrations. The AERMOD results presented in Section 3 were paired in space for each receptor and then averaged over multiple years for comparison with the NAAQS. The values given here are the unprocessed AERMOD results for each year and are the maximum 98th percentile values anywhere in the domain. For this analysis, the background concentration for $PM_{2.5}$ was estimated to be 10.2 ug/m³.

Table B-4a. Maximum AERMOD-Derived 98th Percentile (8th High) 24-Hour $PM_{2.5}$ Concentration for Each Simulation Year for the Construction Scenarios (No Background)

Year	AERMOD-Derived 24-Hour $PM_{2.5}$ Concentration (µg/m³)				
	Well-Pad Construction	Pipeline Construction	Resource Road Construction	Access Road Construction	Other Construction
2006	8.2	10.1	8.6	0.5	5.6
2007	8.8	10.9	9.1	0.5	6.0
2008	11.0	13.2	11.5	0.7	7.5
2009	7.7	9.5	8.1	0.5	5.3
2010	7.6	9.3	8.0	0.5	5.2

Table B-4b. Maximum AERMOD-Derived 98th Percentile (8th High) 24-Hour $PM_{2.5}$ Concentration for Each Simulation Year for the Construction Scenarios (With Background)

Year	AERMOD-Derived 24-Hour $PM_{2.5}$ Concentration (µg/m³)				
	Well-Pad Construction	Pipeline Construction	Resource Road Construction	Access Road Construction	Other Construction
2006	18.4	20.3	18.8	10.7	15.8
2007	19.0	21.1	19.3	10.7	16.2
2008	21.2	23.4	21.7	10.9	17.7
2009	17.9	19.7	18.3	10.7	15.5
2010	17.8	19.5	18.2	10.7	5.2

Calculation of the multi-year average quality metrics presented in Section 3 assumed that all construction activities on a given well pad would be completed within a two-year period. For comparison with the NAAQS and WAAQS, AERMOD was run with the two-year averaging option to obtain the maximum value, paired in space, and averaged over two consecutive years. The maximum for any two-year period was selected and multiplied by a factor of 2/3 to represent the three-year average concentration.

Table B-5a. Maximum AERMOD-Derived 98th Percentile (8th High) 24-Hour $PM_{2.5}$ Concentration for Each Simulation Year for the Drilling and Completion Scenario (No Background)

Year	AERMOD-Derived 24-Hour $PM_{2.5}$ Concentration ($\mu g/m^3$)
2006	28.3
2007	28.8
2008	**37.9**
2009	25.6
2010	22.5

Table B-5b. Maximum AERMOD-Derived 98th Percentile (8th High) 24-Hour $PM_{2.5}$ Concentration for Each Simulation Year for the Drilling and Completion Scenario (With Background)

Year	AERMOD-Derived 24-Hour $PM_{2.5}$ Concentration ($\mu g/m^3$)
2006	**38.5**
2007	**39.0**
2008	**48.1**
2009	**35.8**
2010	32.7

Calculation of the multi-year average quality metrics presented in Section 3 assumed that all drilling and completion activities for a given section would be conducted over a two-year period. For comparison with the NAAQS and WAAQS, AERMOD was run with the two-year averaging option to obtain the maximum value, paired in space, and averaged over two consecutive years. The maximum for any two-year period was selected and multiplied by a factor of 2/3 to represent the three-year average concentration.

Table B-6a. Maximum AERMOD-Derived 98th Percentile (8th High) 24-Hour $PM_{2.5}$ Concentration for Each Simulation Year for the Production Scenario (No Background)

Year	AERMOD-Derived 24-Hour $PM_{2.5}$ Concentration (µg/m^3)
2006	0.4
2007	0.4
2008	0.6
2009	0.4
2010	0.4

Table B-6b. Maximum AERMOD-Derived 98th Percentile (8th High) 24-Hour $PM_{2.5}$ Concentration for Each Simulation Year for the Production Scenario (With Background)

Year	AERMOD-Derived 24-Hour $PM_{2.5}$ Concentration (µg/m^3)
2006	10.6
2007	10.6
2008	10.8
2009	10.6
2010	10.6

Calculation of the multi-year average quality metrics presented in Section 3 assumed that all production would occur for five or more years. For comparison with the NAAQS and WAAQS, AERMOD was run with the three-year averaging option to obtain the maximum value, paired in space, and averaged over three consecutive years. The maximum for any three-year period was selected.

The maximum 98th percentile (or 8th highest) simulated values of 1-hour NO_2 over all receptors and for each year of the five year simulation period are presented in Tables B-7 through B-9 for the construction, drilling and completion, and production scenarios, both without and with background concentrations. The AERMOD results presented in Section 3 were paired in space for each receptor and then averaged over multiple years for comparison with the NAAQS. The values given here are the unprocessed AERMOD results for each year and are the maximum 98th percentile values anywhere in the domain. For this analysis, the background concentration for NO_2 was estimated to be 11.9 ug/m^3.

Table B-7a. Maximum AERMOD-Derived 98th Percentile (8th High) 1-Hour NO_2 Concentration for Each Simulation Year for the Construction Scenarios (No Background)

Year	AERMOD-Derived 1-Hour NO_2 Concentration (μg/m^3)				
	Well-Pad Construction	Pipeline Construction	Resource Road Construction	Access Road Construction	Other Construction
2006	131.7	158.5	131.4	0.2	131.5
2007	133.7	165.6	132.6	0.2	133.1
2008	163.1	**194.4**	162.0	0.2	162.5
2009	127.8	155.3	126.8	0.2	127.2
2010	138.9	165.6	138.6	0.2	138.7

Table B-7b. Maximum AERMOD-Derived 98th Percentile (8th High) 1-Hour NO_2 Concentration for Each Simulation Year for the Construction Scenarios (With Background)

Year	AERMOD-Derived 1-Hour NO_2 Concentration (μg/m^3)				
	Well-Pad Construction	Pipeline Construction	Resource Road Construction	Access Road Construction	Other Construction
2006	143.6	170.4	143.3	12.1	143.4
2007	145.6	177.5	144.5	12.1	145.0
2008	175.0	**206.3**	173.9	12.1	174.4
2009	139.7	167.2	138.7	12.1	139.1
2010	150.8	177.5	150.5	12.1	150.6

Calculation of the multi-year average quality metrics presented in Section 3 assumed that all construction activities on a given well pad would be completed within a two-year period. For comparison with the NAAQS and WAAQS, AERMOD was run with the two-year averaging option to obtain the maximum value, paired in space and averaged over two consecutive years. The maximum for any two-year period was selected and multiplied by a factor of 2/3 to represent the three-year average concentration.

Table B-8a. Maximum AERMOD-Derived 98th Percentile (8th High) 1-Hour NO_2 Concentration for Each Simulation Year for the Drilling and Completion Scenario (No Background)

Year	AERMOD-Derived 1-Hour NO_2 Concentration ($\mu g/m^3$)
2006	160.8
2007	147.0
2008	166.4
2009	153.1
2010	155.5

Table B-8b. Maximum AERMOD-Derived 98th Percentile (8th High) 1-Hour NO_2 Concentration for Each Simulation Year for the Drilling and Completion Scenario (With Background)

Year	AERMOD-Derived 1-Hour NO_2 Concentration ($\mu g/m^3$)
2006	172.7
2007	158.9
2008	178.3
2009	165.0
2010	167.4

Calculation of the multi-year average quality metrics presented in Section 3 assumed that all drilling and completion activities for a given section would be conducted over a two-year period. For comparison with the NAAQS and WAAQS, AERMOD was run with the two-year averaging option to obtain the maximum value, paired in space, and averaged over two consecutive years. The maximum for any two-year period was selected and multiplied by a factor of 2/3 to represent the three-year average concentration.

Table B-9a. Maximum AERMOD-Derived 98th Percentile (8th High) 1-Hour NO_2 Concentration for Each Simulation Year for the Production Scenario (No Background)

Year	AERMOD-Derived 1-Hour NO_2 Concentration ($\mu g/m^3$)
2006	0.4
2007	0.4
2008	0.5
2009	0.4
2010	0.4

Table B-9b. Maximum AERMOD-Derived 98th Percentile (8th High) 1-Hour NO_2 Concentration for Each Simulation Year for the Production Scenario (With Background)

Year	AERMOD-Derived 1-Hour NO_2 Concentration ($\mu g/m^3$)
2006	12.3
2007	12.3
2008	12.4
2009	12.3
2010	12.3

Calculation of the multi-year average quality metrics presented in Section 3 assumed that all production would occur for five or more years. For comparison with the NAAQS and WAAQS, AERMOD was run with the three-year averaging option to obtain the maximum value, paired in space, and averaged over three consecutive years. The maximum for any three-year period was selected.

APPENDIX C: DETAILED SUMMARY OF THE COMBINATION SCENARIO COMPONENTS

As noted earlier, for the combination scenario the AERMOD results for construction (one year), drilling and completion (one year), and production (three years) were combined and used to calculate the various metrics for comparison with the NAAQS and WAAQS. Well-pad construction was used to represent construction since it resulted in the highest values for most pollutants. The simulated values for each year for 8-hour CO, 1-hour SO_2, 1-hour NO_2, 24-hour $PM_{2.5}$, and 24-hour PM_{10} are presented in Table C-1 through C-5, both with and without the background concentrations. Selected metrics are provided for each pollutant and the values are consistent with the form of the standard for that pollutant/metric. The AERMOD-derived CO values are the maximum 2nd highest 8-hour average values anywhere in the domain. The SO_2 values are the maximum 99th percentile 1-hour values anywhere in the domain. The NO_2 values are the maximum 98th percentile 1-hour values anywhere in the domain. The $PM_{2.5}$ values are the maximum 98th percentile 24-hour values anywhere in the domain. The PM_{10} values are the 2nd highest 24-hour values anywhere in the domain.

Table C-1. Maximum AERMOD-Derived 2nd High 8-Hour CO Concentration for Each Simulation Year for the Combination Scenario

Year	Scenario	AERMOD-Derived 8-Hour CO Concentration (µg/m³)	Background CO Concentration (µg/m³)	Total (AERMOD-Derived + Background) CO Concentration (µg/m³)
2006	Well-Pad Construction	54.0	780	834.0
2007	Drilling and Completion	145.3	780	925.3
2008	Production	0.6	780	780.6
2009	Production	0.4	780	780.4
2010	Production	0.4	780	780.4

Table C-2. Maximum AERMOD-Derived 99th Percentile 1-Hour SO_2 Concentration for Each Simulation Year for the Combination Scenario

Year	Scenario	AERMOD-Derived 1-Hour SO_2 Concentration ($\mu g/m^3$)	Background SO_2 Concentration ($\mu g/m^3$)	Total (AERMOD-Derived + Background) SO_2 Concentration ($\mu g/m^3$)
2006	Well-Pad Construction	16.4	22.5	38.9
2007	Drilling and Completion	34.7	22.5	57.2
2008	Production	0.0	22.5	22.5
2009	Production	0.0	22.5	22.5
2010	Production	0.0	22.5	22.5

Table C-3. Maximum AERMOD-Derived 98th Percentile 1-Hour NO_2 Concentration for Each Simulation Year for the Combination Scenario

Year	Scenario	AERMOD-Derived 1-Hour NO_2 Concentration ($\mu g/m^3$)	Background NO_2 Concentration ($\mu g/m^3$)	Total (AERMOD-Derived + Background) NO_2 Concentration ($\mu g/m^3$)
2006	Well-Pad Construction	131.7	11.9	143.6
2007	Drilling and Completion	147.0	11.9	158.9
2008	Production	0.5	11.9	12.4
2009	Production	0.4	11.9	12.3
2010	Production	0.4	11.9	12.3

Table C-4. Maximum AERMOD-Derived 98th Percentile 24-Hour $PM_{2.5}$ Concentration for Each Simulation Year for the Combination Scenario

Year	Scenario	AERMOD-Derived 1-Hour $PM_{2.5}$ Concentration (µg/m³)	Background $PM_{2.5}$ Concentration (µg/m³)	Total (AERMOD-Derived + Background) $PM_{2.5}$ Concentration (µg/m³)
2006	Well-Pad Construction	8.2	10.2	18.4
2007	Drilling and Completion	28.8	10.2	**39.0**
2008	Production	0.6	10.2	10.8
2009	Production	0.4	10.2	10.6
2010	Production	0.4	10.2	10.6

Table C-5. Maximum AERMOD-Derived 2nd High 24-Hour PM_{10} Concentration for Each Simulation Year for the Combination Scenario

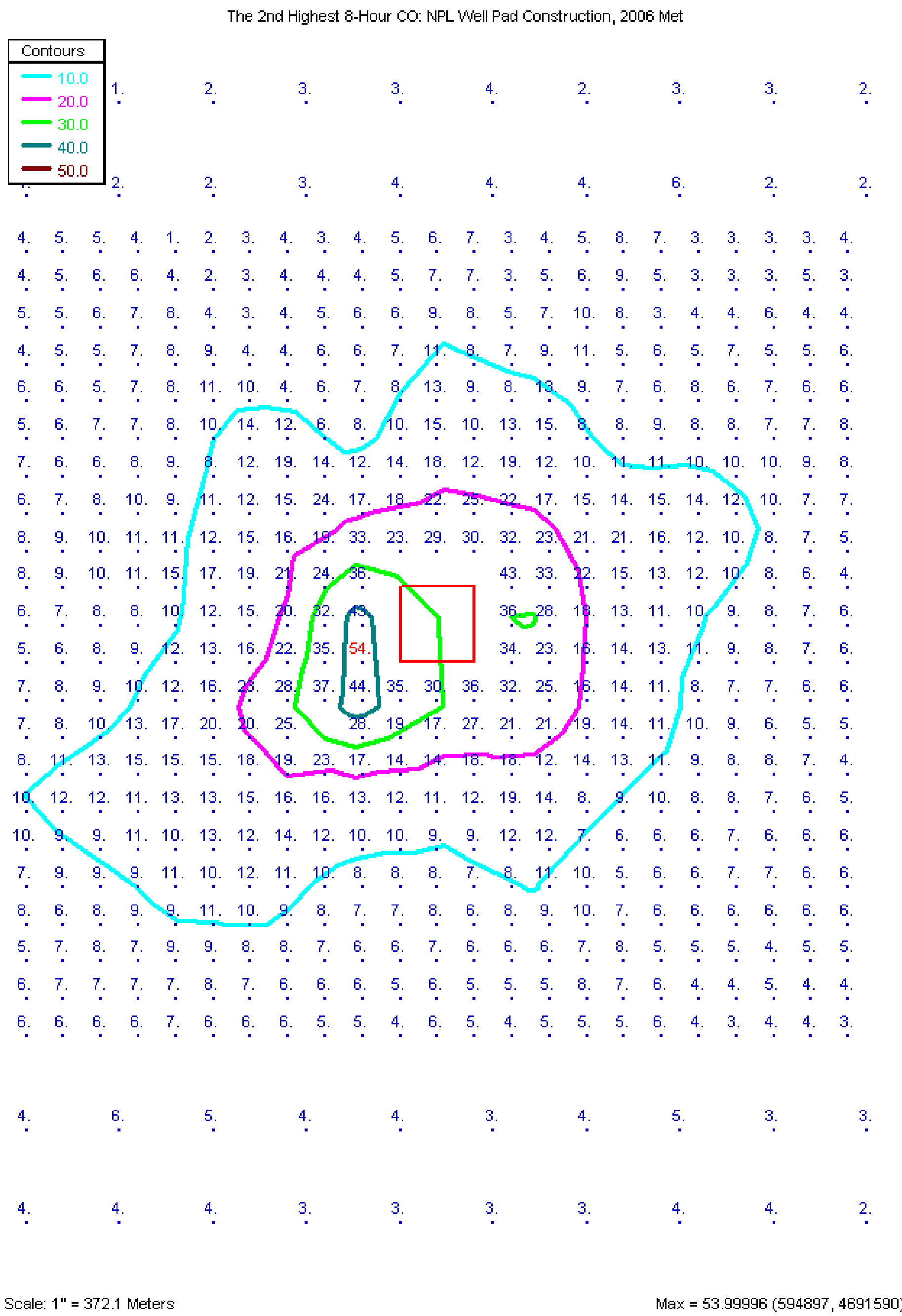
Year	Scenario	AERMOD-Derived 24-Hour PM_{10} Concentration (µg/m³)	Background PM_{10} Concentration (µg/m³)	Total (AERMOD-Derived + Background) PM_{10} Concentration (µg/m³)
2006	Well-Pad Construction	68.4	32.7	101.1
2007	Drilling and Completion	**287.6**	32.7	**320.3**
2008	Production	7.5	32.7	40.2
2009	Production	4.7	32.7	37.4
2010	Production	4.4	32.7	37.1

For SO_2, NO_2 and $PM_{2.5}$, three-year averages were calculated and the maximum three-year average value was compared with the NAAQS in Section 3. For PM_{10}, since the 2nd high value for all years but 2007 is below the NAAQS (150 µg/m³), the 4th high value for 2007 was used for comparison with the NAAQS in Section 3.

Contour plots for each pollutant for each scenario and year used in the combination scenario are also presented in the remainder of this appendix (Figures C-1 through C-5). Note that these plots show the AERMOD-derived concentrations and do not include the background values.

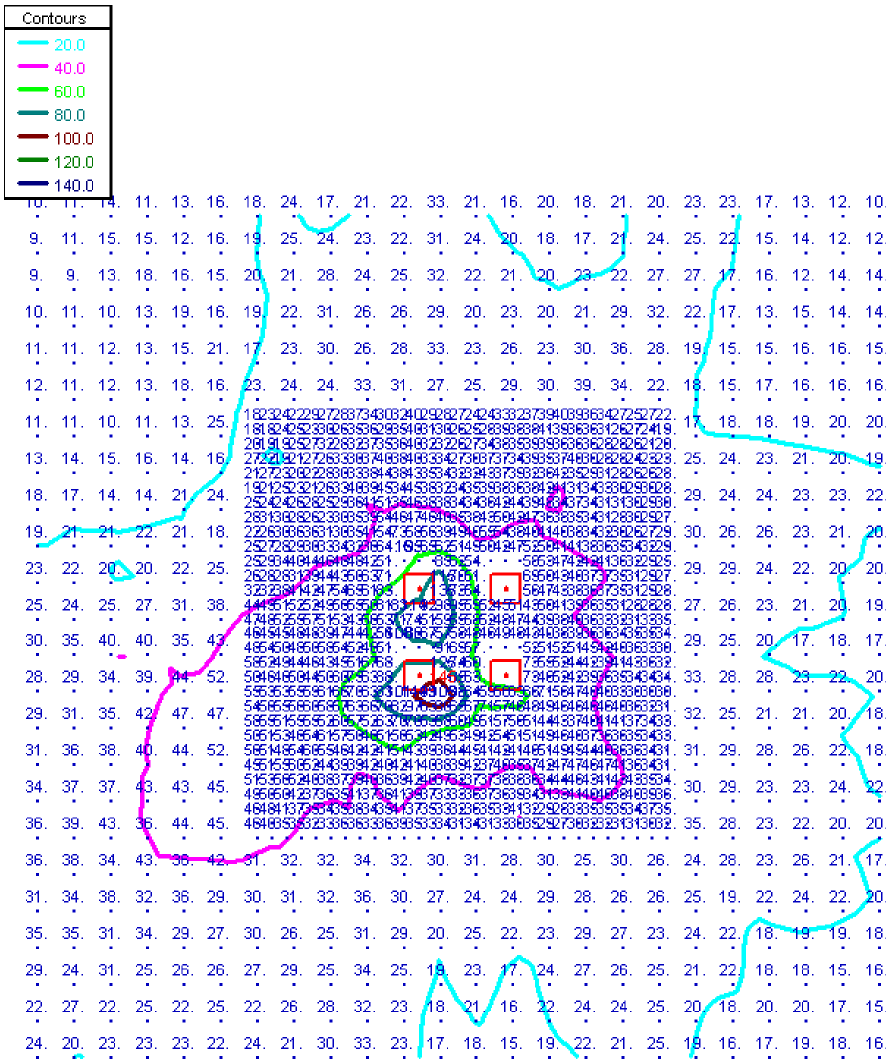
Figure C-1. AERMOD-Derived 2nd High 8-Hour CO Concentration

2006 (Well Pad Construction)



2007 (Drilling and Completion)

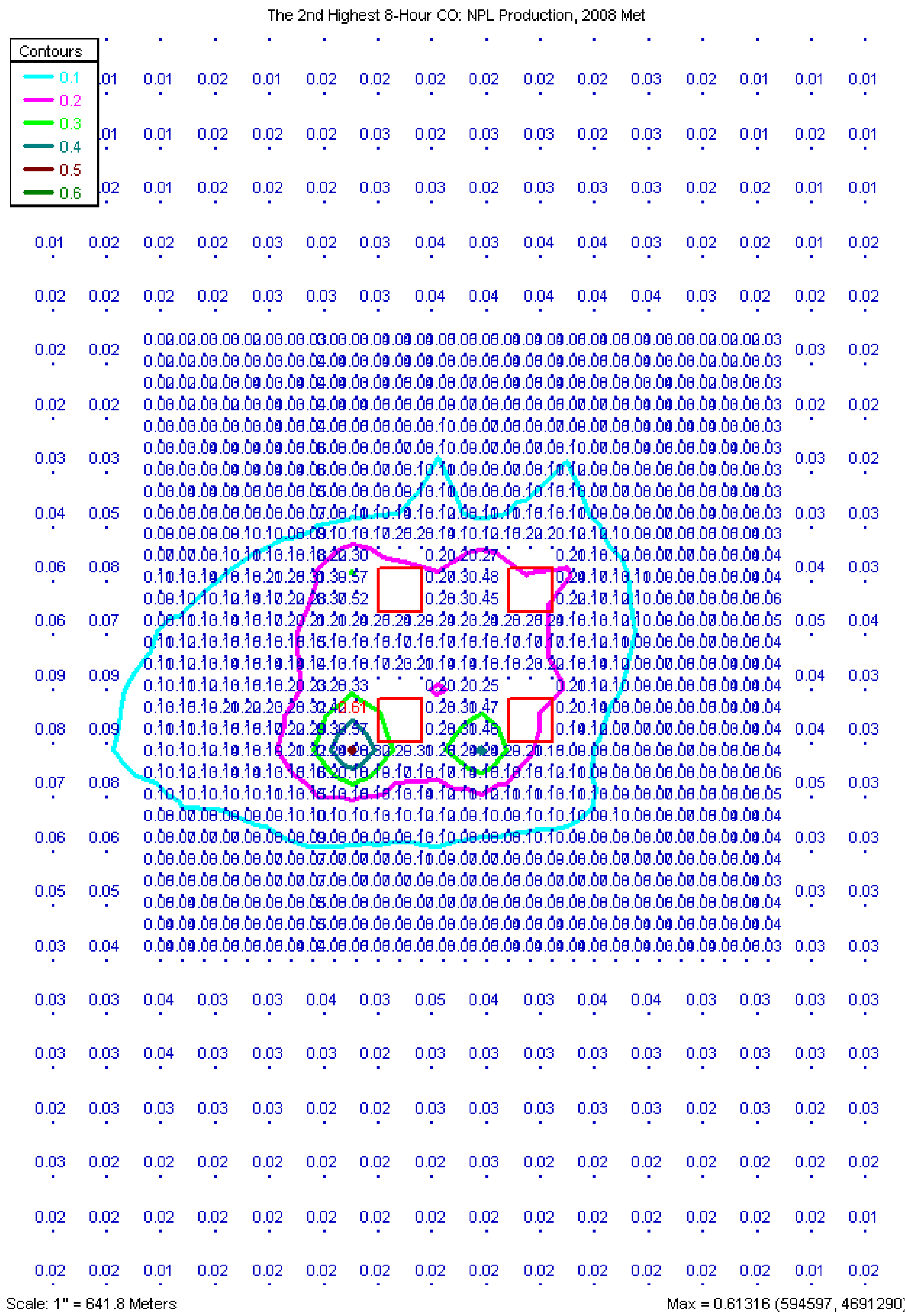
The 2nd Highest 8-Hour CO: NPL Drilling and Completion, 2007 Met



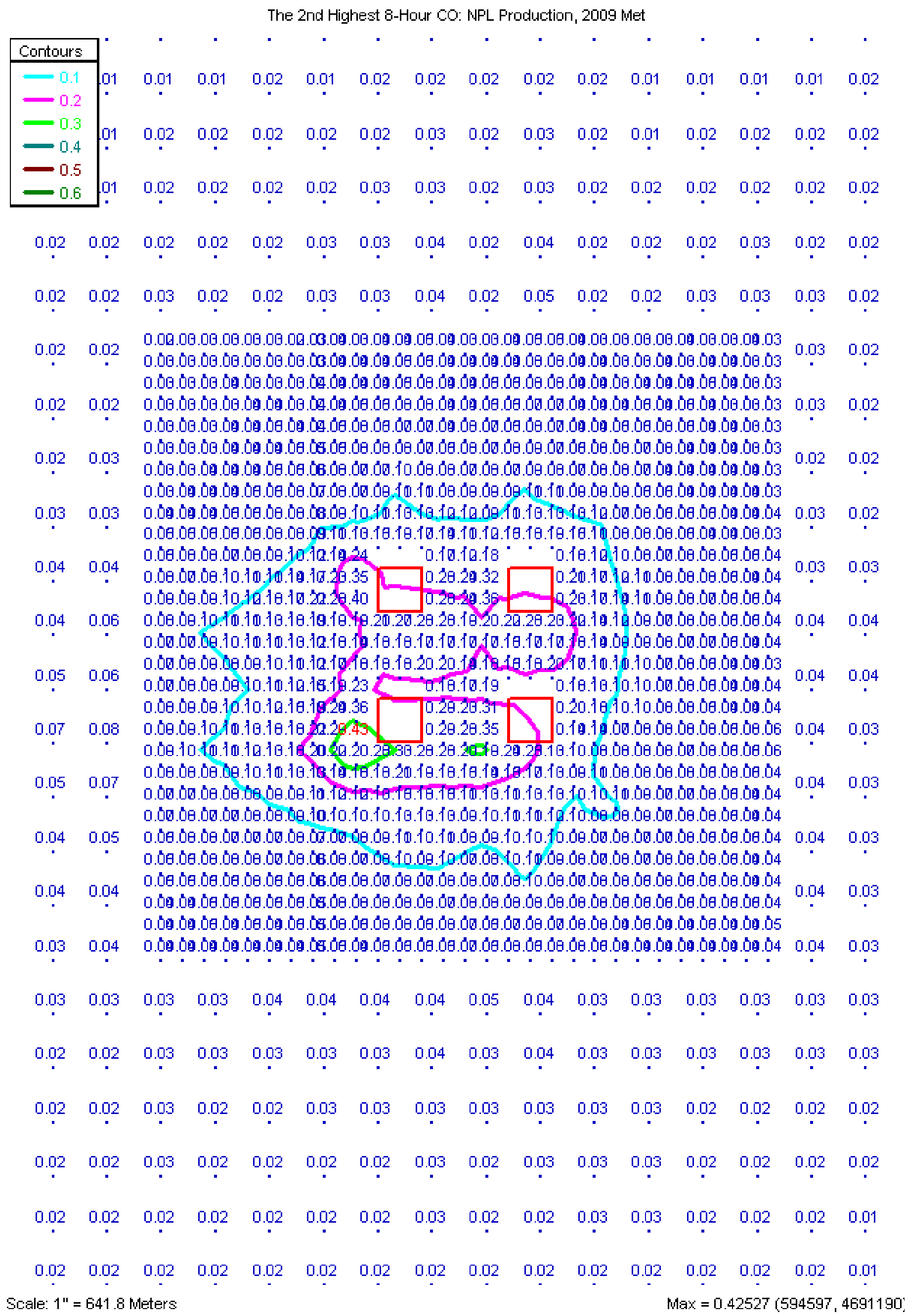
Scale: 1" = 962.7 Meters

Max = 145.3387 (594997, 4691190)

2008 (Production)



2009 (Production)



2010 (Production)

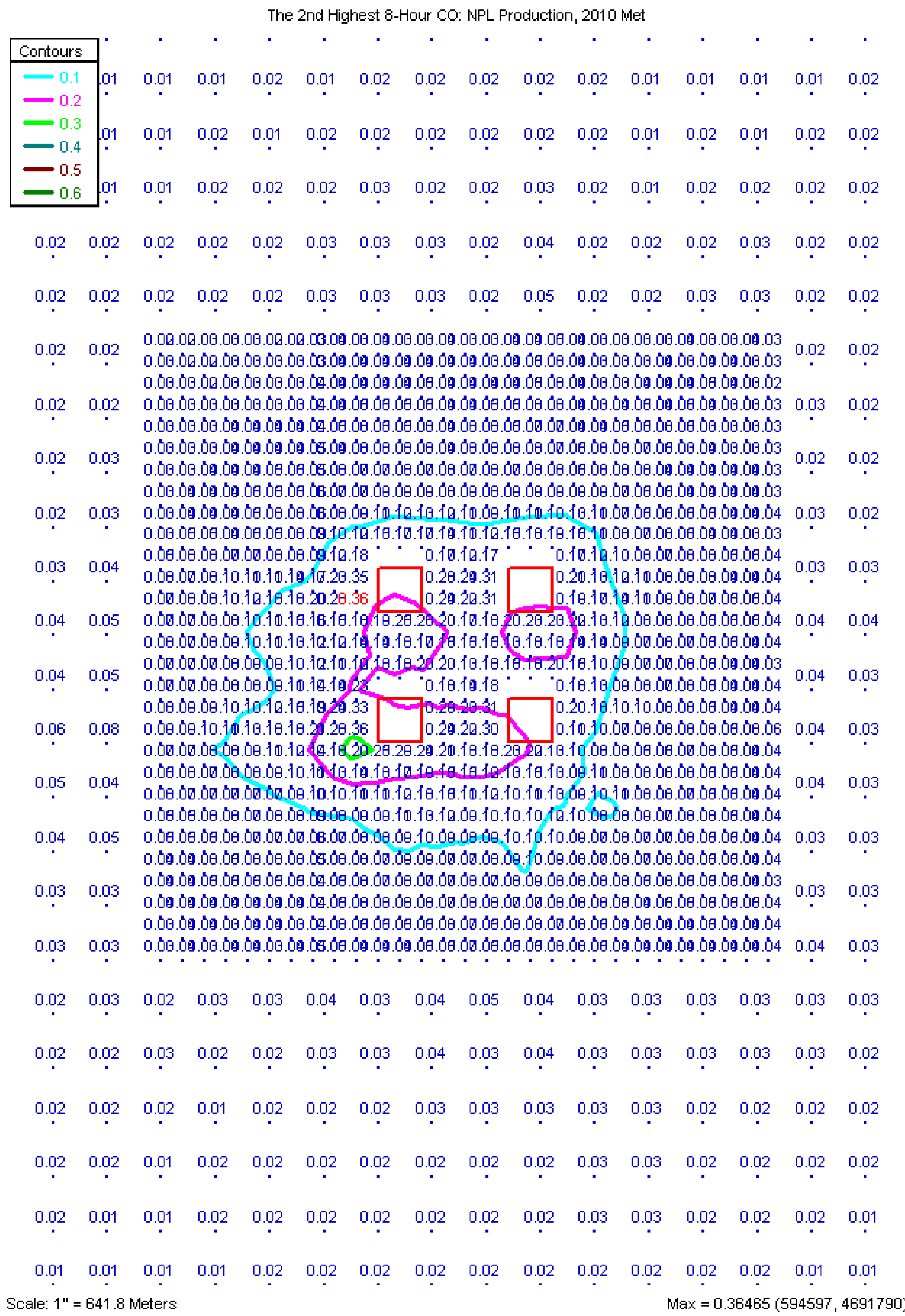
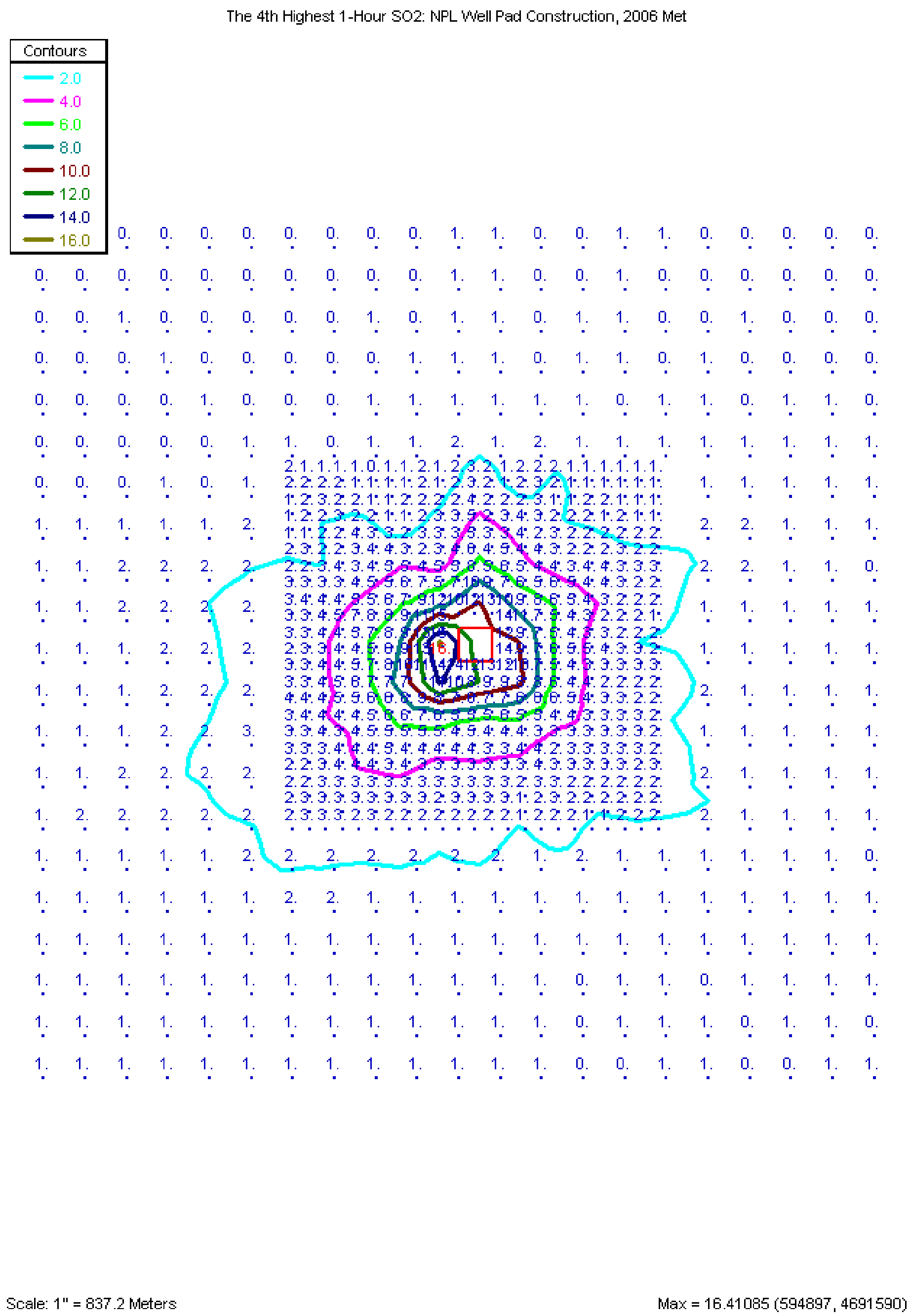


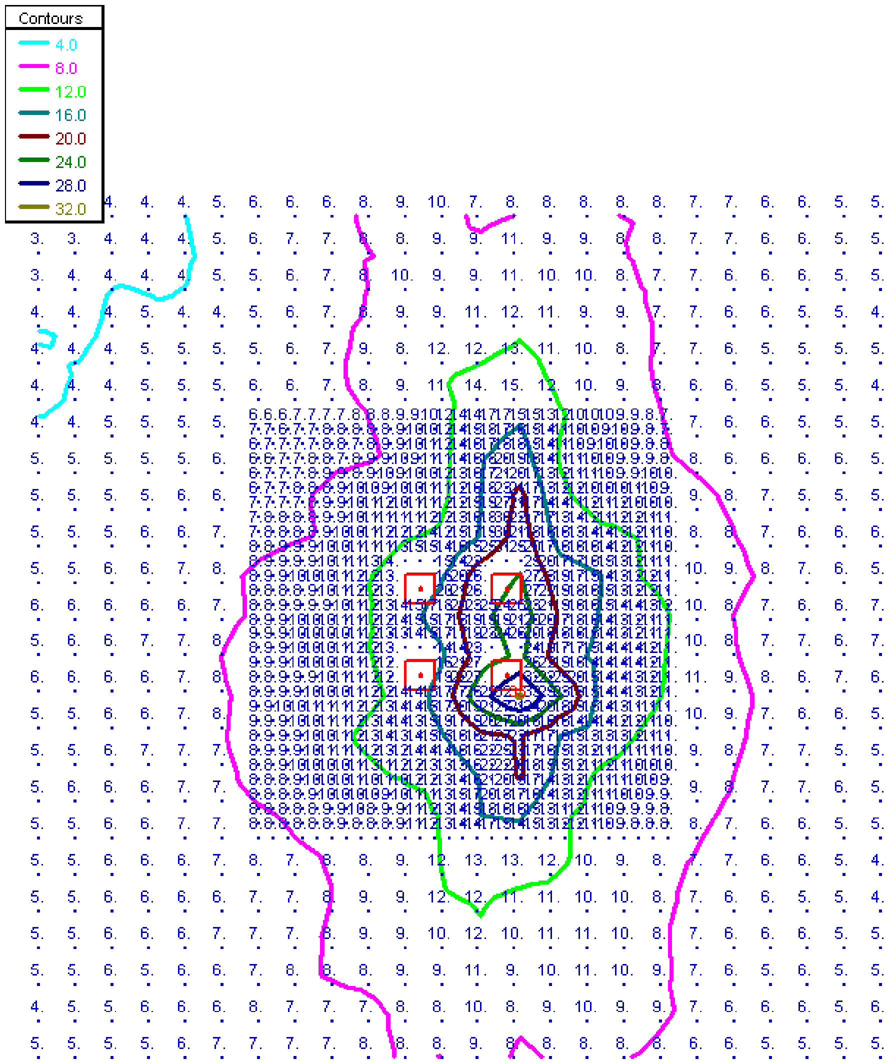
Figure C-2. AERMOD-Derived 4th High 1-Hour SO_2 Concentration

2006 (Well Pad Construction)



2007 (Drilling and Completion)

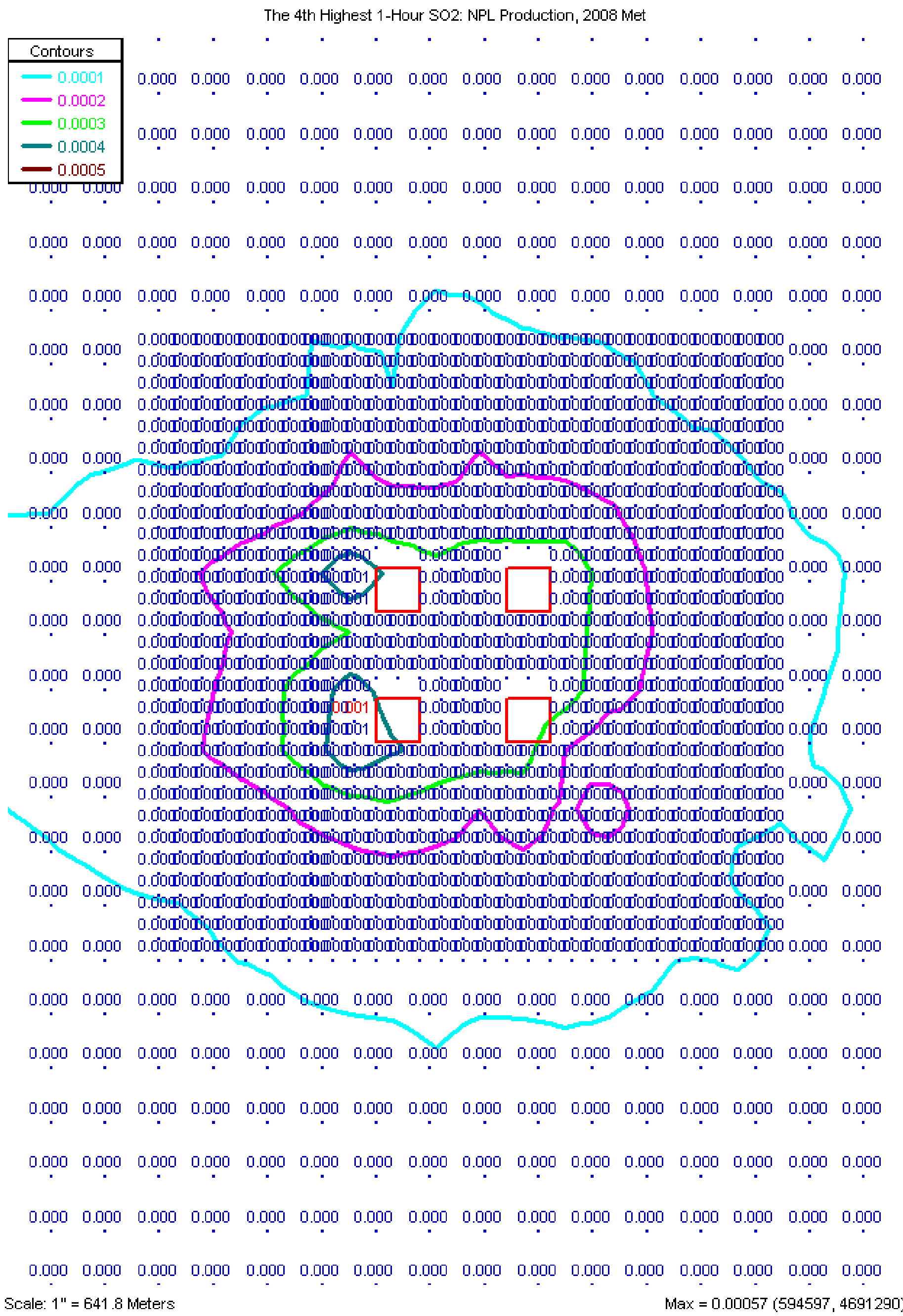
The 4th Highest 1-Hour SO2: NPL Drilling and Completion, 2007 Met



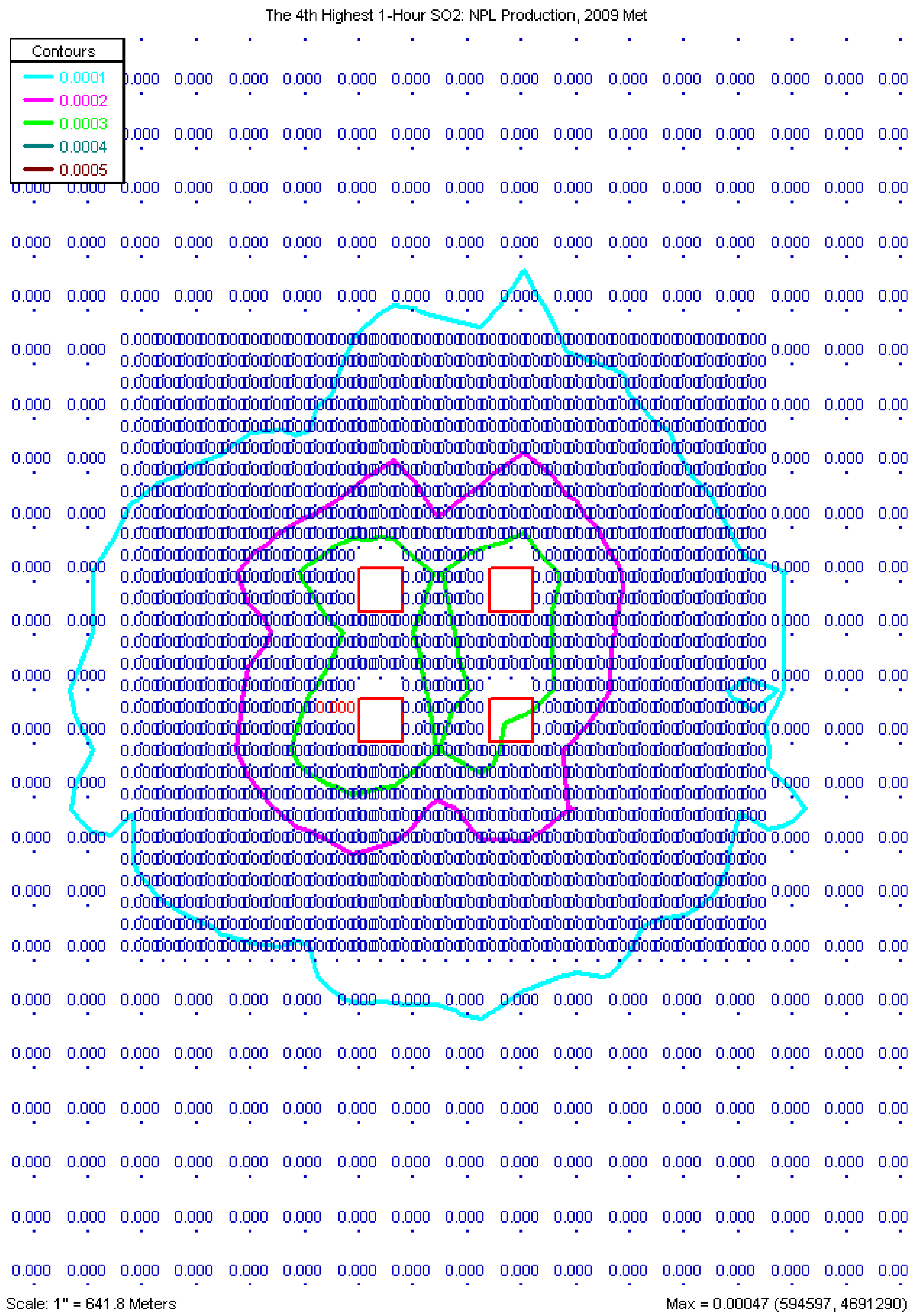
Scale: 1" = 962.7 Meters

Max = 34.67054 (595497, 4691090)

2008 (Production)



2009 (Production)



2010 (Production)

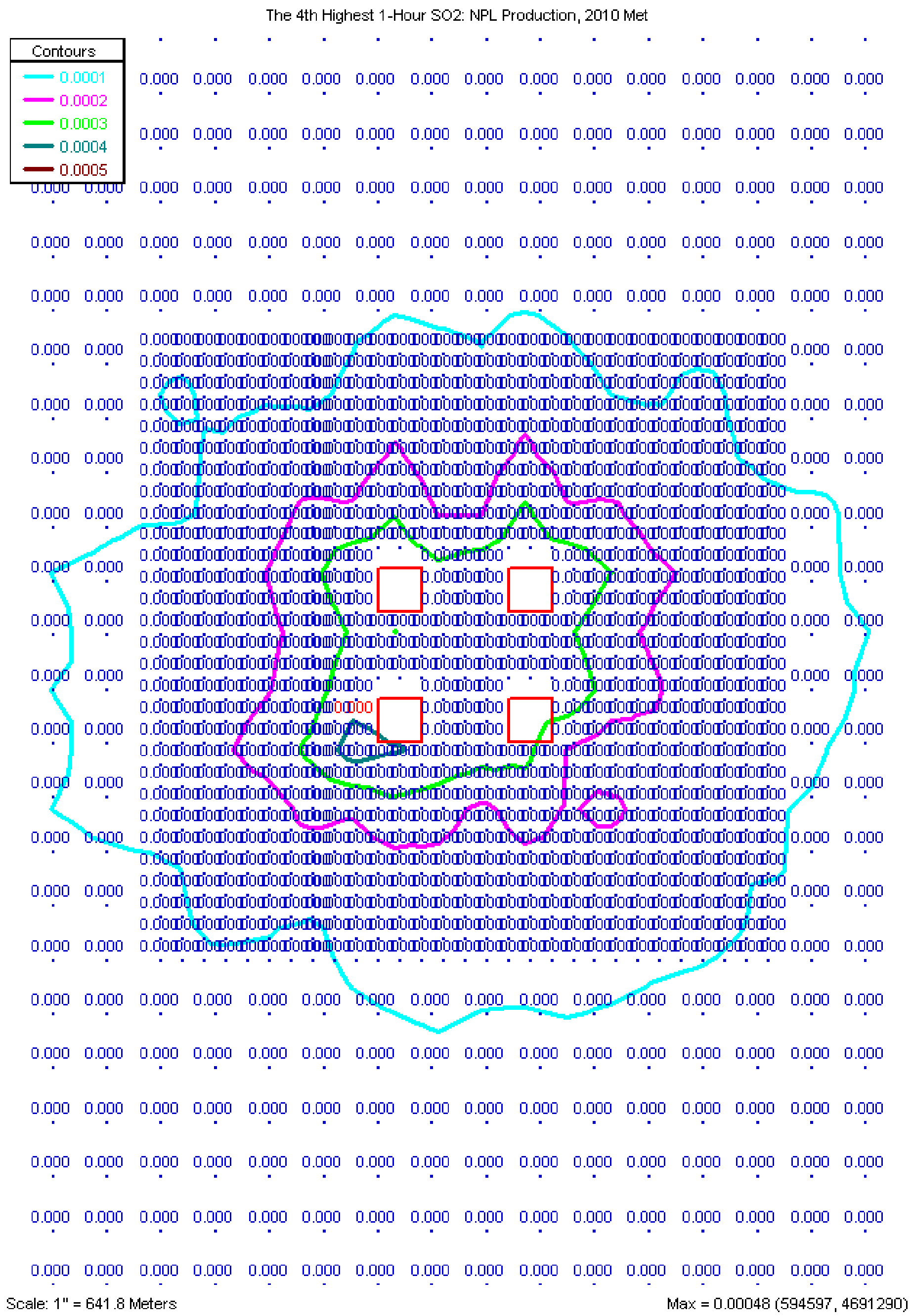
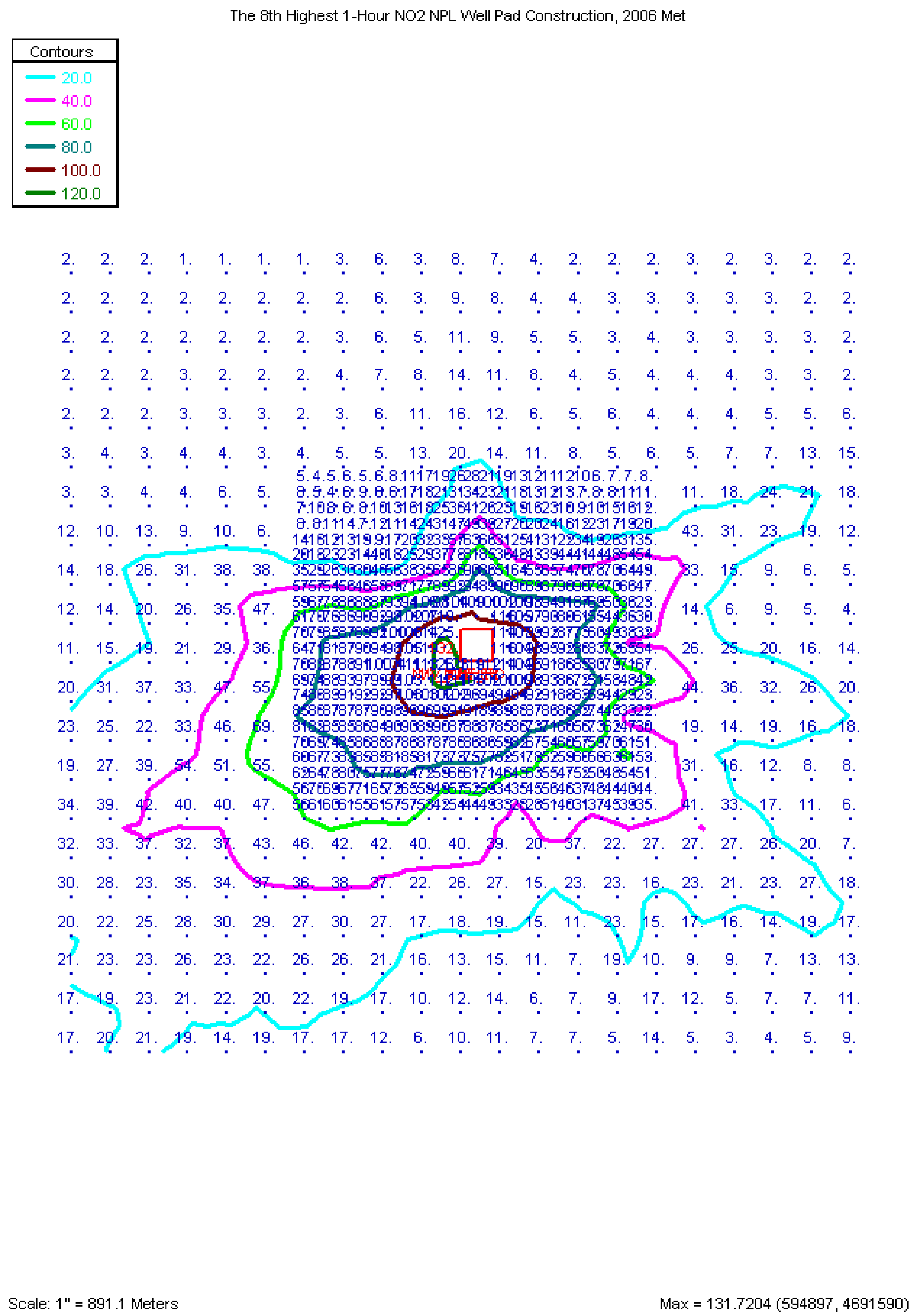


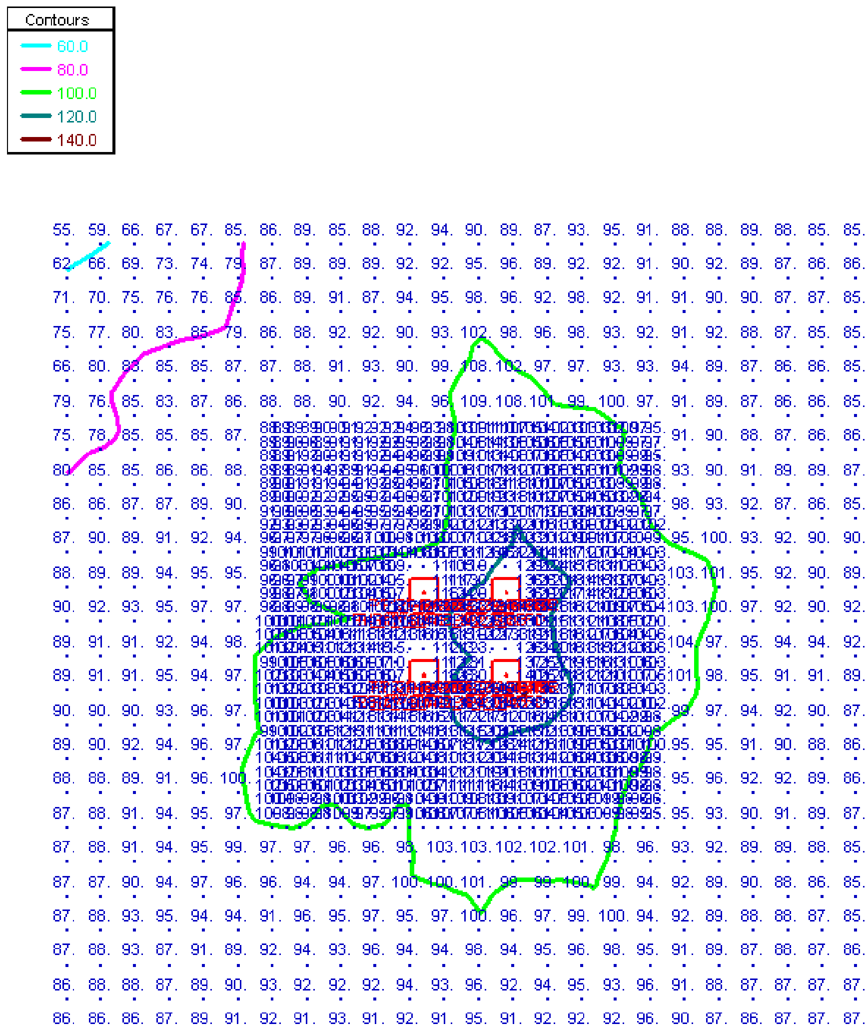
Figure C-3. AERMOD-Derived 8th High 1-Hour NO_2 Concentration

2006 (Well Pad Construction)



2007 (Drilling and Completion)

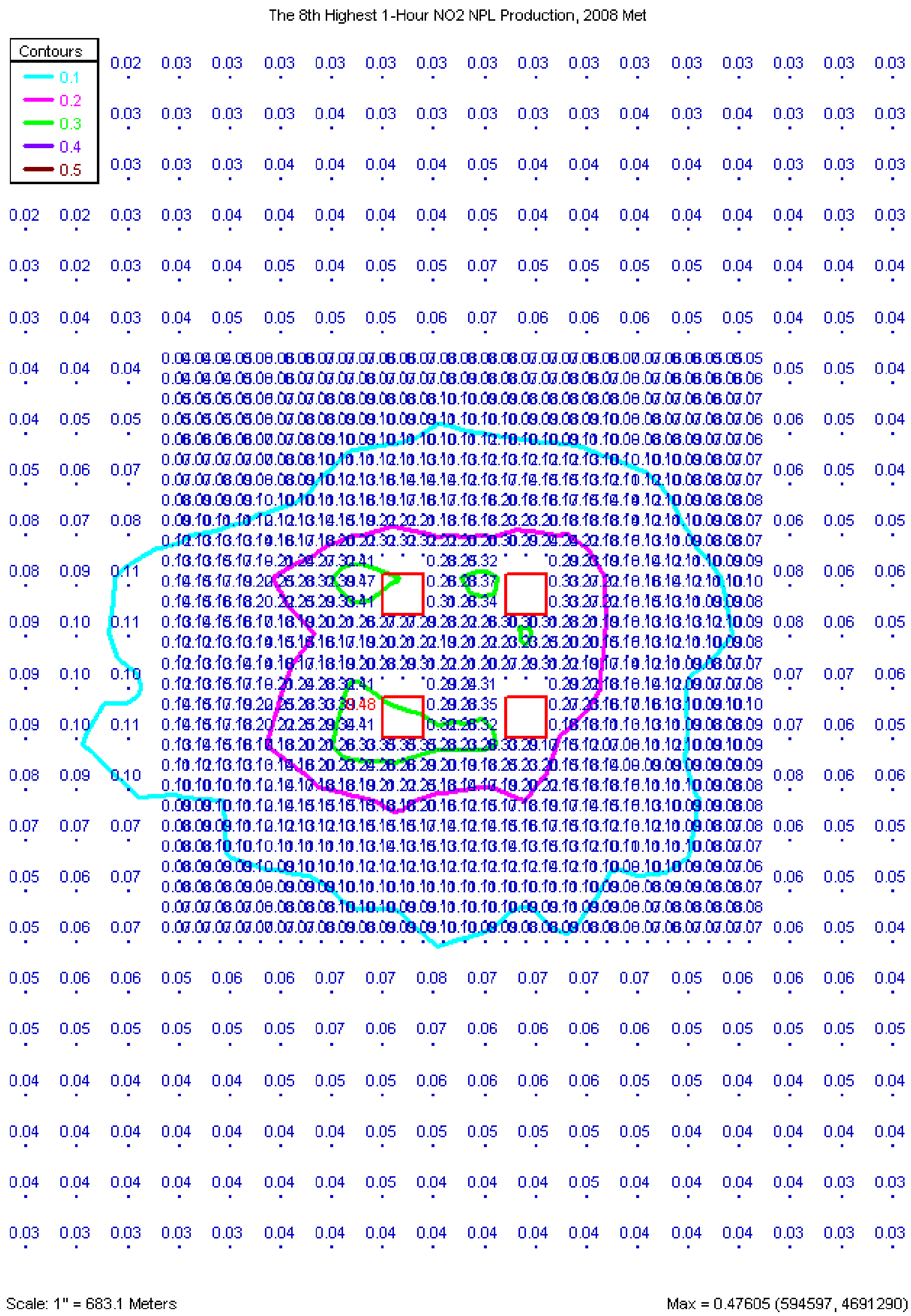
The 8th Highest 1-Hour NO2 NPL Drilling and Completion, 2007 Met



Scale: 1" = 1024.6 Meters

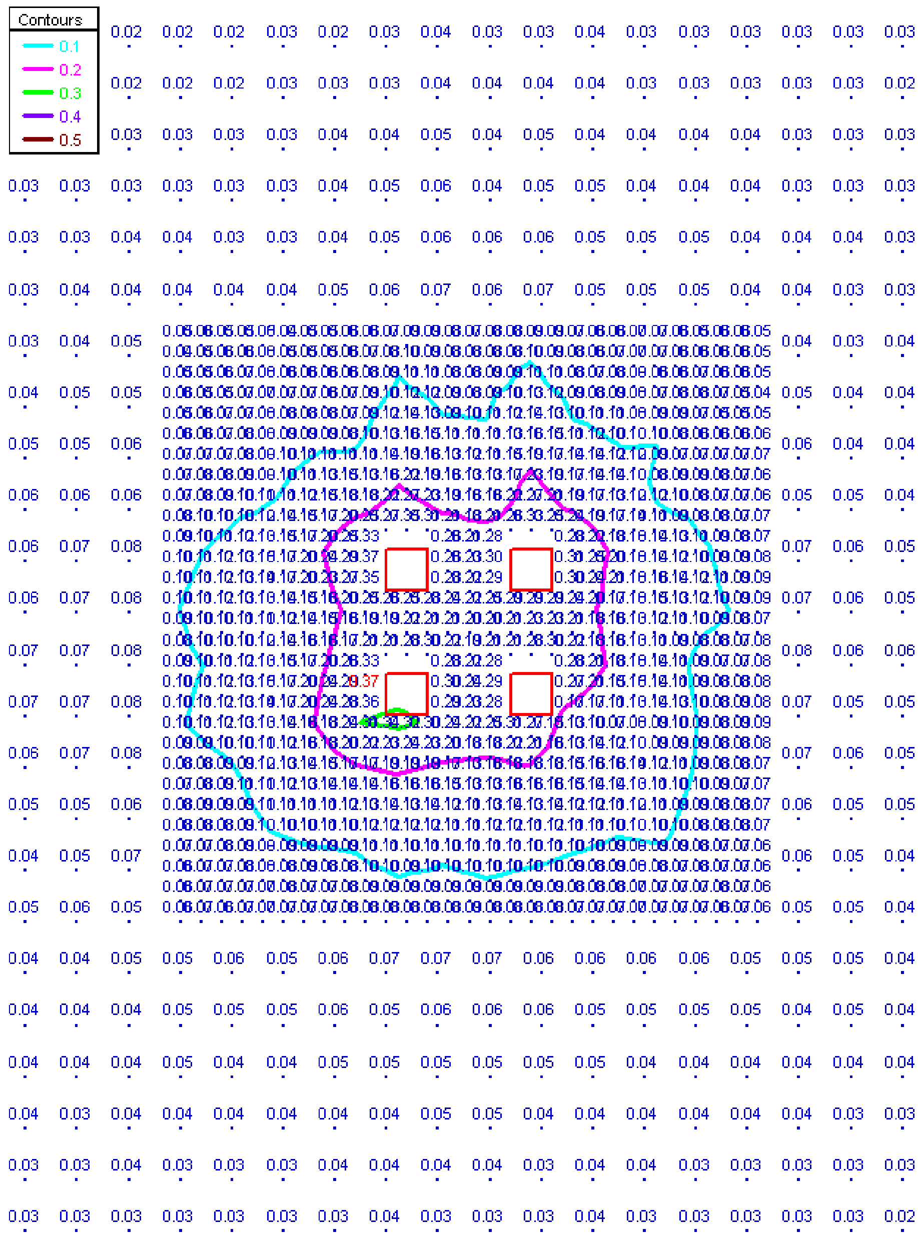
Max = 146.9866 (595597, 4691090)

2008 (Production)



2009 (Production)

The 8th Highest 1-Hour NO2 NPL Production, 2009 Met



Scale: 1" = 683.1 Meters

Max = 0.37145 (594597, 4691290)

2010 (Production)

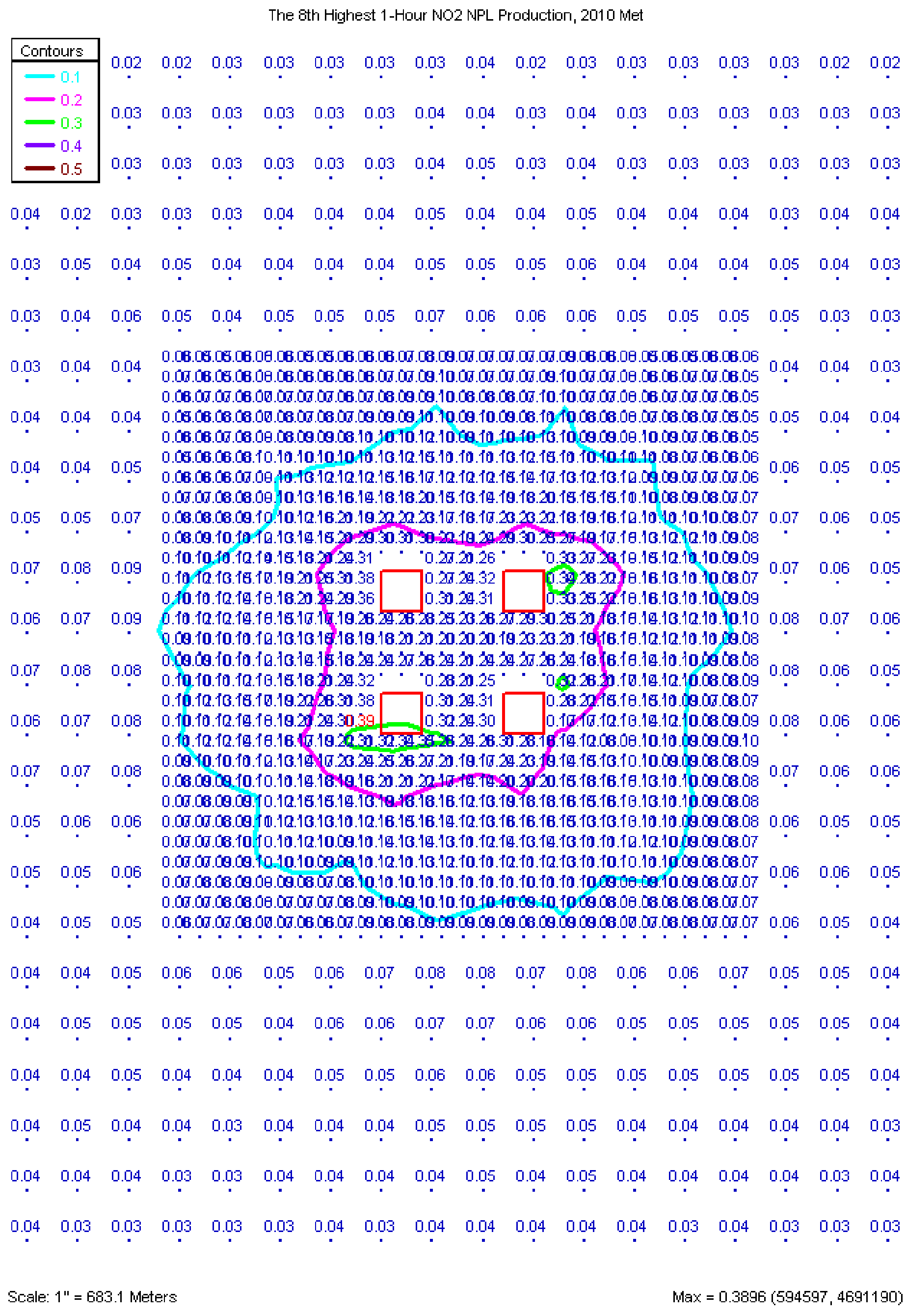
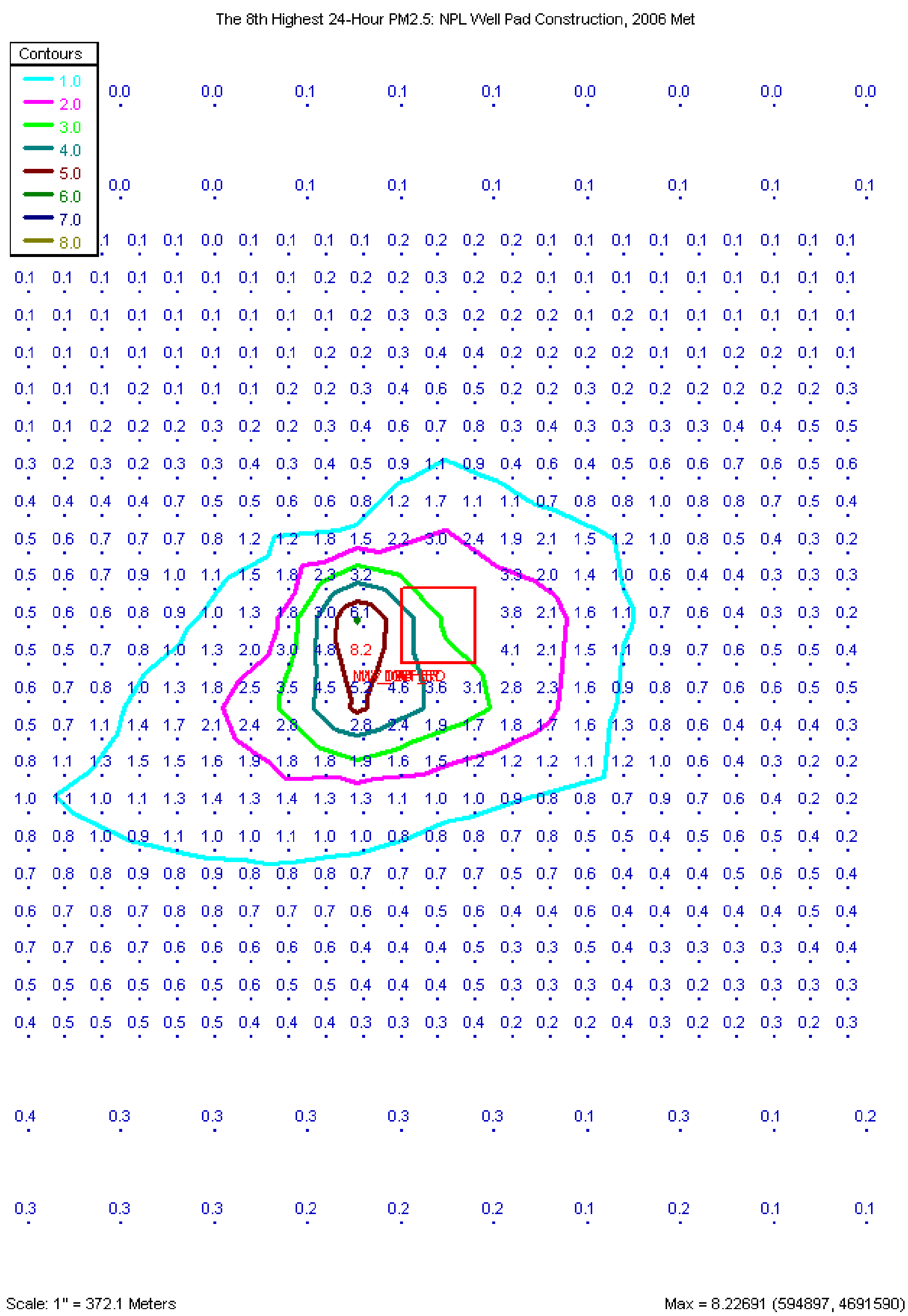
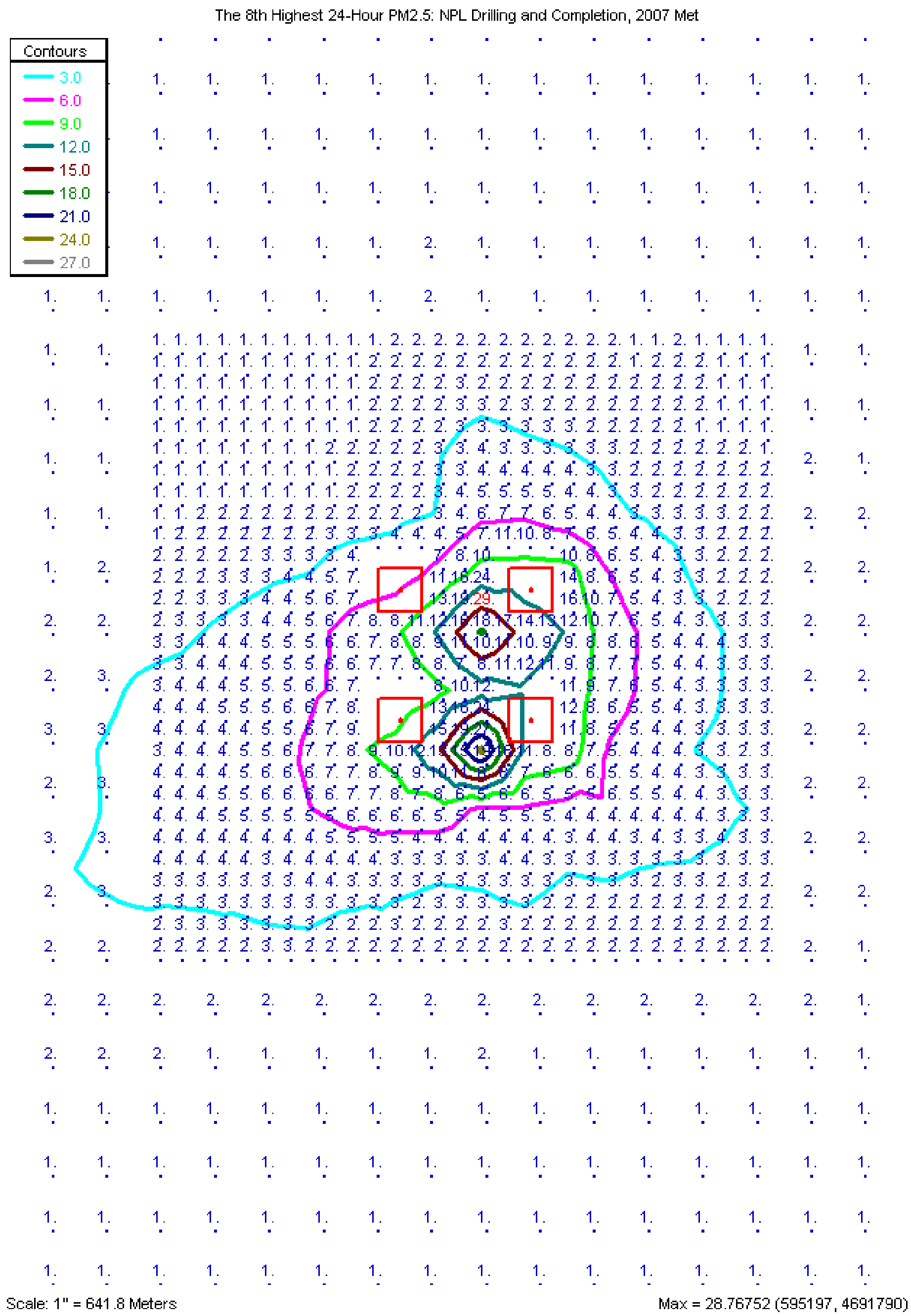


Figure C-4. AERMOD-Derived 8th High 24-Hour $PM_{2.5}$ Concentration

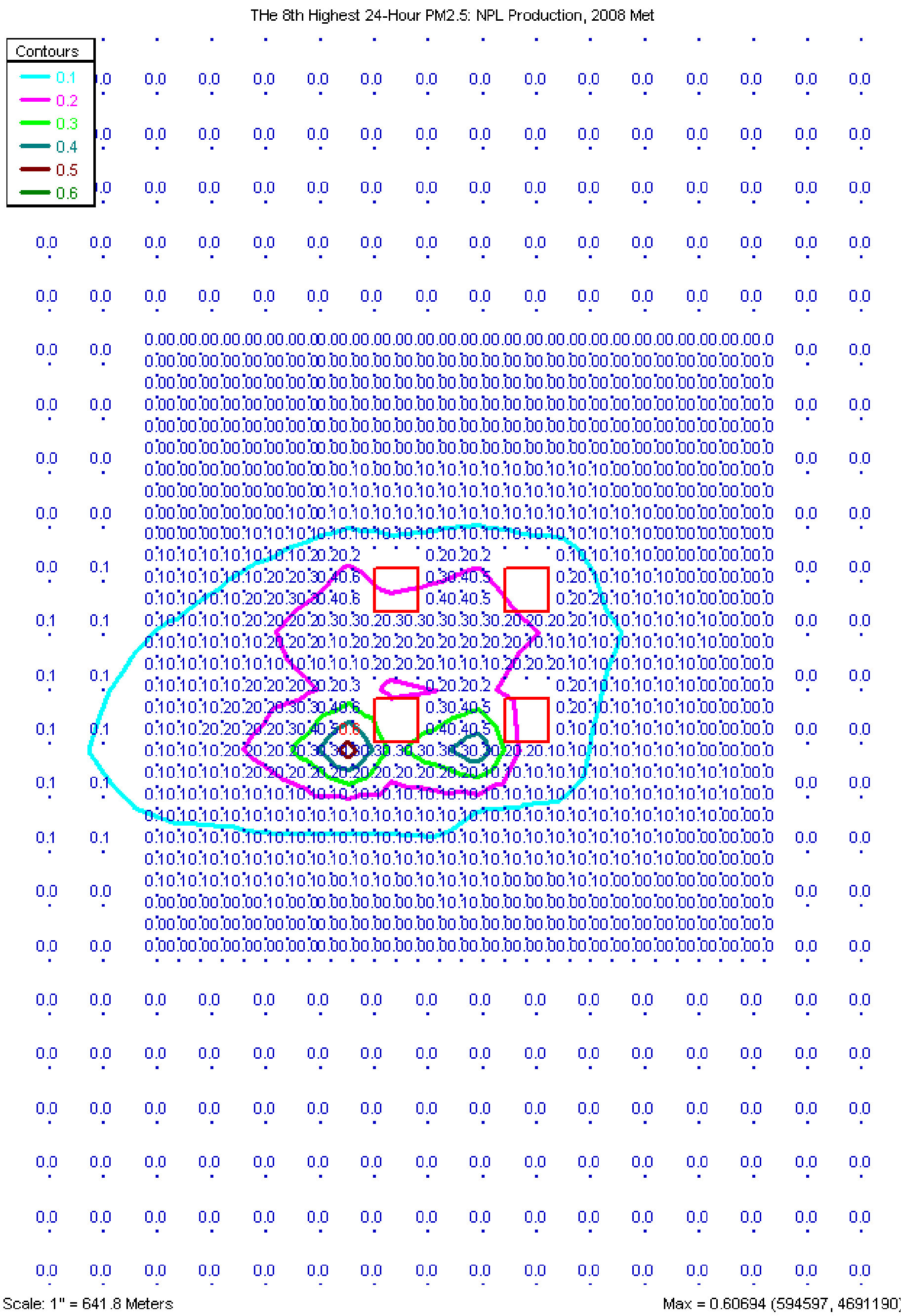
2006 (Well Pad Construction)



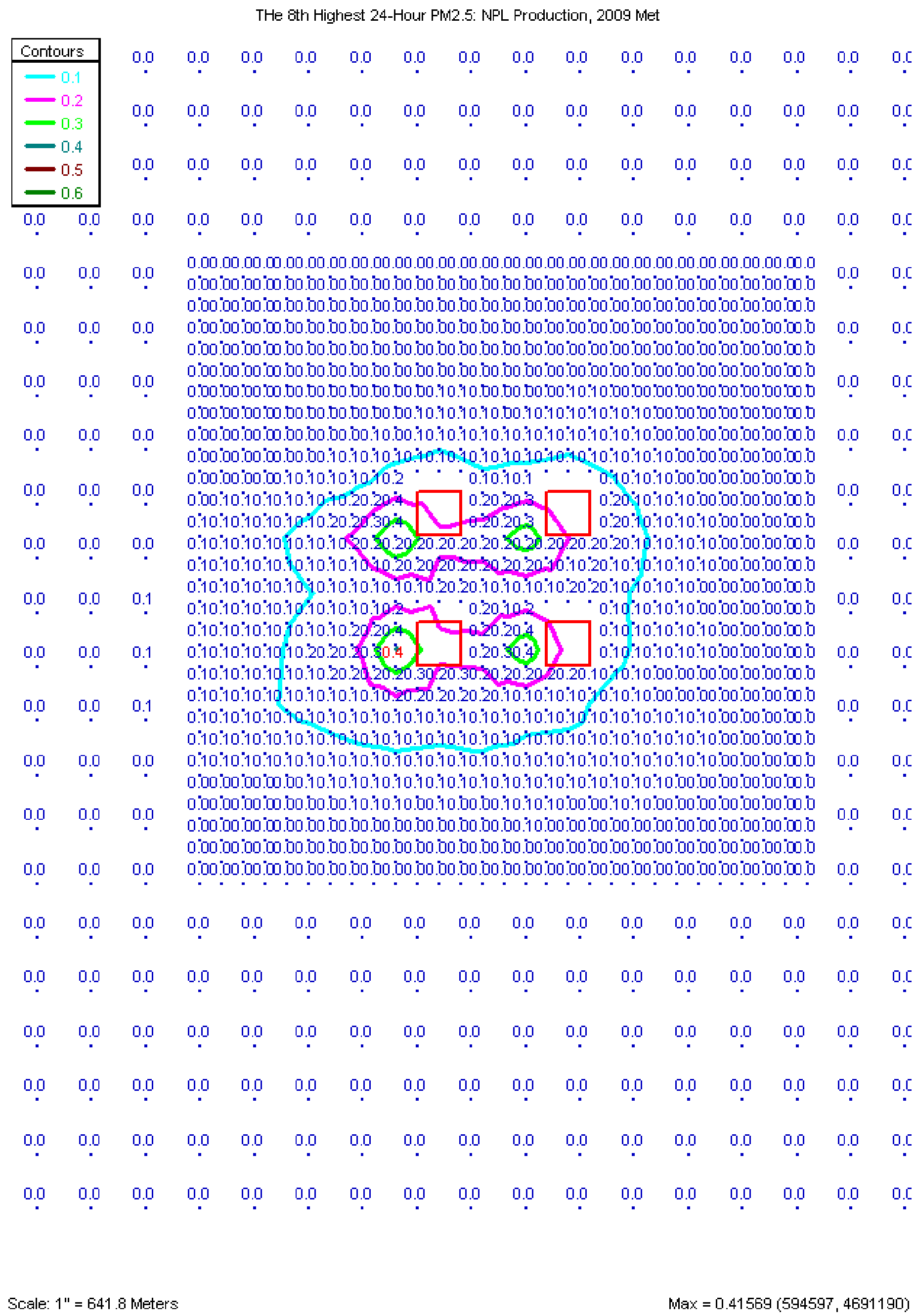
2007 (Drilling and Completion)



2008 (Production)



2009 (Production)



2010 (Production)

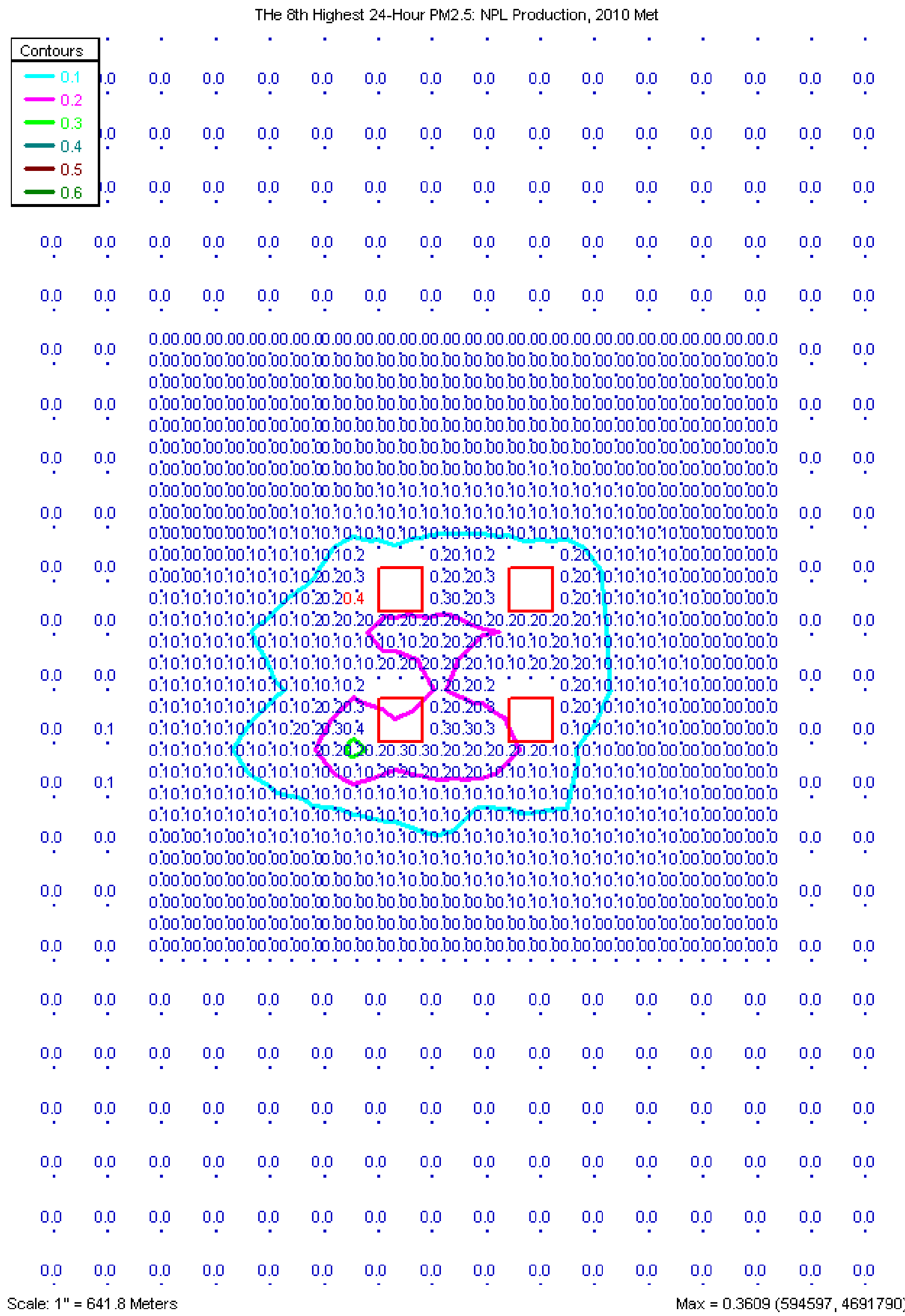
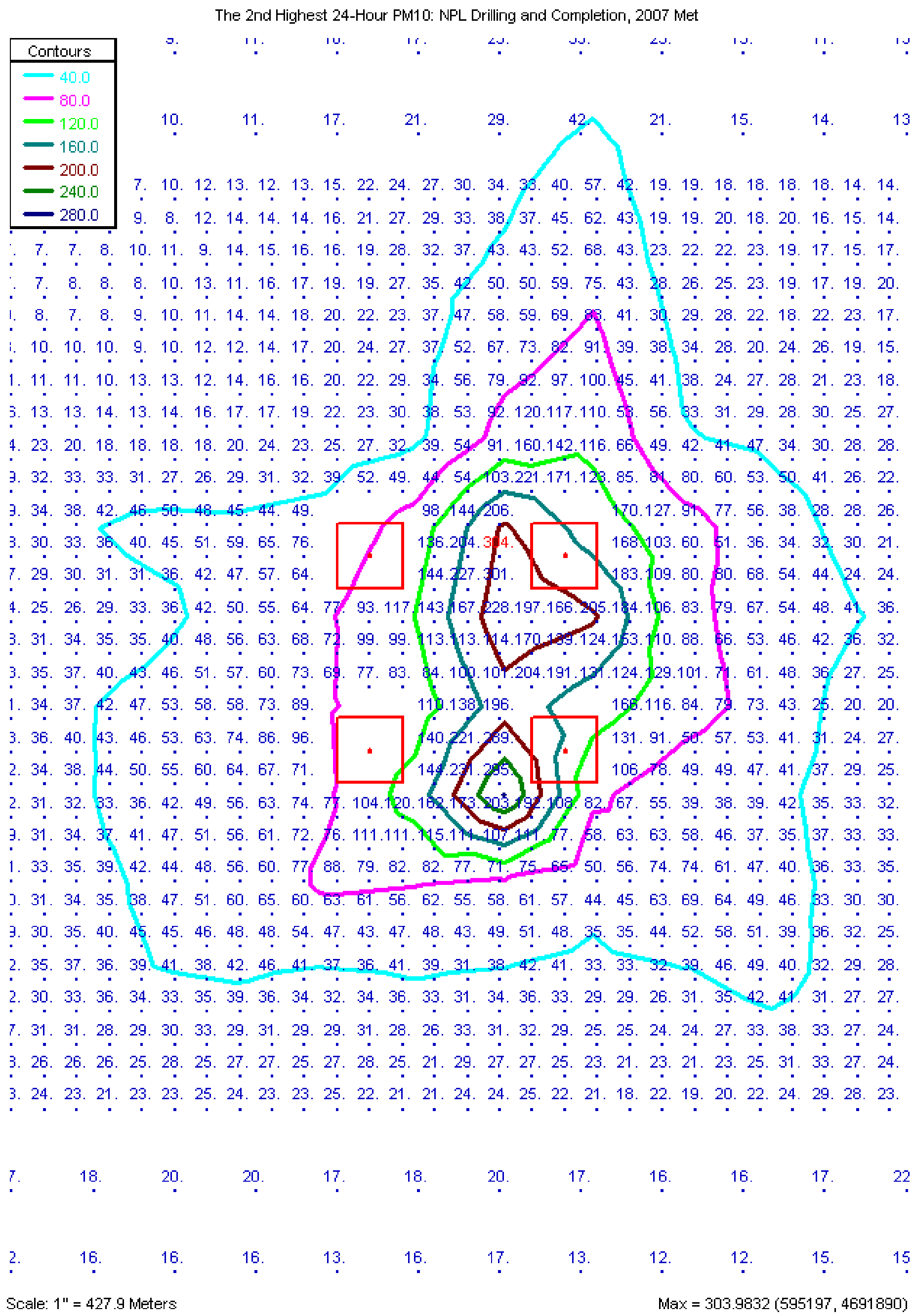


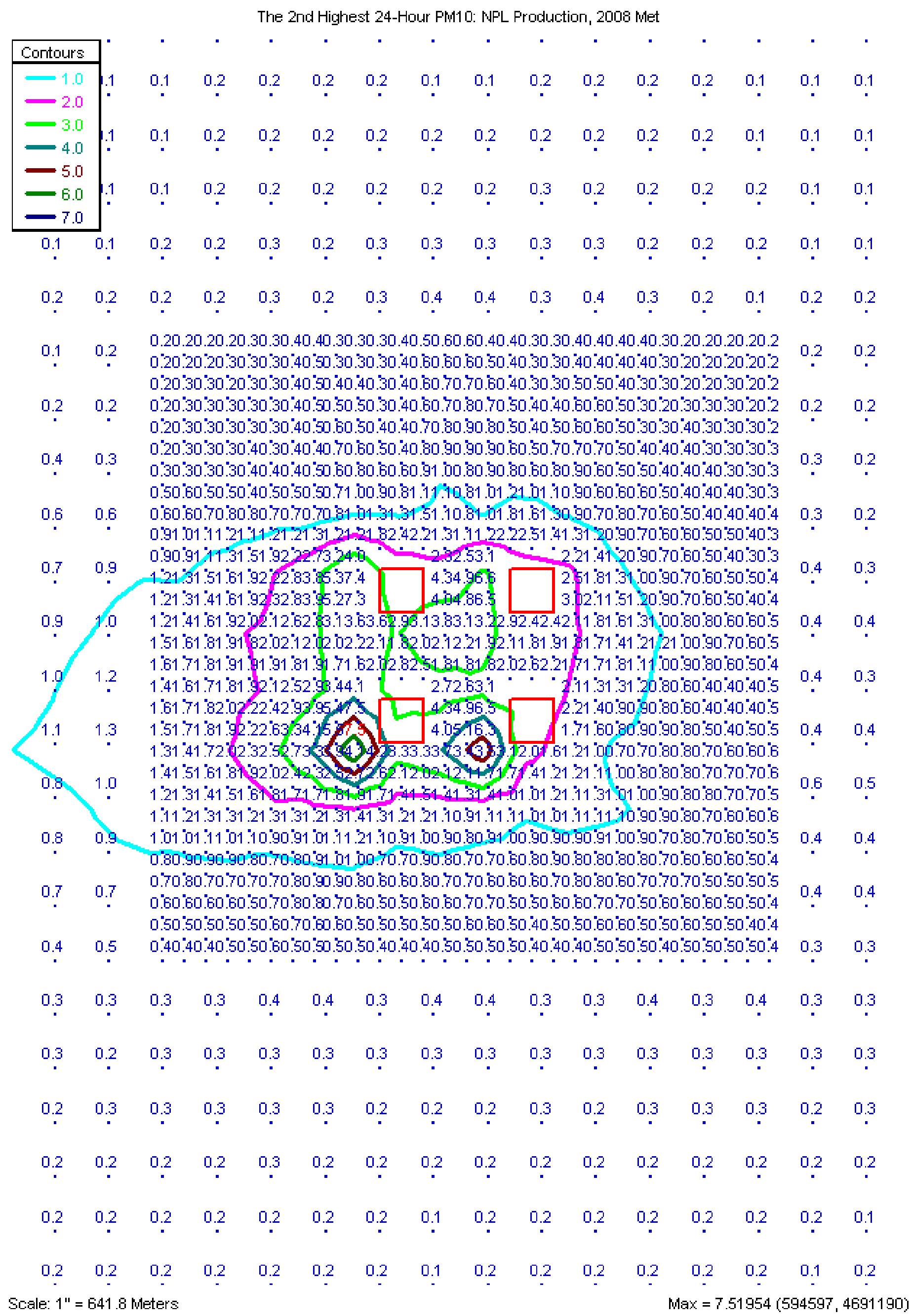
Figure C-5. AERMOD-Derived 2nd High 24-Hour PM_{10} Concentration

2006 (Well Pad Construction)

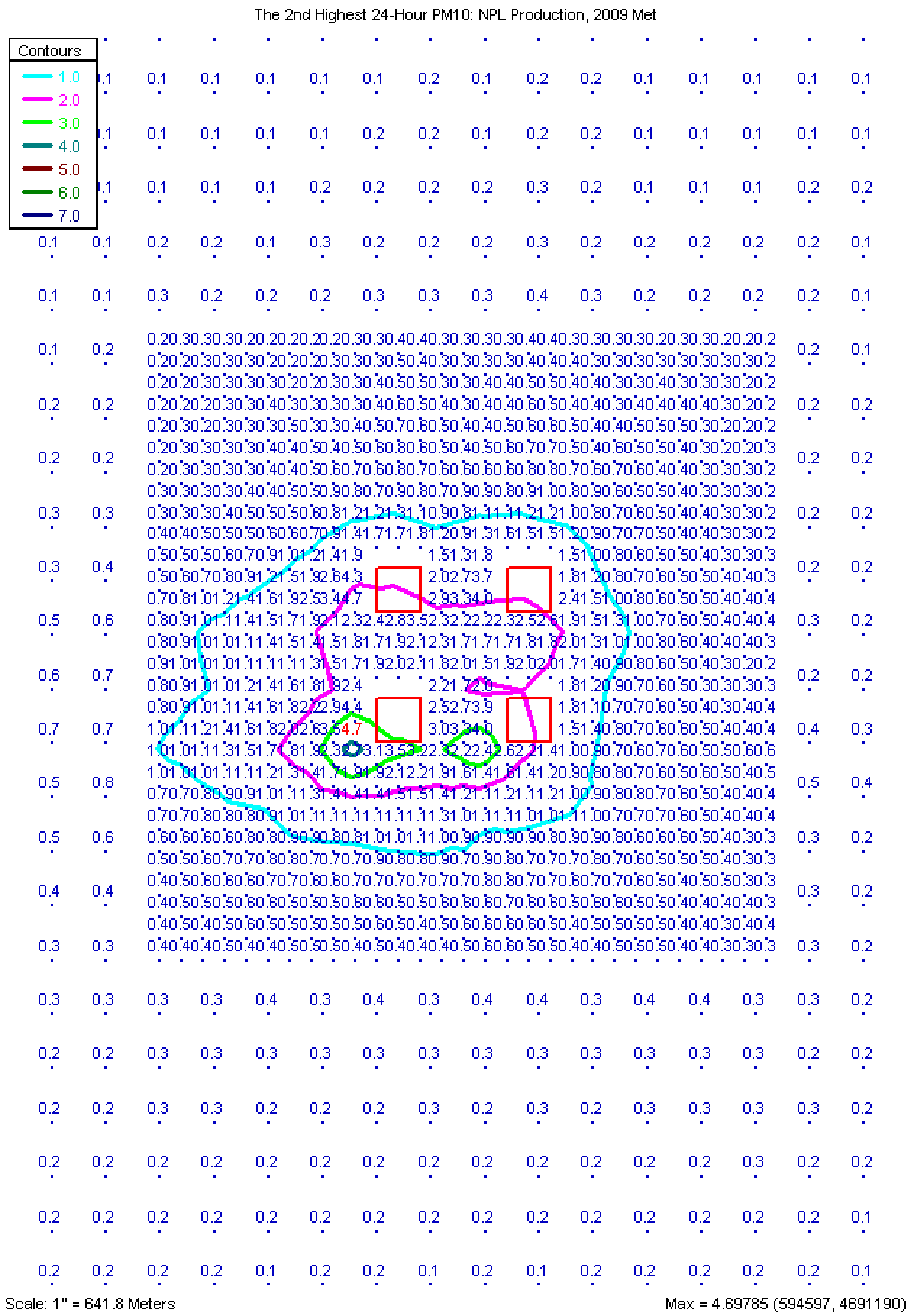
2007 (Drilling and Completion)



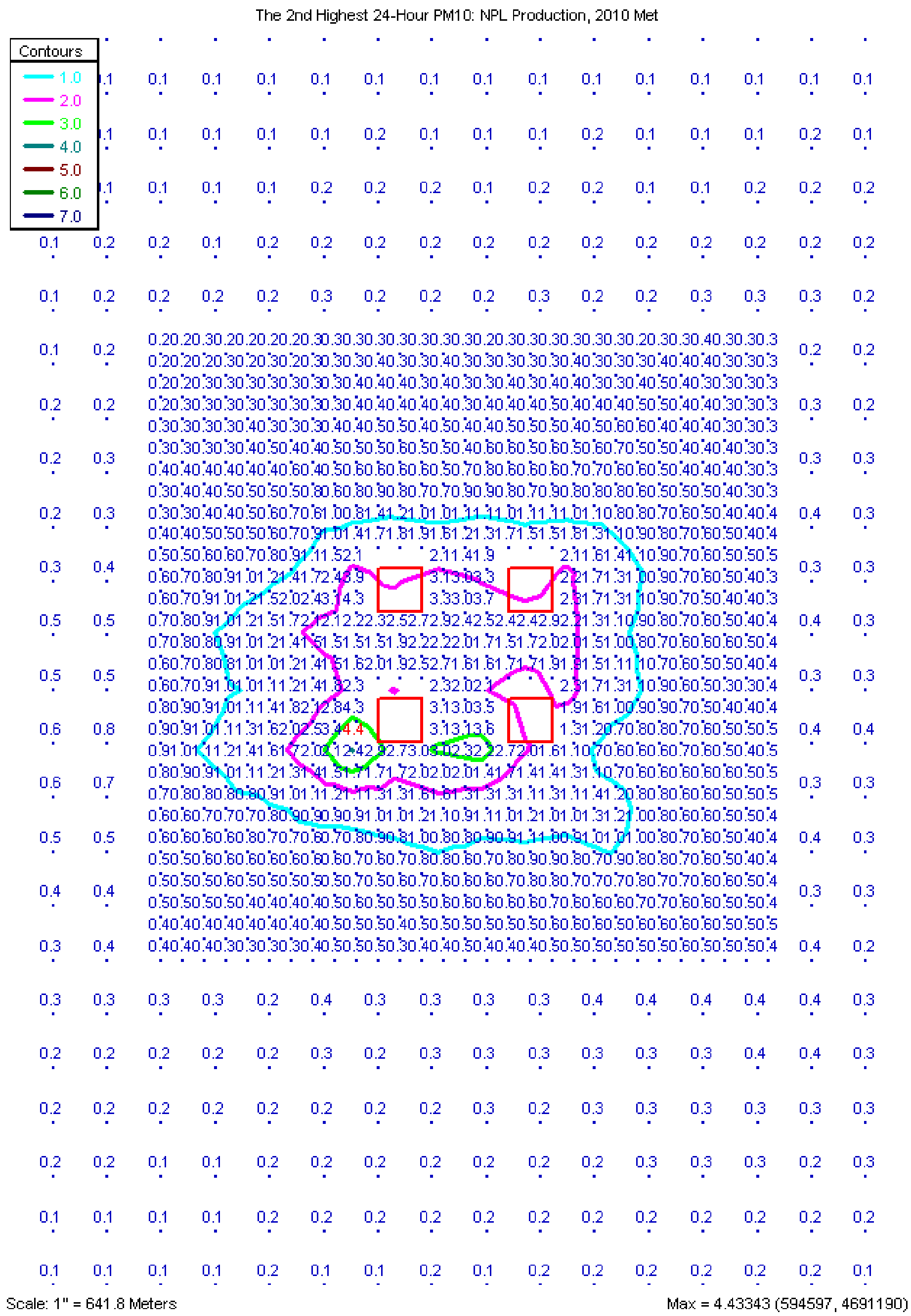
2008 (Production)



2009 (Production)



2010 (Production)



APPENDIX D: CALPUFF INPUT FILE

NPL Only

```
CALPUFF simulation for NPL project-specific emissions modeled
      as 56 area sources (4km by 4km) using r1 version of metdata
      7,095 Class I, Class II and Lake receptors

---------------- Run title (3 lines) ------------------------------------------

                CALPUFF MODEL CONTROL FILE
                --------------------------

-------------------------------------------------------------------------------

INPUT GROUP: 0 -- Input and Output File Names

--------------
Default Name  Type        File Name
------------  ----        ---------
CALMET.DAT    input    * METDAT =          *
   or
ISCMET.DAT    input    * ISCDAT =          *
   or
PLMMET.DAT    input    * PLMDAT =          *
   or
PROFILE.DAT   input    * PRFDAT =          *
SURFACE.DAT   input    * SFCDAT =          *
RESTARTB.DAT  input    * RSTARTB=          *
-------------------------------------------------------------------------------
CALPUFF.LST   output   ! PUFLST =npl_rfd_calpuff_ann_r1.lst  !
CONC.DAT      output   ! CONDAT =npl_rfd_calpuff_ann_r1.con  !
DFLX.DAT      output   ! DFDAT  =npl_rfd_calpuff_ann_r1.dry  !
WFLX.DAT      output   ! WFDAT  =npl_rfd_calpuff_ann_r1.wet  !

VISB.DAT      output   ! VISDAT =npl_rfd_calpuff_ann_r1.vis  !
TK2D.DAT      output   * T2DDAT =          *
RHO2D.DAT     output   * RHODAT =          *
RESTARTE.DAT  output   * RSTARTE=          *
-------------------------------------------------------------------------------
Emission Files
--------------
PTEMARB.DAT   input    * PTDAT  =          *
VOLEMARB.DAT  input    * VOLDAT =          *
BAEMARB.DAT   input    * ARDAT  =          *
LNEMARB.DAT   input    * LNDAT  =          *
-------------------------------------------------------------------------------
Other Files
-----------
OZONE.DAT     input    ! OZDAT  =../o3_data/npl_calpuff_hourly_ozone.dat.rv !
VD.DAT        input    * VDDAT  =          *
CHEM.DAT      input    * CHEMDAT=          *
H2O2.DAT      input    * H2O2DAT=          *
HILL.DAT      input    * HILDAT=           *
HILLRCT.DAT   input    * RCTDAT=           *
COASTLN.DAT   input    * CSTDAT=           *
```

```
FLUXBDY.DAT   input    * BDYDAT=          *
BCON.DAT     input    * BCNDAT=          *
DEBUG.DAT    output   * DEBUG =          *
MASSFLX.DAT   output   * FLXDAT=          *
MASSBAL.DAT   output   * BALDAT=          *
FOG.DAT      output   * FOGDAT=          *
-------------------------------------------------------------------------------
All file names will be converted to lower case if LCFILES = T
Otherwise, if LCFILES = F, file names will be converted to UPPER CASE
       T = lower case      ! LCFILES = T !
       F = UPPER CASE
NOTE: (1) file/path names can be up to 70 characters in length


Provision for multiple input files
----------------------------------

    Number of CALMET.DAT files for run (NMETDAT)
                         Default: 1      ! NMETDAT =   14   !

    Number of PTEMARB.DAT files for run (NPTDAT)
                         Default: 0      ! NPTDAT =  0  !

    Number of BAEMARB.DAT files for run (NARDAT)
                         Default: 0      ! NARDAT =  0  !

    Number of VOLEMARB.DAT files for run (NVOLDAT)
                         Default: 0      ! NVOLDAT =  0  !

!END!

-------------
Subgroup (0a)
-------------

  The following CALMET.DAT filenames are processed in sequence if NMETDAT>1

Default Name  Type         File Name
------------  ----         ---------
 none       input    ! METDAT=/n1/npl/mmif_r1/jan/calpuff_wrf.jan.r1.met     ! !END!
 none       input    ! METDAT=/n1/npl/mmif_r1/feb/calpuff_wrf.feb.r1.met     ! !END!
 none       input    ! METDAT=/n1/npl/mmif_r1/mar/calpuff_wrf.mar.r1.met     ! !END!
 none       input    ! METDAT=/n1/npl/mmif_r1/mar/calpuff_wrf.mar2.r1.met    ! !END!
 none       input    ! METDAT=/n1/npl/mmif_r1/april/calpuff_wrf.april.r1.met ! !END!
 none       input    ! METDAT=/n1/npl/mmif_r1/may/calpuff_wrf.may.r1.met     ! !END!
 none       input    ! METDAT=/n1/npl/mmif_r1/jun/calpuff_wrf.jun.r1.met     ! !END!
 none       input    ! METDAT=/n1/npl/mmif_r1/jul/calpuff_wrf.jul.r1.met     ! !END!
 none       input    ! METDAT=/n1/npl/mmif_r1/aug/calpuff_wrf.aug.r1.met     ! !END!
 none       input    ! METDAT=/n1/npl/mmif_r1/sept/calpuff_wrf.sept.r1.met   ! !END!
 none       input    ! METDAT=/n1/npl/mmif_r1/oct/calpuff_wrf.oct.r1.met     ! !END!
 none       input    ! METDAT=/n1/npl/mmif_r1/oct/calpuff_wrf.oct2.r1.met    ! !END!
 none       input    ! METDAT=/n1/npl/mmif_r1/nov/calpuff_wrf.nov.r1.met     ! !END!
 none       input    ! METDAT=/n1/npl/mmif_r1/dec/calpuff_wrf.dec.r1.met     ! !END!


-------------------------------------------------------------------------------

INPUT GROUP: 1 -- General run control parameters
```

```
--------------

 Option to run all periods found
 in the met. file     (METRUN)   Default: 0      ! METRUN =   0  !

      METRUN = 0 - Run period explicitly defined below
      METRUN = 1 - Run all periods in met. file

  Starting date:   Year (IBYR) -- No default      ! IBYR =  2008  !
  (used only if   Month (IBMO) -- No default      ! IBMO =  1  !
   METRUN = 0)      Day (IBDY) -- No default      ! IBDY =  1  !
              Hour (IBHR) -- No default      ! IBHR =  1  !

  Note: IBHR is the time at the END of the first hour of the simulation
        (IBHR=1, the first hour of a day, runs from 00:00 to 01:00)

  Base time zone       (XBTZ) -- No default      ! XBTZ = 7.0  !
  The zone is the number of hours that must be
  ADDED to the time to obtain UTC (or GMT)
  Examples: PST = 8., MST = 7.
            CST = 6., EST = 5.

  Length of run (hours) (IRLG) -- No default      ! IRLG =  8777  !

  Number of chemical species (NSPEC)
                          Default: 5      ! NSPEC = 7  !

  Number of chemical species
  to be emitted  (NSE)          Default: 3      ! NSE =  4   !

  Flag to stop run after
  SETUP phase (ITEST)           Default: 2      ! ITEST =  2   !
  (Used to allow checking
  of the model inputs, files, etc.)
        ITEST = 1 - STOPS program after SETUP phase
        ITEST = 2 - Continues with execution of program
                    after SETUP

  Restart Configuration:

    Control flag (MRESTART)     Default: 0      ! MRESTART =  0   !

      0 = Do not read or write a restart file
      1 = Read a restart file at the beginning of
          the run
      2 = Write a restart file during run
      3 = Read a restart file at beginning of run
          and write a restart file during run

    Number of periods in Restart
    output cycle (NRESPD)       Default: 0      ! NRESPD =  0   !

      0 = File written only at last period
     >0 = File updated every NRESPD periods

  Meteorological Data Format (METFM)
                          Default: 1      ! METFM =  1   !
```

```
        METFM = 1 - CALMET binary file (CALMET.MET)
        METFM = 2 - ISC ASCII file (ISCMET.MET)
        METFM = 3 - AUSPLUME ASCII file (PLMMET.MET)
        METFM = 4 - CTDM plus tower file (PROFILE.DAT) and
                surface parameters file (SURFACE.DAT)
        METFM = 5 - AERMET tower file (PROFILE.DAT) and
                surface parameters file (SURFACE.DAT)

    Meteorological Profile Data Format (MPRFFM)
        (used only for METFM = 1, 2, 3)
                        Default: 1      ! MPRFFM =  1   !

        MPRFFM = 1 - CTDM plus tower file (PROFILE.DAT)
        MPRFFM = 2 - AERMET tower file (PROFILE.DAT)

    PG sigma-y is adjusted by the factor (AVET/PGTIME)**0.2
    Averaging Time (minutes) (AVET)
                        Default: 60.0    ! AVET = 60. !
    PG Averaging Time (minutes) (PGTIME)
                        Default: 60.0    ! PGTIME = 60. !


!END!


-------------------------------------------------------------------------------

INPUT GROUP: 2 -- Technical options
--------------


    Vertical distribution used in the
    near field (MGAUSS)              Default: 1     ! MGAUSS =  1   !
      0 = uniform
      1 = Gaussian

    Terrain adjustment method
    (MCTADJ)                   Default: 3     ! MCTADJ =  3   !
      0 = no adjustment
      1 = ISC-type of terrain adjustment
      2 = simple, CALPUFF-type of terrain
         adjustment
      3 = partial plume path adjustment

    Subgrid-scale complex terrain
    flag (MCTSG)                 Default: 0     ! MCTSG =  0   !
      0 = not modeled
      1 = modeled

    Near-field puffs modeled as
    elongated slugs? (MSLUG)          Default: 0     ! MSLUG =  0   !
      0 = no
      1 = yes (slug model used)

    Transitional plume rise modeled?
    (MTRANS)                   Default: 1     ! MTRANS =  1   !
      0 = no  (i.e., final rise only)
      1 = yes (i.e., transitional rise computed)
```

```
Stack tip downwash? (MTIP)          Default: 1     ! MTIP =  1  !
  0 = no  (i.e., no stack tip downwash)
  1 = yes (i.e., use stack tip downwash)

Method used to simulate building
downwash? (MBDW)                   Default: 1     ! MBDW =   1  !
  1 = ISC method
  2 = PRIME method

Vertical wind shear modeled above
stack top? (MSHEAR)                Default: 0     ! MSHEAR =  0  !
  0 = no  (i.e., vertical wind shear not modeled)
  1 = yes (i.e., vertical wind shear modeled)

Puff splitting allowed? (MSPLIT)    Default: 0     ! MSPLIT =  0  !
  0 = no (i.e., puffs not split)
  1 = yes (i.e., puffs are split)

Chemical mechanism flag (MCHEM)     Default: 1     ! MCHEM =  1   !
  0 = chemical transformation not
      modeled
  1 = transformation rates computed
      internally (MESOPUFF II scheme)
  2 = user-specified transformation
      rates used
  3 = transformation rates computed
      internally (RIVAD/ARM3 scheme)
  4 = secondary organic aerosol formation
      computed (MESOPUFF II scheme for OH)

Aqueous phase transformation flag (MAQCHEM)
(Used only if MCHEM = 1, or 3)      Default: 0     ! MAQCHEM =  0   !
  0 = aqueous phase transformation
      not modeled
  1 = transformation rates adjusted
      for aqueous phase reactions

Wet removal modeled ? (MWET)        Default: 1     ! MWET =  1   !
  0 = no
  1 = yes

Dry deposition modeled ? (MDRY)     Default: 1     ! MDRY =  1   !
  0 = no
  1 = yes
  (dry deposition method specified
   for each species in Input Group 3)


Gravitational settling (plume tilt)
modeled ? (MTILT)                  Default: 0     ! MTILT =  0   !
  0 = no
  1 = yes
  (puff center falls at the gravitational
   settling velocity for 1 particle species)

Restrictions:
   - MDRY  = 1
```

```
    - NSPEC = 1  (must be particle species as well)
    - sg    = 0  GEOMETRIC STANDARD DEVIATION in Group 8 is
             set to zero for a single particle diameter

 Method used to compute dispersion
 coefficients (MDISP)              Default: 3     ! MDISP =  3   !

   1 = dispersion coefficients computed from measured values
       of turbulence, sigma v, sigma w
   2 = dispersion coefficients from internally calculated
       sigma v, sigma w using micrometeorological variables
       (u*, w*, L, etc.)
   3 = PG dispersion coefficients for RURAL areas (computed using
       the ISCST multi-segment approximation) and MP coefficients in
       urban areas
   4 = same as 3 except PG coefficients computed using
       the MESOPUFF II eqns.
   5 = CTDM sigmas used for stable and neutral conditions.
       For unstable conditions, sigmas are computed as in
       MDISP = 3, described above.  MDISP = 5 assumes that
       measured values are read

 Sigma-v/sigma-theta, sigma-w measurements used? (MTURBVW)
 (Used only if MDISP = 1 or 5)        Default: 3     ! MTURBVW =  3  !
   1 = use sigma-v or sigma-theta measurements
       from PROFILE.DAT to compute sigma-y
       (valid for METFM = 1, 2, 3, 4, 5)
   2 = use sigma-w measurements
       from PROFILE.DAT to compute sigma-z
       (valid for METFM = 1, 2, 3, 4, 5)
   3 = use both sigma-(v/theta) and sigma-w
       from PROFILE.DAT to compute sigma-y and sigma-z
       (valid for METFM = 1, 2, 3, 4, 5)
   4 = use sigma-theta measurements
       from PLMMET.DAT to compute sigma-y
       (valid only if METFM = 3)

 Back-up method used to compute dispersion
 when measured turbulence data are
 missing (MDISP2)                  Default: 3     ! MDISP2 =  3  !
 (used only if MDISP = 1 or 5)
   2 = dispersion coefficients from internally calculated
       sigma v, sigma w using micrometeorological variables
       (u*, w*, L, etc.)
   3 = PG dispersion coefficients for RURAL areas (computed using
       the ISCST multi-segment approximation) and MP coefficients in
       urban areas
   4 = same as 3 except PG coefficients computed using
       the MESOPUFF II eqns.

 [DIAGNOSTIC FEATURE]
 Method used for Lagrangian timescale for Sigma-y
 (used only if MDISP=1,2 or MDISP2=1,2)
 (MTAULY)                          Default: 0     ! MTAULY =  0  !
   0 = Draxler default 617.284 (s)
   1 = Computed as Lag. Length / (.75 q) -- after SCIPUFF
  10 < Direct user input (s)           -- e.g., 306.9
```

[DIAGNOSTIC FEATURE]
Method used for Advective-Decay timescale for Turbulence
(used only if MDISP=2 or MDISP2=2)
(MTAUADV) Default: 0 ! MTAUADV = 0 !
0 = No turbulence advection
1 = Computed (OPTION NOT IMPLEMENTED)
10 < Direct user input (s) -- e.g., 300

Method used to compute turbulence sigma-v &
sigma-w using micrometeorological variables
(Used only if MDISP = 2 or MDISP2 = 2)
(MCTURB) Default: 1 ! MCTURB = 1 !
1 = Standard CALPUFF subroutines
2 = AERMOD subroutines

PG sigma-y,z adj. for roughness? Default: 0 ! MROUGH = 0 !
(MROUGH)
0 = no
1 = yes

Partial plume penetration of Default: 1 ! MPARTL = 1 !
elevated inversion?
(MPARTL)
0 = no
1 = yes

Strength of temperature inversion Default: 0 ! MTINV = 0 !
provided in PROFILE.DAT extended records?
(MTINV)
0 = no (computed from measured/default gradients)
1 = yes

PDF used for dispersion under convective conditions?
Default: 0 ! MPDF = 0 !
(MPDF)
0 = no
1 = yes

Sub-Grid TIBL module used for shore line?
Default: 0 ! MSGTIBL = 0 !
(MSGTIBL)
0 = no
1 = yes

Boundary conditions (concentration) modeled?
Default: 0 ! MBCON = 0 !
(MBCON)
0 = no
1 = yes, using formatted BCON.DAT file
2 = yes, using unformatted CONC.DAT file

Note: MBCON > 0 requires that the last species modeled
be 'BCON'. Mass is placed in species BCON when
generating boundary condition puffs so that clean
air entering the modeling domain can be simulated
in the same way as polluted air. Specify zero

```
      emission of species BCON for all regular sources.

   Individual source contributions saved?
                              Default: 0     ! MSOURCE = 0  !
   (MSOURCE)
     0 = no
     1 = yes


   Analyses of fogging and icing impacts due to emissions from
   arrays of mechanically-forced cooling towers can be performed
   using CALPUFF in conjunction with a cooling tower emissions
   processor (CTEMISS) and its associated postprocessors.  Hourly
   emissions of water vapor and temperature from each cooling tower
   cell are computed for the current cell configuration and ambient
   conditions by CTEMISS. CALPUFF models the dispersion of these
   emissions and provides cloud information in a specialized format
   for further analysis. Output to FOG.DAT is provided in either
   'plume mode' or 'receptor mode' format.

   Configure for FOG Model output?
                              Default: 0     ! MFOG =  0   !
   (MFOG)
     0 = no
     1 = yes  - report results in PLUME Mode format
     2 = yes  - report results in RECEPTOR Mode format


   Test options specified to see if
   they conform to regulatory
   values? (MREG)                 Default: 1     ! MREG =  1   !

     0 = NO checks are made
     1 = Technical options must conform to USEPA
        Long Range Transport (LRT) guidance
              METFM    1 or 2
              AVET     60. (min)
              PGTIME   60. (min)
              MGAUSS   1
              MCTADJ   3
              MTRANS   1
              MTIP     1
              MCHEM    1 or 3 (if modeling SOx, NOx)
              MWET     1
              MDRY     1
              MDISP    2 or 3
              MPDF     0 if MDISP=3
                       1 if MDISP=2
              MROUGH   0
              MPARTL   1
              SYTDEP   550. (m)
              MHFTSZ   0
              SVMIN    0.5 (m/s)


!END!
```

```
-------------------------------------------------------------------------------

INPUT GROUP: 3a, 3b -- Species list
-------------------

------------
Subgroup (3a)
------------

  The following species are modeled:

! CSPEC =        SO2 !        !END!
! CSPEC =        SO4 !        !END!
! CSPEC =        NOX !        !END!
! CSPEC =       HNO3 !        !END!
! CSPEC =        NO3 !        !END!
! CSPEC =       PM10 !        !END!
! CSPEC =       PM25 !        !END!

                                   Dry              OUTPUT GROUP
   SPECIES        MODELED        EMITTED      DEPOSITED              NUMBER
    NAME       (0=NO, 1=YES)   (0=NO, 1=YES)   (0=NO,              (0=NONE,
  (Limit: 12                            1=COMPUTED-GAS       1=1st CGRUP,
   Characters                            2=COMPUTED-PARTICLE   2=2nd CGRUP,
   in length)                           3=USER-SPECIFIED)     3= etc.)

!        SO2  =       1,            1,         1,              0   !
!        SO4  =       1,            0,         2,              0   !
!        NOX  =       1,            1,         1,              0   !
!       HNO3  =       1,            0,         1,              0   !
!        NO3  =       1,            0,         2,              0   !
!       PM10  =       1,            1,         2,              0   !
!       PM25  =       1,            1,         2,              0   !

!END!

  Note:  The last species in (3a) must be 'BCON' when using the
         boundary condition option (MBCON > 0).  Species BCON should
         typically be modeled as inert (no chem transformation or
         removal).


-------------
Subgroup (3b)
-------------
  The following names are used for Species-Groups in which results
  for certain species are combined (added) prior to output.  The
  CGRUP name will be used as the species name in output files.
  Use this feature to model specific particle-size distributions
  by treating each size-range as a separate species.
  Order must be consistent with 3(a) above.



-------------------------------------------------------------------------------


INPUT GROUP: 4 -- Map Projection and Grid control parameters
```

```
--------------

    Projection for all (X,Y):
    -------------------------

    Map projection
    (PMAP)                  Default: UTM    ! PMAP = LCC  !

       UTM :  Universal Transverse Mercator
       TTM :  Tangential Transverse Mercator
       LCC :  Lambert Conformal Conic
        PS :  Polar Stereographic
        EM :  Equatorial Mercator
      LAZA :  Lambert Azimuthal Equal Area

    False Easting and Northing (km) at the projection origin
    (Used only if PMAP= TTM, LCC, or LAZA)
    (FEAST)                 Default=0.0     ! FEAST  = 0.000  !
    (FNORTH)                Default=0.0     ! FNORTH = 0.000  !

    UTM zone (1 to 60)
    (Used only if PMAP=UTM)
    (IUTMZN)                No Default      ! IUTMZN =  19   !

    Hemisphere for UTM projection?
    (Used only if PMAP=UTM)
    (UTMHEM)                Default: N      ! UTMHEM = N  !
       N   :  Northern hemisphere projection
       S   :  Southern hemisphere projection

    Latitude and Longitude (decimal degrees) of projection origin
    (Used only if PMAP= TTM, LCC, PS, EM, or LAZA)
    (RLAT0)                 No Default      ! RLAT0 = 40.0N  !
    (RLON0)                 No Default      ! RLON0 = 97.0W  !

       TTM :  RLON0 identifies central (true N/S) meridian of projection
              RLAT0 selected for convenience
       LCC :  RLON0 identifies central (true N/S) meridian of projection
              RLAT0 selected for convenience
       PS  :  RLON0 identifies central (grid N/S) meridian of projection
              RLAT0 selected for convenience
       EM  :  RLON0 identifies central meridian of projection
              RLAT0 is REPLACED by 0.0N (Equator)
       LAZA:  RLON0 identifies longitude of tangent-point of mapping plane
              RLAT0 identifies latitude of tangent-point of mapping plane

    Matching parallel(s) of latitude (decimal degrees) for projection
    (Used only if PMAP= LCC or PS)
    (XLAT1)                 No Default      ! XLAT1 = 45.0N  !
    (XLAT2)                 No Default      ! XLAT2 = 33.0N  !

       LCC :  Projection cone slices through Earth's surface at XLAT1 and XLAT2
       PS  :  Projection plane slices through Earth at XLAT1
              (XLAT2 is not used)

    ----------
    Note:  Latitudes and longitudes should be positive, and include a
           letter N,S,E, or W indicating north or south latitude, and
```

east or west longitude. For example,
35.9 N Latitude = 35.9N
118.7 E Longitude = 118.7E

Datum-region

The Datum-Region for the coordinates is identified by a character string. Many mapping products currently available use the model of the Earth known as the World Geodetic System 1984 (WGS-84). Other local models may be in use, and their selection in CALMET will make its output consistent with local mapping products. The list of Datum-Regions with official transformation parameters is provided by the National Imagery and Mapping Agency (NIMA).

NIMA Datum - Regions(Examples)

WGS-84 WGS-84 Reference Ellipsoid and Geoid, Global coverage (WGS84)
NAS-C NORTH AMERICAN 1927 Clarke 1866 Spheroid, MEAN FOR CONUS (NAD27)
NAR-C NORTH AMERICAN 1983 GRS 80 Spheroid, MEAN FOR CONUS (NAD83)
NWS-84 NWS 6370KM Radius, Sphere
ESR-S ESRI REFERENCE 6371KM Radius, Sphere

Datum-region for output coordinates
(DATUM) Default: WGS-84 ! DATUM = NWS-84 !

METEOROLOGICAL Grid:

Rectangular grid defined for projection PMAP,
with X the Easting and Y the Northing coordinate

No. X grid cells (NX) No default ! NX = 132 !
No. Y grid cells (NY) No default ! NY = 159 !
No. vertical layers (NZ) No default ! NZ = 10 !

Grid spacing (DGRIDKM) No default ! DGRIDKM = 4.0 !
Units: km

Cell face heights
(ZFACE(nz+1)) No defaults
Units: m
! ZFACE = .0, 20.0, 40.0, 80.0, 160.0, 320.0, 640.0, 1200.0, 2000.0, 3000.0,
4000.0 !

Reference Coordinates
of SOUTHWEST corner of
grid cell(1, 1):

X coordinate (XORIGKM) No default ! XORIGKM = -1188.0 !
Y coordinate (YORIGKM) No default ! YORIGKM = 72.0 !
Units: km

COMPUTATIONAL Grid:

The computational grid is identical to or a subset of the MET. grid.

The lower left (LL) corner of the computational grid is at grid point
(IBCOMP, JBCOMP) of the MET. grid. The upper right (UR) corner of the
computational grid is at grid point (IECOMP, JECOMP) of the MET. grid.
The grid spacing of the computational grid is the same as the MET. grid.

X index of LL corner (IBCOMP) No default ! IBCOMP = 1 !
(1 <= IBCOMP <= NX)

Y index of LL corner (JBCOMP) No default ! JBCOMP = 1 !
(1 <= JBCOMP <= NY)

X index of UR corner (IECOMP) No default ! IECOMP = 132 !
(1 <= IECOMP <= NX)

Y index of UR corner (JECOMP) No default ! JECOMP = 159 !
(1 <= JECOMP <= NY)

SAMPLING Grid (GRIDDED RECEPTORS):

The lower left (LL) corner of the sampling grid is at grid point
(IBSAMP, JBSAMP) of the MET. grid. The upper right (UR) corner of the
sampling grid is at grid point (IESAMP, JESAMP) of the MET. grid.
The sampling grid must be identical to or a subset of the computational
grid. It may be a nested grid inside the computational grid.
The grid spacing of the sampling grid is DGRIDKM/MESHDN.

Logical flag indicating if gridded
receptors are used (LSAMP) Default: T ! LSAMP = F !
(T=yes, F=no)

X index of LL corner (IBSAMP) No default ! IBSAMP = 29 !
(IBCOMP <= IBSAMP <= IECOMP)

Y index of LL corner (JBSAMP) No default ! JBSAMP = 40 !
(JBCOMP <= JBSAMP <= JECOMP)

X index of UR corner (IESAMP) No default ! IESAMP = 48 !
(IBCOMP <= IESAMP <= IECOMP)

Y index of UR corner (JESAMP) No default ! JESAMP = 70 !
(JBCOMP <= JESAMP <= JECOMP)

Nesting factor of the sampling
grid (MESHDN) Default: 1 ! MESHDN = 1 !
(MESHDN is an integer >= 1)

!END!

INPUT GROUP: 5 -- Output Options

```
--------------
                         *                 *
   FILE              DEFAULT VALUE        VALUE THIS RUN
   ----              -------------     --------------

  Concentrations (ICON)          1              !  ICON =  1   !
  Dry Fluxes (IDRY)              1              !  IDRY =  1   !
  Wet Fluxes (IWET)              1              !  IWET =  1   !
  2D Temperature (IT2D)          0              !  IT2D =  0   !
  2D Density (IRHO)              0              !  IRHO =  0   !
  Relative Humidity (IVIS)       1              !  IVIS =  1   !
   (relative humidity file is
    required for visibility
    analysis)
  Use data compression option in output file?
  (LCOMPRS)                  Default: T      ! LCOMPRS = T !

  *
   0 = Do not create file, 1 = create file


   QA PLOT FILE OUTPUT OPTION:

     Create a standard series of output files (e.g.
     locations of sources, receptors, grids ...)
     suitable for plotting?
     (IQAPLOT)               Default: 1       !  IQAPLOT =  1   !
       0 = no
       1 = yes

   DIAGNOSTIC MASS FLUX OUTPUT OPTIONS:

     Mass flux across specified boundaries
     for selected species reported?
     (IMFLX)                 Default: 0       ! IMFLX =  0  !
       0 = no
       1 = yes (FLUXBDY.DAT and MASSFLX.DAT filenames
               are specified in Input Group 0)

     Mass balance for each species
     reported?
     (IMBAL)                 Default: 0       ! IMBAL =  0  !
       0 = no
       1 = yes (MASSBAL.DAT filename is
            specified in Input Group 0)


   LINE PRINTER OUTPUT OPTIONS:

     Print concentrations (ICPRT)    Default: 0       ! ICPRT =  1   !
     Print dry fluxes (IDPRT)        Default: 0       ! IDPRT =  1   !
     Print wet fluxes (IWPRT)        Default: 0       ! IWPRT =  1   !
     (0 = Do not print, 1 = Print)

     Concentration print interval
     (ICFRQ) in timesteps        Default: 1       ! ICFRQ =  1   !
     Dry flux print interval
     (IDFRQ) in timesteps        Default: 1       ! IDFRQ =  1   !
```

```
     Wet flux print interval
     (IWFRQ) in timesteps          Default: 1        ! IWFRQ =  1   !

     Units for Line Printer Output
     (IPRTU)                    Default: 1        ! IPRTU =  3   !
                  for           for
             Concentration    Deposition
        1 =      g/m**3        g/m**2/s
        2 =     mg/m**3       mg/m**2/s
        3 =     ug/m**3       ug/m**2/s
        4 =     ng/m**3       ng/m**2/s
        5 =    Odour Units

     Messages tracking progress of run
     written to the screen ?
     (IMESG)                    Default: 2        ! IMESG =  2   !
       0 = no
       1 = yes (advection step, puff ID)
       2 = yes (YYYYJJJHH, # old puffs, # emitted puffs)


   SPECIES (or GROUP for combined species) LIST FOR OUTPUT OPTIONS

             ---- CONCENTRATIONS ----   ------ DRY FLUXES ------   ------ WET FLUXES ------   -- MASS FLUX --
   SPECIES
   /GROUP       PRINTED?  SAVED ON DISK?   PRINTED?  SAVED ON DISK?   PRINTED?  SAVED ON DISK?   SAVED ON DISK?
   -------      ------------------------   ------------------------   ------------------------   ---------------
!        SO2 =     1,          1,          1,          1,          1,          1,          0   !
!        SO4 =     0,          1,          0,          1,          0,          1,          0   !
!        NOX =     1,          1,          1,          1,          1,          1,          0   !
!       HNO3 =     0,          1,          0,          1,          0,          1,          0   !
!        NO3 =     0,          1,          0,          1,          0,          1,          0   !
!       PM10 =     1,          1,          1,          1,          1,          1,          0   !
!       PM25 =     1,          1,          1,          1,          1,          1,          0   !

  Note:  Species BCON (for MBCON > 0) does not need to be saved on disk.


   OPTIONS FOR PRINTING "DEBUG" QUANTITIES (much output)

     Logical for debug output
     (LDEBUG)                     Default: F     ! LDEBUG = F !

     First puff to track
     (IPFDEB)                     Default: 1     ! IPFDEB =  1  !

     Number of puffs to track
     (NPFDEB)                     Default: 1     ! NPFDEB =  1  !

     Met. period to start output
     (NN1)                        Default: 1     ! NN1 =  1   !

     Met. period to end output
     (NN2)                        Default: 10    ! NN2 =  10  !

!END!
```

```
--------------------------------------------------------------------------------


INPUT GROUP: 6a, 6b, & 6c -- Subgrid scale complex terrain inputs
-------------------------

---------------
Subgroup (6a)
---------------
      Number of terrain features (NHILL)      Default: 0     ! NHILL =  0   !

      Number of special complex terrain
      receptors  (NCTREC)                   Default: 0     ! NCTREC =  0   !

      Terrain and CTSG Receptor data for
      CTSG hills input in CTDM format ?
      (MHILL)                          No Default     ! MHILL =  2   !
      1 = Hill and Receptor data created
         by CTDM processors & read from
         HILL.DAT and HILLRCT.DAT files
      2 = Hill data created by OPTHILL &
         input below in Subgroup (6b);
         Receptor data in Subgroup (6c)

      Factor to convert horizontal dimensions  Default: 1.0   ! XHILL2M = 1.0 !
      to meters (MHILL=1)

      Factor to convert vertical dimensions    Default: 1.0   ! ZHILL2M = 1.0 !
      to meters (MHILL=1)

      X-origin of CTDM system relative to      No Default     ! XCTDMKM = 0 !
      CALPUFF coordinate system, in Kilometers (MHILL=1)

      Y-origin of CTDM system relative to      No Default     ! YCTDMKM = 0 !
      CALPUFF coordinate system, in Kilometers (MHILL=1)

! END !

---------------
Subgroup (6b)
---------------

                  1 **
    HILL information


HILL         XC       YC      THETAH  ZGRID  RELIEF    EXPO 1    EXPO 2   SCALE 1    SCALE 2    AMAX1     AMAX2
 NO.        (km)     (km)     (deg.)  (m)    (m)     (m)      (m)      (m)       (m)      (m)      (m)
----        ----     ----     ------  -----  ------    ------    ------   -------   -------    -----     -----

---------------
Subgroup (6c)
---------------

   COMPLEX TERRAIN RECEPTOR INFORMATION

                  XRCT       YRCT       ZRCT        XHH
                  (km)       (km)       (m)
```

```
              ------     -----    ------      ----


-------------------
1
   Description of Complex Terrain Variables:
      XC, YC  = Coordinates of center of hill
      THETAH  = Orientation of major axis of hill (clockwise from
            North)
      ZGRID   = Height of the  0  of the grid above mean sea
            level
      RELIEF  = Height of the crest of the hill above the grid elevation
      EXPO 1  = Hill-shape exponent for the major axis
      EXPO 2  = Hill-shape exponent for the major axis
      SCALE 1 = Horizontal length scale along the major axis
      SCALE 2 = Horizontal length scale along the minor axis
      AMAX    = Maximum allowed axis length for the major axis
      BMAX    = Maximum allowed axis length for the major axis

      XRCT, YRCT = Coordinates of the complex terrain receptors
      ZRCT    = Height of the ground (MSL) at the complex terrain
            Receptor
      XHH     = Hill number associated with each complex terrain receptor
            (NOTE: MUST BE ENTERED AS A REAL NUMBER)

  **
   NOTE: DATA for each hill and CTSG receptor are treated as a separate
        input subgroup and therefore must end with an input group terminator.

-------------------------------------------------------------------------------


INPUT GROUP: 7 -- Chemical parameters for dry deposition of gases
--------------

    SPECIES   DIFFUSIVITY    ALPHA STAR    REACTIVITY   MESOPHYLL RESISTANCE    HENRY'S LAW COEFFICIENT
     NAME      (cm**2/s)                                  (s/cm)          (dimensionless)
    -------   -----------    ----------    ----------   --------------------    -----------------------

!       SO2 =     .1509,       1000.0,         8.0,            .0,              .04 !
!       NOX =     .1656,          1.0,         8.0,           5.0,              3.5 !
!      HNO3 =     .1628,          1.0,        18.0,            .0,             8.e-8 !

!END!


-------------------------------------------------------------------------------


INPUT GROUP: 8 -- Size parameters for dry deposition of particles
--------------

   For SINGLE SPECIES, the mean and standard deviation are used to
   compute a deposition velocity for NINT (see group 9) size-ranges,
   and these are then averaged to obtain a mean deposition velocity.

   For GROUPED SPECIES, the size distribution should be explicitly
   specified (by the 'species' in the group), and the standard deviation
```

```
    for each should be entered as 0.  The model will then use the
    deposition velocity for the stated mean diameter.

     SPECIES     GEOMETRIC MASS MEAN       GEOMETRIC STANDARD
      NAME           DIAMETER                DEVIATION
                    (microns)               (microns)
     -------     -------------------      ------------------
!        SO4 =         .48,                2.0   !
!        NO3 =         .48,                2.0   !
!       PM10 =        5.00,                2.0   !
!       PM25 =         .48,                2.0   !

!END!


-------------------------------------------------------------------------------


INPUT GROUP: 9 -- Miscellaneous dry deposition parameters
--------------

    Reference cuticle resistance (s/cm)
    (RCUTR)                    Default: 30    !  RCUTR = 30.0 !
    Reference ground resistance  (s/cm)
    (RGR)                      Default: 10    !    RGR = 10.0 !
    Reference pollutant reactivity
    (REACTR)                   Default: 8     ! REACTR = 8.0 !

    Number of particle-size intervals used to
    evaluate effective particle deposition velocity
    (NINT)                     Default: 9     !   NINT =  9  !

    Vegetation state in unirrigated areas
    (IVEG)                     Default: 1     !   IVEG =  1   !
      IVEG=1 for active and unstressed vegetation
      IVEG=2 for active and stressed vegetation
      IVEG=3 for inactive vegetation

!END!


-------------------------------------------------------------------------------


INPUT GROUP: 10 -- Wet Deposition Parameters
---------------


                 Scavenging Coefficient -- Units: (sec)**(-1)

      Pollutant      Liquid Precip.       Frozen Precip.
      ---------      --------------       --------------
!        SO2 =        3.0E-05,             0.0E00 !
!        SO4 =        1.0E-04,             3.0E-05 !
!        NOX =          0.0,               0.0 !
!       HNO3 =        6.0E-05,             0.0E00 !
!        NO3 =        1.0E-04,             3.0E-05 !
!       PM10 =        1.0E-04,             3.0E-05 !
```

```
!       PM25 =        1.0E-04,           3.0E-05 !

!END!


-------------------------------------------------------------------------------


INPUT GROUP: 11 -- Chemistry Parameters
---------------

    Ozone data input option (MOZ)     Default: 1           ! MOZ =  1   !
    (Used only if MCHEM = 1, 3, or 4)
      0 = use a monthly background ozone value
      1 = read hourly ozone concentrations from
         the OZONE.DAT data file

    Monthly ozone concentrations
    (Used only if MCHEM = 1, 3, or 4 and
     MOZ = 0 or MOZ = 1 and all hourly O3 data missing)
    (BCKO3) in ppb                Default: 12*80.
    !  BCKO3 = 40.00, 40.00, 40.00, 40.00, 40.00, 40.00, 40.00, 40.00, 40.00, 40.00, 40.00, 40.00 !

    Monthly ammonia concentrations
    (Used only if MCHEM = 1, or 3)
    (BCKNH3) in ppb                Default: 12*10.
    !  BCKNH3 = 0.28, 0.25, 0.30, 0.26, 0.28, 0.44, 1.03, 0.95, 0.61, 0.27, 0.14, 0.21 !

    Nighttime SO2 loss rate (RNITE1)
    in percent/hour                Default: 0.2         ! RNITE1 = .2 !

    Nighttime NOx loss rate (RNITE2)
    in percent/hour                Default: 2.0         ! RNITE2 = 2.0 !

    Nighttime HNO3 formation rate (RNITE3)
    in percent/hour                Default: 2.0         ! RNITE3 = 2.0 !

    H2O2 data input option (MH2O2)    Default: 1           ! MH2O2 =  1   !
    (Used only if MAQCHEM = 1)
      0 = use a monthly background H2O2 value
      1 = read hourly H2O2 concentrations from
         the H2O2.DAT data file

    Monthly H2O2 concentrations
    (Used only if MQACHEM = 1 and
     MH2O2 = 0 or MH2O2 = 1 and all hourly H2O2 data missing)
    (BCKH2O2) in ppb               Default: 12*1.
    !  BCKH2O2 = 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00 !


 --- Data for SECONDARY ORGANIC AEROSOL (SOA) Option
    (used only if MCHEM = 4)

    The SOA module uses monthly values of:
        Fine particulate concentration in ug/m^3 (BCKPMF)
        Organic fraction of fine particulate     (OFRAC)
        VOC / NOX ratio (after reaction)         (VCNX)
    to characterize the air mass when computing
```

```
   the formation of SOA from VOC emissions.
   Typical values for several distinct air mass types are:

     Month    1    2    3    4    5    6    7    8    9   10   11   12
             Jan  Feb  Mar  Apr  May  Jun  Jul  Aug  Sep  Oct  Nov  Dec

   Clean Continental
     BCKPMF   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.
     OFRAC  .15  .15  .20  .20  .20  .20  .20  .20  .20  .20  .20  .15
     VCNX   50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.

   Clean Marine (surface)
     BCKPMF  .5   .5   .5   .5   .5   .5   .5   .5   .5   .5   .5   .5
     OFRAC  .25  .25  .30  .30  .30  .30  .30  .30  .30  .30  .30  .25
     VCNX   50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.

   Urban - low biogenic (controls present)
     BCKPMF  30.  30.  30.  30.  30.  30.  30.  30.  30.  30.  30.  30.
     OFRAC  .20  .20  .25  .25  .25  .25  .25  .25  .20  .20  .20  .20
     VCNX    4.   4.   4.   4.   4.   4.   4.   4.   4.   4.   4.   4.

   Urban - high biogenic (controls present)
     BCKPMF  60.  60.  60.  60.  60.  60.  60.  60.  60.  60.  60.  60.
     OFRAC  .25  .25  .30  .30  .30  .55  .55  .55  .35  .35  .35  .25
     VCNX   15.  15.  15.  15.  15.  15.  15.  15.  15.  15.  15.  15.

   Regional Plume
     BCKPMF  20.  20.  20.  20.  20.  20.  20.  20.  20.  20.  20.  20.
     OFRAC  .20  .20  .25  .35  .25  .40  .40  .40  .30  .30  .30  .20
     VCNX   15.  15.  15.  15.  15.  15.  15.  15.  15.  15.  15.  15.

   Urban - no controls present
     BCKPMF 100. 100. 100. 100. 100. 100. 100. 100. 100. 100. 100. 100.
     OFRAC  .30  .30  .35  .35  .35  .55  .55  .55  .35  .35  .35  .30
     VCNX    2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.

   Default: Clean Continental
   !  BCKPMF = 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00 !
   !  OFRAC  = 0.15, 0.15, 0.20, 0.20, 0.20, 0.20, 0.20, 0.20, 0.20, 0.20, 0.20, 0.15 !
   !  VCNX   = 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00 !


!END!


-------------------------------------------------------------------------------


INPUT GROUP: 12 -- Misc. Dispersion and Computational Parameters
---------------

   Horizontal size of puff (m) beyond which
   time-dependent dispersion equations (Heffter)
   are used to determine sigma-y and
   sigma-z (SYTDEP)                     Default: 550.   ! SYTDEP = 5.5E02 !

   Switch for using Heffter equation for sigma z
   as above (0 = Not use Heffter; 1 = use Heffter
```

```
(MHFTSZ)                    Default: 0     ! MHFTSZ =  0   !

Stability class used to determine plume
growth rates for puffs above the boundary
layer (JSUP)                Default: 5     ! JSUP =  5   !

Vertical dispersion constant for stable
conditions (k1 in Eqn. 2.7-3)  (CONK1)    Default: 0.01   ! CONK1 = .01 !

Vertical dispersion constant for neutral/
unstable conditions (k2 in Eqn. 2.7-4)
(CONK2)                     Default: 0.1    ! CONK2 = .1 !

Factor for determining Transition-point from
Schulman-Scire to Huber-Snyder Building Downwash
scheme (SS used for Hs < Hb + TBD * HL)
(TBD)                       Default: 0.5    ! TBD = .5 !
  TBD < 0   ==> always use Huber-Snyder
  TBD = 1.5 ==> always use Schulman-Scire
  TBD = 0.5 ==> ISC Transition-point

Range of land use categories for which
urban dispersion is assumed
(IURB1, IURB2)                Default: 10    ! IURB1 =  10  !
                            19     ! IURB2 =  19  !

Site characterization parameters for single-point Met data files ---------
(needed for METFM = 2,3,4,5)

  Land use category for modeling domain
  (ILANDUIN)                  Default: 20     ! ILANDUIN =  20  !

  Roughness length (m) for modeling domain
  (Z0IN)                    Default: 0.25   ! Z0IN = .25 !

  Leaf area index for modeling domain
  (XLAIIN)                  Default: 3.0    ! XLAIIN = 3.0 !

  Elevation above sea level (m)
  (ELEVIN)                  Default: 0.0    ! ELEVIN = .0 !

  Latitude (degrees) for met location
  (XLATIN)                  Default: -999.  ! XLATIN = -999. !

  Longitude (degrees) for met location
  (XLONIN)                  Default: -999.  ! XLONIN = -999. !

Specialized information for interpreting single-point Met data files -----

  Anemometer height (m) (Used only if METFM = 2,3)
  (ANEMHT)                    Default: 10.    ! ANEMHT = 10.0 !

  Form of lateral turbulance data in PROFILE.DAT file
  (Used only if METFM = 4,5 or MTURBVW = 1 or 3)
  (ISIGMAV)                 Default: 1      ! ISIGMAV =  1  !
     0 = read sigma-theta
     1 = read sigma-v
```

```
  Choice of mixing heights (Used only if METFM = 4)
  (IMIXCTDM)                  Default: 0      ! IMIXCTDM =  0  !
     0 = read PREDICTED mixing heights
     1 = read OBSERVED mixing heights

Maximum length of a slug (met. grid units)
(XMXLEN)                      Default: 1.0    ! XMXLEN = 1.0 !

Maximum travel distance of a puff/slug (in
grid units) during one sampling step
(XSAMLEN)                     Default: 1.0    ! XSAMLEN = 1.0 !

Maximum Number of slugs/puffs release from
one source during one time step
(MXNEW)                       Default: 99     ! MXNEW =  99   !

Maximum Number of sampling steps for
one puff/slug during one time step
(MXSAM)                       Default: 99     ! MXSAM =  99   !

Number of iterations used when computing
the transport wind for a sampling step
that includes gradual rise (for CALMET
and PROFILE winds)
(NCOUNT)                      Default: 2      ! NCOUNT =  2   !

Minimum sigma y for a new puff/slug (m)
(SYMIN)                       Default: 1.0    ! SYMIN = 1.0  !

Minimum sigma z for a new puff/slug (m)
(SZMIN)                       Default: 1.0    ! SZMIN = 1.0  !

Default minimum turbulence velocities sigma-v and sigma-w
for each stability class over land and over water (m/s)
(SVMIN(12) and SWMIN(12))

            ----------  LAND  ----------      ---------  WATER  ----------
  Stab Class :  A   B   C   D   E   F       A   B   C   D   E   F
            ---  ---  ---  ---  ---  ---      ---  ---  ---  ---  ---  ---
Default SVMIN : .50, .50, .50, .50, .50, .50,      .50, .50, .50, .50, .50, .50
Default SWMIN : .20, .12, .08, .06, .03, .016,     .20, .12, .08, .06, .03, .016

    ! SVMIN = 0.500, 0.500, 0.500, 0.500, 0.500, 0.500, 0.500, 0.500, 0.500, 0.500, 0.500, 0.500!
    ! SWMIN = 0.200, 0.120, 0.080, 0.060, 0.030, 0.016, 0.200, 0.120, 0.080, 0.060, 0.030, 0.016!

Divergence criterion for dw/dz across puff
used to initiate adjustment for horizontal
convergence (1/s)
Partial adjustment starts at CDIV(1), and
full adjustment is reached at CDIV(2)
(CDIV(2))                     Default: 0.0,0.0  ! CDIV = .0, .0 !

Minimum wind speed (m/s) allowed for
non-calm conditions. Also used as minimum
speed returned when using power-law
extrapolation toward surface
(WSCALM)                      Default: 0.5    ! WSCALM = .5 !
```

```
Maximum mixing height (m)
(XMAXZI)                    Default: 3000.  ! XMAXZI = 3000.0 !

Minimum mixing height (m)
(XMINZI)                    Default: 50.    ! XMINZI = 20.0 !

Default wind speed classes --
5 upper bounds (m/s) are entered;
the 6th class has no upper limit
(WSCAT(5))               Default   :
                    ISC RURAL : 1.54, 3.09, 5.14, 8.23, 10.8 (10.8+)

               Wind Speed Class :  1     2     3     4     5
                                  ---   ---   ---   ---   ---
                     ! WSCAT = 1.54, 3.09, 5.14, 8.23, 10.80 !

Default wind speed profile power-law
exponents for stabilities 1-6
(PLX0(6))                Default   : ISC RURAL values
                    ISC RURAL : .07, .07, .10, .15, .35, .55
                    ISC URBAN : .15, .15, .20, .25, .30, .30

               Stability Class :  A     B     C     D     E     F
                                  ---   ---   ---   ---   ---   ---
                     ! PLX0 = 0.07, 0.07, 0.10, 0.15, 0.35, 0.55 !

Default potential temperature gradient
for stable classes E, F (degK/m)
(PTG0(2))                Default: 0.020, 0.035
                     ! PTG0 = 0.020,   0.035 !

Default plume path coefficients for
each stability class (used when option
for partial plume height terrain adjustment
is selected -- MCTADJ=3)
(PPC(6))           Stability Class :  A     B     C     D     E     F
                   Default  PPC : .50,  .50,  .50,  .50,  .35,  .35
                                  ---   ---   ---   ---   ---   ---
                     !  PPC = 0.50, 0.50, 0.50, 0.50, 0.35, 0.35 !

Slug-to-puff transition criterion factor
equal to sigma-y/length of slug
(SL2PF)                  Default: 10.       ! SL2PF = 10.0 !

Puff-splitting control variables ------------------------

  VERTICAL SPLIT
  --------------

  Number of puffs that result every time a puff
  is split - nsplit=2 means that 1 puff splits
  into 2
  (NSPLIT)                 Default:   3       ! NSPLIT =  3  !

  Time(s) of a day when split puffs are eligible to
  be split once again; this is typically set once
  per day, around sunset before nocturnal shear develops.
  24 values: 0 is midnight (00:00) and 23 is 11 PM (23:00)
```

0=do not re-split   1=eligible for re-split
(IRESPLIT(24))   Default: Hour 17 = 1
! IRESPLIT = 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0,0 !

Split is allowed only if last hour's mixing
height (m) exceeds a minimum value
(ZISPLIT)   Default: 100.   ! ZISPLIT = 100.0 !

Split is allowed only if ratio of last hour's
mixing ht to the maximum mixing ht experienced
by the puff is less than a maximum value (this
postpones a split until a nocturnal layer develops)
(ROLDMAX)   Default: 0.25   ! ROLDMAX = 0.25 !

HORIZONTAL SPLIT

Number of puffs that result every time a puff
is split - nsplith=5 means that 1 puff splits
into 5
(NSPLITH)   Default: 5   ! NSPLITH = 5 !

Minimum sigma-y (Grid Cells Units) of puff
before it may be split
(SYSPLITH)   Default: 1.0   ! SYSPLITH = 1.0 !

Minimum puff elongation rate (SYSPLITH/hr) due to
wind shear, before it may be split
(SHSPLITH)   Default: 2.   ! SHSPLITH = 2.0 !

Minimum concentration (g/m^3) of each
species in puff before it may be split
Enter array of NSPEC values; if a single value is
entered, it will be used for ALL species
(CNSPLITH)   Default: 1.0E-07   ! CNSPLITH = 1.0E-07 !

Integration control variables ------------------------

Fractional convergence criterion for numerical SLUG
sampling integration
(EPSSLUG)   Default: 1.0e-04 ! EPSSLUG = 1.0E-04 !

Fractional convergence criterion for numerical AREA
source integration
(EPSAREA)   Default: 1.0e-06 ! EPSAREA = 1.0E-06 !

Trajectory step-length (m) used for numerical rise
integration
(DSRISE)   Default: 1.0   ! DSRISE = 1.0 !

Boundary Condition (BC) Puff control variables ------------------------

Minimum height (m) to which BC puffs are mixed as they are emitted
(MBCON=2 ONLY). Actual height is reset to the current mixing height
at the release point if greater than this minimum.
(HTMINBC)   Default: 500.   ! HTMINBC = 500.0 !

```
     Search radius (km) about a receptor for sampling nearest BC puff.
     BC puffs are typically emitted with a spacing of one grid cell
     length, so the search radius should be greater than DGRIDKM.
     (RSAMPBC)                  Default:   10.     ! RSAMPBC = 10.0 !

     Near-Surface depletion adjustment to concentration profile used when
     sampling BC puffs?
     (MDEPBC)                   Default:   1       ! MDEPBC =  1  !
       0 = Concentration is NOT adjusted for depletion
       1 = Adjust Concentration for depletion

!END!


--------------------------------------------------------------------------------


INPUT GROUPS: 13a, 13b, 13c, 13d -- Point source parameters
--------------------------------

---------------
Subgroup (13a)
---------------

    Number of point sources with
    parameters provided below      (NPT1)  No default  !  NPT1 =  0  !

    Units used for point source
    emissions below               (IPTU)  Default: 1  !  IPTU =   1  !
         1 =        g/s
         2 =       kg/hr
         3 =       lb/hr
         4 =     tons/yr
         5 =     Odour Unit * m**3/s  (vol. flux of odour compound)
         6 =     Odour Unit * m**3/min
         7 =     metric tons/yr

    Number of source-species
    combinations with variable
    emissions scaling factors
    provided below in (13d)        (NSPT1) Default: 0  !  NSPT1 =  0  !

    Number of point sources with
    variable emission parameters
    provided in external file      (NPT2)  No default  !  NPT2 =  0  !

    (If NPT2 > 0, these point
    source emissions are read from
    the file: PTEMARB.DAT)

!END!

---------------
Subgroup (13b)
---------------
                               a
        POINT SOURCE: CONSTANT DATA
        -----------------------------
```

```
                                                  b      c
 Source     X        Y       Stack    Base     Stack    Exit  Exit    Bldg.  Emission
  No.    Coordinate Coordinate Height Elevation Diameter  Vel.  Temp.   Dwash   Rates
           (km)      (km)      (m)      (m)       (m)  (m/s) (deg. K)
 ------   ---------- ---------- ------  ------   -------- ----- -------- ----- --------

--------
```

a
Data for each source are treated as a separate input subgroup
and therefore must end with an input group terminator.

SRCNAM is a 12-character name for a source
(No default)
X is an array holding the source data listed by the column headings
(No default)
SIGYZI is an array holding the initial sigma-y and sigma-z (m)
(Default: 0.,0.)
FMFAC is a vertical momentum flux factor (0. or 1.0) used to represent
the effect of rain-caps or other physical configurations that
reduce momentum rise associated with the actual exit velocity.
(Default: 1.0 -- full momentum used)
ZPLTFM is the platform height (m) for sources influenced by an isolated
structure that has a significant open area between the surface
and the bulk of the structure, such as an offshore oil platform.
The Base Elevation is that of the surface (ground or ocean),
and the Stack Height is the release height above the Base (not
above the platform). Building heights entered in Subgroup 13c
must be those of the buildings on the platform, measured from
the platform deck. ZPLTFM is used only with MBDW=1 (ISC
downwash method) for sources with building downwash.
(Default: 0.0)

b
0. = No building downwash modeled
1. = Downwash modeled for buildings resting on the surface
2. = Downwash modeled for buildings raised above the surface (ZPLTFM > 0.)
NOTE: must be entered as a REAL number (i.e., with decimal point)

c
An emission rate must be entered for every pollutant modeled.
Enter emission rate of zero for secondary pollutants that are
modeled, but not emitted. Units are specified by IPTU
(e.g. 1 for g/s).

```
---------------
Subgroup (13c)
---------------

         BUILDING DIMENSION DATA FOR SOURCES SUBJECT TO DOWNWASH
         -------------------------------------------------------
Source                                            a
 No.      Effective building height, width, length and X/Y offset (in meters)
         every 10 degrees.  LENGTH, XBADJ, and YBADJ are only needed for
         MBDW=2 (PRIME downwash option)
------    --------------------------------------------------------------------
```

----

a
Building height, width, length, and X/Y offset from the source are treated
as a separate input subgroup for each source and therefore must end with
an input group terminator. The X/Y offset is the position, relative to the
stack, of the center of the upwind face of the projected building, with the
x-axis pointing along the flow direction.

Subgroup (13d)
----

a
POINT SOURCE: VARIABLE EMISSIONS DATA

Use this subgroup to describe temporal variations in the emission
rates given in 13b. Factors entered multiply the rates in 13b.
Skip sources here that have constant emissions. For more elaborate
variation in source parameters, use PTEMARB.DAT and NPT2 > 0.

IVARY determines the type of variation, and is source-specific:
(IVARY) Default: 0
0 = Constant
1 = Diurnal cycle (24 scaling factors: hours 1-24)
2 = Monthly cycle (12 scaling factors: months 1-12)
3 = Hour & Season (4 groups of 24 hourly scaling factors,
where first group is DEC-JAN-FEB)
4 = Speed & Stab. (6 groups of 6 scaling factors, where
first group is Stability Class A,
and the speed classes have upper
bounds (m/s) defined in Group 12
5 = Temperature (12 scaling factors, where temperature
classes have upper bounds (C) of:
0, 5, 10, 15, 20, 25, 30, 35, 40,
45, 50, 50+)

----
a
Data for each species are treated as a separate input subgroup
and therefore must end with an input group terminator.

INPUT GROUPS: 14a, 14b, 14c, 14d -- Area source parameters

Subgroup (14a)

Number of polygon area sources with
parameters specified below (NAR1) No default ! NAR1 = 56 !

```
    Units used for area source
    emissions below         (IARU)     Default: 1  !  IARU =   2  !
        1 =      g/m**2/s
        2 =     kg/m**2/hr
        3 =     lb/m**2/hr
        4 =    tons/m**2/yr
        5 =    Odour Unit * m/s  (vol. flux/m**2 of odour compound)
        6 =    Odour Unit * m/min
        7 =    metric tons/m**2/yr

    Number of source-species
    combinations with variable
    emissions scaling factors
    provided below in (14d)      (NSAR1) Default: 0  !  NSAR1 =  0  !

    Number of buoyant polygon area sources
    with variable location and emission
    parameters (NAR2)                 No default  !  NAR2 =  0   !
    (If NAR2 > 0, ALL parameter data for
    these sources are read from the file: BAEMARB.DAT)

!END!

---------------
Subgroup (14b)
---------------
                           a
       AREA SOURCE: CONSTANT DATA
       ----------------------------
                                        b
Source        Effect.   Base     Initial   Emission
 No.          Height  Elevation  Sigma z    Rates
              (m)      (m)       (m)
-------       ------   ------   --------  ---------
100001 ! SRCNAM =    1 !
100001 ! X =       0.0,    2927.60,     0.00,   1.100E-12,0.000E+00,5.558E-10,0.000E+00,0.000E+00,7.738E-12,2.896E-11 !
     !END!
100002 ! SRCNAM =    2 !
100002 ! X =       0.0,    2859.90,     0.00,   8.630E-13,0.000E+00,4.362E-10,0.000E+00,0.000E+00,6.072E-12,2.272E-11 !
     !END!
100003 ! SRCNAM =    3 !
100003 ! X =       0.0,    2715.70,     0.00,   8.479E-13,0.000E+00,4.286E-10,0.000E+00,0.000E+00,5.967E-12,2.233E-11 !
     !END!
100004 ! SRCNAM =    4 !
100004 ! X =       0.0,    2604.10,     0.00,   2.067E-13,0.000E+00,1.044E-10,0.000E+00,0.000E+00,1.454E-12,5.441E-12 !
     !END!
100005 ! SRCNAM =    5 !
100005 ! X =       0.0,    2748.40,     0.00,   1.594E-13,0.000E+00,8.056E-11,0.000E+00,0.000E+00,1.122E-12,4.197E-12 !
     !END!
100006 ! SRCNAM =    6 !
100006 ! X =       0.0,    2811.30,     0.00,   2.272E-12,0.000E+00,1.148E-09,0.000E+00,0.000E+00,1.599E-11,5.981E-11 !
     !END!
100007 ! SRCNAM =    7 !
100007 ! X =       0.0,    2785.00,     0.00,   2.273E-12,0.000E+00,1.149E-09,0.000E+00,0.000E+00,1.600E-11,5.986E-11 !
     !END!
100008 ! SRCNAM =    8 !
100008 ! X =       0.0,    2653.90,     0.00,   2.273E-12,0.000E+00,1.149E-09,0.000E+00,0.000E+00,1.600E-11,5.986E-11 !
     !END!
```

```
100009 ! SRCNAM =    9 !
100009 ! X =        0.0,    2525.60,     0.00,   1.107E-12,0.000E+00,5.595E-10,0.000E+00,0.000E+00,7.790E-12,2.915E-11 !
    !END!
100010 ! SRCNAM =   10 !
100010 ! X =        0.0,    2588.30,     0.00,   7.804E-13,0.000E+00,3.944E-10,0.000E+00,0.000E+00,5.492E-12,2.055E-11 !
    !END!
100011 ! SRCNAM =   11 !
100011 ! X =        0.0,    2594.70,     0.00,   2.273E-12,0.000E+00,1.149E-09,0.000E+00,0.000E+00,1.600E-11,5.986E-11 !
    !END!
100012 ! SRCNAM =   12 !
100012 ! X =        0.0,    2588.30,     0.00,   2.273E-12,0.000E+00,1.149E-09,0.000E+00,0.000E+00,1.600E-11,5.986E-11 !
    !END!
100013 ! SRCNAM =   13 !
100013 ! X =        0.0,    2526.00,     0.00,   2.273E-12,0.000E+00,1.149E-09,0.000E+00,0.000E+00,1.600E-11,5.986E-11 !
    !END!
100014 ! SRCNAM =   14 !
100014 ! X =        0.0,    2442.90,     0.00,   1.230E-12,0.000E+00,6.219E-10,0.000E+00,0.000E+00,8.658E-12,3.240E-11 !
    !END!
100015 ! SRCNAM =   15 !
100015 ! X =        0.0,    2376.60,     0.00,   1.348E-13,0.000E+00,6.815E-11,0.000E+00,0.000E+00,9.488E-13,3.551E-12 !
    !END!
100016 ! SRCNAM =   16 !
100016 ! X =        0.0,    2721.60,     0.00,   1.671E-09,0.000E+00,7.936E-08,0.000E+00,0.000E+00,2.193E-07,3.736E-08 !
    !END!
100017 ! SRCNAM =   17 !
100017 ! X =        0.0,    2600.20,     0.00,   1.229E-12,0.000E+00,6.210E-10,0.000E+00,0.000E+00,8.645E-12,3.235E-11 !
    !END!
100018 ! SRCNAM =   18 !
100018 ! X =        0.0,    2491.50,     0.00,   2.232E-12,0.000E+00,1.128E-09,0.000E+00,0.000E+00,1.571E-11,5.878E-11 !
    !END!
100019 ! SRCNAM =   19 !
100019 ! X =        0.0,    2493.40,     0.00,   2.273E-12,0.000E+00,1.149E-09,0.000E+00,0.000E+00,1.600E-11,5.986E-11 !
    !END!
100020 ! SRCNAM =   20 !
100020 ! X =        0.0,    2516.60,     0.00,   2.508E-09,0.000E+00,1.197E-07,0.000E+00,0.000E+00,3.290E-07,5.608E-08 !
    !END!
100021 ! SRCNAM =   21 !
100021 ! X =        0.0,    2499.00,     0.00,   2.273E-12,0.000E+00,1.149E-09,0.000E+00,0.000E+00,1.600E-11,5.986E-11 !
    !END!
100022 ! SRCNAM =   22 !
100022 ! X =        0.0,    2473.70,     0.00,   2.273E-12,0.000E+00,1.149E-09,0.000E+00,0.000E+00,1.600E-11,5.986E-11 !
    !END!
100023 ! SRCNAM =   23 !
100023 ! X =        0.0,    2495.50,     0.00,   7.502E-13,0.000E+00,3.792E-10,0.000E+00,0.000E+00,5.279E-12,1.975E-11 !
    !END!
100024 ! SRCNAM =   24 !
100024 ! X =        0.0,    2722.80,     0.00,   5.501E-14,0.000E+00,2.780E-11,0.000E+00,0.000E+00,3.871E-13,1.448E-12 !
    !END!
100025 ! SRCNAM =   25 !
100025 ! X =        0.0,    2729.40,     0.00,   5.014E-09,0.000E+00,2.381E-07,0.000E+00,0.000E+00,6.580E-07,1.121E-07 !
    !END!
100026 ! SRCNAM =   26 !
100026 ! X =        0.0,    2610.00,     0.00,   2.508E-09,0.000E+00,1.197E-07,0.000E+00,0.000E+00,3.290E-07,5.608E-08 !
    !END!
100027 ! SRCNAM =   27 !
100027 ! X =        0.0,    2538.50,     0.00,   1.420E-08,0.000E+00,6.727E-07,0.000E+00,0.000E+00,1.864E-06,3.175E-07 !
    !END!
100028 ! SRCNAM =   28 !
```

```
100028 ! X =    0.0,   2644.50,    0.00,   5.849E-09,0.000E+00,2.774E-07,0.000E+00,0.000E+00,7.676E-07,1.308E-07 !
    !END!
100029 ! SRCNAM =   29 !
100029 ! X =    0.0,   2754.40,    0.00,   2.508E-09,0.000E+00,1.194E-07,0.000E+00,0.000E+00,3.290E-07,5.607E-08 !
    !END!
100030 ! SRCNAM =   30 !
100030 ! X =    0.0,   2809.20,    0.00,   5.014E-09,0.000E+00,2.381E-07,0.000E+00,0.000E+00,6.580E-07,1.121E-07 !
    !END!
100031 ! SRCNAM =   31 !
100031 ! X =    0.0,   2839.30,    0.00,   2.273E-12,0.000E+00,1.149E-09,0.000E+00,0.000E+00,1.600E-11,5.986E-11 !
    !END!
100032 ! SRCNAM =   32 !
100032 ! X =    0.0,   2833.10,    0.00,   2.610E-13,0.000E+00,1.319E-10,0.000E+00,0.000E+00,1.836E-12,6.871E-12 !
    !END!
100033 ! SRCNAM =   33 !
100033 ! X =    0.0,   2762.30,    0.00,   3.717E-13,0.000E+00,1.879E-10,0.000E+00,0.000E+00,2.615E-12,9.787E-12 !
    !END!
100034 ! SRCNAM =   34 !
100034 ! X =    0.0,   2783.80,    0.00,   2.273E-12,0.000E+00,1.149E-09,0.000E+00,0.000E+00,1.600E-11,5.986E-11 !
    !END!
100035 ! SRCNAM =   35 !
100035 ! X =    0.0,   2727.10,    0.00,   3.344E-09,0.000E+00,1.592E-07,0.000E+00,0.000E+00,4.387E-07,7.475E-08 !
    !END!
100036 ! SRCNAM =   36 !
100036 ! X =    0.0,   2608.00,    0.00,   8.356E-09,0.000E+00,3.962E-07,0.000E+00,0.000E+00,1.097E-06,1.868E-07 !
    !END!
100037 ! SRCNAM =   37 !
100037 ! X =    0.0,   2682.70,    0.00,   7.520E-09,0.000E+00,3.564E-07,0.000E+00,0.000E+00,9.869E-07,1.681E-07 !
    !END!
100038 ! SRCNAM =   38 !
100038 ! X =    0.0,   2913.60,    0.00,   2.604E-14,0.000E+00,1.316E-11,0.000E+00,0.000E+00,1.832E-13,6.857E-13 !
    !END!
100039 ! SRCNAM =   39 !
100039 ! X =    0.0,   3119.70,    0.00,   2.506E-09,0.000E+00,1.187E-07,0.000E+00,0.000E+00,3.290E-07,5.603E-08 !
    !END!
100040 ! SRCNAM =   40 !
100040 ! X =    0.0,   3210.90,    0.00,   8.236E-13,0.000E+00,4.163E-10,0.000E+00,0.000E+00,5.796E-12,2.169E-11 !
    !END!
100041 ! SRCNAM =   41 !
100041 ! X =    0.0,   3124.00,    0.00,   1.878E-16,0.000E+00,9.492E-14,0.000E+00,0.000E+00,1.322E-15,4.945E-15 !
    !END!
100042 ! SRCNAM =   42 !
100042 ! X =    0.0,   2831.00,    0.00,   7.176E-13,0.000E+00,3.627E-10,0.000E+00,0.000E+00,5.050E-12,1.889E-11 !
    !END!
100043 ! SRCNAM =   43 !
100043 ! X =    0.0,   2872.60,    0.00,   2.273E-12,0.000E+00,1.149E-09,0.000E+00,0.000E+00,1.600E-11,5.986E-11 !
    !END!
100044 ! SRCNAM =   44 !
100044 ! X =    0.0,   2897.70,    0.00,   2.273E-12,0.000E+00,1.149E-09,0.000E+00,0.000E+00,1.600E-11,5.986E-11 !
    !END!
100045 ! SRCNAM =   45 !
100045 ! X =    0.0,   2773.50,    0.00,   2.273E-12,0.000E+00,1.149E-09,0.000E+00,0.000E+00,1.600E-11,5.986E-11 !
    !END!
100046 ! SRCNAM =   46 !
100046 ! X =    0.0,   2701.90,    0.00,   2.508E-09,0.000E+00,1.197E-07,0.000E+00,0.000E+00,3.290E-07,5.608E-08 !
    !END!
100047 ! SRCNAM =   47 !
100047 ! X =    0.0,   2803.60,    0.00,   3.307E-13,0.000E+00,1.672E-10,0.000E+00,0.000E+00,2.327E-12,8.709E-12 !
```

```
      !END!
100048 ! SRCNAM =    48 !
100048 ! X =        0.0,    2974.00,     0.00,   5.455E-13,0.000E+00,2.757E-10,0.000E+00,0.000E+00,3.839E-12,1.436E-11 !
      !END!
100049 ! SRCNAM =    49 !
100049 ! X =        0.0,    3073.70,     0.00,   1.496E-12,0.000E+00,7.563E-10,0.000E+00,0.000E+00,1.053E-11,3.940E-11 !
      !END!
100050 ! SRCNAM =    50 !
100050 ! X =        0.0,    3116.10,     0.00,   1.811E-12,0.000E+00,9.154E-10,0.000E+00,0.000E+00,1.275E-11,4.769E-11 !
      !END!
100051 ! SRCNAM =    51 !
100051 ! X =        0.0,    3077.00,     0.00,   2.137E-12,0.000E+00,1.080E-09,0.000E+00,0.000E+00,1.504E-11,5.626E-11 !
      !END!
100052 ! SRCNAM =    52 !
100052 ! X =        0.0,    2992.10,     0.00,   2.273E-12,0.000E+00,1.149E-09,0.000E+00,0.000E+00,1.600E-11,5.986E-11 !
      !END!
100053 ! SRCNAM =    53 !
100053 ! X =        0.0,    2895.60,     0.00,   9.854E-13,0.000E+00,4.981E-10,0.000E+00,0.000E+00,6.934E-12,2.595E-11 !
      !END!
100054 ! SRCNAM =    54 !
100054 ! X =        0.0,    3330.30,     0.00,   9.206E-16,0.000E+00,4.653E-13,0.000E+00,0.000E+00,6.478E-15,2.424E-14 !
      !END!
100055 ! SRCNAM =    55 !
100055 ! X =        0.0,    3315.30,     0.00,   1.051E-12,0.000E+00,5.314E-10,0.000E+00,0.000E+00,7.398E-12,2.768E-11 !
      !END!
100056 ! SRCNAM =    56 !
100056 ! X =        0.0,    3266.90,     0.00,   5.034E-13,0.000E+00,2.544E-10,0.000E+00,0.000E+00,3.543E-12,1.326E-11 !
      !END!


--------
   a
    Data for each source are treated as a separate input subgroup
    and therefore must end with an input group terminator.
   b
    An emission rate must be entered for every pollutant modeled.
    Enter emission rate of zero for secondary pollutants that are
    modeled, but not emitted.  Units are specified by IARU
    (e.g. 1 for g/m**2/s).

---------------
Subgroup (14c)
---------------

         COORDINATES (km) FOR EACH VERTEX(4) OF EACH POLYGON
         --------------------------------------------------------
Source                                                   a
 No.       Ordered list of X followed by list of Y, grouped by source
------     ------------------------------------------------------------
100001 ! SRCNAM =     1 !
100001 ! XVERT = -1060.,-1056.,-1056.,-1060. !
100001 ! YVERT =   336.,  336.,  340.,  340. !
      !END!
100002 ! SRCNAM =     2 !
100002 ! XVERT = -1060.,-1056.,-1056.,-1060. !
100002 ! YVERT =   340.,  340.,  344.,  344. !
      !END!
100003 ! SRCNAM =     3 !
```

```
100003 ! XVERT = -1060.,-1056.,-1056.,-1060. !
100003 ! YVERT =   344.,  344.,  348.,  348. !
    !END!
100004 ! SRCNAM =     4 !
100004 ! XVERT = -1060.,-1056.,-1056.,-1060. !
100004 ! YVERT =   348.,  348.,  352.,  352. !
    !END!
100005 ! SRCNAM =     5 !
100005 ! XVERT = -1056.,-1052.,-1052.,-1056. !
100005 ! YVERT =   332.,  332.,  336.,  336. !
    !END!
100006 ! SRCNAM =     6 !
100006 ! XVERT = -1056.,-1052.,-1052.,-1056. !
100006 ! YVERT =   336.,  336.,  340.,  340. !
    !END!
100007 ! SRCNAM =     7 !
100007 ! XVERT = -1056.,-1052.,-1052.,-1056. !
100007 ! YVERT =   340.,  340.,  344.,  344. !
    !END!
100008 ! SRCNAM =     8 !
100008 ! XVERT = -1056.,-1052.,-1052.,-1056. !
100008 ! YVERT =   344.,  344.,  348.,  348. !
    !END!
100009 ! SRCNAM =     9 !
100009 ! XVERT = -1056.,-1052.,-1052.,-1056. !
100009 ! YVERT =   348.,  348.,  352.,  352. !
    !END!
100010 ! SRCNAM =    10 !
100010 ! XVERT = -1052.,-1048.,-1048.,-1052. !
100010 ! YVERT =   332.,  332.,  336.,  336. !
    !END!
100011 ! SRCNAM =    11 !
100011 ! XVERT = -1052.,-1048.,-1048.,-1052. !
100011 ! YVERT =   336.,  336.,  340.,  340. !
    !END!
100012 ! SRCNAM =    12 !
100012 ! XVERT = -1052.,-1048.,-1048.,-1052. !
100012 ! YVERT =   340.,  340.,  344.,  344. !
    !END!
100013 ! SRCNAM =    13 !
100013 ! XVERT = -1052.,-1048.,-1048.,-1052. !
100013 ! YVERT =   344.,  344.,  348.,  348. !
    !END!
100014 ! SRCNAM =    14 !
100014 ! XVERT = -1052.,-1048.,-1048.,-1052. !
100014 ! YVERT =   348.,  348.,  352.,  352. !
    !END!
100015 ! SRCNAM =    15 !
100015 ! XVERT = -1052.,-1048.,-1048.,-1052. !
100015 ! YVERT =   352.,  352.,  356.,  356. !
    !END!
100016 ! SRCNAM =    16 !
100016 ! XVERT = -1048.,-1044.,-1044.,-1048. !
100016 ! YVERT =   324.,  324.,  328.,  328. !
    !END!
100017 ! SRCNAM =    17 !
100017 ! XVERT = -1048.,-1044.,-1044.,-1048. !
100017 ! YVERT =   328.,  328.,  332.,  332. !
```

```
   !END!
100018 ! SRCNAM =    18 !
100018 ! XVERT = -1048.,-1044.,-1044.,-1048. !
100018 ! YVERT =   332.,  332.,  336.,  336. !
   !END!
100019 ! SRCNAM =    19 !
100019 ! XVERT = -1048.,-1044.,-1044.,-1048. !
100019 ! YVERT =   336.,  336.,  340.,  340. !
   !END!
100020 ! SRCNAM =    20 !
100020 ! XVERT = -1048.,-1044.,-1044.,-1048. !
100020 ! YVERT =   340.,  340.,  344.,  344. !
   !END!
100021 ! SRCNAM =    21 !
100021 ! XVERT = -1048.,-1044.,-1044.,-1048. !
100021 ! YVERT =   344.,  344.,  348.,  348. !
   !END!
100022 ! SRCNAM =    22 !
100022 ! XVERT = -1048.,-1044.,-1044.,-1048. !
100022 ! YVERT =   348.,  348.,  352.,  352. !
   !END!
100023 ! SRCNAM =    23 !
100023 ! XVERT = -1048.,-1044.,-1044.,-1048. !
100023 ! YVERT =   352.,  352.,  356.,  356. !
   !END!
100024 ! SRCNAM =    24 !
100024 ! XVERT = -1044.,-1040.,-1040.,-1044. !
100024 ! YVERT =   320.,  320.,  324.,  324. !
   !END!
100025 ! SRCNAM =    25 !
100025 ! XVERT = -1044.,-1040.,-1040.,-1044. !
100025 ! YVERT =   324.,  324.,  328.,  328. !
   !END!
100026 ! SRCNAM =    26 !
100026 ! XVERT = -1044.,-1040.,-1040.,-1044. !
100026 ! YVERT =   328.,  328.,  332.,  332. !
   !END!
100027 ! SRCNAM =    27 !
100027 ! XVERT = -1044.,-1040.,-1040.,-1044. !
100027 ! YVERT =   332.,  332.,  336.,  336. !
   !END!
100028 ! SRCNAM =    28 !
100028 ! XVERT = -1044.,-1040.,-1040.,-1044. !
100028 ! YVERT =   336.,  336.,  340.,  340. !
   !END!
100029 ! SRCNAM =    29 !
100029 ! XVERT = -1044.,-1040.,-1040.,-1044. !
100029 ! YVERT =   340.,  340.,  344.,  344. !
   !END!
100030 ! SRCNAM =    30 !
100030 ! XVERT = -1044.,-1040.,-1040.,-1044. !
100030 ! YVERT =   344.,  344.,  348.,  348. !
   !END!
100031 ! SRCNAM =    31 !
100031 ! XVERT = -1044.,-1040.,-1040.,-1044. !
100031 ! YVERT =   348.,  348.,  352.,  352. !
   !END!
100032 ! SRCNAM =    32 !
```

```
100032 ! XVERT = -1044.,-1040.,-1040.,-1044. !
100032 ! YVERT =   352.,  352.,  356.,  356. !
       !END!
100033 ! SRCNAM =    33 !
100033 ! XVERT = -1040.,-1036.,-1036.,-1040. !
100033 ! YVERT =   320.,  320.,  324.,  324. !
       !END!
100034 ! SRCNAM =    34 !
100034 ! XVERT = -1040.,-1036.,-1036.,-1040. !
100034 ! YVERT =   324.,  324.,  328.,  328. !
       !END!
100035 ! SRCNAM =    35 !
100035 ! XVERT = -1040.,-1036.,-1036.,-1040. !
100035 ! YVERT =   328.,  328.,  332.,  332. !
       !END!
100036 ! SRCNAM =    36 !
100036 ! XVERT = -1040.,-1036.,-1036.,-1040. !
100036 ! YVERT =   332.,  332.,  336.,  336. !
       !END!
100037 ! SRCNAM =    37 !
100037 ! XVERT = -1040.,-1036.,-1036.,-1040. !
100037 ! YVERT =   336.,  336.,  340.,  340. !
       !END!
100038 ! SRCNAM =    38 !
100038 ! XVERT = -1040.,-1036.,-1036.,-1040. !
100038 ! YVERT =   340.,  340.,  344.,  344. !
       !END!
100039 ! SRCNAM =    39 !
100039 ! XVERT = -1040.,-1036.,-1036.,-1040. !
100039 ! YVERT =   344.,  344.,  348.,  348. !
       !END!
100040 ! SRCNAM =    40 !
100040 ! XVERT = -1040.,-1036.,-1036.,-1040. !
100040 ! YVERT =   348.,  348.,  352.,  352. !
       !END!
100041 ! SRCNAM =    41 !
100041 ! XVERT = -1040.,-1036.,-1036.,-1040. !
100041 ! YVERT =   352.,  352.,  356.,  356. !
       !END!
100042 ! SRCNAM =    42 !
100042 ! XVERT = -1036.,-1032.,-1032.,-1036. !
100042 ! YVERT =   320.,  320.,  324.,  324. !
       !END!
100043 ! SRCNAM =    43 !
100043 ! XVERT = -1036.,-1032.,-1032.,-1036. !
100043 ! YVERT =   324.,  324.,  328.,  328. !
       !END!
100044 ! SRCNAM =    44 !
100044 ! XVERT = -1036.,-1032.,-1032.,-1036. !
100044 ! YVERT =   328.,  328.,  332.,  332. !
       !END!
100045 ! SRCNAM =    45 !
100045 ! XVERT = -1036.,-1032.,-1032.,-1036. !
100045 ! YVERT =   332.,  332.,  336.,  336. !
       !END!
100046 ! SRCNAM =    46 !
100046 ! XVERT = -1036.,-1032.,-1032.,-1036. !
100046 ! YVERT =   336.,  336.,  340.,  340. !
```

```
     !END!
100047 ! SRCNAM =    47 !
100047 ! XVERT = -1036.,-1032.,-1032.,-1036. !
100047 ! YVERT =   340.,  340.,  344.,  344. !
     !END!
100048 ! SRCNAM =    48 !
100048 ! XVERT = -1032.,-1028.,-1028.,-1032. !
100048 ! YVERT =   320.,  320.,  324.,  324. !
     !END!
100049 ! SRCNAM =    49 !
100049 ! XVERT = -1032.,-1028.,-1028.,-1032. !
100049 ! YVERT =   324.,  324.,  328.,  328. !
     !END!
100050 ! SRCNAM =    50 !
100050 ! XVERT = -1032.,-1028.,-1028.,-1032. !
100050 ! YVERT =   328.,  328.,  332.,  332. !
     !END!
100051 ! SRCNAM =    51 !
100051 ! XVERT = -1032.,-1028.,-1028.,-1032. !
100051 ! YVERT =   332.,  332.,  336.,  336. !
     !END!
100052 ! SRCNAM =    52 !
100052 ! XVERT = -1032.,-1028.,-1028.,-1032. !
100052 ! YVERT =   336.,  336.,  340.,  340. !
     !END!
100053 ! SRCNAM =    53 !
100053 ! XVERT = -1032.,-1028.,-1028.,-1032. !
100053 ! YVERT =   340.,  340.,  344.,  344. !
     !END!
100054 ! SRCNAM =    54 !
100054 ! XVERT = -1028.,-1024.,-1024.,-1028. !
100054 ! YVERT =   332.,  332.,  336.,  336. !
     !END!
100055 ! SRCNAM =    55 !
100055 ! XVERT = -1028.,-1024.,-1024.,-1028. !
100055 ! YVERT =   336.,  336.,  340.,  340. !
     !END!
100056 ! SRCNAM =    56 !
100056 ! XVERT = -1028.,-1024.,-1024.,-1028. !
100056 ! YVERT =   340.,  340.,  344.,  344. !
     !END!


--------
  a
   Data for each source are treated as a separate input subgroup
   and therefore must end with an input group terminator.


---------------
Subgroup (14d)
---------------
                                   a
      AREA SOURCE: VARIABLE EMISSIONS DATA
      --------------------------------------

   Use this subgroup to describe temporal variations in the emission
   rates given in 14b.  Factors entered multiply the rates in 14b.
```

Skip sources here that have constant emissions. For more elaborate
variation in source parameters, use BAEMARB.DAT and NAR2 > 0.

IVARY determines the type of variation, and is source-specific:
(IVARY) Default: 0
0 = Constant
1 = Diurnal cycle (24 scaling factors: hours 1-24)
2 = Monthly cycle (12 scaling factors: months 1-12)
3 = Hour & Season (4 groups of 24 hourly scaling factors,
where first group is DEC-JAN-FEB)
4 = Speed & Stab. (6 groups of 6 scaling factors, where
first group is Stability Class A,
and the speed classes have upper
bounds (m/s) defined in Group 12
5 = Temperature (12 scaling factors, where temperature
classes have upper bounds (C) of:
0, 5, 10, 15, 20, 25, 30, 35, 40,
45, 50, 50+)

----
a
Data for each species are treated as a separate input subgroup
and therefore must end with an input group terminator.

INPUT GROUPS: 15a, 15b, 15c -- Line source parameters

Subgroup (15a)

Number of buoyant line sources
with variable location and emission
parameters (NLN2) No default ! NLN2 = 0 !

(If NLN2 > 0, ALL parameter data for
these sources are read from the file: LNEMARB.DAT)

Number of buoyant line sources (NLINES) No default ! NLINES = 0 !

Units used for line source
emissions below (ILNU) Default: 1 ! ILNU = 1 !
1 = g/s
2 = kg/hr
3 = lb/hr
4 = tons/yr
5 = Odour Unit * m**3/s (vol. flux of odour compound)
6 = Odour Unit * m**3/min
7 = metric tons/yr

Number of source-species
combinations with variable
emissions scaling factors

```
    provided below in (15c)       (NSLN1) Default: 0  !  NSLN1 =  0  !

    Maximum number of segments used to model
    each line (MXNSEG)                     Default: 7   ! MXNSEG =  7  !

    The following variables are required only if NLINES > 0.  They are
    used in the buoyant line source plume rise calculations.

      Number of distances at which             Default: 6   ! NLRISE =  6  !
      transitional rise is computed

      Average building length (XL)             No default   ! XL = .0 !
                                  (in meters)

      Average building height (HBL)            No default   ! HBL = .0 !
                                  (in meters)

      Average building width (WBL)             No default   ! WBL = .0 !
                                  (in meters)

      Average line source width (WML)          No default   ! WML = .0 !
                                  (in meters)

      Average separation between buildings (DXL)  No default   ! DXL = .0 !
                                  (in meters)

      Average buoyancy parameter (FPRIMEL)      No default   ! FPRIMEL = .0 !
                                  (in m**4/s**3)

!END!

---------------
Subgroup (15b)
---------------

        BUOYANT LINE SOURCE: CONSTANT DATA
        ----------------------------------
                                                                   a
Source    Beg. X     Beg. Y     End. X    End. Y    Release   Base       Emission
 No.    Coordinate  Coordinate  Coordinate Coordinate  Height    Elevation      Rates
          (km)       (km)        (km)       (km)       (m)       (m)
------   ----------  ----------  ---------  ----------  -------   ---------    ---------

--------

   a
    Data for each source are treated as a separate input subgroup
    and therefore must end with an input group terminator.

   b
    An emission rate must be entered for every pollutant modeled.
    Enter emission rate of zero for secondary pollutants that are
    modeled, but not emitted.  Units are specified by ILNTU
    (e.g. 1 for g/s).

---------------
Subgroup (15c)
---------------
```

a
BUOYANT LINE SOURCE: VARIABLE EMISSIONS DATA

Use this subgroup to describe temporal variations in the emission
rates given in 15b. Factors entered multiply the rates in 15b.
Skip sources here that have constant emissions.

IVARY determines the type of variation, and is source-specific:
(IVARY) Default: 0
0 = Constant
1 = Diurnal cycle (24 scaling factors: hours 1-24)
2 = Monthly cycle (12 scaling factors: months 1-12)
3 = Hour & Season (4 groups of 24 hourly scaling factors,
where first group is DEC-JAN-FEB)
4 = Speed & Stab. (6 groups of 6 scaling factors, where
first group is Stability Class A,
and the speed classes have upper
bounds (m/s) defined in Group 12
5 = Temperature (12 scaling factors, where temperature
classes have upper bounds (C) of:
0, 5, 10, 15, 20, 25, 30, 35, 40,
45, 50, 50+)

----
a
Data for each species are treated as a separate input subgroup
and therefore must end with an input group terminator.

INPUT GROUPS: 16a, 16b, 16c -- Volume source parameters

Subgroup (16a)

Number of volume sources with
parameters provided in 16b,c (NVL1) No default ! NVL1 = 0 !

Units used for volume source
emissions below in 16b (IVLU) Default: 1 ! IVLU = 1 !
1 = g/s
2 = kg/hr
3 = lb/hr
4 = tons/yr
5 = Odour Unit * m**3/s (vol. flux of odour compound)
6 = Odour Unit * m**3/min
7 = metric tons/yr

Number of source-species
combinations with variable
emissions scaling factors

```
    provided below in (16c)     (NSVL1)    Default: 0  !  NSVL1 =  0  !

    Number of volume sources with
    variable location and emission
    parameters                (NVL2)     No default  !  NVL2 =   0   !

    (If NVL2 > 0, ALL parameter data for
     these sources are read from the VOLEMARB.DAT file(s) )

!END!

---------------
Subgroup (16b)
---------------
                              a
        VOLUME SOURCE: CONSTANT DATA
        ------------------------------
                                                         b
      X         Y       Effect.    Base     Initial    Initial    Emission
    Coordinate  Coordinate   Height   Elevation  Sigma y    Sigma z     Rates
      (km)      (km)        (m)      (m)       (m)      (m)
    ----------  ----------   ------    ------    --------   --------   --------



--------
   a
    Data for each source are treated as a separate input subgroup
    and therefore must end with an input group terminator.

   b
    An emission rate must be entered for every pollutant modeled.
    Enter emission rate of zero for secondary pollutants that are
    modeled, but not emitted.  Units are specified by IVLU
    (e.g. 1 for g/s).

---------------
Subgroup (16c)
---------------
                                    a
       VOLUME SOURCE: VARIABLE EMISSIONS DATA
       ----------------------------------------

    Use this subgroup to describe temporal variations in the emission
    rates given in 16b.  Factors entered multiply the rates in 16b.
    Skip sources here that have constant emissions.  For more elaborate
    variation in source parameters, use VOLEMARB.DAT and NVL2 > 0.

    IVARY determines the type of variation, and is source-specific:
    (IVARY)                          Default: 0
        0 =     Constant
        1 =     Diurnal cycle (24 scaling factors: hours 1-24)
        2 =     Monthly cycle (12 scaling factors: months 1-12)
        3 =     Hour & Season (4 groups of 24 hourly scaling factors,
                         where first group is DEC-JAN-FEB)
        4 =     Speed & Stab. (6 groups of 6 scaling factors, where
                         first group is Stability Class A,
                         and the speed classes have upper
                         bounds (m/s) defined in Group 12
```

```
        5 =     Temperature   (12 scaling factors, where temperature
                         classes have upper bounds (C) of:
                         0, 5, 10, 15, 20, 25, 30, 35, 40,
                         45, 50, 50+)



--------
   a
    Data for each species are treated as a separate input subgroup
    and therefore must end with an input group terminator.


-------------------------------------------------------------------------------

INPUT GROUPS: 17a & 17b -- Non-gridded (discrete) receptor information
----------------------

---------------
Subgroup (17a)
---------------

    Number of non-gridded receptors (NREC)  No default  !  NREC =  7095   !

!END!

---------------
Subgroup (17b)
---------------
                                   a
        NON-GRIDDED (DISCRETE) RECEPTOR DATA
        ------------------------------------

              X          Y        Ground       Height   b
Receptor     Coordinate  Coordinate   Elevation   Above Ground
  No.          (km)       (km)         (m)         (m)
--------     ----------  ----------   ---------   ------------
     1 ! X =   -988.0950,    354.3553,    2770.00,      0.000! ! END !
     2 ! X =   -986.7481,    354.1742,    2871.00,      0.000! ! END !
     3 ! X =   -985.4012,    353.9933,    2906.00,      0.000! ! END !
     4 ! X =   -984.0542,    353.8127,    2987.00,      0.000! ! END !
     5 ! X =   -982.7073,    353.6324,    2811.00,      0.000! ! END !
     6 ! X =   -981.3603,    353.4523,    2815.00,      0.000! ! END !
     7 ! X =   -980.0132,    353.2724,    2876.00,      0.000! ! END !
     8 ! X =   -978.6661,    353.0928,    2987.00,      0.000! ! END !
     9 ! X =   -977.3190,    352.9134,    3292.00,      0.000! ! END !
    10 ! X =   -989.1953,    356.3664,    2863.00,      0.000! ! END !
    Continued…
```

Normally Pressured Lance Natural Gas Development Project

Draft Environmental Impact Statement

Appendix M

General Conformity Determination

NORMALLY PRESSURED LANCE OIL AND GAS DEVELOPMENT PROJECT

GENERAL CONFORMITY DETERMINATION

Prepared by:
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Bureau of Land Management, Wyoming State Office

July 2016

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List of Acronyms and Abbreviations

BLM Bureau of Land Management
CAA Clean Air Act
CFR Code of Federal Regulations
CO Carbon Monoxide
DEIS Draft Environmental Impact Statement
DOI United States Department of the Interior
EPA United States Environmental Protection Agency
FR Federal Register
NAAQS National Ambient Air Quality Standard
NEPA National Environmental Policy Act
NO2 Nitrogen Dioxide
NOx Nitrogen Oxides
NPL Normally Pressured Lance
NSR New Source Review
O3 Ozone
PM10 Particulate matter less than 10 microns in diameter
PM2.5 Particulate matter less than 2.5 microns in diameter
SO2 Sulfur Dioxide
SIP State Implementation Plan
UGRB Upper Green River Basin
VOC Volatile Organic Compound
WAQSR Wyoming Air Quality Standards and Regulations

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APPENDIX M

NPL PROJECT CONFORMITY DETERMINATION

1.0 INTRODUCTION

Section 176(c)(1) of the Clean Air Act (CAA) requires any entity of the federal government that engages in, supports, or in any way provides financial support for, licenses, or permits, or approves any activity, to demonstrate that the action conforms to the applicable State Implementation Plan (SIP) for achieving and maintaining the National Ambient Air Quality Standards (NAAQS) for criteria pollutants before the action is otherwise approved (General Conformity Rule). Section 176(c)(1) also assigns primary oversight responsibility for conformity assurance to the agencies themselves, not to the United States Environmental Protection Agency (U.S. EPA) or the states. Specifically, for there to be conformity, a federal action must not contribute to new violations of standards for ambient air quality, increase the frequency or severity of existing violations, or delay timely attainment of standards in the area of concern. A General Conformity evaluation is required for project-related direct and indirect net emissions of criteria pollutants and their precursors in nonattainment or maintenance areas. The CAA defines nonattainment areas as geographic regions designated as not meeting one or more of the NAAQS.

A SIP is a state's compilation of its air quality control plans and rules that will be implemented to achieve compliance with the NAAQS. Criteria pollutants are six major air pollutants for which the U.S. EPA has established NAAQS. These pollutants are ozone (O3), particulate matter (particulate matter less than 10 microns in diameter [PM10] and particulate matter less than 2.5 microns in diameter [PM2.5]), carbon monoxide (CO), nitrogen dioxide (NO2), sulfur dioxide (SO2), and lead.

As a result of the 2012 ozone nonattainment designation of Wyoming's Upper Green River Basin, the BLM and other federal agencies within the area must comply with the General Conformity regulations in 40 CFR 93 Subpart B and Chapter 8, Section 3 of the Wyoming Air Quality Standards and Regulations (WAQSR). Per these regulations, federal agencies must demonstrate that new actions occurring within the nonattainment area will conform with the Wyoming State Implementation Plan either through an applicability analysis to demonstrate that the total of direct and indirect emissions from the proposed federal action do not exceed the de minimis emission levels specified in WAQSR Chapter 8, Section 3 or through a conformity determination if approval of the federal action will exceed the de minimis emission levels of 100 tons/year of nitrogen oxides (NO_x) or volatile organic compounds (VOC), the precursor pollutants that form ozone in the atmosphere. Federal actions estimated to have an annual net emissions increase less than the de minimis levels are not required to demonstrate conformity under the General Conformity regulations. In addition, any portion of the project or action that is permitted under the State of Wyoming's New Source Review (NSR) program are excluded from the agency's general conformity analysis per Chapter 8, Section 3 of the WAQSR.

The EPA issued a Final Rule on May 4, 2016, effective June 3, 2016, that included a Determination of Attainment for the UGRB by the attainment date of July 20, 2015 for marginal nonattainment areas. This Determination of Attainment does not constitute a re-designation of attainment. BLM and other federal agencies within the area must continue to comply with General Conformity regulations while the WDEQ meets a number of additional statutory criteria for the UGRB to be re-designated in attainment.

The proposed Normally Pressured Lance (NPL) project is entirely on BLM-managed land within the Upper Green River Basin ozone nonattainment area. The Project is considered a major federal action that, under the National Environmental Policy Act (NEPA), requires an Environmental Impact Statement (EIS) and a conformity analysis before the project can be authorized by the agency. The BLM has estimated the annual project emissions that would be subject to General Conformity in order to determine if the net emissions of these pollutants are above the General Conformity *de minimis* thresholds, and thus subject to the General Conformity Rule. This draft General Conformity Determination for the NPL project provides the BLM's analysis of the proposed action emissions as well as the BLM's Conformity analysis for the project.

2.0 GENERAL CONFORMITY RULE

The General Conformity regulations establish certain procedural requirements that must be followed when preparing a General Conformity Determination. This section addresses the regulatory background, requirements, and processes of the General Conformity Rule.

2.1 GENERAL CONFORMITY REGULATORY BACKGROUND

The U.S. EPA promulgated the General Conformity Rule on November 30, 1993 to implement the conformity provision of Title I, Section 176(c) of the federal CAA (42 U.S.C. § 7506(c)). Section 176(c)(1) requires that the federal government not engage, support, or provide financial assistance for permit or license, or approve any activity that fails to conform to an approved SIP.

The General Conformity Rule is codified in 40 Code of Federal Regulations (CFR) Part 93 (40 CFR 93), Subpart B, "*Determining Conformity of General Federal Actions to State or Federal Implementation Plans*". The General Conformity Rule applies to all federal actions, except programs and projects that require funds or approval from the U.S. Department of Transportation (U.S. DOT), the Federal Highway Administration (FHWA), or the Federal Transit Administration (FTA). In lieu of a General Conformity analysis, these latter types of programs and projects must comply with the Transportation Conformity Rule promulgated by U.S. DOT on November 24, 1993 (58 FR 62197). The federal General Conformity Rule is often incorporated into the state regulations. The State of Wyoming has incorporated the federal regulation into the Wyoming Air Quality Standards and Regulations (WAQSR) Chapter 8, Section 3: *Conformity of general federal actions to state implementation plans*, and therefore, the state has primacy and authority to enforce the General Conformity regulations.

2.2 GENERAL CONFORMITY REQUIREMENTS

As defined in the CAA, conformity means to uphold air quality goals through reduction or elimination of NAAQS violations. Accordingly, the Federal agency must demonstrate that the proposed action or activity achieves conformity by demonstrating that the associated emissions will not:

- Cause or contribute to new violations of any NAAQS in any area;
- Increase the frequency or severity of any existing violation of any NAAQS; or
- Delay timely attainment of any NAAQS or interim emission reductions.

The General Conformity Rule allows for conformity analysis in coordination with and as part of the NEPA environmental review process. The General Conformity Rule affects air pollutant emissions associated with actions that are federally funded, licensed, permitted, or approved; and ensures the net emissions do not contribute to air quality degradation, or prevent the achievement of state and federal air quality goals. In short, General Conformity, if applicable, refers to the process to evaluate plans, programs, and projects to determine and demonstrate that they satisfy the requirements of the CAA and the SIP.

2.3 GENERAL CONFORMITY PROCESSES

The process to evaluate General Conformity for a proposed federal action involves the General Conformity applicability review and analysis, the General Conformity evaluation and determination process, and the General Conformity Determination draft review process. The applicability review process and analysis is required for any federal action (if it is not exempt) that would contribute pollutant emissions within the nonattainment area. A Conformity Determination is required for each criteria pollutant and its precursors where the total of direct and indirect net annual emissions in a nonattainment or maintenance area would equal or exceed the General Conformity *de minimis* thresholds. The *de minimis* thresholds are based on the severity of the nonattainment status. The Upper Green River Basin, was designated as marginal nonattainment for ozone (2008 standard) by the U.S. EPA, thus the applicable *de minimis* thresholds for the ozone precursors of NOx and VOC are 100 tons per year for any Federal action. The Federal agency must prepare a draft Conformity determination which must be made publicly available for review and comment before the agency issues the final determination and decision for the Federal action.

Based on the regulatory definitions, direct emissions are caused by the action itself, such as the emissions from the construction of a facility. Indirect emissions are also caused by the action, but are removed from the action in either time or space. For example, emissions from employees commuting to a facility are indirect emissions. The General Conformity analysis for the NPL project is based on the total direct and indirect net emissions from the proposed action excluding emission sources that are permitted through WDEQ's NSR Permit Program. Since the NPL project spans many years, the year during which the emissions for the proposed action are projected to be the greatest on an annual basis was calculated and evaluated for the General Conformity analysis.

3.0 NPL PROJECT EMISSIONS

Ozone precursor emissions of NOx and VOC were calculated for each year of the project development and the year of maximum emissions for the NPL project was evaluated for General Conformity. Emissions from construction, drilling, and the operational phase of the project are included in the BLM's Conformity analysis excluding emission sources that are permitted through WDEQ's NSR Permit Program. Since Jonah Energy has a federally-enforceable drill rig permit (Air Quality Permit CT-8122A2) issued by the WDEQ through the New Source Review program, drill rig emissions from the proposed action are presumed to conform and were also excluded from the BLM's Conformity analysis.

The original proposed drilling schedule of up to 350 wells per year resulted in estimated NO_x emissions that exceeded the 100 tpy *de minimis* emission threshold even after the exclusion of permitted sources. The primary emission source causing the exceedance of the *de minimis* threshold are the completion rigs (based on drilling 350 wells per year).

The following emission sources are permitted by the WDEQ under the authority of Chapter 6, Section 2 of the WAQSR, and were excluded from the BLM's Conformity analysis per Chapter 8, Section 3: *Conformity of general federal actions to state implementation plans*

- Storage tanks
- Dehydration units
- Pneumatic equipment
- Separation vessels
- Truck loading
- Fugitives
- Process heaters
- Green completions
- Blowdowns

4.0 GENERAL CONFORMITY ANALYSIS

The General Conformity regulation provides options available for a Federal agency to demonstrate conformity for a Federal action, such as fully offsetting new emissions resulting in a no-net increase or the State regulatory authority for air quality can develop an emissions budget for a nonattainment area and/or incorporate Federal agency actions into the SIP. However, the requirements for Marginal nonattainment areas do not require preparation of an emissions budget or nonattainment SIP. The BLM and WDEQ have worked cooperatively to address General Conformity requirements in the UGRB for several years utilizing the annual de minimis emissions thresholds for NOx and VOCs. The only option available at this time to demonstrate conformity for the NPL project is for the BLM to reduce and limit the pace of development in order to not exceed the annual *de-minimis* emissions thresholds for NOx and VOCs.

In order to accomplish this and determine what level of development can be authorized in the Record of Decision, the BLM conducted an analysis to determine the allowable number of wells that could be drilled in the NPL project area while still meeting the NO_x and VOC emission threshold of 100 tons per year (tpy) for each pollutant. For the purposes of the BLM's General Conformity analysis, the following emission sources were quantified since these sources are <u>not</u> permitted through WDEQ's NSR Permit Program:

- Construction Mobile Equipment
- Drill Rig Mobile Equipment
- Completion Rigs
- Completion Mobile Equipment
- Workovers
- Production Mobile Equipment
- Employee and Workforce Commuting Traffic for all Phases of Development

For the Conformity emission inventory (see Attachment A), proposed well and pad counts were reduced in the proposed action inventory until the de minimis emission threshold was reached. The reduced schedule includes drilling up to 160 wells per year and construction of 10 well pads per year. This reduces the estimated NO_x emissions to 97.7 tons/year in the maximum year. Annual emission totals for the Conformity emission inventory are provided in Table 1. The complete emissions inventory developed for the Conformity determination is included as Attachment A. In modifying the original proposed action emission inventory to estimate the annual number of wells for the conformity threshold comparison, the following assumptions and modifications were made:

- The original proposed action inventory was modified to allow for the computation of the number of pads needed per year to accommodate the proposed number of wells. Based on the configuration of 16 wells per pad, 10 pads per year would be allowed.

- The ramp-up period for well drilling was changed from the original proposed values of 60, 180, and 240 wells per year for the first 3 years and 350 wells per year for all remaining years, to 60 wells per year in Year 1 and 160 wells per year in Years 2-10.

- The number of facilities and the construction schedule for facilities and other infrastructure (roads, pipelines, etc.) were analyzed at the same emissions levels as the original proposed action. However, emissions for these activities are likely to decrease as well due to the reduction in well pads and wells drilled annually.

- Although production rates and throughput would be expected to decrease with the decreased schedule of well development, production rates, traffic, and other indirect emission sources were also held at the same emission levels as the proposed action for the purposes of this analysis to ensure a conservative estimate.

Table 1. ANNUAL EMISSION TOTALS FOR GENERAL CONFORMITY DEVELOPMENT SCENARIO

Year	CO	NOx	PM10	PM2.5	SO2	VOC
1	42.8	49.5	234.2	33.9	1.7	58.9
2	51.0	97.7	461.2	66.3	3.9	58.5
3	49.0	96.7	444.8	64.4	3.9	55.7
4	48.1	97.5	461.1	66.2	3.9	58.5
5	45.8	95.5	428.4	62.6	3.8	52.6
6	45.2	96.4	444.7	64.4	3.9	55.5
7	44.3	96.3	444.7	64.4	3.9	55.4
8	43.0	95.4	428.3	62.6	3.8	52.6
9	42.6	96.2	444.7	64.4	3.9	55.3
10	41.5	95.3	428.3	62.6	3.8	52.6

Source: Refer to NPL EIS Appendix L (*Air Quality TSD*)

5.0 GENERAL CONFORMITY DETERMINATION

Based on the BLM's General Conformity Development Scenario of 160 wells/years, the NPL project can be authorized at a reduced pace of development and demonstrate Conformity with the Wyoming SIP. This Conformity Determination can be revised in the future if the operator can demonstrate additional reductions in NOx emissions from the project or the State of Wyoming develops an emissions budget for the nonattainment area that is inclusive of the NPL project emissions. Either case will require the BLM to prepare a new Draft Conformity Determination for the project and require a public notice and comment period.

6.0 REFERENCES

URS Corporation. (October 2012). *CALNEV PIPELINE EXPANSION PROJECT*: *DRAFT CONFORMITY DETERMINATION*. La Jolla, CA.

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ATTACHMENT A. NPL PROJECT GENERAL CONFOMRITY EMISSIONS CALCULATIONS

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NPL Project General Conformity Emissions Inventory

Table 1. Development Scenario

NPL Natural Gas Development Field - Sublette County, Wyoming 7/16/2015

Emission inventory that reflects the maximum number of wells that can be drilled annually to meet the General Conformity emission limits of 100 tpy for NOx and VOC.

Well Pad		2			2
pads/yr		10			10
pad/section		4			4
pad spacing (acre)		160			160
acres/pad		18			18
well/pad		16			16
wells/yr		160			160
development years		10			10

Construction					
days/pad		5			5
days/road seg		3			3
days/pipe seg		3			3
resource road/pad (ft)		2640			2640
resource road acre/pad		4.55			4.55
lateral pipe/pad (ft)		2640			2640
resource road ROW (ft)		75			75
PAD ROW Pipe (ft)		0			0
local road (ft)		574			574
local road ROW (ft)		60			60
Gathering Pipe (mile)		280			280
Gathering ROW (acre)		1229			1229
Gathering ROW Pipe (ft)		36			36

Notes: Resource ROW includes road and pipeline

Assumes 60 wells drilled in Year 1 and 160 wells/year drilled in Years 2-10

NPL Project General Conformity Emissions Inventory

Table 2. Pad, Road and Gas Gathering Pipeline Disturbance

Year	Pads (acres)	New Pads (number)	Local Roads (miles)	Local Roads (acres)	Resource Roads (Miles)	Resource Roads (acres)	Pipelines (miles)	Pipelines (acres)	Annual Total (acres)
Existing		0							
New	1800	100			50	454.54545	330	0	2254.5455

Table 3. Well Pad Constrution/Expansion - Per Acre

Project: **NPL**
Scenario: **4 Pad/Section**
Activity: **Well Pad Construction**
Emissions: **Fugitive Particulate Emissions from Well Pad Construction**

Well Pad Area (Expansion)	Worst-Case Construction Activity PM_{10} Emission Factor[1]	$PM_{2.5}$/PM10 Ratio for Fugitive Dust from Construction [2]	Construction Activity Duration[3]	Construction Activity Duration	Emission Control Efficiency	PM_{10} Emissions (controlled)	$PM_{2.5}$ Emissions (controlled)
(acre)	(tons/acre-month)		(days/acre)	(hours/day)	(%)	(lb/acre)	(lb/acre)
18	0.42	0.1	0.28	10	50	70.00	7.00

[1] Countess Environmental, 2006. WRAP Fugitive Dust Handbook. WGA Contract No. 30204-111.
[2] Countess Environmental, 2006. WRAP Fugitive Dust Handbook. WGA Contract No. 30204-111, Section 3.3.1
[3] Construction Activity Duration taken from an average of durations provided by Shell, Ultra and Questar.
Monthly emissions converted to daily and hourly emissions based on 30-day month.

Table 4. Local Road Construction - Per Mile

Project: NPL
Scenario: 4 Pad/Section
Activity: Access Road Construction per Pad
Emissions: Fugitive Particulate Emissions from Local Road Construction

Road Length	Local Road Area[1]	Worst-Case Construction Activity PM_{10} Emission Factor[2]	$PM_{2.5}/PM_{10}$ Ratio for Fugitive Dust from Construction[3]	Construction Activity Duration[3]	Construction Activity Duration	Emission Control Efficiency	PM_{10} Emissions (controlled)	$PM_{2.5}$ Emissions (controlled)
(mi)	(acres)	(tons/acre-month)		(days/mi)	(hours/day)	(%)	(lb/mi)	(lb/mi)
0.11	1	0.42	0.1	3	12	50	33.21	3.32

[1] Construction Area taken from average of current field activity of 4.51 acres/mile for Local Roads.
[2] Countess Environmental, 2006. WRAP Fugitive Dust Handbook. WGA Contract No. 30204-111, Section 3.3.1
[3] Construction Activity Duration taken from an average of durations provided by Shell, Ultra and Questar.
Monthly emissions converted to daily and hourly emissions based on 30-day month.

NPL Project General Conformity Emissions Inventory

Table 5. Resource Road Construction - Per Mile

Project: NPL
Scenario: 4 Pad/Section
Activity: Access Road Construction per Pad
Emissions: Fugitive Particulate Emissions from Resource Road Construction

Road Length	Resource Road Area	Worst-Case Construction Activity PM_{10} Emission Factor[1]	$PM_{2.5}/PM_{10}$ Ratio for Fugitive Dust from Construction[2]	Construction Activity Duration	Construction Activity Duration	Emission Control Efficiency	PM_{10} Emissions (controlled)	$PM_{2.5}$ Emissions (controlled)
(mi)	(acres)	(tons/acre-month)		(days/mi)	(hours/day)	(%)	(lb/mi)	(lb/mi)
0.5	4.55	0.42	0.1	3	10	50	45.45	4.55

[1] Countess Environmental, 2006. WRAP Fugitive Dust Handbook. WGA Contract No. 30204-111, Section 3.3.1
[2] Construction Activity Duration taken from an average of durations provided by Shell, Ultra and Questar.
Monthly emissions converted to daily and hourly emissions based on 30-day month.

NPL Project General Conformity Emissions Inventory

Table 6. Pipeline Construction - Per Mile

Accounted for under road construction

Project: **NPL**
Scenario: **4 Pad/Section**
Activity: **Pipeline Construction per Pad**
Emissions: **Fugitive Particulate Emissions from Pipeline Construction**

Pipeline Length	Pipeline Area[1]	Worst-Case Construction Activity PM_{10} Emission Factor[2]	$PM_{2.5}/PM_{10}$ Ratio for Fugitive Dust from Construction[3]	Construction Activity Duration[4]	Construction Activity Duration	Emission Control Efficiency	PM_{10} Emissions (controlled)	$PM_{2.5}$ Emissions (controlled)
(mi)	(acres)	(tons/acre-month)		(days/mi)	(hours/day)	(%)	(lb/mi)	(lb/mi)
2.80	12.3	0.42	0.1	14	10	50	1.20	0.12

[1] Includes both laterals and trunks.
[2] Countess Environmental, 2006. WRAP Fugitive Dust Handbook. WGA Contract No. 30204-111, Section 3.3.1
[3] Construction Activity Duration taken from an average of durations provided by Shell, Ultra and Questar.
Monthly emissions converted to daily and hourly emissions based on 30-day month.
[4] Construction Activity Duration assumed to be similar to road construction.

NPL Project General Conformity Emissions Inventory

Table 7. Other Construction Activities

Project: NPL
Scenario: 4 Pad/Section
Activity: Facility Construction
Emissions: Fugitive Particulate Emissions from Const. Activities

Construction Activity	Construction Area[1]	Worst-Case Construction Activity PM_{10}	$PM_{2.5}/PM_{10}$ Ratio for Fugitive Dust from Construction	Construction Activity Duration[4]	Construction Activity Duration	Emission Control Efficiency	PM_{10} Emissions (controlled)		$PM_{2.5}$ Emissions (controlled)	
	(acres)	(tons/acre-month)		(days)	(hours/day)	(%)	(lbs)	(tpy)	(lbs)	(tpy)
Central Facility 1	15.00	0.42	0.1	4.17	10	50	875.00	0.44	87.50	0.04
Central Facility 2	15.00	0.42	0.1	4.17	10	50	875.00	0.44	87.50	0.04
Central Facility 3	15.00	0.42	0.1	4.17	10	50	875.00	0.44	87.50	0.04
Central Facility 4	15.00	0.42	0.1	4.17	10	50	875.00	0.44	87.50	0.04
Central Facility 5	15.00	0.42	0.1	4.17	10	50	875.00	0.44	87.50	0.04
Central Facility 6	15.00	0.42	0.1	4.17	10	50	875.00	0.44	87.50	0.04
Central Facility 7	15.00	0.42	0.1	4.17	10	50	875.00	0.44	87.50	0.04
Central Facility 8	15.00	0.42	0.1	4.17	10	50	875.00	0.44	87.50	0.04
Central Facility 9	15.00	0.42	0.1	4.17	10	50	875.00	0.44	87.50	0.04
Central Facility 10	15.00	0.42	0.1	4.17	10	50	875.00	0.44	87.50	0.04
Central Facility 11	15.00	0.42	0.1	4.17	10	50	875.00	0.44	87.50	0.04
Total Other Construction:	165.00	0.42	0.1	45.83	10	50	9625.00	4.81	962.50	0.48

[1] Estimated.
[2] Countess Environmental, 2006. WRAP Fugitive Dust Handbook. WGA Contract No. 30204-111, Section 3.3.1
[3] Construction Activity Duration taken from an average of durations provided by Shell, Ultra and Questar. Monthly emissions converted to daily and hourly emissions based on 30-day month.
[4] Construction Activity Duration assumed to be similar to pad construction and pipeline construction for stabilizer faclity/compressor station and gathering system, respectively.

NPL Project General Conformity Emissions Inventory

Table 8. Construction Wind Erosion - Per Acre of Disturbance

Project: **NPL**
Scenario: **4 Pad/Section**
Activity: **Well Pad, Resource Road, Pipeline Construction**
Emissions: **Wind Erosion**

Emission Factor (PM_{10})[1] : 0.0611 lb/hr-acre
Emission Factor ($PM_{2.5}$)[1] : 0.0092 lb/hr-acre

24 hr/day

Control Efficiency[2]: 50 %

Disturbed Area:
Well Pad Construction/Exp.: 18 acres

Access Road Construction: 5.34 acres

Pipeline Construction 12 acres

Central Facility Construction 15 acres

Emissions Calculations:

	PM_{10} Emission Facto	$PM_{2.5}$ Emission Factor	Area	Control Efficiency	Construction Hours	PM_{10} Emissions	$PM_{2.5}$ Emissions	Controlled PM_{10} Emissions	Controlled $PM_{2.5}$ Emissions
	(lb/hr-acre)	(lb/hr-acre)	(acre)	(%)	per pad or facil	(lb/hr)	(lb/hr)	(ton/pad)	(ton/pad)
Well Pad Construction (per p	0.0611	0.0092	18.00	50	120.0	0.55	0.08	0.03	0.00
Road Construction (per pad)	0.0611	0.0092	5.34	50	151.3	0.16	0.02	0.01	0.00
Pipeline Construction (per pa	0.0611	0.0092	12.29	50	672.0	0.38	0.06	0.13	0.02
Central Facilty Construction (per facility)	0.0611	0.0092	15.00	50	240.0	0.46	0.07	0.06	0.01

[1] Based on AP-42 Chapter 13.2.5 (EPA 2004), Industrial Wind Erosion using Area meteorological data. See 'WindErosion Data' sheet for details.
[2] AP-42 (EPA 2004), Section 13.2.3, "Heavy Construction Operations".

NPL Project General Conformity Emissions Inventory

Table 9. Well Pad Construction Traffic

Project: **NPL**
Scenario: **4 Pad/Section**
Activity: **Pad Const. Traffic**
Emissions: **Fugitive Particulate Emissions from Traffic on Unpaved Roads**

Vehicle Type	Road Type	Dust Control Method[1]	Average Vehicle Weight (lb)	Average Vehicle Speed (mph)	Silt Content[2] (%)	Moisture Content[3] (%)	Vehicle Count	Round Trips (RTs) (RT/pad	RT Distance (miles)	Vehicle Miles Traveled (VMT)[4] (VMT/pad)	Emission Control Efficiency[5] (%)	PM_{10} Emission Factor[6] (lb/VMT)	$PM_{2.5}$ Emission Factor[6] (lb/VMT)	PM_{10} Emissions[7] (controlled) (lb/pad)	$PM_{2.5}$ Emissions[7] (controlled) (lb/pad)	
3/4 ton Pickup	Local	Chemical +	5,800	25	5.1	2.4	5	11	34	1870	85	0.51	0.05	143.01	14.21	1b
	Resource	Water +	5,800	20	5.1	2.4	5	11	1	55	50	0.68	0.07	18.81	1.88	1a
1 ton Roustabout w/ trailer	Local	Chemical +	7,500	25	5.1	2.4	1	2	34	68	85	0.51	0.05	5.20	0.52	1b
	Resource	Water +	7,500	20	5.1	2.4	1	2	1	2	50	0.77	0.08	0.77	0.08	1a
Semi w/ bellydump	Local	Chemical +	70,000	25	5.1	2.4	1	10	34	340	85	0.51	0.05	26.00	2.58	1b
	Resource	Water +	70,000	20	5.1	2.4	1	10	1	10	50	2.10	0.21	10.49	1.05	1a
Semi w/ lowboy trailer	Local	Chemical +	75,000	25	5.1	2.4	2	2	34	136	85	0.51	0.05	10.40	1.03	1b
	Resource	Water +	75,000	20	5.1	2.4	2	2	1	4	50	2.16	0.22	4.33	0.43	1a
Bulk fuel truck	Local	Chemical +	35,000	25	5.1	2.4	1	1	34	34	85	0.51	0.05	2.60	0.26	1b
	Resource	Water +	35,000	20	5.1	2.4	1	1	1	1	50	1.54	0.15	0.77	0.08	1a
Water Truck	Local	Chemical +	35,000	25	5.1	2.4	1	5	34	170	85	0.51	0.05	13.00	1.29	1b
	Resource	Water +	35,000	20	5.1	2.4	1	5	1	5	50	1.54	0.15	3.84	0.38	1a
Total Unpaved Road Traffic Emissions (lb/pad)														167.78	16.69	

[1] Dust control methods include using water (resource road) or chemical (loacal road) as a dust suppressants along with vehicle restriction speed limit of 25 mph.
[2] AP-42 (EPA 2004), Table 13.2.2-1, Western surface coal mining - plant road, "Typical Silt Content Values of Surface Material on Industrial and Rural Unpaved Roads."
[3] AP-42 (EPA 2004), Table 11.9-3, "Typical Values for Correction Factors Applicable to the Predictive Emission Factor Equations."
[4] Calculated as Round Trips per Vehicle Type x Round Trip Distance.
[5] AP-42 (EPA 2004), Figure 13.2.2-2, "Watering control effectiveness for unpaved travel surfaces.", Fugitive Dust Handbook (WRAP 2006) Chapter 6.
[6] AP-42 (EPA 2004), Section 13.2.2 "Unpaved Roads", equations 1a and 1b.
[7] Calculated as lb/VMT x VMT/pad x control efficiency.

NPL Project General Conformity Emissions Inventory

Table 10. Road Construction Traffic - All Operators

Most Accounted for under Pad Construction

Project: NPL
Scenario: 4 Pad/Section
Activity: Resource Road Const. Traffic
Emissions: Fugitive Particulate Emissions from Traffic on Unpaved Roads

Vehicle Type	Road Type	Dust Control Method[1]	Average Vehicle Weight	Average Vehicle Speed	Silt Content[2]	Moisture Content[3]	Vehicle Count	Round Trips (RTs)	RT Distance	Vehicle Miles Traveled (VMT)[4]	Emission Control Efficiency[5]	PM_{10} Emission Factor[6]	$PM_{2.5}$ Emission Factor[6]	PM_{10} Emissions[7] (controlled)	$PM_{2.5}$ Emissions[7] (controlled)
			(lb)	(mph)	(%)	(%)		(RT/pad	(miles)	(VMT/pad)	(%)	(lb/VMT)	(lb/VMT)	(lb/pad)	(lb/pad)
3/4 ton Pickup	Local	Chemical +	5,800	25	5.1	2.4	5	6	34	1020	85	0.51	0.05	78.00	7.75
	Resource	Water +	5,800	20	5.1	2.4	5	6	1	30	50	0.68	0.07	10.26	1.03
1 ton Roustabout w/ trailer	Local	Chemical +	7,500	25	5.1	2.4	1	2	0	0	85	0.51	0.05	0.00	0.00
	Resource	Water +	7,500	20	5.1	2.4	1	2	0	0	50	0.77	0.08	0.00	0.00
Semi w/ bellydump	Local	Chemical +	70,000	25	5.1	2.4	1	10	0	0	85	0.51	0.05	0.00	0.00
	Resource	Water +	70,000	20	5.1	2.4	1	10	0	0	50	2.10	0.21	0.00	0.00
Semi w/ lowboy trailer	Local	Chemical +	75,000	25	5.1	2.4	2	2	0	0	85	0.51	0.05	0.00	0.00
	Resource	Water +	75,000	20	5.1	2.4	2	2	0	0	50	2.16	0.22	0.00	0.00
Bulk fuel truck	Local	Chemical +	35,000	25	5.1	2.4	1	1	0	0	85	0.51	0.05	0.00	0.00
	Resource	Water +	35,000	20	5.1	2.4	1	1	0	0	50	1.54	0.15	0.00	0.00
Water Truck	Local	Chemical +	35,000	25	5.1	2.4	1	5	0	0	85	0.51	0.05	0.00	0.00
	Resource	Water +	35,000	20	5.1	2.4	1	5	0	0	50	1.54	0.15	0.00	0.00
												Total Unpaved Road Traffic Emissions (lb/pad)		88.26	8.78

1 Dust control methods include using water (resource road) or chemical (loacal road) as a dust suppressants along with vehicle restriction speed limit of 25 mph.
2 AP-42 (EPA 2004), Table 13.2.2-1, Western surface coal mining - plant road, "Typical Silt Content Values of Surface Material on Industrial and Rural Unpaved Roads."
3 AP-42 (EPA 2004), Table 11.9-3, "Typical Values for Correction Factors Applicable to the Predictive Emission Factor Equations."
4 Calculated as Round Trips per Vehicle Type x Round Trip Distance.
5 AP-42 (EPA 2004), Figure 13.2.2-2, "Watering control effectiveness for unpaved travel surfaces.", Fugitive Dust Handbook (WRAP 2006) Chapter 6.
6 AP-42 (EPA 2004), Section 13.2.2 "Unpaved Roads", equations 1a and 1b.
7 Calculated as lb/VMT x VMT/pad x control efficiency.

Table 11. Pipeline Construction Traffic

Project: **NPL**
Scenario: **4 Pad/Section**
Activity: **Pipeline Construction**
Emissions: **Fugitive Particulate Emissions from Unpaved Road Traffic**

Vehicle Type	Road Type	Dust Control Method[1]	Average Vehicle Weight[2] (lb)	Average Vehicle Speed (mph)	Silt Content[3] (%)	Moisture Content[4] (%)	Vehicle Count	RTs per mile	RT Distance (miles)	VMT[5] VMT/pad	Emission Control Efficiency[6] (%)	PM_{10} Emission Factor[7] (lb/VMT)	$PM_{2.5}$ Emission Factor[7] (lb/VMT)	PM_{10} Emissions[8] (controlled) (lb/pad)	$PM_{2.5}$ Emissions[8] (controlled) (lb/pad)
Light truck/pick-ups	Local	Chemical +	5,800	25	5.1	2.4	10	28	34	9520	85	0.51	0.05	728.03	72.36
	Resource	Water +	5,800	20	5.1	2.4	10	28	1	280	50	0.68	0.07	95.75	9.58
Sideboom	Local	Chemical +	70,000	25	5.1	2.4	3	0.1	34	10.2	85	0.51	0.05	0.78	0.08
	Resource	Water +	70,000	20	5.1	2.4	3	0.1	1	0.3	50	2.10	0.21	0.31	0.03
Trencher	Local	Chemical +	43,000	25	5.1	2.4	1	0.1	34	3.4	85	0.51	0.05	0.26	0.03
	Resource	Water +	43,000	20	5.1	2.4	1	0.1	1	0.1	50	1.68	0.17	0.08	0.01
Track Hoe	Local	Chemical +	45,000	25	5.1	2.4	3	0.1	34	10.2	85	0.51	0.05	0.78	0.08
	Resource	Water +	45,000	20	5.1	2.4	3	0.1	1	0.3	50	1.72	0.17	0.26	0.03
Dozer	Local	Chemical +	28,500	25	5.1	2.4	1	0.1	34	3.4	85	0.51	0.05	0.26	0.03
	Resource	Water +	28,500	20	5.1	2.4	1	0.1	1	0.1	50	1.40	0.14	0.07	0.01
Grader	Local	Chemical +	51,000	25	5.1	2.4	1	0.1	34	3.4	85	0.51	0.05	0.26	0.03
	Resource	Water +	51,000	20	5.1	2.4	1	0.1	1	0.1	50	1.82	0.18	0.09	0.01
Total Unpaved Road Traffic Emissions (lb/pad)														826.59	82.21

1. Dust control methods include using water (resource road) or chemical (loacal road) as a dust suppressants along with vehicle restriction speed limit of 25 mph.
2. Semi vehicle weight range is 28,000-60,000 lbs; average weight of 44,000 lbs used for calculations.
3. AP-42 (EPA 2004), Table 13.2.2-1, Western surface coal mining - plant road, "Typical Silt Content Values of Surface Material on Industrial and Rural Unpaved Roads."
4. AP-42 (EPA 2004), Table 11.9-3, "Typical Values for Correction Factors Applicable to the Predictive Emission Factor Equations."
5. Calculated as Round Trips per Vehicle Type x Round Trip Distance.
6. AP-42 (EPA 2004), Figure 13.2.2-2, "Watering control effectiveness for unpaved travel surfaces.", Fugitive Dust Handbook (WRAP 2006) Chapter 6.
7. AP-42 (EPA 2004), Section 13.2.2 "Unpaved Roads", equations 1a and 1b.
8. Calculated as lb/VMT x VMT/pad x control efficiency.

NPL Project General Conformity Emissions Inventory

Table 12. Well Pad Construction - Heavy Equipment Tailpipe

Project: NPL
Scenario: 4 Pad/Section
Activity: Pad Construction Heavy Equip.
Emissions: Diesel Combustion Emissions from Heavy Equipment Tailpipes

Heavy Equipment	Engine Horsepower (hp)	Number Required	Operating Load Factor[1]	Pollutant Emission Factor[2] (g/hp-hr): CO	NO_x	SO_2	VOC	PM_{10}	$PM_{2.5}$	Benzene	Ethylbenzene	Formaldehyde	H_2S	n-Hexane	Toluene	Xylenes	CH_4[3]	CO_2	N_2O[3]	Construction Activity Duration (days/pad)	(hrs/day)
Cat 430D Backhoe	94	1	0.43	7.36	6.61	0.15	1.59	1.14	1.1								0.102266	692	6.82E-03	1.5	8
Cat D8R Dozer	350	1	0.43	1.26	3.91	0.12	0.3	0.25	0.24								0.0792709	536.4	5.28E-03	5	9
Cat 627F Scraper	350	2.5	0.43	1.26	3.94	0.12	0.3	0.25	0.25								0.0792709	536.4	5.28E-03	4	9
Cat 14H Grader	220	1	0.43	1.47	4.08	0.12	0.33	0.32	0.31								0.0792562	536.3	5.28E-03	5	9

Pollutant Emissions (lb/pad)

CO	NO_x	SO_2	VOC	PM_{10}	$PM_{2.5}$	Benzene	Ethylbenzene	Formaldehyde	H_2S	n-Hexane	Toluene	Xylenes	CH_4	CO_2	N_2O
7.9	7.1	0.2	1.7	1.2	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	740.0	0.0
18.8	58.4	1.8	4.5	3.7	3.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	8008.8	0.1
37.6	117.7	3.6	9.0	7.5	7.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.4	16017.5	0.2
13.8	38.3	1.1	3.1	3.0	2.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	5033.1	0.0

HD Vehicle traffic Emissions [4]

g/mile

	miles/pad	CO	NO_x	SO_2	VOC	PM_{10}	$PM_{2.5}$	Benze	Ethylb	Forma	H_2S	n-Hex	Tolue	Xylen	CH_4[3]	CO_2	N_2O[3]
1 ton Roustabout w/ trailer	70	2.25E+00	9.64E+00	1.47E-02	3.76E-01	5.02E-01	4.44E-01	4.07E-03		3.03E-02					2.67E-02	1.94E+03	1.76E-03
Semi w/ bellydump	350	2.25E+00	9.64E+00	1.47E-02	3.76E-01	5.02E-01	4.44E-01	4.07E-03		3.03E-02					2.67E-02	1.94E+03	1.76E-03
Semi w/ lowboy trailer	140	2.25E+00	9.64E+00	1.47E-02	3.76E-01	5.02E-01	4.44E-01	4.07E-03		3.03E-02					2.67E-02	1.94E+03	1.76E-03
Bulk fuel truck	35	2.16E+00	8.64E+00	1.15E-02	4.00E-01	4.74E-01	4.12E-01	4.33E-03		3.23E-02					2.76E-02	1.52E+03	1.88E-03
Water Truck	175	2.16E+00	8.64E+00	1.15E-02	4.00E-01	4.74E-01	4.12E-01	4.33E-03		3.23E-02					2.76E-02	1.52E+03	1.88E-03

lb/pad

	CO	NO_x	SO_2	VOC	PM_{10}	$PM_{2.5}$	Benzene	Ethylbenzene	Formaldehyde	H_2S	n-Hexane	Toluene	Xylenes	CH_4	CO_2	N_2O
1 ton Roustabout w/ trailer	3.47E-01	1.49E+00	2.26E-03	5.80E-02	7.74E-02	6.86E-02	6.28E-04		4.68E-03					4.12E-03	3.00E+02	2.72E-04
Semi w/ bellydump	1.74E+00	7.44E+00	1.13E-02	2.90E-01	3.87E-01	3.43E-01	3.14E-03		2.34E-02					2.06E-02	1.50E+03	1.36E-03
Semi w/ lowboy trailer	6.94E-01	2.98E+00	4.52E-03	1.16E-01	1.55E-01	1.37E-01	1.26E-03		9.36E-03					8.25E-03	6.00E+02	5.44E-04
Bulk fuel truck	1.66E-01	6.67E-01	8.87E-04	3.09E-02	3.66E-02	3.18E-02	3.34E-04		2.49E-03					2.13E-03	1.18E+02	1.45E-04
Water Truck	8.32E-01	3.33E+00	4.44E-03	1.54E-01	1.83E-01	1.59E-01	1.67E-03		1.25E-02					1.07E-02	5.88E+02	7.24E-04
Total Heavy Equipment Tailpipe Emissions	81.9	237.3	6.7	18.9	16.3	15.9	0.0	0.0	0.1	0.0	0.0	0.0	0.0	4.4	32906.3	0.3

[1] Taken from "Median Life Annual Activity, and Load Factor Values for Nonroad Engine Emissions Modeling, Table 9, 7-cycle average (7/2010)

[2] Emission factors from NONROADS 2008, run for 2009.

Fuel Oxygen 2.440 wt%;Dsl Sulfur 0.0351 %

[3] CO_2 = 10.15 kg CO2 / gal diesel fuel. CO2 value provided in NOANROADs 2008 run for 2009. NO2 and CHR are not. CH4=0.0015 kg/gal diesel fuel, NO2 = 0.001 kg/gal diesel fuel

Factor for CH4 = 0.0015/10.15, factor for NO2 = 0.0001/10.15

[4] MOVES 2013

NPL Project General Conformity Emissions Inventory

Table 13. Road Construction - Heavy Equipment Tailpipe

Project: NPL
Scenario: 4 Pad/Section
Activity: Road Construction Heavy Equip.
Emissions: Diesel Combustion Emissions from Heavy Equipment Tailpipes

Heavy Equipment	Engine Horsepower	Number Required	Operating Load Factor[1]	Pollutant Emission Factor[2] (g/hp-hr)																Construction Activity Duration	
	(hp)			CO	NO_x	SO_2	VOC	PM_{10}	$PM_{2.5}$	Benzene	Ethylbenzene	Formaldehyde	H_2S	n-Hexane	Toluene	Xylenes	CH_4[3]	CO_2	N_2O[3]	(days/pad)	(hrs/day)
Cat 430D Backhoe	94	1	0.43	7.36	6.61	0.15	1.59	1.14	1.1								0.102	692	6.82E-03	0.9	8
Cat D8R Dozer	350	1	0.43	1.26	3.91	0.12	0.3	0.25	0.24								0.079	536.4	5.28E-03	3	9
Cat 627F Scraper	350	2.5	0.43	1.26	3.94	0.12	0.3	0.25	0.25								0.079	536.4	5.28E-03	2.4	9
Cat 14H Grader	220	1	0.43	1.47	4.08	0.12	0.33	0.32	0.31								0.079	536.3	5.28E-03	3	9

Pollutant Emissions (lb/pad)

	CO	NO_x	SO_2	VOC	PM_{10}	$PM_{2.5}$	Benzene	Ethylbenzene	Formaldehyde	H_2S	n-Hexane	Toluene	Xylenes	CH_4	CO_2	N_2O
	4.7	4.2	0.1	1.0	0.7	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	444.0	0.0
Cat 430D Backhoe	11.3	35.0	1.1	2.7	2.2	2.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	4805.3	0.0
Cat D8R Dozer	22.6	70.6	2.2	5.4	4.5	4.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.4	9610.5	0.1
Cat 627F Scraper	8.3	23.0	0.7	1.9	1.8	1.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	3019.9	0.0
Cat 14H Grader																
Total Heavy Equipment Tailpipe Emissions	46.9	132.8	4.0	10.9	9.3	9.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.6	17879.6	0.2

[1] Taken from "Median Life Annual Activity, and Load Factor Values for Nonroad Engine Emissions Modeling, Table 9, 7-cycle average (7/2010)

[2] Emission factors from NONROADS 2008, run for 2009.
Fuel Oxygen 2.440 wt%;Dsl Sulfur 0.0351 %

[3] CO_2 = 10.15 kg CO2 / gal diesel fuel. CO2 value provided in NOANROADs 2008 run for 2009. NO2 and CHR are not. CH4=0.0015 kg/gal diesel fuel, NO2 = 0.001 kg/gal diesel fuel
Factor for CH4 = 0.0015/10.15, factor for NO2 = 0.0001/10.15

NPL Project General Conformity Emissions Inventory

Table 14. Pipeline Heavy Equipment Tailpipe

Project: NPL
Scenario: 4 Pad/Section
Activity: Pipeline Construction
Emissions: Diesel Combustion Emissions from Heavy Equipment Tailpipes

Heavy Equipment	Engine Horsepower (hp)	Number Required	Operating Load Factor[1]	Pollutant Emission Factor[2] (g/hp-hr)																Construction Activity Duration	
				CO	NO_x	SO_2	VOC	PM_{10}	$PM_{2.5}$	Benzene	Ethylbenzene	Formaldehyde	H_2S	n-Hexane	Toluene	Xylenes	CH_4[3]	CO_2	N_2O[3]	(days/mile)	(hrs/day)
Sideboom	240	3	0.43	1.06	4.6	0.11	0.35	0.25	0.25								0.078	530.5	5.23E-03	10	10
Trencher	215	1	0.43	1.57	4.61	0.12	0.35	0.3	0.29								0.079	536.3	5.28E-03	10	10
Track Hoe	150	3	0.43	7.77	6.69	0.15	1.59	1.19	1.16								0.102	691.9	6.82E-03	10	10
Dozer	125	1	0.43	3.92	4.69	0.13	0.47	0.54	0.52								0.088	595.3	5.87E-03	10	10
Grader	185	1	0.43	1.47	4.08	0.12	0.33	0.32	0.31								0.079	536.3	5.28E-03	10	10

Pollutant Emissions (lb/pad) << these are per mile when summing multiply by miles/pad

	CO	NO_x	SO_2	VOC	PM_{10}	$PM_{2.5}$	Benzene	Ethylbenzene	Formaldehyde	H_2S	n-Hexane	Toluene	Xylenes	CH_4	CO_2	N_2O	
Sideboom	72.3	314.0	7.5	23.9	17.1	17.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.4	36208.7	0.4	appears to be per mile
Trencher	32.0	94.0	2.4	7.1	6.1	5.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.6	10930.5	0.1	
Track Hoe	331.5	285.4	6.4	67.8	50.8	49.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.4	29515.6	0.3	
Dozer	46.5	55.6	1.5	5.6	6.4	6.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	7054.1	0.1	
Grader	25.8	71.6	2.1	5.8	5.6	5.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.4	9405.3	0.1	
Total Emissions from Heavy Equipment Tailpipes	508	820	20	110	86	84	0	0	0	0	0	0	0	14	93114	1	

[1] Taken from "Median Life Annual Activity, and Load Factor Values for Nonroad Engine Emissions Modeling, Table 9, 7-cycle average (7/2010)

[2] Emission factors from NONROADS 2008, run for 2009.
Fuel Oxygen 2.440 wt%;Dsl Sulfur 0.0351 %

[3] CO_2 = 10.15 kg CO2 / gal diesel fuel. CO2 value provided in NOANROADs 2008 run for 2009. NO2 and CHR are not. CH4=0.0015 kg/gal diesel fuel, NO2 = 0.001 kg/gal diesel fuel
Factor for CH4 = 0.0015/10.15, factor for NO2 = 0.0001/10.15

NPL Project General Conformity Emissions Inventory

Table 15. Compressor Station Construction - Heavy Equipment Tailpipe

Project: NPL
Scenario: 4 Pad/Section
Activity: Compressor Station Construction Heavy Equip.
Emissions: Diesel Combustion Emissions from Heavy Equipment Tailpipes

Heavy Equipment	Engine Horsepower (hp)	Number Required	Operating Load Factor[1]	Pollutant Emission Factor[2] (g/hp-hr) CO	NO_x	SO_2	VOC	PM_{10}	$PM_{2.5}$	Benzene	Ethylbenzene	Formaldehyde	H_2S	n-Hexane	Toluene	Xylenes	CH_4[3]	CO_2	N_2O[3]	Construction Activity Duration (days/pad)	(hrs/day)
Cat 430D Backhoe	94	1	0.43	7.36	6.61	0.15	1.59	1.14	1.1								0.102	692	6.82E-03	1.5	8
Cat D8R Dozer	350	1	0.43	1.26	3.91	0.12	0.3	0.25	0.24								0.079	536.4	5.28E-03	5	9
Cat 627F Scraper	350	2.5	0.43	1.26	3.94	0.12	0.3	0.25	0.25								0.079	536.4	5.28E-03	4	9
Cat 14H Grader	220	1	0.43	1.47	4.08	0.12	0.33	0.32	0.31								0.079	536.3	5.28E-03	5	9

Pollutant Emissions (lb/pad)

	CO	NO_x	SO_2	VOC	PM_{10}	$PM_{2.5}$	Benzene	Ethylbenzene	Formaldehyde	H_2S	n-Hexane	Toluene	Xylenes	CH_4	CO_2	N_2O
Cat 430D Backhoe	7.9	7.1	0.2	1.7	1.2	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	740.0	0.0
Cat D8R Dozer	18.8	58.4	1.8	4.5	3.7	3.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	8008.8	0.1
Cat 627F Scraper	37.6	117.7	3.6	9.0	7.5	7.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.4	16017.5	0.2
Cat 14H Grader	13.8	38.3	1.1	3.1	3.0	2.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	5033.1	0.0
Total Heavy Equipment Tailpipe Emissions	78.1	221.4	6.7	18.2	15.4	15.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.4	29799.3	0.3

[1] Taken from "Median Life Annual Activity, and Load Factor Values for Nonroad Engine Emissions Modeling, Table 9, 7-cycle average (7/2010)

[2] Emission factors from NONROADS 2008, run for 2009.
Fuel Oxygen 2.440 wt%;Dsl Sulfur 0.0351 %

[3] CO_2 = 10.15 kg CO2 / gal diesel fuel. CO2 value provided in NOANROADs 2008 run for 2009. NO2 and CHR are not. CH4=0.0015 kg/gal diesel fuel, NO2 = 0.001 kg/gal diesel fuel
Factor for CH4 = 0.0015/10.15, factor for NO2 = 0.0001/10.15

Table 16. Drilling Traffic

Project: NPL
Scenario: 4 Pad/Section
Activity: Drilling
Emissions: Fugitive Particulate Emissions from Traffic on Unpaved Roads

Vehicle Type	Road Type	Dust Control Method[1]	Average Vehicle Weight	Average Vehicle Speed	Silt Content[2]	Moisture Content[3]	Vehicle Count	RTs per Well	RT Distance	VMT [4]	Emission Control Efficiency[5]	PM_{10} Emission Factor[6]	$PM_{2.5}$ Emission Factor[6]	PM_{10} Emissions[6] (controlled)	$PM_{2.5}$ Emissions[6] (controlled)
			(lb)	(mph)	(%)	(%)			(miles)	(VMT/Well)	(%)	(lb/VMT)	(lb/VMT)	(lb/pad)	(lb/pad)
Light truck/pick-ups	Local Road	Chemical + Restriction	5,800	25	5.1	2.4	1	40	6	240	85	0.51	0.05	293.66	29.19
	Resource Road	Water + Restriction	5,800	20	5.1	2.4	1	40	10	400	50	0.68	0.07	2,188.60	218.86
Tandem Tractor Drilling muds	Local Road	Chemical + Restriction	60,000	20	5.1	2.4	1	2	34	68	85	0.46	0.05	74.41	7.39
	Resource Road	Water + Restriction	60,000	15	5.1	2.4	1	2	10	20	50	1.96	0.20	313.16	31.32
Tandem Tractor Fresh Water	Local Road	Chemical + Restriction	60,000	20	5.1	2.4	1	15	8	120	85	0.46	0.05	131.31	13.04
	Resource Road	Water + Restriction	60,000	15	5.1	2.4	1	15	10	150	50	1.96	0.20	2,348.67	234.87
Tandem Tractor Processed Water	Local Road	Chemical + Restriction	60,000	20	5.1	2.4	1	50	10	500	85	0.46	0.05	547.14	54.34
	Resource Road	Water + Restriction	60,000	15	5.1	2.4	1	50	10	500	50	1.96	0.20	7,828.91	782.89
Tandem Tractor Casing	Local Road	Chemical + Restriction	60,000	20	5.1	2.4	1	2	34	68	85	0.46	0.05	74.41	7.39
	Resource Road	Water + Restriction	60,000	15	5.1	2.4	1	2	10	20	50	1.96	0.20	313.16	31.32
Tandem Tractor Cement	Local Road	Chemical + Restriction	60,000	20	5.1	2.4	1	2	34	68	85	0.46	0.05	74.41	7.39
	Resource Road	Water + Restriction	60,000	15	5.1	2.4	1	2	10	20	50	1.96	0.20	313.16	31.32
Light Duty Misc	Local Road	Chemical + Restriction	5,000	20	5.1	2.4	1	20	34	680	85	0.46	0.05	744.12	73.90
	Resource Road	Water + Restriction	5,000	15	5.1	2.4	1	20	10	200	50	0.64	0.06	1,023.60	102.36
Company Man	Local Road	Chemical + Restriction	5,800	25	5.1	2.4	1	10	6	60	85	0.51	0.05	73.42	7.30
	Resource Road	Water + Restriction	5,800	20	5.1	2.4	1	10	10	100	50	0.68	0.07	547.15	54.71
Total Unpaved Road Traffic Emissions (lb/pad)														16,889.28	1,687.57

[1] Dust control methods include using water (resource road) or chemical (loacal road) as a dust suppressants along with vehicle restriction speed limit of 25 mph.

[2] AP-42 (EPA 2004), Table 13.2.2-1, "Typical Silt Content Values of Surface Material on Industrial and Rural Unpaved Roads."

[3] AP-42 (EPA 2004), Table 11.9-3, "Typical Values for Correction Factors Applicable to the Predictive Emission Factor Equations."

[4] Calculated as Round Trips per Vehicle Type x Round Trip Distance.

[5] AP-42 (EPA 2004), Figure 13.2.2-2, "Watering control effectiveness for unpaved travel surfaces.", Fugitive Dust Handbook (WRAP 2006) Chapter 6.

[6] AP-42 (EPA 2004), Section 13.2.2 "Unpaved Roads", equations 1a and 1b.

[7] Calculated as lb/VMT x VMT/pad x control efficiency.

NPL Project General Conformity Emissions Inventory

Table 17. Rig Move Traffic

Project: NPL
Scenario: 4 Pad/Section
Activity: Rig Move
Emissions: Fugitive Particulate Emissions from Traffic on Unpaved Roads

Vehicle Type	Road Type	Dust Control Method[1]	Average Vehicle Weight (lb)	Average Vehicle Speed (mph)	Silt Content[2] (%)	Moisture Content[3] (%)	Vehicle Count	RTs per Pad	RT Distance (miles)	VMT [4] (VMT/pad)	Emission Control Efficiency[5] (%)	PM_{10} Emission Factor[6] (lb/VMT)	$PM_{2.5}$ Emission Factor[6] (lb/VMT)	PM_{10} Emissions[7] (controlled) (lb/pad)	$PM_{2.5}$ Emissions[7] (controlled) (lb/pad)	
Rig Haul Trucks	Local Road	Chemical + Restriction	80,000	25	5.1	2.4	10	3	6	180	85	0.51	0.05	13.77	1.37	1b
	Resource Road	Water + Restriction	80,000	20	5.1	2.4	10	3	14	420	50	2.23	0.22	467.82	46.78	1a
Light Trucks	Local Road	Chemical + Restriction	5,800	25	5.1	2.4	2	3	6	36	85	0.51	0.05	2.75	0.27	1b
	Resource Road	Water + Restriction	5,800	20	5.1	2.4	2	3	14	84	50	0.68	0.10	28.73	4.40	1a
											Total Unpaved Road Traffic Emissions (lb/pad)			513.07	52.83	

[1] Dust control methods include using water (resource road) or chemical (loacal road) as a dust suppressants along with vehicle restriction speed limit of 25 mph.

[2] AP-42 (EPA 2004), Table 13.2.2-1, "Typical Silt Content Values of Surface Material on Industrial and Rural Unpaved Roads."

[3] AP-42 (EPA 2004), Table 11.9-3, "Typical Values for Correction Factors Applicable to the Predictive Emission Factor Equations."

[4] Calculated as Round Trips per Vehicle Type x Round Trip Distance.

[5] AP-42 (EPA 2004), Figure 13.2.2-2, "Watering control effectiveness for unpaved travel surfaces.", Fugitive Dust Handbook (WRAP 2006) Chapter 6.

[6] AP-42 (EPA 2004), Section 13.2.2 "Unpaved Roads", equations 1a and 1b.

[7] Calculated as lb/VMT x VMT/well x control efficiency.

Table 18. Drilling Haul Truck Tailpipe

Project: NPL
Scenario: 4 Pad/Section
Activity: Drilling Traffic
Emissions: Diesel Combustion Emissions from Heavy Equipment Tailpipes

Vehicle Type	Pollutant	Pollutant Emission Factor[1] (g/mile)	Total Haul Truck RTs (RTs/well)	RT Distance Avg. (miles/RT)	Truck Miles Traveled (miles/well)	Haul Activity Duration[3] (days/well)	Haul Activity Duration (hours/day)	Emissions (lb/pad)
Heavy Duty	CO	1.25	71	22	1,534	17	24	67
	NO_x	3.18	71	22	1,534	17	24	172
	PM_{10}	0.21	71	22	1,534	17	24	11
	$PM_{2.5}$	0.17	71	22	1,534	17	24	9
	SO_2	0.01	71	22	1,534	17	24	0
	VOC	0.32	71	22	1,534	17	24	17
	Benzene	3.45E-03	71	22	1,534	17	24	0
	Ethylbenzene		71	22	1,534	17	24	0
	Formaldehyde	2.57E-02	71	22	1,534	17	24	1
	H_2S		71	22	1,534	17	24	0
	n-Hexane		71	22	1,534	17	24	0
	Toluene		71	22	1,534	17	24	0
	Xylenes		71	22	1,534	17	24	0
	CH_4	3.73E-02	71	22	1,534	17	24	2
	CO_2[2]	854.68	71	22	1,534	17	24	46246
	N_2O	1.88E-03	71	22	1,534	17	24	0

[1] MOVES, 2013 heavy duty short haul truck
[2] CO2 from CO2(eq) {CO2(eq)-21*CH4-320*N20}
[3] Based on average spud to release date for Jonah wells.

NPL Project General Conformity Emissions Inventory

Table 19. Rig Move Haul Truck Tailpipe

Project: NPL
Scenario: 4 Pad/Section
Activity: Rig Move
Emissions: Diesel Combustion Emissions from Haul Truck Tailpipes

Pollutant	Pollutant Emission Factor[1]	Total Haul Truck RTs	RT Distance	Total Haul Truck Miles Traveled	Haul Activity Duration	Haul Activity Duration	Emissions
	(g/mile)	(RTs/pad)	(miles/RT)	(miles/pad)	(days/move)	(hours/day)	(lb/pad)
CO	1.25	3	20	600	3	24	1.65
NO_x	3.18	3	20	600	3	24	4.20
PM_{10}	0.21	3	20	600	3	24	0.28
$PM_{2.5}$	0.17	3	20	600	3	24	0.22
SO_2[2]	0.01	3	20	600	3	24	0.01
VOC	0.32	3	20	600	3	24	0.42
Benzene	3.45E-03	3	20	600	3	24	4.56E-03
Ethylbenzene		3	20	600	3	24	0.00
Formaldehyde	2.57E-02	3	20	600	3	24	3.40E-02
H_2S		3	20	600	3	24	0.00
n-Hexane		3	20	600	3	24	0.00
Toluene		3	20	600	3	24	0.00
Xylenes		3	20	600	3	24	0.00
CH_4	3.73E-02	3	20	600	3	24	4.94E-02
CO_2[2]	854.68	3	20	600	3	24	1130.53
N_2O	1.88E-03	3	20	600	3	24	2.49E-03

[1] MOVES, 2013 heavy duty short haul truck

[2] CO2 from CO2(eq) {CO2(eq)-21*CH4-320*N20}

NPL Project General Conformity Emissions Inventory

Table 20. Material Balance

Gas Composition

	MW (g/mol)	Carbons	mol %	mol%*MW	Wt %	C%	Wt-C
Carbon Dioxide	44	1	0.54	23.61	1.28	27.27	34.95
Hydrogen Sulfide		0	0	0.00	0		
Nitrogen		0	0.21	0.00	0		
Methane	16.04	1	89.82	1440.67	78.19	74.81	5849.30
Ethane	30.07	2	5.59	167.97	9.12	79.81	727.57
Propane	44.09	3	2.14	94.45	5.13	81.65	418.51
Isobutane	58.12	4	0.518	30.09	1.63	82.59	134.86
n-Butane	58.12	4	0.520	30.23	1.64	82.59	135.50
Isopentane	72.15	5	0.204	14.73	0.80	83.16	66.48
n-Pentane	72.15	5	0.144	10.38	0.56	83.16	46.87
Cyclopentane	70.13	5	0	0.00	0	85.56	0
n-hexane	86.18	6	0.049	4.24	0.23	83.55	19.22
Cyclohexane	84.16	6	0.028	2.36	0.13	85.55	10.97
Other Hexanes	86.18	6	0.085	7.35	0.40	83.55	33.34
Heptanes	100.21	7	0.063	6.34	0.34	83.82	28.84
Methylcyclohexane	98.19	7	0.037	3.62	0.20	85.55	16.81
2,2,4-Trimethylpentane	114.23	8	0.005	0.53	0.029	84.04	2.43
Benzene	78.11	6	0.012	0.94	0.051	92.18	4.71
Toluene	92.14	7	0.015	1.39	0.076	91.17	6.90
Ethylbenzene	106.17	8	0.001	0.057	0.003	90.42	0.28
Xylenes	106.17	8	0.005	0.517	0.028	90.42	2.54
C8+Heavies	128.26	9	0.024	3.134	0.17	84.20	14.32
Total			***100.00***	***1842.63***	***100.00***	***1635.05***	***7554.40***
					11.42		

MW Fuel	18.43	lb fuel/lb-mol fuel
Wt% Fuel	98.72	fuel
Wt% C	0.77	lb C/lb fuel
CO_2 Factor	6.18E-05	tonne/scf
	122.25	lb/MMbtu
	0.14	lb/scf

Dehy - Post condenser gas composition

	MW (g/mol)	Carbons	mol %	mol%*MW	Wt %	C%	Wt-C
H2O		0	18.6	0.00	0.00		
Oxygen		0	0	0.00	0.00		
CO2	44	1	4.63	203.72	5.18	27.27	141.40
N2		0	0.0671	0.00	0.00		
Methane	16.04	1	31.1	498.84	12.70	74.81	949.79
Ethane	30.07	2	7.42	223.12	5.68	79.81	453.21
Propane	44.09	3	7.95	350.52	8.92	81.65	728.38

MW Fuel	39.29	lb fuel/lb-mol fuel
Wt% Fuel	100.00	fuel
Wt% C	0.79	lb C/lb fuel
CO_2 Factor	1.36E-04	tonne/scf
	144.98	lb/MMbtu
	0.30	lb/scf

Isobutane	58.12	4	3.02	175.52	4.47	82.59	368.92
n-Butane	58.12	4	4.26	247.59	6.30	82.59	520.40
Isopentane	72.15	5	1.35	97.40	2.48	83.16	206.15
n-Pentane	72.15	5	1.15	82.97	2.11	83.16	175.61
Hexane+	100.21	7	20.4529	2049.59	52.16	83.82	4372.42
Total			***100.00***	***3929.27***	***100.00***	***678.87***	***7916.28***

Dehy - Flash tank off gas composition

	MW (g/mol)	Carbons	mol %	mol%*MW	Wt %	C%	Wt-C
H2O		0	1.07	0.00	0.00		
Oxygen		0	0	0.00	0.00		
CO2	44	1	1.21	53.24	2.52	27.27	68.64
N2		0	0.189	0.00	0.00		
Methane	16.04	1	81.7	1310.47	61.95	74.81	4634.92
Ethane	30.07	2	6.59	198.16	9.37	79.81	747.71
Propane	44.09	3	3.39	149.47	7.07	81.65	576.95
I-Butane	58.12	4	1.05	61.03	2.89	82.59	238.27
N-Butane	58.12	4	2.6	151.11	7.14	82.59	590.00
I-Pentane	72.15	5	0.561	40.48	1.91	83.16	159.13
N-Pentane	72.15	5	0.465	33.55	1.59	83.16	131.90
Hexane+	100.21	7	1.175	117.75	5.57	83.82	466.61
Total			***100.00***	***2115.25***	***100.00***	***678.87***	***7614.15***

MW Fuel	21.15	lb fuel/lb-mol fuel
Wt% Fuel	100.00	fuel
Wt% C	0.76	lb C/lb fuel
CO_2 Factor	7.06E-05	tonne/scf
	124.56	lb/MMbtu
	0.16	lb/scf

Condensate Composition

	MW (g/mol)	Carbons	mol %	mol%*MW	Wt %	C%	Wt-C
Methane	16.04	1	5.19	83.24	0.81	74.81	60.36
Ethane	30.07	2	2.65	79.73	0.77	79.81	61.68
Propane	44.09	3	3.67	161.90	1.57	81.65	128.14
i-Butane	58.12	4	2.18	126.47	1.23	82.59	101.25
n-Butane	58.12	4	3.15	183.06	1.77	82.59	146.56
neoPentane	72.15	5	0.07	5.01	0.05	83.16	4.04
i-Pentane	72.15	5	2.84	204.77	1.99	83.16	165.08
n-Pentane	72.15	5	2.79	201.15	1.95	83.16	162.16
2,2-DMB	86.18	6	0.16	13.82	0.13	83.55	11.19
2,3-DMB	86.18	6	0.61	52.98	0.51	83.55	42.91
2-MP	86.18	6	1.90	163.43	1.58	83.55	132.36
3-MP	86.18	6	1.06	91.21	0.88	83.55	73.87

MW Fuel	103.16	lb fuel/lb-mol fuel
Wt% Fuel	14.80	fuel
Wt% C	0.82	lb C/lb fuel
CO_2 Factor	3.73E-04	tonne/scf
	657.18	lb/MMbtu
	0.82	lb/scf

n-Hexane	86.18	6	1.86	159.94	1.55	83.55	129.53
Heptane	100.21	7	16.91	1694.30	16.42	83.82	1376.76
Octanes	114.23	8	7.39	844.06	8.18	84.04	687.65
Nonanes	128.26	9	12.85	1648.13	15.98	84.20	1345.32
Decanes+	156.31	11	20.29	3171.74	30.75	84.45	2596.47
N2		0	0.00	0.00	0.00		
CO2	44	1	0.09	3.81	0.04	27.27	1.01
Benzene	78.11	6	1.15	89.90	0.87	92.18	80.33
Toluene	92.14	7	5.59	515.09	4.99	91.17	455.21
E-Benzene	106.17	8	0.66	70.35	0.68	90.42	61.67
m&p Xylenes	106.17	8	5.22	554.67	5.38	90.42	486.19
o Xylene	106.17	8	1.00	106.06	1.03	90.42	92.96
2,2,4-TMP	114.23	8	0.80	90.91	0.88	84.04	74.06
Total			***100.07***	***10315.74***	***100.00***	***1971.10***	***8476.78***
					98.42		

Condensate Storage Tank - Flash gas composition

	MW (g/mol)	Carbons	mol %	mol%*MW	Wt %	C%	Wt-C
CO2	44	1	0.77	33.88	1.10	27.27	29.96
Methane	16.04	1	48.32	775.05	25.13	74.81	1879.96
Ethane	30.07	2	20.10	604.41	19.60	79.81	1564.04
Propane	44.09	3	16.19	713.82	23.14	81.65	1889.69
Isobutane	58.12	4	4.80	278.98	9.04	82.59	747.00
n-Butane	58.12	4	4.97	288.86	9.37	82.59	773.46
Isopentane	72.15	5	1.64	118.33	3.84	83.16	319.03
n-Pentane	72.15	5	1.25	90.19	2.92	83.16	243.17
n-Hexane	86.18	6	0.22	18.96	0.61	83.55	51.36
other Hexanes	86.18	6	0.76	65.50	2.12	83.55	177.41
Heptanes	100.21	7	0.54	54.11	1.75	83.82	147.07
Benzene	78.11	6	0.12	9.37	0.30	92.18	28.01
Toluene	92.14	7	0.16	14.74	0.48	91.17	43.58
Ethylbenzene	106.17	8	0.01	1.06	0.03	90.42	3.11
Xylenes	106.17	8	0.04	4.25	0.14	90.42	12.45
C8+ Heavies	128.26	9	0.10	12.83	0.42	84.20	35.02
Total			***99.99***	***3084.32***	***100.00***	***1294.35***	***7944.30***
					54.18		

MW Fuel	30.84	lb fuel/lb-mol fuel
Wt% Fuel	98.90	fuel
Wt% C	0.80	lb C/lb fuel
CO_2 Factor	1.09E-04	tonne/scf
	134.55	lb/MMbtu
	0.24	lb/scf

NPL Project General Conformity Emissions Inventory

Table 21. Drill Rigs

Project: NPL
Scenario: 4 Pad/Section
Effective Dates: 2009
Emissions: Combustion Emissions from Drilling Engines

Engine	Pollutant	EPA Tier Certification	Pollutant Emission Factor	Emission Factor Reference	Fuel Heating Value[2]	Fuel Consumption Rate[3]	Drilling Activity Duration	Drilling Activity Duration	Emissions	Emissions per Well	Emissions per Pad
			(lb/MMbtu)		(btu/scf) or (btu/gal)	(mcf/hr) or (gal/hr)	(days/well)	(hours/day)	(lb/hr)	(lb)	(tons)
Cat 3516G	CO	Tier 3+	1.04	1	1115	10.11	10.5	24	11.77	2,965.70	23.73
(Main)	NOx	Tier 3+	0.44	1	1115	10.11	10.5	24	5.01	1,261.27	10.09
	SO_2	Tier 3+	5.88E-05	6	1115	10.11	10.5	24	0.00	0.17	0.00
	VOC	Tier 3+	0.05	1	1115	10.11	10.5	24	0.51	127.83	1.02
	PM_{10}	Tier 3+	0.01	1	1115	10.11	10.5	24	0.07	17.04	0.14
	$PM_{2.5}$		7.71E-05	4	1115	10.11	10.5	24	0.00	0.22	0.00
	Benzene		4.40E-04	4	1115	10.11	10.5	24	0.00	1.25	0.01
	Ethylbenzene		3.97E-05	4	1115	10.11	10.5	24	0.00	0.11	0.00
	Formaldehyde		0.07	1	1115	10.11	10.5	24	0.79	198.85	1.59
	H_2S		0.00E+00	6	1115	10.11	10.5	24	0.00	0.00	0.00
	n-Hexane		1.11E-03	4	1115	10.11	10.5	24	0.01	3.15	0.03
	Toluene		4.08E-04	4	1115	10.11	10.5	24	0.00	1.16	0.01
	Xylenes		1.84E-04	4	1115	10.11	10.5	24	0.00	0.52	0.00
	CH_4		1.52	7	1115	10.11	10.5	24	17.12	4,315.04	34.52
	CO_2		122.25	8	1115	10.11	10.5	24	1378.08	347,277	2,778.21
	N_2O		2.28E-04	9	1115	10.11	10.5	24	0.00	0.65	0.01
	Acetaldehyde		3.31E-03	11	1115	10.11	10.5	24	3.73E-02	9.40	0.08
	Acrolein		2.03E-03	11	1115	10.11	10.5	24	2.29E-02	5.77	0.05
	Methanol		9.89E-04	11	1115	10.11	10.5	24	1.11E-02	2.81	0.02
Cat C27/	CO	Tier 1+	0.34	1	137030	4.29	10.5	24	0.20	50.37	0.40
Det R1237M36	NOx	Tier 1+	1.78	1	137030	4.29	10.5	24	1.04	262.95	2.10
(Cold Start)	SO_2	Tier 1+	6.30E-02	1	137030	4.29	10.5	24	0.04	9.33	0.07
	VOC	Tier 1+	0.32	1	137030	4.29	10.5	24	0.19	46.66	0.37
	PM_{10}	Tier 1+	0.09	1	137030	4.29	10.5	24	0.05	13.33	0.11
	$PM_{2.5}$		0.09		137030	4.29	10.5	24	0.05	13.33	0.11
	Benzene		9.33E-04	5	137030	4.29	10.5	24	0.00	0.14	0.00
	Ethylbenzene				137030	4.29	10.5	24	0.00	0.00	0.00
	Formaldehyde		1.18E-03	5	137030	4.29	10.5	24	0.00	0.17	0.00
	H_2S				137030	4.29	10.5	24	0.00	0.00	0.00
	n-Hexane				137030	4.29	10.5	24	0.00	0.00	0.00
	Toluene		4.09E-04	5	137030	4.29	10.5	24	0.00	0.06	0.00
	Xylenes		2.85E-04	5	137030	4.29	10.5	24	0.00	0.04	0.00
	CH_4		1.60E-04	7	137030	4.29	10.5	24	0.00	0.02	0.00
	CO_2		164	10	137030	4.29	10.5	24	96.41	24,295.02	194.36
	N_2O		1.32E-03	9	137030	4.29	10.5	24	0.00	0.20	0.00
	Acetaldehyde		7.67E-04	11	137030	4.29	10.5	24	4.51E-04	0.11	0.00
	Acrolein		9.25E-05	11	137030	4.29	10.5	24	5.44E-05	0.01	0.00
	Methanol		0.00	11	137030	4.29	10.5	24	0.00E+00	0.00	0.00
William & Davis	CO	Tier 3+	0.08	1	1115	0.43	10.5	24	0.04	9.91	0.08
(Boiler)	NOx	Tier 3+	0.10	1	1115	0.43	10.5	24	0.05	11.84	0.09
	SO_2	Tier 3+	0.00	6	1115	0.43	10.5	24	0.00	0.07	0.00
	VOC	Tier 3+	0.01	1	1115	0.43	10.5	24	0.00	0.65	0.01
	PM_{10}	Tier 3+	7.50E-03	1	1115	0.43	10.5	24	0.00	0.91	0.01

	$PM_{2.5}$	7.71E-05	4	1115	0.43	10.5	24	0.00	0.01	0.00
	Benzene	4.40E-04	4	1115	0.43	10.5	24	0.00	0.05	0.00
	Ethylbenzene	3.97E-05	4	1115	0.43	10.5	24	0.00	0.00	0.00
	Formaldehyde	0.07	1	1115	0.43	10.5	24	0.03	8.46	0.07
	H_2S	0.00E+00	6	1115	0.43	10.5	24	0.00	0.00	0.00
	n-Hexane	1.11E-03	4	1115	0.43	10.5	24	0.00	0.13	0.00
	Toluene	4.08E-04	4	1115	0.43	10.5	24	0.00	0.05	0.00
	Xylenes	1.84E-04	4	1115	0.43	10.5	24	0.00	0.02	0.00
	CH_4	2.30E-03	7	1115	0.43	10.5	24	0.00	0.28	0.00
	CO_2	117.60	8	1115	0.43	10.5	24	56.38	14,209	113.67
	N_2O	2.16E-03	9	1115	0.43	10.5	24	0.00	0.26	0.00
	Acetaldehyde	8.36E-03	11	1115	0.43	10.5	24	0.00	1	0.01
	Acrolein	5.14E-03	11	1115	0.43	10.5	24	0.00	0.62	0.00
	Methanol	2.50E-03	11	1115	0.43	10.5	24	0.00	0	0.00
Total	CO						CO	12.01	3025.97	24.21
	NOx						NOx	6.10	1536.06	12.29
	SO_2						SO_2	0.04	9.57	0.08
	VOC						VOC	0.70	175.15	1.40
	PM_{10}						PM_{10}	0.12	31.28	0.25
	$PM_{2.5}$						$PM_{2.5}$	0.05	13.56	0.11
	Benzene						Benzene	0.01	1.44	0.01
	Ethylbenzene						Ethylbenzene	0.00	0.12	0.00
	Formaldehyde						Formaldehyde	0.82	207.48	1.66
	H_2S						H_2S	0.00	0.00	0.00
	n-Hexane						n-Hexane	0.01	3.29	0.03
	Toluene						Toluene	0.01	1.27	0.01
	Xylenes						Xylenes	0.00	0.59	0.00
	CH_4						CH_4	17.12	4315.34	34.52
	CO_2						CO_2	1530.87	385,780	3086.24
	N_2O						N_2O	0.00	1.10	0.01
	Acetaldehyde						Acetaldehyde	0.04	10.53	0.08
	Acrolein						Acrolein	0.03	6.40	0.05
	Methanol						Methanol	0.01	3.11	0.02

[1] Encana Drill Rig Permit (WDEQ 2010) and fuel usage (averaged from 2008-2009 reports submitted to BLM).
[2] Fuel heating value of natural gas based on average of 2008-2009 analysis in Jonah Infill. Diesel heating value from API 2004 Greenhouse Compendium, Table 3-5.
[3] Fuel consumption rate based on average of actual usage during 2009-2010 in Jonah Infill.
[4] AP-42 (EPA 2004) "Natural Gas-fired Reciprocating Engines" Table 3.2-2.
[5] AP-42 (EPA 2004) Section 3.3 "Gasoline and Diesel Industrial Engines" Table 3.3-2. Emission factor in units of lb/MMbtu.
[6] All SO_2 emissions based on S-balance equation in Section 3.4 and 1200 ppm diesel fuel.
[7] Greenhouse Gas Compendium (API 2009) Table 4-9. Natural gas fired engines have adjusted for fuel heating value.
[8] Greenhouse Gas Compendium (API 2009) Section 4-3. See 'Material Balance' sheet for calculation.
[9] Greenhouse Gas Compendium (API 2009) Table 4-5.
[10] Greenhouse Gas Compendium (API 2009) Table 4-3.
[11] HAP EF originally provided by Encana

NPL Project General Conformity Emissions Inventory

Table 22. Frac/Other Completion Engine Emissions

Project: NPL
Scenario: 4 Pad/Section
Effective Dates: All
Emissions: Diesel Combustion Emissions from Frac/Other Completion Engines

Engine	Pollutant	EPA Tier Certification	Pollutant Emission Factor	Emission Factor Reference	Engine Count	Horsepower[1]	Overall Load Factor[2]	Activity Duration	Activity Duration	Emissions per Well	Emissions per Hour	Emissions per Pad
			(g/hp-hr)			(hp)		(days/well)	(hours/day)	(lb/well)	(lb/hr)	(tons)
Cat 5EN2368	CO	Tier 2	0.87	3	1	170	0.30	2	24	4.68	0.10	3.74E-02
	NOx	Tier 2	4.10	3	1	170	0.30	2	24	22.13	0.46	1.77E-01
	SO_2	Tier 2	0.20	3	1	170	0.30	2	24	1.08	0.02	8.64E-03
	VOC	Tier 2	0.34	3	1	170	0.30	2	24	1.83	0.04	1.46E-02
	PM_{10}	Tier 2	0.18	3	1	170	0.30	2	24	0.97	0.02	7.77E-03
	$PM_{2.5}$		0.18		1	170	0.30	2	24	0.97	0.02	7.77E-03
	Benzene		2.96E-03	4, 8	1	170	0.30	2	24	0.02	0.00	1.28E-04
	Ethylbenzene				1	170	0.30	2	24	0.00	0.00	0.00E+00
	Formaldehyde		3.75E-03	4, 8	1	170	0.30	2	24	0.02	0.00	1.62E-04
	H_2S				1	170	0.30	2	24	0.00	0.00	0.00E+00
	n-Hexane				1	170	0.30	2	24	0.00	0.00	0.00E+00
	Toluene		1.30E-03	4, 8	1	170	0.30	2	24	0.01	0.00	5.61E-05
	Xylenes		9.05E-04	4, 8	1	170	0.30	2	24	0.00	0.00	3.91E-05
	CH_4		5.08E-04	5, 8	1	170	0.30	2	24	0.00	0.00	2.19E-05
	CO_2		521	6, 8	1	170	0.30	2	24	2,810.37	58.55	2.25E+01
	N_2O		4.19E-03	7, 8	1	170	0.30	2	24	0.02	0.00	1.81E-04
	Acetaldehyde		2.44E-03	4,8	1	170	0.30	2	24	1.31E-02	2.74E-04	1.05E-04
	Acrolein		2.94E-04	4,8	1	170	0.30	2	24	1.59E-03	3.30E-05	1.27E-05
Cat BCX00314	CO	Tier 2	0.84	3	1	425	0.30	2	24	11.37	0.24	9.09E-02
	NOx	Tier 2	4.34	3	1	425	0.30	2	24	58.49	1.22	4.68E-01
	SO_2	Tier 2	0.20	3	1	425	0.30	2	24	2.70	0.06	2.16E-02
	VOC	Tier 2	0.17	3	1	425	0.30	2	24	2.25	0.05	1.80E-02
	PM_{10}	Tier 2	0.13	3	1	425	0.30	2	24	1.78	0.04	1.42E-02
	$PM_{2.5}$		0.13		1	425	0.30	2	24	1.78	0.04	1.42E-02
	Benzene		2.96E-03	4, 8	1	425	0.30	2	24	0.04	0.00	3.20E-04
	Ethylbenzene				1	425	0.30	2	24	0.00	0.00	0.00E+00
	Formaldehyde		3.75E-03	4, 8	1	425	0.30	2	24	0.05	0.00	4.04E-04
	H_2S				1	425	0.30	2	24	0.00	0.00	0.00E+00
	n-Hexane				1	425	0.30	2	24	0.00	0.00	0.00E+00
	Toluene		1.30E-03	4, 8	1	425	0.30	2	24	0.02	0.00	1.40E-04
	Xylenes		9.05E-04	4, 8	1	425	0.30	2	24	0.01	0.00	9.77E-05
	CH_4		5.08E-04	5, 8	1	425	0.30	2	24	0.01	0.00	5.48E-05
	CO_2		521	6, 8	1	425	0.30	2	24	7,025.91	146.37	5.62E+01
	N_2O		4.19E-03	7, 8	1	425	0.30	2	24	0.06	0.00	4.52E-04
	Acetaldehyde		2.44E-03	4,8	1	425	0.30	2	24	3.29E-02	6.85E-04	2.63E-04

	Acrolein		2.94E-04	4,8	1	425	0.30	2	24	3.96E-03	8.26E-05	3.17E-05
Cat 2AF00204	CO	Tier 2	0.76	3	2	2,250	0.30	2	24	109.17	2.27	8.73E-01
	NOx	Tier 2	4.10	3	2	2,250	0.30	2	24	585.73	12.20	4.69E+00
	SO_2	Tier 2	0.20	3	2	2,250	0.30	2	24	28.57	0.60	2.29E-01
	VOC	Tier 2	0.17	3	2	2,250	0.30	2	24	23.84	0.50	1.91E-01
	PM_{10}	Tier 2	0.13	3	2	2,250	0.30	2	24	18.80	0.39	1.50E-01
	$PM_{2.5}$		0.13		2	2,250	0.30	2	24	18.80	0.39	1.50E-01
	Benzene		2.96E-03	4, 8	2	2,250	0.30	2	24	0.42	0.01	3.39E-03
	Ethylbenzene				2	2,250	0.30	2	24	0.00	0.00	0.00E+00
	Formaldehyde		3.75E-03	4, 8	2	2,250	0.30	2	24	0.54	0.01	4.28E-03
	H_2S				2	2,250	0.30	2	24	0.00	0.00	0.00E+00
	n-Hexane				2	2,250	0.30	2	24	0.00	0.00	0.00E+00
	Toluene		1.30E-03	4, 8	2	2,250	0.30	2	24	0.19	0.00	1.48E-03
	Xylenes		9.05E-04	4, 8	2	2,250	0.30	2	24	0.13	0.00	1.03E-03
	CH_4		5.08E-04	5, 8	2	2,250	0.30	2	24	0.07	0.00	5.81E-04
	CO_2		521	6, 8	2	2,250	0.30	2	24	74,392.04	1,549.83	5.95E+02
	N_2O		4.19E-03	7, 8	2	2,250	0.30	2	24	0.60	0.01	4.79E-03
	Acetaldehyde		2.44E-03	4,8	2	2,250	0.30	2	24	3.48E-01	7.25E-03	2.78E-03
	Acrolein		2.94E-04	4,8	2	2,250	0.30	2	24	4.20E-02	8.74E-04	3.36E-04
DDC 12VF014134	CO	Tier 2	0.76	3	1	750	0.30	2	24	18.20	0.38	1.46E-01
	NOx	Tier 2	4.10	3	1	750	0.30	2	24	97.62	2.03	7.81E-01
	SO_2	Tier 2	0.20	3	1	750	0.30	2	24	4.76	0.10	3.81E-02
	VOC	Tier 2	0.17	3	1	750	0.30	2	24	3.97	0.08	3.18E-02
	PM_{10}	Tier 2	0.13	3	1	750	0.30	2	24	3.13	0.07	2.51E-02
	$PM_{2.5}$		0.13		1	750	0.30	2	24	3.13	0.07	2.51E-02
	Benzene		2.96E-03	4, 8	1	750	0.30	2	24	0.07	0.00	5.64E-04
	Ethylbenzene				1	750	0.30	2	24	0.00	0.00	0.00E+00
	Formaldehyde		3.75E-03	4, 8	1	750	0.30	2	24	0.09	0.00	7.14E-04
	H_2S				1	750	0.30	2	24	0.00	0.00	0.00E+00
	n-Hexane				1	750	0.30	2	24	0.00	0.00	0.00E+00
	Toluene		1.30E-03	4, 8	1	750	0.30	2	24	0.03	0.00	2.47E-04
	Xylenes		9.05E-04	4, 8	1	750	0.30	2	24	0.02	0.00	1.72E-04
	CH_4		5.08E-04	5, 8	1	750	0.30	2	24	0.01	0.00	9.68E-05
	CO_2		521	6, 8	1	750	0.30	2	24	12,398.67	258.31	9.92E+01
	N_2O		4.19E-03	7, 8	1	750	0.30	2	24	0.10	0.00	7.98E-04
	Acetaldehyde		2.44E-03	4,8	1	750	0.30	2	24	5.80E-02	1.21E-03	4.64E-04
	Acrolein		2.94E-04	4,8	1	750	0.30	2	24	6.99E-03	1.46E-04	5.59E-05
CUM 10723297	CO	Tier 2	0.84	3	1	600	0.30	2	24	16.05	0.33	1.28E-01
	NOx	Tier 2	4.34	3	1	600	0.30	2	24	82.58	1.72	6.61E-01
	SO_2	Tier 2	0.20	3	1	600	0.30	2	24	3.81	0.08	3.05E-02
	VOC	Tier 2	0.17	3	1	600	0.30	2	24	3.18	0.07	2.54E-02
	PM_{10}	Tier 2	0.13	3	1	600	0.30	2	24	2.51	0.05	2.01E-02
	$PM_{2.5}$		0.13		1	600	0.30	2	24	2.51	0.05	2.01E-02
	Benzene		2.96E-03	4, 8	1	600	0.30	2	24	0.06	0.00	4.51E-04
	Ethylbenzene				1	600	0.30	2	24	0.00	0.00	0.00E+00
	Formaldehyde		3.75E-03	4, 8	1	600	0.30	2	24	0.07	0.00	5.71E-04
	H_2S				1	600	0.30	2	24	0.00	0.00	0.00E+00
	n-Hexane				1	600	0.30	2	24	0.00	0.00	0.00E+00
	Toluene		1.30E-03	4, 8	1	600	0.30	2	24	0.02	0.00	1.98E-04
	Xylenes		9.05E-04	4, 8	1	600	0.30	2	24	0.02	0.00	1.38E-04
	CH_4		5.08E-04	5, 8	1	600	0.30	2	24	0.01	0.00	7.74E-05
	CO_2		521	6, 8	1	600	0.30	2	24	9,918.94	206.64	7.94E+01
	N_2O		4.19E-03	7, 8	1	600	0.30	2	24	0.08	0.00	6.39E-04

	Acetaldehyde		2.44E-03	4,8	1	600	0.30	2	24	4.64E-02	9.66E-04	3.71E-04
	Acrolein		2.94E-04	4,8	1	600	0.30	2	24	5.59E-03	1.17E-04	4.48E-05
Backhoe	CO	Tier 1	2.37	3	1	100	0.40	2	6	2.50	0.21	2.00E-02
	NOx	Tier 1	5.60	3	1	100	0.40	2	6	5.92	0.49	4.74E-02
	SO_2	Tier 1	0.20	3	1	100	0.40	2	6	0.21	0.02	1.69E-03
	VOC	Tier 1	0.52	3	1	100	0.40	2	6	0.55	0.05	4.41E-03
	PM_{10}	Tier 1	0.47	3	1	100	0.40	2	6	0.50	0.04	4.00E-03
	$PM_{2.5}$		0.47		1	100	0.40	2	6	0.50	0.04	4.00E-03
	Benzene		2.96E-03	4, 8	1	100	0.40	2	6	0.00	0.00	2.51E-05
	Ethylbenzene				1	100	0.40	2	6	0.00	0.00	0.00E+00
	Formaldehyde		3.75E-03	4, 8	1	100	0.40	2	6	0.00	0.00	3.17E-05
	H_2S				1	100	0.40	2	6	0.00	0.00	0.00E+00
	n-Hexane				1	100	0.40	2	6	0.00	0.00	0.00E+00
	Toluene		1.30E-03	4, 8	1	100	0.40	2	6	0.00	0.00	1.10E-05
	Xylenes		9.05E-04	4, 8	1	100	0.40	2	6	0.00	0.00	7.66E-06
	CH_4		5.08E-04	5, 8	1	100	0.40	2	6	0.00	0.00	4.30E-06
	CO_2		521	6, 8	1	100	0.40	2	6	551.05	45.92	4.41E+00
	N_2O		4.19E-03	7, 8	1	100	0.40	2	6	0.00	0.00	3.55E-05
	Acetaldehyde		2.44E-03	4,8	1	100	0.40	2	6	2.58E-03	2.15E-04	2.06E-05
	Acrolein		2.94E-04	4,8	1	100	0.40	2	6	3.11E-04	2.59E-05	2.49E-06
Bulldozer	CO	Tier 1	0.75	3	1	200	0.40	1.5	6	1.19	0.13	9.49E-03
	NOx	Tier 1	5.58	3	1	200	0.40	1.5	6	8.85	0.98	7.08E-02
	SO_2	Tier 1	0.20	3	1	200	0.40	1.5	6	0.32	0.04	2.54E-03
	VOC	Tier 1	0.31	3	1	200	0.40	1.5	6	0.49	0.05	3.92E-03
	PM_{10}	Tier 1	0.25	3	1	200	0.40	1.5	6	0.40	0.04	3.20E-03
	$PM_{2.5}$		0.25		1	200	0.40	1.5	6	0.40	0.04	3.20E-03
	Benzene		2.96E-03	4, 8	1	200	0.40	1.5	6	0.00	0.00	3.76E-05
	Ethylbenzene				1	200	0.40	1.5	6	0.00	0.00	0.00E+00
	Formaldehyde		3.75E-03	4, 8	1	200	0.40	1.5	6	0.01	0.00	4.76E-05
	H_2S				1	200	0.40	1.5	6	0.00	0.00	0.00E+00
	n-Hexane				1	200	0.40	1.5	6	0.00	0.00	0.00E+00
	Toluene		1.30E-03	4, 8	1	200	0.40	1.5	6	0.00	0.00	1.65E-05
	Xylenes		9.05E-04	4, 8	1	200	0.40	1.5	6	0.00	0.00	1.15E-05
	CH_4		5.08E-04	5, 8	1	200	0.40	1.5	6	0.00	0.00	6.45E-06
	CO_2		521	6, 8	1	200	0.40	1.5	6	826.58	91.84	6.61E+00
	N_2O		4.19E-03	7, 8	1	200	0.40	1.5	6	0.01	0.00	5.32E-05
	Acetaldehyde		2.44E-03	4,8	1	200	0.40	1.5	6	3.87E-03	4.30E-04	3.09E-05
	Acrolein		2.94E-04	4,8	1	200	0.40	1.5	6	4.66E-04	5.18E-05	3.73E-06
Wireline	CO	Tier 1	2.37	3	1	100	0.40	2.5	7.5	3.91	0.21	3.13E-02
	NOx	Tier 1	5.60	3	1	100	0.40	2.5	7.5	9.26	0.49	7.41E-02
	SO_2	Tier 1	0.20	3	1	100	0.40	2.5	7.5	0.33	0.02	2.65E-03
	VOC	Tier 1	0.52	3	1	100	0.40	2.5	7.5	0.86	0.05	6.90E-03
	PM_{10}	Tier 1	0.47	3	1	100	0.40	2.5	7.5	0.78	0.04	6.26E-03
	$PM_{2.5}$		0.47		1	100	0.40	2.5	7.5	0.78	0.04	6.26E-03
	Benzene		2.96E-03	4, 8	1	100	0.40	2.5	7.5	0.00	0.00	3.92E-05
	Ethylbenzene				1	100	0.40	2.5	7.5	0.00	0.00	0.00E+00
	Formaldehyde		3.75E-03	4, 8	1	100	0.40	2.5	7.5	0.01	0.00	4.96E-05
	H_2S				1	100	0.40	2.5	7.5	0.00	0.00	0.00E+00
	n-Hexane				1	100	0.40	2.5	7.5	0.00	0.00	0.00E+00
	Toluene		1.30E-03	4, 8	1	100	0.40	2.5	7.5	0.00	0.00	1.72E-05
	Xylenes		9.05E-04	4, 8	1	100	0.40	2.5	7.5	0.00	0.00	1.20E-05
	CH_4		5.08E-04	5, 8	1	100	0.40	2.5	7.5	0.00	0.00	6.72E-06
	CO_2		521	6, 8	1	100	0.40	2.5	7.5	861.02	45.92	6.89E+00

	N_2O		4.19E-03	7, 8	1	100	0.40	2.5	7.5	0.01	0.00	5.54E-05
	Acetaldehyde		2.44E-03	4,8	1	100	0.40	2.5	7.5	4.03E-03	2.15E-04	3.22E-05
	Acrolein		2.94E-04	4,8	1	100	0.40	2.5	7.5	4.86E-04	2.59E-05	3.89E-06
Crane	CO	Tier 1	1.53	3	1	30	0.40	2.5	1	0.10	0.04	8.11E-04
	NOx	Tier 1	4.73	3	1	30	0.40	2.5	1	0.31	0.13	2.50E-03
	SO_2	Tier 1	0.20	3	1	30	0.40	2.5	1	0.01	0.01	1.06E-04
	VOC	Tier 1	0.28	3	1	30	0.40	2.5	1	0.02	0.01	1.48E-04
	PM_{10}	Tier 1	0.34	3	1	30	0.40	2.5	1	0.02	0.01	1.79E-04
	$PM_{2.5}$		0.34		1	30	0.40	2.5	1	0.02	0.01	1.79E-04
	Benzene		2.96E-03	4, 8	1	30	0.40	2.5	1	0.00	0.00	1.57E-06
	Ethylbenzene				1	30	0.40	2.5	1	0.00	0.00	0.00E+00
	Formaldehyde		3.75E-03	4, 8	1	30	0.40	2.5	1	0.00	0.00	1.98E-06
	H_2S				1	30	0.40	2.5	1	0.00	0.00	0.00E+00
	n-Hexane				1	30	0.40	2.5	1	0.00	0.00	0.00E+00
	Toluene		1.30E-03	4, 8	1	30	0.40	2.5	1	0.00	0.00	6.87E-07
	Xylenes		9.05E-04	4, 8	1	30	0.40	2.5	1	0.00	0.00	4.79E-07
	CH_4		5.08E-04	5, 8	1	30	0.40	2.5	1	0.00	0.00	2.69E-07
	CO_2		521	6, 8	1	30	0.40	2.5	1	34.44	13.78	2.76E-01
	N_2O		4.19E-03	7, 8	1	30	0.40	2.5	1	0.00	0.00	2.22E-06
	Acetaldehyde		2.44E-03	4,8	1	30	0.40	2.5	1	1.61E-04	6.44E-05	1.29E-06
	Acrolein		2.94E-04	4,8	1	30	0.40	2.5	1	1.94E-05	7.77E-06	1.55E-07
Wellhead Heater	CO	Tier 1	2.37	3	5	170	0.40	2	6.5	23.05	1.77	1.84E-01
	NOx	Tier 1	5.60	3	5	170	0.40	2	6.5	54.56	4.20	4.36E-01
	SO_2	Tier 1	0.20	3	5	170	0.40	2	6.5	1.95	0.15	1.56E-02
	VOC	Tier 1	0.52	3	5	170	0.40	2	6.5	5.08	0.39	4.06E-02
	PM_{10}	Tier 1	0.47	3	5	170	0.40	2	6.5	4.61	0.35	3.69E-02
	$PM_{2.5}$		0.47		5	170	0.40	2	6.5	4.61	0.35	3.69E-02
	Benzene		2.96E-03	4, 8	5	170	0.40	2	6.5	0.03	0.00	2.31E-04
	Ethylbenzene				5	170	0.40	2	6.5	0.00	0.00	0.00E+00
	Formaldehyde		3.75E-03	4, 8	5	170	0.40	2	6.5	0.04	0.00	2.92E-04
	H_2S				5	170	0.40	2	6.5	0.00	0.00	0.00E+00
	n-Hexane				5	170	0.40	2	6.5	0.00	0.00	0.00E+00
	Toluene		1.30E-03	4, 8	5	170	0.40	2	6.5	0.01	0.00	1.01E-04
	Xylenes		9.05E-04	4, 8	5	170	0.40	2	6.5	0.01	0.00	7.05E-05
	CH_4		5.08E-04	5, 8	5	170	0.40	2	6.5	0.00	0.00	3.96E-05
	CO_2		521	6, 8	5	170	0.40	2	6.5	5,074.27	390.33	4.06E+01
	N_2O		4.19E-03	7, 8	5	170	0.40	2	6.5	0.04	0.00	3.27E-04
	Acetaldehyde		2.44E-03	4,8	5	170	0.40	2	6.5	2.37E-02	1.83E-03	1.90E-04
	Acrolein		2.94E-04	4,8	5	170	0.40	2	6.5	2.86E-03	2.20E-04	2.29E-05
Total	CO					6,445.00				190.22	5.68	1.52E+00
	NOx									925.45	23.93	7.40E+00
	SO_2									43.74	1.08	3.50E-01
	VOC									42.08	1.28	3.37E-01
	PM_{10}									33.50	1.06	2.68E-01
	$PM_{2.5}$									33.50	1.06	2.68E-01
	Benzene									0.65	0.02	5.18E-03
	Ethylbenzene									0.00	0.00	0.00E+00
	Formaldehyde									0.82	0.02	6.56E-03
	H_2S									0.00	0.00	0.00E+00
	n-Hexane									0.00	0.00	0.00E+00
	Toluene									0.28	0.01	2.27E-03
	Xylenes									0.20	0.00	1.58E-03

CH_4	0.11	0.00	8.89E-04
CO_2	113,893.29	2,807.50	9.11E+02
N_2O	0.92	0.02	7.33E-03
Acetaldehyde	5.33E-01	1.31E-02	4.26E-03
Acrolein	6.42E-02	1.58E-03	5.14E-04

[1] Horsepower based on current contractor equipment.
[2] Load factor based on weighted average of full load and idle conditions during frac operations.
[3] Emission factors from Exhaust and Crankcase Emission Factors for Nonroad Engine Modeling--Compression-Ignition, Table A-2; (EPA 420-P-04-009 April 2004).
[4] AP-42 (EPA 1996) Section 3.3 "Gasoline and Diesel Industrial Engines" Table 3.3-2.
[5] Greenhouse Gas Compendium (API 2009) Table 4-9.
[6] Greenhouse Gas Compendium (API 2009) Table 4-3.
[7] Greenhouse Gas Compendium (API 2009) Table 4-5.
[8] Emission factor converted from lb/Mmbtu to g/hp-hr assuming an average BSFC of 7,000 btu/hp-hr (AP-42 Table 3.3-1).

grams/lb	**453.6**	Acetaldehyde	7.67E-04 lb/MMBtu	2.44E-03 g/hp-hr
		Acrolein	< 9.25E-05 lb/MMBtu	2.94E-04 g/hp-hr

NPL Project General Conformity Emissions Inventory

Table 23. Well Completion Emissions

Project: **NPL**
Scenario: **4 Pad/Section**
Effective Dates: **All**
Emissions: **Well completion emissions**

Activity	Average Gas Volume[1]	Event Duration[2]	Wells	Pollutant	Weight Fraction[3]	Emission Factor[4]	Emissions per Well	Emissions per Pad
	(mcf/well)	(day/well)				(lb/MMbtu)	(lb/yr)	(tons/yr)
Completions	77	60	160	CO		0.37	2.56	0.02
				NOx		0.14	0.97	7.75E-03
				SO_2		0.00	0.00	0.00
Molecular Weight		18.43		VOC	0.11		8.54	0.07
Fuel Heating Value (actual)		1,124	Btu/scf	PM_{10}		0.007	4.85E-02	3.88E-04
Gas Volume to Flare[5]		8	%	$PM_{2.5}$		0.007	4.85E-02	3.88E-04
Gas Volume Vented[5]		2	%	Benzene	5.12E-04		3.83E-02	3.06E-04
				Ethylbenzene	3.07E-05		2.30E-03	1.84E-05
				Formaldehyde		8.10E-05	5.61E-04	4.49E-06
				H_2S	0.00		0.00	0.00
				n-Hexane	2.30E-03		1.72E-01	1.38E-03
				Toluene	7.57E-04		5.66E-02	4.53E-04
				Xylenes	2.80E-04		2.10E-02	1.68E-04
				CH_4	0.78		58.49	4.68E-01
				CO_2[6]	0.013	122.252	847.41	6.78
				N_2O[7]		1.04E-07	7.20E-07	5.76E-09

[1] Data from Jonah Infill well completions 2008-2010.
[2] Data from Jonah Infill well completions 2008-2010.
[3] Weight fraction based on gas composition. See 'Material Balance' sheet.
[4] Emission factors taken from WDEQ "Oil and Gas Production Facilities - Chapter 6, Section 2 Permitting Guidance" and AP-42, Table 1.4-2.
[5] Encana originally committed to capturing 90% of the hydrocarbons through flareless completions in the 2006 Infill ROD and proposes to continue this in the NPL.
[6] See 'Material Balance' sheet.
[7] Greenhouse Gas Compendium (API 2009) Table 4-5.

Table 24. Completion/Testing Traffic

Project: NPL
Scenario: 4 Pad/Section
Activity: Completion/Testing Traffic
Emissions: Fugitive Particulate Emissions from Traffic on Unpaved Roads

Vehicle Type	Road Type	Dust Control Method[1]	Average Vehicle Weight (lb)	Average Vehicle Speed (mph)	Silt Content[2] (%)	Moisture Content[3] (%)	RTs per Well	RT Distance (miles)	VMT[4] (VMT/well)	Emission Control Efficiency[5] (%)	PM_{10} Emissions[6] (lb/VMT)	$PM_{2.5}$ Emissions[6] (lb/VMT)	PM_{10} Emissions[7] (controlled) (lb/pad)	$PM_{2.5}$ Emissions[7] (controlled) (lb/pad)	
Light Trucks/ Pickups	Local	Chemical + Restriction	5,800	25	5.1	2.4	60	10	600	85	0.51	0.05	734	73	1b
	Resource	Water + Restriction	5,800	20	5.1	2.4	60	1	60	50	0.68	0.07	328	33	1a
Water Truck	Local	Chemical + Restriction	60,000	20	5.1	2.4	240	8	1,920	85	0.46	0.05	2,101	209	1b
	Resource	Water + Restriction	60,000	15	5.1	2.4	240	10	2,400	50	1.96	0.30	37,579	5,762	1a
Sand Truck	Local	Chemical + Restriction	60,000	20	5.1	2.4	40	34	1,360	85	0.46	0.05	1,488	148	1b
	Resource	Water + Restriction	60,000	15	5.1	2.4	40	10	400	50	1.96	0.30	6,263	960	1a
Winch Truck	Local	Chemical + Restriction	60,000	20	5.1	2.4	36	6	216	85	0.46	0.05	236	23	1b
	Resource	Water + Restriction	60,000	15	5.1	2.4	36	10	360	50	1.96	0.30	5,637	864	1a
Total Unpaved Road Traffic Emissions (lb/pad)													54,367	8,072	

[1] Dust control methods include using water (resource road) or chemical (loacal road) as a dust suppressants along with vehicle restriction speed limit of 25 mph.

[2] AP-42 (EPA 2004), Table 13.2.2-1, "Typical Silt Content Values of Surface Material on Industrial and Rural Unpaved Roads."

[3] AP-42 (EPA 2004), Table 11.9-3, "Typical Values for Correction Factors Applicable to the Predictive Emission Factor Equations."

[4] Calculated as Round Trips per Vehicle Type x Round Trip Distance.

[5] AP-42 (EPA 2004), Figure 13.2.2-2, "Watering control effectiveness for unpaved travel surfaces.", Fugitive Dust Handbook (WRAP 2006) Chapter 6.

[6] AP-42 (EPA 2004), Section 13.2.2 "Unpaved Roads", equations 1a and 1b.

[7] Calculated as lb/VMT x VMT/well x control efficiency.

NPL Project General Conformity Emissions Inventory

Table 25. Completion/Testing Haul Truck Tailpipe

Project: **NPL**
Scenario: **4 Pad/Section**
Activity: **Completion/Testing**
Emissions: **Diesel Combustion Emissions from Heavy Equipment Tailpipes**

Pollutant	Pollutant Emission Factor[1]	Total Haul Truck RTs	RT Distance	Total Haul Truck Miles Traveled	Haul Activity Duration[3]	Haul Activity Duration[3]	Emissions	Emissions
	(g/mile)	(RTs/well)	(miles/RT)	(miles/well)	(days/well)	(hours/day)	(lb/well)	(lb/pad)
CO	1.25	316	21	6,656	10	18	18.29	293
NO_x	3.18	316	21	6,656	10	18	46.60	746
PM_{10}	0.21	316	21	6,656	10	18	3.08	49
$PM_{2.5}$	0.17	316	21	6,656	10	18	2.43	39
SO_2[2]	0.01	316	21	6,656	10	18	0.09	1.48E+00
VOC	0.32	316	21	6,656	10	18	4.67	75
Benzene	3.45E-03	316	21	6,656	10	18	0.05	8.10E-01
Ethylbenzene		316	21	6,656	10	18	0.00	0
Formaldehyde	2.57E-02	316	21	6,656	10	18	0.38	6.03E+00
H_2S		316	21	6,656	10	18	0.00	0
n-Hexane		316	21	6,656	10	18	0.00	0
Toluene		316	21	6,656	10	18	0.00	0
Xylenes		316	21	6,656	10	18	0.00	0
CH_4	3.73E-02	316	21	6,656	10	18	0.55	8.76E+00
CO_2[2]	854.68	316	21	6,656	10	18	12541.34	200661
N_2O	1.88E-03	316	21	6,656	10	18	0.03	4.41E-01

[1] MOVES, 2013 heavy duty short haul truck

[2] CO2 from CO2(eq) {CO2(eq)-21*CH4-320*N20}

[3] Haul Activity Duration for completion activities based on an average of 10 days per well and an average of 24 hr/day for 5 days and 12 hr/day for 5 days.

NPL Project General Conformity Emissions Inventory

Table 26. Workover Traffic

Project: NPL
Scenario: 4 Pad/Section
Activity: Workover Traffic
Emissions: Fugitive Particulate Emissions from Traffic on Unpaved Roads

Vehicle Type	Road Type	Dust Control Method[1]	Average Vehicle Weight	Average Vehicle Speed	Silt Content[2]	Moisture Content[3]	RTs per Well	RT Distance	VMT[4]	Emission Control Efficiency[5]	PM_{10} Emissions[6]	$PM_{2.5}$ Emissions[6]	PM_{10} Emissions[7] (controlled)	$PM_{2.5}$ Emissions[7] (controlled)	
			(lb)	(mph)	(%)	(%)		(miles)	(VMT/well)	(%)	(lb/VMT)	(lb/VMT)	(lb/pad)	(lb/pad)	
Light Trucks/ Pickups	Local	Chemical + Restriction	5,800	25	5.1	2.4	6	10	60	85	0.51	0.05	73	7	1b
	Resource	Water + Restriction	5,800	20	5.1	2.4	6	1	6	50	0.68	0.07	33	3	1a
Water Truck	Local	Chemical + Restriction	60,000	20	5.1	2.4	24	8	192	85	0.46	0.05	210	21	1b
	Resource	Water + Restriction	60,000	15	5.1	2.4	24	10	240	50	1.96	0.20	3,758	376	1a
Sand Truck	Local	Chemical + Restriction	60,000	20	5.1	2.4	4	34	136	85	0.46	0.05	149	15	1b
	Resource	Water + Restriction	60,000	15	5.1	2.4	4	10	40	50	1.96	0.20	626	63	1a
Winch Truck	Local	Chemical + Restriction	60,000	20	5.1	2.4	4	6	24	85	0.46	0.05	26	3	1b
	Resource	Water + Restriction	60,000	15	5.1	2.4	4	10	40	50	1.96	0.20	626	63	1a
												Total Unpaved Road Traffic Emissions (lb/pad)	5,502	550	

1 Dust control methods include using water (resource road) or chemical (loacal road) as a dust suppressants along with vehicle restriction speed limit of 25 mph.

2 AP-42 (EPA 2004), Table 13.2.2-1, "Typical Silt Content Values of Surface Material on Industrial and Rural Unpaved Roads."

3 AP-42 (EPA 2004), Table 11.9-3, "Typical Values for Correction Factors Applicable to the Predictive Emission Factor Equations."

4 Calculated as Round Trips per Vehicle Type x Round Trip Distance.

5 AP-42 (EPA 2004), Figure 13.2.2-2, "Watering control effectiveness for unpaved travel surfaces.", Fugitive Dust Handbook (WRAP 2006) Chapter 6.

6 AP-42 (EPA 2004), Section 13.2.2 "Unpaved Roads", equations 1a and 1b.

7 Calculated as lb/VMT x VMT/well x control efficiency.

NPL Project General Conformity Emissions Inventory

Table 27. Workover Tailpipe

Project: NPL
Scenario: 4 Pad/Section
Activity: Well Workover
Emissions: Diesel Combustion Emissions from Heavy Equipment Tailpipes

Pollutant	Pollutant Emission Factor[1] (g/mile)	Total Haul Truck RTs (RTs/well)	RT Distance (miles/RT)	Total Haul Truck Miles Traveled (miles/well)	Haul Activity Duration[3] (days/well)	Haul Activity Duration[3] (hours/day)	Emissions (lb/well)	Emissions (lb/pad)
CO	1.25	32	21	664	10	18	1.82	29
NO_x	3.18	32	21	664	10	18	4.65	74
PM_{10}	0.21	32	21	664	10	18	0.31	4.91E+00
$PM_{2.5}$	0.17	32	21	664	10	18	0.24	3.87E+00
SO_2[2]	0.01	32	21	664	10	18	0.01	0
VOC	0.32	32	21	664	10	18	0.47	7.45E+00
Benzene	3.45E-03	32	21	664	10	18	0.01	8.07E-02
Ethylbenzene		32	21	664	10	18	0.00	0
Formaldehyde	2.57E-02	32	21	664	10	18	0.04	6.01E-01
H_2S		32	21	664	10	18	0.00	0
n-Hexane		32	21	664	10	18	0.00	0
Toluene		32	21	664	10	18	0.00	0
Xylenes		32	21	664	10	18	0.00	0
CH_4	3.73E-02	32	21	664	10	18	0.05	8.74E-01
CO_2[2]	854.68	32	21	664	10	18	1250.37	20006
N_2O	1.88E-03	32	21	664	10	18	0.00	4.40E-02

[1] MOVES, 2013 heavy duty short haul truck

[2] CO2 from CO2(eq) {CO2(eq)-21*CH4-320*N20}

[3] Haul Activity Duration for completion activities based on an average of 10 days per well and an average of 24 hr/day for 5 days and 12 hr/day for 5 days.

Table 28. Well Workover and Blowdown Emissions

Project: NPL
Scenario: 4 Pad/Section
Effective Dates: All
Emissions: Well workover and blowdown emissions

Activity	Volume Gas Vented[1]	Event Duration[2]	Events	Wells	Control Efficiency[3]	Pollutant	Weight Fraction[4]	Emissions per Well	Emissions per Pad
	(mcf/well)	(hour/well)	(well/year)		(%)			(lb/well-yr)	(tons/yr)
Venting	53.6	0.15	0.5	160	0	CO	0.00		
						NOx	0.00		
						SO_2	0.00		
Molecular Weight	18.43					VOC	0.11	133.78	1.07
Fuel Heating Value (actual)	1,124	Btu/scf				PM_{10}	0.00		
						$PM_{2.5}$	0.00		
						Benzene	5.12E-04	0.60	0.00
						Ethylbenzene	3.07E-05	0.04	0.00
						Formaldehyde	0.00		
						H_2S	0.00		
						n-Hexane	2.30E-03	2.70	0.02
						Toluene	7.57E-04	0.89	0.01
						Xylenes	2.80E-04	0.33	0.00
						CH_4	0.78	916.14	7.33
						CO_2	0.013	15.01	0.12
						N_2O	0.00		

[1] Based on volume of gas vented from NPL wells during 2010 and proposed operations for the NPL development.
[2] Operator knowledge of actual vent time for NPL wells.
[3] None
[4] Weight fraction based on gas composition. See 'Material Balance' sheet.

NPL Project General Conformity Emissions Inventory

Table 29. Production Facility Development

Project: NPL
Scenario: Gas Throughput (MMscfd)
Activity: Production Facility Development
Emissions:

Date:

Facility	Year 1	2	3	4	5	6	7	8	9	10
1	75	75	75	75	75	75	75	75	75	70
2	45	50	50	50	50	50	50	50	50	45
3	43	65	65	65	75	75	75	75	75	70
4		26	50	50	50	50	50	50	50	45
5		27	48	50	50	50	50	50	50	45
6			17	29	41	51	61	69	75	75
7				20	28	28	40	40	40	35
8				15	30	44	44	50	50	50
9						15	18	31	40	40
10							12	17	25	25
11									10	10
Totals	163	243	305	354	399	438	475	507	540	510

Project: Jonah NPL
Scenario: Horsepower
Activity: Production Facility Development
Emissions:

Date:

Facility	Year 1	2	3	4	5	6	7	8	9	10
1	10118	10118	10118	10118	10118	10118	10118	10118	10118	10118
2	6475	6475	6475	6475	6475	6475	6475	6475	6475	6475
3	6475	10118	6475	10118	10118	10118	10118	10118	10118	10118
4		3373	6475	6475	6475	6475	6475	6475	6475	6475
5		3373	6475	6475	6475	6475	6475	6475	6475	6475
6			3373	6475	6475	10118	10118	10118	10118	10118
7				3373	6475	6475	6475	6475	6475	6475
8				3373	6475	6475	6475	6475	6475	6475
9						3373	3373	6475	6475	6475
10							3373	3373	3373	3373
11									3373	3373
Totals	23068	33457	39391	52882	59086	66102	69475	72577	75950	75950

Table 30. Production Traffic – Per Round Trip

Project: NPL
Scenario: 4 Pad/Section
Activity: Production Traffic
Emissions: Fugitive Particulate Emissions from Traffic on Unpaved Roads

Vehicle Type	Road Type	Dust Control Method[1]	Average Vehicle Weight	Average Vehicle Speed	Silt Content[2]	Moisture Content[3]	RTs	RT Distance	VMT[4]	Emission Control Efficiency[5]	PM_{10} Emission Factor[6]	$PM_{2.5}$ Emission Factor[6]	PM_{10} Emissions[7] (controlled)	$PM_{2.5}$ Emissions[7] (controlled)	
			(lb)	(mph)	(%)	(%)	(RTs)	(miles\pad)	(VMT)	(%)	(lb/VMT)	(lb/VMT)	(lb/pad)	(lb/pad)	
Light Truck	Local	Chemical + Restriction	5,800	25	5.1	2.4	365	9	3,285	85	0.51	0.05	251.22	24.97	1b
	Resource	Water + Restriction	5,800	20	5.1	2.4	365	1	365	50	0.68	0.07	124.82	12.48	1a
Total Access and Unimproved Road Emissions (lb/pad)													376.04	37.45	

[1] Dust control methods include using water (resource road) or chemical (loacal road) as a dust suppressants along with vehicle restriction speed limit of 25 mph.
[2] AP-42 (EPA 2004), Table 13.2.2-1, "Typical Silt Content Values of Surface Material on Industrial and Rural Unpaved Roads."
[3] AP-42 (EPA 2004), Table 11.9-3, "Typical Values for Correction Factors Applicable to the Predictive Emission Factor Equations."
[4] Calculated as Round Trips per Vehicle Type x Round Trip Distance
[5] AP-42 (EPA 2004), Figure 13.2.2-2, "Watering control effectiveness for unpaved travel surfaces.", Fugitive Dust Handbook (WRAP 2006) Chapter 6.
[6] AP-42 (EPA 2004), Section 13.2.2 "Unpaved Roads", equations 1a and 1b.
[7] Calculated as lb/VMT x VMT/RT x control efficiency.

Table 31. Liquids Gathering Traffic - Per Round Trip

Project: NPL
Scenario: 4 Pad/Section
Activity: Production Traffic
Emissions: Fugitive Particulate Emissions from Traffic on Unpaved Roads

Vehicle Type	Road Type	Dust Control Method[1]	Average Vehicle Weight	Average Vehicle Speed	Silt Content[2]	Moisture Content[3]	RTs	RT Distance	VMT[4]	Emission Control Efficiency[5]	PM_{10} Emission Factor[6]	$PM_{2.5}$ Emission Factor[6]	PM_{10} Emissions[7] (controlled)	$PM_{2.5}$ Emissions[7] (controlled)
			(lb)	(mph)	(%)	(%)	(RT)	(miles)	(VMT/RT)	(%)	(lb/VMT)	(lb/VMT)	(lb/yr)	(lb/yr)
Haul Truck	Local	Chemical + Restriction	54,000	25	5.1	2.4	4,149	34	141,082	85	0.51	0.05	10,789.11	1,072.29
	Resource	Water + Restriction	54,000	20	5.1	2.4	4,149	2	8,299	50	1.87	0.19	7,745.39	774.54
												Total Access and Unimproved Road Emissions (lb/RT)	18,534.50	1,846.83

[1] Dust control methods include using water (resource road) or chemical (loacal road) as a dust suppressants along with vehicle restriction speed limit of 25 mph.
[2] AP-42 (EPA 2004), Table 13.2.2-1, "Typical Silt Content Values of Surface Material on Industrial and Rural Unpaved Roads."
[3] AP-42 (EPA 2004), Table 11.9-3, "Typical Values for Correction Factors Applicable to the Predictive Emission Factor Equations."
[4] Calculated as Round Trips per Vehicle Type x Round Trip Distance
[5] AP-42 (EPA 2004), Figure 13.2.2-2, "Watering control effectiveness for unpaved travel surfaces.", Fugitive Dust Handbook (WRAP 2006) Chapter 6.
[6] AP-42 (EPA 2004), Section 13.2.2 "Unpaved Roads", equations 1a and 1b.
[7] Calculated as lb/VMT x VMT/RT x control efficiency.

NPL Project General Conformity Emissions Inventory

Table 32. Tanker Traffic Tailpipe - Per Round Trip

Project: NPL
Scenario: 4 Pad/Section
Activity: Production Tailpipe
Emissions: Diesel Combustion Emissions from Heavy Equipment Tailpipes

Pollutant	Pollutant Emission Factor[1] (g/mi)	RT (RT)	Single Round Trip Distance (mi/RT)	Yearly VMT (mi)	Central Facility Emissions (lb/yr)
CO	1.25	365	10	3650	10.03
NO_x	3.18	365	10	3650	25.55
PM_{10}	0.21	365	10	3650	1.69
$PM_{2.5}$	0.17	365	10	3650	1.33
SO_2[2]	0.01	365	10	3650	0.05
VOC	0.32	365	10	3650	2.56
Benzene	3.45E-03	365	10	3650	2.77E-02
Ethylbenzene		365	10	3650	0.00
Formaldehyde	2.57E-02	365	10	3650	2.07E-01
H_2S		365	10	3650	0.00
n-Hexane		365	10	3650	0.00
Toluene		365	10	3650	0.00
Xylenes		365	10	3650	0.00
CH_4	3.73E-02	365	10	3650	3.00E-01
CO_2[2]	854.68	365	10	3650	6877.54
N_2O	1.88E-03	365	10	3650	1.51E-02

[1] MOVES, 2013 heavy duty short haul truck
[2] CO2 from CO2(eq) {CO2(eq)-21*CH4-320*N20}

Table 33. Tanker Traffic Tailpipe - Per Round Trip

Project: NPL
Scenario: 4 Pad/Section
Activity: Tanker Tailpipe
Emissions: Diesel Combustion Emissions from Heavy Equipment Tailpipes

Pollutant	Pollutant Emission Factor[1]	RT	Single Round Trip Distance	Yearly VMT	Central Facility Emissions
	(g/mi)	(RT)	(mi/RT)	(mi)	(lb/yr)
CO	1.25	4,149	36	149381	410.44
NO_x	3.18	4,149	36	149381	1045.87
PM_{10}	0.21	4,149	36	149381	69.05
$PM_{2.5}$	0.17	4,149	36	149381	54.48
SO_2[2]	0.01	4,149	36	149381	2.07
VOC	0.32	4,149	36	149381	104.77
Benzene	3.45E-03	4,149	36	149381	1.14
Ethylbenzene		4,149	36	149381	0.00
Formaldehyde	2.57E-02	4,149	36	149381	8.46
H_2S		4,149	36	149381	0.00
n-Hexane		4,149	36	149381	0.00
Toluene		4,149	36	149381	0.00
Xylenes		4,149	36	149381	0.00
CH_4	3.73E-02	4,149	36	149381	12.29
CO_2[2]	854.68	4,149	36	149381	281472.42
N_2O	1.88E-03	4,149	36	149381	6.19E-01

[1] MOVES, 2013 heavy duty short haul truck
[2] CO2 from CO2(eq) {CO2(eq)-21*CH4-320*N20}

NPL Project General Conformity Emissions Inventory

Table 34. Wind Erosion Data

			Peak Wind Speed		Friction Velocity	Threshold Friction Velocity	Exceed Threshold		
Year	Month	Day	(mph)	u^{+}_{10} (m/s)[1]	u* (m/s)[2]	u^{*}_{t}[3]	Friction Velocity	P (g/m^2)[4]	ΣP (g/m^2-yr)
2008	1	1	7	3.13	0.17	1.02	No		
2008	1	2	7	3.13	0.17	1.02	No		
2008	1	3	6	2.68	0.14	1.02	No		
2008	1	4	7	3.13	0.17	1.02	No		
2008	1	5	31	13.86	0.73	1.02	No		
2008	1	6	10	4.47	0.24	1.02	No		
2008	1	7	9	4.02	0.21	1.02	No		
2008	1	8	9	4.02	0.21	1.02	No		
2008	1	9	12	5.36	0.28	1.02	No		
2008	1	10	8	3.58	0.19	1.02	No		
2008	1	11	21	9.39	0.50	1.02	No		
2008	1	12	8	3.58	0.19	1.02	No		
2008	1	13	14	6.26	0.33	1.02	No		
2008	1	14	10	4.47	0.24	1.02	No		
2008	1	15	33	14.75	0.78	1.02	No		
2008	1	16	13	5.81	0.31	1.02	No		
2008	1	17	22	9.83	0.52	1.02	No		
2008	1	18	14	6.26	0.33	1.02	No		
2008	1	19	8	3.58	0.19	1.02	No		
2008	1	20	14	6.26	0.33	1.02	No		
2008	1	21	14	6.26	0.33	1.02	No		
2008	1	22	7	3.13	0.17	1.02	No		
2008	1	23	10	4.47	0.24	1.02	No		
2008	1	24	9	4.02	0.21	1.02	No		
2008	1	25	9	4.02	0.21	1.02	No		
2008	1	26	10	4.47	0.24	1.02	No		
2008	1	27	16	7.15	0.38	1.02	No		
2008	1	28	37	16.54	0.88	1.02	No		
2008	1	29	13	5.81	0.31	1.02	No		

2008	1	30	22	9.83	0.52	1.02	No		
2008	1	31	7	3.13	0.17	1.02	No		
2008	2	1	12	5.36	0.28	1.02	No		
2008	2	2	7	3.13	0.17	1.02	No		
2008	2	3	7	3.13	0.17	1.02	No		
2008	2	4	12	5.36	0.28	1.02	No		
2008	2	5	13	5.81	0.31	1.02	No		
2008	2	6	20	8.94	0.47	1.02	No		
2008	2	7	38	16.99	0.90	1.02	No		
2008	2	8	21	9.39	0.50	1.02	No		
2008	2	9	16	7.15	0.38	1.02	No		
2008	2	10	10	4.47	0.24	1.02	No		
2008	2	11	21	9.39	0.50	1.02	No		
2008	2	12	17	7.60	0.40	1.02	No		
2008	2	13	23	10.28	0.54	1.02	No		
2008	2	14	13	5.81	0.31	1.02	No		
2008	2	15	6	2.68	0.14	1.02	No		
2008	2	16	22	9.83	0.52	1.02	No		
2008	2	17	18	8.05	0.43	1.02	No		
2008	2	18	17	7.60	0.40	1.02	No		
2008	2	19	10	4.47	0.24	1.02	No		
2008	2	20	6	2.68	0.14	1.02	No		
2008	2	21	6	2.68	0.14	1.02	No		
2008	2	22	9	4.02	0.21	1.02	No		
2008	2	23	8	3.58	0.19	1.02	No		
2008	2	24	10	4.47	0.24	1.02	No		
2008	2	25	10	4.47	0.24	1.02	No		
2008	2	26	15	6.71	0.36	1.02	No		
2008	2	27	8	3.58	0.19	1.02	No		
2008	2	28	16	7.15	0.38	1.02	No		
2008	2	29	9	4.02	0.21	1.02	No		
2008	3	1	23	10.28	0.54	1.02	No		
2008	3	2	21	9.39	0.50	1.02	No		
2008	3	3	10	4.47	0.24	1.02	No		
2008	3	4	21	9.39	0.50	1.02	No		
2008	3	5	21	9.39	0.50	1.02	No		
2008	3	6	17	7.60	0.40	1.02	No		

2008	3	7	16	7.15	0.38	1.02	No		
2008	3	8	12	5.36	0.28	1.02	No		
2008	3	9	8	3.58	0.19	1.02	No		
2008	3	10	9	4.02	0.21	1.02	No		
2008	3	11	23	10.28	0.54	1.02	No		
2008	3	12	15	6.71	0.36	1.02	No		
2008	3	13	17	7.60	0.40	1.02	No		
2008	3	14	18	8.05	0.43	1.02	No		
2008	3	15	13	5.81	0.31	1.02	No		
2008	3	16	14	6.26	0.33	1.02	No		
2008	3	17	15	6.71	0.36	1.02	No		
2008	3	18	13	5.81	0.31	1.02	No		
2008	3	19	18	8.05	0.43	1.02	No		
2008	3	20	25	11.18	0.59	1.02	No		
2008	3	21	29	12.96	0.69	1.02	No		
2008	3	22	13	5.81	0.31	1.02	No		
2008	3	23	8	3.58	0.19	1.02	No		
2008	3	24	30	13.41	0.71	1.02	No		
2008	3	25	18	8.05	0.43	1.02	No		
2008	3	26	49	21.90	1.16	1.02	Yes	4.68	
2008	3	27	31	13.86	0.73	1.02	No		
2008	3	28	18	8.05	0.43	1.02	No		
2008	3	29	29	12.96	0.69	1.02	No		
2008	3	30	9	4.02	0.21	1.02	No		
2008	3	31	35	15.65	0.83	1.02	No		
2008	4	1	15	6.71	0.36	1.02	No		
2008	4	2	15	6.71	0.36	1.02	No		
2008	4	3	20	8.94	0.47	1.02	No		
2008	4	4	20	8.94	0.47	1.02	No		
2008	4	5	35	15.65	0.83	1.02	No		
2008	4	6	15	6.71	0.36	1.02	No		
2008	4	7	30	13.41	0.71	1.02	No		
2008	4	8	20	8.94	0.47	1.02	No		
2008	4	9	21	9.39	0.50	1.02	No		
2008	4	10	23	10.28	0.54	1.02	No		
2008	4	11	26	11.62	0.62	1.02	No		
2008	4	12	22	9.83	0.52	1.02	No		

2008	4	13	17	7.60	0.40	1.02	No		
2008	4	14	30	13.41	0.71	1.02	No		
2008	4	15	29	12.96	0.69	1.02	No		
2008	4	16	18	8.05	0.43	1.02	No		
2008	4	17	20	8.94	0.47	1.02	No		
2008	4	18	39	17.43	0.92	1.02	No		
2008	4	19	31	13.86	0.73	1.02	No		
2008	4	20	44	19.67	1.04	1.02	Yes	0.59	
2008	4	21	32	14.31	0.76	1.02	No		
2008	4	22	23	10.28	0.54	1.02	No		
2008	4	23	31	13.86	0.73	1.02	No		
2008	4	24	29	12.96	0.69	1.02	No		
2008	4	25	41	18.33	0.97	1.02	No		
2008	4	26	22	9.83	0.52	1.02	No		
2008	4	27	17	7.60	0.40	1.02	No		
2008	4	28	32	14.31	0.76	1.02	No		
2008	4	29	41	18.33	0.97	1.02	No		
2008	4	30	24	10.73	0.57	1.02	No		
2008	5	1	26	11.62	0.62	1.02	No		
2008	5	2	25	11.18	0.59	1.02	No		
2008	5	3	14	6.26	0.33	1.02	No		
2008	5	4	21	9.39	0.50	1.02	No		
2008	5	5	28	12.52	0.66	1.02	No		
2008	5	6	24	10.73	0.57	1.02	No		
2008	5	7	18	8.05	0.43	1.02	No		
2008	5	8	28	12.52	0.66	1.02	No		
2008	5	9	30	13.41	0.71	1.02	No		
2008	5	10	23	10.28	0.54	1.02	No		
2008	5	11	36	16.09	0.85	1.02	No		
2008	5	12	23	10.28	0.54	1.02	No		
2008	5	13	21	9.39	0.50	1.02	No		
2008	5	14	23	10.28	0.54	1.02	No		
2008	5	15	16	7.15	0.38	1.02	No		
2008	5	16	22	9.83	0.52	1.02	No		
2008	5	17	24	10.73	0.57	1.02	No		
2008	5	18	37	16.54	0.88	1.02	No		
2008	5	19	29	12.96	0.69	1.02	No		

2008	5	20	68	30.40	1.61	1.02	Yes	35.05	
2008	5	21	24	10.73	0.57	1.02	No		
2008	5	22	14	6.26	0.33	1.02	No		
2008	5	23	21	9.39	0.50	1.02	No		
2008	5	24	32	14.31	0.76	1.02	No		
2008	5	25	15	6.71	0.36	1.02	No		
2008	5	26	35	15.65	0.83	1.02	No		
2008	5	27	25	11.18	0.59	1.02	No		
2008	5	28	32	14.31	0.76	1.02	No		
2008	5	29	36	16.09	0.85	1.02	No		
2008	5	30	23	10.28	0.54	1.02	No		
2008	5	31	18	8.05	0.43	1.02	No		
2008	6	1	26	11.62	0.62	1.02	No		
2008	6	2	35	15.65	0.83	1.02	No		
2008	6	3	26	11.62	0.62	1.02	No		
2008	6	4	23	10.28	0.54	1.02	No		
2008	6	5	31	13.86	0.73	1.02	No		
2008	6	6	43	19.22	1.02	1.02	No		
2008	6	7	32	14.31	0.76	1.02	No		
2008	6	8	30	13.41	0.71	1.02	No		
2008	6	9	31	13.86	0.73	1.02	No		
2008	6	10	32	14.31	0.76	1.02	No		
2008	6	11	31	13.86	0.73	1.02	No		
2008	6	12	32	14.31	0.76	1.02	No		
2008	6	13	30	13.41	0.71	1.02	No		
2008	6	14	32	14.31	0.76	1.02	No		
2008	6	15	31	13.86	0.73	1.02	No		
2008	6	16	28	12.52	0.66	1.02	No		
2008	6	17	37	16.54	0.88	1.02	No		
2008	6	18	26	11.62	0.62	1.02	No		
2008	6	19	26	11.62	0.62	1.02	No		
2008	6	20	28	12.52	0.66	1.02	No		
2008	6	21	28	12.52	0.66	1.02	No		
2008	6	22	36	16.09	0.85	1.02	No		
2008	6	23	36	16.09	0.85	1.02	No		
2008	6	24	32	14.31	0.76	1.02	No		
2008	6	25	26	11.62	0.62	1.02	No		

2008	6	26	66	29.50	1.56	1.02	Yes	30.74	
2008	6	27	29	12.96	0.69	1.02	No		
2008	6	28	28	12.52	0.66	1.02	No		
2008	6	29	16	7.15	0.38	1.02	No		
2008	6	30	56	25.03	1.33	1.02	Yes	13.13	
2008	7	1	35	15.65	0.83	1.02	No		
2008	7	2	30	13.41	0.71	1.02	No		
2008	7	3	29	12.96	0.69	1.02	No		
2008	7	4	36	16.09	0.85	1.02	No		
2008	7	5	26	11.62	0.62	1.02	No		
2008	7	6	31	13.86	0.73	1.02	No		
2008	7	7	25	11.18	0.59	1.02	No		
2008	7	8	30	13.41	0.71	1.02	No		
2008	7	9	26	11.62	0.62	1.02	No		
2008	7	10	30	13.41	0.71	1.02	No		
2008	7	11	28	12.52	0.66	1.02	No		
2008	7	12	23	10.28	0.54	1.02	No		
2008	7	13	24	10.73	0.57	1.02	No		
2008	7	14	31	13.86	0.73	1.02	No		
2008	7	15	26	11.62	0.62	1.02	No		
2008	7	16	25	11.18	0.59	1.02	No		
2008	7	17	24	10.73	0.57	1.02	No		
2008	7	18	36	16.09	0.85	1.02	No		
2008	7	19	32	14.31	0.76	1.02	No		
2008	7	20	24	10.73	0.57	1.02	No		
2008	7	21	26	11.62	0.62	1.02	No		
2008	7	22	37	16.54	0.88	1.02	No		
2008	7	23	28	12.52	0.66	1.02	No		
2008	7	24	32	14.31	0.76	1.02	No		
2008	7	25	21	9.39	0.50	1.02	No		
2008	7	26	31	13.86	0.73	1.02	No		
2008	7	27	28	12.52	0.66	1.02	No		
2008	7	28	28	12.52	0.66	1.02	No		
2008	7	29	29	12.96	0.69	1.02	No		
2008	7	30	36	16.09	0.85	1.02	No		
2008	7	31	29	12.96	0.69	1.02	No		
2008	8	1	31	13.86	0.73	1.02	No		

2008	8	2	31	13.86	0.73	1.02	No		
2008	8	3	33	14.75	0.78	1.02	No		
2008	8	4	31	13.86	0.73	1.02	No		
2008	8	5	30	13.41	0.71	1.02	No		
2008	8	6	28	12.52	0.66	1.02	No		
2008	8	7	32	14.31	0.76	1.02	No		
2008	8	8	31	13.86	0.73	1.02	No		
2008	8	9	37	16.54	0.88	1.02	No		
2008	8	10	48	21.46	1.14	1.02	Yes	3.73	
2008	8	11	30	13.41	0.71	1.02	No		
2008	8	12	25	11.18	0.59	1.02	No		
2008	8	13	33	14.75	0.78	1.02	No		
2008	8	14	33	14.75	0.78	1.02	No		
2008	8	15	24	10.73	0.57	1.02	No		
2008	8	16	17	7.60	0.40	1.02	No		
2008	8	17	17	7.60	0.40	1.02	No		
2008	8	18	15	6.71	0.36	1.02	No		
2008	8	19	21	9.39	0.50	1.02	No		
2008	8	20	33	14.75	0.78	1.02	No		
2008	8	21	43	19.22	1.02	1.02	No		
2008	8	22	23	10.28	0.54	1.02	No		
2008	8	23	20	8.94	0.47	1.02	No		
2008	8	24	21	9.39	0.50	1.02	No		
2008	8	25	43	19.22	1.02	1.02	No		
2008	8	26	33	14.75	0.78	1.02	No		
2008	8	27	39	17.43	0.92	1.02	No		
2008	8	28	28	12.52	0.66	1.02	No		
2008	8	29	17	7.60	0.40	1.02	No		
2008	8	30	25	11.18	0.59	1.02	No		
2008	8	31	44	19.67	1.04	1.02	Yes	0.59	
2008	9	1	32	14.31	0.76	1.02	No		
2008	9	2	15	6.71	0.36	1.02	No		
2008	9	3	30	13.41	0.71	1.02	No		
2008	9	4	39	17.43	0.92	1.02	No		
2008	9	5	26	11.62	0.62	1.02	No		
2008	9	6	26	11.62	0.62	1.02	No		
2008	9	7	28	12.52	0.66	1.02	No		

2008	9	8	15	6.71	0.36	1.02	No		
2008	9	9	36	16.09	0.85	1.02	No		
2008	9	10	35	15.65	0.83	1.02	No		
2008	9	11	23	10.28	0.54	1.02	No		
2008	9	12	26	11.62	0.62	1.02	No		
2008	9	13	28	12.52	0.66	1.02	No		
2008	9	14	22	9.83	0.52	1.02	No		
2008	9	15	12	5.36	0.28	1.02	No		
2008	9	16	14	6.26	0.33	1.02	No		
2008	9	17	23	10.28	0.54	1.02	No		
2008	9	18	35	15.65	0.83	1.02	No		
2008	9	19	17	7.60	0.40	1.02	No		
2008	9	20	29	12.96	0.69	1.02	No		
2008	9	21	26	11.62	0.62	1.02	No		
2008	9	22	26	11.62	0.62	1.02	No		
2008	9	23	24	10.73	0.57	1.02	No		
2008	9	24	28	12.52	0.66	1.02	No		
2008	9	25	30	13.41	0.71	1.02	No		
2008	9	26	25	11.18	0.59	1.02	No		
2008	9	27	30	13.41	0.71	1.02	No		
2008	9	28	22	9.83	0.52	1.02	No		
2008	9	29	14	6.26	0.33	1.02	No		
2008	9	30		0.00	0.00	1.02	No		
2008	10	1	28	12.52	0.66	1.02	No		
2008	10	2	25	11.18	0.59	1.02	No		
2008	10	3	23	10.28	0.54	1.02	No		
2008	10	4	21	9.39	0.50	1.02	No		
2008	10	5	26	11.62	0.62	1.02	No		
2008	10	6	23	10.28	0.54	1.02	No		
2008	10	7	26	11.62	0.62	1.02	No		
2008	10	8	41	18.33	0.97	1.02	No		
2008	10	9	38	16.99	0.90	1.02	No		
2008	10	10	21	9.39	0.50	1.02	No		
2008	10	11	31	13.86	0.73	1.02	No		
2008	10	12	18	8.05	0.43	1.02	No		
2008	10	13	15	6.71	0.36	1.02	No		
2008	10	14	24	10.73	0.57	1.02	No		

2008	10	15	10	4.47	0.24	1.02	No		
2008	10	16	18	8.05	0.43	1.02	No		
2008	10	17	12	5.36	0.28	1.02	No		
2008	10	18	23	10.28	0.54	1.02	No		
2008	10	19	13	5.81	0.31	1.02	No		
2008	10	20		0.00	0.00	1.02	No		
2008	10	21	41	18.33	0.97	1.02	No		
2008	10	22		0.00	0.00	1.02	No		
2008	10	23	27	12.07	0.64	1.02	No		
2008	10	24	24	10.73	0.57	1.02	No		
2008	10	25	35	15.65	0.83	1.02	No		
2008	10	26	17	7.60	0.40	1.02	No		
2008	10	27	14	6.26	0.33	1.02	No		
2008	10	28	12	5.36	0.28	1.02	No		
2008	10	29	26	11.62	0.62	1.02	No		
2008	10	30	14	6.26	0.33	1.02	No		
2008	10	31	8	3.58	0.19	1.02	No		
2008	11	1	20	8.94	0.47	1.02	No		
2008	11	2	31	13.86	0.73	1.02	No		
2008	11	3	22	9.83	0.52	1.02	No		
2008	11	4	26	11.62	0.62	1.02	No		
2008	11	5	37	16.54	0.88	1.02	No		
2008	11	6	37	16.54	0.88	1.02	No		
2008	11	7	24	10.73	0.57	1.02	No		
2008	11	8	16	7.15	0.38	1.02	No		
2008	11	9	14	6.26	0.33	1.02	No		
2008	11	10	25	11.18	0.59	1.02	No		
2008	11	11	21	9.39	0.50	1.02	No		
2008	11	12	29	12.96	0.69	1.02	No		
2008	11	13	44	19.67	1.04	1.02	Yes	0.59	
2008	11	14	24	10.73	0.57	1.02	No		
2008	11	15	33	14.75	0.78	1.02	No		
2008	11	16	13	5.81	0.31	1.02	No		
2008	11	17	15	6.71	0.36	1.02	No		
2008	11	18	17	7.60	0.40	1.02	No		
2008	11	19	13	5.81	0.31	1.02	No		
2008	11	20	22	9.83	0.52	1.02	No		

2008	11	21	30	13.41	0.71	1.02	No		
2008	11	22	13	5.81	0.31	1.02	No		
2008	11	23	26	11.62	0.62	1.02	No		
2008	11	24	13	5.81	0.31	1.02	No		
2008	11	25	10	4.47	0.24	1.02	No		
2008	11	26	12	5.36	0.28	1.02	No		
2008	11	27	12	5.36	0.28	1.02	No		
2008	11	28	38	16.99	0.90	1.02	No		
2008	11	29	51	22.80	1.21	1.02	Yes	6.77	
2008	11	30	47	21.01	1.11	1.02	Yes	2.85	
2008	12	1	25	11.18	0.59	1.02	No		
2008	12	2	35	15.65	0.83	1.02	No		
2008	12	3	25	11.18	0.59	1.02	No		
2008	12	4	16	7.15	0.38	1.02	No		
2008	12	5	29	12.96	0.69	1.02	No		
2008	12	6	20	8.94	0.47	1.02	No		
2008	12	7	20	8.94	0.47	1.02	No		
2008	12	8	26	11.62	0.62	1.02	No		
2008	12	9	20	8.94	0.47	1.02	No		
2008	12	10	30	13.41	0.71	1.02	No		
2008	12	11	25	11.18	0.59	1.02	No		
2008	12	12	22	9.83	0.52	1.02	No		
2008	12	13	26	11.62	0.62	1.02	No		
2008	12	14	12	5.36	0.28	1.02	No		
2008	12	15	10	4.47	0.24	1.02	No		
2008	12	16	17	7.60	0.40	1.02	No		
2008	12	17	17	7.60	0.40	1.02	No		
2008	12	18	15	6.71	0.36	1.02	No		
2008	12	19	26	11.62	0.62	1.02	No		
2008	12	20	26	11.62	0.62	1.02	No		
2008	12	21	8	3.58	0.19	1.02	No		
2008	12	22	15	6.71	0.36	1.02	No		
2008	12	23	15	6.71	0.36	1.02	No		
2008	12	24	15	6.71	0.36	1.02	No		
2008	12	25	18	8.05	0.43	1.02	No		
2008	12	26	36	16.09	0.85	1.02	No		
2008	12	27	20	8.94	0.47	1.02	No		

2008	12	28	12	5.36	0.28	1.02	No		
2008	12	29	48	21.46	1.14	1.02	Yes	3.73	
2008	12	30	48	21.46	1.14	1.02	Yes	3.73	
2008	12	31		0.00	0.00	1.02	No		106.17
2009	1	1	37	16.54	0.88	1.02	No		
2009	1	2	49	21.90	1.16	1.02	Yes	4.68	
2009	1	3	24	10.73	0.57	1.02	No		
2009	1	4	10	4.47	0.24	1.02	No		
2009	1	5	13	5.81	0.31	1.02	No		
2009	1	6	28	12.52	0.66	1.02	No		
2009	1	7	29	12.96	0.69	1.02	No		
2009	1	8	37	16.54	0.88	1.02	No		
2009	1	9	29	12.96	0.69	1.02	No		
2009	1	10	23	10.28	0.54	1.02	No		
2009	1	11	38	16.99	0.90	1.02	No		
2009	1	12	30	13.41	0.71	1.02	No		
2009	1	13	35	15.65	0.83	1.02	No		
2009	1	14	29	12.96	0.69	1.02	No		
2009	1	15	23	10.28	0.54	1.02	No		
2009	1	16	24	10.73	0.57	1.02	No		
2009	1	17	25	11.18	0.59	1.02	No		
2009	1	18	10	4.47	0.24	1.02	No		
2009	1	19	10	4.47	0.24	1.02	No		
2009	1	20	9	4.02	0.21	1.02	No		
2009	1	21	8	3.58	0.19	1.02	No		
2009	1	22	12	5.36	0.28	1.02	No		
2009	1	23	17	7.60	0.40	1.02	No		
2009	1	24	13	5.81	0.31	1.02	No		
2009	1	25	23	10.28	0.54	1.02	No		
2009	1	26	25	11.18	0.59	1.02	No		
2009	1	27	26	11.62	0.62	1.02	No		
2009	1	28	24	10.73	0.57	1.02	No		
2009	1	29	35	15.65	0.83	1.02	No		
2009	1	30	25	11.18	0.59	1.02	No		
2009	1	31	17	7.60	0.40	1.02	No		
2009	2	1	22	9.83	0.52	1.02	No		
2009	2	2	30	13.41	0.71	1.02	No		

2009	2	3	21	9.39	0.50	1.02	No		
2009	2	4	9	4.02	0.21	1.02	No		
2009	2	5	14	6.26	0.33	1.02	No		
2009	2	6	31	13.86	0.73	1.02	No		
2009	2	7	12	5.36	0.28	1.02	No		
2009	2	8	12	5.36	0.28	1.02	No		
2009	2	9	14	6.26	0.33	1.02	No		
2009	2	10	24	10.73	0.57	1.02	No		
2009	2	11	10	4.47	0.24	1.02	No		
2009	2	12	12	5.36	0.28	1.02	No		
2009	2	13	12	5.36	0.28	1.02	No		
2009	2	14	14	6.26	0.33	1.02	No		
2009	2	15	12	5.36	0.28	1.02	No		
2009	2	16	10	4.47	0.24	1.02	No		
2009	2	17	22	9.83	0.52	1.02	No		
2009	2	18	26	11.62	0.62	1.02	No		
2009	2	19	21	9.39	0.50	1.02	No		
2009	2	20	33	14.75	0.78	1.02	No		
2009	2	21	10	4.47	0.24	1.02	No		
2009	2	22	12	5.36	0.28	1.02	No		
2009	2	23	10	4.47	0.24	1.02	No		
2009	2	24	35	15.65	0.83	1.02	No		
2009	2	25	31	13.86	0.73	1.02	No		
2009	2	26	38	16.99	0.90	1.02	No		
2009	2	27	33	14.75	0.78	1.02	No		
2009	2	28	12	5.36	0.28	1.02	No		
2009	3	1	13	5.81	0.31	1.02	No		
2009	3	2	14	6.26	0.33	1.02	No		
2009	3	3	36	16.09	0.85	1.02	No		
2009	3	4	43	19.22	1.02	1.02	No		
2009	3	5	41	18.33	0.97	1.02	No		
2009	3	6	26	11.62	0.62	1.02	No		
2009	3	7	29	12.96	0.69	1.02	No		
2009	3	8	32	14.31	0.76	1.02	No		
2009	3	9	24	10.73	0.57	1.02	No		
2009	3	10	30	13.41	0.71	1.02	No		
2009	3	11	10	4.47	0.24	1.02	No		

2009	3	12	24	10.73	0.57	1.02	No		
2009	3	13	14	6.26	0.33	1.02	No		
2009	3	14	17	7.60	0.40	1.02	No		
2009	3	15	35	15.65	0.83	1.02	No		
2009	3	16	51	22.80	1.21	1.02	Yes	6.77	
2009	3	17	33	14.75	0.78	1.02	No		
2009	3	18	24	10.73	0.57	1.02	No		
2009	3	19	16	7.15	0.38	1.02	No		
2009	3	20	31	13.86	0.73	1.02	No		
2009	3	21	35	15.65	0.83	1.02	No		
2009	3	22	40	17.88	0.95	1.02	No		
2009	3	23	46	20.56	1.09	1.02	Yes	2.03	
2009	3	24	30	13.41	0.71	1.02	No		
2009	3	25	35	15.65	0.83	1.02	No		
2009	3	26	20	8.94	0.47	1.02	No		
2009	3	27	29	12.96	0.69	1.02	No		
2009	3	28	30	13.41	0.71	1.02	No		
2009	3	29	44	19.67	1.04	1.02	Yes	0.59	
2009	3	30	37	16.54	0.88	1.02	No		
2009	3	31	35	15.65	0.83	1.02	No		
2009	4	1	38	16.99	0.90	1.02	No		
2009	4	2	26	11.62	0.62	1.02	No		
2009	4	3	29	12.96	0.69	1.02	No		
2009	4	4	26	11.62	0.62	1.02	No		
2009	4	5	21	9.39	0.50	1.02	No		
2009	4	6	16	7.15	0.38	1.02	No		
2009	4	7	10	4.47	0.24	1.02	No		
2009	4	8	31	13.86	0.73	1.02	No		
2009	4	9	35	15.65	0.83	1.02	No		
2009	4	10	24	10.73	0.57	1.02	No		
2009	4	11	25	11.18	0.59	1.02	No		
2009	4	12	32	14.31	0.76	1.02	No		
2009	4	13	36	16.09	0.85	1.02	No		
2009	4	14	32	14.31	0.76	1.02	No		
2009	4	15	55	24.59	1.30	1.02	Yes	11.73	
2009	4	16	28	12.52	0.66	1.02	No		
2009	4	17	22	9.83	0.52	1.02	No		

2009	4	18	30	13.41	0.71	1.02	No		
2009	4	19	31	13.86	0.73	1.02	No		
2009	4	20	36	16.09	0.85	1.02	No		
2009	4	21	41	18.33	0.97	1.02	No		
2009	4	22	45	20.12	1.07	1.02	Yes	1.28	
2009	4	23	46	20.56	1.09	1.02	Yes	2.03	
2009	4	24	35	15.65	0.83	1.02	No		
2009	4	25	22	9.83	0.52	1.02	No		
2009	4	26	29	12.96	0.69	1.02	No		
2009	4	27	31	13.86	0.73	1.02	No		
2009	4	28	37	16.54	0.88	1.02	No		
2009	4	29	38	16.99	0.90	1.02	No		
2009	4	30	39	17.43	0.92	1.02	No		
2009	5	1	17	7.60	0.40	1.02	No		
2009	5	2	26	11.62	0.62	1.02	No		
2009	5	3	28	12.52	0.66	1.02	No		
2009	5	4	30	13.41	0.71	1.02	No		
2009	5	5	43	19.22	1.02	1.02	No		
2009	5	6	48	21.46	1.14	1.02	Yes	3.73	
2009	5	7		0.00	0.00	1.02	No		
2009	5	8	25	11.18	0.59	1.02	No		
2009	5	9	22	9.83	0.52	1.02	No		
2009	5	10	26	11.62	0.62	1.02	No		
2009	5	11	43	19.22	1.02	1.02	No		
2009	5	12	48	21.46	1.14	1.02	Yes	3.73	
2009	5	13	39	17.43	0.92	1.02	No		
2009	5	14	37	16.54	0.88	1.02	No		
2009	5	15	24	10.73	0.57	1.02	No		
2009	5	16	22	9.83	0.52	1.02	No		
2009	5	17	23	10.28	0.54	1.02	No		
2009	5	18	26	11.62	0.62	1.02	No		
2009	5	19	36	16.09	0.85	1.02	No		
2009	5	20	38	16.99	0.90	1.02	No		
2009	5	21	25	11.18	0.59	1.02	No		
2009	5	22	35	15.65	0.83	1.02	No		
2009	5	23	41	18.33	0.97	1.02	No		
2009	5	24	37	16.54	0.88	1.02	No		

2009	5	25	38	16.99	0.90	1.02	No		
2009	5	26	30	13.41	0.71	1.02	No		
2009	5	27	26	11.62	0.62	1.02	No		
2009	5	28	24	10.73	0.57	1.02	No		
2009	5	29	30	13.41	0.71	1.02	No		
2009	5	30	36	16.09	0.85	1.02	No		
2009	5	31	32	14.31	0.76	1.02	No		
2009	6	1	26	11.62	0.62	1.02	No		
2009	6	2		0.00	0.00	1.02	No		
2009	6	3	40	17.88	0.95	1.02	No		
2009	6	4	39	17.43	0.92	1.02	No		
2009	6	5	58	25.93	1.37	1.02	Yes	16.13	
2009	6	6	31	13.86	0.73	1.02	No		
2009	6	7	38	16.99	0.90	1.02	No		
2009	6	8	40	17.88	0.95	1.02	No		
2009	6	9		0.00	0.00	1.02	No		
2009	6	10	21	9.39	0.50	1.02	No		
2009	6	11	26	11.62	0.62	1.02	No		
2009	6	12	24	10.73	0.57	1.02	No		
2009	6	13	31	13.86	0.73	1.02	No		
2009	6	14		0.00	0.00	1.02	No		
2009	6	15	23	10.28	0.54	1.02	No		
2009	6	16	21	9.39	0.50	1.02	No		
2009	6	17	20	8.94	0.47	1.02	No		
2009	6	18	24	10.73	0.57	1.02	No		
2009	6	19	20	8.94	0.47	1.02	No		
2009	6	20	52	23.25	1.23	1.02	Yes	7.91	
2009	6	21	47	21.01	1.11	1.02	Yes	2.85	
2009	6	22	30	13.41	0.71	1.02	No		
2009	6	23	23	10.28	0.54	1.02	No		
2009	6	24	24	10.73	0.57	1.02	No		
2009	6	25	21	9.39	0.50	1.02	No		
2009	6	26	47	21.01	1.11	1.02	Yes	2.85	
2009	6	27	22	9.83	0.52	1.02	No		
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2009	6	29	43	19.22	1.02	1.02	No		
2009	6	30	31	13.86	0.73	1.02	No		

2009	7	1	28	12.52	0.66	1.02	No		
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2009	7	3	43	19.22	1.02	1.02	No		
2009	7	4	26	11.62	0.62	1.02	No		
2009	7	5	16	7.15	0.38	1.02	No		
2009	7	6	35	15.65	0.83	1.02	No		
2009	7	7	35	15.65	0.83	1.02	No		
2009	7	8	39	17.43	0.92	1.02	No		
2009	7	9	33	14.75	0.78	1.02	No		
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2009	7	11	23	10.28	0.54	1.02	No		
2009	7	12	32	14.31	0.76	1.02	No		
2009	7	13	40	17.88	0.95	1.02	No		
2009	7	14	23	10.28	0.54	1.02	No		
2009	7	15	28	12.52	0.66	1.02	No		
2009	7	16	31	13.86	0.73	1.02	No		
2009	7	17	38	16.99	0.90	1.02	No		
2009	7	18	31	13.86	0.73	1.02	No		
2009	7	19	39	17.43	0.92	1.02	No		
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2009	7	21	25	11.18	0.59	1.02	No		
2009	7	22	25	11.18	0.59	1.02	No		
2009	7	23	15	6.71	0.36	1.02	No		
2009	7	24	40	17.88	0.95	1.02	No		
2009	7	25	30	13.41	0.71	1.02	No		
2009	7	26	25	11.18	0.59	1.02	No		
2009	7	27	40	17.88	0.95	1.02	No		
2009	7	28	26	11.62	0.62	1.02	No		
2009	7	29	26	11.62	0.62	1.02	No		
2009	7	30	23	10.28	0.54	1.02	No		
2009	7	31	40	17.88	0.95	1.02	No		
2009	8	1	28	12.52	0.66	1.02	No		
2009	8	2	24	10.73	0.57	1.02	No		
2009	8	3	36	16.09	0.85	1.02	No		
2009	8	4	25	11.18	0.59	1.02	No		
2009	8	5	39	17.43	0.92	1.02	No		
2009	8	6	44	19.67	1.04	1.02	Yes	0.59	

2009	8	7	33	14.75	0.78	1.02	No		
2009	8	8	20	8.94	0.47	1.02	No		
2009	8	9	23	10.28	0.54	1.02	No		
2009	8	10	18	8.05	0.43	1.02	No		
2009	8	11	24	10.73	0.57	1.02	No		
2009	8	12	23	10.28	0.54	1.02	No		
2009	8	13	51	22.80	1.21	1.02	Yes	6.77	
2009	8	14	39	17.43	0.92	1.02	No		
2009	8	15	38	16.99	0.90	1.02	No		
2009	8	16	30	13.41	0.71	1.02	No		
2009	8	17	15	6.71	0.36	1.02	No		
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2009	8	25	24	10.73	0.57	1.02	No		
2009	8	26	22	9.83	0.52	1.02	No		
2009	8	27	32	14.31	0.76	1.02	No		
2009	8	28	30	13.41	0.71	1.02	No		
2009	8	29	46	20.56	1.09	1.02	Yes	2.03	
2009	8	30	30	13.41	0.71	1.02	No		
2009	8	31	37	16.54	0.88	1.02	No		
2009	9	1	29	12.96	0.69	1.02	No		
2009	9	2	32	14.31	0.76	1.02	No		
2009	9	3	22	9.83	0.52	1.02	No		
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2009	9	5	36	16.09	0.85	1.02	No		
2009	9	6	26	11.62	0.62	1.02	No		
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2009	9	9	17	7.60	0.40	1.02	No		
2009	9	10	29	12.96	0.69	1.02	No		
2009	9	11	25	11.18	0.59	1.02	No		
2009	9	12	25	11.18	0.59	1.02	No		

2009	9	13	38	16.99	0.90	1.02	No		
2009	9	14	44	19.67	1.04	1.02	Yes	0.59	
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2009	9	17	16	7.15	0.38	1.02	No		
2009	9	18	17	7.60	0.40	1.02	No		
2009	9	19	35	15.65	0.83	1.02	No		
2009	9	20	40	17.88	0.95	1.02	No		
2009	9	21	29	12.96	0.69	1.02	No		
2009	9	22	31	13.86	0.73	1.02	No		
2009	9	23	30	13.41	0.71	1.02	No		
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2009	9	25	29	12.96	0.69	1.02	No		
2009	9	26	29	12.96	0.69	1.02	No		
2009	9	27	17	7.60	0.40	1.02	No		
2009	9	28	18	8.05	0.43	1.02	No		
2009	9	29	38	16.99	0.90	1.02	No		
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2009	10	18		0.00	0.00	1.02	No		
2009	10	19		0.00	0.00	1.02	No		

2009	10	20	22	9.83	0.52	1.02	No		
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2009	11	14	13	5.81	0.31	1.02	No		
2009	11	15	26	11.62	0.62	1.02	No		
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2009	12	7	9	4.02	0.21	1.02	No		
2009	12	8	23	10.28	0.54	1.02	No		
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2009	12	14	21	9.39	0.50	1.02	No		
2009	12	15	10	4.47	0.24	1.02	No		
2009	12	16	12	5.36	0.28	1.02	No		
2009	12	17	18	8.05	0.43	1.02	No		
2009	12	18	12	5.36	0.28	1.02	No		
2009	12	19	13	5.81	0.31	1.02	No		
2009	12	20	33	14.75	0.78	1.02	No		
2009	12	21	15	6.71	0.36	1.02	No		
2009	12	22	14	6.26	0.33	1.02	No		
2009	12	23	38	16.99	0.90	1.02	No		
2009	12	24	33	14.75	0.78	1.02	No		
2009	12	25	33	14.75	0.78	1.02	No		
2009	12	26	8	3.58	0.19	1.02	No		
2009	12	27	10	4.47	0.24	1.02	No		
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2010	1	14	29	12.96	0.69	1.02	No		
2010	1	15	13	5.81	0.31	1.02	No		
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2010	1	20	18	8.05	0.43	1.02	No		
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2010	1	25	13	5.81	0.31	1.02	No		
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2010	1	30	13	5.81	0.31	1.02	No		
2010	1	31	10	4.47	0.24	1.02	No		
2010	2	1	18	8.05	0.43	1.02	No		
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2010	2	4	17	7.60	0.40	1.02	No		
2010	2	5	9	4.02	0.21	1.02	No		
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2010	2	8	9	4.02	0.21	1.02	No		
2010	2	9	14	6.26	0.33	1.02	No		
2010	2	10	18	8.05	0.43	1.02	No		
2010	2	11	23	10.28	0.54	1.02	No		
2010	2	12	15	6.71	0.36	1.02	No		
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2010	2	14	7	3.13	0.17	1.02	No		
2010	2	15	7	3.13	0.17	1.02	No		
2010	2	16	32	14.31	0.76	1.02	No		
2010	2	17	6	2.68	0.14	1.02	No		
2010	2	18		0.00	0.00	1.02	No		
2010	2	19	12	5.36	0.28	1.02	No		
2010	2	20	13	5.81	0.31	1.02	No		
2010	2	21	10	4.47	0.24	1.02	No		
2010	2	22	13	5.81	0.31	1.02	No		
2010	2	23	10	4.47	0.24	1.02	No		
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2010	2	26	7	3.13	0.17	1.02	No		
2010	2	27	9	4.02	0.21	1.02	No		
2010	2	28	8	3.58	0.19	1.02	No		
2010	3	1	10	4.47	0.24	1.02	No		
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2010	3	3	17	7.60	0.40	1.02	No		
2010	3	4	16	7.15	0.38	1.02	No		
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2010	3	26	36	16.09	0.85	1.02	No		
2010	3	27	30	13.41	0.71	1.02	No		
2010	3	28	21	9.39	0.50	1.02	No		
2010	3	29	24	10.73	0.57	1.02	No		
2010	3	30	49	21.90	1.16	1.02	Yes	4.68	
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2010	4	2	26	11.62	0.62	1.02	No		
2010	4	3	48	21.46	1.14	1.02	Yes	3.73	
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2010	4	23	41	18.33	0.97	1.02	No		
2010	4	24	32	14.31	0.76	1.02	No		
2010	4	25	31	13.86	0.73	1.02	No		
2010	4	26	30	13.41	0.71	1.02	No		
2010	4	27	56	25.03	1.33	1.02	Yes	13.13	
2010	4	28	58	25.93	1.37	1.02	Yes	16.13	
2010	4	29	35	15.65	0.83	1.02	No		
2010	4	30	46	20.56	1.09	1.02	Yes	2.03	
2010	5	1	32	14.31	0.76	1.02	No		
2010	5	2	37	16.54	0.88	1.02	No		
2010	5	3	45	20.12	1.07	1.02	Yes	1.28	
2010	5	4	50	22.35	1.18	1.02	Yes	5.69	
2010	5	5		0.00	0.00	1.02	No		
2010	5	6	31	13.86	0.73	1.02	No		
2010	5	7	17	7.60	0.40	1.02	No		
2010	5	8	27	12.07	0.64	1.02	No		
2010	5	9	31	13.86	0.73	1.02	No		
2010	5	10	38	16.99	0.90	1.02	No		
2010	5	11	55	24.59	1.30	1.02	Yes	11.73	
2010	5	12		0.00	0.00	1.02	No		
2010	5	13	32	14.31	0.76	1.02	No		
2010	5	14	16	7.15	0.38	1.02	No		
2010	5	15	37	16.54	0.88	1.02	No		
2010	5	16		0.00	0.00	1.02	No		
2010	5	17	21	9.39	0.50	1.02	No		
2010	5	18	30	13.41	0.71	1.02	No		
2010	5	19	38	16.99	0.90	1.02	No		
2010	5	20	31	13.86	0.73	1.02	No		
2010	5	21	24	10.73	0.57	1.02	No		
2010	5	22	38	16.99	0.90	1.02	No		
2010	5	23	39	17.43	0.92	1.02	No		
2010	5	24	39	17.43	0.92	1.02	No		
2010	5	25	18	8.05	0.43	1.02	No		
2010	5	26	33	14.75	0.78	1.02	No		
2010	5	27	43	19.22	1.02	1.02	No		
2010	5	28	47	21.01	1.11	1.02	Yes	2.85	
2010	5	29	37	16.54	0.88	1.02	No		

2010	5	30	25	11.18	0.59	1.02	No		
2010	5	31	35	15.65	0.83	1.02	No		
2010	6	1		0.00	0.00	1.02	No		
2010	6	2	24	10.73	0.57	1.02	No		
2010	6	3	27	12.07	0.64	1.02	No		
2010	6	4	38	16.99	0.90	1.02	No		
2010	6	5	24	10.73	0.57	1.02	No		
2010	6	6	32	14.31	0.76	1.02	No		
2010	6	7	32	14.31	0.76	1.02	No		
2010	6	8	21	9.39	0.50	1.02	No		
2010	6	9	32	14.31	0.76	1.02	No		
2010	6	10	25	11.18	0.59	1.02	No		
2010	6	11	27	12.07	0.64	1.02	No		
2010	6	12		0.00	0.00	1.02	No		
2010	6	13	33	14.75	0.78	1.02	No		
2010	6	14	25	11.18	0.59	1.02	No		
2010	6	15	37	16.54	0.88	1.02	No		
2010	6	16	53	23.69	1.26	1.02	Yes	9.12	
2010	6	17	32	14.31	0.76	1.02	No		
2010	6	18	17	7.60	0.40	1.02	No		
2010	6	19	30	13.41	0.71	1.02	No		
2010	6	20	32	14.31	0.76	1.02	No		
2010	6	21	25	11.18	0.59	1.02	No		
2010	6	22	35	15.65	0.83	1.02	No		
2010	6	23	17	7.60	0.40	1.02	No		
2010	6	24	31	13.86	0.73	1.02	No		
2010	6	25	25	11.18	0.59	1.02	No		
2010	6	26	31	13.86	0.73	1.02	No		
2010	6	27	21	9.39	0.50	1.02	No		
2010	6	28		0.00	0.00	1.02	No		
2010	6	29		0.00	0.00	1.02	No		
2010	6	30	28	12.52	0.66	1.02	No		
2010	7	1	36	16.09	0.85	1.02	No		
2010	7	2	39	17.43	0.92	1.02	No		
2010	7	3	25	11.18	0.59	1.02	No		
2010	7	4	31	13.86	0.73	1.02	No		
2010	7	5	30	13.41	0.71	1.02	No		

2010	7	6	30	13.41	0.71	1.02	No		
2010	7	7	30	13.41	0.71	1.02	No		
2010	7	8	31	13.86	0.73	1.02	No		
2010	7	9		0.00	0.00	1.02	No		
2010	7	10	41	18.33	0.97	1.02	No		
2010	7	11	25	11.18	0.59	1.02	No		
2010	7	12	37	16.54	0.88	1.02	No		
2010	7	13	39	17.43	0.92	1.02	No		
2010	7	14	23	10.28	0.54	1.02	No		
2010	7	15	22	9.83	0.52	1.02	No		
2010	7	16	32	14.31	0.76	1.02	No		
2010	7	17		0.00	0.00	1.02	No		
2010	7	18	45	20.12	1.07	1.02	Yes	1.28	
2010	7	19	32	14.31	0.76	1.02	No		
2010	7	20	25	11.18	0.59	1.02	No		
2010	7	21		0.00	0.00	1.02	No		
2010	7	22	33	14.75	0.78	1.02	No		
2010	7	23	25	11.18	0.59	1.02	No		
2010	7	24		0.00	0.00	1.02	No		
2010	7	25	20	8.94	0.47	1.02	No		
2010	7	26	48	21.46	1.14	1.02	Yes	3.73	
2010	7	27		0.00	0.00	1.02	No		
2010	7	28	29	12.96	0.69	1.02	No		
2010	7	29	40	17.88	0.95	1.02	No		
2010	7	30		0.00	0.00	1.02	No		
2010	7	31		0.00	0.00	1.02	No		
2010	8	1	31	13.86	0.73	1.02	No		
2010	8	2	18	8.05	0.43	1.02	No		
2010	8	3	40	17.88	0.95	1.02	No		
2010	8	4	32	14.31	0.76	1.02	No		
2010	8	5		0.00	0.00	1.02	No		
2010	8	6	55	24.59	1.30	1.02	Yes	11.73	
2010	8	7	43	19.22	1.02	1.02	No		
2010	8	8	28	12.52	0.66	1.02	No		
2010	8	9	43	19.22	1.02	1.02	No		
2010	8	10	24	10.73	0.57	1.02	No		
2010	8	11	36	16.09	0.85	1.02	No		

2010	8	12	43	19.22	1.02	1.02	No		
2010	8	13	23	10.28	0.54	1.02	No		
2010	8	14	25	11.18	0.59	1.02	No		
2010	8	15		0.00	0.00	1.02	No		
2010	8	16	37	16.54	0.88	1.02	No		
2010	8	17	16	7.15	0.38	1.02	No		
2010	8	18	32	14.31	0.76	1.02	No		
2010	8	19	30	13.41	0.71	1.02	No		
2010	8	20	24	10.73	0.57	1.02	No		
2010	8	21	28	12.52	0.66	1.02	No		
2010	8	22	54	24.14	1.28	1.02	Yes	10.39	
2010	8	23	23	10.28	0.54	1.02	No		
2010	8	24		0.00	0.00	1.02	No		
2010	8	25		0.00	0.00	1.02	No		
2010	8	26	23	10.28	0.54	1.02	No		
2010	8	27	36	16.09	0.85	1.02	No		
2010	8	28	41	18.33	0.97	1.02	No		
2010	8	29	39	17.43	0.92	1.02	No		
2010	8	30	24	10.73	0.57	1.02	No		
2010	8	31	23	10.28	0.54	1.02	No		
2010	9	1	33	14.75	0.78	1.02	No		
2010	9	2		0.00	0.00	1.02	No		
2010	9	3		0.00	0.00	1.02	No		
2010	9	4	51	22.80	1.21	1.02	Yes	6.77	
2010	9	5	44	19.67	1.04	1.02	Yes	0.59	
2010	9	6	20	8.94	0.47	1.02	No		
2010	9	7	21	9.39	0.50	1.02	No		
2010	9	8	32	14.31	0.76	1.02	No		
2010	9	9	64	28.61	1.52	1.02	Yes	26.70	
2010	9	10	25	11.18	0.59	1.02	No		
2010	9	11	20	8.94	0.47	1.02	No		
2010	9	12	18	8.05	0.43	1.02	No		
2010	9	13	32	14.31	0.76	1.02	No		
2010	9	14	48	21.46	1.14	1.02	Yes	3.73	
2010	9	15		0.00	0.00	1.02	No		
2010	9	16	39	17.43	0.92	1.02	No		
2010	9	17	31	13.86	0.73	1.02	No		

2010	9	18	21	9.39	0.50	1.02	No		
2010	9	19	36	16.09	0.85	1.02	No		
2010	9	20	37	16.54	0.88	1.02	No		
2010	9	21	30	13.41	0.71	1.02	No		
2010	9	22	40	17.88	0.95	1.02	No		
2010	9	23	23	10.28	0.54	1.02	No		
2010	9	24	31	13.86	0.73	1.02	No		
2010	9	25		0.00	0.00	1.02	No		
2010	9	26		0.00	0.00	1.02	No		
2010	9	27	18	8.05	0.43	1.02	No		
2010	9	28	21	9.39	0.50	1.02	No		
2010	9	29		0.00	0.00	1.02	No		
2010	9	30		0.00	0.00	1.02	No		
2010	10	1		0.00	0.00	1.02	No		
2010	10	2		0.00	0.00	1.02	No		
2010	10	3		0.00	0.00	1.02	No		
2010	10	4	37	16.54	0.88	1.02	No		
2010	10	5		0.00	0.00	1.02	No		
2010	10	6	55	24.59	1.30	1.02	Yes	11.73	
2010	10	7	31	13.86	0.73	1.02	No		
2010	10	8	30	13.41	0.71	1.02	No		
2010	10	9	33	14.75	0.78	1.02	No		
2010	10	10	23	10.28	0.54	1.02	No		
2010	10	11	30	13.41	0.71	1.02	No		
2010	10	12		0.00	0.00	1.02	No		
2010	10	13		0.00	0.00	1.02	No		
2010	10	14		0.00	0.00	1.02	No		
2010	10	15	23	10.28	0.54	1.02	No		
2010	10	16	25	11.18	0.59	1.02	No		
2010	10	17	22	9.83	0.52	1.02	No		
2010	10	18		0.00	0.00	1.02	No		
2010	10	19	20	8.94	0.47	1.02	No		
2010	10	20		0.00	0.00	1.02	No		
2010	10	21		0.00	0.00	1.02	No		
2010	10	22	18	8.05	0.43	1.02	No		
2010	10	23	23	10.28	0.54	1.02	No		
2010	10	24	25	11.18	0.59	1.02	No		

2010	10	25	40	17.88	0.95	1.02	No		
2010	10	26	27	12.07	0.64	1.02	No		
2010	10	27	25	11.18	0.59	1.02	No		
2010	10	28		0.00	0.00	1.02	No		
2010	10	29		0.00	0.00	1.02	No		
2010	10	30		0.00	0.00	1.02	No		
2010	10	31		0.00	0.00	1.02	No		
2010	11	1		0.00	0.00	1.02	No		
2010	11	2	27	12.07	0.64	1.02	No		
2010	11	3		0.00	0.00	1.02	No		
2010	11	4		0.00	0.00	1.02	No		
2010	11	5		0.00	0.00	1.02	No		
2010	11	6	22	9.83	0.52	1.02	No		
2010	11	7		0.00	0.00	1.02	No		
2010	11	8	28	12.52	0.66	1.02	No		
2010	11	9	33	14.75	0.78	1.02	No		
2010	11	10		0.00	0.00	1.02	No		
2010	11	11	30	13.41	0.71	1.02	No		
2010	11	12	31	13.86	0.73	1.02	No		
2010	11	13	32	14.31	0.76	1.02	No		
2010	11	14	33	14.75	0.78	1.02	No		
2010	11	15	36	16.09	0.85	1.02	No		
2010	11	16	44	19.67	1.04	1.02	Yes	0.59	
2010	11	17	20	8.94	0.47	1.02	No		
2010	11	18	35	15.65	0.83	1.02	No		
2010	11	19	23	10.28	0.54	1.02	No		
2010	11	20	35	15.65	0.83	1.02	No		
2010	11	21	29	12.96	0.69	1.02	No		
2010	11	22	32	14.31	0.76	1.02	No		
2010	11	23	38	16.99	0.90	1.02	No		
2010	11	24	28	12.52	0.66	1.02	No		
2010	11	25	23	10.28	0.54	1.02	No		
2010	11	26	10	4.47	0.24	1.02	No		
2010	11	27	10	4.47	0.24	1.02	No		
2010	11	28	25	11.18	0.59	1.02	No		
2010	11	29	29	12.96	0.69	1.02	No		
2010	11	30	16	7.15	0.38	1.02	No		

2010	12	1	9	4.02	0.21	1.02	No			
2010	12	2	17	7.60	0.40	1.02	No			
2010	12	3	21	9.39	0.50	1.02	No			
2010	12	4	9	4.02	0.21	1.02	No			
2010	12	5		0.00	0.00	1.02	No			
2010	12	6		0.00	0.00	1.02	No			
2010	12	7	14	6.26	0.33	1.02	No			
2010	12	8	9	4.02	0.21	1.02	No			
2010	12	9	13	5.81	0.31	1.02	No			
2010	12	10	44	19.67	1.04	1.02	Yes	0.59		
2010	12	11	16	7.15	0.38	1.02	No			
2010	12	12		0.00	0.00	1.02	No			
2010	12	13	29	12.96	0.69	1.02	No			
2010	12	14	24	10.73	0.57	1.02	No			
2010	12	15	25	11.18	0.59	1.02	No			
2010	12	16	14	6.26	0.33	1.02	No			
2010	12	17	8	3.58	0.19	1.02	No			
2010	12	18	16	7.15	0.38	1.02	No			
2010	12	19	15	6.71	0.36	1.02	No			
2010	12	20	41	18.33	0.97	1.02	No			
2010	12	21	9	4.02	0.21	1.02	No			
2010	12	22	9	4.02	0.21	1.02	No			
2010	12	23	21	9.39	0.50	1.02	No			
2010	12	24	9	4.02	0.21	1.02	No			
2010	12	25	10	4.47	0.24	1.02	No			
2010	12	26	10	4.47	0.24	1.02	No			
2010	12	27	12	5.36	0.28	1.02	No			
2010	12	28	12	5.36	0.28	1.02	No			
2010	12	29	31	13.86	0.73	1.02	No			
2010	12	30	24	10.73	0.57	1.02	No			
2010	12	31	20	8.94	0.47	1.02	No		165.63	
Notes:	Meteorological data from the Big Piney Station, National Weather Service.							ΣP (avg)	120.02	g/m^2-yr
	1 The conversion from miles per hour to meter per second is 0.44704.							ΣP (avg)	0.122	lb/hr-acre
	2 The friction velocity is calculated using AP-42 Chapter 13 Section 2.5 "Industrial Wind Erosion" Equation 4.							k (PM_{10})[5]	0.5	
	3 The threshold velocity is taken from AP-42 Chapter 13 Section 2.5 "Industrial Wind Erosion" Table 13.2.5-2.							k ($PM_{2.5}$)[5]	0.075	

	4 The erosion potential P is calculated using AP-42 Chapter 13 Section 2.5 "Industrial Wind Erosion" Equation 3.									
	5 k, the particle size multiplier is from AP-42 Chapter 13 Section 2.5 "Industrial Wind Erosion" page 13.2.5-3.									
							Emission Factor (PM_{10})		0.061	lb/hr-acre
							Emission Factor ($PM_{2.5}$)		0.009	lb/hr-acre

4/15/2014 added 25* factor to P eqn

Table 35. Production Wind Erosion - Per Acre of Disturbance

Project: NPL
Scenario: 4 Pad/Section
Activity: Production Wind Erosion

Emissions: Wind Erosion

Emission Factor (PM_{10})[1] : 0.0611 lb/hr-acre
Emission Factor ($PM_{2.5}$)[1] : 0.0092 lb/hr-acre

Control Efficiency[2]: 50 %

Disturbed Area:

Well Pad and Road:	18	acres	assume 30% of pads/facility will have equipment on it
Central Facility:	11	acres	assume 30% of pads/facility will have equipment on it

Emissions Calculations:

	PM_{10} Emission Factor (lb/hr-acre)	$PM_{2.5}$ Emission Factor (lb/hr-acre)	Area (acre)	Control Efficiency (%)	Controlled PM_{10} Emissions (lb/hr)	Controlled $PM_{2.5}$ Emissions (lb/hr)	Controlled PM_{10} Emissions (tons/yr)	Controlled $PM_{2.5}$ Emissions (tons/yr)
Well Pad and Road	0.0611	0.0092	17.94	50	0.55	0.08	2.40	0.36
Compressor Station	0.0611	0.0092	10.50	50	0.32	0.05	1.41	0.21
Total							3.81	0.57

[1] Based on AP-42 Chapter 13.2.5 (EPA 2004), Industrial Wind Erosion using Area meteorological data. See 'WindErosion Data' sheet for details.
[2] AP-42 (EPA 2004), Section 13.2.3, "Heavy Construction Operations".

Table 36. Compressor Engine Emissions

Project: NPL
Scenario: Option 3 - Electric Engines
Effective Dates: All
Emissions: Combustion Emissions from Compressor Engines

Engine	Pollutant	EPA Tier Certification	Pollutant Emission Factor[1]	Engine Count	Horse-power[2]	Overall Load Factor[3]	Annual Activity	Daily Ops	Emissions per Facility	Emissions per Hour	Emissions per Facility	
			(g/hp-hr)		(hp)		(days/yr)	(hrs/day)	(lb/facility)	(lb/hr)	(tons)	
Cat 3612 w/SCO AFRC	CO	Electric	0.00	1	3,500	0.90	365	24	0.00	0.00	0.00	0.170732
Combustion	NOx	Electric	0.00	1	3,500	0.90	365	24	0.00	0.00	0.00	
	SO_2	Electric	0.00	1	3,500	0.90	365	24	0.00	0.00	0.00	
	VOC	Electric	0.00	1	3,500	0.90	365	24	0.00	0.00	0.00	
	PM_{10}	Electric	0.00	1	3,500	0.90	365	24	0.00	0.00	0.00	
	$PM_{2.5}$	Electric	0.00	1	3,500	0.90	365	24	0.00	0.00	0.00	
	Benzene	Electric	0.00	1	3,500	0.90	365	24	0.00	0.00	0.00	
	Ethylbenzene	Electric	0.00	1	3,500	0.90	365	24	0.00	0.00	0.00	
	Formaldehyde	Electric	0.00	1	3,500	0.90	365	24	0.00	0.00	0.00	
	H_2S	Electric	0.00	1	3,500	0.90	365	24	0.00	0.00	0.00	
	n-Hexane	Electric	0.00	1	3,500	0.90	365	24	0.00	0.00	0.00	
	Toluene	Electric	0.00	1	3,500	0.90	365	24	0.00	0.00	0.00	
	Xylenes	Electric	0.00	1	3,500	0.90	365	24	0.00	0.00	0.00	
	CH_4	Electric	0.00	1	3,500	0.90	365	24	0.00	0.00	0.00	
	CO_2	Electric	0.00	1	3,500	0.90	365	24	0.00	0.00	0.00	
	N_2O	Electric	0.00	1	3,500	0.90	365	24	0.00	0.00	0.00	

Engine	Pollutant	Compressor Volume (scf)[4]	Events per Year	MW Gas	Weight Fraction	lb/compressor-	lb/hr	/compressor-yr
Cat 3612 w/SCO AFRC	CO							
Blowdown	NOx							
	SO_2							
	VOC	650	24	18.53	0.12	91.45	0.01	0.05
	PM_{10}							
	$PM_{2.5}$							
	Benzene	650	24	18.53	5.12E-04	0.39	0.00	0.00
	Ethylbenzene	650	24	18.53	3.07E-05	0.02	0.00	0.00
	Formaldehyde							
	H_2S							
	n-Hexane	650	24	18.53	2.30E-03	1.75	0.00	0.00
	Toluene	650	24	18.53	7.57E-04	0.58	0.00	0.00
	Xylenes	650	24	18.53	2.80E-04	0.21	0.00	0.00
	CH_4	650	24	18.53	0.782	595.86	0.07	0.30
	CO_2	650	24	18.53	1.28E-02	9.77	0.00	0.00
	N_2O							

Engine	Pollutant	Emissions per Facility (lb/facility)	Emissions per Hour (lb/hr)	Emissions per Facility (tons)
Total	CO	0.00	0.00	0.00
	NOx	0.00	0.00	0.00
	SO_2	0.00	0.00	0.00
	VOC	91.45	0.01	0.05
	PM_{10}	0.00	0.00	0.00
	$PM_{2.5}$	0.00	0.00	0.00

Benzene	0.39	0.00	0.00
Ethylbenzene	0.02	0.00	0.00
Formaldehyde	0.00	0.00	0.00
H_2S	0.00	0.00	0.00
n-Hexane	1.75	0.00	0.00
Toluene	0.58	0.00	0.00
Xylenes	0.21	0.00	0.00
CH_4	595.86	0.07	0.30
CO_2	9.77	0.00	0.00
N_2O	0.00	0.00	0.00

ton/yr

Facility	Year	HP	Engine Count	CO	NOx	PM_{10}	$PM_{2.5}$	SO_2	VOC	Benzene	Ethylbenzen	Formaldehyd	H_2S	n-Hexane	Toluene	Xylenes	CH_4	CO_2	N_2O
1	9	10118	3	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.89	0.01	0.00
2	9	6475	2	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.60	0.01	0.00
3	9	10118	3	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.89	0.01	0.00
4	9	6475	2	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.60	0.01	0.00
5	9	6475	2	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.60	0.01	0.00
6	9	10118	3	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.89	0.01	0.00
7	9	6475	2	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.60	0.01	0.00
8	9	6475	2	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.60	0.01	0.00
9	9	6475	2	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.60	0.01	0.00
10	9	3373	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.00	0.00
11	9	3373	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.00	0.00
									1.05										

[1] Emission factors taken from EMIT quotes for emissions control devices and used for previously permitted engines.
[2] Justin Barberio - assume 140hp/MMscfd.
[3] Justin Barberio.
[4] API Greenhouse Gas Compendium Table 5-21 (2004). Includes both start-ups and blowdown

Project: Jonah NPL
Scenario: Horsepower
Activity: Production Facility Development
Emissions:

Date:

Facility	Year									
	1	2	3	4	5	6	7	8	9	10
1	10118	10118	10118	10118	10118	10118	10118	10118	10118	10118
2	6475	6475	6475	6475	6475	6475	6475	6475	6475	6475
3	6475	10118	6475	10118	10118	10118	10118	10118	10118	10118
4		3373	6475	6475	6475	6475	6475	6475	6475	6475
5		3373	6475	6475	6475	6475	6475	6475	6475	6475
6			3373	6475	6475	10118	10118	10118	10118	10118
7				3373	6475	6475	6475	6475	6475	6475
8				3373	6475	6475	6475	6475	6475	6475
9						3373	3373	6475	6475	6475
10							3373	3373	3373	3373
11									3373	3373
Totals	23068	33457	39391	52882	59086	66102	69475	72577	75950	75950

NPL Project General Conformity Emissions Inventory

Table 37. Misc Compressor Engine Emissions

Project: NPL
Scenario: Option 3 - Electric Engines
Effective Dates: All
Emissions: Natural Gas Combustion Emissions from Misc Engines

Engine	Pollutant	EPA Tier Certification	Pollutant Emission Factor	Engine Count	Horse power	Overall Load Factor	Annual Activity	Daily Ops	Emissions per Hour	Emissions per Year
			(g/hp-hr)		(hp)		(days/yr)	(hrs/day)	(lb/hr)	(tons/yr)
Generac GS140	CO	Electric	0.00	3	175	0.90	365	24	0.00	0.00
Generator	NOx	Electric	0.00	3	175	0.90	365	24	0.00	0.00
Water Mng Facilities	SO_2	Electric	0.00	3	175	0.90	365	24	0.00	0.00
	VOC	Electric	0.00	3	175	0.90	365	24	0.00	0.00
	PM_{10}	Electric	0.00	3	175	0.90	365	24	0.00	0.00
	$PM_{2.5}$	Electric	0.00	3	175	0.90	365	24	0.00	0.00
	Benzene	Electric	0.00	3	175	0.90	365	24	0.00	0.00
	Ethylbenzene	Electric	0.00	3	175	0.90	365	24	0.00	0.00
	Formaldehyde	Electric	0.00	3	175	0.90	365	24	0.00	0.00
	H_2S	Electric	0.00	3	175	0.90	365	24	0.00	0.00
	n-Hexane	Electric	0.00	3	175	0.90	365	24	0.00	0.00
	Toluene	Electric	0.00	3	175	0.90	365	24	0.00	0.00
	Xylenes	Electric	0.00	3	175	0.90	365	24	0.00	0.00
	CH_4	Electric	0.00	3	175	0.90	365	24	0.00	0.00
	CO_2	Electric	0.00	3	175	0.90	365	24	0.00	0.00
	N_2O	Electric	0.00	3	175	0.90	365	24	0.00	0.00
Caterpillar 3512	CO	Electric	0.00	3	950	0.90	365	24	0.00	0.00
Water Injection	NOx	Electric	0.00	3	950	0.90	365	24	0.00	0.00
Water Mng Facilities	SO_2	Electric	0.00	3	950	0.90	365	24	0.00	0.00
	VOC	Electric	0.00	3	950	0.90	365	24	0.00	0.00
	PM_{10}	Electric	0.00	3	950	0.90	365	24	0.00	0.00
	$PM_{2.5}$	Electric	0.00	3	950	0.90	365	24	0.00	0.00
	Benzene	Electric	0.00	3	950	0.90	365	24	0.00	0.00
	Ethylbenzene	Electric	0.00	3	950	0.90	365	24	0.00	0.00
	Formaldehyde	Electric	0.00	3	950	0.90	365	24	0.00	0.00
	H_2S	Electric	0.00	3	950	0.90	365	24	0.00	0.00
	n-Hexane	Electric	0.00	3	950	0.90	365	24	0.00	0.00
	Toluene	Electric	0.00	3	950	0.90	365	24	0.00	0.00
	Xylenes	Electric	0.00	3	950	0.90	365	24	0.00	0.00
	CH_4	Electric	0.00	3	950	0.90	365	24	0.00	0.00
	CO_2	Electric	0.00	3	950	0.90	365	24	0.00	0.00
	N_2O	Electric	0.00	3	950	0.90	365	24	0.00	0.00
VRU Compression	CO	Electric	0.00							
	NOx	Electric	0.00							
	SO_2	Electric	0.00							
	VOC	Electric	0.00							
	PM_{10}	Electric	0.00							
	$PM_{2.5}$	Electric	0.00							
	Benzene	Electric	0.00							
	Ethylbenzene	Electric	0.00							
	Formaldehyde	Electric	0.00							
	H_2S	Electric	0.00							
	n-Hexane	Electric	0.00							
	Toluene	Electric	0.00							
	Xylenes	Electric	0.00							
	CH_4	Electric	0.00							
	CO_2	Electric	0.00							
	N_2O	Electric	0.00							

Facility (VRU)	HP	Hours	Load	CO	NOx	PM_{10}	$PM_{2.5}$	SO_2	VOC	Benzene	Ethylbenzene (ton/yr)	Formaldehyde	H_2S	n-Hexane	Toluene	Xylenes	CH_4	CO_2	N_2O
1	240	8585	100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	160	8585	100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	240	8585	100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	160	8585	100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	160	8585	100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	240	8585	100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	130	8585	100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	160	8585	100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	130	8585	100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	80	8585	100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	35	8585	100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

NPL Project General Conformity Emissions Inventory

Table 38. Separator/Indirect Line Heaters

Electric therefore emissions are set to zero

Project: NPL
Scenario: All
Activity: Production
Emissions: Separator/Line Heaters

Fuel Combustion Source:

Unit Description	Separator/Line Heaters	
Average Design Firing Rate	0.33	MMBTU/hr

Operating Parameters:

Annual Operating hours	4380	
	Total Hours	% Operating
Winter (Nov. - Apr.)	4344	85
Summer (May - Oct.)	4416	15.6

Actual Fuel Combustion for the Year for Unit:

Average Natural Gas Combusted	1.29	MMscf/yr
Fuel Heating Value (actual)	1,124	Btu/scf
Fuel Heating Value (Em. Factor)	1,020	Btu/scf

Potential Emission Data:

	Emission Factor (lb/MMscf)	(lb/hr) Winter	(lb/hr) Summer	(lb/facility) Total
Total PM	0.0	0.00000	0.00000	0.000
SO_2	0.0	0.00000	0.00000	0.000
NO_x	0.0	0.00000	0.00000	0.000
CO	0.0	0.00000	0.00000	0.000
VOC	0.0	0.00000	0.00000	0.000

	Emission Factor (lb/MMscf)	(lb/hr) Winter	(lb/hr) Summer	(lb/facility) Total
Benzene	0.0	0.00000	0.00000	0.000
Ethylbenzene	0.0	0.00000	0.00000	0.000
Formaldehyde	0.0	0.00000	0.00000	0.000
H_2S	0.0	0.00000	0.00000	0.000
n-Hexane	0.0	0.00000	0.00000	0.000

	Emission Factor[2] (lb/MMscf)	(lb/hr) Winter	(lb/hr) Summer	(lb/facility) Total
Toluene	0.00E+00	0.00000	0.00000	0.000
Xylenes	0.0	0.00000	0.00000	0.000
CH_4	0.00	0.00000	0.00000	0.000
CO_2	0.00E+00	0.00000	0.00000	0.000
N_2O	0.00	0.00000	0.00000	0.000

ton/yr

Facility	MMbtu/hr	CO	NOx	PM_{10}	$PM_{2.5}$	SO_2	VOC	Benzene	Ethylbenzen	Formaldehyd	H_2S	n-Hexane	Toluene	Xylenes	CH_4	CO_2	N_2O
1	0.5	0.00	0.00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00
2	0.35	0.00	0.00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00
3	0.5	0.00	0.00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00
4	0.35	0.00	0.00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00
5	0.35	0.00	0.00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00
6	0.5	0.00	0.00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00
7	0.25	0.00	0.00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00
8	0.35	0.00	0.00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00
9	0.25	0.00	0.00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00
10	0.16	0.00	0.00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00
11	0.1	0.00	0.00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00

NPL Project General Conformity Emissions Inventory

Table 39. Dehy Reboiler Heater

Electric therefore emissions are set to zero

Project: NPL
Scenario: All
Activity: Production
Emissions: Dehy Reboiler Heater

Fuel Combustion Source:

Unit Description	Dehy Reboiler Heater	
Average Design Firing Rate	1.47	MMBTU/hr

Operating Parameters:

Annual Operating hours	6570	
	Total Hours	Operation %
Winter (Nov. - Apr.)	4344	100
Summer (May - Oct.)	4416	50.5

Actual Fuel Combustion for the Year for Unit:

Average Natural Gas Combusted	8.59	MMscf/yr
Fuel Heating Value (actual)	1,124	Btu/scf
Fuel Heating Value (Em. Factor)	1,020	Btu/scf

Potential Emission Data:

	Emission Factor (lb/MMscf)	(lb/hr) Winter	(lb/hr) Summer	(lb/facility) Total
Total PM	0.0	0.00000	0.00000	0.000
SO_2	0.0	0.00000	0.00000	0.000
NO_x	0.0	0.00000	0.00000	0.000
CO	0.0	0.00000	0.00000	0.000
VOC	0.0	0.00000	0.00000	0.000

	Emission Factor (lb/MMscf)	(lb/hr) Winter	(lb/hr) Summer	(lb/facility) Total
Benzene	0.0E+00	0.00000	0.00000	0.000
Ethylbenzene	0.0	0.00000	0.00000	0.000
Formaldehyde	0.0E+00	0.00000	0.00000	0.000
H_2S	0.0	0.00000	0.00000	0.000
n-Hexane	0.0	0.00000	0.00000	0.000

	Emission Factor[2] (lb/MMscf)	(lb/hr) Winter	(lb/hr) Summer	(lb/facility) Total
Toluene	0.00E+00	0.00000	0.00000	0.000
Xylenes	0.0	0.00000	0.00000	0.000
CH_4	0.00	0.00000	0.00000	0.000
CO_2	0.00E+00	0.00000	0.00000	0.000
N_2O	0.00	0.00000	0.00000	0.000

ton/yr

Facility	MMbtu/hr	CO	NOx	PM_{10}	$PM_{2.5}$	SO_2	VOC	Benzene	Ethylbenzen	Formaldehyd	H_2S	n-Hexane	Toluene	Xylenes	CH_4	CO_2	N_2O
1	2.25	0.00	0.00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00
2	1.5	0.00	0.00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00
3	2.25	0.00	0.00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00
4	1.5	0.00	0.00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00
5	1.5	0.00	0.00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00
6	2.25	0.00	0.00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00
7	1.2	0.00	0.00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00
8	1.5	0.00	0.00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00
9	1.2	0.00	0.00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00
10	0.75	0.00	0.00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00
11	0.3	0.00	0.00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00

NPL Project General Conformity Emissions Inventory

Table 40. Dehy Flash Tank Heater

Electric therefore emissions are set to zero

Project: **NPL**
Scenario: **All**
Activity: **Production**
Emissions: **Dehy Flash Tank Heater**

Fuel Combustion Source:

Unit Description	Flash Tank Heaters	
Average Design Firing Rate	0.12	MMBTU/hr

Operating Parameters:

Annual Operating hours	4380	
	Total Hours	Operation %
Winter (Nov. - Apr.)	4344	85
Summer (May - Oct.)	4416	15.6

Actual Fuel Combustion for the Year for Unit:

Average Natural Gas Combusted	0.47	MMscf/yr
Fuel Heating Value (actual)	1,124	Btu/scf
Fuel Heating Value (Em. Factor)	1,020	Btu/scf

Potential Emission Data:

	Emission Factor (lb/MMscf)	(lb/hr) Winter	(lb/hr) Summer	(lb/facility) Total
Total PM	0.0	0.00000	0.00000	0.000
SO_2	0.0	0.00000	0.00000	0.000
NO_x	0.0	0.00000	0.00000	0.000
CO	0.0	0.00000	0.00000	0.000
VOC	0.0	0.00000	0.00000	0.000

	Emission Factor (lb/MMscf)	(lb/hr) Winter	(lb/hr) Summer	(lb/facility) Total
Benzene	0.0E+00	0.00000	0.00000	0.000
Ethylbenzene	0.0	0.00000	0.00000	0.000
Formaldehyde	0.0E+00	0.00000	0.00000	0.000
H_2S	0.0	0.00000	0.00000	0.000
n-Hexane	0.0	0.00000	0.00000	0.000

	Emission Factor[2] (lb/MMscf)	(lb/hr) Winter	(lb/hr) Summer	(lb/facility) Total
Toluene	0.00E+00	0.00000	0.00000	0.000
Xylenes	0.0	0.00000	0.00000	0.000
CH_4	0.00	0.00000	0.00000	0.000
CO_2	0.00E+00	0.00000	0.00000	0.000
N_2O	0.00	0.00000	0.00000	0.000

ton/yr

Facility	MMbtu/hr	CO	NOx	PM_{10}	$PM_{2.5}$	SO_2	VOC	Benzene	Ethylbenzen	Formaldehyd	H_2S	n-Hexane	Toluene	Xylenes	CH_4	CO_2	N_2O
1	0.12	0.00	0.00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00
2	0.12	0.00	0.00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00
3	0.12	0.00	0.00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00
4	0.12	0.00	0.00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00
5	0.12	0.00	0.00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00
6	0.12	0.00	0.00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00
7	0.12	0.00	0.00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00
8	0.12	0.00	0.00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00
9	0.12	0.00	0.00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00
10	0.12	0.00	0.00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00
11	0.12	0.00	0.00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00

NPL Project General Conformity Emissions Inventory

Table 41. Condensate Tank Heater

Electric therefore emissions are set to zero

Project: NPL
Scenario: All
Activity: Production
Emissions: Condensate Tank Heater

Fuel Combustion Source:

Unit Description	Condensate Tank Heaters	
Average Design Firing Rate	0.16	MMBTU/hr

Operating Parameters:

Annual Operating hours	6570	
	Total Hours	Operation %
Winter (Nov. - Apr.)	4344	100
Summer (May - Oct.)	4416	34

Actual Fuel Combustion for the Year for Unit:

Average Natural Gas Combusted	0.94	MMscf/yr
Fuel Heating Value (actual)	1,124	Btu/scf
Fuel Heating Value (Em. Factor)	1,020	Btu/scf

Potential Emission Data:

	Emission Factor (lb/MMscf)	(lb/hr) Winter	(lb/hr) Summer	(lb/facility) Total
Total PM	0.0	0.00000	0.00000	0.000
SO_2	0.0	0.00000	0.00000	0.000
NO_x	0.0	0.00000	0.00000	0.000
CO	0.0	0.00000	0.00000	0.000
VOC	0.0	0.00000	0.00000	0.000

	Emission Factor (lb/MMscf)	(lb/hr) Winter	(lb/hr) Summer	(lb/facility) Total
Benzene	0.0E+00	0.00000	0.00000	0.000
Ethylbenzene		0.00000	0.00000	0.000
Formaldehyde	0.0E+00	0.00000	0.00000	0.000
H_2S		0.00000	0.00000	0.000
n-Hexane	0.0	0.00000	0.00000	0.000

	Emission Factor[2] (lb/MMscf)	(lb/hr) Winter	(lb/hr) Summer	(lb/facility) Total
Toluene	0.00E+00	0.00000	0.00000	0.000
Xylenes	0.0	0.00000	0.00000	0.000
CH_4	0.00	0.00000	0.00000	0.000
CO_2	0.00E+00	0.00000	0.00000	0.000
N_2O	0.00	0.00000	0.00000	0.000

ton/yr

Facility	MMbtu/hr	CO	NOx	PM_{10}	$PM_{2.5}$	SO_2	VOC	Benzene	Ethylbenzen	Formaldehyd	H_2S	n-Hexane	Toluene	Xylenes	CH_4	CO_2	N_2O
1	0.16	0.00	0.00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00
2	0.16	0.00	0.00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00
3	0.16	0.00	0.00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00
4	0.16	0.00	0.00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00
5	0.16	0.00	0.00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00
6	0.16	0.00	0.00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00
7	0.16	0.00	0.00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00
8	0.16	0.00	0.00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00
9	0.16	0.00	0.00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00
10	0.16	0.00	0.00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00
11	0.16	0.00	0.00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00

Table 42. Dehydrator Flashing

Project: NPL
Scenario: Option 3 - Electric Engines and VRU Control/Combustor backup
Activity: Production
Emissions: TEG Dehydrator Emissions

Pollutant	Uncontrolled[1] (tpy)	Uncontrolled[1] (lb/hr)	Controlled[2] (tpy)	Controlled[2] (lb/hr)
VOC	171.47	39.15	0.07	0.02
HAP	101.95	23.28	0.04	0.01
Benzene	16.63	3.80	0.01	0.00
Ethylbenzene	2.76	0.63	0.00	0.00
Formaldehyde	0.00			
H_2S	0.00			
n-Hexane	2.00	0.46	0.00	0.00
Toluene	41.64	9.51	0.02	0.00
Xylenes	38.67	8.83	0.02	0.00
CH_4	74.06	16.91	0.03	0.01
CO_2	3.74	0.86	0.00	0.00

Throughput (MMscf/day)	49
Regenerator Flow (scf/day)	802
Regenerator HV (btu/scf)	2074
Flash Tank Flow (scf/day)	107448
Flash Tank HV (btu/scf)	1250
Combustor Control Efficiency	0.98
Fraction Combustor Operation	0.02
VRU Control Efficiency	1
Fraction VRU Operation	0.98

Combustion Emission Factor[3]

CO	0.37	lb/MMbtu	
CO_2[4]	0.30	lb/scf	Regenator
CO_2[4]	0.16	lb/scf	Flash Tank
Formaldehyde	8.10E-05	lb/MMbtu	
NOx	0.14	lb/MMbtu	
PM_{10}	0.007	lb/MMbtu	
$PM_{2.5}$	0.007	lb/MMbtu	
N_2O[5]	1.04E-07	lb/MMbtu	
SO_2	0	lb/MMbtu	

		From Combustor					ton/yr									From Combustor	
Facility	Throughput (MMscf/day)	CO	NOx	PM_{10}	$PM_{2.5}$	SO_2	VOC	Benzene	Ethylbenzene	Formaldehyde	H_2S	n-Hexane	Toluene	Xylenes	CH_4	CO_2	N_2O
1	75	0.28	0.11	0.005	0.005	0	0.10	1.02E-02	1.69E-03	6.16E-05	0	0.00	0.03	0.02	0.05	94.81	7.90E-08
2	50	0.19	0.07	0.004	0.004	0	0.07	6.79E-03	1.12E-03	4.10E-05	0	0.00	0.02	0.02	0.03	63.21	5.27E-08
3	75	0.28	0.11	0.005	0.005	0	0.10	1.02E-02	1.69E-03	6.16E-05	0	0.00	0.03	0.02	0.05	94.81	7.90E-08
4	50	0.19	0.07	0.004	0.004	0	0.07	6.79E-03	1.12E-03	4.10E-05	0	0.00	0.02	0.02	0.03	63.21	5.27E-08
5	50	0.19	0.07	0.004	0.004	0	0.07	6.79E-03	1.12E-03	4.10E-05	0	0.00	0.02	0.02	0.03	63.21	5.27E-08
6	75	0.28	0.11	0.005	0.005	0	0.10	1.02E-02	1.69E-03	6.16E-05	0	0.00	0.03	0.02	0.05	94.81	7.90E-08
7	40	0.15	0.06	0.003	0.003	0	0.06	5.43E-03	9.00E-04	3.28E-05	0	0.00	0.01	0.01	0.02	50.56	4.21E-08
8	50	0.19	0.07	0.004	0.004	0	0.07	6.79E-03	1.12E-03	4.10E-05	0	0.00	0.02	0.02	0.03	63.21	5.27E-08
9	40	0.15	0.06	0.003	0.003	0	0.06	5.43E-03	9.00E-04	3.28E-05	0	0.00	0.01	0.01	0.02	50.56	4.21E-08
10	25	0.09	0.04	0.002	0.002	0	0.03	3.39E-03	5.62E-04	2.05E-05	0	0.00	0.01	0.01	0.02	31.60	2.63E-08
11	10	0.04	0.01	0.001	0.001	0	0.01	1.36E-03	2.25E-04	8.21E-06	0	0.00	0.00	0.00	0.01	12.64	1.05E-08

[1] Data based on GRI-GLYCalc V. 4.0, 49 MMSCFD, max glycol flow rate, average representative gas analysis. See supporting documentation for details.
[2] 100% VRU control efficiency 98% of the operational time and 98% combustor control efficiency 2% of the operational time.
[3] Emission factors taken from WDEQ "Oil and Gas Production Facilities - Chapter 6, Section 2 Permitting Guidance", AP-42 (EPA 1998) Table 1.4-2, and (API 2009).
[4] For composition of vented streams, see 'Material Balance' sheet.
[5] Greenhouse Gas Compendium (API 2009) Table 4-5.

NPL Project General Conformity Emissions Inventory

Table 43. Pneumatic Venting

Air or Electric, so no emissions

Project: NPL
Scenario: Option 3 - Electric Engines and VRU Control/Combustor backup
Activity: Production
Emissions: Pneumatic Emissions

Pollutant	Weight Fractions	Uncontrolled (tpy)	Uncontrolled (lb/hr)	Controlled (tpy)	Controlled (lb/hr)
VOC	0.00	0.00	0.00	0.00	0.00
HAP	0	0.00	0.00	0.00	0.00
Benzene	0.00E+00	0.00	0.00	0.00	0.00
Ethylbenzene	0.00E+00	0.00	0.00	0.00	0.00
Formaldehyde	0.00E+00				
H_2S	0.00E+00				
n-Hexane	0.00E+00	0.00	0.00	0.00	0.00
Toluene	0.00E+00	0.00	0.00	0.00	0.00
Xylenes	0.00E+00	0.00	0.00	0.00	0.00
CH_4	0.00	0.00	0.00	0.00	0.00
CO_2	0.000	0.00	0.00	0.00	0.00

Model	Flow (scf/hr)	Count	Op Hours
Textsteam 5000 Methai	50	2	4380
Husky-Wilden 1040 Gly	600	5	4380

Parameter	Value	Units
Gas Molecular Weight	18.426	lb/lb-mol
Fuel Heating Value (actual)	0	Btu/scf
Fuel Heating Value (Em. Factor)[1]	1,020	Btu/scf
Combustor Control Efficiency	0.98	
Fraction Combustor Operation	0.02	
VRU Control Efficiency	1	
Fraction VRU Operation	0.98	

Combustor Emission Factor[3]		
CO	0.37	lb/MMbtu
CO_2	0.00	lb/scf
Formaldehyde	8.10E-05	lb/MMbtu
NOx	0.14	lb/MMbtu
PM_{10}	0.007	lb/MMbtu
$PM_{2.5}$	0.007	lb/MMbtu
N_2O	1.04E-07	lb/MMbtu
SO_2	0	lb/MMbtu

ton/yr

Facility	CO (From Combustor)	NOx (From Combustor)	PM_{10} (From Combustor)	$PM_{2.5}$ (From Combustor)	SO_2 (From Combustor)	VOC	Benzene	Ethylbenzen	Formaldehyd	H_2S	n-Hexane	Toluene	Xylenes	CH_4	CO_2 (From Combustor)	N_2O (From Combustor)
1	0.00	0.00	0.00E+00	0.00E+00	0	0.00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00E+00
2	0.00	0.00	0.00E+00	0.00E+00	0	0.00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00E+00
3	0.00	0.00	0.00E+00	0.00E+00	0	0.00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00E+00
4	0.00	0.00	0.00E+00	0.00E+00	0	0.00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00E+00
5	0.00	0.00	0.00E+00	0.00E+00	0	0.00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00E+00
6	0.00	0.00	0.00E+00	0.00E+00	0	0.00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00E+00
7	0.00	0.00	0.00E+00	0.00E+00	0	0.00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00E+00
8	0.00	0.00	0.00E+00	0.00E+00	0	0.00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00E+00
9	0.00	0.00	0.00E+00	0.00E+00	0	0.00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00E+00
10	0.00	0.00	0.00E+00	0.00E+00	0	0.00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00E+00
11	0.00	0.00	0.00E+00	0.00E+00	0	0.00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00E+00

Air or Electric, so no emissions

NPL Project General Conformity Emissions Inventory

Table 44. Fugitive Emissions - Per Facility

Project: NPL
Scenario: All
Activity: Production
Emissions: Fugitive VOC/HAP Emissions

Gas Analysis Weight Fraction[1]		Condensate Analysis Weight Fraction[1]		Water Analysis Weight Fraction[2]		DI&M Control Efficiency
VOC	0.11417	VOC	0.98420	VOC	0.29200	75.0%
Benzene	0.00051	Benzene	0.00871	Benzene	0.00052	
Toluene	0.00076	Toluene	0.04993	Toluene	0.00091	
Ethlybenzene	0.00003	Ethlybenzene	0.00682	Ethlybenze	0.00003	
Xylene	0.00028	Xylene	0.05377	Xylene	0.00036	
n-hexane	0.00230	n-hexane	0.01550	n-hexane	0.00131	
CH_4	0.78186	CH_4	0.00807	CH_4	0.00239	
CO_2	0.01281	CO_2	0.00037	CO_2	0.00011	

Source	Service	Quantity	Emission Factor[2] (lb/hr/component)	Non-methane Hydrocarbons[3] (lb/hr)	Non-methane Hydrocarbons (tpy)	Benzene[3] (lb/hr)	Benzene (tpy)	Toluene[3] (lb/hr)	Toluene (tpy)	Ethlybenzene[3] (lb/hr)	Ethlybenzene (tpy)	Xylenes[3] (lb/hr)	Xylenes (tpy)	n-Hexane[3] (lb/hr)	n-Hexane (tpy)	CH_4[3] (lb/hr)	CH_4 (tpy)	CO_2[3] (lb/hr)	CO_2 (tpy)
Valves	Gas	577	0.01	0.1647	0.721	0.00074	0.00323	0.00109	0.00478	0.000044	0.000194	0.00040	0.00177	0.00332	0.0145	1.1278	4.9399	0.0185	0.0810
Flanges	Gas	407	0.000875	0.0102	0.045	0.00005	0.00020	0.00007	0.00030	0.000003	0.000012	0.00002	0.00011	0.00020	0.0009	0.0696	0.3049	0.0011	0.0050
Connections	Gas	5386	0.000458	0.0704	0.308	0.00032	0.00138	0.00047	0.00204	0.000019	0.000083	0.00017	0.00076	0.00142	0.0062	0.4822	2.1119	0.0079	0.0346
Pump seals	Gas	2	0.00542	0.0003	0.001	0.00000	0.00001	0.00000	0.00001	0.000000	0.000000	0.00000	0.00000	0.00001	0.0000	0.0021	0.0093	0.0000	0.0002
Open ended lines	Gas	80	0.004583	0.0105	0.046	0.00005	0.00021	0.00007	0.00030	0.000003	0.000012	0.00003	0.00011	0.00021	0.0009	0.0717	0.3139	0.0012	0.0051
Other	Gas	522	0.01958	0.2917	1.278	0.00131	0.00572	0.00193	0.00847	0.000079	0.000344	0.00072	0.00314	0.00588	0.0258	1.9978	8.7503	0.0327	0.1434
Valves	Light Liquids	40	0.00542	0.0062	0.027	0.00003	0.00012	0.00004	0.00018	0.000002	0.000007	0.00002	0.00007	0.00012	0.0005	0.0424	0.1855	0.0007	0.0030
Flanges	Light Liquids	0	0.00024	0.0000	0.000	0.00000	0.00000	0.00000	0.00000	0.000000	0.000000	0.00000	0.00000	0.00000	0.0000	0.0000	0.0000	0.0000	0.0000
Connections	Light Liquids	1084	0.00046	0.0142	0.062	0.00006	0.00028	0.00009	0.00041	0.000004	0.000017	0.00003	0.00015	0.00029	0.0013	0.0970	0.4250	0.0016	0.0070
Pump seals	Light Liquids	0	0.02875	0.0000	0.000	0.00000	0.00000	0.00000	0.00000	0.000000	0.000000	0.00000	0.00000	0.00000	0.0000	0.0000	0.0000	0.0000	0.0000
Open ended lines	Light Liquids	0	0.00310	0.0000	0.000	0.00000	0.00000	0.00000	0.00000	0.000000	0.000000	0.00000	0.00000	0.00000	0.0000	0.0000	0.0000	0.0000	0.0000
Other	Light Liquids	0	0.01667	0.0000	0.000	0.00000	0.00000	0.00000	0.00000	0.000000	0.000000	0.00000	0.00000	0.00000	0.0000	0.0000	0.0000	0.0000	0.0000
Valves	Water-Oil	108	0.00022	0.0007	0.003	0.00000	0.00001	0.00000	0.00002	0.000000	0.000001	0.00000	0.00001	0.00001	0.0001	0.0046	0.0201	0.0001	0.0003
Flanges	Water-Oil	0	0.00001	0.0000	0.000	0.00000	0.00000	0.00000	0.00000	0.000000	0.000000	0.00000	0.00000	0.00000	0.0000	0.0000	0.0000	0.0000	0.0000
Connections	Water-Oil	1488	0.00024	0.0103	0.045	0.00005	0.00020	0.00007	0.00030	0.000003	0.000012	0.00003	0.00011	0.00021	0.0009	0.0704	0.3083	0.0012	0.0051
Pump seals	Water-Oil	6	0.00005	0.0000	0.000	0.00000	0.00000	0.00000	0.00000	0.000000	0.000000	0.00000	0.00000	0.00000	0.0000	0.0001	0.0003	0.0000	0.0000
Open ended lines	Water-Oil	0	0.00054	0.0000	0.000	0.00000	0.00000	0.00000	0.00000	0.000000	0.000000	0.00000	0.00000	0.00000	0.0000	0.0000	0.0000	0.0000	0.0000
Other	Water-Oil	16	0.03083	0.0141	0.062	0.00006	0.00028	0.00009	0.00041	0.000004	0.000017	0.00003	0.00015	0.00028	0.0012	0.0964	0.4224	0.0016	0.0069
			Total Emissions/Facility	0.5932	2.5980	0.0027	0.0116	0.0039	0.0172	0.0002	0.0007	0.0015	0.0064	0.0120	0.0524	4.0620	17.7917	0.0666	0.2916

[1] See 'Material Balance' sheet.
[1] "Oil and Gas Production Facilities Chapter 6, Section 2 Permitting Guidance" (WDEQ 2010).

NPL Project General Conformity Emissions Inventory

Table 45. Fugitive HAPs and VOC - Per Wellhead

Project: NPL
Scenario: All
Activity: Production
Emissions: Fugitive VOC/HAP Emissions

Gas Analysis Weight Fraction		Condensate Analysis Weight Fraction		Water Analysis Weight Fraction	
VOC	0.11417	VOC	0.98420	VOC	0.29200
Benzene	0.00051	Benzene	0.00871	Benzene	0.00052
Toluene	0.00076	Toluene	0.04993	Toluene	0.00091
Ethlybenzene	0.00003	Ethlybenzene	0.00682	Ethlybenze	0.00003
Xylene	0.00028	Xylene	0.05377	Xylene	0.00036
n-hexane	0.00230	n-hexane	0.01550	n-hexane	0.00131
CH_4	0.78186	CH_4	0.00807	CH_4	0.00239
CO_2	0.01281	CO_2	0.00037	CO_2	0.00011

Source	Service	Quantity	Emission Factor[1] (lb/hr/component)	Non-methane Hydrocarbons[2] (lb/hr)	Non-methane Hydrocarbons (tpy)	Benzene[2] (lb/hr)	Benzene (tpy)	Toluene[2] (lb/hr)	Toluene (tpy)	Ethlybenzene[2] (lb/hr)	Ethlybenzene (tpy)	Xylene[2] (lb/hr)	Xylene (tpy)	n-Hexane[2] (lb/hr)	n-Hexane (tpy)	CH_4[3] (lb/hr)	CH_4 (tpy)	CO_2[3] (lb/hr)	CO_2 (tpy)
Valves	Gas	22	0.01	0.0251	0.110	0.00011	0.00049	0.00017	0.00073	0.000007	0.000030	0.00006	0.00027	0.00051	0.0022	0.1720	0.7534	0.0028	0.0123
Flanges	Gas	15	0.000875	0.0015	0.007	0.00001	0.00003	0.00001	0.00004	0.000000	0.000002	0.00000	0.00002	0.00003	0.0001	0.0103	0.0449	0.0002	0.0007
Connections	Gas	6	0.000458	0.0003	0.001	0.00000	0.00001	0.00000	0.00001	0.000000	0.000000	0.00000	0.00000	0.00001	0.0000	0.0021	0.0094	0.0000	0.0002
Pump seals	Gas	0	0.00542	0.0000	0.000	0.00000	0.00000	0.00000	0.00000	0.000000	0.000000	0.00000	0.00000	0.00000	0.0000	0.0000	0.0000	0.0000	0.0000
Open ended lines	Gas	2	0.004583	0.0010	0.005	0.00000	0.00002	0.00001	0.00003	0.000000	0.000001	0.00000	0.00001	0.00002	0.0001	0.0072	0.0314	0.0001	0.0005
Other	Gas	2	0.01958	0.0045	0.020	0.00002	0.00009	0.00003	0.00013	0.000001	0.000005	0.00001	0.00005	0.00009	0.0004	0.0306	0.1341	0.0005	0.0022
Valves	Light Liquids	0	0.00542	0.0000	0.000	0.00000	0.00000	0.00000	0.00000	0.000000	0.000000	0.00000	0.00000	0.00000	0.0000	0.0000	0.0000	0.0000	0.0000
Flanges	Light Liquids	0	0.00024	0.0000	0.000	0.00000	0.00000	0.00000	0.00000	0.000000	0.000000	0.00000	0.00000	0.00000	0.0000	0.0000	0.0000	0.0000	0.0000
Connections	Light Liquids	0	0.00046	0.0000	0.000	0.00000	0.00000	0.00000	0.00000	0.000000	0.000000	0.00000	0.00000	0.00000	0.0000	0.0000	0.0000	0.0000	0.0000
Pump seals	Light Liquids	0	0.02875	0.0000	0.000	0.00000	0.00000	0.00000	0.00000	0.000000	0.000000	0.00000	0.00000	0.00000	0.0000	0.0000	0.0000	0.0000	0.0000
Open ended lines	Light Liquids	0	0.00310	0.0000	0.000	0.00000	0.00000	0.00000	0.00000	0.000000	0.000000	0.00000	0.00000	0.00000	0.0000	0.0000	0.0000	0.0000	0.0000
Other	Light Liquids	0	0.01667	0.0000	0.000	0.00000	0.00000	0.00000	0.00000	0.000000	0.000000	0.00000	0.00000	0.00000	0.0000	0.0000	0.0000	0.0000	0.0000
Valves	Water-Oil	0	0.00022	0.0000	0.000	0.00000	0.00000	0.00000	0.00000	0.000000	0.000000	0.00000	0.00000	0.00000	0.0000	0.0000	0.0000	0.0000	0.0000
Flanges	Water-Oil	0	0.00001	0.0000	0.000	0.00000	0.00000	0.00000	0.00000	0.000000	0.000000	0.00000	0.00000	0.00000	0.0000	0.0000	0.0000	0.0000	0.0000
Connections	Water-Oil	0	0.00024	0.0000	0.000	0.00000	0.00000	0.00000	0.00000	0.000000	0.000000	0.00000	0.00000	0.00000	0.0000	0.0000	0.0000	0.0000	0.0000
Pump seals	Water-Oil	0	0.00005	0.0000	0.000	0.00000	0.00000	0.00000	0.00000	0.000000	0.000000	0.00000	0.00000	0.00000	0.0000	0.0000	0.0000	0.0000	0.0000
Open ended lines	Water-Oil	0	0.00054	0.0000	0.000	0.00000	0.00000	0.00000	0.00000	0.000000	0.000000	0.00000	0.00000	0.00000	0.0000	0.0000	0.0000	0.0000	0.0000
Other	Water-Oil	0	0.03083	0.0000	0.000	0.00000	0.00000	0.00000	0.00000	0.000000	0.000000	0.00000	0.00000	0.00000	0.0000	0.0000	0.0000	0.0000	0.0000
			Total Emissions/Facility	0.0324	0.1421	0.0001	0.0006	0.0002	0.0009	0.0000	0.0000	0.0001	0.0003	0.0007	0.0029	0.2222	0.9732	0.0036	0.0160

[1] Taken from the WDEQ (2010) "Oil and Gas Production Facilities Chapter 6, Section 2 Permitting Guidance".
[2] Calculated as weight fraction * emissions factor * quantity of source.

Table 46. Condensate Storage Emissions - Per Facility

Project: NPL
Scenario: Option 3 - Electric Engines and VRU Control/Combustor backup
Activity: Production
Emissions: Condensate Storage Tanks

Pollutant	Tank Flash[1] Uncontrolled (tpy)	Tank Flash[1] Uncontrolled (lb/hr)	Tank Flash[1] Controlled[3] (tpy)	Tank Flash[1] Controlled[3] (lb/hr)	Working Breathing[2] Uncontrolled (tpy)	Working Breathing[2] Controlled[3] (tpy)	Total Controlled[3] (tpy)
HC	442.60	101.05	0.18	0.04			0.18
VOC	239.30	54.63	0.10	0.02	5.30	0.00	0.10
HAP	7.30	1.67	0.00	0.00			0.00
Benzene	1.40	0.32	0.00	0.00			0.00
Ethylbenzene	0.08	0.02	0.00	0.00			0.00
Formaldehyde	0.00	0.00	0.00	0.00			0.00
H_2S	0.00	0.00	0.00	0.00			0.00
n-Hexane	2.70	0.62	0.00	0.00			0.00
Toluene	2.07	0.47	0.00	0.00			0.00
Xylenes	0.60	0.14	0.00	0.00			0.00
CH_4	111.20	25.39	0.04	0.01			0.04
CO_2	4.90	1.12	0.00	0.00			0.00

Average Condensate Production	294	bbl/day
Flash Gas Flow Rate	1243.33	scf/hr
Flash Gas Heating Value	1780	btu/scf
Oil to Gas Ratio	6	bbl/MMscf
Combustor Control Efficiency	0.98	
Fraction Combustor Operation	0.02	
VRU Control Efficiency	1	
Fraction VRU Operation	0.98	

Combustor Emission Factor[2]		
CO	0.37	lb/MMbtu
CO_2[4]	0.24	lb/scf
Formaldehyde	8.10E-05	lb/MMbtu
NOx	0.14	lb/MMbtu
PM_{10}	0.007	lb/MMbtu
$PM_{2.5}$	0.007	lb/MMbtu
N_2O[5]	1.04E-07	lb/MMbtu
SO_2	0	lb/MMbtu

Facility	Throughput (MMscf/day)	CO (From Combustor)	NOx (From Combustor)	PM_{10} (From Combustor)	$PM_{2.5}$ (From Combustor)	SO_2 (From Combustor)	VOC	Benzene	Ethylbenzene	Formaldehyd	H_2S	n-Hexane	Toluene	Xylenes	CH_4	CO_2 (From Combustor)	N_2O (From Combustor)
		ton/yr															
1	75	0.11	0.04	2.08E-03	2.08E-03	0	0.15	8.56E-04	4.72E-05	2.40E-05	0	1.65E-03	1.27E-03	3.67E-04	0.07	0.00	3.09E-08
2	50	0.00	0.00	1.38E-03	1.38E-03	0	0.10	5.70E-04	3.15E-05	1.60E-05	0	1.10E-03	8.47E-04	2.45E-04	0.05	0.00	2.06E-08
3	75	0.00	0.00	2.08E-03	2.08E-03	0	0.15	8.56E-04	4.72E-05	2.40E-05	0	1.65E-03	1.27E-03	3.67E-04	0.07	0.00	3.09E-08
4	50	0.00	0.00	1.38E-03	1.38E-03	0	0.10	5.70E-04	3.15E-05	1.60E-05	0	1.10E-03	8.47E-04	2.45E-04	0.05	0.00	2.06E-08
5	50	0.00	0.00	1.38E-03	1.38E-03	0	0.10	5.70E-04	3.15E-05	1.60E-05	0	1.10E-03	8.47E-04	2.45E-04	0.05	0.00	2.06E-08
6	75	0.00	0.00	2.08E-03	2.08E-03	0	0.15	8.56E-04	4.72E-05	2.40E-05	0	1.65E-03	1.27E-03	3.67E-04	0.07	0.00	3.09E-08
7	40	0.00	0.00	1.11E-03	1.11E-03	0	0.08	4.56E-04	2.52E-05	1.28E-05	0	8.82E-04	6.77E-04	1.96E-04	0.04	0.00	1.65E-08
8	50	0.00	0.00	1.38E-03	1.38E-03	0	0.10	5.70E-04	3.15E-05	1.60E-05	0	1.10E-03	8.47E-04	2.45E-04	0.05	0.00	2.06E-08
9	40	0.00	0.00	1.11E-03	1.11E-03	0	0.08	4.56E-04	2.52E-05	1.28E-05	0	8.82E-04	6.77E-04	1.96E-04	0.04	0.00	1.65E-08
10	25	0.00	0.00	6.92E-04	6.92E-04	0	0.05	2.85E-04	1.57E-05	8.01E-06	0	5.51E-04	4.23E-04	1.22E-04	0.02	0.00	1.03E-08
11	10	0.00	0.00	2.77E-04	2.77E-04	0	0.02	1.14E-04	6.29E-06	3.21E-06	0	2.20E-04	1.69E-04	4.90E-05	0.01	0.00	4.11E-09

[1] HYSYS output based on average of 294 bbl/day. See 'Material Balance' sheet.
[2] Emission factors taken from WDEQ "Oil and Gas Production Facilities - Chapter 6, Section 2 Permitting Guidance" and AP-42, Table 1.4-2.
[3] 100% VRU control efficiency 98% of the operational time and 98% combustor control efficiency 2% of the operational time.
[4] For flash gas composition, see 'Material Balance' sheet.
[5] Greenhouse Gas Compendium (API 2009) Table 4-5.

Table 47. Condensate Loading Emissions - Per Facility

Project: NPL
Scenario: Option 3 - Electric Engines and VRU Control/Combustor backup
Activity: Production
Emissions: Condensate Loading

Average Condensate Loadout Emissions

Uncontrolled Emissions[1]			Controlled Emissions[2]		
CO	0	ton/facility	CO	4.54E-04	ton/facility
NOx	0	ton/facility	NOx	1.72E-04	ton/facility
PM_{10}	0	ton/facility	PM_{10}	8.58E-06	ton/facility
$PM_{2.5}$	0	ton/facility	$PM_{2.5}$	8.58E-06	ton/facility
SO_2	0	ton/facility	SO_2	0.0000	ton/facility
VOC	4.54	ton/facility	VOC	0.0081	ton/facility
Benzene	0.0265	ton/facility	Benzene	2.76E-07	ton/facility
Ethylbenzene	0.0015	ton/facility	Ethylbenzene	8.38E-10	ton/facility
Formaldehyde	0		Formaldehyde	0	ton/facility
H_2S	0		H_2S	0	ton/facility
n-Hexane	0.0512		n-Hexane	1.03E-06	ton/facility
Toluene	0.0394		Toluene	6.07E-07	ton/facility
Xylenes	0.0114		Xylenes	5.08E-08	ton/facility
CH_4	2.1097		CH_4	1.74E-03	ton/facility
CO_2	0		CO_2	0.16	ton/facility
N_2O	0		N_2O	1.28E-10	ton/facility

Average Condensate Production	294	bbl/day
Oil to Gas Ratio	6	bbl/MMscf
Vapor Molecular Weight	50	lb/lb-mol
Vapor Heating Value	1780	btu/scf
Combustor Control Efficiency	0.98	
Fraction Combustor Operation	0.02	
VRU Control Efficiency	1	
Fraction VRU Operation	0.98	

Combustor Emission Factor[3]

CO	0.37	lb/MMbtu
CO_2[4]	0.24	lb/scf
Formaldehyde	8.10E-05	lb/MMbtu
NOx	0.14	lb/MMbtu
PM_{10}	0.007	lb/MMbtu
$PM_{2.5}$	0.007	lb/MMbtu
N_2O[5]	1.04E-07	lb/MMbtu
SO_2	0	lb/MMbtu

Facility	Throughput (MMscf/day)	From Combustor CO	NOx	PM_{10}	$PM_{2.5}$	SO_2	VOC (ton/yr)	Benzene	Ethylbenzen	Formaldehyc	H_2S	n-Hexane	Toluene	Xylenes	CH_4	From Combustor CO_2	N_2O
1	75	6.94E-04	2.63E-04	1.31E-05	1.31E-05	0	0.012367	4.22E-07	1.28E-09	1.52E-07	0	1.57E-06	9.30E-07	7.77E-08	2.67E-03	0.252503	1.95E-10
2	50	4.63E-04	1.75E-04	8.76E-06	8.76E-06	0	0.008245	2.81E-07	8.56E-10	1.01E-07	0	1.05E-06	6.20E-07	5.18E-08	1.78E-03	0.168336	1.30E-10
3	75	6.94E-04	2.63E-04	1.31E-05	1.31E-05	0	0.012367	4.22E-07	1.28E-09	1.52E-07	0	1.57E-06	9.30E-07	7.77E-08	2.67E-03	0.252503	1.95E-10
4	50	4.63E-04	1.75E-04	8.76E-06	8.76E-06	0	0.008245	2.81E-07	8.56E-10	1.01E-07	0	1.05E-06	6.20E-07	5.18E-08	1.78E-03	0.168336	1.30E-10
5	50	4.63E-04	1.75E-04	8.76E-06	8.76E-06	0	0.008245	2.81E-07	8.56E-10	1.01E-07	0	1.05E-06	6.20E-07	5.18E-08	1.78E-03	0.168336	1.30E-10
6	75	6.94E-04	2.63E-04	1.31E-05	1.31E-05	0	0.012367	4.22E-07	1.28E-09	1.52E-07	0	1.57E-06	9.30E-07	7.77E-08	2.67E-03	0.252503	1.95E-10
7	40	3.70E-04	1.40E-04	7.01E-06	7.01E-06	0	0.006596	2.25E-07	6.84E-10	8.11E-08	0	8.40E-07	4.96E-07	4.15E-08	1.42E-03	0.134668	1.04E-10
8	50	4.63E-04	1.75E-04	8.76E-06	8.76E-06	0	0.008245	2.81E-07	8.56E-10	1.01E-07	0	1.05E-06	6.20E-07	5.18E-08	1.78E-03	0.168336	1.30E-10
9	40	3.70E-04	1.40E-04	7.01E-06	7.01E-06	0	0.006596	2.25E-07	6.84E-10	8.11E-08	0	8.40E-07	4.96E-07	4.15E-08	1.42E-03	0.134668	1.04E-10
10	25	2.31E-04	8.76E-05	4.38E-06	4.38E-06	0	0.004122	1.41E-07	4.28E-10	5.07E-08	0	5.25E-07	3.10E-07	2.59E-08	8.90E-04	0.084168	6.51E-11
11	10	9.26E-05	3.50E-05	1.75E-06	1.75E-06	0	0.001649	5.62E-08	1.71E-10	2.03E-08	0	2.10E-07	1.24E-07	1.04E-08	3.56E-04	0.033667	2.60E-11
Total in 2024 (all Facilities operating)		5.00E-03	1.89E-03	9.46E-05	9.46E-05	0.00E+00	8.90E-02										

[1] Based on average of 294 bbl/day production and AP-42 (EPA 1995) Section 5.2 Loadout emissions calculation.
[2] 100% VRU control efficiency 98% of the operational time and 98% combustor control efficiency 2% of the operational time.
[3] Emission factors taken from WDEQ "Oil and Gas Production Facilities - Chapter 6, Section 2 Permitting Guidance" and AP-42 (EPA 2008), Section 5.2.
[4] For flash gas composition, see 'Material Balance' sheet.
[5] Greenhouse Gas Compendium (API 2009) Table 4-5.

LL= 12.46 * S P M /T

LL = Loading loss (Lb/1,000 gal.), of liquid loaded
S = Saturation factor (from AP-42 Table 5.2-1)
P = True vapor pressure of liquid loaded (psia), (from AP-42 Table 7.1-2)
M = Molecular weight of vapors (Lb/Lb-mole)
T = Temperature of liquid loaded (0R = 460 + 0F)

S= **0.6** (For dedicated Hydrocarbon service)
P= **2.8** True Vapor Pressure (psia) @ T=60 for a RVP=10 fluid
M= **50** Lb/Lb-mole (from composition of vapor phase as per Tanks 4.09)
181.6 **T=** **60** 0F or **520** 0R
1377.62
2452159 **LL= 2.0128 Lb/1,000 gal. Loaded**

-For a facility making: **0** bbl/yr or **294** bbl/day

LL (TPY) = LL (Lb/1,000 gal) * annual production (bbl/yr) * 42 gal/bbl * 1ton/2000Lbs

Truck Loadout Emissions = 0.0 TPY of VOC

LL (lb/hr) = LL (Lb/1,000 gal) * 240 bbl tank truck * 42 gal/bbl * 1 hr loadout duration

Truck Loadout Emissions = 20.29 lb/hr of VOC

Truck Loadout Emissions = 0.1 TPY of HAP

Truck Loadout Emissions = 0.60 lb/hr of HAP

NPL Project General Conformity Emissions Inventory

Table 48. Passenger Vehicles

	Construction[1]	Drilling-Completion[2]	Production		
	(mile/pad)	(mile/well)	(mile/operator)		
	12775	1,646	3,650		
	Pads	Wells	Operators		
	(per year)	(per year)	(per year)		
	10	160	28		
Total mile/yea	127750	263360	102200		
		Commuters			
	one-way	round trip	no. people	trips/year	total
	(miles)	(miles)			miles/year
Contractors	35	70	60	52	218400
Employees	35	70	28	300	588000

Assume contractors are 50/50 dielsel/gas

Assume workers are CNG

[1] Includes Pad, Road, Pipeline

[2] Includes Tabs 16,17,24&26 (added company man 4/9/2014)

T/year

	NOx	PM10	PM2.5	SO2	CO	VOC	CO2	CH4	N_2O^a	Benzene	Formaldehy
2013											
Pad											
Gas	0.07	0.00	0.00	0.00	0.35	0.01	30.91	5.11E-04	3.07E-04	3.64E-04	1.35E-04
Diesel	0.15	0.01	0.01	0.00	0.09	0.02	44.33	1.11E-03	1.06E-04	2.05E-04	1.53E-03
Well											
Gas	0.14	0.00	0.00	0.00	0.73	0.02	63.72	1.05E-03	6.32E-04	7.50E-04	2.79E-04
Diesel	0.31	0.02	0.02	0.00	0.19	0.04	91.40	2.28E-03	2.19E-04	4.23E-04	3.15E-03
CNG											
Operators	0.40	0.01	0.00	0.00	4.21	0.00	104.02	2.49E-03	4.49E-03	0.00E+00	0.00E+00

Contractors											
Gas	0.11	0.00	0.00	0.00	0.60	0.02	52.84	8.74E-04	5.24E-04	6.22E-04	2.31E-04
Diesel	0.26	0.02	0.02	0.00	0.16	0.03	75.79	1.89E-03	1.82E-04	3.51E-04	2.61E-03
Employees -	2.30	0.03	0.01	0.00	24.23	0.00	598.47	1.43E-02	2.58E-02	0.00E+00	0.00E+00
Total:	3.73	0.10	0.06	0.00	30.57	0.14	1061.47	2.45E-02	3.23E-02	2.72E-03	7.94E-03
2014											
Pad											
Gas	0.06	0.00	0.00	0.00	0.33	0.01	30.36	4.78E-04	2.76E-04	3.29E-04	1.23E-04
Diesel	0.14	0.01	0.01	0.00	0.09	0.02	44.16	1.19E-03	1.06E-04	1.79E-04	1.33E-03
Well											
Gas	0.12	0.00	0.00	0.00	0.69	0.02	62.59	9.86E-04	5.68E-04	6.78E-04	2.53E-04
Diesel	0.28	0.02	0.02	0.00	0.18	0.03	91.03	2.45E-03	2.19E-04	3.69E-04	2.75E-03
CNG											
Operators	0.39	0.01	0.00	0.00	3.93	0.00	104.02	2.30E-03	4.49E-03	0.00E+00	0.00E+00
Contractors											
Gas	0.10	0.00	0.00	0.00	0.57	0.02	51.91	8.18E-04	4.71E-04	5.62E-04	2.09E-04
Diesel	0.23	0.02	0.01	0.00	0.15	0.03	75.49	2.03E-03	1.82E-04	3.06E-04	2.28E-03
Employees -	2.27	0.03	0.01	0.00	22.59	0.00	598.47	1.32E-02	2.58E-02	0.00E+00	0.00E+00
Total:	3.60	0.09	0.06	0.00	28.52	0.12	1058.01	2.35E-02	3.21E-02	2.42E-03	6.94E-03
2015											
Pad											
Gas	0.06	0.00	0.00	0.00	0.32	0.01	29.79	4.45E-04	2.48E-04	2.97E-04	1.11E-04
Diesel	0.12	0.01	0.01	0.00	0.08	0.01	43.96	1.26E-03	1.06E-04	1.56E-04	1.16E-03
Well											
Gas	0.11	0.00	0.00	0.00	0.65	0.02	61.42	9.18E-04	5.12E-04	6.12E-04	2.29E-04
Diesel	0.25	0.02	0.01	0.00	0.16	0.03	90.63	2.60E-03	2.19E-04	3.21E-04	2.39E-03
CNG											
Operators	0.39	0.01	0.00	0.00	3.66	0.00	104.02	2.12E-03	4.49E-03	0.00E+00	0.00E+00
Contractors											
Gas	0.09	0.00	0.00	0.00	0.54	0.01	50.94	7.61E-04	4.25E-04	5.08E-04	1.90E-04
Diesel	0.21	0.01	0.01	0.00	0.13	0.02	75.16	2.16E-03	1.82E-04	2.66E-04	1.98E-03
Employees -	2.23	0.03	0.01	0.00	21.05	0.00	598.47	1.22E-02	2.58E-02	0.00E+00	0.00E+00
Total:	3.47	0.08	0.05	0.00	26.59	0.11	1054.39	2.25E-02	3.20E-02	2.16E-03	6.07E-03
2016											
Pad											

Gas	0.05	0.00	0.00	0.00	0.30	0.01	29.16	4.04E-04	2.25E-04	2.63E-04	1.01E-03
Diesel	0.11	0.01	0.01	0.00	0.07	0.01	43.73	1.33E-03	1.06E-04	1.36E-04	1.01E-03
Well											
Gas	0.10	0.00	0.00	0.00	0.61	0.02	60.12	8.33E-04	4.63E-04	5.43E-04	2.09E-03
Diesel	0.23	0.01	0.01	0.00	0.15	0.03	90.15	2.75E-03	2.19E-04	2.80E-04	2.09E-03
CNG											
Operators	0.38	0.01	0.00	0.00	3.41	0.00	104.02	1.97E-03	4.49E-03	0.00E+00	0.00E+00
Contractors											
Gas	0.09	0.00	0.00	0.00	0.51	0.01	49.86	6.91E-04	3.84E-04	4.50E-04	1.73E-03
Diesel	0.19	0.01	0.01	0.00	0.12	0.02	74.76	2.28E-03	1.82E-04	2.32E-04	1.73E-03
Employees -	2.20	0.03	0.01	0.00	19.64	0.00	598.47	1.13E-02	2.58E-02	0.00E+00	0.00E+00
Total:	3.36	0.08	0.05	0.00	24.82	0.10	1050.27	2.16E-02	3.19E-02	1.90E-03	9.66E-03
2017											
Pad											
Gas	0.05	0.00	0.00	0.00	0.28	0.01	28.58	3.73E-04	2.04E-04	2.38E-04	8.95E-05
Diesel	0.10	0.01	0.01	0.00	0.07	0.01	43.53	1.40E-03	1.06E-04	1.18E-04	8.81E-04
Well											
Gas	0.10	0.00	0.00	0.00	0.59	0.01	58.92	7.70E-04	4.20E-04	4.90E-04	1.85E-04
Diesel	0.21	0.01	0.01	0.00	0.14	0.02	89.75	2.88E-03	2.19E-04	2.44E-04	1.82E-03
CNG											
Operators	0.38	0.01	0.00	0.00	3.20	0.00	104.02	1.85E-03	4.49E-03	0.00E+00	0.00E+00
Contractors											
Gas	0.08	0.00	0.00	0.00	0.49	0.01	48.86	6.38E-04	3.49E-04	4.06E-04	1.53E-04
Diesel	0.17	0.01	0.01	0.00	0.12	0.02	74.43	2.39E-03	1.82E-04	2.02E-04	1.51E-03
Employees -	2.18	0.03	0.01	0.00	18.39	0.00	598.47	1.06E-02	2.58E-02	0.00E+00	0.00E+00
Total:	3.26	0.08	0.04	0.00	23.26	0.09	1046.55	2.09E-02	3.18E-02	1.70E-03	4.63E-03
2018											
Pad											
Gas	0.04	0.00	0.00	0.00	0.27	0.01	28.02	3.47E-04	1.86E-04	2.16E-04	8.17E-05
Diesel	0.09	0.01	0.00	0.00	0.06	0.01	43.33	1.45E-03	1.06E-04	1.03E-04	7.70E-04
Well											
Gas	0.09	0.00	0.00	0.00	0.56	0.01	57.76	7.15E-04	3.83E-04	4.46E-04	1.69E-04
Diesel	0.19	0.01	0.01	0.00	0.13	0.02	89.33	3.00E-03	2.19E-04	2.13E-04	1.59E-03
CNG											
Operators	0.37	0.01	0.00	0.00	3.00	0.00	104.02	1.74E-03	4.49E-03	0.00E+00	0.00E+00

Contractors											
Gas	0.07	0.00	0.00	0.00	0.46	0.01	47.90	5.93E-04	3.18E-04	3.70E-04	1.40E-04
Diesel	0.16	0.01	0.01	0.00	0.11	0.02	74.08	2.48E-03	1.82E-04	1.77E-04	1.32E-03
Employees -	2.15	0.03	0.01	0.00	17.28	0.00	598.47	1.00E-02	2.58E-02	0.00E+00	0.00E+00
Total:	3.17	0.07	0.04	0.00	21.89	0.08	1042.90	2.04E-02	3.17E-02	1.52E-03	4.06E-03
2019											
Pad											
Gas	0.04	0.00	0.00	0.00	0.26	0.01	27.49	3.21E-04	1.70E-04	1.97E-04	7.49E-05
Diesel	0.09	0.01	0.00	0.00	0.06	0.01	43.13	1.50E-03	1.06E-04	9.07E-05	6.75E-04
Well											
Gas	0.08	0.00	0.00	0.00	0.54	0.01	56.68	6.63E-04	3.50E-04	4.07E-04	1.54E-04
Diesel	0.18	0.01	0.01	0.00	0.13	0.02	88.91	3.10E-03	2.19E-04	1.87E-04	1.39E-03
CNG											
Operators	0.37	0.01	0.00	0.00	2.83	0.00	104.02	1.60E-03	4.49E-03	0.00E+00	0.00E+00
Contractors											
Gas	0.07	0.00	0.00	0.00	0.45	0.01	47.00	5.50E-04	2.90E-04	3.37E-04	1.28E-04
Diesel	0.15	0.01	0.01	0.00	0.11	0.01	73.73	2.57E-03	1.82E-04	1.55E-04	1.15E-03
Employees -	2.13	0.03	0.01	0.00	16.30	0.00	598.46	9.23E-03	2.58E-02	0.00E+00	0.00E+00
Total:	3.10	0.07	0.04	0.00	20.67	0.07	1039.43	1.95E-02	3.16E-02	1.37E-03	3.58E-03
2020											
Pad											
Gas	0.04	0.00	0.00	0.00	0.25	0.01	27.01	3.00E-04	1.56E-04	1.81E-04	6.89E-05
Diesel	0.08	0.00	0.00	0.00	0.06	0.01	42.94	1.55E-03	1.06E-04	7.97E-05	5.94E-04
Well											
Gas	0.08	0.00	0.00	0.00	0.52	0.01	55.68	6.18E-04	3.22E-04	3.73E-04	1.42E-04
Diesel	0.16	0.01	0.01	0.00	0.12	0.02	88.52	3.20E-03	2.19E-04	1.64E-04	1.22E-03
CNG											
Operators	0.37	0.01	0.00	0.00	2.68	0.00	104.02	1.49E-03	4.49E-03	0.00E+00	0.00E+00
Contractors											
Gas	0.06	0.00	0.00	0.00	0.43	0.01	46.18	5.12E-04	2.67E-04	3.09E-04	1.18E-04
Diesel	0.13	0.01	0.01	0.00	0.10	0.01	73.41	2.65E-03	1.82E-04	1.36E-04	1.01E-03
Employees -	2.11	0.03	0.01	0.00	15.45	0.00	598.47	8.56E-03	2.58E-02	0.00E+00	0.00E+00
Total:	3.03	0.07	0.03	0.00	19.62	0.06	1036.22	1.89E-02	3.15E-02	1.24E-03	3.16E-03
2021											
Pad											

Gas	0.03	0.00	0.00	0.00	0.24	0.01	26.56	2.84E-04	1.44E-04	1.67E-04	6.37E-05
Diesel	0.07	0.00	0.00	0.00	0.06	0.01	42.76	1.59E-03	1.06E-04	7.02E-05	5.23E-04
Well											
Gas	0.07	0.00	0.00	0.00	0.50	0.01	54.76	5.86E-04	2.97E-04	3.43E-04	1.31E-04
Diesel	0.15	0.01	0.01	0.00	0.12	0.01	88.16	3.28E-03	2.19E-04	1.45E-04	1.08E-03
CNG											
Operators	0.36	0.01	0.00	0.00	2.55	0.00	104.02	1.42E-03	4.49E-03	0.00E+00	0.00E+00
Contractors											
Gas	0.06	0.00	0.00	0.00	0.42	0.01	45.41	4.86E-04	2.46E-04	2.85E-04	1.09E-04
Diesel	0.13	0.01	0.01	0.00	0.10	0.01	73.11	2.72E-03	1.82E-04	1.20E-04	8.93E-04
Employees -	2.10	0.03	0.01	0.00	14.69	0.00	598.47	8.16E-03	2.58E-02	0.00E+00	0.00E+00
Total:	2.98	0.07	0.03	0.00	18.69	0.05	1033.24	1.85E-02	3.15E-02	1.13E-03	2.80E-03
2022											
Pad											
Gas	0.03	0.00	0.00	0.00	0.24	0.00	26.16	2.72E-04	1.34E-04	1.54E-04	5.93E-05
Diesel	0.07	0.00	0.00	0.00	0.06	0.01	42.60	1.63E-03	1.06E-04	6.18E-05	4.60E-04
Well											
Gas	0.07	0.00	0.00	0.00	0.49	0.01	53.92	5.62E-04	2.76E-04	3.18E-04	1.22E-04
Diesel	0.14	0.01	0.01	0.00	0.12	0.01	87.83	3.36E-03	2.19E-04	1.27E-04	9.48E-04
CNG											
Operators	0.36	0.01	0.00	0.00	2.44	0.00	104.02	1.36E-03	4.49E-03	0.00E+00	0.00E+00
Contractors											
Gas	0.05	0.00	0.00	0.00	0.41	0.01	44.72	4.66E-04	2.29E-04	2.64E-04	1.01E-04
Diesel	0.12	0.01	0.00	0.00	0.10	0.01	72.83	2.79E-03	1.82E-04	1.06E-04	7.86E-04
Employees -	2.09	0.03	0.01	0.00	14.03	0.00	598.47	7.82E-03	2.58E-02	0.00E+00	0.00E+00
Total:	2.92	0.06	0.03	0.00	17.88	0.05	1030.55	1.83E-02	3.14E-02	1.03E-03	2.48E-03
2023											
Pad											
Gas	0.03	0.00	0.00	0.00	0.23	0.00	25.79	2.59E-04	1.25E-04	1.43E-04	5.54E-05
Diesel	0.06	0.00	0.00	0.00	0.06	0.01	42.45	1.66E-03	1.06E-04	5.45E-05	4.06E-04
Well											
Gas	0.06	0.00	0.00	0.00	0.48	0.01	53.16	5.33E-04	2.57E-04	2.96E-04	1.14E-04
Diesel	0.13	0.01	0.01	0.00	0.12	0.01	87.52	3.42E-03	2.19E-04	1.12E-04	8.36E-04
CNG											
Operators	0.36	0.01	0.00	0.00	2.33	0.00	104.02	1.28E-03	4.49E-03	0.00E+00	0.00E+00

Contractors											
Gas	0.05	0.00	0.00	0.00	0.39	0.01	44.09	4.42E-04	2.13E-04	2.45E-04	9.47E-05
Diesel	0.11	0.01	0.00	0.00	0.10	0.01	72.58	2.84E-03	1.82E-04	9.31E-05	6.94E-04
Employees -	2.07	0.03	0.01	0.00	13.41	0.00	598.47	7.36E-03	2.58E-02	0.00E+00	0.00E+00
Total:	2.88	0.06	0.03	0.00	17.10	0.04	1028.07	1.78E-02	3.14E-02	9.44E-04	2.20E-03
2024											
Pad											
Gas	0.03	0.00	0.00	0.00	0.22	0.00	25.45	2.42E-04	1.16E-04	1.33E-04	5.16E-05
Diesel	0.06	0.00	0.00	0.00	0.06	0.00	42.33	1.68E-03	1.06E-04	4.80E-05	3.58E-04
Well											
Gas	0.06	0.00	0.00	0.00	0.46	0.01	52.46	4.98E-04	2.40E-04	2.74E-04	1.06E-04
Diesel	0.12	0.01	0.00	0.00	0.11	0.01	87.26	3.47E-03	2.19E-04	9.90E-05	7.37E-04
CNG											
Operators	0.36	0.01	0.00	0.00	2.22	0.00	104.02	1.18E-03	4.49E-03	0.00E+00	0.00E+00
Contractors											
Gas	0.05	0.00	0.00	0.00	0.38	0.01	43.51	4.13E-04	1.99E-04	2.27E-04	8.82E-05
Diesel	0.10	0.01	0.00	0.00	0.09	0.01	72.36	2.88E-03	1.82E-04	8.21E-05	6.11E-04
Employees -	2.06	0.03	0.01	0.00	12.78	0.00	598.47	6.77E-03	2.58E-02	0.00E+00	0.00E+00
Total:	2.84	0.06	0.03	0.00	16.34	0.04	1025.85	1.71E-02	3.14E-02	8.64E-04	1.95E-03
2025											
Pad											
Gas	0.03	0.00	0.00	0.00	0.22	0.00	25.14	2.28E-04	1.09E-04	1.23E-04	4.81E-05
Diesel	0.06	0.00	0.00	0.00	0.05	0.00	42.20	1.71E-03	1.06E-04	4.26E-05	3.17E-04
Well											
Gas	0.05	0.00	0.00	0.00	0.45	0.01	51.83	4.70E-04	2.24E-04	2.55E-04	9.92E-05
Diesel	0.12	0.01	0.00	0.00	0.11	0.01	86.99	3.52E-03	2.19E-04	8.77E-05	6.53E-04
CNG											
Operators	0.36	0.01	0.00	0.00	2.14	0.00	104.02	1.10E-03	4.49E-03	0.00E+00	0.00E+00
Contractors											
Gas	0.05	0.00	0.00	0.00	0.37	0.01	42.98	3.89E-04	1.86E-04	2.11E-04	8.23E-05
Diesel	0.10	0.01	0.00	0.00	0.09	0.01	72.14	2.92E-03	1.82E-04	7.28E-05	5.42E-04
Employees -	2.05	0.03	0.01	0.00	12.29	0.00	598.47	6.32E-03	2.58E-02	0.00E+00	0.00E+00
Total:	2.80	0.06	0.03	0.00	15.73	0.04	1023.78	1.67E-02	3.13E-02	7.92E-04	1.74E-03

Notes: Fuel - assume construction, drilling and completion vehicles

will be 50% gasoline and 50% diesel. Production vehicles
will be compressed natural gas.

Mobile Source - Moves run for 2013-2005, WY
Emission factors for Commuting Vehicles Exhaust

Emission Factors for Commuting Vehicles										
Emission Factors (gm/mile)										
Project Year	**NOx**	**PM10**	**PM2.5**	**SO2**	**CO**	**VOC**	**CO2**	**CH_4**	**N_2O^a**	**Benzene**	**Form**
2013											
LDGT2	0.94	0.03	0.02	0.01	5.01	0.15	438.97	0.01	0.00	0.01	0.00
LDDT	2.14	0.15	0.13	0.00	1.32	0.27	629.66	0.02	0.00	0.00	0.02
CNG (transit	3.55	0.05	0.02	0.00	37.38	0.00	923.35	0.02	0.04	0.00	0.00
2014											
LDGT2	0.86	0.03	0.02	0.01	4.74	0.14	431.22	0.01	0.00	0.00	0.00
LDDT	1.93	0.13	0.11	0.00	1.21	0.23	627.13	0.02	0.00	0.00	0.02
CNG (transit	3.50	0.05	0.02	0.00	34.86	0.00	923.35	0.02	0.04	0.00	0.00
2015											
LDGT2	0.79	0.03	0.02	0.01	4.48	0.12	423.17	0.01	0.00	0.00	0.00
LDDT	1.74	0.11	0.10	0.00	1.11	0.20	624.38	0.02	0.00	0.00	0.02
CNG (transit	3.45	0.05	0.02	0.00	32.48	0.00	923.35	0.02	0.04	0.00	0.00
2016											
LDGT2	0.72	0.03	0.02	0.01	4.23	0.11	414.22	0.01	0.00	0.00	0.01
LDDT	1.58	0.10	0.09	0.00	1.04	0.18	621.07	0.02	0.00	0.00	0.01
CNG (transit	3.40	0.05	0.02	0.00	30.30	0.00	923.35	0.02	0.04	0.00	0.00
2017											
LDGT2	0.66	0.03	0.02	0.01	4.03	0.10	405.89	0.01	0.00	0.00	0.00
LDDT	1.44	0.09	0.07	0.00	0.97	0.15	618.31	0.02	0.00	0.00	0.01
CNG (transit	3.36	0.05	0.02	0.00	28.37	0.00	923.35	0.02	0.04	0.00	0.00
2018											
LDGT2	0.61	0.03	0.02	0.01	3.86	0.09	397.90	0.00	0.00	0.00	0.00
LDDT	1.32	0.08	0.06	0.00	0.92	0.14	615.46	0.02	0.00	0.00	0.01
CNG (transit	3.32	0.05	0.02	0.00	26.66	0.00	923.35	0.02	0.04	0.00	0.00
2019											
LDGT2	0.56	0.03	0.02	0.01	3.70	0.08	390.47	0.00	0.00	0.00	0.00
LDDT	1.21	0.07	0.06	0.00	0.88	0.12	612.55	0.02	0.00	0.00	0.01
CNG (transit	3.29	0.05	0.02	0.00	25.14	0.00	923.34	0.01	0.04	0.00	0.00
2020											
LDGT2	0.52	0.03	0.02	0.01	3.57	0.08	383.62	0.00	0.00	0.00	0.00
LDDT	1.12	0.07	0.05	0.00	0.86	0.10	609.84	0.02	0.00	0.00	0.01
CNG (transit	3.26	0.05	0.02	0.00	23.83	0.00	923.35	0.01	0.04	0.00	0.00

2021											
LDGT2	0.48	0.03	0.02	0.01	3.46	0.07	377.25	0.00	0.00	0.00	0.00
LDDT	1.04	0.06	0.05	0.00	0.84	0.09	607.35	0.02	0.00	0.00	0.01
CNG	3.24	0.05	0.02	0.00	22.67	0.00	923.35	0.01	0.04	0.00	0.00
2022											
LDGT2	0.45	0.03	0.02	0.01	3.37	0.07	371.51	0.00	0.00	0.00	0.00
LDDT	0.97	0.05	0.04	0.00	0.82	0.08	605.08	0.02	0.00	0.00	0.01
CNG	3.22	0.05	0.02	0.00	21.65	0.00	923.35	0.01	0.04	0.00	0.00
2023											
LDGT2	0.43	0.03	0.02	0.01	3.27	0.06	366.25	0.00	0.00	0.00	0.00
LDDT	0.90	0.05	0.04	0.00	0.80	0.07	602.95	0.02	0.00	0.00	0.01
CNG	3.20	0.05	0.02	0.00	20.68	0.00	923.35	0.01	0.04	0.00	0.00
2024											
LDGT2	0.40	0.03	0.02	0.01	3.18	0.06	361.45	0.00	0.00	0.00	0.00
LDDT	0.85	0.05	0.03	0.00	0.79	0.06	601.15	0.02	0.00	0.00	0.01
CNG	3.18	0.05	0.02	0.00	19.73	0.00	923.35	0.01	0.04	0.00	0.00
2025											
LDGT2	0.37	0.03	0.02	0.01	3.10	0.05	357.10	0.00	0.00	0.00	0.00
LDDT	0.80	0.04	0.03	0.00	0.78	0.06	599.33	0.02	0.00	0.00	0.00
CNG	3.16	0.05	0.01	0.00	18.97	0.00	923.35	0.01	0.04	0.00	0.00

NPL Project General Conformity Emissions Inventory

Table 49. Construction Emission Summary

	ton																Pads per
per	**CO**	**NOx**	**PM_{10}**	**$PM_{2.5}$**	**SO_2**	**VOC**	**Benzene**	**Ethylbenzene**	**Formaldehyde**	**H_2S**	**n-Hexane**	**Toluene**	**Xylenes**	**CH_4**	**CO_2**	**N_2O**	year
Pad/Road/Pipe	0.78	1.33	1.49	0.42	0.03	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	155.75	0.00	10
Facility	0.04	0.11	0.50	0.06	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.90	0.00	

	ton																	Facility
Year	**CO**	**NOx**	**PM_{10}**	**$PM_{2.5}$**	**SO_2**	**VOC**	**Benzene**	**Ethylbenzene**	**Formaldehyde**	**H_2S**	**n-Hexane**	**Toluene**	**Xylenes**	**CH_4**	**CO_2**	**N_2O**	**CO2e**	
1	7.87	13.67	16.41	4.38	0.34	1.72	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.23	1602.23	0.02	1,613	3
2	7.83	13.56	15.91	4.32	0.34	1.71	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.23	1587.33	0.02	1,598	2
3	7.80	13.45	15.41	4.26	0.34	1.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.23	1572.43	0.02	1,583	1
4	7.83	13.56	15.91	4.32	0.34	1.71	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.23	1587.33	0.02	1,598	2
5	7.76	13.34	14.91	4.20	0.33	1.69	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.23	1557.53	0.02	1,568	0
6	7.80	13.45	15.41	4.26	0.34	1.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.23	1572.43	0.02	1,583	1
7	7.80	13.45	15.41	4.26	0.34	1.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.23	1572.43	0.02	1,583	1
8	7.76	13.34	14.91	4.20	0.33	1.69	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.23	1557.53	0.02	1,568	0
9	7.80	13.45	15.41	4.26	0.34	1.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.23	1572.43	0.02	1,583	1
10	7.76	13.34	14.91	4.20	0.33	1.69	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.23	1557.53	0.02	1,568	0

NPL Project General Conformity Emissions Inventory

Table 50. Total Drilling Summary

Wells/Pad 16

Combined ton

	CO	NOx	PM_{10}	$PM_{2.5}$	SO_2	VOC	Benzene	Ethylbenzene	Formaldehyde	H_2S	n-Hexane	Toluene	Xylenes	CH_4	CO_2	N_2O	Pads	Acetaldehyde	Acrolein
Per Pad	25.9	20.2	39.2	5.6	0.4	1.9	0.0	0.0	1.7	0.0	0.0	0.0	0.0	35.0	4138.2	0.0	22.0	0.1	0.1
						per pad													

Drilling ton

	CO	NOx	PM_{10}	$PM_{2.5}$	SO_2	VOC	Benzene	Ethylbenzene	Formaldehyde	H_2S	n-Hexane	Toluene	Xylenes	CH_4	CO_2	N_2O	Pads	Acetaldehyde	Acrolein
Per Pad	24.24	12.38	8.96	0.98	0.08	1.41	0.01	0.00	1.66	0.00	0.03	0.01	0.00	34.52	3109.93	0.01	22.0	0.08	0.05
						yes, per pad													

Completion ton

	CO	NOx	PM_{10}	$PM_{2.5}$	SO_2	VOC	Benzene	Ethylbenzene	Formaldehyde	H_2S	n-Hexane	Toluene	Xylenes	CH_4	CO_2	N_2O	Pads	Acetaldehyde	Acrolein
Per Pad	1.7	7.8	30.2	4.6	0.4	0.4	5.93E-03	0.0	9.88E-03	0.0	0.0	0.0	0.0	0.5	1028.3	0.0	22.0	4.3E-03	5.1E-04
						per pad													

Commuter

	CO	NOx	PM_{10}	$PM_{2.5}$	SO_2	VOC	Benzene	Ethylbenzene	Formaldehyde	H_2S	n-Hexane	Toluene	Xylenes	CH_4	CO_2	N_2O
1	26.59	3.47	0.08	0.05	0.00	0.11	2.16E-03		6.07E-03					0.02	1054.39	0.03
2	24.82	3.36	0.08	0.05	0.00	0.10	1.90E-03		9.66E-03					0.02	1050.27	0.03
3	23.26	3.26	0.08	0.04	0.00	0.09	1.70E-03		4.63E-03					0.02	1046.55	0.03
4	21.89	3.17	0.07	0.04	0.00	0.08	1.52E-03		4.06E-03					0.02	1042.90	0.03
5	20.67	3.10	0.07	0.04	0.00	0.07	1.37E-03		3.58E-03					0.02	1039.43	0.03
6	19.62	3.03	0.07	0.03	0.00	0.06	1.24E-03		3.16E-03					0.02	1036.22	0.03
7	18.69	2.98	0.07	0.03	0.00	0.05	1.13E-03		2.80E-03					0.02	1033.24	0.03
8	17.88	2.92	0.06	0.03	0.00	0.05	1.03E-03		2.48E-03					0.02	1030.55	0.03
9	17.10	2.88	0.06	0.03	0.00	0.04	9.44E-04		2.20E-03					0.02	1028.07	0.03
10	16.34	2.84	0.06	0.03	0.00	0.04	8.64E-04		1.95E-03					0.02	1025.85	0.03

ton

Year	CO	NOx	PM_{10}	$PM_{2.5}$	SO_2	VOC	Benzene	Ethylbenzene	Formaldehyde	H_2S	n-Hexane	Toluene	Xylenes	CH_4	CO_2	N_2O	CO2e	Acetaldehyde	Acrolein	Pads	Wells
1	123.9	79.21	147.0	21.0	1.6	7.07	0.1	0.0	6.3	0.0	0.1	0.0	0.0	131.3	16572.6	0.1	19,882	0.3	0.2		60
2	284.3	205.34	392.0	55.9	4.3	18.66	0.2	0.0	16.7	0.0	0.3	0.1	0.1	350.0	42432.2	0.2	51,241	0.9	0.5		160
3	282.7	205.24	391.9	55.9	4.3	18.65	0.2	0.0	16.7	0.0	0.3	0.1	0.1	350.0	42428.4	0.2	51,237	0.9	0.5		160
4	281.3	205.15	391.9	55.9	4.3	18.64	0.2	0.0	16.7	0.0	0.3	0.1	0.1	350.0	42424.8	0.2	51,233	0.9	0.5		160
5	280.1	205.08	391.9	55.9	4.3	18.63	0.2	0.0	16.7	0.0	0.3	0.1	0.1	350.0	42421.3	0.2	51,230	0.9	0.5		160
6	279.1	205.01	391.9	55.9	4.3	18.62	0.2	0.0	16.7	0.0	0.3	0.1	0.1	350.0	42418.1	0.2	51,226	0.9	0.5		160
7	278.1	204.95	391.9	55.9	4.3	18.61	0.2	0.0	16.7	0.0	0.3	0.1	0.1	350.0	42415.1	0.2	51,223	0.9	0.5		160
8	277.3	204.90	391.9	55.9	4.3	18.61	0.2	0.0	16.7	0.0	0.3	0.1	0.1	350.0	42412.4	0.2	51,221	0.9	0.5		160
9	276.6	204.86	391.9	55.9	4.3	18.60	0.2	0.0	16.7	0.0	0.3	0.1	0.1	350.0	42410.0	0.2	51,218	0.9	0.5		160
10	275.8	204.81	391.9	55.9	4.3	18.60	0.2	0.0	16.7	0.0	0.3	0.1	0.1	350.0	42407.7	0.2	51,216	0.9	0.5		160

NPL Project General Conformity Emissions Inventory

Table 50b. Drilling Summary for Conformity

Wells/Pad 16

Combined ton

	CO	NOx	PM_{10}	$PM_{2.5}$	SO_2	VOC	Benzene	Ethylbenzene	Formaldehyde	H_2S	n-Hexane	Toluene	Xylenes	CH_4	CO_2	N_2O	Pads	Acetaldehyde	Acrolein
Per Pad	1.7	7.9	38.9	5.5	0.4	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	1051.9	0.0	22.0	0.0	0.0
						per pad													

Drilling ton

	CO	NOx	PM_{10}	$PM_{2.5}$	SO_2	VOC	Benzene	Ethylbenzene	Formaldehyde	H_2S	n-Hexane	Toluene	Xylenes	CH_4	CO_2	N_2O	Pads	Acetaldehyde	Acrolein
Per Pad	0.03	0.09	8.71	0.87	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	23.69	0.00	22.0		

per pad

Completion ton

	CO	NOx	PM_{10}	$PM_{2.5}$	SO_2	VOC	Benzene	Ethylbenzene	Formaldehyde	H_2S	n-Hexane	Toluene	Xylenes	CH_4	CO_2	N_2O	Pads	Acetaldehyde	Acrolein
Per Pad	1.7	7.8	30.2	4.6	0.4	0.4	5.93E-03	0.0	9.88E-03	0.0	0.0	0.0	0.0	0.5	1028.3	0.0	22.0	4.3E-03	5.1E-04

per pad

Commuter

1	26.59	3.47	0.08	0.05	0.00	0.11	2.16E-03		6.07E-03					0.02	1054.39	0.03
2	24.82	3.36	0.08	0.05	0.00	0.10	1.90E-03		9.66E-03					0.02	1050.27	0.03
3	23.26	3.26	0.08	0.04	0.00	0.09	1.70E-03		4.63E-03					0.02	1046.55	0.03
4	21.89	3.17	0.07	0.04	0.00	0.08	1.52E-03		4.06E-03					0.02	1042.90	0.03
5	20.67	3.10	0.07	0.04	0.00	0.07	1.37E-03		3.58E-03					0.02	1039.43	0.03
6	19.62	3.03	0.07	0.03	0.00	0.06	1.24E-03		3.16E-03					0.02	1036.22	0.03
7	18.69	2.98	0.07	0.03	0.00	0.05	1.13E-03		2.80E-03					0.02	1033.24	0.03
8	17.88	2.92	0.06	0.03	0.00	0.05	1.03E-03		2.48E-03					0.02	1030.55	0.03
9	17.10	2.88	0.06	0.03	0.00	0.04	9.44E-04		2.20E-03					0.02	1028.07	0.03
10	16.34	2.84	0.06	0.03	0.00	0.04	8.64E-04		1.95E-03					0.02	1025.85	0.03

ton

Year	CO	NOx	PM_{10}	$PM_{2.5}$	SO_2	VOC	Benzene	Ethylbenzene	Formaldehyde	H_2S	n-Hexane	Toluene	Xylenes	CH_4	CO_2	N_2O	CO2e	Acetaldehyde	Acrolein	Pads	Wells
1	33.1	33.13	146.1	20.6	1.3	1.82	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.8	4999.2	0.1	5,062	0.0	0.0		60
2	42.2	82.45	389.4	54.8	3.5	4.65	0.1	0.0	0.1	0.0	0.0	0.0	0.0	4.8	11569.7	0.1	11,721	0.1	0.0		160
3	40.6	82.35	389.4	54.8	3.5	4.63	0.1	0.0	0.1	0.0	0.0	0.0	0.0	4.8	11566.0	0.1	11,717	0.0	0.0		160
4	39.3	82.27	389.4	54.8	3.5	4.62	0.1	0.0	0.1	0.0	0.0	0.0	0.0	4.8	11562.4	0.1	11,714	0.0	0.0		160
5	38.0	82.19	389.4	54.8	3.5	4.62	0.1	0.0	0.1	0.0	0.0	0.0	0.0	4.8	11558.9	0.1	11,710	0.0	0.0		160
6	37.0	82.13	389.4	54.8	3.5	4.61	0.1	0.0	0.1	0.0	0.0	0.0	0.0	4.8	11555.7	0.1	11,707	0.0	0.0		160
7	36.1	82.07	389.4	54.8	3.5	4.60	0.1	0.0	0.1	0.0	0.0	0.0	0.0	4.8	11552.7	0.1	11,704	0.0	0.0		160
8	35.3	82.02	389.4	54.8	3.5	4.60	0.1	0.0	0.1	0.0	0.0	0.0	0.0	4.8	11550.0	0.1	11,701	0.0	0.0		160
9	34.5	81.97	389.4	54.8	3.5	4.59	0.1	0.0	0.1	0.0	0.0	0.0	0.0	4.8	11547.5	0.1	11,699	0.0	0.0		160
10	33.7	81.93	389.4	54.8	3.5	4.59	0.1	0.0	0.1	0.0	0.0	0.0	0.0	4.8	11545.3	0.1	11,697	0.0	0.0		160

NPL Project General Conformity Emissions Inventory

Table 50c. Drill Rig Engines Only

Wells/Pad 16

Drilling **tons**

	CO	NOx	PM_{10}	$PM_{2.5}$	SO_2	VOC	Benzene	Ethylbenzene	Formaldehyde	H_2S	n-Hexane	Toluene	Xylenes	CH_4	CO_2	N_2O	Pads	Acetaldehyde	Acrolein
Per Pad	24.21	12.29	0.25	0.11	0.08	1.40	0.01	0.00	1.66	0.00	0.03	0.01	0.00	34.52	3086.24	0.01	22.0	0.03	0.01
						per pad													

tons/year

Year	CO	NOx	PM_{10}	$PM_{2.5}$	SO_2	VOC	Benzene	Ethylbenzene	Formaldehyde	H_2S	n-Hexane	Toluene	Xylenes	CH_4	CO_2	N_2O	CO2e	Acetaldehyde	Acrolein	Pads	Wells
1	90.8	46.08	0.9	0.4	0.3	5.25	0.0	0.0	6.2	0.0	0.1	0.0	0.0	129.5	11573.4	0.0	14,820	0.1	0.0		60
2	242.1	122.89	2.5	1.1	0.8	14.01	0.1	0.0	16.6	0.0	0.3	0.1	0.0	345.2	30862.4	0.1	39,519	0.3	0.1		160
3	242.1	122.89	2.5	1.1	0.8	14.01	0.1	0.0	16.6	0.0	0.3	0.1	0.0	345.2	30862.4	0.1	39,519	0.3	0.1		160
4	242.1	122.89	2.5	1.1	0.8	14.01	0.1	0.0	16.6	0.0	0.3	0.1	0.0	345.2	30862.4	0.1	39,519	0.3	0.1		160
5	242.1	122.89	2.5	1.1	0.8	14.01	0.1	0.0	16.6	0.0	0.3	0.1	0.0	345.2	30862.4	0.1	39,519	0.3	0.1		160
6	242.1	122.89	2.5	1.1	0.8	14.01	0.1	0.0	16.6	0.0	0.3	0.1	0.0	345.2	30862.4	0.1	39,519	0.3	0.1		160
7	242.1	122.89	2.5	1.1	0.8	14.01	0.1	0.0	16.6	0.0	0.3	0.1	0.0	345.2	30862.4	0.1	39,519	0.3	0.1		160
8	242.1	122.89	2.5	1.1	0.8	14.01	0.1	0.0	16.6	0.0	0.3	0.1	0.0	345.2	30862.4	0.1	39,519	0.3	0.1		160
9	242.1	122.89	2.5	1.1	0.8	14.01	0.1	0.0	16.6	0.0	0.3	0.1	0.0	345.2	30862.4	0.1	39,519	0.3	0.1		160
10	242.1	122.89	2.5	1.1	0.8	14.01	0.1	0.0	16.6	0.0	0.3	0.1	0.0	345.2	30862.4	0.1	39,519	0.3	0.1		160

NPL Project General Conformity Emissions Inventory

Table 51. Production Emission Summary - (Cummulative)

tons

Facility	CO	NOx	PM_{10}	$PM_{2.5}$	SO_2	VOC	Benzene	Ethylbenzene	Formaldehyde	H_2S	n-Hexane	Toluene	Xylenes	CH_4	CO_2	N_2O	Year Comes Online
1	0.7	0.9	14.5	1.6	0.0	3.1	0.02	0.002	0.006	0.000	0.058	0.045	0.031	18.81	304.9	0.000	1
2	0.5	0.8	14.5	1.6	0.0	2.9	0.02	0.002	0.006	0.000	0.056	0.036	0.023	18.47	273.2	0.000	1
3	0.6	0.9	14.5	1.6	0.0	3.1	0.02	0.002	0.006	0.000	0.058	0.045	0.031	18.81	304.9	0.000	1
4	0.5	0.8	14.5	1.6	0.0	2.9	0.02	0.002	0.006	0.000	0.056	0.036	0.023	18.47	273.2	0.000	2
5	0.5	0.8	14.5	1.6	0.0	2.9	0.02	0.002	0.006	0.000	0.056	0.036	0.023	18.47	273.2	0.000	2
6	0.6	0.9	14.5	1.6	0.0	3.1	0.02	0.002	0.006	0.000	0.058	0.045	0.031	18.81	304.9	0.000	3
7	0.5	0.8	14.5	1.6	0.0	2.9	0.02	0.002	0.006	0.000	0.056	0.032	0.019	18.46	260.5	0.000	4
8	0.5	0.8	14.5	1.6	0.0	2.9	0.02	0.002	0.006	0.000	0.056	0.036	0.023	18.47	273.2	0.000	4
9	0.5	0.8	14.5	1.6	0.0	2.9	0.02	0.002	0.006	0.000	0.056	0.032	0.019	18.46	260.5	0.000	6
10	0.4	0.8	14.5	1.6	0.0	2.8	0.02	0.001	0.006	0.000	0.054	0.026	0.015	18.14	241.5	0.000	7
11	0.3	0.8	14.5	1.6	0.0	2.8	0.01	0.001	0.006	0.000	0.054	0.021	0.010	18.11	222.5	0.000	9

Blowdown Per Pad	0.00	0.00	0.00	0.00	0.00	1.07	0.00	0.00	0.00	0.00	0.02	0.01	0.00	7.33	0.12	0.00	22	Pad/year

Wind Erosion Production

Year			PM_{10}	$PM_{2.5}$			Facility cummulativ	pads
1			28.22	4.23			3	10
2			55.04	8.26			5	20
3			80.45	12.07			6	30
4			107.27	16.09			8	40
5			131.27	19.69			8	50
6			156.68	23.50			9	60
7			182.09	27.31			10	70
8			206.10	30.92			10	80
9			231.51	34.73			11	90
10			255.52	38.33			11	100

tons

Year	CO	NOx	PM_{10}	$PM_{2.5}$	SO_2	VOC	Benzene	Ethylbenzene	Formaldehyde	H_2S	n-Hexane	Toluene	Xylenes	CH_4	CO_2	N_2O	CO2e
1	1.8	2.66	71.7	8.9	0.0	55.38	0.3	0.0	0.019	0.0	1.1	0.4	0.2	373.1	885.6	1.38E-03	10,212
2	2.8	4.36	127.5	16.0	0.0	107.55	0.5	0.0	0.032	0.0	2.1	0.8	0.4	727.0	1439.7	2.31E-03	19,614
3	3.4	5.25	167.4	21.4	0.0	156.91	0.8	0.1	0.038	0.0	3.1	1.2	0.5	1062.7	1749.8	2.77E-03	28,319
4	4.3	6.93	223.2	28.5	0.0	209.05	1.0	0.1	0.051	0.0	4.2	1.5	0.7	1416.6	2288.7	3.69E-03	37,705
5	4.3	6.93	247.2	32.1	0.0	255.33	1.2	0.1	0.051	0.0	5.1	1.8	0.8	1733.6	2293.9	3.69E-03	45,635
6	4.8	7.77	287.1	37.5	0.0	304.53	1.4	0.1	0.057	0.0	6.1	2.2	0.9	2069.0	2559.6	4.15E-03	54,286
7	5.2	8.58	327.0	42.9	0.0	353.62	1.7	0.1	0.064	0.0	7.1	2.5	1.0	2404.1	2806.3	4.61E-03	62,910
8	5.2	8.58	351.0	46.5	0.0	399.90	1.9	0.1	0.064	0.0	7.6	2.8	1.1	2721.1	2811.5	4.61E-03	70,839
9	5.5	9.37	390.9	51.8	0.0	448.94	2.1	0.1	0.070	0.0	9.0	3.1	1.3	3056.1	3039.1	5.07E-03	79,444
10	5.5	9.37	414.9	55.4	0.0	495.23	2.3	0.1	0.070	0.0	9.9	3.5	1.4	3373.1	3044.3	5.07E-03	87,373

Well fugitives - add to production above

Year	Pad							Tons							
1	10					22.7	0.1	0.0			0.5	0.2	0.1	155.7	2.6
2	20					45.5	0.2	0.0			0.9	0.3	0.1	311.4	5.1
3	30					68.2	0.3	0.0			1.4	0.5	0.2	467.2	7.7
4	40					91.0	0.4	0.0			1.8	0.6	0.2	622.9	10.2
5	50					113.7	0.5	0.0			2.3	0.8	0.3	778.6	12.8
6	60					136.4	0.6	0.0			2.7	0.9	0.3	934.3	15.3
7	70					159.2	0.7	0.0			3.2	1.1	0.4	1090.0	17.9
8	80					181.9	0.8	0.0			3.7	1.2	0.4	1245.8	20.4
9	90					204.7	0.9	0.1			4.1	1.4	0.5	1401.5	23.0
10	100					227.4	1.0	0.1			4.6	1.5	0.6	1557.2	25.5

NPL Project General Conformity Emissions Inventory

Table 51b. Production Comformity Emission Summary

									tons								
Year	**CO**	**NOx**	**PM_{10}**	**$PM_{2.5}$**	**SO_2**	**VOC**	**Benzene**	**Ethylbenzene**	**Formaldehyde**	**H_2S**	**n-Hexane**	**Toluene**	**Xylenes**	**CH_4**	**CO_2**	**N_2O**	**CO2e**
1	1.8	2.7	71.7	8.9	0.0	55.4	2.76E-01	1.93E-02	1.91E-02	0.00E+00	1.10E+00	4.32E-01	1.98E-01	373.1	885.6	1.38E-03	10,212
2	1.0	1.7	55.8	7.1	0.0	52.2	2.48E-01	1.62E-02	1.27E-02	0.00E+00	1.04E+00	3.78E-01	1.59E-01	353.9	554.1	9.22E-04	9,402
3	0.6	0.9	39.9	5.4	0.0	49.4	2.31E-01	1.49E-02	6.38E-03	0.00E+00	9.91E-01	3.52E-01	1.44E-01	335.8	310.1	4.61E-04	8,704
4	0.9	1.7	55.8	7.1	0.0	52.1	2.46E-01	1.60E-02	1.27E-02	0.00E+00	1.04E+00	3.74E-01	1.56E-01	353.9	538.9	9.22E-04	9,386
5	0.0	0.0	24.0	3.6	0.0	46.3	2.07E-01	1.25E-02	0.00E+00	0.00E+00	9.33E-01	3.07E-01	1.14E-01	317.0	5.2	0.00E+00	7,929
6	0.5	0.8	39.9	5.4	0.0	49.2	2.26E-01	1.41E-02	6.34E-03	0.00E+00	9.88E-01	3.39E-01	1.33E-01	335.4	265.7	4.61E-04	8,651
7	0.4	0.8	39.9	5.4	0.0	49.1	2.24E-01	1.37E-02	6.32E-03	0.00E+00	9.87E-01	3.33E-01	1.28E-01	335.1	246.7	4.61E-04	8,624
8	0.0	0.0	24.0	3.6	0.0	46.3	2.07E-01	1.25E-02	0.00E+00	0.00E+00	4.75E-01	3.07E-01	1.14E-01	317.0	5.2	0.00E+00	7,929
9	0.3	0.8	39.9	5.4	0.0	49.0	2.22E-01	1.34E-02	6.31E-03	0.00E+00	1.44E+00	3.28E-01	1.23E-01	335.1	227.7	4.61E-04	8,605
10	0.0	0.0	24.0	3.6	0.0	46.3	2.07E-01	1.25E-02	0.00E+00	0.00E+00	9.33E-01	3.07E-01	1.14E-01	317.0	5.2	0.00E+00	7,929

Table 52. Total Emission Summary

tons

Year	CO	NOx	PM_{10}	$PM_{2.5}$	SO_2	VOC	Benzene	Ethylbenzene	Formaldehyde	H_2S	n-Hexane	Toluene	Xylenes	CH_4	CO_2	N_2O	CO2e	Acetaldehyde	Acrolein
1	133.5	95.54	235.1	34.3	2.0	64.17	0.3	0.0	6.3	0.0	1.2	0.5	0.2	505	19060	0.1	31,707	0.3	0.2
2	294.9	223.26	535.3	76.2	4.6	127.92	0.7	0.0	16.7	0.0	2.4	0.9	0.4	1077	45459	0.2	72,453	0.9	0.5
3	293.9	223.93	574.7	81.5	4.6	177.26	0.9	0.1	16.7	0.0	3.4	1.3	0.6	1413	45751	0.2	81,139	0.9	0.5
4	293.5	225.64	631.0	88.7	4.6	229.40	1.2	0.1	16.8	0.0	4.5	1.7	0.7	1767	46301	0.2	90,536	0.9	0.5
5	292.2	225.34	654.0	92.2	4.6	275.65	1.4	0.1	16.8	0.0	5.4	2.0	0.8	2084	46273	0.2	98,432	0.9	0.5
6	291.6	226.23	694.4	97.6	4.6	324.85	1.6	0.1	16.8	0.0	6.4	2.3	1.0	2419	46550	0.2	107,095	0.9	0.5
7	291.1	226.98	734.3	103.0	4.6	373.94	1.8	0.1	16.8	0.0	7.4	2.6	1.1	2754	46794	0.2	115,716	0.9	0.5
8	290.2	226.82	757.8	106.5	4.6	420.21	2.0	0.1	16.8	0.0	7.8	3.0	1.2	3071	46781	0.2	123,628	0.9	0.5
9	289.9	227.68	798.2	112.0	4.6	469.25	2.3	0.1	16.8	0.0	9.3	3.3	1.3	3406	47022	0.2	132,245	0.9	0.5
10	289.0	227.52	821.7	115.5	4.6	515.52	2.5	0.2	16.8	0.0	10.2	3.6	1.4	3723	47010	0.2	140,157	0.9	0.5

Table 52b. Overall Confomity Emission Summary

tons

Year	CO	NOx	PM_{10}	$PM_{2.5}$	SO_2	VOC	Benzene	Ethylbenzene	Formaldehyde	H_2S	n-Hexane	Toluene	Xylenes	CH_4	CO_2	N_2O	CO2e	Acetaldehyde	Acrolein	Wells (Completion)
1	42.8	49.5	234.2	33.9	1.7	58.9	0.3	0.0	0.1	0.0	1.1	0.4	0.2	375.1	7487.1	0.1	16,888	0.0	0.0	60
2	51.0	97.7	461.2	66.3	3.9	58.5	0.3	0.0	0.1	0.0	1.1	0.4	0.2	358.9	13711.1	0.1	22,721	0.1	0.0	160
3	49.0	96.7	444.8	64.4	3.9	55.7	0.3	0.0	0.1	0.0	1.0	0.4	0.2	340.8	13448.5	0.1	22,005	0.0	0.0	160
4	48.1	97.5	461.1	66.2	3.9	58.5	0.3	0.0	0.1	0.0	1.1	0.4	0.2	358.9	13688.6	0.1	22,698	0.0	0.0	160
5	45.8	95.5	428.4	62.6	3.8	52.6	0.3	0.0	0.1	0.0	0.9	0.3	0.1	322.0	13121.6	0.1	21,207	0.0	0.0	160
6	45.2	96.4	444.7	64.4	3.9	55.5	0.3	0.0	0.1	0.0	1.0	0.4	0.2	340.4	13393.8	0.1	21,941	0.0	0.0	160
7	44.3	96.3	444.7	64.4	3.9	55.4	0.3	0.0	0.1	0.0	1.0	0.4	0.1	340.1	13371.8	0.1	21,911	0.0	0.0	160
8	43.0	95.4	428.3	62.6	3.8	52.6	0.3	0.0	0.1	0.0	0.5	0.3	0.1	322.0	13112.8	0.1	21,198	0.0	0.0	160
9	42.6	96.2	444.7	64.4	3.9	55.3	0.3	0.0	0.1	0.0	1.5	0.4	0.1	340.1	13347.7	0.1	21,886	0.0	0.0	160
10	41.5	95.3	428.3	62.6	3.8	52.6	0.3	0.0	0.1	0.0	0.9	0.3	0.1	322.0	13108.1	0.1	21,193	0.0	0.0	160

NPL Project General Conformity Emissions Inventory

CONFORMITY PLOT DATA

CO (tons)

Year	1	2	3	4	5	6	7	8	9	10
Constructic	7.87	7.83	7.80	7.83	7.76	7.80	7.80	7.76	7.80	7.76
Drilling	33.11	42.20	40.64	39.27	38.05	36.99	36.07	35.25	34.48	33.71
Production	1.78	0.99	0.59	0.95	0.00	0.46	0.40	0.00	0.34	0.00

NOx (tons)

Year	1	2	3	4	5	6	7	8	9	10
Constructic	13.67	13.56	13.45	13.56	13.34	13.45	13.45	13.34	13.45	13.34
Drilling	33.13	82.45	82.35	82.27	82.19	82.13	82.07	82.02	81.97	81.93
Production	2.66	1.70	0.89	1.68	0.00	0.84	0.81	0.00	0.79	0.00

PM10 (tons)

Year	1	2	3	4	5	6	7	8	9	10
Constructic	16.41	15.91	15.41	15.91	14.91	15.41	15.41	14.91	15.41	14.91
Drilling	146.10	389.45	389.44	389.44	389.44	389.44	389.43	389.43	389.43	389.43
Production	71.69	55.80	39.90	55.79	24.01	39.90	39.90	24.01	39.90	24.01

PM2.5 (tons)

	1	2	3	4	5	6	7	8	9	10
Year	2015	2015	2016	2017	2018	2019	2020	2021	2022	2023
Constructic	4.38	4.32	4.26	4.32	4.20	4.26	4.26	4.20	4.26	4.20
Drilling	20.58	54.80	54.80	54.80	54.79	54.79	54.79	54.79	54.79	54.79
Production	8.90	7.13	5.37	7.13	3.60	5.36	5.36	3.60	5.36	3.60

VOC (tons)

Year	1	2	3	4	5	6	7	8	9	10
Constructic	1.72	1.71	1.70	1.71	1.69	1.70	1.70	1.69	1.70	1.69
Drilling	1.82	4.65	4.63	4.62	4.62	4.61	4.60	4.60	4.59	4.59
Production	55.38	52.17	49.36	52.14	46.28	49.19	49.09	46.28	49.04	46.28

CH4 (tons)

Year	1	2	3	4	5	6	7	8	9	10
Constructic	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23
Drilling	1.80	4.77	4.77	4.77	4.77	4.77	4.77	4.77	4.76	4.76
Production	373.06	353.91	335.77	353.89	316.96	335.42	335.10	316.96	335.07	316.96

CO2 (tons)

Year	1	2	3	4	5	6	7	8	9	10
Constructic	1602.23	1587.33	1572.43	1587.33	1557.53	1572.43	1572.43	1557.53	1572.43	1557.53
Drilling	4999.19	11569.75	11566.03	11562.38	11558.90	11555.69	11552.72	11550.03	11547.55	11545.33
Production	885.64	554.06	310.07	538.89	5.19	265.71	246.69	5.19	227.68	5.19

N2O (tons)

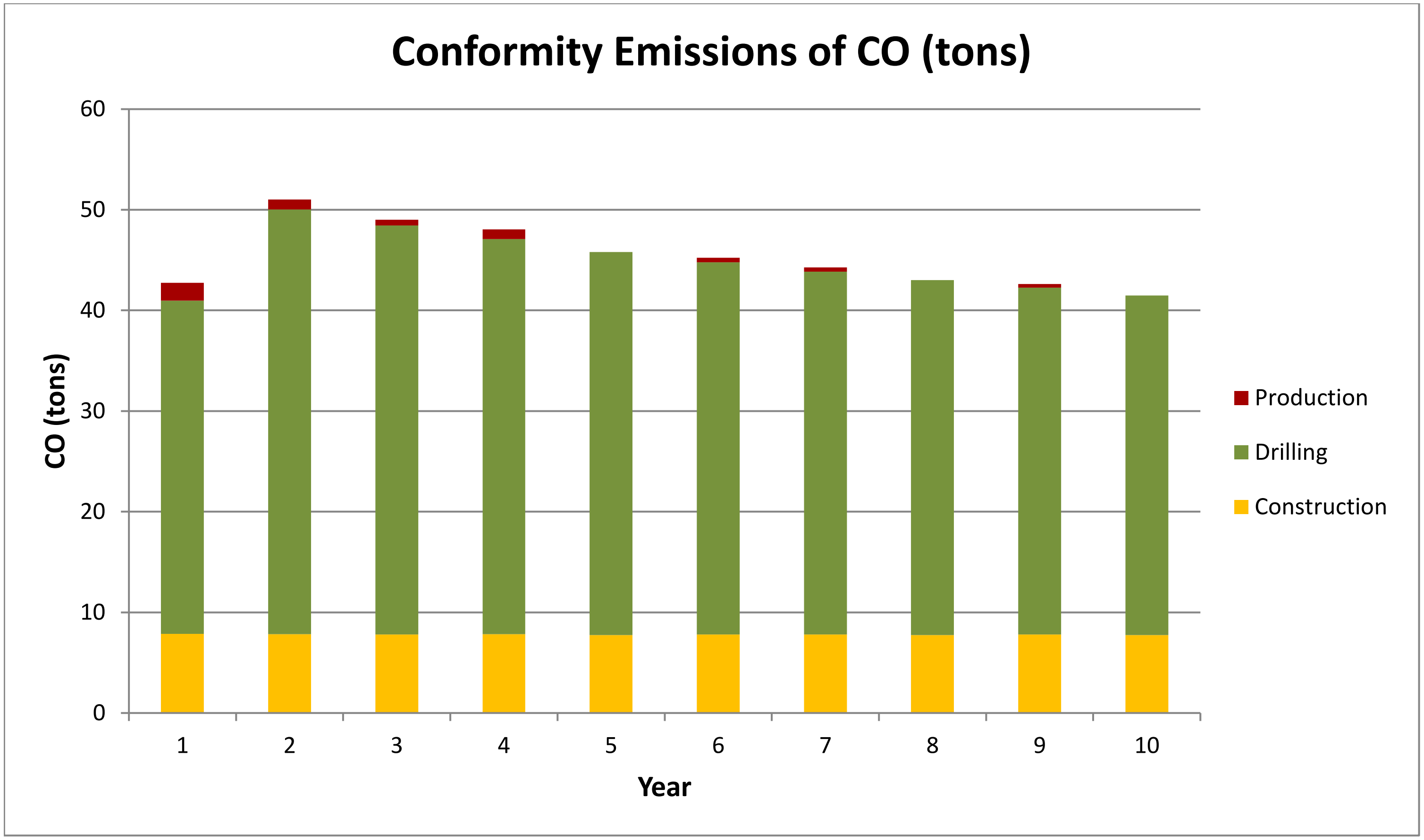
Year	1	2	3	4	5	6	7	8	9	10
Constructic	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Drilling	0.06	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
Production	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

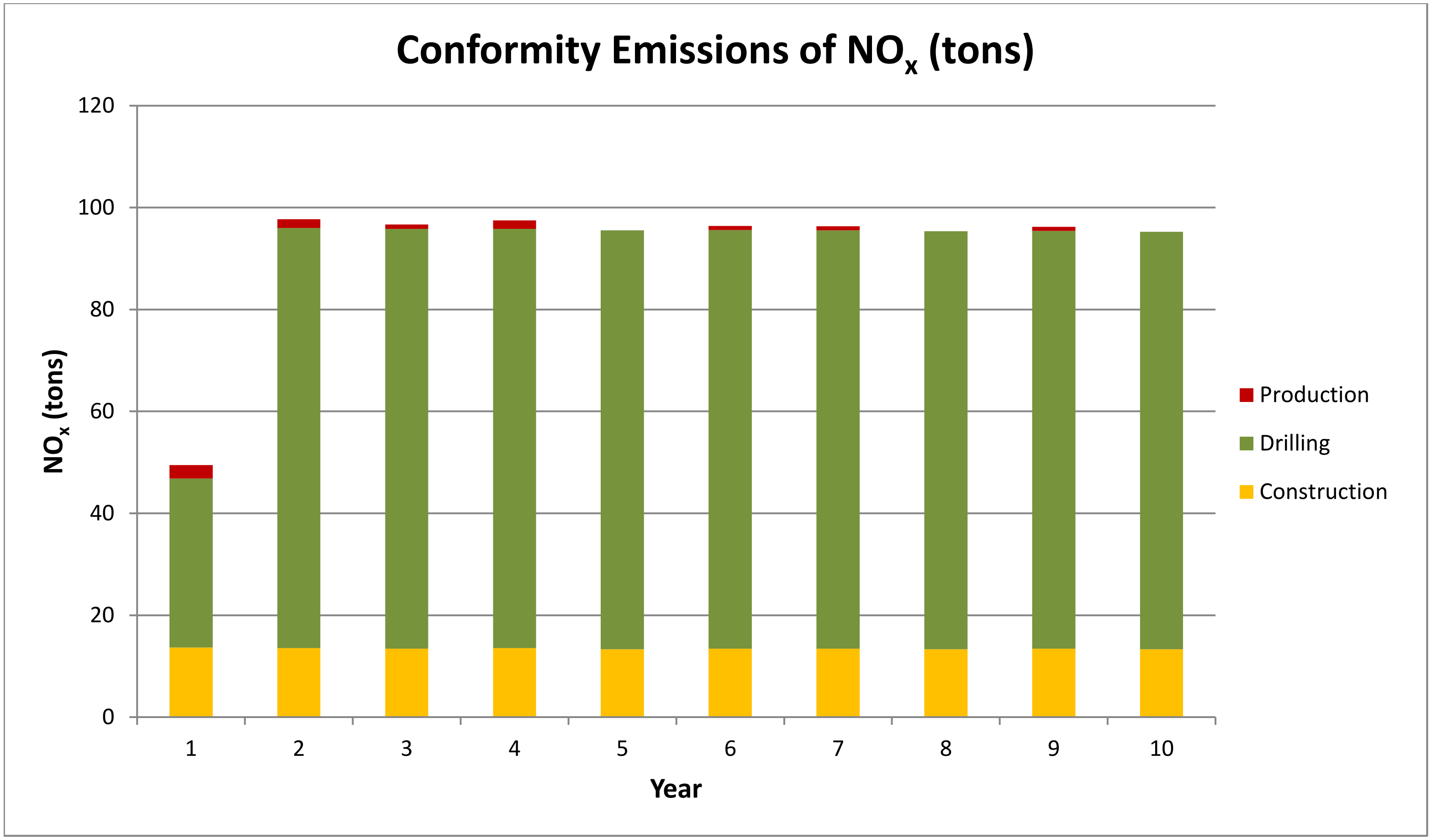
SO2 (tons)

Year	1	2	3	4	5	6	7	8	9	10
Constructic	0.34	0.34	0.34	0.34	0.33	0.34	0.34	0.33	0.34	0.33
Drilling	1.32	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51
Production	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

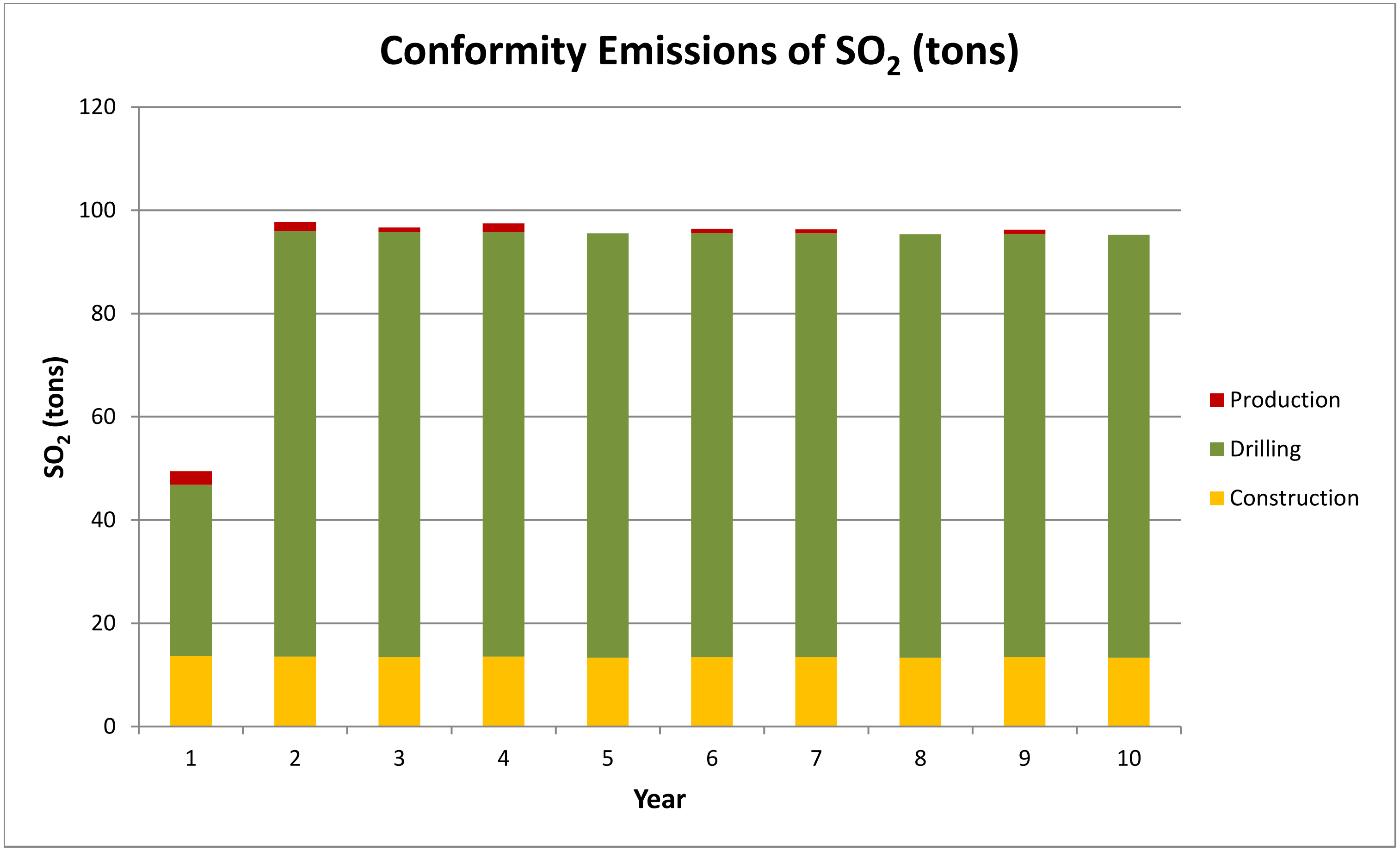
CO2eq (tons)

Year	1	2	3	4	5	6	7	8	9	10
Constructic	1612.76	1597.76	1582.76	1597.76	1567.76	1582.76	1582.76	1567.76	1582.76	1567.76
Drilling	5062.31	11721.19	11717.42	11713.74	11710.22	11706.97	11703.97	11701.26	11698.75	11696.51
Production	10212.43	9402.03	8704.47	9386.48	7929.18	8651.30	8624.25	7929.18	8604.66	7929.18

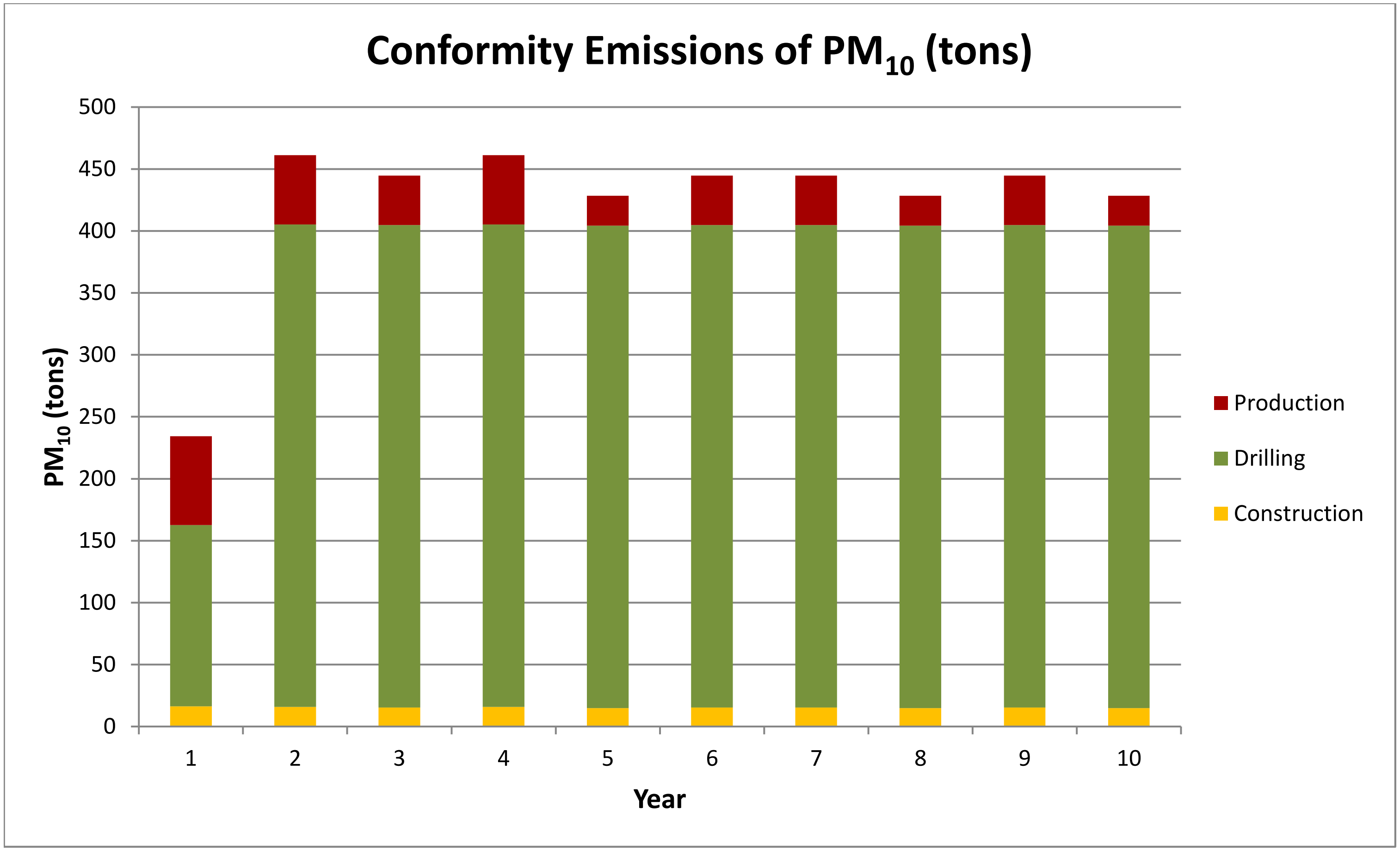

Conformity Emissions of CO (tons)
CO (tons)
60
50
40
30
20
10
0
1
2
3
4
5
6
7
8
9
10
Year
Production
Drilling
Construction



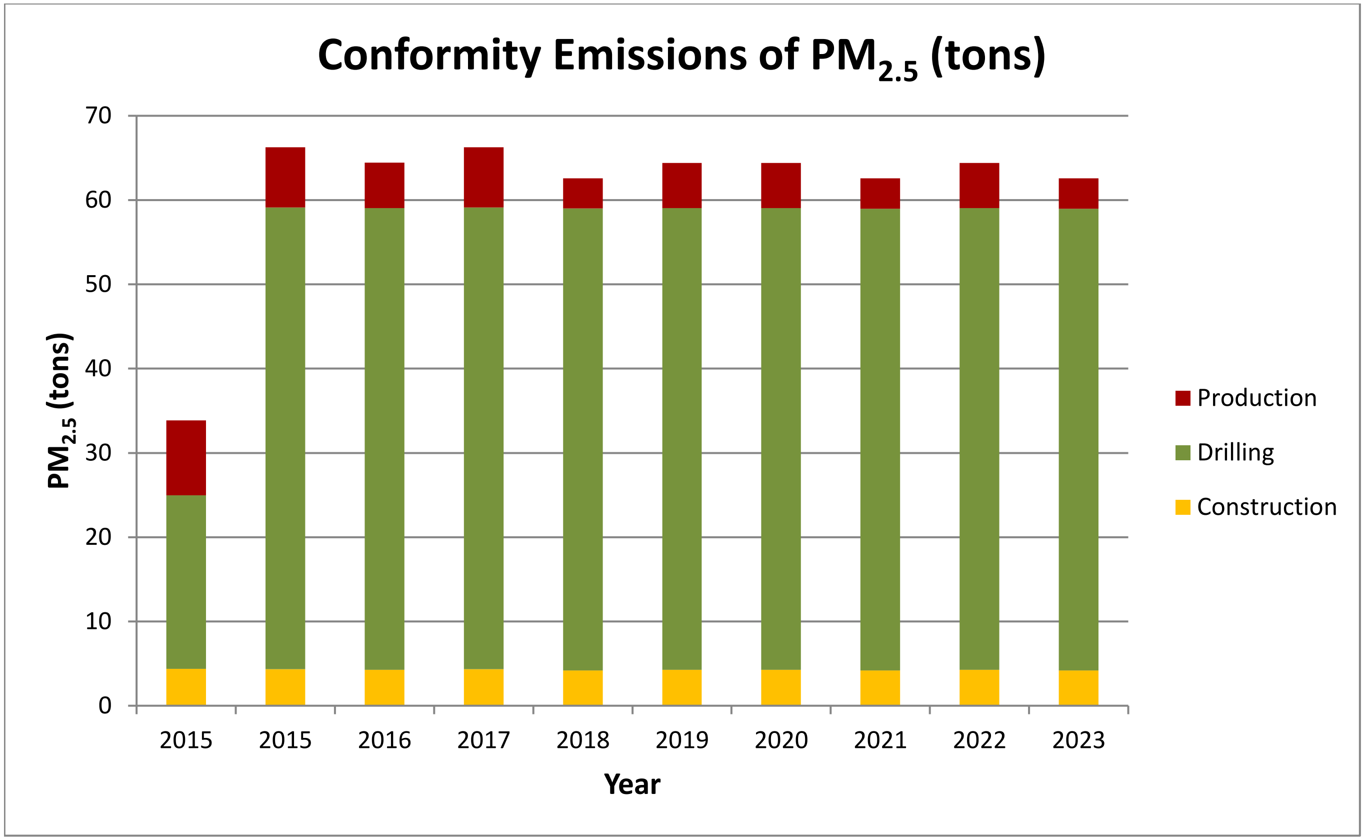
Conformity Emissions of NO_x (tons)
120
100
80
60
40
20
0
NO_x (tons)
1
2
3
4
5
6
7
8
9
10
Year
Production
Drilling
Construction

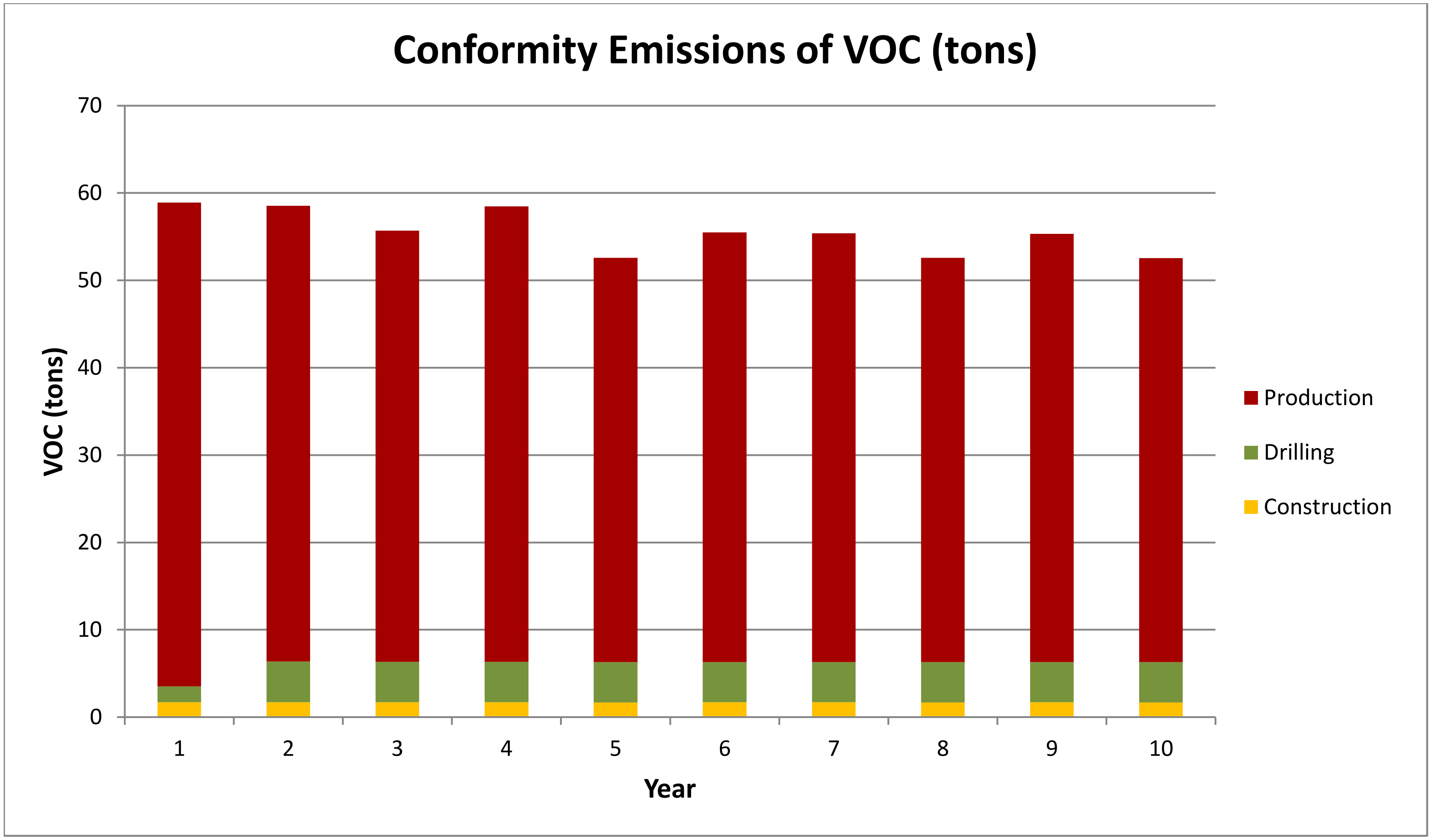


Conformity Emissions of SO_2 (tons)
120
100
80
60
40
20
0
SO_2 (tons)
1
2
3
4
5
6
7
8
9
10
Year
Production
Drilling
Construction

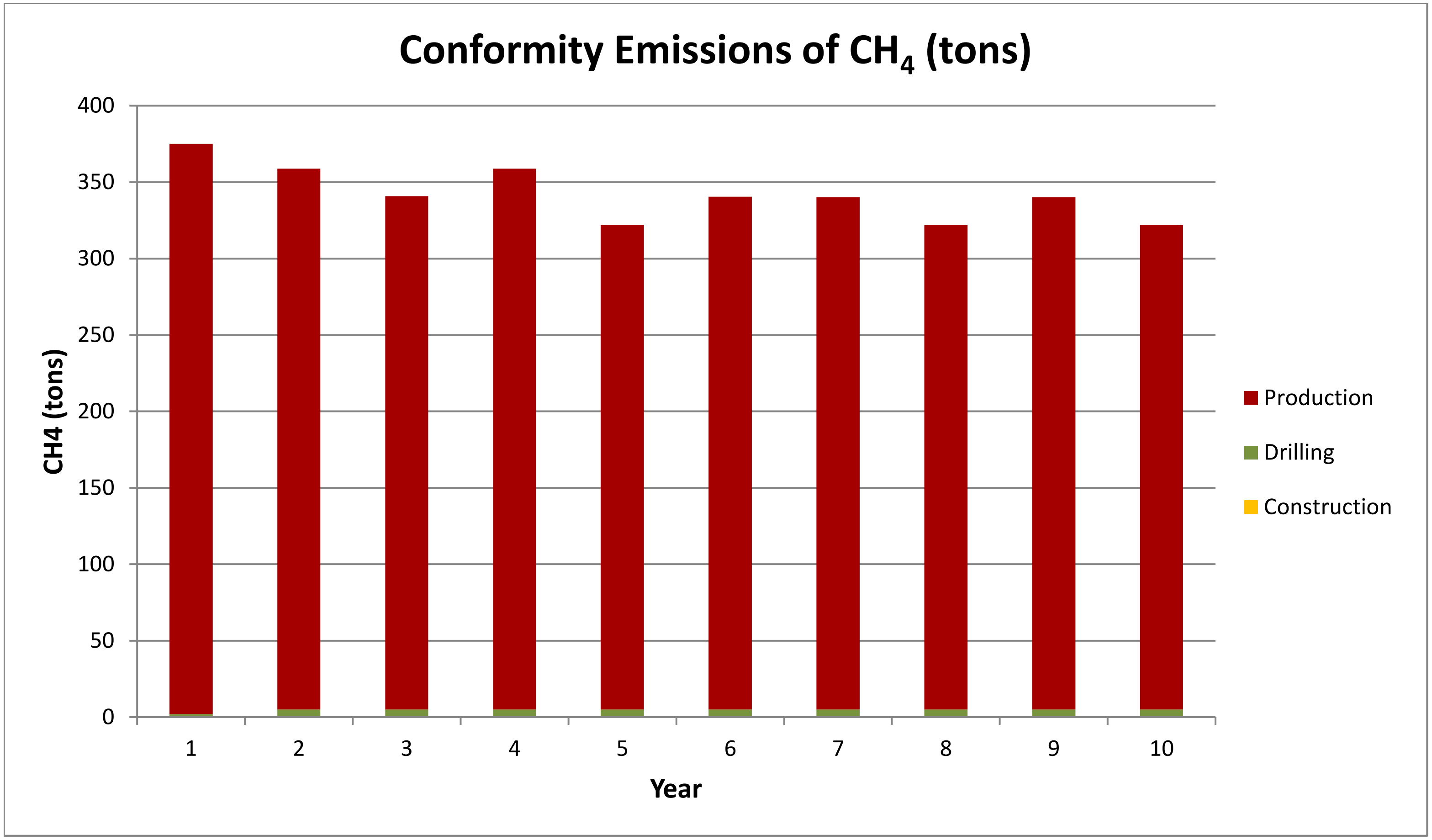


Conformity Emissions of PM10 (tons)
500
450
400
350
300
250
200
150
100
50
0
PM10 (tons)
1
2
3
4
5
6
7
8
9
10
Year
Production
Drilling
Construction

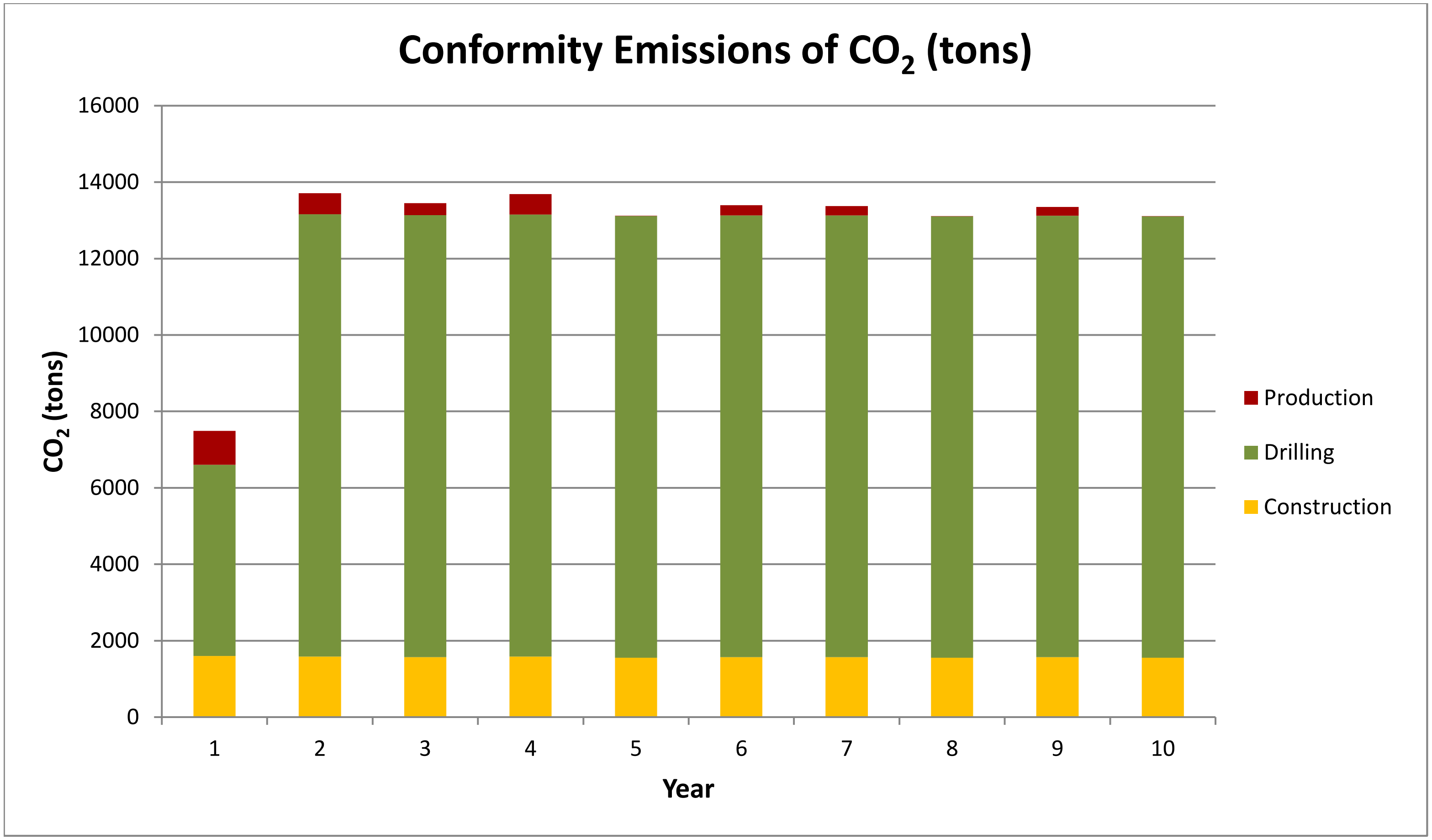

Conformity Emissions of PM2.5 (tons)
70
60
50
40
30
20
10
0
PM2.5 (tons)
2015
2015
2016
2017
2018
2019
2020
2021
2022
2023
Year
Production
Drilling
Construction



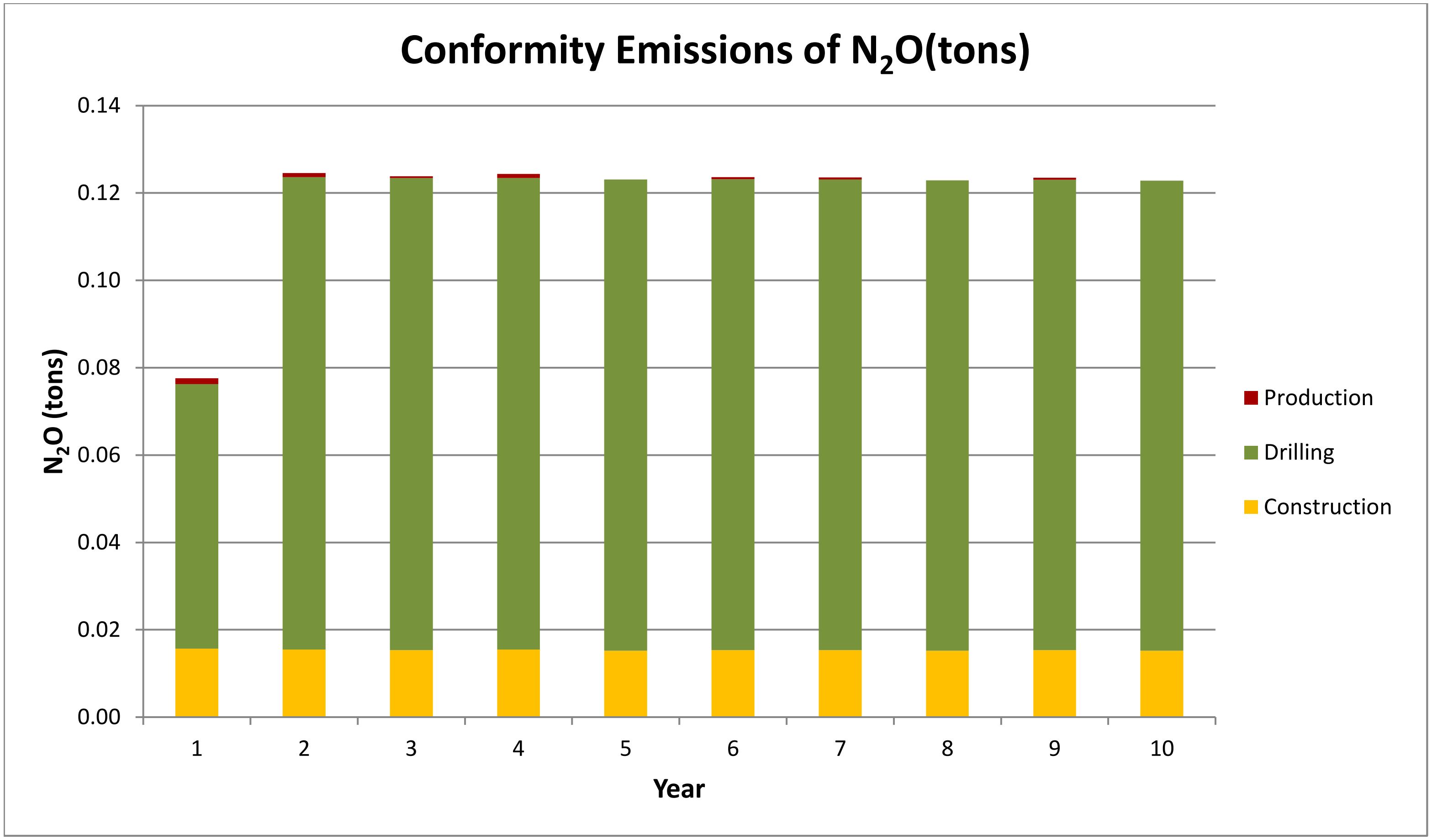
Conformity Emissions of VOC (tons)
70
60
50
40
30
20
10
0
VOC (tons)
1
2
3
4
5
6
7
8
9
10
Year
Production
Drilling
Construction



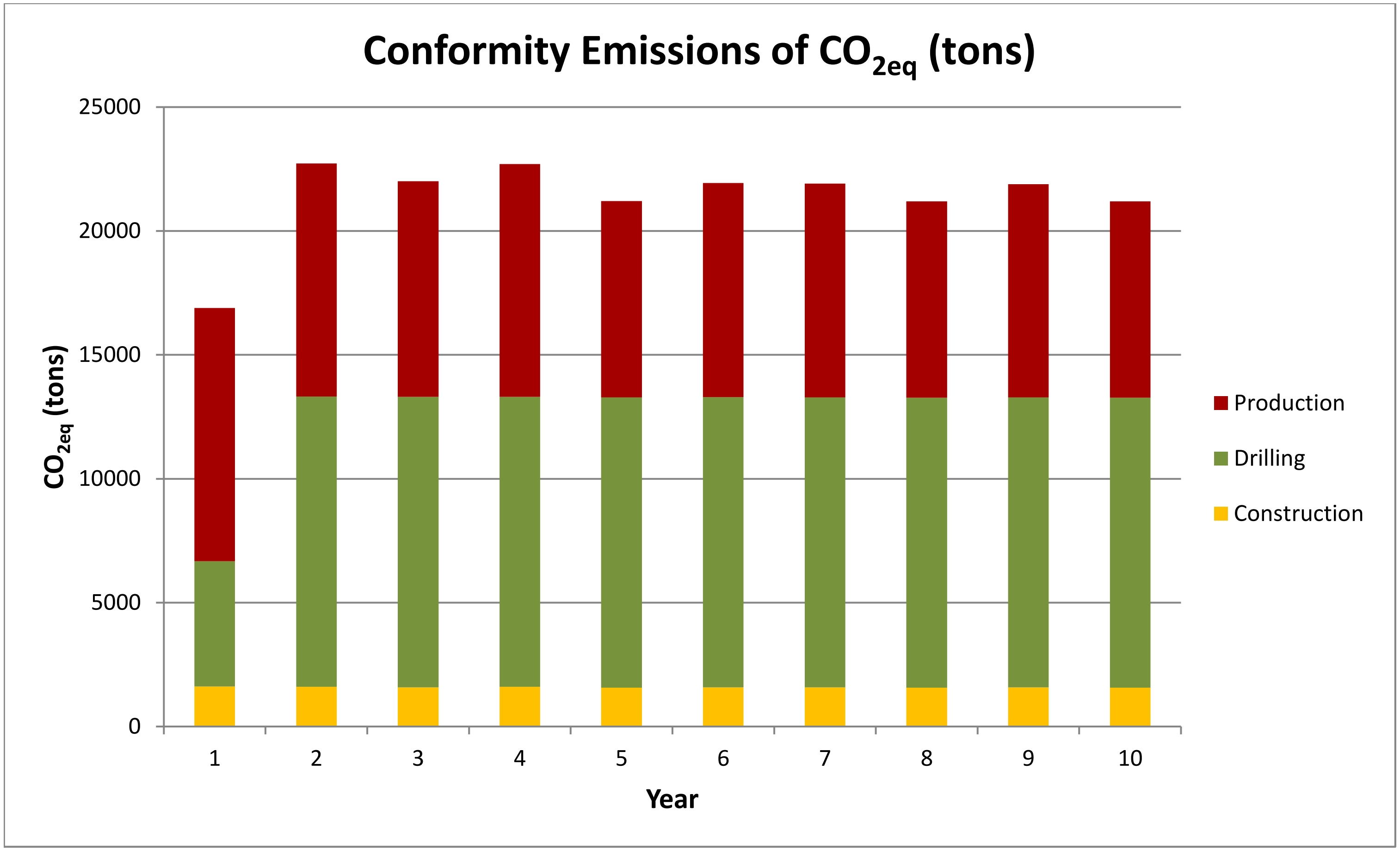
Conformity Emissions of CH_4 (tons)
400
350
300
250
200
150
100
50
0
CH4 (tons)
1
2
3
4
5
6
7
8
9
10
Year
Production
Drilling
Construction



Conformity Emissions of CO_2 (tons)
16000
14000
12000
10000
8000
6000
4000
2000
0
CO_2 (tons)
1
2
3
4
5
6
7
8
9
10
Year
Production
Drilling
Construction



Conformity Emissions of N2O(tons)
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
N2O (tons)
1
2
3
4
5
6
7
8
9
10
Year
Production
Drilling
Construction


Conformity Emissions of CO_{2eq} (tons)
25000
20000
15000
10000
5000
0
CO_{2eq} (tons)
1
2
3
4
5
6
7
8
9
10
Year
Production
Drilling
Construction

MOVES DATA

Sum of emisRate				Pollutant	RateUnit																					=CO2(eq)-(CH4*21)-(NO2*320)				
				PM2.5 Tirewear	PM2.5 Brakewear	PM10 Tirewear	PM10 Brakewear	PM10 Total Exh	VOC	SO2	NOx	CO	Methane (CH4)	N2O	Benzene	Formaldehyde	CO2 Equivalent	PM2.5 Total Exh	NOx	PM10	PM2.5	SO2	CO	VOC	CO2	Methane (CH4)	N2O	Benzene	Formaldehyde	CO2 Equivalent
RoadType	yearID	FuelType	SourceType	g/mi	g/mi	g/mi	g/mi	g/mi	g/mi	g/mi	g/mi	g/mi	g/mi	g/mi	g/mi	g/mi	g/mi	g/mi												
Rural Unrestricted Access	2013	Diesel Fuel	Combination Long-haul Truck	4.44E-03	1.07E-02	1.85E-02	4.09E-02	4.42E-01	3.76E-01	#######	9.64E+00	2.25E+00	2.67E-02	#######	4.07E-03	3.03E-02	1.95E+03	4.29E-01	9.64E+00	#######	#######	1.47E-02	2.25E+00	3.76E-01	1.94E+03	2.67E-02	#######	4.07E-03	3.03E-02	1.95E+03
			Combination Short-haul Truck	4.04E-03	9.93E-03	1.69E-02	3.79E-02	3.96E-01	3.65E-01	#######	8.98E+00	2.06E+00	2.80E-02	#######	3.96E-03	2.95E-02	1.87E+03	3.84E-01	8.98E+00	#######	#######	1.40E-02	2.06E+00	3.65E-01	1.86E+03	2.80E-02	#######	3.96E-03	2.95E-02	1.87E+03
			Intercity Bus	4.86E-03	1.62E-02	2.03E-02	6.17E-02	5.77E-01	4.55E-01	#######	1.17E+01	2.80E+00	2.56E-02	#######	4.94E-03	3.68E-02	1.62E+03	5.60E-01	1.17E+01	#######	#######	1.24E-02	2.80E+00	4.55E-01	1.62E+03	2.56E-02	#######	4.94E-03	3.68E-02	1.62E+03
			Passenger Car	1.27E-03	1.92E-03	5.30E-03	7.33E-03	1.47E-02	2.26E-02	#######	5.73E-01	3.73E-01	2.29E-03	#######	2.45E-04	1.83E-03	3.51E+02	1.43E-02	5.73E-01	#######	#######	2.62E-03	3.73E-01	2.26E-02	3.50E+02	2.29E-03	#######	2.45E-04	1.83E-03	3.51E+02
			Passenger Truck	1.62E-03	3.03E-03	6.75E-03	1.16E-02	1.27E-01	2.69E-01	#######	2.14E+00	1.32E+00	1.57E-02	#######	2.92E-03	2.17E-02	6.30E+02	1.23E-01	2.14E+00	#######	#######	4.75E-03	1.32E+00	2.69E-01	6.30E+02	1.57E-02	#######	2.92E-03	2.17E-02	6.30E+02
			School Bus	3.93E-03	1.37E-02	1.64E-02	5.25E-02	2.97E-01	4.17E-01	#######	5.56E+00	1.72E+00	2.20E-02	#######	4.52E-03	3.37E-02	8.14E+02	2.88E-01	5.56E+00	#######	#######	6.22E-03	1.72E+00	4.17E-01	8.13E+02	2.20E-02	#######	4.52E-03	3.37E-02	8.14E+02
			Single Unit Long-haul Truck	2.89E-03	1.07E-02	1.21E-02	4.10E-02	1.53E-01	3.37E-01	#######	3.03E+00	1.29E+00	3.67E-02	#######	3.65E-03	2.72E-02	8.01E+02	1.48E-01	3.03E+00	#######	#######	5.91E-03	1.29E+00	3.37E-01	8.00E+02	3.67E-02	#######	3.65E-03	2.72E-02	8.01E+02
			Single Unit Short-haul Truck	2.89E-03	1.08E-02	1.21E-02	4.11E-02	1.56E-01	3.18E-01	#######	3.18E+00	1.25E+00	3.73E-02	#######	3.45E-03	2.57E-02	8.56E+02	1.52E-01	3.18E+00	#######	#######	6.28E-03	1.25E+00	3.18E-01	8.55E+02	3.73E-02	#######	3.45E-03	2.57E-02	8.56E+02
			Transit Bus	2.61E-03	8.11E-03	1.09E-02	3.10E-02	4.34E-01	4.72E-01	#######	8.75E+00	2.79E+00	2.12E-02	#######	5.11E-03	3.81E-02	1.19E+03	4.21E-01	8.75E+00	#######	#######	9.01E-03	2.79E+00	4.72E-01	1.19E+03	2.12E-02	#######	5.11E-03	3.81E-02	1.19E+03
			Motor Home	2.28E-03	8.51E-03	9.53E-03	3.25E-02	2.31E-01	4.82E-01	#######	4.46E+00	1.63E+00	3.26E-02	#######	5.23E-03	3.89E-02	8.84E+02	2.24E-01	4.46E+00	#######	#######	6.65E-03	1.63E+00	4.82E-01	8.83E+02	3.26E-02	#######	5.23E-03	3.89E-02	8.84E+02
			Refuse Truck	4.57E-03	1.26E-02	1.90E-02	4.81E-02	4.07E-01	4.00E-01	#######	8.64E+00	2.16E+00	2.76E-02	#######	4.33E-03	3.23E-02	1.53E+03	3.95E-01	8.64E+00	#######	#######	1.15E-02	2.16E+00	4.00E-01	1.52E+03	2.76E-02	#######	4.33E-03	3.23E-02	1.53E+03
			Light Commercial Truck	1.65E-03	3.31E-03	6.88E-03	1.27E-02	1.65E-01	3.58E-01	#######	2.63E+00	1.67E+00	1.23E-02	#######	3.89E-03	2.89E-02	6.25E+02	1.60E-01	2.63E+00	#######	#######	4.80E-03	1.67E+00	3.58E-01	6.24E+02	1.23E-02	#######	3.89E-03	2.89E-02	6.25E+02
		Gasoline	Combination Short-haul Truck	2.29E-03	6.47E-03	9.55E-03	2.47E-02	1.31E-01	3.75E+00	#######	1.67E+01	1.34E+02	9.24E-02	#######	1.27E-01	4.60E-02	1.72E+03	1.21E-01	1.67E+01	#######	#######	3.02E-02	1.34E+02	3.75E+00	1.72E+03	9.24E-02	#######	1.27E-01	4.60E-02	1.72E+03
			Motorcycle	6.37E-04	1.66E-04	2.66E-03	6.33E-04	4.70E-02	7.62E-01	#######	8.50E-01	1.57E+01	2.90E-02	#######	2.57E-02	1.03E-02	3.71E+02	4.33E-02	8.50E-01	#######	#######	6.49E-03	1.57E+01	7.62E-01	3.70E+02	2.90E-02	#######	2.57E-02	1.03E-02	3.71E+02
			Passenger Car	1.27E-03	1.92E-03	5.30E-03	7.33E-03	9.03E-03	5.17E-02	#######	3.69E-01	2.31E+00	4.85E-03	#######	1.77E-03	6.56E-04	3.18E+02	8.31E-03	3.69E-01	#######	#######	5.56E-03	2.31E+00	5.17E-02	3.17E+02	4.85E-03	#######	1.77E-03	6.56E-04	3.18E+02
			Passenger Truck	1.30E-03	3.16E-03	5.42E-03	1.21E-02	1.52E-02	1.52E-01	#######	9.37E-01	5.01E+00	7.26E-03	#######	5.17E-03	1.92E-03	4.41E+02	1.40E-02	9.37E-01	#######	#######	7.71E-03	5.01E+00	1.52E-01	4.39E+02	7.26E-03	#######	5.17E-03	1.92E-03	4.41E+02
			School Bus	2.27E-03	8.84E-03	9.46E-03	3.38E-02	3.30E-02	1.18E+00	#######	4.42E+00	3.12E+01	5.54E-02	#######	3.99E-02	1.47E-02	7.73E+02	3.04E-02	4.42E+00	#######	#######	1.35E-02	3.12E+01	1.18E+00	7.67E+02	5.54E-02	#######	3.99E-02	1.47E-02	7.73E+02
			Single Unit Long-haul Truck	2.30E-03	9.22E-03	9.60E-03	3.52E-02	8.28E-03	3.91E-01	#######	3.32E+00	1.43E+01	8.55E-03	#######	1.32E-02	5.17E-03	8.04E+02	7.63E-03	3.32E+00	#######	#######	1.41E-02	1.43E+01	3.91E-01	8.01E+02	8.55E-03	#######	1.32E-02	5.17E-03	8.04E+02
			Single Unit Short-haul Truck	2.30E-03	9.23E-03	9.60E-03	3.53E-02	9.81E-03	4.38E-01	#######	3.51E+00	1.58E+01	1.06E-02	#######	1.48E-02	5.76E-03	8.56E+02	9.03E-03	3.51E+00	#######	#######	1.50E-02	1.58E+01	4.38E-01	8.53E+02	1.06E-02	#######	1.48E-02	5.76E-03	8.56E+02
			Transit Bus	2.27E-03	8.40E-03	9.46E-03	3.21E-02	1.05E-02	8.81E-01	#######	4.09E+00	2.90E+01	1.55E-02	#######	2.98E-02	1.15E-02	1.13E+03	9.67E-03	4.09E+00	#######	#######	1.97E-02	2.90E+01	8.81E-01	1.12E+03	1.55E-02	#######	2.98E-02	1.15E-02	1.13E+03
			Motor Home	2.21E-03	8.33E-03	9.22E-03	3.18E-02	2.30E-02	7.35E-01	#######	4.47E+00	2.52E+01	2.51E-02	#######	2.49E-02	9.36E-03	8.72E+02	2.11E-02	4.47E+00	#######	#######	1.52E-02	2.52E+01	7.35E-01	8.67E+02	2.51E-02	#######	2.49E-02	9.36E-03	8.72E+02
			Refuse Truck	2.21E-03	7.31E-03	9.22E-03	2.79E-02	1.56E-02	9.05E-01	#######	5.61E+00	3.79E+01	1.49E-02	#######	3.06E-02	1.18E-02	1.42E+03	1.44E-02	5.61E+00	#######	#######	2.49E-02	3.79E+01	9.05E-01	1.42E+03	1.49E-02	#######	3.06E-02	1.18E-02	1.42E+03
			Light Commercial Truck	1.33E-03	3.17E-03	5.53E-03	1.21E-02	1.49E-02	1.62E-01	#######	1.02E+00	5.23E+00	7.61E-03	#######	5.51E-03	2.06E-03	4.36E+02	1.37E-02	1.02E+00	#######	#######	7.62E-03	5.23E+00	1.62E-01	4.34E+02	7.61E-03	#######	5.51E-03	2.06E-03	4.36E+02
		Compressed Natural Gas (CNG)	Transit Bus	2.27E-03	8.41E-03	9.47E-03	3.21E-02	5.37E-03	0.00E+00		3.55E+00	3.74E+01	2.21E-02	#######			9.37E+02	5.37E-03	3.55E+00	#######	#######	#######	3.74E+01	0.00E+00	9.23E+02	2.21E-02	#######	#######	0.00E+00	9.37E+02
	2014	Diesel Fuel	Combination Long-haul Truck	4.44E-03	1.07E-02	1.85E-02	4.09E-02	3.89E-01	3.32E-01	#######	8.58E+00	2.00E+00	2.87E-02	#######	3.59E-03	2.68E-02	1.95E+03	3.77E-01	8.58E+00	#######	#######	1.45E-02	2.00E+00	3.32E-01	1.94E+03	2.87E-02	#######	3.59E-03	2.68E-02	1.95E+03
			Combination Short-haul Truck	4.04E-03	9.93E-03	1.69E-02	3.79E-02	3.41E-01	3.18E-01	#######	7.87E+00	1.81E+00	3.01E-02	#######	3.45E-03	2.57E-02	1.87E+03	3.31E-01	7.87E+00	#######	#######	1.38E-02	1.81E+00	3.18E-01	1.86E+03	3.01E-02	#######	3.45E-03	2.57E-02	1.87E+03
			Intercity Bus	4.86E-03	1.62E-02	2.03E-02	6.17E-02	5.15E-01	4.15E-01	#######	1.06E+01	2.56E+00	2.77E-02	#######	4.50E-03	3.35E-02	1.62E+03	5.00E-01	1.06E+01	#######	#######	1.23E-02	2.56E+00	4.15E-01	1.62E+03	2.77E-02	#######	4.50E-03	3.35E-02	1.62E+03
			Passenger Car	1.27E-03	1.92E-03	5.30E-03	7.33E-03	1.22E-02	1.95E-02	#######	5.00E-01	4.57E-01	2.83E-03	#######	2.11E-04	1.57E-03	3.43E+02	1.18E-02	5.00E-01	#######	#######	2.53E-03	4.57E-01	1.95E-02	3.43E+02	2.83E-03	#######	2.11E-04	1.57E-03	3.43E+02
			Passenger Truck	1.62E-03	3.03E-03	6.75E-03	1.16E-02	1.10E-01	2.34E-01	#######	1.93E+00	1.21E+00	1.69E-02	#######	2.54E-03	1.89E-02	6.28E+02	1.07E-01	1.93E+00	#######	#######	4.68E-03	1.21E+00	2.34E-01	6.27E+02	1.69E-02	#######	2.54E-03	1.89E-02	6.28E+02
			School Bus	3.93E-03	1.37E-02	1.64E-02	5.25E-02	2.68E-01	3.83E-01	#######	5.07E+00	1.58E+00	2.39E-02	#######	4.15E-03	3.09E-02	8.14E+02	2.60E-01	5.07E+00	#######	#######	6.16E-03	1.58E+00	3.83E-01	8.13E+02	2.39E-02	#######	4.15E-03	3.09E-02	8.14E+02
			Single Unit Long-haul Truck	2.89E-03	1.07E-02	1.21E-02	4.10E-02	1.31E-01	2.94E-01	#######	2.68E+00	1.15E+00	3.86E-02	#######	3.19E-03	2.37E-02	8.01E+02	1.27E-01	2.68E+00	#######	#######	5.84E-03	1.15E+00	2.94E-01	8.00E+02	3.86E-02	#######	3.19E-03	2.37E-02	8.01E+02
			Single Unit Short-haul Truck	2.89E-03	1.08E-02	1.21E-02	4.11E-02	1.31E-01	2.72E-01	#######	2.76E+00	1.10E+00	3.91E-02	#######	2.95E-03	2.20E-02	8.56E+02	1.27E-01	2.76E+00	#######	#######	6.21E-03	1.10E+00	2.72E-01	8.55E+02	3.91E-02	#######	2.95E-03	2.20E-02	8.56E+02
			Transit Bus	2.61E-03	8.11E-03	1.09E-02	3.10E-02	3.84E-01	4.28E-01	#######	7.76E+00	2.52E+00	2.35E-02	#######	4.64E-03	3.45E-02	1.19E+03	3.73E-01	7.76E+00	#######	#######	8.91E-03	2.52E+00	4.28E-01	1.19E+03	2.35E-02	#######	4.64E-03	3.45E-02	1.19E+03
			Motor Home	2.28E-03	8.51E-03	9.53E-03	3.25E-02	2.04E-01	4.38E-01	#######	4.03E+00	1.51E+00	3.49E-02	#######	4.74E-03	3.53E-02	8.84E+02	1.98E-01	4.03E+00	#######	#######	6.59E-03	1.51E+00	4.38E-01	8.83E+02	3.49E-02	#######	4.74E-03	3.53E-02	8.84E+02
			Refuse Truck	4.58E-03	1.26E-02	1.91E-02	4.83E-02	3.52E-01	3.50E-01	#######	7.58E+00	1.90E+00	2.99E-02	#######	3.79E-03	2.82E-02	1.53E+03	3.41E-01	7.58E+00	#######	#######	1.14E-02	1.90E+00	3.50E-01	1.52E+03	2.99E-02	#######	3.79E-03	2.82E-02	1.53E+03
			Light Commercial Truck	1.65E-03	3.30E-03	6.88E-03	1.26E-02	1.46E-01	3.21E-01	#######	2.41E+00	1.54E+00	1.37E-02	#######	3.48E-03	2.59E-02	6.23E+02	1.42E-01	2.41E+00	#######	#######	4.73E-03	1.54E+00	3.21E-01	6.22E+02	1.37E-02	#######	3.48E-03	2.59E-02	6.23E+02
		Gasoline	Combination Short-haul Truck	2.30E-03	6.49E-03	9.59E-03	2.48E-02	1.29E-01	3.75E+00	#######	1.67E+01	1.34E+02	9.18E-02	#######	1.27E-01	4.60E-02	1.72E+03	1.19E-01	1.67E+01	#######	#######	3.02E-02	1.34E+02	3.75E+00	1.72E+03	9.18E-02	#######	1.27E-01	4.60E-02	1.72E+03
			Motorcycle	6.37E-04	1.66E-04	2.66E-03	6.33E-04	4.70E-02	7.36E-01	#######	8.39E-01	1.53E+01	2.89E-02	#######	2.48E-02	9.93E-03	3.71E+02	4.33E-02	8.39E-01	#######	#######	6.50E-03	1.53E+01	7.36E-01	3.70E+02	2.89E-02	#######	2.48E-02	9.93E-03	3.71E+02
			Passenger Car	1.27E-03	1.92E-03	5.30E-03	7.33E-03	8.58E-03	4.32E-02	#######	3.11E-01	2.15E+00	4.58E-03	#######	1.47E-03	5.50E-04	3.14E+02	7.90E-03	3.11E-01	#######	#######	5.50E-03	2.15E+00	4.32E-02	3.13E+02	4.58E-03	#######	1.47E-03	5.50E-04	3.14E+02
			Passenger Truck	1.30E-03	3.16E-03	5.41E-03	1.21E-02	1.49E-02	1.37E-01	#######	8.58E-01	4.74E+00	6.80E-03	#######	4.67E-03	1.74E-03	4.33E+02	1.37E-02	8.58E-01	#######	#######	7.57E-03	4.74E+00	1.37E-01	4.31E+02	6.80E-03	#######	4.67E-03	1.74E-03	4.33E+02
			School Bus	2.27E-03	8.84E-03	9.46E-03	3.38E-02	2.90E-02	1.10E+00	#######	4.22E+00	2.96E+01	4.99E-02	#######	3.73E-02	1.38E-02	7.73E+02	2.67E-02	4.22E+00	#######	#######	1.35E-02	2.96E+01	1.10E+00	7.67E+02	4.99E-02	#######	3.73E-02	1.38E-02	7.73E+02
			Single Unit Long-haul Truck	2.30E-03	9.22E-03	9.60E-03	3.52E-02	8.22E-03	3.86E-01	#######	3.29E+00	1.41E+01	8.04E-03	#######	1.30E-02	5.11E-03	8.04E+02	7.57E-03	3.29E+00	#######	#######	1.41E-02	1.41E+01	3.86E-01	8.01E+02	8.04E-03	#######	1.30E-02	5.11E-03	8.04E+02
			Single Unit Short-haul Truck	2.30E-03	9.23E-03	9.60E-03	3.53E-02	9.22E-03	4.23E-01	#######	3.44E+00	1.53E+01	9.50E-03	#######	1.42E-02	5.58E-03	8.56E+02	8.49E-03	3.44E+00	#######	#######	1.50E-02	1.53E+01	4.23E-01	8.53E+02	9.50E-03	#######	1.42E-02	5.58E-03	8.56E+02
			Transit Bus	2.27E-03	8.40E-03	9.46E-03	3.21E-02	1.05E-02	8.68E-01	#######	4.03E+00	2.75E+01	1.45E-02	#######	2.92E-02	1.14E-02	1.13E+03	9.68E-03	4.03E+00	#######	#######	1.97E-02	2.75E+01	8.68E-01	1.12E+03	1.45E-02	#######	2.92E-02	1.14E-02	1.13E+03
			Motor Home	2.21E-03	8.33E-03	9.22E-03	3.18E-02	2.13E-02	7.01E-01	#######	4.33E+00	2.43E+01	2.25E-02	#######	2.37E-02	8.95E-03	8.71E+02	1.96E-02	4.33E+00	#######	#######	1.52E-02	2.43E+01	7.01E-01	8.67E+02	2.25E-02	#######	2.37E-02	8.95E-03	8.71E+02
			Refuse Truck	2.21E-03	7.31E-03	9.22E-03	2.79E-02	1.50E-02	8.61E-01	#######	5.46E+00	3.52E+01	1.34E-02	#######	2.90E-02	1.12E-02	1.42E+03	1.39E-02	5.46E+00	#######	#######	2.49E-02	3.52E+01	8.61E-01	1.42E+03	1.34E-02	#######	2.90E-02	1.12E-02	1.42E+03
			Light Commercial Truck	1.33E-03	3.17E-03	5.53E-03	1.21E-02	1.46E-02	1.48E-01	#######	9.45E-01	4.96E+00	7.11E-03	#######	5.01E-03	1.88E-03	4.29E+02	1.34E-02	9.45E-01	#######	#######	7.50E-03	4.96E+00	1.48E-01	4.27E+02	7.11E-03	#######	5.01E-03	1.88E-03	4.29E+02
		Compressed Natural Gas (CNG)	Transit Bus	2.27E-03	8.41E-03	9.47E-03	3.21E-02	5.34E-03	0.00E+00		3.50E+00	3.49E+01	2.04E-02	#######			9.37E+02	5.34E-03	3.50E+00	#######	#######	#######	3.49E+01	0.00E+00	9.23E+02	2.04E-02	#######	#######	0.00E+00	9.37E+02
	2015	Diesel Fuel	Combination Long-haul Truck	4.44E-03	1.07E-02	1.85E-02	4.09E-02	3.40E-01	2.91E-01	#######	7.61E+00	1.77E+00	3.05E-02	#######	3.16E-03	2.35E-02	1.95E+03	3.30E-01	7.61E+00	#######	#######	1.43E-02	1.77E+00	2.91E-01	1.94E+03	3.05E-02	#######	3.16E-03	2.35E-02	1.95E+03
			Combination Short-haul Truck	4.04E-03	9.92E-03	1.68E-02	3.79E-02	2.93E-01	2.76E-01	#######	6.87E+00	1.59E+00	3.19E-02	#######	2.99E-03	2.23E-02	1.87E+03	2.84E-01	6.87E+00	#######	#######	1.37E-02	1.59E+00	2.76E-01	1.86E+03	3.19E-02	#######	2.99E-03	2.23E-02	1.87E+03
			Intercity Bus	4.86E-03	1.62E-02	2.03E-02	6.17E-02	4.53E-01	3.76E-01	#######	9.51E+00	2.32E+00	2.98E-02	#######	4.07E-03	3.03E-02	1.62E+03	4.40E-01	9.51E+00	#######	#######	1.21E-02	2.32E+00	3.76E-01	1.62E+03	2.98E-02	#######	4.07E-03	3.03E-02	1.62E+03
			Passenger Car	1.27E-03	1.92E-03	5.30E-03	7.33E-03	9.99E-03	1.66E-02	#######	4.30E-01	5.37E-01	3.35E-03	#######	1.80E-04	1.34E-03	3.34E+02	9.69E-03	4.30E-01	#######	#######	2.44E-03	5.37E-01	1.66E-02	3.34E+02	3.35E-03	#######	1.80E-04	1.34E-03	3.34E+02
			Passenger Truck	1.62E-03	3.02E-03	6.75E-03	1.16E-02	9.56E-02	2.04E-01	#######	1.74E+00	1.11E+00	1.79E-02	#######	2.21E-03	1.65E-02	6.25E+02	9.27E-02	1.74E+00	#######	#######	4.61E-03	1.11E+00	2.04E-01	6.24E+02	1.79E-02	#######	2.21E-03	1.65E-02	6.25E+02
			School Bus	3.93E-03	1.37E-02	1.64E-02	5.25E-02	2.41E-01	3.49E-01	#######	4.61E+00	1.45E+00	2.56E-02	#######	3.78E-03	2.82E-02	8.15E+02	2.34E-01	4.61E+00	#######	#######	6.11E-03	1.45E+00	3.49E-01	8.13E+02	2.56E-02	#######	3.78E-03	2.82E-02	8.15E+02
			Single Unit Long-haul Truck	2.89E-03	1.07E-02	1.21E-02	4.10E-02	1.12E-01	2.58E-01	#######	2.38E+00	1.04E+00	4.01E-02	#######	2.79E-03	2.08E-02	8.01E+02	1.09E-01	2.38E+00	#######	#######	5.79E-03	1.04E+00	2.58E-01	8.00E+02	4.01E-02	#######	2.79E-03	2.08E-02	8.01E+02
			Single Unit Short-haul Truck	2.89E-03	1.08E-02	1.21E-02	4.11E-02	1.10E-01	2.33E-01	#######	2.41E+00	9.69E-01	4.06E-02	#######	2.53E-03	1.88E-02	8.56E+02	1.07E-01	2.41E+00	#######	#######	6.15E-03	9.69E-01	2.33E-01	8.55E+02	4.06E-02	#######	2.53E-03	1.88E-02	8.56E+02
			Transit Bus	2.61E-03	8.11E-03	1.09E-02	3.10E-02	3.37E-01	3.83E-01	#######	6.86E+00	2.25E+00	2.62E-02	#######	4.15E-03	3.09E-02	1.19E+03	3.27E-01	6.86E+00	#######	#######	8.82E-03	2.25E+00	3.83E-01	1.19E+03	2.62E-02	#######	4.15E-03	3.09E-02	1.19E+03
			Motor Home	2.28E-03	8.51E-03	9.53E-03	3.25E-02	1.80E-01	3.97E-01	#######	3.64E+00	1.39E+00	3.70E-02	#######	4.30E-03	3.21E-02	8.84E+02	1.75E-01	3.64E+00	#######	#######	6.53E-03	1.39E+00	3.97E-01	8.83E+02	3.70E-02	#######	4.30E-03	3.21E-02	8.84E+02
			Refuse Truck	4.60E-03	1.27E-02	1.92E-02	4.84E-02	3.02E-01	3.03E-01	#######	6.60E+00	1.67E+00	3.20E-02	#######	3.29E-03	2.45E-02	1.53E+03	2.93E-01	6.60E+00	#######	#######	1.12E-02	1.67E+00	3.03E-01	1.52E+03	3.20E-02	#######	3.29E-03	2.45E-02	1.53E+03
			Light Commercial Truck	1.65E-03	3.30E-03	6.88E-03	1.26E-02	1.29E-01	2.86E-01	#######	2.21E+00	1.42E+00	1.49E-02	#######	3.10E-03	2.31E-02	6.21E+02	1.26E-01	2.21E+00	#######	#######	4.67E-03	1.42E+00	2.86E-01	6.20E+02	1.49E-02	#######	3.10E-03	2.31E-02	6.21E+02
		Gasoline	Combination Short-haul Truck	2.33E-03	6.56E-03	9.73E-03	2.50E-02	1.19E-01	3.76E+00	#######	1.67E+01	1.34E+02	8.91E-02	#######	1.27E-01	4.60E-02	1.72E+03	1.09E-01	1.67E+01	#######	#######	3.02E-02	1.34E+02	3.76E+00	1.72E+03	8.91E-02	#######	1.27E-01	4.60E-02	1.72E+03
			Motorcycle	6.37E-04	1.66E-04	2.66E-03	6.33E-04	4.70E-02	7.16E-01	#######	8.30E-01	1.49E+01	2.89E-02	#######	2.41E-02	9.65E-03	3.71E+02	4.33E-02	8.30E-01	#######	#######	6.50E-03	1.49E+01	7.16E-01	3.70E+02	2.89E-02	#######	2.41E-02	9.65E-03	3.71E+02
			Passenger Car	1.27E-03	1.92E-03	5.30E-03	7.33E-03	8.17E-03	3.63E-02	#######	2.61E-01	2.01E+00	4.39E-03	#######	1.23E-03	4.63E-04	3.08E+02	7.52E-03	2.61E-01	#######	#######	5.41E-03	2.01E+00	3.63E-02	3.08E+02	4.39E-03	#######	1.23E-03	4.63E-04	3.08E+02
			Passenger Truck	1.30E-03	3.16E-03	5.41E-03	1.21E-02	1.45E-02	1.25E-01	#######	7.86E-01	4.48E+00	6.33E-03	#######	4.22E-03	1.58E-03	4.24E+02	1.34E-02	7.86E-01	#######	#######	7.43E-03	4.48E+00	1.25E-01	4.23E+02	6.33E-03	#######	4.22E-03	1.58E-03	4.24E+02
			School Bus	2.27E-03	8.84E-03	9.46E-03	3.38E-02	2.17E-02	1.00E+00	#######	3.95E+00	2.75E+01	4.25E-02	#######	3.39E-02	1.26E-02	7.72E+02	2.00E-02	3.95E+00	#######	#######	1.35E-02	2.75E+01	1.00E+00	7.67E+02	4.25E-02	#######	3.39E-02	1.26E-02	7.72E+02
			Single Unit Long-haul Truck	2.30E-03	9.22E-03	9.60E-03	3.52E-02	7.99E-03	3.79E-01	#######	3.25E+00	1.38E+01	7.61E-03	#######	1.27E-02	5.02E-03	8.04E+02	7.36E-03	3.25E+00	#######	#######	1.41E-02	1.38E+01	3.79E-01	8.01E+02	7.61E-03	#######	1.27E-02	5.02E-03	8.04E+02
			Single Unit Short-haul Truck	2.30E-03	9.23E-03	9.60E-03	3.53E-02	8.63E-03	4.09E-01	#######	3.38E+00	1.48E+01	8.67E-03	#######	1.37E-02	5.40E-03	8.56E+02	7.95E-03	3.38E+00	#######	#######	1.50E-02	1.48E+01	4.09E-01	8.53E+02	8.67E-03	#######	1.37E-02	5.40E-03	8.56E+02
			Transit Bus	2.27E-03	8.40E-03	9.46E-03	3.21E-02	1.04E-02	8.51E-01	#######	3.97E+00	2.61E+01	1.35E-02	#######	2.86E-02	1.12E-02	1.13E+03	9.55E-03	3.97E+00	#######	#######	1.97E-02	2.61E+01	8.51E-01	1.12E+03	1.35E-02	#######	2.86E-02	1.12E-02	1.13E+03
			Motor Home	2.21E-03	8.33E-03	9.22E-03	3.18E-02	1.86E-02	6.64E-01	#######	4.19E+00	2.33E+01	1.99E-02	#######	2.24E-02	8.49E-03	8.71E+02	1.71E-02	4.19E+00	#######	#######	1.52E-02	2.33E+01	6.64E-01	8.67E+02	1.99E-02	#######	2.24E-02	8.49E-03	8.71E+02
			Refuse Truck	2.21E-03	7.31E-03	9.22E-03	2.79E-02	1.42E-02	8.16E-01	#######	5.32E+00	3.26E+01	1.20E-02	#######	2.74E-02	1.07E-02	1.42E+03	1.31E-02	5.32E+00	#######	#######	2.49E-02	3.26E+01	8.16E-01	1.42E+03	1.20E-02	#######	2.74E-02	1.07E-02	1.42E+03
			Light Commercial Truck	1.32E-03	3.17E-03	5.52E-03	1.21E-02	1.43E-02	1.35E-01	#######	8.75E-01	4.71E+00	6.61E-03	#######	4.55E-03	1.71E-03	4.21E+02	1.31E-02	8.75E-01	#######	#######	7.37E-03	4.71E+00	1.35E-01	4.20E+02	6.61E-03	#######	4.55E-03	1.71E-03	4.21E+02
		Compressed Natural Gas (CNG)	Transit Bus	2.27E-03	8.41E-03	9.47E-03	3.21E-02	5.25E-03	0.00E+00		3.45E+00	3.25E+01	1.88E-02	#######			9.36E+02	5.25E-03	3.45E+00	#######	#######	#######	3.25E+01	0.00E+00	9.23E+02	1.88E-02	#######	#######	0.00E+00	9.36E+02
	2016	Diesel Fuel	Combination Long-haul Truck	4.44E-03	1.07E-02	1.85E-02	4.09E-02	2.96E-01	2.55E-01	#######	6.74E+00	1.56E+00	3.21E-02	#######	2.76E-03	2.05E-02	1.95E+03	2.87E-01	6.74E+00	#######	#######	1.42E-02	1.56E+00	2.55E-01	1.94E+03	3.21E-02	#######	2.76E-03	2.05E-02	1.95E+03
			Combination Short-haul Truck	4.04E-03	9.92E-03	1.68E-02	3.79E-02	2.49E-01	2.38E-01	#######	5.99E+00	1.39E+00	3.35E-02	#######	2.57E-03	1.92E-02	1.87E+03	2.42E-01	5.99E+00	#######	#######	1.35E-02	1.39E+00	2.38E-01	1.86E+03	3.35E-02	#######	2.57E-03	1.92E-02	1.87E+03
			Intercity Bus	4.86E-03	1.62E-02	2.03E-02	6.17E-02	3.95E-01	3.39E-01	#######	8.51E+00	2.10E+00	3.17E-02	#######	3.67E-03	2.74E-02	1.62E+03	3.83E-01	8.51E+00	#######	#######	1.20E-02	2.10E+00	3.39E-01	1.62E+03	3.17E-02	#######	3.67E-03	2.74E-02	1.62E+03
			Passenger Car	1.27E-03	1.92E-03	5.30E-03	7.33E-03	8.17E-03	1.42E-02	#######	3.66E-01	6.30E-01	4.04E-03	#######	1.54E-04	1.15E-03	3.24E+02	7.92E-03	3.66E-01	#######	#######	2.35E-03	6.30E-01	1.42E-02	3.24E+02	4.04E-03	#######	1.54E-04	1.15E-03	3.24E+02
			Passenger Truck	1.62E-03	3.02E-03	6.75E-03	1.15E-02	8.30E-02	1.78E-01	#######	1.58E+00	1.04E+00	1.89E-02	#######	1.93E-03	1.44E-02	6.22E+02	8.05E-02	1.58E+00	#######	#######	4.55E-03	1.04E+00	1.78E-01	6.21E+02	1.89E-02	#######	1.93E-03	1.44E-02	6.22E+02
			School Bus	3.93E-03	1.37E-02	1.64E-02	5.25E-02	2.15E-01	3.17E-01	#######	4.18E+00	1.33E+00	2.71E-02	#######	3.44E-03	2.56E-02	8.15E+02	2.08E-01	4.18E+00	#######	#######	6.06E-03	1.33E+00	3.17E-01	8.13E+02	2.71E-02	#######	3.44E-03	2.56E-02	8.15E+02
			Single Unit Long-haul Truck	2.89E-03	1.07E-02	1.21E-02	4.10E-02	9.63E-02	2.25E-01	#######	2.12E+00	9.29E-01	4.12E-02	#######	2.44E-03	1.82E-02	8.01E+02	9.34E-02	2.12E+00	#######	#######	5.74E-03	9.29E-01	2.25E-01	8.00E+02	4.12E-02	#######	2.44E-03	1.82E-02	8.01E+02
			Single Unit Short-haul Truck	2.89E-03	1.08E-02	1.21E-02	4.11E-02	9.25E-02	2.00E-01	#######	2.12E+00	8.59E-01	4.16E-02	#######	2.17E-03	1.62E-02	8.56E+02	8.97E-02	2.12E+00	#######	#######	6.10E-03	8.59E-01	2.00E-01	8.55E+02	4.16E-02	#######	2.17E-03	1.62E-02	8.56E+02
			Transit Bus	2.61E-03	8.11E-03	1.09E-02	3.10E-02	2.94E-01	3.41E-01	#######	6.06E+00	2.00E+00	2.82E-02	#######	3.69E-03	2.75E-02	1.19E+03	2.85E-01	6.06E+00	#######	#######	8.74E-03	2.00E+00	3.41E-01	1.19E+03	2.82E-02	#######	3.69E-03	2.75E-02	1.19E+03
			Motor Home	2.28E-03	8.51E-03	9.53E-03	3.25E-02	1.58E-01	3.60E-01	#######	3.30E+00	1.29E+00	3.85E-02	#######	3.90E-03	2.91E-02	8.85E+02	1.54E-01	3.30E+00	#######	#######	6.48E-03	1.29E+00	3.60E-01	8.83E+02	3.85E-02	#######	3.90E-03	2.91E-02	8.85E+02
			Refuse Truck	4.61E-03	1.27E-02	1.92E-02	4.85E-02	2.56E-01	2.61E-01	#######	5.73E+00	1.46E+00	3.39E-02	#######	2.82E-03	2.10E-02	1.53E+03	2.49E-01	5.73E+00	#######	#######	1.11E-02	1.46E+00	2.61E-01	1.52E+03	3.39E-02	#######	2.82E-03	2.10E-02	1.53E+03
			Light Commercial Truck	1.65E-03	3.29E-03	6.87E-03	1.26E-02	1.14E-01	2.54E-01	#######	2.02E+00	1.31E+00	1.61E-02	#######	2.76E-03	2.05E-02	6.18E+02	1.11E-01	2.02E+00	#######	#######	4.60E-03	1.31E+00	2.54E-01	6.17E+02	1.61E-02	#######	2.76E-03	2.05E-02	6.18E+02
		Gasoline	Combination Short-haul Truck	2.65E-03	7.18E-03	1.10E-02	2.74E-02	1.16E-01	3.76E+00	#######	1.67E+01	1.34E+02	8.72E-02	#######	1.27E-01	4.60E-02	1.72E+03	1.07E-01	1.67E+01	#######	#######	3.02E-02	1.34E+02	3.76E+00	1.72E+03	8.72E-02	#######	1.27E-01	4.60E-02	1.72E+03
			Motorcycle	6.37E-04	1.66E-04	2.66E-03	6.33E-04	4.70E-02	6.99E-01	#######	8.23E-01	1.46E+01	2.89E-02	#######	2.35E-02	9.42E-03	3.72E+02	4.33E-02	8.23E-01	#######	#######	6.50E-03	1.46E+01	6.99E-01	3.70E+02	2.89E-02	#######	2.35E-02	9.42E-03	3.72E+02
			Passenger Car	1.27E-03	1.92E-03	5.30E-03	7.33E-03	7.88E-03	3.05E-02	#######	2.18E-01	1.89E+00	4.22E-03	#######	1.03E-03	3.90E-04	3.02E+02	7.26E-03	2.18E-01	#######	#######	5.29E-03	1.89E+00	3.05E-02	3.01E+02	4.22E-03	#######	1.03E-03	3.90E-04	3.02E+02
			Passenger Truck	1.30E-03	3.16E-03	5.41E-03	1.21E-02	1.42E-02	1.11E-01	#######	7.16E-01	4.23E+00	5.74E-03	#######	3.74E-03	1.40E-03	4.15E+02	1.31E-02	7.16E-01	#######	#######	7.27E-03	4.23E+00	1.11E-01	4.14E+02	5.74E-03	#######	3.74E-03	1.40E-03	4.15E+02
			School Bus	2.27E-03	8.84E-03	9.46E-03	3.38E-02	1.73E-02	8.98E-01	#######	3.67E+00	2.54E+01	3.55E-02	#######	3.02E-02	1.14E-02	7.72E+02	1.59E-02	3.67E+00	#######	#######	1.35E-02	2.54E+01	8.98E-01	7.67E+02	3.55E-02	#######	3.02E-02	1.14E-02	7.72E+02
			Single Unit Long-haul Truck	2.30E-03	9.22E-03	9.60E-03	3.52E-02	7.82E-03	3.73E-01	#######	3.22E+00	1.36E+01	7.25E-03	#######	1.25E-02	4.95E-03	8.03E+02	7.21E-03	3.22E+00	#######	#######	1.41E-02	1.36E+01	3.73E-01	8.01E+02	7.25E-03	#######	1.25E-02	4.95E-03	8.03E+02
			Single Unit Short-haul Truck	2.30E-03	9.23E-03	9.60E-03	3.53E-02	8.20E-03	3.97E-01	#######	3.33E+00	1.44E+01	8.00E-03	#######	1.33E-02	5.25E-03	8.55E+02	7.55E-03	3.33E+00	#######	#######	1.50E-02	1.44E+01	3.97E-01	8.53E+02	8.00E-03	#######	1.33E-02	5.25E-03	8.55E+02
			Transit Bus	2.27E-03	8.40E-03	9.46E-03	3.21E-02	1.02E-02	8.36E-01	#######	3.92E+00	2.48E+01	1.27E-02	#######	2.80E-02	1.10E-02	1.13E+03	9.43E-03	3.92E+00	#######	#######	1.97E-02	2.48E+01	8.36E-01	1.12E+03	1.27E-02	#######	2.80E-02	1.10E-02	1.13E+03
			Motor Home	2.21E-03	8.33E-03	9.22E-03	3.18E-02	1.67E-02	6.30E-01	#######	4.05E+00	2.24E+01	1.77E-02	#######	2.12E-02	8.07E-03	8.71E+02	1.54E-02	4.05E+00	#######	#######	1.52E-02	2.24E+01	6.30E-01	8.67E+02	1.77E-02	#######	2.12E-02	8.07E-03	8.71E+02
			Refuse Truck	2.21E-03	7.31E-03	9.22E-03	2.79E-02	1.35E-02	7.77E-01	#######	5.19E+00	3.03E+01	1.08E-02	#######	2.60E-02	1.02E-02	1.42E+03	1.25E-02	5.19E+00	#######	#######	2.49E-02	3.03E+01	7.77E-01	1.42E+03	1.08E-02	#######	2.60E-02	1.02E-02	1.42E+03
			Light Commercial Truck	1.32E-03	3.17E-03	5.52E-03	1.21E-02	1.39E-02	1.21E-01	#######	8.09E-01	4.46E+00	5.98E-03	#######	4.08E-03	1.54E-03	4.13E+02	1.28E-02	8.09E-01	#######	#######	7.22E-03	4.46E+00	1.21E-01	4.11E+02	5.98E-03	#######	4.08E-03	1.54E-03	4.13E+02
		Compressed Natural Gas (CNG)	Transit Bus	2.27E-03	8.41E-03	9.47E-03	3.21E-02	5.13E-03	0.00E+00		3.40E+00	3.03E+01	1.74E-02	#######			9.36E+02	5.13E-03	3.40E+00	#######	#######	#######	3.03E+01	0.00E+00	9.23E+02	1.74E-02	#######	#######	0.00E+00	9.36E+02
	2017	Diesel Fuel	Combination Long-haul Truck	4.44E-03	1.07E-02	1.85E-02	4.09E-02	2.57E-01	2.22E-01	#######	5.96E+00	1.38E+00	3.34E-02	#######	2.41E-03	1.79E-02	1.95E+03	2.49E-01	5.96E+00	#######	#######	1.41E-02	1.38E+00	2.22E-01	1.94E+03	3.34E-02	#######	2.41E-03	1.79E-02	1.95E+03
			Combination Short-haul Truck	4.03E-03	9.91E-03	1.68E-02	3.79E-02	2.10E-01	2.04E-01	#######	5.21E+00	1.21E+00	3.47E-02	#######	2.21E-03	1.65E-02	1.87E+03	2.04E-01	5.21E+00	#######	#######	1.34E-02	1.21E+00	2.04E-01	1.86E+03	3.47E-02	#######	2.21E-03	1.65E-02	1.87E+03
			Intercity Bus	4.86E-03	1.62E-02	2.03E-02	6.17E-02	3.41E-01	3.04E-01	#######	7.58E+00	1.89E+00	3.34E-02	#######	3.30E-03	2.46E-02	1.62E+03	3.31E-01	7.58E+00	#######	#######	1.19E-02	1.89E+00	3.04E-01	1.62E+03	3.34E-02	#######	3.30E-03	2.46E-02	1.62E+03
			Passenger Car	1.27E-03	1.92E-03	5.30E-03	7.33E-03	6.91E-03	1.23E-02	#######	3.06E-01	7.17E-01	4.68E-03	#######	1.33E-04	9.90E-04	3.15E+02	6.71E-03	3.06E-01	#######	#######	2.26E-03	7.17E-01	1.23E-02	3.15E+02	4.68E-03	#######	1.33E-04	9.90E-04	3.15E+02
			Passenger Truck	1.62E-03	3.02E-03	6.75E-03	1.15E-02	7.14E-02	1.55E-01	#######	1.44E+00	9.72E-01	1.98E-02	#######	1.68E-03	1.25E-02	6.19E+02	6.93E-02	1.44E+00	#######	#######	4.49E-03	9.72E-01	1.55E-01	6.18E+02	1.98E-02	#######	1.68E-03	1.25E-02	6.19E+02
			School Bus	3.93E-03	1.37E-02	1.64E-02	5.25E-02	1.89E-01	2.86E-01	#######	3.77E+00	1.21E+00	2.84E-02	#######	3.10E-03	2.31E-02	8.15E+02	1.84E-01	3.77E+00	#######	#######	6.01E-03	1.21E+00	2.86E-01	8.13E+02	2.84E-02	#######	3.10E-03	2.31E-02	8.15E+02
			Single Unit Long-haul Truck	2.89E-03	1.07E-02	1.21E-02	4.10E-02	8.26E-02	1.96E-01	#######	1.90E+00	8.33E-01	4.18E-02	#######	2.13E-03	1.58E-02	8.01E+02	8.01E-02	1.90E+00	#######	#######	5.70E-03	8.33E-01	1.96E-01	8.00E+02	4.18E-02	#######	2.13E-03	1.58E-02	8.01E+02
			Single Unit Short-haul Truck	2.89E-03	1.08E-02	1.21E-02	4.11E-02	7.73E-02	1.72E-01	#######	1.87E+00	7.63E-01	4.21E-02	#######	1.86E-03	1.38E-02	8.56E+02	7.50E-02	1.87E+00	#######	#######	6.06E-03	7.63E-01	1.72E-01	8.55E+02	4.21E-02	#######	1.86E-03	1.38E-02	8.56E+02
			Transit Bus	2.61E-03	8.11E-03	1.09E-02	3.10E-02	2.53E-01	2.99E-01	#######	5.33E+00	1.77E+00	3.01E-02	#######	3.24E-03	2.42E-02	1.19E+03	2.46E-01	5.33E+00	#######	#######	8.67E-03	1.77E+00	2.99E-01	1.19E+03	3.01E-02	#######	3.24E-03	2.42E-02	1.19E+03
			Motor Home	2.28E-03	8.51E-03	9.53E-03	3.25E-02	1.40E-01	3.24E-01	#######	2.99E+00	1.18E+00	3.96E-02	#######	3.52E-03	2.62E-02	8.85E+02	1.35E-01	2.99E+00	#######	#######	6.43E-03	1.18E+00	3.24E-01	8.83E+02	3.96E-02	#######	3.52E-03	2.62E-02	8.85E+02
			Refuse Truck	4.62E-03	1.27E-02	1.93E-02	4.86E-02	2.15E-01	2.23E-01	#######	4.95E+00	1.27E+00	3.54E-02	#######	2.41E-03	1.80E-02	1.53E+03	2.08E-01	4.95E+00	#######	#######	1.10E-02	1.27E+00	2.23E-01	1.52E+03	3.54E-02	#######	2.41E-03	1.80E-02	1.53E+03
			Light Commercial Truck	1.65E-03	3.29E-03	6.87E-03	1.26E-02	1.01E-01	2.25E-01	#######	1.85E+00	1.22E+00	1.73E-02	#######	2.44E-03	1.82E-02	6.15E+02	9.80E-02	1.85E+00	#######	#######	4.54E-03	1.22E+00	2.25E-01	6.15E+02	1.73E-02	#######	2.44E-03	1.82E-02	6.15E+02
		Gasoline	Combination Short-haul Truck	2.65E-03	7.18E-03	1.10E-02	2.74E-02	1.17E-01	3.75E+00	#######	1.67E+01	1.34E+02	8.16E-02	#######	1.27E-01	4.60E-02	1.72E+03	1.08E-01	1.67E+01	#######	#######	3.02E-02	1.34E+02	3.75E+00	1.72E+03	8.16E-02	#######	1.27E-01	4.60E-02	1.72E+03
			Motorcycle	6.37E-04	1.66E-04	2.66E-03	6.33E-04	4.70E-02	6.85E-01	#######	8.17E-01	1.44E+01	2.89E-02	#######	2.30E-02	9.23E-03	3.72E+02	4.33E-02	8.17E-01	#######	#######	6.50E-03	1.44E+01	6.85E-01	3.70E+02	2.89E-02	#######	2.30E-02	9.23E-03	3.72E+02
			Passenger Car	1.27E-03	1.92E-03	5.30E-03	7.33E-03	7.62E-03	2.61E-02	#######	1.84E-01	1.79E+00	4.11E-03	#######	8.76E-04	3.35E-04	2.96E+02	7.01E-03	1.84E-01	#######	#######	5.19E-03	1.79E+00	2.61E-02	2.96E+02	4.11E-03	#######	8.76E-04	3.35E-04	2.96E+02
			Passenger Truck	1.30E-03	3.16E-03	5.41E-03	1.21E-02	1.40E-02	1.00E-01	#######	6.57E-01	4.03E+00	5.30E-03	#######	3.38E-03	1.27E-03	4.07E+02	1.29E-02	6.57E-01	#######	#######	7.13E-03	4.03E+00	1.00E-01	4.06E+02	5.30E-03	#######	3.38E-03	1.27E-03	4.07E+02
			School Bus	2.27E-03	8.84E-03	9.46E-03	3.38E-02	1.51E-02	8.13E-01	#######	3.44E+00	2.35E+01	2.99E-02	#######	2.73E-02	1.03E-02	7.72E+02	1.39E-02	3.44E+00	#######	#######	1.35E-02	2.35E+01	8.13E-01	7.67E+02	2.99E-02	#######	2.73E-02	1.03E-02	7.72E+02
			Single Unit Long-haul Truck	2.30E-03	9.22E-03	9.60E-03	3.52E-02	7.70E-03	3.69E-01	#######	3.20E+00	1.34E+01	7.14E-03	#######	1.23E-02	4.89E-03	8.03E+02	7.09E-03	3.20E+00	#######	#######	1.41E-02	1.34E+01	3.69E-01	8.01E+02	7.14E-03	#######	1.23E-02	4.89E-03	8.03E+02
			Single Unit Short-haul Truck	2.30E-03	9.23E-03	9.60E-03	3.53E-02	7.87E-03	3.87E-01	#######	3.30E+00	1.41E+01	7.60E-03	#######	1.29E-02	5.14E-03	8.55E+02	7.25E-03	3.30E+00	#######	#######	1.50E-02	1.41E+01	3.87E-01	8.53E+02	7.60E-03	#######	1.29E-02	5.14E-03	8.55E+02
			Transit Bus	2.27E-03	8.40E-03	9.46E-03	3.21E-02	1.01E-02	8.25E-01	#######	3.87E+00	2.37E+01	1.23E-02	#######	2.76E-02	1.08E-02	1.13E+03	9.32E-03	3.87E+00	#######	#######	1.97E-02	2.37E+01	8.25E-01	1.12E+03	1.23E-02	#######	2.76E-02	1.08E-02	1.13E+03
			Motor Home	2.21E-03	8.33E-03	9.22E-03	3.18E-02	1.56E-02	6.00E-01	#######	3.94E+00	2.16E+01	1.59E-02	#######	2.01E-02	7.71E-03	8.71E+02	1.44E-02	3.94E+00	#######	#######	1.52E-02	2.16E+01	6.00E-01	8.67E+02	1.59E-02	#######	2.01E-02	7.71E-03	8.71E+02
			Refuse Truck	2.21E-03	7.31E-03	9.22E-03	2.79E-02	1.28E-02	7.42E-01	#######	5.08E+00	2.83E+01	9.89E-03	#######	2.48E-02	9.74E-03	1.42E+03	1.18E-02	5.08E+00	#######	#######	2.49E-02	2.83E+01	7.42E-01	1.42E+03	9.89E-03	#######	2.48E-02	9.74E-03	1.42E+03

		Light Commercial Truck	1.32E-03	3.17E-03	5.52E-03	1.21E-02	1.37E-02	1.11E-01	#######	7.52E-01	4.28E+00	5.53E-03	#######	3.72E-03	1.41E-03	4.05E+02	1.26E-02	7.52E-01	#######	#######	7.08E-03	4.28E+00	1.11E-01	4.04E+02	5.53E-03	#######	3.72E-03	1.41E-03	4.05E+02
	Compressed Natural Gas (CNG)	Transit Bus	2.27E-03	8.41E-03	9.47E-03	3.21E-02	5.09E-03	0.00E+00		3.36E+00	2.84E+01	1.64E-02	#######			9.36E+02	5.09E-03	3.36E+00	#######	#######	#######	2.84E+01	0.00E+00	9.23E+02	1.64E-02	#######	#######	0.00E+00	9.36E+02
2018	Diesel Fuel	Combination Long-haul Truck	4.44E-03	1.07E-02	1.85E-02	4.09E-02	2.22E-01	1.92E-01	#######	5.26E+00	1.21E+00	3.45E-02	#######	2.09E-03	1.55E-02	1.95E+03	2.15E-01	5.26E+00	#######	#######	1.40E-02	1.21E+00	1.92E-01	1.94E+03	3.45E-02	#######	2.09E-03	1.55E-02	1.95E+03
		Combination Short-haul Truck	4.03E-03	9.91E-03	1.68E-02	3.79E-02	1.76E-01	1.74E-01	#######	4.53E+00	1.06E+00	3.57E-02	#######	1.88E-03	1.40E-02	1.87E+03	1.71E-01	4.53E+00	#######	#######	1.33E-02	1.06E+00	1.74E-01	1.86E+03	3.57E-02	#######	1.88E-03	1.40E-02	1.87E+03
		Intercity Bus	4.86E-03	1.62E-02	2.03E-02	6.17E-02	2.87E-01	2.73E-01	#######	6.73E+00	1.70E+00	3.49E-02	#######	2.96E-03	2.20E-02	1.62E+03	2.78E-01	6.73E+00	#######	#######	1.18E-02	1.70E+00	2.73E-01	1.62E+03	3.49E-02	#######	2.96E-03	2.20E-02	1.62E+03
		Passenger Car	1.27E-03	1.92E-03	5.30E-03	7.33E-03	5.91E-03	1.07E-02	#######	2.53E-01	8.04E-01	5.45E-03	#######	1.16E-04	8.65E-04	3.07E+02	5.74E-03	2.53E-01	#######	#######	2.19E-03	8.04E-01	1.07E-02	3.07E+02	5.45E-03	#######	1.16E-04	8.65E-04	3.07E+02
		Passenger Truck	1.62E-03	3.02E-03	6.75E-03	1.15E-02	6.20E-02	1.35E-01	#######	1.32E+00	9.23E-01	2.06E-02	#######	1.47E-03	1.09E-02	6.16E+02	6.01E-02	1.32E+00	#######	#######	4.44E-03	9.23E-01	1.35E-01	6.15E+02	2.06E-02	#######	1.47E-03	1.09E-02	6.16E+02
		School Bus	3.93E-03	1.37E-02	1.64E-02	5.25E-02	1.64E-01	2.55E-01	#######	3.39E+00	1.10E+00	2.95E-02	#######	2.76E-03	2.06E-02	8.15E+02	1.59E-01	3.39E+00	#######	#######	5.96E-03	1.10E+00	2.55E-01	8.13E+02	2.95E-02	#######	2.76E-03	2.06E-02	8.15E+02
		Single Unit Long-haul Truck	2.89E-03	1.07E-02	1.21E-02	4.10E-02	7.09E-02	1.68E-01	#######	1.71E+00	7.43E-01	4.24E-02	#######	1.82E-03	1.35E-02	8.01E+02	6.88E-02	1.71E+00	#######	#######	5.66E-03	7.43E-01	1.68E-01	8.00E+02	4.24E-02	#######	1.82E-03	1.35E-02	8.01E+02
		Single Unit Short-haul Truck	2.90E-03	1.08E-02	1.21E-02	4.11E-02	6.47E-02	1.45E-01	#######	1.67E+00	6.76E-01	4.26E-02	#######	1.57E-03	1.17E-02	8.56E+02	6.28E-02	1.67E+00	#######	#######	6.02E-03	6.76E-01	1.45E-01	8.55E+02	4.26E-02	#######	1.57E-03	1.17E-02	8.56E+02
		Transit Bus	2.61E-03	8.11E-03	1.09E-02	3.10E-02	2.15E-01	2.61E-01	#######	4.69E+00	1.55E+00	3.14E-02	#######	2.83E-03	2.11E-02	1.19E+03	2.09E-01	4.69E+00	#######	#######	8.60E-03	1.55E+00	2.61E-01	1.19E+03	3.14E-02	#######	2.83E-03	2.11E-02	1.19E+03
		Motor Home	2.28E-03	8.51E-03	9.53E-03	3.25E-02	1.23E-01	2.87E-01	#######	2.72E+00	1.08E+00	4.05E-02	#######	3.11E-03	2.32E-02	8.85E+02	1.19E-01	2.72E+00	#######	#######	6.39E-03	1.08E+00	2.87E-01	8.83E+02	4.05E-02	#######	3.11E-03	2.32E-02	8.85E+02
		Refuse Truck	4.63E-03	1.27E-02	1.93E-02	4.87E-02	1.78E-01	1.89E-01	#######	4.27E+00	1.10E+00	3.67E-02	#######	2.05E-03	1.53E-02	1.53E+03	1.73E-01	4.27E+00	#######	#######	1.09E-02	1.10E+00	1.89E-01	1.52E+03	3.67E-02	#######	2.05E-03	1.53E-02	1.53E+03
		Light Commercial Truck	1.65E-03	3.28E-03	6.87E-03	1.25E-02	8.88E-02	1.99E-01	#######	1.69E+00	1.14E+00	1.83E-02	#######	2.16E-03	1.61E-02	6.13E+02	8.62E-02	1.69E+00	#######	#######	4.48E-03	1.14E+00	1.99E-01	6.12E+02	1.83E-02	#######	2.16E-03	1.61E-02	6.13E+02
	Gasoline	Combination Short-haul Truck	2.65E-03	7.18E-03	1.10E-02	2.74E-02	1.17E-01	3.76E+00	#######	1.67E+01	1.34E+02	7.69E-02	#######	1.27E-01	4.60E-02	1.72E+03	1.08E-01	1.67E+01	#######	#######	3.02E-02	1.34E+02	3.76E+00	1.72E+03	7.69E-02	#######	1.27E-01	4.60E-02	1.72E+03
		Motorcycle	6.37E-04	1.66E-04	2.66E-03	6.33E-04	4.70E-02	6.73E-01	#######	8.12E-01	1.42E+01	2.89E-02	#######	2.26E-02	9.07E-03	3.72E+02	4.33E-02	8.12E-01	#######	#######	6.51E-03	1.42E+01	6.73E-01	3.71E+02	2.89E-02	#######	2.26E-02	9.07E-03	3.72E+02
		Passenger Car	1.27E-03	1.92E-03	5.30E-03	7.33E-03	7.42E-03	2.28E-02	#######	1.58E-01	1.72E+00	4.03E-03	#######	7.64E-04	2.95E-04	2.90E+02	6.83E-03	1.58E-01	#######	#######	5.09E-03	1.72E+00	2.28E-02	2.90E+02	4.03E-03	#######	7.64E-04	2.95E-04	2.90E+02
		Passenger Truck	1.30E-03	3.16E-03	5.41E-03	1.21E-02	1.38E-02	9.15E-02	#######	6.06E-01	3.86E+00	4.92E-03	#######	3.07E-03	1.16E-03	3.99E+02	1.27E-02	6.06E-01	#######	#######	6.99E-03	3.86E+00	9.15E-02	3.98E+02	4.92E-03	#######	3.07E-03	1.16E-03	3.99E+02
		School Bus	2.27E-03	8.84E-03	9.46E-03	3.38E-02	1.34E-02	7.44E-01	#######	3.24E+00	2.18E+01	2.48E-02	#######	2.49E-02	9.51E-03	7.71E+02	1.23E-02	3.24E+00	#######	#######	1.35E-02	2.18E+01	7.44E-01	7.67E+02	2.48E-02	#######	2.49E-02	9.51E-03	7.71E+02
		Single Unit Long-haul Truck	2.30E-03	9.22E-03	9.60E-03	3.52E-02	7.58E-03	3.66E-01	#######	3.18E+00	1.33E+01	7.01E-03	#######	1.22E-02	4.86E-03	8.03E+02	6.98E-03	3.18E+00	#######	#######	1.41E-02	1.33E+01	3.66E-01	8.01E+02	7.01E-03	#######	1.22E-02	4.86E-03	8.03E+02
		Single Unit Short-haul Truck	2.30E-03	9.23E-03	9.60E-03	3.53E-02	7.62E-03	3.81E-01	#######	3.27E+00	1.39E+01	7.26E-03	#######	1.27E-02	5.07E-03	8.55E+02	7.01E-03	3.27E+00	#######	#######	1.50E-02	1.39E+01	3.81E-01	8.53E+02	7.26E-03	#######	1.27E-02	5.07E-03	8.55E+02
		Transit Bus	2.27E-03	8.40E-03	9.46E-03	3.21E-02	9.99E-03	8.16E-01	#######	3.83E+00	2.28E+01	1.19E-02	#######	2.72E-02	1.07E-02	1.13E+03	9.20E-03	3.83E+00	#######	#######	1.97E-02	2.28E+01	8.16E-01	1.12E+03	1.19E-02	#######	2.72E-02	1.07E-02	1.13E+03
		Motor Home	2.21E-03	8.33E-03	9.22E-03	3.18E-02	1.45E-02	5.73E-01	#######	3.83E+00	2.08E+01	1.41E-02	#######	1.92E-02	7.38E-03	8.70E+02	1.33E-02	3.83E+00	#######	#######	1.52E-02	2.08E+01	5.73E-01	8.67E+02	1.41E-02	#######	1.92E-02	7.38E-03	8.70E+02
		Refuse Truck	2.21E-03	7.31E-03	9.22E-03	2.79E-02	1.22E-02	7.13E-01	#######	4.99E+00	2.67E+01	9.08E-03	#######	2.38E-02	9.39E-03	1.42E+03	1.12E-02	4.99E+00	#######	#######	2.49E-02	2.67E+01	7.13E-01	1.42E+03	9.08E-03	#######	2.38E-02	9.39E-03	1.42E+03
		Light Commercial Truck	1.32E-03	3.17E-03	5.52E-03	1.21E-02	1.35E-02	1.02E-01	#######	7.04E-01	4.12E+00	5.14E-03	#######	3.43E-03	1.30E-03	3.97E+02	1.24E-02	7.04E-01	#######	#######	6.95E-03	4.12E+00	1.02E-01	3.96E+02	5.14E-03	#######	3.43E-03	1.30E-03	3.97E+02
	Compressed Natural Gas (CNG)	Transit Bus	2.27E-03	8.41E-03	9.47E-03	3.21E-02	5.00E-03	0.00E+00		3.32E+00	2.67E+01	1.55E-02	#######			9.36E+02	5.00E-03	3.32E+00	#######	#######	#######	2.67E+01	0.00E+00	9.23E+02	1.55E-02	#######	#######	0.00E+00	9.36E+02
2019	Diesel Fuel	Combination Long-haul Truck	4.44E-03	1.07E-02	1.85E-02	4.09E-02	1.91E-01	1.67E-01	#######	4.65E+00	1.07E+00	3.55E-02	#######	1.81E-03	1.34E-02	1.95E+03	1.85E-01	4.65E+00	#######	#######	1.39E-02	1.07E+00	1.67E-01	1.94E+03	3.55E-02	#######	1.81E-03	1.34E-02	1.95E+03
		Combination Short-haul Truck	4.03E-03	9.90E-03	1.68E-02	3.78E-02	1.49E-01	1.48E-01	#######	3.95E+00	9.21E-01	3.66E-02	#######	1.60E-03	1.19E-02	1.87E+03	1.45E-01	3.95E+00	#######	#######	1.32E-02	9.21E-01	1.48E-01	1.86E+03	3.66E-02	#######	1.60E-03	1.19E-02	1.87E+03
		Intercity Bus	4.86E-03	1.62E-02	2.03E-02	6.17E-02	2.55E-01	2.44E-01	#######	5.98E+00	1.53E+00	3.62E-02	#######	2.64E-03	1.97E-02	1.62E+03	2.47E-01	5.98E+00	#######	#######	1.18E-02	1.53E+00	2.44E-01	1.62E+03	3.62E-02	#######	2.64E-03	1.97E-02	1.62E+03
		Passenger Car	1.27E-03	1.92E-03	5.30E-03	7.33E-03	5.19E-03	9.54E-03	#######	2.10E-01	8.88E-01	6.19E-03	#######	1.03E-04	7.71E-04	3.00E+02	5.04E-03	2.10E-01	#######	#######	2.12E-03	8.88E-01	9.54E-03	2.99E+02	6.19E-03	#######	1.03E-04	7.71E-04	3.00E+02
		Passenger Truck	1.62E-03	3.02E-03	6.75E-03	1.15E-02	5.44E-02	1.19E-01	#######	1.21E+00	8.83E-01	2.14E-02	#######	1.29E-03	9.59E-03	6.13E+02	5.27E-02	1.21E+00	#######	#######	4.39E-03	8.83E-01	1.19E-01	6.13E+02	2.14E-02	#######	1.29E-03	9.59E-03	6.13E+02
		School Bus	3.93E-03	1.37E-02	1.64E-02	5.25E-02	1.46E-01	2.26E-01	#######	3.04E+00	9.93E-01	3.06E-02	#######	2.45E-03	1.83E-02	8.15E+02	1.41E-01	3.04E+00	#######	#######	5.92E-03	9.93E-01	2.26E-01	8.13E+02	3.06E-02	#######	2.45E-03	1.83E-02	8.15E+02
		Single Unit Long-haul Truck	2.89E-03	1.07E-02	1.21E-02	4.10E-02	6.10E-02	1.43E-01	#######	1.55E+00	6.65E-01	4.28E-02	#######	1.55E-03	1.16E-02	8.01E+02	5.91E-02	1.55E+00	#######	#######	5.63E-03	6.65E-01	1.43E-01	8.00E+02	4.28E-02	#######	1.55E-03	1.16E-02	8.01E+02
		Single Unit Short-haul Truck	2.90E-03	1.08E-02	1.21E-02	4.11E-02	5.47E-02	1.23E-01	#######	1.49E+00	6.03E-01	4.30E-02	#######	1.33E-03	9.90E-03	8.56E+02	5.31E-02	1.49E+00	#######	#######	5.99E-03	6.03E-01	1.23E-01	8.55E+02	4.30E-02	#######	1.33E-03	9.90E-03	8.56E+02
		Transit Bus	2.61E-03	8.11E-03	1.09E-02	3.10E-02	1.87E-01	2.28E-01	#######	4.12E+00	1.36E+00	3.25E-02	#######	2.47E-03	1.84E-02	1.19E+03	1.82E-01	4.12E+00	#######	#######	8.53E-03	1.36E+00	2.28E-01	1.19E+03	3.25E-02	#######	2.47E-03	1.84E-02	1.19E+03
		Motor Home	2.29E-03	8.51E-03	9.53E-03	3.25E-02	1.08E-01	2.51E-01	#######	2.48E+00	9.77E-01	4.14E-02	#######	2.73E-03	2.03E-02	8.85E+02	1.05E-01	2.48E+00	#######	#######	6.35E-03	9.77E-01	2.51E-01	8.83E+02	4.14E-02	#######	2.73E-03	2.03E-02	8.85E+02
		Refuse Truck	4.63E-03	1.28E-02	1.93E-02	4.87E-02	1.50E-01	1.61E-01	#######	3.68E+00	9.60E-01	3.78E-02	#######	1.74E-03	1.30E-02	1.53E+03	1.46E-01	3.68E+00	#######	#######	1.08E-02	9.60E-01	1.61E-01	1.52E+03	3.78E-02	#######	1.74E-03	1.30E-02	1.53E+03
		Light Commercial Truck	1.65E-03	3.28E-03	6.87E-03	1.25E-02	7.82E-02	1.76E-01	#######	1.55E+00	1.07E+00	1.93E-02	#######	1.90E-03	1.42E-02	6.10E+02	7.58E-02	1.55E+00	#######	#######	4.43E-03	1.07E+00	1.76E-01	6.09E+02	1.93E-02	#######	1.90E-03	1.42E-02	6.10E+02
	Gasoline	Motorcycle	6.37E-04	1.66E-04	2.66E-03	6.33E-04	4.70E-02	6.63E-01	#######	8.07E-01	1.40E+01	2.88E-02	#######	2.23E-02	8.94E-03	3.72E+02	4.33E-02	8.07E-01	#######	#######	6.51E-03	1.40E+01	6.63E-01	3.71E+02	2.88E-02	#######	2.23E-02	8.94E-03	3.72E+02
		Passenger Car	1.27E-03	1.92E-03	5.30E-03	7.33E-03	7.29E-03	2.04E-02	#######	1.37E-01	1.66E+00	4.02E-03	#######	6.82E-04	2.65E-04	2.85E+02	6.71E-03	1.37E-01	#######	#######	5.00E-03	1.66E+00	2.04E-02	2.85E+02	4.02E-03	#######	6.82E-04	2.65E-04	2.85E+02
		Passenger Truck	1.30E-03	3.16E-03	5.41E-03	1.21E-02	1.36E-02	8.37E-02	#######	5.60E-01	3.70E+00	4.57E-03	#######	2.80E-03	1.06E-03	3.91E+02	1.25E-02	5.60E-01	#######	#######	6.86E-03	3.70E+00	8.37E-02	3.90E+02	4.57E-03	#######	2.80E-03	1.06E-03	3.91E+02
		School Bus	2.27E-03	8.84E-03	9.46E-03	3.38E-02	1.13E-02	6.83E-01	#######	3.07E+00	2.02E+01	2.07E-02	#######	2.28E-02	8.79E-03	7.71E+02	1.04E-02	3.07E+00	#######	#######	1.35E-02	2.02E+01	6.83E-01	7.67E+02	2.07E-02	#######	2.28E-02	8.79E-03	7.71E+02
		Single Unit Long-haul Truck	2.30E-03	9.22E-03	9.60E-03	3.52E-02	7.46E-03	3.64E-01	#######	3.17E+00	1.32E+01	6.62E-03	#######	1.21E-02	4.84E-03	8.03E+02	6.87E-03	3.17E+00	#######	#######	1.41E-02	1.32E+01	3.64E-01	8.01E+02	6.62E-03	#######	1.21E-02	4.84E-03	8.03E+02
		Single Unit Short-haul Truck	2.30E-03	9.23E-03	9.60E-03	3.53E-02	7.40E-03	3.77E-01	#######	3.25E+00	1.37E+01	6.78E-03	#######	1.26E-02	5.02E-03	8.55E+02	6.81E-03	3.25E+00	#######	#######	1.50E-02	1.37E+01	3.77E-01	8.53E+02	6.78E-03	#######	1.26E-02	5.02E-03	8.55E+02
		Transit Bus	2.27E-03	8.40E-03	9.46E-03	3.21E-02	9.86E-03	8.10E-01	#######	3.80E+00	2.21E+01	1.11E-02	#######	2.69E-02	1.06E-02	1.13E+03	9.08E-03	3.80E+00	#######	#######	1.97E-02	2.21E+01	8.10E-01	1.12E+03	1.11E-02	#######	2.69E-02	1.06E-02	1.13E+03
		Motor Home	2.21E-03	8.33E-03	9.22E-03	3.18E-02	1.32E-02	5.50E-01	#######	3.74E+00	2.02E+01	1.24E-02	#######	1.83E-02	7.10E-03	8.70E+02	1.22E-02	3.74E+00	#######	#######	1.52E-02	2.02E+01	5.50E-01	8.67E+02	1.24E-02	#######	1.83E-02	7.10E-03	8.70E+02
		Refuse Truck	2.21E-03	7.31E-03	9.22E-03	2.79E-02	1.17E-02	6.90E-01	#######	4.91E+00	2.53E+01	8.30E-03	#######	2.30E-02	9.10E-03	1.42E+03	1.08E-02	4.91E+00	#######	#######	2.49E-02	2.53E+01	6.90E-01	1.42E+03	8.30E-03	#######	2.30E-02	9.10E-03	1.42E+03
		Light Commercial Truck	1.32E-03	3.17E-03	5.52E-03	1.21E-02	1.33E-02	9.47E-02	#######	6.60E-01	3.97E+00	4.73E-03	#######	3.16E-03	1.21E-03	3.90E+02	1.22E-02	6.60E-01	#######	#######	6.83E-03	3.97E+00	9.47E-02	3.89E+02	4.73E-03	#######	3.16E-03	1.21E-03	3.90E+02
	Compressed Natural Gas (CNG)	Transit Bus	2.27E-03	8.41E-03	9.47E-03	3.21E-02	4.87E-03	0.00E+00		3.29E+00	2.51E+01	1.42E-02	#######			9.36E+02	4.87E-03	3.29E+00	#######	#######	#######	2.51E+01	0.00E+00	9.23E+02	1.42E-02	#######	#######	0.00E+00	9.36E+02
2020	Diesel Fuel	Combination Long-haul Truck	4.44E-03	1.07E-02	1.85E-02	4.09E-02	1.64E-01	1.44E-01	#######	4.11E+00	9.45E-01	3.63E-02	#######	1.56E-03	1.16E-02	1.95E+03	1.59E-01	4.11E+00	#######	#######	1.38E-02	9.45E-01	1.44E-01	1.94E+03	3.63E-02	#######	1.56E-03	1.16E-02	1.95E+03
		Combination Short-haul Truck	4.03E-03	9.90E-03	1.68E-02	3.78E-02	1.26E-01	1.26E-01	#######	3.46E+00	8.08E-01	3.73E-02	#######	1.36E-03	1.01E-02	1.87E+03	1.22E-01	3.46E+00	#######	#######	1.31E-02	8.08E-01	1.26E-01	1.86E+03	3.73E-02	#######	1.36E-03	1.01E-02	1.87E+03
		Intercity Bus	4.86E-03	1.62E-02	2.03E-02	6.17E-02	2.25E-01	2.18E-01	#######	5.30E+00	1.37E+00	3.74E-02	#######	2.36E-03	1.76E-02	1.62E+03	2.19E-01	5.30E+00	#######	#######	1.17E-02	1.37E+00	2.18E-01	1.62E+03	3.74E-02	#######	2.36E-03	1.76E-02	1.62E+03
		Passenger Car	1.27E-03	1.92E-03	5.30E-03	7.33E-03	4.66E-03	8.86E-03	#######	1.76E-01	9.82E-01	7.07E-03	#######	9.61E-05	7.16E-04	2.93E+02	4.52E-03	1.76E-01	#######	#######	2.05E-03	9.82E-01	8.86E-03	2.93E+02	7.07E-03	#######	9.61E-05	7.16E-04	2.93E+02
		Passenger Truck	1.62E-03	3.02E-03	6.75E-03	1.15E-02	4.77E-02	1.04E-01	#######	1.12E+00	8.57E-01	2.20E-02	#######	1.13E-03	8.43E-03	6.11E+02	4.63E-02	1.12E+00	#######	#######	4.34E-03	8.57E-01	1.04E-01	6.10E+02	2.20E-02	#######	1.13E-03	8.43E-03	6.11E+02
		School Bus	3.93E-03	1.37E-02	1.64E-02	5.25E-02	1.29E-01	2.01E-01	#######	2.74E+00	8.99E-01	3.15E-02	#######	2.18E-03	1.62E-02	8.15E+02	1.26E-01	2.74E+00	#######	#######	5.88E-03	8.99E-01	2.01E-01	8.13E+02	3.15E-02	#######	2.18E-03	1.62E-02	8.15E+02
		Single Unit Long-haul Truck	2.90E-03	1.07E-02	1.21E-02	4.10E-02	5.24E-02	1.23E-01	#######	1.41E+00	5.98E-01	4.32E-02	#######	1.33E-03	9.90E-03	8.01E+02	5.09E-02	1.41E+00	#######	#######	5.61E-03	5.98E-01	1.23E-01	8.00E+02	4.32E-02	#######	1.33E-03	9.90E-03	8.01E+02
		Single Unit Short-haul Truck	2.90E-03	1.08E-02	1.21E-02	4.11E-02	4.64E-02	1.04E-01	#######	1.35E+00	5.43E-01	4.33E-02	#######	1.13E-03	8.41E-03	8.56E+02	4.50E-02	1.35E+00	#######	#######	5.97E-03	5.43E-01	1.04E-01	8.55E+02	4.33E-02	#######	1.13E-03	8.41E-03	8.56E+02
		Transit Bus	2.61E-03	8.11E-03	1.09E-02	3.10E-02	1.63E-01	1.98E-01	#######	3.61E+00	1.19E+00	3.32E-02	#######	2.15E-03	1.60E-02	1.19E+03	1.58E-01	3.61E+00	#######	#######	8.48E-03	1.19E+00	1.98E-01	1.19E+03	3.32E-02	#######	2.15E-03	1.60E-02	1.19E+03
		Motor Home	2.29E-03	8.51E-03	9.53E-03	3.25E-02	9.53E-02	2.20E-01	#######	2.26E+00	8.87E-01	4.21E-02	#######	2.38E-03	1.78E-02	8.85E+02	9.25E-02	2.26E+00	#######	#######	6.31E-03	8.87E-01	2.20E-01	8.83E+02	4.21E-02	#######	2.38E-03	1.78E-02	8.85E+02
		Refuse Truck	4.64E-03	1.28E-02	1.94E-02	4.88E-02	1.26E-01	1.36E-01	#######	3.19E+00	8.40E-01	3.87E-02	#######	1.47E-03	1.10E-02	1.53E+03	1.22E-01	3.19E+00	#######	#######	1.08E-02	8.40E-01	1.36E-01	1.52E+03	3.87E-02	#######	1.47E-03	1.10E-02	1.53E+03
		Light Commercial Truck	1.65E-03	3.28E-03	6.87E-03	1.25E-02	6.84E-02	1.54E-01	#######	1.42E+00	1.01E+00	2.03E-02	#######	1.67E-03	1.25E-02	6.07E+02	6.64E-02	1.42E+00	#######	#######	4.38E-03	1.01E+00	1.54E-01	6.07E+02	2.03E-02	#######	1.67E-03	1.25E-02	6.07E+02
	Gasoline	Motorcycle	6.37E-04	1.66E-04	2.66E-03	6.33E-04	4.70E-02	6.54E-01	#######	8.03E-01	1.38E+01	2.88E-02	#######	2.20E-02	8.82E-03	3.72E+02	4.33E-02	8.03E-01	#######	#######	6.51E-03	1.38E+01	6.54E-01	3.71E+02	2.88E-02	#######	2.20E-02	8.82E-03	3.72E+02
		Passenger Car	1.27E-03	1.92E-03	5.30E-03	7.33E-03	7.20E-03	1.88E-02	#######	1.22E-01	1.62E+00	4.01E-03	#######	6.24E-04	2.44E-04	2.81E+02	6.63E-03	1.22E-01	#######	#######	4.92E-03	1.62E+00	1.88E-02	2.80E+02	4.01E-03	#######	6.24E-04	2.44E-04	2.81E+02
		Passenger Truck	1.30E-03	3.16E-03	5.41E-03	1.21E-02	1.35E-02	7.69E-02	#######	5.20E-01	3.57E+00	4.26E-03	#######	2.57E-03	9.79E-04	3.84E+02	1.24E-02	5.20E-01	#######	#######	6.73E-03	3.57E+00	7.69E-02	3.84E+02	4.26E-03	#######	2.57E-03	9.79E-04	3.84E+02
		School Bus	2.27E-03	8.84E-03	9.46E-03	3.38E-02	9.39E-03	6.28E-01	#######	2.92E+00	1.90E+01	1.71E-02	#######	2.09E-02	8.13E-03	7.71E+02	8.65E-03	2.92E+00	#######	#######	1.35E-02	1.90E+01	6.28E-01	7.67E+02	1.71E-02	#######	2.09E-02	8.13E-03	7.71E+02
		Single Unit Long-haul Truck	2.30E-03	9.22E-03	9.60E-03	3.52E-02	7.34E-03	3.63E-01	#######	3.15E+00	1.32E+01	6.30E-03	#######	1.21E-02	4.82E-03	8.03E+02	6.76E-03	3.15E+00	#######	#######	1.41E-02	1.32E+01	3.63E-01	8.01E+02	6.30E-03	#######	1.21E-02	4.82E-03	8.03E+02
		Single Unit Short-haul Truck	2.30E-03	9.23E-03	9.60E-03	3.53E-02	7.22E-03	3.73E-01	#######	3.23E+00	1.36E+01	6.43E-03	#######	1.24E-02	4.97E-03	8.55E+02	6.65E-03	3.23E+00	#######	#######	1.50E-02	1.36E+01	3.73E-01	8.53E+02	6.43E-03	#######	1.24E-02	4.97E-03	8.55E+02
		Transit Bus	2.27E-03	8.40E-03	9.46E-03	3.21E-02	9.75E-03	8.04E-01	#######	3.77E+00	2.14E+01	1.04E-02	#######	2.67E-02	1.06E-02	1.13E+03	8.98E-03	3.77E+00	#######	#######	1.97E-02	2.14E+01	8.04E-01	1.12E+03	1.04E-02	#######	2.67E-02	1.06E-02	1.13E+03
		Motor Home	2.21E-03	8.33E-03	9.22E-03	3.18E-02	1.20E-02	5.27E-01	#######	3.64E+00	1.96E+01	1.09E-02	#######	1.75E-02	6.83E-03	8.70E+02	1.10E-02	3.64E+00	#######	#######	1.52E-02	1.96E+01	5.27E-01	8.67E+02	1.09E-02	#######	1.75E-02	6.83E-03	8.70E+02
		Refuse Truck	2.21E-03	7.31E-03	9.22E-03	2.79E-02	1.13E-02	6.71E-01	#######	4.84E+00	2.42E+01	7.69E-03	#######	2.24E-02	8.87E-03	1.42E+03	1.04E-02	4.84E+00	#######	#######	2.49E-02	2.42E+01	6.71E-01	1.42E+03	7.69E-03	#######	2.24E-02	8.87E-03	1.42E+03
		Light Commercial Truck	1.32E-03	3.17E-03	5.52E-03	1.21E-02	1.32E-02	8.83E-02	#######	6.23E-01	3.85E+00	4.39E-03	#######	2.94E-03	1.13E-03	3.84E+02	1.22E-02	6.23E-01	#######	#######	6.72E-03	3.85E+00	8.83E-02	3.83E+02	4.39E-03	#######	2.94E-03	1.13E-03	3.84E+02
	Compressed Natural Gas (CNG)	Transit Bus	2.27E-03	8.41E-03	9.47E-03	3.21E-02	4.74E-03	0.00E+00		3.26E+00	2.38E+01	1.32E-02	#######			9.36E+02	4.74E-03	3.26E+00	#######	#######	#######	2.38E+01	0.00E+00	9.23E+02	1.32E-02	#######	#######	0.00E+00	9.36E+02
2021	Diesel Fuel	Combination Long-haul Truck	4.44E-03	1.07E-02	1.85E-02	4.09E-02	1.41E-01	1.25E-01	#######	3.66E+00	8.37E-01	3.71E-02	#######	1.35E-03	1.01E-02	1.95E+03	1.37E-01	3.66E+00	#######	#######	1.37E-02	8.37E-01	1.25E-01	1.94E+03	3.71E-02	#######	1.35E-03	1.01E-02	1.95E+03
		Combination Short-haul Truck	4.03E-03	9.90E-03	1.68E-02	3.78E-02	1.06E-01	1.07E-01	#######	3.06E+00	7.14E-01	3.79E-02	#######	1.16E-03	8.67E-03	1.87E+03	1.03E-01	3.06E+00	#######	#######	1.31E-02	7.14E-01	1.07E-01	1.86E+03	3.79E-02	#######	1.16E-03	8.67E-03	1.87E+03
		Intercity Bus	4.86E-03	1.62E-02	2.03E-02	6.17E-02	1.99E-01	1.94E-01	#######	4.74E+00	1.23E+00	3.85E-02	#######	2.10E-03	1.57E-02	1.62E+03	1.93E-01	4.74E+00	#######	#######	1.16E-02	1.23E+00	1.94E-01	1.62E+03	3.85E-02	#######	2.10E-03	1.57E-02	1.62E+03
		Passenger Car	1.27E-03	1.92E-03	5.30E-03	7.33E-03	4.27E-03	8.46E-03	#######	1.50E-01	1.07E+00	7.88E-03	#######	9.17E-05	6.83E-04	2.87E+02	4.14E-03	1.50E-01	#######	#######	2.00E-03	1.07E+00	8.46E-03	2.87E+02	7.88E-03	#######	9.17E-05	6.83E-04	2.87E+02
		Passenger Truck	1.62E-03	3.02E-03	6.75E-03	1.15E-02	4.17E-02	9.19E-02	#######	1.04E+00	8.35E-01	2.26E-02	#######	9.97E-04	7.42E-03	6.08E+02	4.04E-02	1.04E+00	#######	#######	4.30E-03	8.35E-01	9.19E-02	6.07E+02	2.26E-02	#######	9.97E-04	7.42E-03	6.08E+02
		School Bus	3.93E-03	1.37E-02	1.64E-02	5.25E-02	1.14E-01	1.77E-01	#######	2.46E+00	8.10E-01	3.24E-02	#######	1.92E-03	1.43E-02	8.15E+02	1.10E-01	2.46E+00	#######	#######	5.84E-03	8.10E-01	1.77E-01	8.13E+02	3.24E-02	#######	1.92E-03	1.43E-02	8.15E+02
		Single Unit Long-haul Truck	2.90E-03	1.07E-02	1.21E-02	4.10E-02	4.52E-02	1.05E-01	#######	1.29E+00	5.43E-01	4.35E-02	#######	1.14E-03	8.51E-03	8.01E+02	4.38E-02	1.29E+00	#######	#######	5.59E-03	5.43E-01	1.05E-01	8.00E+02	4.35E-02	#######	1.14E-03	8.51E-03	8.01E+02
		Single Unit Short-haul Truck	2.90E-03	1.08E-02	1.21E-02	4.11E-02	3.95E-02	8.92E-02	#######	1.23E+00	4.93E-01	4.35E-02	#######	9.66E-04	7.20E-03	8.56E+02	3.84E-02	1.23E+00	#######	#######	5.94E-03	4.93E-01	8.92E-02	8.55E+02	4.35E-02	#######	9.66E-04	7.20E-03	8.56E+02
		Transit Bus	2.61E-03	8.11E-03	1.09E-02	3.10E-02	1.41E-01	1.71E-01	#######	3.19E+00	1.04E+00	3.38E-02	#######	1.86E-03	1.38E-02	1.19E+03	1.36E-01	3.19E+00	#######	#######	8.43E-03	1.04E+00	1.71E-01	1.19E+03	3.38E-02	#######	1.86E-03	1.38E-02	1.19E+03
		Motor Home	2.29E-03	8.51E-03	9.53E-03	3.25E-02	8.40E-02	1.93E-01	#######	2.08E+00	8.07E-01	4.28E-02	#######	2.09E-03	1.55E-02	8.85E+02	8.15E-02	2.08E+00	#######	#######	6.28E-03	8.07E-01	1.93E-01	8.83E+02	4.28E-02	#######	2.09E-03	1.55E-02	8.85E+02
		Refuse Truck	4.64E-03	1.28E-02	1.94E-02	4.88E-02	1.06E-01	1.16E-01	#######	2.80E+00	7.38E-01	3.94E-02	#######	1.26E-03	9.35E-03	1.53E+03	1.03E-01	2.80E+00	#######	#######	1.07E-02	7.38E-01	1.16E-01	1.52E+03	3.94E-02	#######	1.26E-03	9.35E-03	1.53E+03
		Light Commercial Truck	1.65E-03	3.27E-03	6.87E-03	1.25E-02	5.97E-02	1.36E-01	#######	1.30E+00	9.62E-01	2.11E-02	#######	1.47E-03	1.10E-02	6.05E+02	5.79E-02	1.30E+00	#######	#######	4.33E-03	9.62E-01	1.36E-01	6.04E+02	2.11E-02	#######	1.47E-03	1.10E-02	6.05E+02
	Gasoline	Motorcycle	6.37E-04	1.66E-04	2.66E-03	6.33E-04	4.70E-02	6.47E-01	#######	8.00E-01	1.37E+01	2.88E-02	#######	2.17E-02	8.72E-03	3.72E+02	4.33E-02	8.00E-01	#######	#######	6.51E-03	1.37E+01	6.47E-01	3.71E+02	2.88E-02	#######	2.17E-02	8.72E-03	3.72E+02
		Passenger Car	1.27E-03	1.92E-03	5.30E-03	7.33E-03	7.16E-03	1.77E-02	#######	1.11E-01	1.60E+00	3.97E-03	#######	5.86E-04	2.30E-04	2.77E+02	6.60E-03	1.11E-01	#######	#######	4.85E-03	1.60E+00	1.77E-02	2.76E+02	3.97E-03	#######	5.86E-04	2.30E-04	2.77E+02
		Passenger Truck	1.30E-03	3.16E-03	5.41E-03	1.21E-02	1.33E-02	7.10E-02	#######	4.84E-01	3.46E+00	4.04E-03	#######	2.37E-03	9.05E-04	3.78E+02	1.23E-02	4.84E-01	#######	#######	6.62E-03	3.46E+00	7.10E-02	3.77E+02	4.04E-03	#######	2.37E-03	9.05E-04	3.78E+02
		School Bus	2.27E-03	8.84E-03	9.46E-03	3.38E-02	8.84E-03	6.08E-01	#######	2.86E+00	1.77E+01	1.48E-02	#######	2.02E-02	7.90E-03	7.70E+02	8.14E-03	2.86E+00	#######	#######	1.35E-02	1.77E+01	6.08E-01	7.67E+02	1.48E-02	#######	2.02E-02	7.90E-03	7.70E+02
		Single Unit Long-haul Truck	2.30E-03	9.22E-03	9.60E-03	3.52E-02	7.31E-03	3.62E-01	#######	3.14E+00	1.31E+01	6.27E-03	#######	1.20E-02	4.81E-03	8.03E+02	6.73E-03	3.14E+00	#######	#######	1.41E-02	1.31E+01	3.62E-01	8.01E+02	6.27E-03	#######	1.20E-02	4.81E-03	8.03E+02
		Single Unit Short-haul Truck	2.30E-03	9.23E-03	9.60E-03	3.53E-02	7.17E-03	3.72E-01	#######	3.22E+00	1.35E+01	6.34E-03	#######	1.24E-02	4.95E-03	8.54E+02	6.60E-03	3.22E+00	#######	#######	1.50E-02	1.35E+01	3.72E-01	8.53E+02	6.34E-03	#######	1.24E-02	4.95E-03	8.54E+02
		Transit Bus	2.27E-03	8.40E-03	9.46E-03	3.21E-02	9.67E-03	8.00E-01	#######	3.74E+00	2.08E+01	1.02E-02	#######	2.65E-02	1.05E-02	1.13E+03	8.90E-03	3.74E+00	#######	#######	1.97E-02	2.08E+01	8.00E-01	1.12E+03	1.02E-02	#######	2.65E-02	1.05E-02	1.13E+03
		Motor Home	2.21E-03	8.33E-03	9.22E-03	3.18E-02	1.15E-02	5.14E-01	#######	3.60E+00	1.90E+01	9.93E-03	#######	1.71E-02	6.68E-03	8.70E+02	1.06E-02	3.60E+00	#######	#######	1.52E-02	1.90E+01	5.14E-01	8.67E+02	9.93E-03	#######	1.71E-02	6.68E-03	8.70E+02
		Refuse Truck	2.21E-03	7.31E-03	9.22E-03	2.79E-02	1.10E-02	6.56E-01	#######	4.80E+00	2.32E+01	7.30E-03	#######	2.19E-02	8.70E-03	1.42E+03	1.01E-02	4.80E+00	#######	#######	2.49E-02	2.32E+01	6.56E-01	1.42E+03	7.30E-03	#######	2.19E-02	8.70E-03	1.42E+03
		Light Commercial Truck	1.32E-03	3.17E-03	5.52E-03	1.21E-02	1.31E-02	8.27E-02	#######	5.90E-01	3.75E+00	4.18E-03	#######	2.75E-03	1.06E-03	3.78E+02	1.20E-02	5.90E-01	#######	#######	6.62E-03	3.75E+00	8.27E-02	3.77E+02	4.18E-03	#######	2.75E-03	1.06E-03	3.78E+02
	Compressed Natural Gas (CNG)	Transit Bus	2.27E-03	8.41E-03	9.47E-03	3.21E-02	4.62E-03	0.00E+00		3.24E+00	2.27E+01	1.26E-02	#######			9.36E+02	4.62E-03	3.24E+00	#######	#######	#######	2.27E+01	0.00E+00	9.23E+02	1.26E-02	#######	#######	0.00E+00	9.36E+02
2022	Diesel Fuel	Combination Long-haul Truck	4.44E-03	1.07E-02	1.85E-02	4.09E-02	1.21E-01	1.08E-01	#######	3.27E+00	7.46E-01	3.77E-02	#######	1.17E-03	8.74E-03	1.95E+03	1.18E-01	3.27E+00	#######	#######	1.36E-02	7.46E-01	1.08E-01	1.94E+03	3.77E-02	#######	1.17E-03	8.74E-03	1.95E+03
		Combination Short-haul Truck	4.03E-03	9.90E-03	1.68E-02	3.78E-02	9.05E-02	9.21E-02	#######	2.73E+00	6.35E-01	3.84E-02	#######	9.98E-04	7.43E-03	1.87E+03	8.78E-02	2.73E+00	#######	#######	1.30E-02	6.35E-01	9.21E-02	1.86E+03	3.84E-02	#######	9.98E-04	7.43E-03	1.87E+03
		Intercity Bus	4.86E-03	1.62E-02	2.03E-02	6.17E-02	1.76E-01	1.73E-01	#######	4.28E+00	1.11E+00	3.94E-02	#######	1.88E-03	1.40E-02	1.62E+03	1.71E-01	4.28E+00	#######	#######	1.15E-02	1.11E+00	1.73E-01	1.62E+03	3.94E-02	#######	1.88E-03	1.40E-02	1.62E+03
		Passenger Car	1.27E-03	1.92E-03	5.30E-03	7.33E-03	4.00E-03	8.24E-03	#######	1.31E-01	1.14E+00	8.60E-03	#######	8.93E-05	6.65E-04	2.82E+02	3.88E-03	1.31E-01	#######	#######	1.96E-03	1.14E+00	8.24E-03	2.82E+02	8.60E-03	#######	8.93E-05	6.65E-04	2.82E+02
		Passenger Truck	1.62E-03	3.02E-03	6.75E-03	1.15E-02	3.67E-02	8.09E-02	#######	9.66E-01	8.16E-01	2.31E-02	#######	8.77E-04	6.53E-03	6.06E+02	3.56E-02	9.66E-01	#######	#######	4.27E-03	8.16E-01	8.09E-02	6.05E+02	2.31E-02	#######	8.77E-04	6.53E-03	6.06E+02
		School Bus	3.93E-03	1.37E-02	1.64E-02	5.25E-02	1.00E-01	1.56E-01	#######	2.22E+00	7.32E-01	3.32E-02	#######	1.69E-03	1.26E-02	8.15E+02	9.74E-02	2.22E+00	#######	#######	5.81E-03	7.32E-01	1.56E-01	8.13E+02	3.32E-02	#######	1.69E-03	1.26E-02	8.15E+02
		Single Unit Long-haul Truck	2.90E-03	1.07E-02	1.21E-02	4.10E-02	3.94E-02	9.15E-02	#######	1.19E+00	4.98E-01	4.38E-02	#######	9.92E-04	7.39E-03	8.01E+02	3.82E-02	1.19E+00	#######	#######	5.57E-03	4.98E-01	9.15E-02	8.00E+02	4.38E-02	#######	9.92E-04	7.39E-03	8.01E+02
		Single Unit Short-haul Truck	2.90E-03	1.08E-02	1.21E-02	4.12E-02	3.42E-02	7.72E-02	#######	1.14E+00	4.54E-01	4.37E-02	#######	8.37E-04	6.23E-03	8.56E+02	3.31E-02	1.14E+00	#######	#######	5.93E-03	4.54E-01	7.72E-02	8.55E+02	4.37E-02	#######	8.37E-04	6.23E-03	8.56E+02
		Transit Bus	2.61E-03	8.11E-03	1.09E-02	3.10E-02	1.21E-01	1.49E-01	#######	2.84E+00	9.11E-01	3.44E-02	#######	1.61E-03	1.20E-02	1.19E+03	1.18E-01	2.84E+00	#######	#######	8.39E-03	9.11E-01	1.49E-01	1.19E+03	3.44E-02	#######	1.61E-03	1.20E-02	1.19E+03
		Motor Home	2.29E-03	8.51E-03	9.53E-03	3.25E-02	7.50E-02	1.69E-01	#######	1.93E+00	7.39E-01	4.33E-02	#######	1.83E-03	1.36E-02	8.85E+02	7.27E-02	1.93E+00	#######	#######	6.25E-03	7.39E-01	1.69E-01	8.83E+02	4.33E-02	#######	1.83E-03	1.36E-02	8.85E+02
		Refuse Truck	4.65E-03	1.28E-02	1.94E-02	4.89E-02	8.95E-02	9.88E-02	#######	2.47E+00	6.55E-01	4.01E-02	#######	1.07E-03	7.98E-03	1.53E+03	8.69E-02	2.47E+00	#######	#######	1.07E-02	6.55E-01	9.88E-02	1.52E+03	4.01E-02	#######	1.07E-03	7.98E-03	1.53E+03
		Light Commercial Truck	1.65E-03	3.27E-03	6.87E-03	1.25E-02	5.26E-02	1.20E-01	#######	1.20E+00	9.21E-01	2.18E-02	#######	1.30E-03	9.66E-03	6.03E+02	5.11E-02	1.20E+00	#######	#######	4.29E-03	9.21E-01	1.20E-01	6.02E+02	2.18E-02	#######	1.30E-03	9.66E-03	6.03E+02
	Gasoline	Motorcycle	6.37E-04	1.66E-04	2.66E-03	6.33E-04	4.70E-02	6.40E-01	#######	7.97E-01	1.36E+01	2.88E-02	#######	2.15E-02	8.63E-03	3.72E+02	4.33E-02	7.97E-01	#######	#######	6.51E-03	1.36E+01	6.40E-01	3.71E+02	2.88E-02	#######	2.15E-02	8.63E-03	3.72E+02
		Passenger Car	1.27E-03	1.92E-03	5.30E-03	7.33E-03	7.15E-03	1.69E-02	#######	1.03E-01	1.58E+00	4.00E-03	#######	5.58E-04	2.21E-04	2.73E+02	6.58E-03	1.03E-01	#######	#######	4.79E-03	1.58E+00	1.69E-02	2.73E+02	4.00E-03	#######	5.58E-04	2.21E-04	2.73E+02
		Passenger Truck	1.30E-03	3.16E-03	5.41E-03	1.21E-02	1.33E-02	6.59E-02	#######	4.53E-01	3.37E+00	3.87E-03	#######	2.19E-03	8.42E-04	3.72E+02	1.22E-02	4.53E-01	#######	#######	6.52E-03	3.37E+00	6.59E-02	3.72E+02	3.87E-03	#######	2.19E-03	8.42E-04	3.72E+02
		School Bus	2.27E-03	8.84E-03	9.46E-03	3.38E-02	8.29E-03	5.93E-01	#######	2.81E+00	1.66E+01	1.30E-02	#######	1.96E-02	7.72E-03	7.70E+02	7.64E-03	2.81E+00	#######	#######	1.35E-02	1.66E+01	5.93E-01	7.67E+02	1.30E-02	#######	1.96E-02	7.72E-03	7.70E+02
		Single Unit Long-haul Truck	2.30E-03	9.22E-03	9.60E-03	3.52E-02	7.29E-03	3.61E-01	#######	3.14E+00	1.31E+01	6.28E-03	#######	1.20E-02	4.80E-03	8.03E+02	6.71E-03	3.14E+00	#######	#######	1.41E-02	1.31E+01	3.61E-01	8.01E+02	6.28E-03	#######	1.20E-02	4.80E-03	8.03E+02
		Single Unit Short-haul Truck	2.30E-03	9.23E-03	9.60E-03	3.53E-02	7.12E-03	3.71E-01	#######	3.21E+00	1.34E+01	6.29E-03	#######	1.23E-02	4.94E-03	8.54E+02	6.55E-03	3.21E+00	#######	#######	1.50E-02	1.34E+01	3.71E-01	8.53E+02	6.29E-03	#######	1.23E-02	4.94E-03	8.54E+02
		Transit Bus	2.27E-03	8.40E-03	9.46E-03	3.21E-02	9.62E-03	7.98E-01	#######	3.73E+00	2.05E+01	1.02E-02	#######	2.65E-02	1.05E-02	1.13E+03	8.86E-03	3.73E+00	#######	#######	1.97E-02	2.05E+01	7.98E-01	1.12E+03	1.02E-02	#######	2.65E-02	1.05E-02	1.13E+03
		Motor Home	2.21E-03	8.33E-03	9.22E-03	3.18E-02	1.11E-02	5.05E-01	#######	3.57E+00	1.85E+01	9.21E-03	#######	1.67E-02	6.56E-03	8.69E+02	1.02E-02	3.57E+00	#######	#######	1.52E-02	1.85E+01	5.05E-01	8.67E+02	9.21E-03	#######	1.67E-02	6.56E-03	8.69E+02
		Refuse Truck	2.21E-03	7.31E-03	9.22E-03	2.79E-02	1.07E-02	6.44E-01	#######	4.76E+00	2.24E+01	6.97E-03	#######	2.15E-02	8.56E-03	1.42E+03	9.87E-03	4.76E+00	#######	#######	2.49E-02	2.24E+01	6.44E-01	1.42E+03	6.97E-03	#######	2.15E-02	8.56E-03	1.42E+03
		Light Commercial Truck	1.32E-03	3.17E-03	5.52E-03	1.21E-02	1.30E-02	7.78E-02	#######	5.61E-01	3.66E+00	4.01E-03	#######	2.58E-03	1.00E-03	3.72E+02	1.20E-02	5.61E-01	#######	#######	6.53E-03	3.66E+00	7.78E-02	3.72E+02	4.01E-03	#######	2.58E-03	1.00E-03	3.72E+02
	Compressed Natural Gas (CNG)	Transit Bus	2.27E-03	8.41E-03	9.47E-03	3.21E-02	4.52E-03	0.00E+00		3.22E+00	2.16E+01	1.21E-02	#######			9.36E+02	4.52E-03	3.22E+00	#######	#######	#######	2.16E+01	0.00E+00	9.23E+02	1.21E-02	#######	#######	0.00E+00	9.36E+02
2023	Diesel Fuel	Combination Long-haul Truck	4.44E-03	1.07E-02	1.85E-02	4.09E-02	1.05E-01	9.44E-02	#######	2.95E+00	6.69E-01	3.82E-02	#######	1.02E-03	7.62E-03	1.95E+03	1.01E-01	2.95E+00	#######	#######	1.36E-02	6.69E-01	9.44E-02	1.94E+03	3.82E-02	#######	1.02E-03	7.62E-03	1.95E+03
		Combination Short-haul Truck	4.03E-03	9.90E-03	1.68E-02	3.78E-02	7.73E-02	7.98E-02	#######	2.46E+00	5.72E-01	3.88E-02	#######	8.65E-04	6.44E-03	1.87E+03	7.50E-02	2.46E+00	#######	#######	1.30E-02	5.72E-01	7.98E-02	1.86E+03	3.88E-02	#######	8.65E-04	6.44E-03	1.87E+03
		Intercity Bus	4.86E-03	1.62E-02	2.03E-02	6.17E-02	1.56E-01	1.55E-01	#######	3.87E+00	1.01E+00	4.02E-02	#######	1.68E-03	1.25E-02	1.62E+03	1.51E-01	3.87E+00	#######	#######	1.15E-02	1.01E+00	1.55E-01	1.62E+03	4.02E-02	#######	1.68E-03	1.25E-02	1.62E+03
		Passenger Car	1.27E-03	1.92E-03	5.30E-03	7.33E-03	3.80E-03	8.13E-03	#######	1.16E-01	1.20E+00	9.19E-03	#######	8.82E-05	6.57E-04	2.77E+02	3.68E-03	1.16E-01	#######	#######	1.92E-03	1.20E+00	8.13E-03	2.77E+02	9.19E-03	#######	8.82E-05	6.57E-04	2.77E+02
		Passenger Truck	1.62E-03	3.02E-03	6.75E-03	1.15E-02	3.23E-02	7.14E-02	#######	9.02E-01	8.00E-01	2.36E-02	#######	7.74E-04	5.76E-03	6.04E+02	3.13E-02	9.02E-01	#######	#######	4.23E-03	8.00E-01	7.14E-02	6.03E+02	2.36E-02	#######	7.74E-04	5.76E-03	6.04E+02

		School Bus	3.93E-03	1.37E-02	1.64E-02	5.25E-02	8.84E-02	1.39E-01	#######	2.01E+00	6.66E-01	3.39E-02	#######	1.50E-03	1.12E-02	8.15E+02	8.58E-02	2.01E+00	#######	#######	5.78E-03	6.66E-01	1.39E-01	8.13E+02	3.39E-02	#######	1.50E-03	1.12E-02	8.15E+02
		Single Unit Long-haul Truck	2.90E-03	1.07E-02	1.21E-02	4.10E-02	3.45E-02	8.12E-02	#######	1.11E+00	4.63E-01	4.40E-02	#######	8.80E-04	6.56E-03	8.01E+02	3.35E-02	1.11E+00	#######	#######	5.55E-03	4.63E-01	8.12E-02	8.00E+02	4.40E-02	#######	8.80E-04	6.56E-03	8.01E+02
		Single Unit Short-haul Truck	2.90E-03	1.08E-02	1.21E-02	4.12E-02	2.98E-02	6.84E-02	#######	1.06E+00	4.24E-01	4.38E-02	#######	7.41E-04	5.52E-03	8.56E+02	2.89E-02	1.06E+00	#######	#######	5.91E-03	4.24E-01	6.84E-02	8.55E+02	4.38E-02	#######	7.41E-04	5.52E-03	8.56E+02
		Transit Bus	2.61E-03	8.11E-03	1.09E-02	3.10E-02	1.05E-01	1.29E-01	#######	2.55E+00	8.03E-01	3.48E-02	#######	1.40E-03	1.04E-02	1.19E+03	1.02E-01	2.55E+00	#######	#######	8.35E-03	8.03E-01	1.29E-01	1.19E+03	3.48E-02	#######	1.40E-03	1.04E-02	1.19E+03
		Motor Home	2.29E-03	8.51E-03	9.53E-03	3.25E-02	6.69E-02	1.52E-01	#######	1.79E+00	6.87E-01	4.38E-02	#######	1.65E-03	1.23E-02	8.85E+02	6.49E-02	1.79E+00	#######	#######	6.23E-03	6.87E-01	1.52E-01	8.83E+02	4.38E-02	#######	1.65E-03	1.23E-02	8.85E+02
		Refuse Truck	4.65E-03	1.28E-02	1.94E-02	4.89E-02	7.62E-02	8.54E-02	#######	2.21E+00	5.89E-01	4.06E-02	#######	9.26E-04	6.89E-03	1.53E+03	7.39E-02	2.21E+00	#######	#######	1.06E-02	5.89E-01	8.54E-02	1.52E+03	4.06E-02	#######	9.26E-04	6.89E-03	1.53E+03
		Light Commercial Truck	1.65E-03	3.27E-03	6.87E-03	1.25E-02	4.65E-02	1.06E-01	#######	1.11E+00	8.87E-01	2.24E-02	#######	1.15E-03	8.53E-03	6.00E+02	4.51E-02	1.11E+00	#######	#######	4.25E-03	8.87E-01	1.06E-01	5.99E+02	2.24E-02	#######	1.15E-03	8.53E-03	6.00E+02
	Gasoline	Motorcycle	6.37E-04	1.66E-04	2.66E-03	6.33E-04	4.70E-02	6.34E-01	#######	7.95E-01	1.35E+01	2.88E-02	#######	2.13E-02	8.55E-03	3.72E+02	4.33E-02	7.95E-01	#######	#######	6.51E-03	1.35E+01	6.34E-01	3.71E+02	2.88E-02	#######	2.13E-02	8.55E-03	3.72E+02
		Passenger Car	1.27E-03	1.92E-03	5.30E-03	7.33E-03	7.15E-03	1.64E-02	#######	9.67E-02	1.57E+00	4.01E-03	#######	5.42E-04	2.15E-04	2.70E+02	6.58E-03	9.67E-02	#######	#######	4.73E-03	1.57E+00	1.64E-02	2.69E+02	4.01E-03	#######	5.42E-04	2.15E-04	2.70E+02
		Passenger Truck	1.30E-03	3.16E-03	5.41E-03	1.21E-02	1.32E-02	6.14E-02	#######	4.25E-01	3.27E+00	3.67E-03	#######	2.04E-03	7.87E-04	3.67E+02	1.22E-02	4.25E-01	#######	#######	6.43E-03	3.27E+00	6.14E-02	3.66E+02	3.67E-03	#######	2.04E-03	7.87E-04	3.67E+02
		School Bus	2.27E-03	8.84E-03	9.46E-03	3.38E-02	8.21E-03	5.91E-01	#######	2.80E+00	1.63E+01	1.26E-02	#######	1.95E-02	7.69E-03	7.70E+02	7.56E-03	2.80E+00	#######	#######	1.35E-02	1.63E+01	5.91E-01	7.67E+02	1.26E-02	#######	1.95E-02	7.69E-03	7.70E+02
		Single Unit Long-haul Truck	2.30E-03	9.22E-03	9.60E-03	3.52E-02	7.27E-03	3.62E-01	#######	3.13E+00	1.31E+01	6.17E-03	#######	1.20E-02	4.81E-03	8.02E+02	6.70E-03	3.13E+00	#######	#######	1.41E-02	1.31E+01	3.62E-01	8.01E+02	6.17E-03	#######	1.20E-02	4.81E-03	8.02E+02
		Single Unit Short-haul Truck	2.30E-03	9.23E-03	9.60E-03	3.53E-02	7.08E-03	3.70E-01	#######	3.21E+00	1.34E+01	6.14E-03	#######	1.23E-02	4.94E-03	8.54E+02	6.52E-03	3.21E+00	#######	#######	1.50E-02	1.34E+01	3.70E-01	8.53E+02	6.14E-03	#######	1.23E-02	4.94E-03	8.54E+02
		Transit Bus	2.27E-03	8.40E-03	9.46E-03	3.21E-02	9.48E-03	7.93E-01	#######	3.70E+00	1.99E+01	9.66E-03	#######	2.63E-02	1.04E-02	1.13E+03	8.73E-03	3.70E+00	#######	#######	1.97E-02	1.99E+01	7.93E-01	1.12E+03	9.66E-03	#######	2.63E-02	1.04E-02	1.13E+03
		Motor Home	2.21E-03	8.33E-03	9.22E-03	3.18E-02	1.07E-02	4.96E-01	#######	3.53E+00	1.81E+01	8.44E-03	#######	1.64E-02	6.46E-03	8.69E+02	9.88E-03	3.53E+00	#######	#######	1.52E-02	1.81E+01	4.96E-01	8.67E+02	8.44E-03	#######	1.64E-02	6.46E-03	8.69E+02
		Refuse Truck	2.21E-03	7.31E-03	9.22E-03	2.79E-02	1.05E-02	6.36E-01	#######	4.73E+00	2.18E+01	6.68E-03	#######	2.12E-02	8.46E-03	1.42E+03	9.70E-03	4.73E+00	#######	#######	2.49E-02	2.18E+01	6.36E-01	1.42E+03	6.68E-03	#######	2.12E-02	8.46E-03	1.42E+03
		Light Commercial Truck	1.32E-03	3.17E-03	5.52E-03	1.21E-02	1.30E-02	7.35E-02	#######	5.35E-01	3.57E+00	3.79E-03	#######	2.44E-03	9.47E-04	3.68E+02	1.19E-02	5.35E-01	#######	#######	6.44E-03	3.57E+00	7.35E-02	3.67E+02	3.79E-03	#######	2.44E-03	9.47E-04	3.68E+02
	Compressed Natural Gas (CNG)	Transit Bus	2.27E-03	8.41E-03	9.47E-03	3.21E-02	4.42E-03	0.00E+00		3.20E+00	2.07E+01	1.14E-02	#######			9.36E+02	4.42E-03	3.20E+00	#######	#######	#######	2.07E+01	0.00E+00	9.23E+02	1.14E-02	#######	#######	0.00E+00	9.36E+02
2024	Diesel Fuel	Combination Long-haul Truck	4.44E-03	1.07E-02	1.85E-02	4.09E-02	9.03E-02	8.24E-02	#######	2.67E+00	6.03E-01	3.86E-02	#######	8.93E-04	6.65E-03	1.95E+03	8.76E-02	2.67E+00	#######	#######	1.35E-02	6.03E-01	8.24E-02	1.94E+03	3.86E-02	#######	8.93E-04	6.65E-03	1.95E+03
		Combination Short-haul Truck	4.02E-03	9.89E-03	1.68E-02	3.78E-02	6.64E-02	6.97E-02	#######	2.24E+00	5.20E-01	3.91E-02	#######	7.55E-04	5.62E-03	1.87E+03	6.44E-02	2.24E+00	#######	#######	1.29E-02	5.20E-01	6.97E-02	1.86E+03	3.91E-02	#######	7.55E-04	5.62E-03	1.87E+03
		Intercity Bus	4.86E-03	1.62E-02	2.03E-02	6.17E-02	1.37E-01	1.38E-01	#######	3.50E+00	9.12E-01	4.09E-02	#######	1.50E-03	1.12E-02	1.62E+03	1.33E-01	3.50E+00	#######	#######	1.14E-02	9.12E-01	1.38E-01	1.62E+03	4.09E-02	#######	1.50E-03	1.12E-02	1.62E+03
		Passenger Car	1.27E-03	1.92E-03	5.30E-03	7.33E-03	3.67E-03	8.09E-03	#######	1.06E-01	1.25E+00	9.67E-03	#######	8.77E-05	6.53E-04	2.73E+02	3.56E-03	1.06E-01	#######	#######	1.88E-03	1.25E+00	8.09E-03	2.73E+02	9.67E-03	#######	8.77E-05	6.53E-04	2.73E+02
		Passenger Truck	1.62E-03	3.02E-03	6.75E-03	1.15E-02	2.85E-02	6.29E-02	#######	8.46E-01	7.85E-01	2.39E-02	#######	6.82E-04	5.08E-03	6.02E+02	2.76E-02	8.46E-01	#######	#######	4.21E-03	7.85E-01	6.29E-02	6.01E+02	2.39E-02	#######	6.82E-04	5.08E-03	6.02E+02
		School Bus	3.93E-03	1.37E-02	1.64E-02	5.25E-02	7.81E-02	1.23E-01	#######	1.83E+00	6.09E-01	3.45E-02	#######	1.34E-03	9.96E-03	8.15E+02	7.58E-02	1.83E+00	#######	#######	5.75E-03	6.09E-01	1.23E-01	8.13E+02	3.45E-02	#######	1.34E-03	9.96E-03	8.15E+02
		Single Unit Long-haul Truck	2.90E-03	1.07E-02	1.21E-02	4.10E-02	3.04E-02	7.24E-02	#######	1.04E+00	4.34E-01	4.41E-02	#######	7.84E-04	5.84E-03	8.01E+02	2.95E-02	1.04E+00	#######	#######	5.54E-03	4.34E-01	7.24E-02	8.00E+02	4.41E-02	#######	7.84E-04	5.84E-03	8.01E+02
		Single Unit Short-haul Truck	2.90E-03	1.08E-02	1.21E-02	4.12E-02	2.62E-02	6.12E-02	#######	1.00E+00	3.99E-01	4.39E-02	#######	6.63E-04	4.94E-03	8.56E+02	2.54E-02	1.00E+00	#######	#######	5.90E-03	3.99E-01	6.12E-02	8.55E+02	4.39E-02	#######	6.63E-04	4.94E-03	8.56E+02
		Transit Bus	2.61E-03	8.11E-03	1.09E-02	3.10E-02	9.10E-02	1.13E-01	#######	2.29E+00	7.11E-01	3.52E-02	#######	1.22E-03	9.09E-03	1.19E+03	8.83E-02	2.29E+00	#######	#######	8.32E-03	7.11E-01	1.13E-01	1.19E+03	3.52E-02	#######	1.22E-03	9.09E-03	1.19E+03
		Motor Home	2.28E-03	8.51E-03	9.53E-03	3.25E-02	6.00E-02	1.37E-01	#######	1.67E+00	6.41E-01	4.42E-02	#######	1.48E-03	1.10E-02	8.85E+02	5.82E-02	1.67E+00	#######	#######	6.21E-03	6.41E-01	1.37E-01	8.83E+02	4.42E-02	#######	1.48E-03	1.10E-02	8.85E+02
		Refuse Truck	4.65E-03	1.28E-02	1.94E-02	4.89E-02	6.50E-02	7.42E-02	#######	1.99E+00	5.33E-01	4.10E-02	#######	8.04E-04	5.99E-03	1.53E+03	6.31E-02	1.99E+00	#######	#######	1.06E-02	5.33E-01	7.42E-02	1.52E+03	4.10E-02	#######	8.04E-04	5.99E-03	1.53E+03
		Light Commercial Truck	1.65E-03	3.27E-03	6.86E-03	1.25E-02	4.10E-02	9.32E-02	#######	1.03E+00	8.55E-01	2.29E-02	#######	1.01E-03	7.53E-03	5.98E+02	3.98E-02	1.03E+00	#######	#######	4.22E-03	8.55E-01	9.32E-02	5.97E+02	2.29E-02	#######	1.01E-03	7.53E-03	5.98E+02
	Gasoline	Motorcycle	6.37E-04	1.66E-04	2.66E-03	6.33E-04	4.70E-02	6.29E-01	#######	7.92E-01	1.34E+01	2.88E-02	#######	2.11E-02	8.48E-03	3.72E+02	4.33E-02	7.92E-01	#######	#######	6.51E-03	1.34E+01	6.29E-01	3.71E+02	2.88E-02	#######	2.11E-02	8.48E-03	3.72E+02
		Passenger Car	1.27E-03	1.92E-03	5.30E-03	7.33E-03	7.15E-03	1.60E-02	#######	9.24E-02	1.57E+00	4.05E-03	#######	5.30E-04	2.11E-04	2.67E+02	6.58E-03	9.24E-02	#######	#######	4.68E-03	1.57E+00	1.60E-02	2.67E+02	4.05E-03	#######	5.30E-04	2.11E-04	2.67E+02
		Passenger Truck	1.30E-03	3.16E-03	5.41E-03	1.21E-02	1.32E-02	5.71E-02	#######	3.98E-01	3.18E+00	3.43E-03	#######	1.89E-03	7.33E-04	3.62E+02	1.21E-02	3.98E-01	#######	#######	6.35E-03	3.18E+00	5.71E-02	3.61E+02	3.43E-03	#######	1.89E-03	7.33E-04	3.62E+02
		School Bus	2.27E-03	8.84E-03	9.46E-03	3.38E-02	8.11E-03	5.81E-01	#######	2.76E+00	1.57E+01	1.11E-02	#######	1.92E-02	7.59E-03	7.70E+02	7.47E-03	2.76E+00	#######	#######	1.35E-02	1.57E+01	5.81E-01	7.67E+02	1.11E-02	#######	1.92E-02	7.59E-03	7.70E+02
		Single Unit Long-haul Truck	2.30E-03	9.22E-03	9.60E-03	3.52E-02	7.28E-03	3.62E-01	#######	3.13E+00	1.31E+01	5.97E-03	#######	1.20E-02	4.81E-03	8.02E+02	6.70E-03	3.13E+00	#######	#######	1.41E-02	1.31E+01	3.62E-01	8.01E+02	5.97E-03	#######	1.20E-02	4.81E-03	8.02E+02
		Single Unit Short-haul Truck	2.30E-03	9.23E-03	9.60E-03	3.53E-02	7.08E-03	3.70E-01	#######	3.20E+00	1.34E+01	5.96E-03	#######	1.23E-02	4.94E-03	8.54E+02	6.52E-03	3.20E+00	#######	#######	1.50E-02	1.34E+01	3.70E-01	8.53E+02	5.96E-03	#######	1.23E-02	4.94E-03	8.54E+02
		Transit Bus	2.27E-03	8.40E-03	9.46E-03	3.21E-02	9.41E-03	7.89E-01	#######	3.68E+00	1.94E+01	9.07E-03	#######	2.61E-02	1.04E-02	1.12E+03	8.66E-03	3.68E+00	#######	#######	1.97E-02	1.94E+01	7.89E-01	1.12E+03	9.07E-03	#######	2.61E-02	1.04E-02	1.12E+03
		Motor Home	2.21E-03	8.33E-03	9.22E-03	3.18E-02	1.06E-02	4.89E-01	#######	3.51E+00	1.77E+01	7.61E-03	#######	1.62E-02	6.38E-03	8.69E+02	9.81E-03	3.51E+00	#######	#######	1.52E-02	1.77E+01	4.89E-01	8.67E+02	7.61E-03	#######	1.62E-02	6.38E-03	8.69E+02
		Refuse Truck	2.21E-03	7.31E-03	9.22E-03	2.79E-02	1.04E-02	6.29E-01	#######	4.71E+00	2.14E+01	6.41E-03	#######	2.09E-02	8.38E-03	1.42E+03	9.60E-03	4.71E+00	#######	#######	2.49E-02	2.14E+01	6.29E-01	1.42E+03	6.41E-03	#######	2.09E-02	8.38E-03	1.42E+03
		Light Commercial Truck	1.32E-03	3.17E-03	5.52E-03	1.21E-02	1.29E-02	6.94E-02	#######	5.10E-01	3.48E+00	3.52E-03	#######	2.29E-03	8.96E-04	3.63E+02	1.19E-02	5.10E-01	#######	#######	6.36E-03	3.48E+00	6.94E-02	3.62E+02	3.52E-03	#######	2.29E-03	8.96E-04	3.63E+02
	Compressed Natural Gas (CNG)	Transit Bus	2.27E-03	8.41E-03	9.47E-03	3.21E-02	4.33E-03	0.00E+00		3.18E+00	1.97E+01	1.04E-02	#######			9.36E+02	4.33E-03	3.18E+00	#######	#######	#######	1.97E+01	0.00E+00	9.23E+02	1.04E-02	#######	#######	0.00E+00	9.36E+02
2025	Diesel Fuel	Combination Long-haul Truck	4.44E-03	1.07E-02	1.85E-02	4.09E-02	7.80E-02	7.23E-02	#######	2.43E+00	5.47E-01	3.90E-02	#######	7.84E-04	5.84E-03	1.95E+03	7.57E-02	2.43E+00	#######	#######	1.35E-02	5.47E-01	7.23E-02	1.94E+03	3.90E-02	#######	7.84E-04	5.84E-03	1.95E+03
		Combination Short-haul Truck	4.02E-03	9.89E-03	1.68E-02	3.78E-02	5.73E-02	6.13E-02	#######	2.06E+00	4.77E-01	3.94E-02	#######	6.65E-04	4.95E-03	1.87E+03	5.56E-02	2.06E+00	#######	#######	1.29E-02	4.77E-01	6.13E-02	1.86E+03	3.94E-02	#######	6.65E-04	4.95E-03	1.87E+03
		Intercity Bus	4.86E-03	1.62E-02	2.03E-02	6.17E-02	1.21E-01	1.23E-01	#######	3.17E+00	8.26E-01	4.16E-02	#######	1.34E-03	9.96E-03	1.62E+03	1.17E-01	3.17E+00	#######	#######	1.14E-02	8.26E-01	1.23E-01	1.62E+03	4.16E-02	#######	1.34E-03	9.96E-03	1.62E+03
		Passenger Car	1.27E-03	1.92E-03	5.30E-03	7.33E-03	3.58E-03	8.13E-03	#######	9.87E-02	1.30E+00	1.01E-02	#######	8.81E-05	6.56E-04	2.69E+02	3.47E-03	9.87E-02	#######	#######	1.85E-03	1.30E+00	8.13E-03	2.69E+02	1.01E-02	#######	8.81E-05	6.56E-04	2.69E+02
		Passenger Truck	1.62E-03	3.02E-03	6.75E-03	1.15E-02	2.49E-02	5.57E-02	#######	7.97E-01	7.76E-01	2.42E-02	#######	6.04E-04	4.50E-03	6.00E+02	2.42E-02	7.97E-01	#######	#######	4.18E-03	7.76E-01	5.57E-02	5.99E+02	2.42E-02	#######	6.04E-04	4.50E-03	6.00E+02
		School Bus	3.93E-03	1.37E-02	1.64E-02	5.25E-02	6.89E-02	1.10E-01	#######	1.68E+00	5.58E-01	3.50E-02	#######	1.19E-03	8.90E-03	8.15E+02	6.68E-02	1.68E+00	#######	#######	5.73E-03	5.58E-01	1.10E-01	8.13E+02	3.50E-02	#######	1.19E-03	8.90E-03	8.15E+02
		Single Unit Long-haul Truck	2.90E-03	1.07E-02	1.21E-02	4.10E-02	2.68E-02	6.49E-02	#######	9.82E-01	4.08E-01	4.43E-02	#######	7.03E-04	5.24E-03	8.01E+02	2.60E-02	9.82E-01	#######	#######	5.53E-03	4.08E-01	6.49E-02	8.00E+02	4.43E-02	#######	7.03E-04	5.24E-03	8.01E+02
		Single Unit Short-haul Truck	2.90E-03	1.08E-02	1.21E-02	4.12E-02	2.32E-02	5.52E-02	#######	9.47E-01	3.79E-01	4.40E-02	#######	5.98E-04	4.45E-03	8.56E+02	2.25E-02	9.47E-01	#######	#######	5.89E-03	3.79E-01	5.52E-02	8.55E+02	4.40E-02	#######	5.98E-04	4.45E-03	8.56E+02
		Transit Bus	2.61E-03	8.11E-03	1.09E-02	3.10E-02	7.84E-02	9.79E-02	#######	2.07E+00	6.30E-01	3.55E-02	#######	1.06E-03	7.90E-03	1.19E+03	7.61E-02	2.07E+00	#######	#######	8.29E-03	6.30E-01	9.79E-02	1.19E+03	3.55E-02	#######	1.06E-03	7.90E-03	1.19E+03
		Motor Home	2.28E-03	8.51E-03	9.53E-03	3.25E-02	5.30E-02	1.23E-01	#######	1.56E+00	5.98E-01	4.45E-02	#######	1.33E-03	9.91E-03	8.85E+02	5.14E-02	1.56E+00	#######	#######	6.19E-03	5.98E-01	1.23E-01	8.83E+02	4.45E-02	#######	1.33E-03	9.91E-03	8.85E+02
		Refuse Truck	4.66E-03	1.28E-02	1.94E-02	4.89E-02	5.57E-02	6.49E-02	#######	1.81E+00	4.87E-01	4.13E-02	#######	7.03E-04	5.24E-03	1.53E+03	5.40E-02	1.81E+00	#######	#######	1.05E-02	4.87E-01	6.49E-02	1.52E+03	4.13E-02	#######	7.03E-04	5.24E-03	1.53E+03
		Light Commercial Truck	1.65E-03	3.27E-03	6.86E-03	1.25E-02	3.58E-02	8.21E-02	#######	9.56E-01	8.29E-01	2.34E-02	#######	8.90E-04	6.63E-03	5.96E+02	3.47E-02	9.56E-01	#######	#######	4.19E-03	8.29E-01	8.21E-02	5.96E+02	2.34E-02	#######	8.90E-04	6.63E-03	5.96E+02
	Gasoline	Motorcycle	6.37E-04	1.66E-04	2.66E-03	6.33E-04	4.70E-02	6.24E-01	#######	7.90E-01	1.33E+01	2.88E-02	#######	2.09E-02	8.41E-03	3.72E+02	4.33E-02	7.90E-01	#######	#######	6.51E-03	1.33E+01	6.24E-01	3.71E+02	2.88E-02	#######	2.09E-02	8.41E-03	3.72E+02
		Passenger Car	1.27E-03	1.92E-03	5.30E-03	7.33E-03	7.17E-03	1.59E-02	#######	8.94E-02	1.57E+00	4.06E-03	#######	5.24E-04	2.09E-04	2.64E+02	6.60E-03	8.94E-02	#######	#######	4.64E-03	1.57E+00	1.59E-02	2.64E+02	4.06E-03	#######	5.24E-04	2.09E-04	2.64E+02
		Passenger Truck	1.30E-03	3.16E-03	5.41E-03	1.21E-02	1.30E-02	5.31E-02	#######	3.74E-01	3.10E+00	3.24E-03	#######	1.75E-03	6.84E-04	3.58E+02	1.20E-02	3.74E-01	#######	#######	6.27E-03	3.10E+00	5.31E-02	3.57E+02	3.24E-03	#######	1.75E-03	6.84E-04	3.58E+02
		School Bus	2.27E-03	8.84E-03	9.46E-03	3.38E-02	7.15E-03	5.71E-01	#######	2.73E+00	1.49E+01	9.55E-03	#######	1.88E-02	7.47E-03	7.69E+02	6.59E-03	2.73E+00	#######	#######	1.35E-02	1.49E+01	5.71E-01	7.67E+02	9.55E-03	#######	1.88E-02	7.47E-03	7.69E+02
		Single Unit Long-haul Truck	2.30E-03	9.22E-03	9.60E-03	3.52E-02	7.19E-03	3.62E-01	#######	3.13E+00	1.30E+01	5.81E-03	#######	1.20E-02	4.81E-03	8.02E+02	6.63E-03	3.13E+00	#######	#######	1.41E-02	1.30E+01	3.62E-01	8.01E+02	5.81E-03	#######	1.20E-02	4.81E-03	8.02E+02
		Single Unit Short-haul Truck	2.30E-03	9.23E-03	9.60E-03	3.53E-02	7.00E-03	3.70E-01	#######	3.20E+00	1.33E+01	5.82E-03	#######	1.23E-02	4.94E-03	8.54E+02	6.44E-03	3.20E+00	#######	#######	1.50E-02	1.33E+01	3.70E-01	8.53E+02	5.82E-03	#######	1.23E-02	4.94E-03	8.54E+02
		Transit Bus	2.27E-03	8.40E-03	9.46E-03	3.21E-02	9.22E-03	7.86E-01	#######	3.66E+00	1.89E+01	8.58E-03	#######	2.60E-02	1.04E-02	1.12E+03	8.49E-03	3.66E+00	#######	#######	1.97E-02	1.89E+01	7.86E-01	1.12E+03	8.58E-03	#######	2.60E-02	1.04E-02	1.12E+03
		Motor Home	2.21E-03	8.33E-03	9.22E-03	3.18E-02	9.56E-03	4.82E-01	#######	3.48E+00	1.73E+01	6.81E-03	#######	1.59E-02	6.29E-03	8.69E+02	8.80E-03	3.48E+00	#######	#######	1.52E-02	1.73E+01	4.82E-01	8.67E+02	6.81E-03	#######	1.59E-02	6.29E-03	8.69E+02
		Refuse Truck	2.21E-03	7.31E-03	9.22E-03	2.79E-02	1.02E-02	6.24E-01	#######	4.69E+00	2.10E+01	6.21E-03	#######	2.07E-02	8.31E-03	1.42E+03	9.38E-03	4.69E+00	#######	#######	2.49E-02	2.10E+01	6.24E-01	1.42E+03	6.21E-03	#######	2.07E-02	8.31E-03	1.42E+03
		Light Commercial Truck	1.32E-03	3.17E-03	5.52E-03	1.21E-02	1.28E-02	6.55E-02	#######	4.88E-01	3.41E+00	3.29E-03	#######	2.16E-03	8.49E-04	3.59E+02	1.18E-02	4.88E-01	#######	#######	6.29E-03	3.41E+00	6.55E-02	3.58E+02	3.29E-03	#######	2.16E-03	8.49E-04	3.59E+02
	Compressed Natural Gas (CNG)	Transit Bus	2.27E-03	8.41E-03	9.47E-03	3.21E-02	4.19E-03	0.00E+00		3.16E+00	1.90E+01	9.76E-03	#######			9.36E+02	4.19E-03	3.16E+00	#######	#######	#######	1.90E+01	0.00E+00	9.23E+02	9.76E-03	#######	#######	0.00E+00	9.36E+02

Normally Pressured Lance Natural Gas Development Project

Draft Environmental Impact Statement

Appendix N

NPL Project Mitigation Determination

APPENDIX N

NPL PROJECT MITIGATION DETERMINATION

The Council on Environmental Quality defines mitigation in its regulations at 40 CFR 1508.20 to include: avoiding impacts, minimizing impacts, rectifying impacts, reducing or eliminating impacts over time, and compensating for remaining residual impacts. Mitigation elements are categorized into three general types that form a sequential mitigation hierarchy: avoidance, minimization, and compensatory mitigation for remaining residual impacts. Compensatory mitigation is intended to offset or compensate for the remaining residual impacts after all appropriate and practicable avoidance and minimization measures have been applied, by replacing or providing substitute resources or environments (See 40 C.F.R. § 1508.20.) through the restoration, establishment, enhancement, or preservation of resources and their values, services, and functions.

This appendix summarizes the NPL Project mitigation strategy to avoid, minimize, and rectify/restore the impacts described in Chapter 4 (*Environmental Consequences*) of the NPL Project EIS. This appendix also identifies the residual impacts that would remain after application of the NPL mitigation strategy and those residual impacts that warrant compensatory mitigation. Refer to Section 4.24 (*Compensatory Mitigation*) in the NPL Project EIS for additional information on compensatory mitigation for the NPL Project.

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Row #	Resource	Impact Indicator[1]	Strategy To Avoid, Minimize, And Rectify Impacts To The Resource[2]			Residual Effects[3]	Warrant Compensatory Mitigation?[4]	Compensatory Mitigation Options to be Considered at Site-Specific Level
			Avoid[5]	Minimize[6]	Rectify/Restore[7]			
1	Air Quality – Atmospheric Deposition	Nitrogen and sulfur deposition to sensitive lakes		Use remote telemetry and SCADA technology to reduce vehicle trips and human presence for well monitoring and control during production activities (**Resource Protection Measures [RPMs] 2; 121)** Utilize specific technologies and devices to minimize or eliminate emissions from facilities and equipment (**RPMs 7-10; 13**) Apply a variety of strategies to address transportation-related air quality concerns (**RPM 15**) Apply measures to reduce emissions from mobile sources (**RPMs 16-19)** Use solar powered equipment and processes whenever practicable (**RPM 14**)		Temporary impacts to atmospheric deposition would be minimized by reducing vehicle trips (RPMs 2 and 121), minimizing or eliminating emissions from facilities and equipment (RPMs 7-10 and 13); addressing transportation-related air quality concerns (RPM 15), reducing emissions from mobile sources (RPMs 16-19), and using solar powered equipment and processes whenever practicable (RPM 14). No residual effects to atmospheric deposition are expected.	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	N/A
2	Air Quality – HAPs	Short-term and long-term human exposure to various hazardous and toxic air pollutants		Do not locate any compressor facility closer than 4 miles from a dwelling or residence (**RPM 11**) Do not locate any producing well closer than 0.25 mile from a dwelling or residence (**RPM 12**)		Impacts to air quality associated with HAPs would be minimized by compressor facility (RPM 11) and producing well (RPM 12) location restrictions. Short-term and long-term exposure to HAPS is estimated to be very small compared to reference concentrations, and no long-term health impacts resulting from HAPs are expected at from these levels of exposure.	No. The nature and extent of residual effects identified through this analysis indicates that effects would be minor and, therefore, do not warrant compensatory mitigation. Also, residual effects would not inhibit achieving land-use plan objectives or compliance with laws regulations, and/or policies. Finally, residual effects related to air quality have not been previously identified in a mitigation strategy or NEPA document as warranting compensatory mitigation.	N/A
3	Air Quality – NAAQS and WAAQS	Proposed Action emissions may result in concentrations that are greater than the NAAQS and WAAQS for 24-hour		Use remote telemetry and SCADA technology to reduce vehicle trips and human presence for well monitoring and control during production activities (**RPMs 2; 121)**	Install monitoring stations as required to comply with WDEQ requirements (**RPM 1**)	Impacts to air quality associated with emissions concentrations that are greater than the NAAQS and WAAQS would be minimized by reducing vehicle trips and human presence (RPMs 2; 121), implementing fugitive dust control measures	No. The nature and extent of residual effects identified through this analysis indicates that effects would be minor and, therefore, do not warrant	N/A

[1] Impact indicators represent the potential impacts to the resources identified in the analysis in Chapter 4 (Environmental Consequences) of the NPL EIS.
[2] Strategies include, but are not limited to, operator committed measures, project design features, mitigation in response to identified impacts, and conditions of approval to be applied at the authorization stage. Strategies listed in a given column (i.e., avoid, minimize, and rectify/restore) may include elements that when considered individually, could be categorized into one or more of the other columns. In these instances, the entire measure was categorized based on the first strategy that would be applied during implementation of the measure or the first strategy listed.
[3] It is assumed that the mitigation strategy would be applied to the entire resource/impact indicator combination, that the mitigation strategy would be effective, and would eliminate residual effects or reduce residual effects to a level that does not warrant compensatory mitigation.
[4] "Compensatory Mitigation" refers to measures that compensate for the impact by replacing or providing substitute resources or environments (40 CFR 1508.20).
[5] "Avoidance" refers to measures that avoid the impact altogether by not taking a certain action or parts of an action (40 CFR 1508.20).
[6] "Minimize" refers to measures that limit the degree or magnitude of the action and its implementation (40 CFR 1508.20).
[7] "Restore/Rectify" refers to measures that would repair, rehabilitate, or restore the affected environment over time (40 CFR 1508.20). For example, reclamation practices or on/off-site mitigation that would reduce or eliminate impacts during and after the life of the project.

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		average PM_{10} if the drilling of two wells and the completion of one well on a given well pad coincides with meteorological conditions similar to the impact-conducive conditions included in the AERMOD meteorological input dataset. Project-related activity would not result in concentrations of other emissions that are greater than the NAAQS and WAAQS.		Implement measures to control fugitive dust through the use of paving, gravelling, mulching, watering, and vehicle speed limits (**RPMs 4-6; 15; 127; 135**) Utilize specific technologies and devices to minimize or eliminate emissions (**RPMs 7-10; 13**) Apply a variety of strategies to address transportation-related air quality concerns (**RPMs 15**) Apply measures to reduce emissions from mobile sources (**RPMs 16-19)** Use solar powered equipment and processes whenever practicable (**RPM 14**) Jonah Energy will use electric compression, eliminating essentially all emissions from gas-driven compressors (**RPM 10)**		(RPMs 4-6; 15; 127; 135), utilizing specific technologies and devices to minimize or eliminate emissions (RPMs 7-10; 13), applying a variety of strategies to address transportation-related air quality concerns (RPMs 15), reducing emissions from mobile sources (RPMs 16-19), using solar powered equipment and processes whenever practicable (RPM 14), and using electric compression to eliminate emissions from gas-driven compressors (RPM 10). These same impacts would be rectified/restored by adaptive management opportunities associated with installing monitoring stations as required to comply with WDEQ requirements (RMP 1).These mitigation strategies would effectively mitigate direct and indirect impacts. The conditions under which drilling and completions could exceed NAAQS and WAAQS would be limited and could be addressed during site-specific permitting.	compensatory mitigation. Also, residual effects would not inhibit achieving land-use plan objectives or compliance with laws regulations, and/or policies. Finally, residual effects related to air quality have not been previously identified in a mitigation strategy or NEPA document as warranting compensatory mitigation.	
4	Air Quality – Visibility	Visibility degradation within a Class I or sensitive Class II area due to project emissions		Use remote telemetry and SCADA technology to reduce vehicle trips and human presence for well monitoring and control during production activities (**RPMs 2; 121)** Implement measures to control fugitive dust through the use of paving, gravelling, mulching, watering, and vehicle speed limits (**RPMs 4-6; 15; 127; 135**) Utilize specific technologies and devices to minimize or eliminate emissions (**RPMs 7-10; 13**) Apply a variety of strategies to address transportation-related air quality concerns (**RPM 15**) Apply measures to reduce emissions from mobile sources (**RPMs 16-19)** Use solar powered equipment and processes whenever practicable (**RPM 14**)	Install monitoring stations as required to comply with WDEQ requirements (**RPM 1**)	Visibility degradation within Class I or sensitive Class II areas would be minimized by using telemetry and SCADA technology to reduce vehicle trips for well monitoring and control during production activities (RPMs 2; 121) and implementing measures to control fugitive dust (RPMs 4-6; 15; 127; 135); and rectified/restored by adaptive management opportunities associated with installing monitoring stations as required to comply with WDEQ requirements (RMP 1). Additionally, modeling results indicate that the impacts on visibility within the nearby Class I and Class II areas would be infrequent and small compared to visibility impairment thresholds less than or equal to 0.02 dv for the 20 percent best days and less than or equal to 0.01 dv for the 20 percent worst days. Therefore, no residual impacts are anticipated.	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	N/A
5	Air Quality – Exceeding de minimis emissions levels of NOx and VOCs in the	The BLM must demonstrate that the total of direct and indirect emissions from the proposed federal action do	BLM will prepare, and include as an appendix to the EIS, a Conformity Determination that demonstrates that NPL actions occurring within the			Preparing a Conformity Determination and only approving a level of development with resulting emissions below the *de minimis* emissions limits would ensure compliance with the General	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit	N/A

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	UGRB Ozone Non-Attainment Zone	not exceed the *de minimis* emission levels specified in the General Conformity regulations at 40 CFR 93.153(b) and Chapter 8, Section 3 of the WAQSR, or through a conformity determination if approval of the federal action will exceed the *de minimis* emission levels of 100 tons/year of nitrogen oxides (NOx) or volatile organic compounds (VOC), the precursor pollutants that form ozone in the atmosphere.	UGRB Ozone nonattainment area will conform with the Wyoming State Implementation Plan (SIP) and Chapter 8, Section 3 of the WAQSR **(Chapter 2 – Common to All Alternatives)** The BLM would only approve a level of development below the *de minimis* emission limits, A reduced annual level of development that results in annual NOx and VOC emissions at or below the 100 tons/year emissions limit would ensure compliance with the General Conformity regulations at 40 CFR 93.153(b), and Chapter 8, Section 3 of the WAQSR requirements (**Chapter 4 – Air Quality - Mitigation Measure**)			Conformity regulations at 40 CFR 93.153(b), and Chapter 8, Section 3 of the WAQSR requirements. Therefore, no residual impacts are anticipated.	achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	
6	Climate Change – GHG Emissions	Potential effects of project-specific GHG emissions on the regional climate		Use remote telemetry and SCADA technology to reduce vehicle trips and human presence for well monitoring and control during production activities (**RPMs 2; 121)** Utilize specific technologies and devices to minimize or eliminate emissions (**RPMs 7-10, 13**) Apply a variety of strategies to address transportation-related air quality concerns (**RPM 15**) Apply measures to reduce emissions from mobile sources (**RPMs 16-19)** Use solar powered equipment and processes whenever practicable (**RPM 14**)		Project-related GHG emissions would be minimized by using remote telemetry and SCADA technology to reduce vehicle trips and for well monitoring and control during production activities (RPM 2; 121), utilizing specific technologies and devices to minimize or eliminate emissions (RPMs 7-10, 13), applying a variety of strategies to address transportation-related air quality concerns (RPM 15), reducing emissions from mobile sources (RPMs 16-19), and using solar powered equipment and processes whenever practicable (RPM 14). Although project emissions would still contribute to the regional and global GHGs in the atmosphere and could contribute to climate change effects, it is not possible at this time to link projected GHG emissions associated with the project to specific environmental impacts within the air quality analysis area. Therefore, residual impacts on climate change from the NPL Project cannot be determined at this time.	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	N/A
7	Cultural Resources – NHTs	Unintentional damage to Sublette Cutoff and North Sublette Meadow Springs Variant from construction and human activity in trail vicinity	Avoid surface disturbance within 0.25 mile or visual horizon of NHTs (**RPM 27**) Implement a workforce education program for NHTs (**RPMRPM 28**)	Site project facilities further than 0.25 mile but within NHT viewsheds to blend with the landscape. (**RPM 27**)	As part of the NPL Project, undertakings within the viewshed of the Sublette Cutoff and the North Sublette Meadow Springs Variant have the potential to cause adverse effects (as defined in 36 CFR §800.5(a)) to	In accordance with Section 106 of the NHPA and the BLM Wyoming and Wyoming SHPO State Protocol, residual impacts and the potential for compensatory mitigation would be determined based on consultation with the Wyoming State Historic Preservation Office, the Advisory Council on Historic Preservation (if participating), and	The need for compensatory mitigation would be determined as part of the Section 106 Consultation Process during site-specific permitting of APDs.	N/A

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			Avoid[5]	Minimize[6]	Rectify/Restore[7]			
			Prohibit surface disturbance within 0.25 mile or visual horizon of historic trails (**RPMRPM 106**) During site-specific permitting, the BLM would assess the potential for installation/replacement of appropriate historic trail markers to clearly identify the location of the Sublette Cutoff and North Sublette Meadow Springs Variant to avoid unintentional damage to trails from construction, maintenance, and operation. (**Mitigation Measure C-1**)		contributing segments of the NHTs. Each undertaking proposed by Jonah Energy within the NHT viewshed portion of the NPL Project Area would be analyzed according to 54 U.S.C. 306108. Should a determination of adverse effect to the NHT be made by the BLM and concurred with by the Wyoming State Historic Preservation Office (SHPO), the adverse effect would require the development of appropriate mitigation, which would be codified into an agreement document with the involvement of consulting parties (36 CFR §800.6(a)(2)). Within the viewshed of the NHT, only delineation wells and related facilities (e.g., powerlines, pipelines, and access roads) would be processed under the current State Protocol Agreement between the BLM Wyoming State Director and the Wyoming SHPO in the absence of a Programmatic Agreement. **(Mitigation Measure C-3).**	other consulting parties. The results of this consultation, including residual effects and mitigation, would be included in the NPL Project ROD and further consultation and results would be considered during site-specific permitting when specific development locations are known, as appropriate. Determinations of potential effects and necessary mitigation would also be further considered during Section 106 consultation and compliance that would be part of the site-specific environmental review process for APDs.		
8	Cultural Resources – NHTs	Introduction of visual elements that diminish the integrity of settings and viewsheds of the Sublette Cutoff and North Sublette Meadow Springs Variant	Avoid surface disturbance within 0.25 mile or visual horizon of NHTs. (**Resource Projection Measure 27**) Prohibit surface disturbance within 0.25 mile or visual horizon of historic trails (**RPM 106**)	Site project facilities further than 0.25 mile but within NHT viewsheds to blend with the landscape. (**RPM 27**)	As part of the NPL Project, undertakings within the viewshed of the Sublette Cutoff and the North Sublette Meadow Springs Variant have the potential to cause adverse effects (as defined in 36 CFR §800.5(a)) to contributing segments of the NHTs. Each undertaking proposed by Jonah Energy within the NHT viewshed portion of the NPL Project Area would be analyzed according to 54 U.S.C. 306108. Should a determination of adverse effect to the NHT be made by the BLM and concurred with by the Wyoming State Historic Preservation Office (SHPO), the adverse effect would require the development of appropriate mitigation, which would be codified into an agreement document with the involvement of consulting parties (36 CFR §800.6(a)(2)). Within the viewshed of the NHT, only delineation wells and related	In accordance with Section 106 of the NHPA and the BLM Wyoming and Wyoming SHPO State Protocol, residual impacts and the potential for compensatory mitigation would be determined based on consultation with the Wyoming State Historic Preservation Office, the Advisory Council on Historic Preservation (if participating), and other consulting parties. The results of this consultation, including residual effects and mitigation, would be included in the NPL Project ROD and further consultation and results would be considered during site-specific permitting when specific development locations are known, as appropriate. Determinations of potential effects and necessary mitigation would also be further considered during Section 106 consultation and compliance that would be part of the site-specific environmental review process for APDs.	The need for compensatory mitigation would be determined as part of the Section 106 Consultation Process during site-specific permitting of APDs.	N/A

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					facilities (e.g., powerlines, pipelines, and access roads) would be processed under the current State Protocol Agreement between the BLM Wyoming State Director and the Wyoming SHPO in the absence of a Programmatic Agreement. **(Mitigation Measure C-3).**			
9	Cultural Resources – NRHP Properties	Project activities that diminish the integrity of a property's location, design, setting, materials, workmanship, feeling, or association that is listed or eligible for listing in the NHRP	Jonah Energy will implement a workforce education program and notify entities involved in the Project about applicable regulations for cultural resources (**RPMs 21; 22; 25**)		Jonah Energy will follow appropriate protocols to reduce potential impacts to cultural resources if they are discovered during construction (**RPMs 21; 26; 30**)	In accordance with Section 106 of the NHPA and the BLM Wyoming and Wyoming SHPO State Protocol, residual impacts and the potential for compensatory mitigation would be determined based on consultation with the Wyoming State Historic Preservation Office, the Advisory Council on Historic Preservation (if participating), and other consulting parties. The results of this consultation, including residual effects and mitigation, would be included in the NPL Project ROD and further consultation and results would be considered during site-specific permitting when specific development locations are known, as appropriate. Determinations of potential effects and necessary mitigation would also be further considered during Section 106 consultation and compliance that would be part of the site-specific environmental review process for APDs.	The need for compensatory mitigation would be determined as part of the Section 106 Consultation Process during site-specific permitting of APDs.	N/A
10	Cultural Resources – Teakettle Dune Field	Damage or destruction of cultural resources from surface-disturbing activities in the Teakettle Dune Field, which has a high concentration of cultural resource sites, including 45 identified sites eligible for listing in the NRHP	Jonah Energy will implement a workforce education program and notify entities involved in the Project about applicable regulations for cultural resources (**RPMs 21; 22; 25**) As part of the NPL Project, project-related development and activity in the Teakettle Dune Field has the potential to result in adverse impacts to cultural resources in the Teakettle Dune Field. If development is proposed in the Teakettle Dune Field, prior to surface disturbance being authorized within the Dune Field, the BLM would further consider an appropriate management plan for development within the Teakettle Dune Field, including consideration of the Dune Field as an archaeological district. (**Mitigation Measure C-4**)		If site-specific cultural surveys during the APD process indicate that adverse effects could occur, the BLM would consult with the Wyoming SHPO and other appropriate parties on resolution of adverse effects in accordance with the Wyoming State Protocol (**Mitigation Measure C-2**)	In accordance with Section 106 of the NHPA and the BLM Wyoming and Wyoming SHPO State Protocol, residual impacts and the potential for compensatory mitigation would be determined based on consultation with the Wyoming State Historic Preservation Office, the Advisory Council on Historic Preservation (if participating), and other consulting parties. The results of this consultation, including residual effects and mitigation, would be included in the NPL Project ROD and further consultation and results would be considered during site-specific permitting when specific development locations are known, as appropriate. Determinations of potential effects and necessary mitigation would also be further considered during Section 106 consultation and compliance that would be part of the site-specific environmental review process for APDs.	The need for compensatory mitigation would be determined as part of the Section 106 Consultation Process during site-specific permitting of APDs.	N/A

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11	Cultural Resources – Vandalism/Illegal Collection	Vandalism and illegal artifact collection could increase due to enhanced vehicular access to the Project Area for project workforce and the public due to the construction of new access roads	Jonah Energy will implement a workforce education program and notify entities involved in the Project about applicable regulations for cultural resources (**RPMs 21, 22, 25**)			In accordance with Section 106 of the NHPA and the BLM Wyoming and Wyoming SHPO State Protocol, residual impacts and the potential for compensatory mitigation would be determined based on consultation with the Wyoming State Historic Preservation Office, the Advisory Council on Historic Preservation (if participating), and other consulting parties. The results of this consultation, including residual effects and mitigation, would be included in the NPL Project ROD and further consultation and results would be considered during site-specific permitting when specific development locations are known, as appropriate. Determinations of potential effects and necessary mitigation would also be further considered during Section 106 consultation and compliance that would be part of the site-specific environmental review process for APDs.	The need for compensatory mitigation would be determined as part of the Section 106 Consultation Process during site-specific permitting of APDs.	N/A
12	Fire and Fuels Management – Wildland Fire	Increased human activity and development could introduce new ignition sources, resulting in increased chance for wildland fires and potential demand for fire prevention and suppression activities		Limit of one disturbance location per 640 acres in DA1 (winter concentration area) and DA 3 (PHMA) (**Preferred Alternative**) Within Winter Concentration Areas, surface disturbance would not exceed 20 acres (5 percent) surface disturbance per 640 acres, inclusive of existing disturbance (**Preferred Alternative)** Jonah Energy will work with local EMS authorities to support volunteer recruitment of fire fighters, wherever needed (**RPM 79**) Jonah Energy will provide flexible work scheduling for employees involved in volunteer efforts and other community service such as fighting fires and EMS training (**RPM 81**) Limit of one disturbance location per 640 acres in PHMA; limit cumulative value of existing disturbances to not exceed 5 percent of suitable habitat of the DDCT area (**RPM 206)**		The potential for new ignition sources causing wildfires would be reduced by limiting development to one disturbance location per 640 acres in DA1 (Winter Concentration Areas) and DA 3 (PHMA) (Preferred Alternative), applying a surface disturbance threshold of 20 acres (5 percent) per 640 acres, inclusive of existing disturbance within Winter Concentration Areas (Preferred Alternative), working with local EMS authorities to support volunteer recruitment of fire fighters (RPM 79), providing flexible work scheduling for employees involved in volunteer efforts and other community service such as fighting fires and EMS training (RPM 81), and limiting the cumulative value of existing disturbances to not exceed 5 percent of suitable habitat of the DDCT area (RPM 206). Wildland fires are inherently hard to predict and therefore residual impacts cannot be predicted to any reasonable degree of accuracy; however, these strategies are anticipated to mitigate direct and indirect impacts, primarily by limiting the expansion of the wildland-industrial interface in portions of the Project Area with limitations on development density.	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	N/A
13	Fire and Fuels Management – Wildland Fire	Establishment or spread of invasive species and noxious weeds that can, over time, alter the fire regime and affect fuels management activities	Implement measures to prevent colonization or control the spread of invasive species and noxious weeds (**RPMs 95, 142-147**)		Conduct successful reclamation in disturbed areas as soon as practicable (**RPMs 89; 129; 141; 143; 149; Appendix C – Reclamation Plan)**	Establishment or spread of invasive species and noxious weeds would be avoided by implementing measures to prevent colonization or control the spread of invasive species and noxious weeds (RPMs 95, 142-147) and rectified/restored by conducting successful reclamation in disturbed areas as soon as	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource	N/A

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			Avoid[5]	Minimize[6]	Rectify/Restore[7]			
						practicable (RPMs 89; 129; 141; 143; 149; Appendix C – Reclamation Plan). No residual effects are expected.	objectives in applicable BLM RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	
14	Geology and Minerals – Geologic Hazards	Damage to project facilities from naturally-occurring earthquakes				An intensity VII earthquake, which is the maximum predicted earthquake intensity for the region encompassing the Project Area, would be unlikely to damage project facilities that are properly designed and constructed. Therefore, no residual effects are anticipated from naturally-occurring earthquakes.	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	N/A
15	Geology and Minerals – Induced Seismicity	Seismic events induced by hydraulic fracturing				Based on the existing seismic record and limited scientific understanding of induced seismic events, there is a very low likelihood for direct and indirect impacts from induced seismicity caused by hydraulic fracturing or the injection of produced water. Therefore, no residual effects are anticipated.	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	N/A
16	Geology and Minerals – Mineral Development	Project-related development and production that could limit or complicate the use and extraction of other mineral resources				The development of solid leasable minerals (e.g., coal, trona, oil-shale, phosphate) and locatable minerals (e.g., gold, uranium) in the analysis area are unlikely due to low potential for occurrence and/or uneconomical recovery options. If development of these resources were to occur, project-related development would not preclude the recovery of solid leasable and	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM	N/A

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						locatable minerals and potential timing and/or location conflicts would be resolved as needed during site-specific permitting. Therefore, no residual effects are anticipated.	RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	
17	Geology and Minerals – Topography	Direct alterations to existing topography, surficial slumping in localized areas due to erosional removal of slope-supporting material, and altered drainage patterns that increase erosion potential			Conduct successful reclamation in disturbed areas as soon as practicable (**RPMs 89; 129; 141; 143; 149; Appendix C – Reclamation Plan**) Implement soil stabilization, erosion control, and reclamation measures (**RPMs 82-117; 148-153**)	Impacts to topography would be rectified and restored by conducting successful reclamation in disturbed areas as soon as practicable (RPMs 89; 129; 141; 143; 149; Appendix C – Reclamation Plan) and implementing soil stabilization, erosion control, and reclamation measures (RPMs 82-117; 148-153). No residual effects are anticipated.	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	N/A
18	Hazardous Materials and Solid Waste – Accidental Spills and Releases	Improper handling, management, and disposal, or accidental releases of hazardous materials or solid waste, which could adversely affect human health and safety		Adherence to all applicable laws, ordinances, and regulations governing the handing, management, and disposal of hazardous materials and solid waste (**Appendix F, *Hazardous and Non-Hazardous Materials Management Summary***) Install shutoff valves or other systems where pipelines cross streams, cultural sites, and paleontological locales to minimize accidental discharges from pipelines (**RPM 34**) Keep SDSs on file for all chemical and hazardous materials (**RPM 35**) Develop and maintain SPCC Plans and a SWPPP detailing prevention and response methods for hydrocarbon spills and storm water discharges (**RPM 36**) Inventory and report on chemical and hazardous materials in accordance with applicable regulations (**RPM 37**)		The potential for accidental spills and releases would be minimized by adhering to all applicable laws, ordinances, and regulations governing the handing, management, and disposal of hazardous materials and solid waste (Appendix F, *Hazardous and Non-Hazardous Materials Management Summary*), installing shutoff valves or other systems where pipelines cross streams, cultural sites, and paleontological locales to minimize accidental discharges from pipelines (RPM 34), keeping SDSs on file for all chemical and hazardous materials (RPM 35), developing and maintaining SPCC Plans and a SWPPP detailing prevention and response methods for hydrocarbon spills and storm water discharges (RPM 36), inventorying and reporting on chemical and hazardous materials in accordance with applicable regulations (RPM 37), and working with local EMS authorities to plan for rapid and effective emergency response (RPM 73-80). No residual effects are anticipated.	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	N/A

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			Avoid[5]	Minimize[6]	Rectify/Restore[7]			
				Work with local EMS authorities to plan for rapid and effective emergency response (**RPMs 73-80**)				
19	Hazardous Materials and Solid Waste – Waste Disposal Capacity	Solid waste, construction waste, and hazardous waste generated by the project could exceed the capacity of waste disposal facilities		Adherence to all applicable laws, ordinances, and regulations governing the handing, management, and disposal of hazardous materials and solid waste (**Appendix F, *Hazardous and Non-Hazardous Materials Management Summary***)		Regulatory requirements governing waste disposal would require Jonah Energy to dispose of wastes in licensed waste disposal facilities. Therefore, even if wastes generated by the project exceed the capacity of nearby facilities, no residual impacts are anticipated because Jonah Energy would be required to identify alternative disposal facilities.	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	N/A
20	Land Use	Loss of acreage for use by other resources and resource uses and increased potential for land use changes and land use conflicts associated with development of the NPL Project.	*Refer to mitigation strategies to reduce impacts from the NPL Project on land uses under their respective sections (e.g., recreation, livestock grazing, transportation and traffic)*		Conduct successful reclamation in disturbed areas as soon as practicable (**RPMs 89; 129; 141; 143; 149; Appendix C – Reclamation Plan**)	*FLPMA directs the BLM to manage public lands for multiple uses.* Strategies to avoid, minimize, rectify/restore potential impacts on specific resource and resource uses (e.g., livestock grazing, recreation, transportation) would reduce potential direct and indirect land use conflicts.	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	N/A
21	Lands with Wilderness Characteristics	The establishment of well pads, roads, and ROWs from project-related development could result in adverse impacts on naturalness and outstanding opportunities for solitude or primitive and unconfined forms of recreation.		Limit of one disturbance location per 640 acres in DA1, which contains all lands containing wilderness characteristics in the Project Area, (**Preferred Alternative**) Within Winter Concentration Areas, surface disturbance would not exceed 20 acres (5 percent) surface disturbance per 640 acres, inclusive of existing disturbance (**Preferred Alternative)**	Conduct successful reclamation in disturbed areas as soon as practicable (**RPMs 89; 129; 141; 143; 149; Appendix C – Reclamation Plan)** Implement soil stabilization, erosion control, and reclamation measures (**RPMs 82-117; 148-153**)	Impacts to lands with wilderness characteristics would be minimized by limiting development to one disturbance location per 640 acres in DA1 (Preferred Alternative), applying a surface disturbance threshold of 20 acres (5 percent) per 640 acres in Winter Concentration Areas (Preferred Alternative), centralizing above-ground facilities to locations outside of Winter Concentration Areas, where technically and economically feasible (Preferred Alternative), phasing development from east to west within Winter Concentration Areas (Preferred Alternative), using remote sensing (telemetry) technology to monitor all well locations	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a	N/A

Row #	Resource	Impact Indicator[1]	Strategy To Avoid, Minimize, And Rectify Impacts To The Resource[2]			Residual Effects[3]	Warrant Compensatory Mitigation?[4]	Compensatory Mitigation Options to be Considered at Site-Specific Level
			Avoid[5]	Minimize[6]	Rectify/Restore[7]			
				Above-ground facilities would be centralized to locations outside of Winter Concentration Areas, where technically and economically feasible (**Preferred Alternative)** Within Winter Concentration Areas development would be phased from east to west. Remote sensing (telemetry) technology would be required to monitor all well locations (**Preferred Alternative)** Buried pipelines would be required to transport produced water and condensate from Regional Gathering Facilities (RGFs) within Winter Concentration Areas to RGFs outside of these areas. Produced water and condensate would then be trucked from these RGFs outside Winter Concentration Areas to sales points. This measure would reduce vehicle traffic and other project-related activity (**Preferred Alternative)**		(Preferred Alternative), and requiring the use of buried pipelines to transport produced water and condensate from Regional Gathering Facilities (RGFs) within Winter Concentration Areas to RGFs outside of these areas. Produced water and condensate would then be trucked from these RGFs outside Winter Concentration Areas to sales points (Preferred Alternative. Short-term surface disturbance and project-related activities in lands with wilderness characteristics would result in an irretrievable loss of wilderness characteristics while the disturbance/activity persists. These impacts would be rectified/restored by conducting successful reclamation in disturbed areas as soon as practicable (RPMs 89; 129; 141; 143; 149; Appendix C – Reclamation Plan) and implementing soil stabilization, erosion control, and reclamation measures (RPMs 82-117; 148-153) after decommissioning of facilities. No residual effects are anticipated.	mitigation strategy or NEPA process as warranting compensatory mitigation.	
22	Livestock Grazing – Forage Availability	Reduced forage availability due to surface disturbance and livestock avoidance of construction areas or restricted movement		Do not conduct project-related activities in the vicinity of Sublette Spring without consultation with the permittee from May 1 to July 1; control noise near lambing and calving operations (**RPMs 49; 50**) Maintain access to cattle movement corridors (**RPMs 51; 194**) Provide gaps in the trenching process to allow cows to move or complete pipeline projects while cattle are not on the allotment (**RPM 53**)	Construct fencing to mitigate impacts to grazing management (**RPMs 38; 39; 59**) Conduct two annual meetings and maintain regular communication with grazing permittees to mitigate impacts to grazing operations (**RPMs 40-48**) Conduct successful reclamation in disturbed areas as soon as practicable (**RPMs 89; 129; 141; 143; 149; Appendix C – Reclamation Plan**) Implement soil stabilization, erosion control, and reclamation measures (**RPMs 82-117; 148-153**)	Impacts to livestock grazing from surface disturbance and construction would be minimized by not conducting project-related activities in the vicinity of Sublette Spring without consultation with the permittee from May 1 to July 1 (RPM 49), controlling noise near lambing and calving operations (RPM 50), maintaining access to cattle movement corridors (RPMs 51; 194), and providing gaps in the trenching process to allow cows to move or complete pipeline projects while cattle are not on the allotment (RPM 53). These same impacts would be rectified/restored by constructing fencing to mitigate impacts to grazing management (RPMs 38; 39; 59), conducting two annual meetings and maintaining regular communication with grazing permittees to mitigate impacts to grazing operations (RPMs 40-48), conducting successful reclamation in disturbed areas as soon as practicable (RPMs 89; 129; 141; 143; 149; Appendix C – Reclamation Plan), and implementing soil stabilization, erosion control, and reclamation measures (RPMs 82-117; 148-153). No residual effects are anticipated.	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	N/A
23	Livestock Grazing – Invasive Species and Noxious Weeds	Reduced forage availability or quality due to the establishment and spread	Implement measures to prevent colonization or control the spread of invasive species and noxious weeds (**RPMs 95; 142-147**)		Conduct successful reclamation in disturbed areas as soon as practicable (**RPMs 89; 129; 141;**	Impacts to livestock forage from spread of noxious weeds and nonnative species would be avoided by implementing measures to prevent colonization or control the spread of invasive	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit	N/A

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			Avoid[5]	Minimize[6]	Rectify/Restore[7]			
		of invasive species and noxious weeds			**143; 149; Appendix C – Reclamation Plan**) Implementation of soil stabilization, erosion control, and reclamation measures (**RPMs 82-117; 148-153**)	species and noxious weeds (RPMs 95; 142-147); and rectified/restored by conducting successful reclamation in disturbed areas as soon as practicable (RPMs 89; 129; 141; 143; 149; Appendix C – Reclamation Plan) and implementing soil stabilization, erosion control, and reclamation measures (RPMs 82-117; 148-153). No residual effects are anticipated.	achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	
24	Livestock Grazing – Range Improvements	Damage to range improvements	Avoid all range improvements by 500 feet unless no other alternative is available and impacts can be mitigated (**RPM 55**)		Repair any damage to the function of range improvements or quality and quantity of livestock water sources (**RPMs 54; 57; 58**)	Damage to range improvements would be avoided by having development avoid all range improvements by 500 feet unless no other alternative is available and impacts can be mitigated (RPM 55) and rectified/restored by repairing any damage to the function of range improvements or quality and quantity of livestock water sources (RPMs 54; 57; 58). No residual effects are anticipated.	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	N/A
25	Livestock Grazing – Vehicular Collisions	Increased risk of vehicular collisions with livestock			Provide compensation for cattle lost to project activities (**RPM 52**).	Vehicular collisions with livestock would be rectified/restored by providing compensation for cattle lost to project activities (RPM 52). No residual effects are anticipated.	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	
26	Noise – Greater Sage-Grouse	Decreased sage-grouse lek attendance due to noise	To avoid potentially significant noise impacts, Jonah Energy will locate compressor engines 2,500 feet or	New project noise levels, either individual or cumulative, should not exceed 10 dBA (as measured by L50)	Employ noise-reducing practices during operation of the NPL Facility (**Mitigation Measure N-3**)	The effects of noise on sage-grouse leks would be minimized by locating compressor engines 2,500 feet or more from sage-grouse leks (RPM	Refer to Row #76 in this table for additional information on potential residual effects and	

Row #	Resource	Impact Indicator[1]	Strategy To Avoid, Minimize, And Rectify Impacts To The Resource[2]			Residual Effects[3]	Warrant Compensatory Mitigation?[4]	Compensatory Mitigation Options to be Considered at Site-Specific Level
			Avoid[5]	Minimize[6]	Rectify/Restore[7]			
		during project construction and operations	more from a dwelling, residence, or sage-grouse lek (**RPM 61**) Prohibit surface occupancy and surface-disturbing activities within 0.6 miles of occupied Sage-Grouse leks in PHMA and within 0.25 miles of leks outside PHMA (**RPMs 207; 208**) New local or collector roads) will be avoided within 1.9 miles of the perimeter of occupied Sage-Grouse leks within PHMAs. All new roads will be prohibited within 0.6 miles of the perimeter of occupied Sage-Grouse leks within PHMA **(RPM 217)**	above baseline noise at the perimeter of the lek from 6:00 p.m. to 8:00 a.m. during the breading season (March 1 – May 15) (**RPM 212**) Limit of one disturbance location per 640 acres in DA1 (winter concentration area) and DA 3 (PHMA) (**Preferred Alternative**) Within Winter Concentration Areas, surface disturbance would not exceed 20 acres (5 percent) surface disturbance per 640 acres, inclusive of existing disturbance (**Preferred Alternative)** Above-ground facilities would be centralized to locations outside of Winter Concentration Areas, where technically and economically feasible (**Preferred Alternative)** Buried pipelines would be required to transport produced water and condensate from RGFs within Winter Concentration Areas and PHMA to RGFs outside of these areas. Products would then be trucked out from RGFs outside of PHMA and Winter Concentration Areas (**Preferred Alternative)** Use remote telemetry and SCADA technology to reduce vehicle trips and human presence for well monitoring and control during production activities (**RPMs 2; 121**) Limit of one disturbance location per 640 acres in PHMA; limit cumulative value of existing disturbances to not exceed 5 percent of suitable habitat of the DDCT area (**RPM 206)** Prohibit heavy truck traffic within two-mile Sage-Grouse lek buffers between the hours of 6:00 p.m. and 8:00 a.m. during Sage-Grouse mating season (**Mitigation Measure N-1**) Employ noise-reducing practices during construction (**Mitigation Measure N-2**)	Implement a noise monitoring program to verify noise levels from NPL construction, operation, and truck traffic do not exceed the 10 dBA noise increase threshold at Sage-Grouse lek perimeters during sensitive breeding hours (**Mitigation Measure M-4**)	61), prohibiting surface occupancy and surface-disturbing activities within 0.6 miles of occupied Sage-Grouse leks in PHMA and within 0.25 miles of leks outside PHMA (RPMs 207; 208), and avoiding new local or collector roads within 1.9 miles of the perimeter of occupied Sage-Grouse leks within PHMAs and prohibiting all new roads within 0.6 miles of the perimeter of occupied Sage-Grouse leks within PHMA (RPM 217); minimized by limiting noise levels to 10 dBA (as measured by L50) above baseline noise at the perimeter of the lek from 6:00 p.m. to 8:00 a.m. during the breading season (March 1 – May 15) (RPM 212), limiting development to one disturbance location per 640 acres in DA1 (winter concentration area) and DA 3 (PHMA) (Preferred Alternative), applying a surface disturbance threshold of 20 acres (5 percent) per 640 acres within Winter Concentration Areas (Preferred Alternative), centralizing above-ground facilities to locations outside of Winter Concentration Areas, where technically and economically feasible (Preferred Alternative), requiring buried pipelines to transport produced water and condensate from RGFs within Winter Concentration Areas and PHMA to RGFs outside of these areas (Preferred Alternative), using remote telemetry and SCADA technology to reduce vehicle trips and human presence for well monitoring and control during production activities (RPMs 2; 121), limiting surface disturbance to one location per 640 acres in PHMA and limiting the cumulative value of existing disturbances to not exceed 5 percent of suitable habitat of the DDCT area (RPM 206), prohibiting heavy truck traffic within two-mile Sage-Grouse lek buffers between the hours of 6:00 p.m. and 8:00 a.m. during Sage-Grouse mating season (Mitigation Measure N-1), and employing noise-reducing practices during construction (Mitigation Measure N-2); and rectified/restored by employing noise-reducing practices during operation of the NPL Facility (Mitigation Measure N-3) and implementing a noise monitoring program to verify noise levels from NPL construction, operation, and truck traffic do not exceed the 10 dBA noise increase threshold at Sage-Grouse lek perimeters during sensitive breeding hours (Mitigation Measure N-4). Residual noise impacts could occur when RGFs are located in Sage-Grouse PHMA and Winter Concentration Areas. Refer to Row #76 in this table for additional information on potential residual effects associated with locating RGFs in	associated compensatory mitigation associated with locating RGFs in Sage-Grouse PHMA and Winter Concentration Areas. No other residual effects are anticipated. Therefore, compensatory mitigation is not warranted.	

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			Avoid[5]	Minimize[6]	Rectify/Restore[7]			
						Sage-Grouse PHMA and Winter Concentration Areas.		
27	Noise – Residential Receptors	Adverse noise impacts on any residences located within 750 feet of construction activities and 2,700 feet of operations activities		Locate compressor engines 2,500 feet or more from a dwelling, residence, or sage-grouse lek (**RPM 61**)		Adverse noise impacts on residences would be minimized by locating compressor engines 2,500 feet or more from a dwelling or residence (RPM 61). No residual effects are anticipated.	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	N/A
28	Noise – Construction and Operation Personnel	Adverse effects on NPL Project construction and operational personnel from noise associated with the NPL Project.		In accordance with the Occupational Safety and Health Act, workers would be affected appropriate protection when sound levels are such that could affect workers.		Given that onsite workers would be protected under OSHA requirements, there are no anticipated adverse noise-related direct, indirect, or residual effects on workers during project construction or operation.	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	N/A
29	Paleontology – Illegal Fossil Collection	Increased illegal vertebrate fossil collection resulting from increased access	Jonah Energy must instruct personnel about the types of fossils they could encounter and the steps to take if they uncover fossils anywhere during construction or operations. Instruction must emphasize the nonrenewable nature of paleontological resources, and that collection or excavation of vertebrate fossil materials from Federal lands without a Federal permit is illegal, as is the disposal of fossils to avoid dealing with or documenting them. Jonah Energy would coordinate with the BLM to ensure that the instructor qualifications and content of the worker education and awareness			The risk of illegal vertebrate fossil collection would be minimized by instructing personnel about the types of fossils they may encounter and informing them of laws pertaining to fossil collection; and minimized, rectified, or restored by instructing personnel to follow appropriate steps in the event that fossils are found (Mitigation Measure P-1). No residual effects are anticipated.	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	N/A

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			Avoid[5]	Minimize[6]	Rectify/Restore[7]			
			program meet BLM requirements. (**Mitigation Measure P-1**)					
30	Paleontology – Surface Disturbance	Surface disturbance in areas underlain by the Wasatch and Bridger formations, or in bedrock exposures of the Laney Member of the Green River Formation, that damage significant paleontological resources	Perform a preconstruction surveys in areas underlain by either the Wasatch or Green River Formations (**RPM 63**) Areas underlain by the Wasatch Formation, including both the Alkali Creek and unnamed variegated member and the Bridger Formation, would be surveyed by a paleontologist prior to surface disturbance associated with the development of oil and gas facilities. Areas underlain by bedrock of the formation are depicted on Map 9. A short report of findings of the survey and recommendations for mitigation would be prepared for each area surveyed. Mitigation during surface disturbance may include spot inspection or full-time monitoring, depending on the recommendations made in the paleontological survey report. (**Mitigation Measure P-2**) Prior to surface disturbance, field surveys would be conducted by a paleontologist in areas where BLM onsite inspection reveals the presence of bedrock belonging to the Laney Member of the Green River Formation. Surface disturbance involving excavation of well pads and sample pits and pipelines would be spot-inspected after excavation. (**Mitigation Measure P-3**)	Implement appropriate procedures in the event that paleontological resources are discovered during surface-disturbing activities (**RPM 62**)	Jonah Energy must instruct personnel about the types of fossils they could encounter and the steps to take if they uncover fossils anywhere during construction or operations. Instruction must emphasize the nonrenewable nature of paleontological resources, and that collection or excavation of vertebrate fossil materials from Federal lands without a Federal permit is illegal, as is the disposal of fossils to avoid dealing with or documenting them. Jonah Energy would coordinate with the BLM to ensure that the instructor qualifications and content of the worker education and awareness program meet BLM requirements. (**Mitigation Measure P-1**) Jonah Energy would ensure that fossil specimens recovered during monitoring are curated into the collections of a museum repository acceptable to the BLM. The Departmental Collections of the Geology and Geophysics Department at the University of Wyoming is the recommended curation facility. Specimens would be prepared to the point of identification, identified, and catalogued into the permanent collections of an established institution. (**Mitigation Measure P-4**) Jonah Energy would submit a final technical report prepared by a paleontologist following completion of the mitigation program to determine if adverse impacts on paleontological resources are have been sufficiently mitigated. The final report would contain the results of the mitigation work conducted, including an accession list of fossil specimens collected, listed by locality, and the final disposition of the fossils. The final report would also contain a discussion of	Damage to significant paleontological resource from surface disturbance would be avoided by performing preconstruction surveys in areas underlain by either the Wasatch or Green River Formations (RPM 63), surveying and preparing site-specific mitigation measures for areas underlain by the Wasatch Formation, including both the Alkali Creek and unnamed variegated member and the Bridger Formation, prior to surface disturbance associated with the development of oil and gas facilities (Mitigation Measure P-2), and surveying and inspecting areas where BLM onsite inspection reveals the presence of bedrock belonging to the Laney Member of the Green River Formation (Mitigation Measure P-3); avoided by implementing appropriate procedures in the event that paleontological resources are discovered during surface-disturbing activities (RPM 62); and rectified/restored by instructing personnel about the types of fossils they may encounter and informing them of laws pertaining to fossil collection; and minimized, rectified, or restored by instructing personnel to follow appropriate steps in the event that fossils are found (Mitigation Measure P-1), ensuring that fossil specimens recovered during monitoring are properly curated into the collections of a museum repository acceptable to the BLM (Mitigation Measure P-4), and submitting a final technical report following completion of the mitigation program to determine if adverse impacts on paleontological resources are have been sufficiently mitigated and to document scientific findings (Mitigation Measure P-5). No residual effects are anticipated.	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	N/A

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			Avoid[5]	Minimize[6]	Rectify/Restore[7]			
					the scientific significance of the specimens and geologic and paleontological setting of the fossils and their localities. A confidential appendix containing copies of locality maps (provided as both static maps and GIS data), and standard locality data sheets for each locality, if any specimens were discovered and collected, would be included with the report, and copies of the report would be filed with Jonah Energy, the BLM, and the repository where the fossils are curated. (**Mitigation Measure P-5**)			
31	Recreation – Experiences	Increased noise, facilities, or other disturbance that reduce recreation opportunities or diminish recreation experiences, especially for those seeking a natural setting or primitive forms of recreation		Jonah Energy will limit ATV use to surveying, wildlife monitoring, and vegetation management contractors (**RPM 64**) Jonah Energy will limit OHV activity by employees and contract workers to the immediate area of authorized activity or existing roads and trails (**RPM 65**)	Conduct successful reclamation in disturbed areas as soon as practicable (**RPM 89; 129; 141; 143; 149; Appendix C – Reclamation Plan**)	Impacts to recreation experiences would be minimized by limiting ATV use to surveying, wildlife monitoring, and vegetation management contractors (RPM 64) and limiting OHV activity by employees and contract workers to the immediate area of authorized activity or existing roads and trails (RPM 65); and rectified/restored by conducting successful reclamation in disturbed areas as soon as practicable (RPM 89; 129; 141; 143; 149; Appendix C – Reclamation Plan). No residual effects are anticipated.	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	N/A
32	Recreation – Hunting	Diminished hunting opportunities due to displacement of wildlife and loss of wildlife habitats	Preservation of migration corridors through coordination between Jonah Energy, BLM, WGFD, and other stakeholders, and avoidance of activities and facilities that create barriers to big game movement (**RPMs 193; 194**) *Refer to other strategies under the corresponding big game and other game species.*	*Refer to other strategies under the corresponding big game and other game species.*	Conduct successful reclamation in disturbed areas as soon as practicable (**RPM 89; 129; 141; 143; 149; Appendix C – Reclamation Plan**) *Refer to other strategies under the corresponding big game and other game species.*	Impacts to hunting opportunities would be avoided by preserving migration routes through coordination between Jonah Energy, BLM, WGFD, and other stakeholders, and avoidance of activities and facilities that create barriers to big game movement (RPMs 193; 194); rectified/restored by conducting successful reclamation in disturbed areas as soon as practicable (RPM 89; 129; 141; 143; 149; Appendix C – Reclamation Plan). Mitigation strategies listed under big game and other game species would also apply. No residual effects are anticipated.	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	N/A
33	Recreation – Recreation Management Areas	Alteration of the recreational setting of the Ross Butte MA (VRM Class	The BLM will manage all uses and activities consistent with an area's visual resource management (VRM)	Limit of one disturbance location per 640 acres in DA1 (winter concentration		Impacts to recreation management areas would be avoided by managing all uses and activities consistent with an area's visual resource	No. There are no anticipated residual effects that warrant compensatory mitigation. The	N/A

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			Avoid[5]	Minimize[6]	Rectify/Restore[7]			
		III) and Green and New Fork Rivers SRMA (VRM Class II)	class as established in the BLM Pinedale Approved RMP and ROD, including VRM Class III and Class II areas. All development in the planning area will adhere to the VRM class objectives established in the RMP. For example **(Pinedale RMP)**. Visual contrast ratings will be required for all major projects proposed for VRM Class I, II, and III areas that have high sensitivity levels (**RPM 163 added from Pinedale RMP**).	area) and DA 3 (PHMA) (**Preferred Alternative**) Within Winter Concentration Areas, surface disturbance would not exceed 20 acres (5 percent) surface disturbance per 640 acres, inclusive of existing disturbance (**Preferred Alternative)** Above-ground facilities would be centralized to locations outside of Winter Concentration Areas, where technically and economically feasible (**Preferred Alternative)** Buried pipelines would be required to transport produced water and condensate from RGFs within Winter Concentration Areas and PHMA to RGFs outside of these areas. Products would then be trucked out from RGFs outside of PHMA and Winter Concentration Areas (**Preferred Alternative)** Consider appropriate mitigation measures and COAs to reduce adverse visual impacts from the use of solar panels during the APD process (**RPM 158**) Install low profile tanks wherever visual sensitivity is an issue (**RPM 159**) Minimize or eliminate effects to viewsheds and visibility within the NPL Project Area when feasible (**RPM 160**) Select locations that provide for vegetative and topographic screening (**RPM 161**) Design well sites to fit the landscape and minimize construction needs (**RPM 162**) Limit of one disturbance location per 640 acres in PHMA; limit cumulative value of existing disturbances to not exceed 5 percent of suitable habitat of the DDCT area (**RPM 206)**		management VRM class objectives as established in the BLM Pinedale Approved RMP and ROD, and requiring visual contrast ratings for all major projects proposed for VRM Class I, II, and III areas that have high sensitivity levels (RPM 163 added from Pinedale RMP); minimized by limiting development to one disturbance location per 640 acres in DA1 (winter concentration area) and DA 3 (PHMA) (Preferred Alternative), applying a surface disturbance threshold of 20 percent (5 acres) per 640 acres, inclusive of existing disturbance (Preferred Alternative), limiting the cumulative value of disturbances not to exceed 5 percent of suitable habitat within a DDCT area (RPM 206), centralizing above-ground facilities to locations outside of Winter Concentration Areas, where technically and economically feasible (Preferred Alternative), requiring buried pipelines to transport produced water and condensate from RGFs within Winter Concentration Areas and PHMA to RGFs outside of these areas (Preferred Alternative), considering appropriate mitigation measures and COAs to reduce adverse visual impacts from the use of solar panels during the APD process (RPM 158), installing low profile tanks wherever visual sensitivity is an issue (RPM 159), minimizing or eliminating effects to viewsheds and visibility within the NPL Project area when feasible (RPM 160), selecting locations that provide for vegetative and topographic screening (RPM 161), and designing well sites to fit the landscape and minimize construction needs (RPM 162). Impacts to the Wind River MA and Wind River SRMA are unlikely due to their distances from the Project Area. No residual effects are anticipated.	project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	
34	Socioeconomics – Environmental Justice	Disproportionate impacts on minority or low income populations.				Several resource impacts could adversely impact environmental justice communities; however, there are no anticipated adverse impacts that would disproportionately affect environmental	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit achieving compliance with	N/A

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			Avoid[5]	Minimize[6]	Rectify/Restore[7]			
						justice communities. Therefore, no residual effects are anticipated.	laws, regulations, and/or policies or identified resource objectives in applicable BLM RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	
35	Socioeconomics – Jobs, Population, and Housing	Creation of new jobs and regional population increase		Conduct outreach for employment and economic development opportunities in local communities (**RPMs 66; 68; 70-72**)		Based on current housing availability in communities surrounding the Project Area, no impacts on the housing market from project-related population growth are anticipated.	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	N/A
36	Soil Resources – Contamination	Release of completions fluids, drilling fluids, produced water, or other materials		Adherence to all applicable laws, ordinances, and regulations governing the handing, management, and disposal of hazardous materials and solid waste (**Appendix F, *Hazardous and Non-Hazardous Materials Management Summary***) Install shutoff valves or other systems where pipelines cross streams, cultural sites, and paleontological locales to minimize accidental discharges from pipelines (**RPM 34**) Keep SDSs on file for all chemical and hazardous materials (**RPM 35**) Develop and maintain SPCC Plans and a SWPPP detailing prevention and response methods for hydrocarbon spills and storm water discharges (**RPM 36**)		Risk of soil contamination would be minimized by adhering to all applicable laws, ordinances, and regulations governing the handing, management, and disposal of hazardous materials and solid waste (Appendix F, *Hazardous and Non-Hazardous Materials Management Summary*), installing shutoff valves or other systems where pipelines cross streams, cultural sites, and paleontological locales to minimize accidental discharges from pipelines (RPM 34), keeping SDSs on file for all chemical and hazardous materials (RPM 35), developing and maintaining SPCC Plans and a SWPPP detailing prevention and response methods for hydrocarbon spills and storm water discharges (RPM 36), inventorying and reporting on chemical and hazardous materials in accordance with applicable regulations (RPM 37), and working with local EMS authorities to plan for efficient emergency response (RPMs 73-80). No residual effects are anticipated.	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	N/A

Row #	Resource	Impact Indicator[1]	Strategy To Avoid, Minimize, And Rectify Impacts To The Resource[2]			Residual Effects[3]	Warrant Compensatory Mitigation?[4]	Compensatory Mitigation Options to be Considered at Site-Specific Level
			Avoid[5]	Minimize[6]	Rectify/Restore[7]			
				Inventory and report on chemical and hazardous materials in accordance with applicable regulations (**RPM 37**) Work with local EMS authorities to plan for efficient emergency response (**RPMs 73-80**)				
37	Soil Resources – Disturbance	Surface-disturbing activities that result in removal of soil and vegetation, bare soil, soil compaction, and undesirable mixing of soil horizons, which decrease soil productivity and increase erosion potential	To reduce challenges with achieving successful interim and final reclamation, the operator would avoid surface-disturbing activities in soils that have high-risk characteristics that could limit reclamation success, where feasible. Soils that have high risk characteristics, including but not limited to the limiting characteristics identified in the analysis above, would be identified and further assessed during onsite visits and site-specific permitting. (**Mitigation Measure S-6**)	Implement soil stabilization, erosion control, and reclamation measures (**RPMs 82-117, 148-153**) The operator would engineer all surface runoff control structures and treatments for higher levels of storm intensity and duration as indicated by the KINEROS2 modeling analysis (e.g., 25-year 24-hour event) described in Appendix J (AGWA Technical Report). (**Mitigation Measure S-3**)	Conduct successful reclamation in disturbed areas as soon as practicable (**RPMs 89; 129; 141; 143; 149; Appendix C – Reclamation Plan**) The intensity and distribution of the prescribed monitoring and mitigation would be determined by the initial model designations of plane or channel impacts and intensity of landscape disturbance, as described in Appendix J (AGWA Technical Report). The BLM would use new monitoring data collected by Jonah Energy during development of the NPL Project to re-parameterize the model and re-run it as necessary (e.g., KINEROS2), to aid in identifying significance thresholds, or action levels, for channel erosion and runoff/salinity increases (**Mitigation Measure S-1**) Because some individual planes in the Watershed Modeling Units exhibited a relatively substantial increase in surface runoff and discharge within the channels, Jonah Energy would implement monitoring and mitigation measures/or other approved measures that are as rigorous and protective as recommended in the Monitoring and Mitigation tables in Section 6.3 of Appendix J (AGWA Technical Report). (**Mitigation Measure S-2**) The operator would be extremely diligent in compliance monitoring of the condition of runoff control structures (e.g., after every precipitation event that resulted in any water movement off pads into detention ponds, off roads, and into wing ditches and	Impacts to soils from surface disturbance would be avoided by avoiding surface-disturbing activities in soils that have high-risk characteristics that could limit reclamation success, where feasible (Mitigation Measure S-6); minimized by implementing soil stabilization, erosion control, and reclamation measures (RPMs 82-117, 148-153) and engineering all surface runoff control structures and treatments for higher levels of storm intensity and duration as indicated by the KINEROS2 modeling analysis (e.g., 25-year 24-hour event) (Mitigation Measure S-3); and rectified/restored by conducting successful reclamation in disturbed areas as soon as practicable (RPM 89; 129; 141; 143; 149; Appendix C – Reclamation Plan); prescribing monitoring and mitigation based on modelling channel erosion and runoff/salinity increases (Mitigation Measure S-1); implementing monitoring and mitigation measures/or other approved measures that are as rigorous and protective as recommended in the Monitoring and Mitigation tables in Section 6.3 of Appendix J (AGWA Technical Report) for those planes in the Watershed Modeling Units that exhibited a relatively substantial increase in surface runoff and discharge within the channels (Mitigation Measure S-2); being extremely diligent in compliance monitoring of the condition of runoff control structures (e.g., after every precipitation event that resulted in any water movement off pads into detention ponds, off roads, and into wing ditches and catchments), and promptly repairing any damage before the next precipitation event (Mitigation Measure S-4); and developing mitigation and Monitoring Plans and Storm Water Pollution Prevention Plans for the NPL Project (Mitigation Measure S-5). No residual effects are anticipated.	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	N/A

Row #	Resource	Impact Indicator[1]	Strategy To Avoid, Minimize, And Rectify Impacts To The Resource[2]			Residual Effects[3]	Warrant Compensatory Mitigation?[4]	Compensatory Mitigation Options to be Considered at Site-Specific Level
			Avoid[5]	Minimize[6]	Rectify/Restore[7]			
					catchments), and promptly repair any damage before the next precipitation event. (**Mitigation Measure S-4**) The operator would develop Mitigation and Monitoring Plans and Storm Water Pollution Prevention Plans for the NPL Project, which incorporate the *Technical Support Document for the Application of the Regional Framework for Water-Resources Monitoring Related to Energy Exploration and Development* (BLM 2013c) and the recommended measures for monitoring and mitigation for each of the impact categories identified in Section 6.3 of Appendix J (AGWA Technical Report). (**Mitigation Measure S-5**)			
38	Special Designations – NHTs	Unintentional damage to Sublette Cutoff and North Sublette Meadow Springs Variant from construction and human activity in trail vicinity	Workforce education program for NHTs (**RPM 28**) Prohibit surface disturbance within 0.25 mile or visual horizon of historic trails (**RPM 106**) During site-specific permitting, the BLM would assess the potential for installation/replacement of appropriate historic trail markers to clearly identify the location of the Sublette Cutoff and North Sublette Meadow Springs Variant to avoid unintentional damage to trails from construction, maintenance, and operation. (**Mitigation Measure C-1**)		As part of the NPL Project, undertakings within the viewshed of the Sublette Cutoff and the North Sublette Meadow Springs Variant have the potential to cause adverse effects (as defined in 36 CFR §800.5(a)) to contributing segments of the NHTs. Each undertaking proposed by Jonah Energy within the NHT viewshed portion of the NPL Project Area would be analyzed according to 54 U.S.C. 306108. Should a determination of adverse effect to the NHT be made by the BLM and concurred with by the Wyoming State Historic Preservation Office (SHPO), the adverse effect would require the development of appropriate mitigation, which would be codified into an agreement document with the involvement of consulting parties (36 CFR §800.6(a)(2)). Within the viewshed of the NHT, only delineation wells and related facilities (e.g., powerlines, pipelines, and access roads) would be processed under the current State Protocol Agreement	Unintentional damage to NHTs would be avoided by implementing a workforce education program (RPM 28), prohibiting surface disturbance within 0.25 mile or visual horizon of historic trails (RPM 106), and assessing the potential for installation/replacement of appropriate historic trail markers to clearly identify the location of the Sublette Cutoff and North Sublette Meadow Springs Variant to avoid unintentional damage to trails from construction, maintenance, and operation. (Mitigation Measure C-1); and rectified/restored by requiring the development of appropriate mitigation should a determination of adverse effect to the NHT be made by the BLM and concurred with by the Wyoming SHPO, which would be codified into an agreement document with the involvement of consulting parties (Mitigation Measure C-3). No residual effects are anticipated.	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	N/A

Row #	Resource	Impact Indicator[1]	Strategy To Avoid, Minimize, And Rectify Impacts To The Resource[2]			Residual Effects[3]	Warrant Compensatory Mitigation?[4]	Compensatory Mitigation Options to be Considered at Site-Specific Level
			Avoid[5]	Minimize[6]	Rectify/Restore[7]			
					between the BLM Wyoming State Director and the Wyoming SHPO in the absence of a Programmatic Agreement. **(Mitigation Measure C-3).**			
39	Special Designations – NHTs	Introduction of visual elements that diminish the integrity of settings and viewsheds of the Sublette Cutoff and North Sublette Meadow Springs Variant	Avoid surface disturbance within 0.25 mile or visual horizon of NHTs. Site project facilities further than 0.25 mile but within NHT viewsheds to blend with the landscape. (**RPM 27**) Implement a workforce education program for NHTs (**RPM 28**) Prohibit surface disturbance within 0.25 mile or visual horizon of historic trails (**RPM 106**) During site-specific permitting, the BLM would assess the potential for installation/replacement of appropriate historic trail markers to clearly identify the location of the Sublette Cutoff and North Sublette Meadow Springs Variant to avoid unintentional damage to trails from construction, maintenance, and operation. (**Mitigation Measure C-1**)		As part of the NPL Project, undertakings within the viewshed of the Sublette Cutoff and the North Sublette Meadow Springs Variant have the potential to cause adverse effects (as defined in 36 CFR §800.5(a)) to contributing segments of the NHTs. Each undertaking proposed by Jonah Energy within the NHT viewshed portion of the NPL Project Area would be analyzed according to 54 U.S.C. 306108. Should a determination of adverse effect to the NHT be made by the BLM and concurred with by the Wyoming State Historic Preservation Office (SHPO), the adverse effect would require the development of appropriate mitigation, which would be codified into an agreement document with the involvement of consulting parties (36 CFR §800.6(a)(2)). Within the viewshed of the NHT, only delineation wells and related facilities (e.g., powerlines, pipelines, and access roads) would be processed under the current State Protocol Agreement between the BLM Wyoming State Director and the Wyoming SHPO in the absence of a Programmatic Agreement. **(Mitigation Measure C-3).**	Visual impacts to NHT viewsheds would be avoided by avoiding surface disturbance within 0.25 mile or visual horizon of NHTs and requiring project facilities further than 0.25 mile but within NHT viewsheds to blend with the landscape. (RPM 27), implementing a workforce education program for NHTs (RPM 28), prohibiting surface disturbance within 0.25 mile or visual horizon of historic trails (RPM 106), and assessing the potential for installation/replacement of appropriate historic trail markers to clearly identify the location of the Sublette Cutoff and North Sublette Meadow Springs Variant to avoid unintentional damage to trails from construction, maintenance, and operation. (Mitigation Measure C-1); and requiring the development of appropriate mitigation should a determination of adverse effect to the NHT be made by the BLM and concurred with by the Wyoming SHPO, which would be codified into an agreement document with the involvement of consulting parties (Mitigation Measure C-3). No residual effects are anticipated.	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	N/A
40	Special Designations – Recreation Management Areas	Alteration of the recreational setting of the Ross Butte MA (VRM Class III) and Green and New Fork Rivers SRMA (VRM Class II)	The BLM will manage all uses and activities consistent with an area's visual resource management (VRM) class as established in the BLM Pinedale Approved RMP and ROD, including VRM Class III and Class II areas. All development in the planning area will adhere to the VRM class objectives established in the RMP. For example **(Pinedale RMP)**. Visual contrast ratings will be required for all major projects proposed for VRM Class I, II, and III areas that have high sensitivity levels	Limit of one disturbance location per 640 acres in DA1 (winter concentration area) and DA 3 (PHMA) (**Preferred Alternative**) Within Winter Concentration Areas, surface disturbance would not exceed 20 acres (5 percent) surface disturbance per 640 acres, inclusive of existing disturbance (**Preferred Alternative)** Above-ground facilities would be centralized to locations outside of Winter Concentration Areas, where		Impacts to recreation management areas would be avoided by managing all uses and activities consistent with an area's visual resource management VRM class objectives as established in the applicable BLM RMPs. requiring visual contrast ratings for all major projects proposed for VRM Class I, II, and III areas that have high sensitivity levels (RPM 163 added from Pinedale RMP); and minimized by limiting development to one disturbance location per 640 acres in DA1 (winter concentration area) and DA 3 (PHMA) (Preferred Alternative), applying a surface disturbance threshold of 20 percent (5 acres) per 640 acres, inclusive of existing disturbance (Preferred	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA	N/A

Row #	Resource	Impact Indicator[1]	Strategy To Avoid, Minimize, And Rectify Impacts To The Resource[2]			Residual Effects[3]	Warrant Compensatory Mitigation?[4]	Compensatory Mitigation Options to be Considered at Site-Specific Level
			Avoid[5]	Minimize[6]	Rectify/Restore[7]			
			(**RPM 163 added from Pinedale RMP**).	technically and economically feasible (**Preferred Alternative)** Buried pipelines would be required to transport produced water and condensate from RGFs within Winter Concentration Areas and PHMA to RGFs outside of these areas. Products would then be trucked out from RGFs outside of PHMA and Winter Concentration Areas (**Preferred Alternative)**		Alternative), limiting the cumulative value disturbances not to exceed 5 percent of suitable habitat within a DDCT area (RPM 206), centralizing above-ground facilities to locations outside of Winter Concentration Areas, where technically and economically feasible (Preferred Alternative), and requiring buried pipelines to transport produced water and condensate from RGFs within Winter Concentration Areas and PHMA to RGFs outside of these areas (Preferred Alternative). Impacts to the Wind River MA and Wind River SRMA are unlikely due to their distances from the Project Area. No residual effects are anticipated.	process as warranting compensatory mitigation.	
41	Transportation and Access – Road Maintenance	Increased road maintenance costs due to road damage and deterioration from project-related vehicle trips		Design roads to follow natural topographic contours and preserve natural drainage patterns, such that the road will have potentially lower construction, maintenance, and reclamation costs (**RPM 123**)	All roads not required for routine maintenance and operation would be closed and reclaimed as soon as possible (**RPMs 129; 141)** Jonah Energy will regularly maintain all lease roads in a safe, usable condition (**RPM 134**)	Road damage and deterioration would be minimized by designing roads to follow natural topographic contours and preserve natural drainage patterns, such that the road will have potentially lower construction, maintenance, and reclamation costs (RPM 123); and rectified/restored by closing and reclaiming all roads not required for routine maintenance and operation as soon as possible (RPMs 129; 141) and regularly maintaining all lease roads in a safe, usable condition (RPM 134). No residual effects are anticipated.	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	N/A
42	Transportation and Access – Vehicle Collisions	Increased risk of traffic-related accidents and collisions with wildlife and livestock.	Avoid the creation of new two-track roads (**RPM 139**)	To the extent possible, the existing Jonah Energy workforce facility would be utilized to house workers; thereby reducing vehicle trips on transportation routes outside the immediate Project Area (**Preferred Alternative)** Post appropriate road warning signs and support the enforcement of speed limits (**RPM 135**) Use content and recommendations in the NPL transportation plan to guide safe and efficient transportation (**RPM 136**)		Risk of traffic-related accidents and collisions with wildlife and livestock would be avoided by avoiding the creation of new two-track roads (RPM 139); minimized by utilizing the existing Jonah Energy workface facility to house workers to the extent possible (Preferred Alternative), posting appropriate road warning signs and supporting the enforcement of speed limits (RPM 135), using content and recommendations in the NPL transportation plan to guide safe and efficient transportation (RPM 136), working with the BLM to enforce speed limits and other road regulations (RPM 137), and using remote telemetry and SCADA technology to reduce vehicle trips and human presence for well monitoring and control during production activities (RPMs 2; 121). No residual effects are anticipated.	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	N/A

Row #	Resource	Impact Indicator[1]	Strategy To Avoid, Minimize, And Rectify Impacts To The Resource[2]			Residual Effects[3]	Warrant Compensatory Mitigation?[4]	Compensatory Mitigation Options to be Considered at Site-Specific Level
			Avoid[5]	Minimize[6]	Rectify/Restore[7]			
				Work with the BLM to enforce speed limits and other road regulations (**RPM 137**) Use remote telemetry and SCADA technology to reduce vehicle trips and human presence for well monitoring and control during production activities (**RPMs 2; 121**)				
43	Transportation and Access – Accidental Spills	Potential for hazardous material spills from increased traffic volumes and vehicles carrying hazardous materials to service the wells.		Adherence to all applicable laws, ordinances, and regulations governing the handing, management, and disposal of hazardous materials and solid waste (**Appendix F, *Hazardous and Non-Hazardous Materials Management Summary***)		The potential for accidental spills and releases would be minimized by adhering to all applicable laws, ordinances, and regulations governing the handing, management, and disposal of hazardous materials and solid waste (Appendix F, *Hazardous and Non-Hazardous Materials Management Summary*). No residual effects are anticipated.	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	N/A
44	Transportation and Access – Traffic	Project-related vehicle trips and construction could increase traffic on roads used to access or travel within the Project Area		Minimize truck traffic through the use of Regional Gathering Facilities with consolidated tank batteries for water and condensate (**Preferred Alternative**) To the extent possible, the existing Jonah Energy workforce facility would be utilized to house workers; thereby reducing vehicle trips on transportation routes outside the immediate Project Area (**Preferred Alternative)** Post appropriate road warning signs and support the enforcement of speed limits (**RPM 135**) Use remote telemetry and SCADA technology to reduce vehicle trips and human presence for well monitoring and control during production activities (**RPM 2; 121**)		Increased traffic due to project-related vehicle trips would be minimized by minimizing truck traffic through the use of Regional Gathering Facilities with consolidated tank batteries for water and condensate (Preferred Alternative), utilizing the existing Jonah Energy workforce facility to house workers to the extent possible (Preferred Alternative), posting appropriate road warning signs and supporting the enforcement of speed limits (RPM 135), and using remote telemetry and SCADA technology to reduce vehicle trips and human presence for well monitoring and control during production activities (RPM 2; 121). No residual effects are anticipated.	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	N/A
45	Vegetation – Invasive Species and Noxious Weeds	Increased potential for establishment and spread of invasive species		Implement measures to prevent colonization or control the spread of invasive species and noxious weeds (**RPMs 95; 142-147**)	Conduct successful reclamation in disturbed areas as soon as practicable (**RPMs 89; 129; 141; 143; 149; Appendix C – Reclamation Plan)**	The potential for establishment and spread of invasive species would be minimized by implementing measures to prevent colonization or control the spread of invasive species and noxious weeds (RPMs 95; 142-147) and rectified/restored by conducting successful reclamation in disturbed areas as soon as practicable (RPMs 89; 129; 141; 143; 149;	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM	N/A

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			Avoid[5]	Minimize[6]	Rectify/Restore[7]			
						Appendix C – Reclamation Plan). No residual effects are anticipated.	RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	
46	Vegetation – Riparian and Wetland Communities	Surface disturbance in riparian and wetland communities	Prohibit surface disturbance within 500 feet of surface waters, riparian areas, wetlands, and 100-year floodplains unless no practicable alternative exists (**RPMs 106; 174; 175**) The BLM would consider linear crossings of 100-year floodplains on a case-by-case basis and would prohibit surface disturbance within 100-year floodplains, wetlands, and riparian areas unless there is no physically practical alternative (**RPM 173**) Prohibit surface disturbance within 100 feet of the edge of intermittent and large ephemeral drainages (**RPM 176**)	Implement soil stabilization, erosion control, and reclamation measures (**RPMs 82-117, 148-153**)	Conduct successful reclamation in disturbed areas as soon as practicable (**RPMs 89; 129; 141; 143; 149; Appendix C – Reclamation Plan)** Begin reclamation of disturbed wetland areas immediately after completion of project activities (**RPM 118**) Restore disturbed streams, wetlands, and riparian areas to as near pre-project conditions as practicable (**RPM 164**) Reclaim all disturbances occurring within the high bank plus 50 feet meet the PFC standards (**RPM 170**)	Surface disturbance in riparian and wetland communities would be avoided by prohibiting surface disturbance within 500 feet of surface waters, riparian areas, wetlands, and 100-year floodplains unless no practicable alternative exists (RPMs 106; 174; 175), considering linear crossings of 100-year floodplains on a case-by-case basis and prohibiting surface disturbance within 100-year floodplains, wetlands, and riparian areas unless there is no physically practical alternative (RPM 173), and prohibiting surface disturbance within 100 feet of the edge of intermittent and large ephemeral drainages (RPM 176); avoided by implementing soil stabilization, erosion control, and reclamation measures (RPMs 82-117, 148-153); and rectified/restored by conducting successful reclamation in disturbed areas as soon as practicable (RPMs 89; 129; 141; 143; 149; Appendix C – Reclamation Plan), beginning reclamation of disturbed wetland areas immediately after completion of project activities (RPM 118), restoring disturbed streams, wetlands, and riparian areas to as near pre-project conditions as practicable (RPM 164), and reclaiming all disturbances occurring within the high bank plus 50 feet meet the PFC standards (RPM 170). No residual effects are anticipated.	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	N/A
47	Vegetation – Sagebrush Steppe Communities	Surface disturbance in sagebrush-steppe communities	*Refer to other strategies under "Wildlife – Sage-Grouse"*	Within Winter Concentration Areas, surface disturbance would not exceed 20 acres (5 percent) surface disturbance per 640 acres, inclusive of existing disturbance (**Preferred Alternative)** Above-ground facilities would be centralized to locations outside of Winter Concentration Areas, where technically and economically feasible (**Preferred Alternative)** Limit of one disturbance location per 640 acres in DA1 (winter concentration	Conduct successful reclamation in disturbed areas as soon as practicable (**RPMs 89; 129; 141; 143; 149; Appendix C – Reclamation Plan)** Implementation of soil stabilization, erosion control, and reclamation measures (**RPMs 82-117; 148-153**) Close and reclaim unnecessary roads to reduce fragmentation and restore habitat integrity (**RPM 141**)	Surface disturbance in sagebrush-steppe communities would be minimized by applying a surface disturbance threshold of 20 acres (5 percent) per 640 acres within Winter Concentration Areas) (Preferred Alternative); limiting cumulative disturbances to not exceed 5 percent of suitable habitat in a DDCT area (RPM 206); centralizing above-ground facilities outside of Winter Concentration Areas where technically and economically feasible (Preferred Alternative); limiting development to one disturbance location per 640 acres in DA1 (winter concentration area) and DA 3 (PHMA) (Preferred Alternative); following transportation plans to maintain the largest undisturbed blocks	Refer to Rows #74 through #76 in this table for mitigation strategies associated with Sage-Grouse habitat in PHMA, Winter Concentration Areas, and wintering habitat and impacts to Sage-Grouse habitat warranting compensatory mitigation. There are no other anticipated residual effects that warrant compensatory mitigation.	N/A

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			Avoid[5]	Minimize[6]	Rectify/Restore[7]			
				area) and DA 3 (PHMA) (**Preferred Alternative**) Follow transportation plans to maintain the largest undisturbed blocks of habitat possible and to minimize the acres of disturbance from roads, pipelines, power lines and other facilities (**RPM 140**) Minimize the disturbance of Gardner's saltbush (*Atriplex gardneri*), winterfat (*Krascheninnikovia lanata*), and bud sagebrush (*Artemisia spinescens*) (**RPM 155**) Protect trees, shrubs, and groundcover in areas not cleared for construction (**RPM 157**) Limit of one disturbance location per 640 acres in PHMA; limit cumulative value of existing disturbances to not exceed 5 percent of suitable habitat of the DDCT area (**RPM 206)** Do not upgrade existing routes in PHMA unless it would minimally impact Sage-Grouse, is necessary for safety, or eliminates the need to construct a new road (**RPM 218**) Use existing roads or realignments to access valid existing rights that are not yet developed in PHMA. If valid existing rights cannot be accessed via existing roads, construct any new road to the absolute minimum standard necessary and add the surface disturbance to the total PHMA (**RPM 219**)		of habitat possible and to minimize the acres of disturbance from roads, pipelines, power lines and other facilities (RPM 140); minimizing the disturbance of Gardner's saltbush (*Atriplex gardneri*), winterfat (*Krascheninnikovia lanata*), and bud sagebrush (*Artemisia spinescens*) (RPM 155); protecting trees, shrubs, and groundcover in areas not cleared for construction (RPM 157); not upgrading existing routes in PHMA unless it would minimally impact Sage-Grouse, is necessary for safety, or eliminates the need to construct a new road (RPM 218), and using existing roads or realignments to access valid existing rights that are not yet developed in PHMA and constructing any new road to the absolute minimum standard necessary and add the surface disturbance to the total PHMA (RPM 219). These same impacts would be rectified/restored by conducting successful reclamation in disturbed areas as soon as practicable (RPMs 89; 129; 141; 143; 149; Appendix C – Reclamation Plan); implementing soil stabilization, erosion control, and reclamation measures (RPMs 82-117; 148-153); and closing and reclaiming unnecessary roads to reduce fragmentation and restore habitat integrity (RPM 141). Refer to Rows #74 through #76 in this table for mitigation strategies associated with Sage-Grouse habitat in PHMA, Winter Concentration Areas, and wintering habitat and associated residual impacts.		
48	Vegetation – Special Status Plant Species	Mortality and destruction of seed banks in disturbance sites	Prohibit aerial application of chemicals within 0.25 mile of special status plant locations (**RPM 144**) Prohibit surface disturbance and OHV use in known locations of special status plant species (**RPM 154**) Finance site-specific surveys for special status plant species prior to surface disturbance, where applicable, and comply with BLM avoidance or mitigation requirements (**RPM 250**)			Mortality and destruction of seed banks in disturbance sites would be avoided by prohibiting aerial application of chemicals within 0.25 mile of special status plant locations (RPM 144); prohibiting surface disturbance and OHV use in known locations of special status plant species (RPM 154); and financing site-specific surveys for special status plant species prior to surface disturbance, where applicable, and comply with BLM avoidance or mitigation requirements (RPM 250). No residual effects are anticipated.	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA	N/A

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			Avoid[5]	Minimize[6]	Rectify/Restore[7]			
							process as warranting compensatory mitigation.	
49	Visual Resources – General	New facilities that modify the visual characteristics of the landscape by creating line, form, color, and texture contrasts		Consider appropriate mitigation measures and COAs to reduce adverse visual impacts from the use of solar panels during the APD process (**RPM 158**) Install low profile tanks wherever visual sensitivity is an issue (**RPM 159**) Minimize or eliminate effects to viewsheds and visibility within the NPL Project area when feasible (**RPM 160**) Select locations that provide for vegetative and topographic screening (**RPM 161**) Design well sites to fit the landscape and minimize construction needs (**RPM 162**)	Conduct successful reclamation in disturbed areas as soon as practicable (**RPMs 89; 129; 141; 143; 149; Appendix C – Reclamation Plan)** Implement soil stabilization, erosion control, and reclamation measures (**RPMs 82-117; 148-153**) Close and reclaim unnecessary roads to reduce fragmentation and restore habitat integrity (**RPM 141**)	Line, form, color, and texture contrasts from new facilities would be minimized by applying appropriate mitigation measures and COAs to reduce adverse visual impacts from the use of solar panels during the APD process (Resource Protection Measure 158), installing low profile tanks wherever visual sensitivity is an issue (Resource Protection Measure 159), minimizing or eliminating effects to viewsheds and visibility within the NPL Project area when feasible (RPM 160), selecting locations that provide for vegetative and topographic screening (RPM 161), and designing well sites to fit the landscape and minimize construction needs (RPM 162). These same impacts would be rectified/restored by conducting successful reclamation in disturbed areas as soon as practicable (RPMs 89; 129; 141; 143; 149; Appendix C – Reclamation Plan); implementing soil stabilization, erosion control, and reclamation measures (RPMs 82-117; 148-153); and closing and reclaiming unnecessary roads to reduce fragmentation and restore habitat integrity (RPM 141). No residual effects are anticipated.	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	N/A
50	Visual Resources – NHTs	Creation of line, form, color, and texture contrasts due to project-related development within the viewsheds of NHTs	Avoid surface disturbance within 0.25 mile or visual horizon of NHTs. Site project facilities further than 0.25 mile but within NHT viewsheds to blend with the landscape. (**RPM 27**) Prohibit surface disturbance within 0.25 mile or visual horizon of historic trails (**RPM 106**)	Consider appropriate mitigation measures and COAs to reduce adverse visual impacts from the use of solar panels during the APD process (**RPM 158**) Install low profile tanks wherever visual sensitivity is an issue (**RPM 159**) Minimize or eliminate effects to viewsheds and visibility within the NPL Project area when feasible (**RPM 160**) Select locations that provide for vegetative and topographic screening (**RPM 161**) Design well sites to fit the landscape and minimize construction needs (**RPM 162**)	As part of the NPL Project, undertakings within the viewshed of the Sublette Cutoff and the North Sublette Meadow Springs Variant have the potential to cause adverse effects (as defined in 36 CFR §800.5 (a)) to contributing segments of the NHTs. Each undertaking proposed by Jonah Energy within the NHT viewshed portion of the NPL Project Area would be analyzed according to 54 U.S.C. 306108. Should a determination of adverse effect to the NHT be made by the BLM and concurred with by the Wyoming State Historic Preservation Office (SHPO), the adverse effect would require the development of appropriate mitigation, which would be codified into an agreement document with the involvement of consulting parties (36 CFR §800.6(a)(2)). Within the viewsheds of these NHTs, only	Creation of line, form, color, and texture contrasts due to project-related development within the viewsheds of NHTs would be avoided by avoiding surface disturbance within 0.25 mile or visual horizon of NHTs and siting project facilities further than 0.25 mile but within NHT viewsheds to blend with the landscape. (RPM 27) and prohibiting surface disturbance within 0.25 mile or visual horizon of historic trails (RPM 106); minimized by considering appropriate mitigation measures and COAs to reduce adverse visual impacts from the use of solar panels during the APD process (RPM 158), installing low profile tanks wherever visual sensitivity is an issue (RPM 159), minimizing or eliminating effects to viewsheds and visibility within the NPL Project area when feasible (RPM 160), selecting locations that provide for vegetative and topographic screening (RPM 161), and designing well sites to fit the landscape and minimize construction needs (RPM 162); and rectified/restored by requiring the development of appropriate mitigation should a determination of adverse effect to the NHT be made by the BLM and concurred with by the Wyoming SHPO, which would be codified	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	N/A

Row #	Resource	Impact Indicator[1]	Strategy To Avoid, Minimize, And Rectify Impacts To The Resource[2]			Residual Effects[3]	Warrant Compensatory Mitigation?[4]	Compensatory Mitigation Options to be Considered at Site-Specific Level
			Avoid[5]	Minimize[6]	Rectify/Restore[7]			
					delineation wells and related facilities (e.g., powerlines, pipelines, and access roads) would be processed in the absence of a Programmatic Agreement. Once a Programmatic Agreement is developed, additional development beyond delineation activities could be authorized. **(Mitigation Measure C-3).**	into an agreement document with the involvement of consulting parties (Mitigation Measure C-3). No residual effects are anticipated.		
51	Visual Resources – Recreation Management Areas	Creation of line, form, color, and texture contrasts due to project-related development in or within the viewsheds of recreation management areas including the Ross Butte MA (VRM Class III) and Green and New Fork Rivers SRMA (VRM Class II)	The BLM will manage all uses and activities consistent with an area's visual resource management (VRM) class as established in the BLM Pinedale Approved RMP and ROD, including VRM Class III and Class II areas. All development in the planning area will adhere to the VRM class objectives established in the RMP. For example **(Pinedale RMP)**. Visual contrast ratings will be required for all major projects proposed for VRM Class I, II, and III areas that have high sensitivity levels (**RPM 163 added from Pinedale RMP**).	Limit of one disturbance location per 640 acres in DA1 (winter concentration area) and DA 3 (PHMA) (**Preferred Alternative**) Within Winter Concentration Areas, surface disturbance would not exceed 20 acres (5 percent) surface disturbance per 640 acres, inclusive of existing disturbance (**Preferred Alternative)** Above-ground facilities would be centralized to locations outside of Winter Concentration Areas, where technically and economically feasible (**Preferred Alternative)** Buried pipelines would be required to transport produced water and condensate from RGFs within Winter Concentration Areas and PHMA to RGFs outside of these areas. Products would then be trucked out from RGFs outside of PHMA and Winter Concentration Areas (**Preferred Alternative)** Consider appropriate mitigation measures and COAs to reduce adverse visual impacts from the use of solar panels during the APD process (**RPM 158**) Install low profile tanks wherever visual sensitivity is an issue (**RPM 159**) Minimize or eliminate effects to viewsheds and visibility within the NPL Project area when feasible (**RPM 160**) Select locations that provide for vegetative and topographic screening (**RPM 161**)		Creation of line, form, color, and texture contrasts due to project-related development in or within the viewsheds of recreation management areas would be avoided by managing all uses and activities consistent with an area's visual resource management VRM class objectives as established in the BLM Pinedale Approved RMP and ROD, and requiring visual contrast ratings for all major projects proposed for VRM Class I, II, and III areas that have high sensitivity levels (RPM 163 added from Pinedale RMP); minimized by limiting development to one disturbance location per 640 acres in DA1 (winter concentration area) and DA 3 (PHMA) (Preferred Alternative), applying a surface disturbance threshold of 20 percent (5 acres) per 640 acres, inclusive of existing disturbance (Preferred Alternative), limiting the cumulative value of disturbances not to exceed 5 percent of suitable habitat within a DDCT area (RPM 206), centralizing above-ground facilities to locations outside of Winter Concentration Areas, where technically and economically feasible (Preferred Alternative), requiring buried pipelines to transport produced water and condensate from RGFs within Winter Concentration Areas and PHMA to RGFs outside of these areas (Preferred Alternative), considering appropriate mitigation measures and COAs to reduce adverse visual impacts from the use of solar panels during the APD process (RPM 158), installing low profile tanks wherever visual sensitivity is an issue (RPM 159), minimizing or eliminating effects to viewsheds and visibility within the NPL Project area when feasible (RPM 160), selecting locations that provide for vegetative and topographic screening (RPM 161), and designing well sites to fit the landscape and minimize construction needs (RPM 162). Impacts to the Wind River MA and Wind River SRMA are unlikely due to their distances from the Project Area.	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	N/A

Row #	Resource	Impact Indicator[1]	Strategy To Avoid, Minimize, And Rectify Impacts To The Resource[2]			Residual Effects[3]	Warrant Compensatory Mitigation?[4]	Compensatory Mitigation Options to be Considered at Site-Specific Level
			Avoid[5]	Minimize[6]	Rectify/Restore[7]			
				Design well sites to fit the landscape and minimize construction needs (**RPM 162**) Limit of one disturbance location per 640 acres in PHMA; limit cumulative value of existing disturbances to not exceed 5 percent of suitable habitat of the DDCT area (**RPM 206)**		No residual effects are anticipated.		
52	Visual Resources – Views from Highways	Alterations to the visual setting for drivers looking west from U.S. Highway 191		Consider appropriate mitigation measures and COAs to reduce adverse visual impacts from the use of solar panels during the APD process (**RPM 158**) Install low profile tanks wherever visual sensitivity is an issue (**RPM 159**) Minimize or eliminate effects to viewsheds and visibility within the NPL Project area when feasible (**RPM 160**) Select locations that provide for vegetative and topographic screening (**RPM 161**) Design well sites to fit the landscape and minimize construction needs (**RPM 162**) Limit of one disturbance location per 640 acres in PHMA; limit cumulative value of existing disturbances to not exceed 5 percent of suitable habitat of the DDCT area (**RPM 206)**		Alterations to the visual setting for drivers looking west from U.S. Highway 191 would be minimized by considering appropriate mitigation measures and COAs to reduce adverse visual impacts from the use of solar panels during the APD process (RPM 158), installing low profile tanks wherever visual sensitivity is an issue (RPM 159), minimizing or eliminating effects to viewsheds and visibility within the NPL Project area when feasible (RPM 160), selecting locations that provide for vegetative and topographic screening (RPM 161), designing well sites to fit the landscape and minimize construction needs (RPM 162), limiting development to one disturbance location per 640 acres in PHMA, and limiting cumulative disturbances to not exceed 5 percent of suitable habitat of the DDCT area (RPM 206). No residual effects are anticipated.	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	N/A
53	Visual Resources – VRM Class III Areas	Creation of line, form, color, and texture contrasts due to project-related development in VRM Class III Areas	Prohibit development in areas of DA 1 containing greater than 5 percent sagebrush canopy cover, except where technically and economically infeasible (**RPM 156**)	Within Winter Concentration Areas, surface disturbance would not exceed 20 acres (5 percent) surface disturbance per 640 acres, inclusive of existing disturbance (**Preferred Alternative)** Above-ground facilities would be centralized to locations outside of Winter Concentration Areas, where technically and economically feasible (**Preferred Alternative)** Limit of one disturbance location per 640 acres in DA1 (winter concentration area) and DA 3 (PHMA) (**Preferred Alternative**)		Creation of line, form, color, and texture contrasts due to project-related development in VRM Class III Areas would be avoided by prohibiting development in areas of DA 1 containing greater than 5 percent sagebrush canopy cover, except where technically and economically infeasible (RPM 156); and minimized by applying a surface disturbance threshold of 20 acres (5 percent) per 640 acres (Preferred Alternative), centralizing above-ground facilities to locations outside of Winter Concentration Areas where technically and economically feasible (Preferred Alternative), limiting development to one disturbance location per 640 acres in DA1 (winter concentration area) and DA 3 (PHMA) (Preferred Alternative), considering appropriate mitigation measures and COAs to reduce adverse visual	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	N/A

Row #	Resource	Impact Indicator[1]	Strategy To Avoid, Minimize, And Rectify Impacts To The Resource[2]			Residual Effects[3]	Warrant Compensatory Mitigation?[4]	Compensatory Mitigation Options to be Considered at Site-Specific Level
			Avoid[5]	Minimize[6]	Rectify/Restore[7]			
				Consider appropriate mitigation measures and COAs to reduce adverse visual impacts from the use of solar panels during the APD process (**RPM 158**) Install low profile tanks wherever visual sensitivity is an issue (**RPM 159**) Minimize or eliminate effects to viewsheds and visibility within the NPL Project area when feasible (**RPM 160**) Select locations that provide for vegetative and topographic screening (**RPM 161**) Design well sites to fit the landscape and minimize construction needs (**RPM 162**)		impacts from the use of solar panels during the APD process (RPM 158), installing low profile tanks wherever visual sensitivity is an issue (RPM 159), minimizing or eliminating effects to viewsheds and visibility within the NPL Project area when feasible (RPM 160), selecting locations that provide for vegetative and topographic screening (RPM 161), and designing well sites to fit the landscape and minimize construction needs (RPM 162). No residual effects are anticipated.		
54	Water Resources – Groundwater	Permanent removal of water from the upper Wasatch resulting in lowering of the potentiometric surface		Construct and operate all water wells according to the requirements of the Wyoming State Engineer's Office (**RPM 184**) Jonah Energy would locate new water supply wells (at surface and at depth) at sufficient distances from existing stock wells to reduce potential impacts to water quantity and quality for stock well users **(Chapter 4 – Groundwater Mitigation Measure)**	Pay a depletion fee for each acre-foot of water depletion in excess of 100 acre-feet from the Colorado River System (**RPM 252**)	Lowering of the potentiometric surface would be minimized by constructing and operating all water wells according to the requirements of the Wyoming State Engineer's Office (RPM 184) and locating new water supply wells (at surface and at depth) at sufficient distances from existing stock wells to reduce potential impacts to water quantity and quality for stock well users (Chapter 4 – Groundwater Mitigation Measure); and rectified/restored by paying a depletion fee for each acre-foot of water depletion in excess of 100 acre-feet from the Colorado River System (RPM 252). No residual effects are anticipated.	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	N/A
55	Water Resources – Groundwater	Contamination of groundwater due to well drilling and completion activities or produced water disposal		Case and cement all natural gas wells to protect subsurface mineral and freshwater zones, and promptly plug and abandon unproductive wells (**RPMs 179; 180**) Water used for drilling of the surface casing must comply with WOGCC water quality regulations (**RPM 181**) Disclose the contents of all drilling muds, drilling additives, and completions constituents prior to drilling or completions and self-report all hydraulic fracturing constituents (**RPM 182**) Implement a groundwater monitoring program in coordination with	Work with permittees, and other stakeholder communities, to disseminate aquifer and water well data and sampling results (**RPM 186**)	Contamination of groundwater due to well drilling and completion activities or produced water disposal would be minimized by casing and cementing all natural gas wells to protect subsurface mineral and freshwater zones, and promptly plug and abandon unproductive wells (RPMs 179; 180); ensuring that water used for drilling of the surface casing complies with WOGCC water quality regulations (RPM 181); disclosing the contents of all drilling muds, drilling additives, and completions constituents prior to drilling or completions and self-report all hydraulic fracturing constituents (RPM 182); implementing a groundwater monitoring program in coordination with appropriate federal, state, and local agencies (RPM 183); equipping water wells with equipment to prevent backflow and siphoning (RPM 184); installing devices to secure water wells against	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	N/A

Row #	Resource	Impact Indicator[1]	Strategy To Avoid, Minimize, And Rectify Impacts To The Resource[2]			Residual Effects[3]	Warrant Compensatory Mitigation?[4]	Compensatory Mitigation Options to be Considered at Site-Specific Level
			Avoid[5]	Minimize[6]	Rectify/Restore[7]			
				appropriate federal, state, and local agencies (**RPM 183**) Equip water wells with equipment to prevent backflow and siphoning (**RPM 184**) Install devices to secure water wells against discharge of fluids into the well (**RPM 185**) When the use of oil-based muds is planned, an intermediate casing string would be cemented in to isolate and protect any usable water zones prior to drilling with oil-based mud **(Chapter 4 – Groundwater Mitigation Measure)** Cement the entire intermediate casing from the top of the Lance Formation to surface casing. Or, for casing with annular space that is not fully cemented, protect the casing from corrosion using a cathodic protection system **(Chapter 4 – Groundwater Mitigation Measure)** Manage the drilling mud program to ensure that the proper balance of mud weight and filter cake properties is maintained to minimize fluid loss to the formations **(Chapter 4 – Groundwater Mitigation Measure)** Jonah Energy would locate new water supply wells (at surface and at depth) at sufficient distances from existing stock wells to reduce potential impacts to water quantity and quality for stock well users **(Chapter 4 – Groundwater Mitigation Measure)** Cement wells to the surface without using bentonite gout, and protect against unauthorized entry and properly plug when no longer used **(Chapter 4 – Groundwater Mitigation Measure)**		discharge of fluids into the well (RPM 185); cementing an intermediate casing string in to isolate and protect any usable water zones prior to drilling with oil-based mud when the use of oil-based muds is planned (Chapter 4 – Groundwater Mitigation Measure); cementing the entire intermediate casing from the top of the Lance Formation to surface casing, or, for casing with annular space that is not fully cemented, protect the casing from corrosion using a cathodic protection system (Chapter 4 – Groundwater Mitigation Measure); managing the drilling mud program to ensure that the proper balance of mud weight and filter cake properties is maintained to minimize fluid loss to the formations (Chapter 4 – Groundwater Mitigation Measure); locating new water supply wells (at surface and at depth) at sufficient distances from existing stock wells to reduce potential impacts to water quantity and quality for stock well users (Chapter 4 – Groundwater Mitigation Measure); and cementing wells to the surface without using bentonite gout, and protect against unauthorized entry and properly plug when no longer used (Chapter 4 – Groundwater Mitigation Measure). These same impacts would be rectified/restored by working with permittees, and other stakeholder communities, to disseminate aquifer and water well data and sampling results (RPM 186). No residual impacts are anticipated.		
56	Water Resources – Surface Water	Alterations of surface water and ephemeral drainages	Prohibit surface disturbance within 500 feet of surface waters, riparian	Implement protective measures to protect surface water resources when	Conduct successful reclamation in disturbed areas as soon as	Alterations of surface water and ephemeral drainages from road and pipeline crossings	No. There are no anticipated residual effects that warrant	N/A

Row #	Resource	Impact Indicator[1]	Strategy To Avoid, Minimize, And Rectify Impacts To The Resource[2]			Residual Effects[3]	Warrant Compensatory Mitigation?[4]	Compensatory Mitigation Options to be Considered at Site-Specific Level
			Avoid[5]	Minimize[6]	Rectify/Restore[7]			
		from road and pipeline crossings	areas, wetlands, and 100-year floodplains unless no practicable alternative exists (**RPMs 106; 174; 175**) The BLM would consider linear crossings of 100-year floodplains on a case-by-case basis and would prohibit surface disturbance within 100-year floodplains, wetlands, and riparian areas unless there is no physically practical alternative (**RPM 173**) Prohibit surface disturbance within 100 feet of the edge of intermittent and large ephemeral drainages (**RPM 176**)	working in drainage crossings (**RPMs 165-169**)	practicable (**RPM 89; 129; 141; 143; 149; Appendix C – Reclamation Plan)** Implementation of soil stabilization, erosion control, and reclamation measures (**RPMs 82-117; 148-153**) Begin reclamation of disturbed wetland areas immediately after completion of project activities (**RPM 118**) Restore disturbed streams, wetlands, and riparian areas to as near pre-project conditions as practicable (**RPM 164**) Reclaim all disturbances occurring within the high bank plus 50 feet meet the PFC standards (**RPM 169**)	would be avoided by prohibiting surface disturbance within 500 feet of surface waters, riparian areas, wetlands, and 100-year floodplains unless no practicable alternative exists (RPMs 106; 174; 175); considering linear crossings of 100-year floodplains on a case-by-case basis and prohibiting surface disturbance within 100-year floodplains, wetlands, and riparian areas unless there is no physically practical alternative (RPM 173); and prohibiting surface disturbance within 100 feet of the edge of intermittent and large ephemeral drainages (RPM 176). These same impacts would be minimized by implementing protective measures to protect surface water resources when working in drainage crossings (RPMs 165-169); and rectified/restored by conducting successful reclamation in disturbed areas as soon as practicable (RPM 89; 129; 141; 143; 149; Appendix C – Reclamation Plan); implementing soil stabilization, erosion control, and reclamation measures (RPMs 82-117; 148-153); beginning reclamation of disturbed wetland areas immediately after completion of project activities (RPM 118); restoring disturbed streams, wetlands, and riparian areas to as near pre-project conditions as practicable (RPM 164); and reclaiming all disturbances occurring within the high bank plus 50 feet meet the PFC standards (RPM 169).	compensatory mitigation. The project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	
57	Water Resources – Surface Water	Degraded surface water quality from sedimentation, turbidity and salinity		Implement soil stabilization, erosion control, and reclamation measures (**RPMs 82-117; 148-153**) The operator would engineer all surface runoff control structures and treatments for higher levels of storm intensity and duration as indicated by the KINEROS2 modeling analysis (e.g., 25-year 24-hour event) described in Appendix J (AGWA Technical Report). (**Mitigation Measure S-3**)	Conduct successful reclamation in disturbed areas as soon as practicable (**RPM 89; 129; 141; 143; 149; Appendix C – Reclamation Plan**) The intensity and distribution of the prescribed monitoring and mitigation would be determined by the initial model designations of plane or channel impacts and intensity of landscape disturbance, as described in Appendix J (AGWA Technical Report). The BLM would use new monitoring data collected by Jonah Energy during development of the NPL Project to re-parameterize the model and re-run it as necessary (e.g., KINEROS2), to aid in identifying significance thresholds, or action levels, for channel erosion and runoff/salinity increases (**Mitigation Measure S-1**)	Degradation of surface water quality from sedimentation, turbidity and salinity would be minimized by implementing soil stabilization, erosion control, and reclamation measures (RPMs 82-117; 148-153); and engineering all surface runoff control structures and treatments for higher levels of storm intensity and duration as indicated by the KINEROS2 modeling analysis (e.g., 25-year 24-hour event) described in Appendix J (AGWA Technical Report). (Mitigation Measure S-3). These same impacts would be rectified/restored by conducting successful reclamation in disturbed areas as soon as practicable (RPM 89; 129; 141; 143; 149; Appendix C – Reclamation Plan); prescribing monitoring and mitigation based on modelling channel erosion and runoff/salinity increases (Mitigation Measure S-1); implementing monitoring and mitigation measures/or other approved measures that are as rigorous and protective as recommended in the Monitoring and Mitigation tables in Section 6.3 of Appendix J (AGWA Technical Report) for those planes in the Watershed Modeling Units that exhibited a relatively substantial increase in surface runoff and discharge within the channels (Mitigation	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	N/A

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			Avoid[5]	Minimize[6]	Rectify/Restore[7]			
					Because some individual planes in the Watershed Modeling Units exhibited a relatively substantial increase in surface runoff and discharge within the channels, Jonah Energy would implement monitoring and mitigation measures/or other approved measures that are as rigorous and protective, as recommended in the Monitoring and Mitigation tables in Section 6.3 of Appendix J (AGWA Technical Report). (**Mitigation Measure S-2**) The operator would be extremely diligent in compliance monitoring of the condition of runoff control structures (e.g., after every precipitation event that resulted in any water movement off pads into detention ponds, off roads, and into wing ditches and catchments), and promptly repair any damage before the next precipitation event. (**Mitigation Measure S-4**) The operator would develop Mitigation and Monitoring Plans and Storm Water Pollution Prevention Plans for the NPL Project, which incorporate the *Technical Support Document for the Application of the Regional Framework for Water-Resources Monitoring Related to Energy Exploration and Development* (BLM 2013c) and the recommended measures for monitoring and mitigation for each of the impact categories identified in Section 6.3 of Appendix J (AGWA Technical Report). (**Mitigation Measure S-5**)	Measure S-2); being extremely diligent in compliance monitoring of the condition of runoff control structures (e.g., after every precipitation event that resulted in any water movement off pads into detention ponds, off roads, and into wing ditches and catchments), and promptly repairing any damage before the next precipitation event (Mitigation Measure S-4); and developing mitigation and Monitoring Plans and Storm Water Pollution Prevention Plans for the NPL Project (Mitigation Measure S-5). No residual effects are anticipated.		
58	Water Resources – Surface Water	Accidental spills of completions fluids, drilling fluids, and formation fluids	Adherence to all applicable laws, ordinances, and regulations governing the handing, management, and disposal of hazardous materials and solid waste (**Appendix F, *Hazardous and Non-Hazardous Materials Management Summary***)	Install shutoff valves or other systems where pipelines cross streams, cultural sites, and paleontological locales to minimize accidental discharges from pipelines (**RPM 34**) Keep SDSs on file for all chemical and hazardous materials (**RPM 35**)		Accidental spills of completions fluids, drilling fluids, and formation fluids would be avoided by adhering to all applicable laws, ordinances, and regulations governing the handing, management, and disposal of hazardous materials and solid waste (Appendix F, *Hazardous and Non-Hazardous Materials Management Summary*); and developing and	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM	N/A

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			Avoid[5]	Minimize[6]	Rectify/Restore[7]			
			Develop and maintain SPCC Plans and a SWPPP detailing prevention and response methods for hydrocarbon spills and storm water discharges (**RPM 36**)	Inventory and report on chemical and hazardous materials in accordance with applicable regulations (**RPM 37**) Work with local EMS authorities to plan for efficient emergency response (**RPMs 73-80**)		maintaining SPCC Plans and a SWPPP detailing prevention and response methods for hydrocarbon spills and storm water discharges (RPM 36). These same impacts would be minimized by installing shutoff valves or other systems where pipelines cross streams, cultural sites, and paleontological locales to minimize accidental discharges from pipelines (RPM 34); keeping SDSs on file for all chemical and hazardous materials (RPM 35); inventorying and reporting on chemical and hazardous materials in accordance with applicable regulations (RPM 37); and working with local EMS authorities to plan for efficient emergency response (RPMs 73-80). No residual effects are anticipated.	RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	
59	Wild Horses – Forage Availability	Loss of forage due to surface disturbance or avoidance of habitat		Implement appropriate mitigation to reduce impacts to wild horses and grazing in the Little Colorado HMA (**RPM 192**)	Conduct successful reclamation in disturbed areas as soon as practicable (**RPMs 89; 129; 141; 143; 149; Appendix C – Reclamation Plan**)	Loss of forage due to surface disturbance or avoidance of habitat would be minimized by implementing appropriate mitigation to reduce impacts to wild horses and grazing in the Little Colorado HMA (RPM 192) and conducting successful reclamation in disturbed areas as soon as practicable (RPMs 89; 129; 141; 143; 149; Appendix C – Reclamation Plan). No residual effects are anticipated.	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	N/A
60	Wild Horses – Vehicle Collisions	Increased risk of vehicular collisions with livestock	Avoid the creation of new two-track roads (**RPM 139**)	Post appropriate road warning signs and support the enforcement of speed limits (**RPM 135**) Use content and recommendations in the NPL transportation plan to guide safe and efficient transportation (**RPM 136**) Work with the BLM to enforce speed limits and other road regulations (**RPM 137**)		Risk of vehicular collisions with livestock would be avoided by avoiding the creation of two-track roads (RPM 139); and minimized by posting appropriate road warning signs and support the enforcement of speed limits (RPM 135), using content and recommendations in the NPL transportation plan to guide safe and efficient transportation (RPM 136), and working with the BLM to enforce speed limits and other road regulations (RPM 137). No residual effects are anticipated.	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	N/A
61	Wildlife – Amphibians and Reptiles	Direct loss of suitable habitat	Prohibit surface disturbance within 500 feet of surface waters, riparian areas, wetlands, and 100-year floodplains unless no practicable alternative exists (**RPMs 106; 174; 175**)	Implement soil stabilization, erosion control, and reclamation measures (**RPMs 82-117; 148-153**)	Conduct successful reclamation in disturbed areas as soon as practicable (**RPMs 89; 129; 141; 143; 149; Appendix C – Reclamation Plan**)	Direct loss of suitable habitat for amphibians and reptiles would be avoided by prohibiting surface disturbance within 500 feet of surface waters, riparian areas, wetlands, and 100-year floodplains unless no practicable alternative exists (RPMs 106; 174; 175); considering linear crossings of 100-year floodplains on a case-by-	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource	N/A

Row #	Resource	Impact Indicator[1]	Strategy To Avoid, Minimize, And Rectify Impacts To The Resource[2]			Residual Effects[3]	Warrant Compensatory Mitigation?[4]	Compensatory Mitigation Options to be Considered at Site-Specific Level
			Avoid[5]	Minimize[6]	Rectify/Restore[7]			
			The BLM would consider linear crossings of 100-year floodplains on a case-by-case basis and would prohibit surface disturbance within 100-year floodplains, wetlands, and riparian areas unless there is no physically practical alternative (**RPM 173**) Prohibit surface disturbance within 100 feet of the edge of intermittent and large ephemeral drainages (**RPM 176**) Record incidental observations of amphibian and reptile species encountered during site-specific wildlife surveys during the APD process (**RPM 244**)		If amphibian habitat cannot be avoided, the operator will work with the BLM and WGFD to determine appropriate protection buffers, mitigation, and monitoring (**RPM 245**)	case basis and would prohibit surface disturbance within 100-year floodplains, wetlands, and riparian areas unless there is no physically practical alternative (RPM 173); prohibiting surface disturbance within 100 feet of the edge of intermittent and large ephemeral drainages (RPM 176); and recording incidental observations of amphibian and reptile species encountered during site-specific wildlife surveys during the APD process (RPM 244). These same impacts would be minimized by implementing soil stabilization, erosion control, and reclamation measures (RPMs 82-117; 148-153); and rectified/restored by conducting successful reclamation in disturbed areas as soon as practicable (RPMs 89; 129; 141; 143; 149; Appendix C – Reclamation Plan) and, if amphibian habitat cannot be avoided, working with the BLM and WGFD to determine appropriate protection buffers, mitigation, and monitoring (RPM 245). No residual effects are anticipated.	objectives in applicable BLM RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	
62	Wildlife – Big Game	Surface disturbance and habitat fragmentation could result in changes in floral species composition and an increase in invasive species that affects the quality and quantity of big game habitat		Implement measures to prevent colonization or control the spread of invasive species and noxious weeds (**RPMs 95, 142-147**)	Implement soil stabilization, erosion control, and reclamation measures (**RPMs 82-117; 148-153**)	Surface disturbance and habitat fragmentation that affects the quality and quantity of big game habitat would be minimized by measures to prevent colonization or control the spread of invasive species and noxious weeds (RPM 95, 142-147); and restored with soil stabilization, erosion control, and reclamation measures (RPMs 82-117; 148-153). Although some risk of impacts to big game habitat quality and quantity remains, the residual effects would not affect habitats of known importance for sustaining big game population life-cycles (except pronghorn, which are addressed separately).	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	N/A
63	Wildlife – Big Game	Increased risk of mortalities from vehicle collisions due to the development of new access roads and increased traffic		Post appropriate road warning signs and support the enforcement of speed limits (**RPM 135**) Use remote telemetry and SCADA technology to reduce vehicle trips and human presence for well monitoring and control during production activities (**RPM 2; 121**)	Close and reclaim unnecessary roads to reduce fragmentation and restore habitat integrity (**RPM 141**)	Increased risk of mortalities from vehicle collisions due to the development of new access roads and increased traffic would be minimized by posting appropriate road warning signs and supporting the enforcement of speed limits (RPM 135) and by using remote telemetry and SCADA technology to reduce vehicle trips and human presence for well monitoring and control during production activities (RPM 2; 121); and rectified and restored by closing and reclaiming unnecessary roads, reducing fragmentation and restoring habitat integrity (RPM 141). Some risk of mortality remains, but these residual effects	No. These residual impacts would not inhibit achieving the Pinedale RMP objectives for big game habitat management. Additionally, these residual impacts would not inhibit achieve compliance with laws and/or policies and are not to resources that are considered important, scarce, sensitive or have a protective legal mandate that have been previously identified in a mitigation strategy or through	N/A

Row #	Resource	Impact Indicator[1]	Strategy To Avoid, Minimize, And Rectify Impacts To The Resource[2]			Residual Effects[3]	Warrant Compensatory Mitigation?[4]	Compensatory Mitigation Options to be Considered at Site-Specific Level
			Avoid[5]	Minimize[6]	Rectify/Restore[7]			
						would be unlikely to occur with high frequency or regularity..	a NEPA process as warranting compensatory mitigation.	
64	Wildlife – Big Game	Exposure to or incidental ingestion of the various hazardous and non-hazardous materials associated with the project	Implement spill prevention and cleanup measures (**RPM 36**) Jonah Energy would not use any open reserve pits (**Preferred Alternative**)	Install well pad perimeter fencing (**RPM 39**) Work with permittees and the BLM to identify wildlife-friendly fencing initiatives (**RPM 203**) All fences should be wildlife friendly (**RPM 204**)		Exposure to or incidental ingestion of the various hazardous and non-hazardous materials associated with the project would be avoided with the implementation of spill prevention and cleanup measures (RPM 36) and Jonah Energy's commitment to not use any open reserve pits (Preferred Alternative); and minimized by installing well pad perimeter fencing (RPM 39), working with permittees and the BLM to identify wildlife-friendly fencing initiatives (RPMs 203, 204). No residual effects are anticipated.	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	N/A
65	Wildlife – Big Game	Project-related activity that degrades migration routes or reduces the potential for pronghorn to migrate to or through the NPL Project Area.	Preservation of migration routes through coordination between Jonah Energy, BLM, WGFD, and other stakeholders, and avoidance of activities and facilities that create barriers to big game movement (**RPMs 194; 195**)	Implement soil stabilization, erosion control, and reclamation measures (**RPMs 82-117; 148-153**) Limit of one disturbance location per 640 acres in DA1 (winter concentration area) and DA 3 (PHMA) (**Preferred Alternative**) Limit of one disturbance location per 640 acres in PHMA; limit cumulative value of existing disturbances to not exceed 5 percent of suitable habitat of the DDCT area (**RPM 206**)	Conduct successful reclamation in disturbed areas as soon as practicable (**RPMs 89; 129; 141; 143; 149; Appendix C – Reclamation Plan**)	Degradation of migration routes or reduction of the potential for pronghorn to migrate to or through the NPL Project Area would be avoided by preservation of migration routes through coordination between Jonah Energy, BLM, WGFD, and other stakeholders, and avoidance of activities and facilities that create barriers to big game movement (RPMs 194; 195); minimized by implementing soil stabilization, erosion control, and reclamation measures (RPMs 82-117; 148-153), limiting development to one disturbance location per 640 acres in DA1 (winter concentration area) and DA 3 (PHMA) (Preferred Alternative), and limiting the cumulative value of disturbances in PHMA to not exceed 5 percent of suitable habitat of the DDCT area (RPM 206); and restored by conducting successful reclamation in disturbed areas as soon as practicable (RPMs 89; 129; 141; 143; 149; Appendix C – Reclamation Plan). However, residual effects to big game species could still occur, especially in DA 2 which would have the highest density of development and overlaps pronghorn crucial winter range and migration routes. Degradation of seasonal habitat and disruptions in migratory routes are of particular concern for pronghorn due to existing/ongoing disturbance in crucial winter range in surrounding areas (e.g., in JIDPA) and the presence of migration routes that connect pronghorn crucial winter range and other pronghorn habitats in the analysis area and the region.	Project-related activity that degrades migration routes or reduces the potential for pronghorn to migrate to or through the NPL Project Area represents a residual effect to a resource that is considered important, scarce, sensitive, or has a protective legal mandate that is identified through this NEPA process as warranting compensatory mitigation.	• Barrier modification/removal (e.g., fences, structures, river crossing improvements, etc.). • Habitat improvement/restoration (e.g. habitat treatments, weed removal, mowing projects, well projects, etc.). • Highway/road crossing improvements. • Mitigation banking. • Inventory and monitoring of pronghorn migration routes to inform appropriate compensatory mitigation during site-specific APD process. Refer to Section 4.24 (*Compensatory Mitigation*) in the NPL EIS for additional information on compensatory mitigation.
66	Wildlife – Big Game	Project-related activity that removes or degrades pronghorn crucial winter range in the Project Area or	Preservation of migration routes through coordination between Jonah Energy, BLM, WGFD, and other stakeholders, and avoidance of	Limit of one disturbance location per 640 acres in DA1 which overlaps 3,838 acres of pronghorn crucial winter range (**Preferred Alternative**).	Conduct successful reclamation in disturbed areas as soon as practicable (**RPMs 89; 129; 141;**	Removal or degradation of pronghorn crucial winter range in the Project Area or reduction of pronghorn access to crucial winter range would be avoided by preservation of migration routes	Project-related activity that removes or degrades pronghorn crucial winter range in the Project Area or project	• Barrier modification/removal (e.g. fences, structures, etc.).

Row #	Resource	Impact Indicator[1]	Strategy To Avoid, Minimize, And Rectify Impacts To The Resource[2]			Residual Effects[3]	Warrant Compensatory Mitigation?[4]	Compensatory Mitigation Options to be Considered at Site-Specific Level
			Avoid[5]	Minimize[6]	Rectify/Restore[7]			
		project-related activity that reduces pronghorn access to crucial winter range.	activities and facilities that create barriers to big game movement (**RPMs 194; 195**) To protect important big game winter habitat, Jonah Energy's activities or surface use will not be allowed from November 15 to April 30 within certain areas encompassed by the authorization. The same criteria apply to defined big game birthing areas from May 1 to June 30 **(RPM 193)** Jonah Energy will avoid activities and facilities that create barriers to the seasonal movements of big game and livestock **(RPM 195)** Activities by Jonah Energy, in crucial habitats will be avoided when practicable **(RPM 196)**	Surface disturbance threshold of 5 percent disturbance (32 acres) per 640 acre area within Sage-Grouse Winter Concentration Areas which overlaps a portion of pronghorn crucial winter range **(Preferred Alternative)**.	**143; 149; Appendix C – Reclamation Plan**)	through coordination between Jonah Energy, BLM, WGFD, and other stakeholders, and avoidance of activities and facilities that create barriers to big game movement (RPMs 194; 195) and not allowing Jonah Energy's activities or surface use from November 15 to April 30 within certain areas encompassed by the authorization (RPM 193), by Jonah Energy avoiding activities and facilities that create barriers to the seasonal movements of big game and livestock (RPM 195), and by Jonah Energy, avoiding activities in crucial habitats when practicable (RPM 196). These same impacts would be minimized by limiting development to one disturbance location per 640 acres in DA1 which overlaps 3,838 acres of pronghorn crucial winter range (Preferred Alternative), applying a surface disturbance threshold of 5 percent disturbance (32 acres) per 640 acre area within Sage-Grouse Winter Concentration Areas which overlaps a portion of pronghorn crucial winter range (Preferred Alternative), and restored by conducting successful reclamation in disturbed areas as soon as practicable (RPMs 89; 129; 141; 143; 149; Appendix C – Reclamation Plan). However, residual impacts to big game species could still occur, especially in DA 2 which would have the highest density of development and overlaps pronghorn crucial winter range and migration routes. Degradation of seasonal habitat and disruptions in migratory routes are of particular concern for pronghorn due to existing/ongoing disturbance in crucial winter range in surrounding areas (e.g., in JIDPA) and the presence of migration routes that connect pronghorn crucial winter range and other pronghorn habitats in the analysis area and the region.	activity that reduces pronghorn access to crucial winter range represents a residual effect to a resource that is considered important, scarce, sensitive, or has a protective legal mandate that is identified through this NEPA process as warranting compensatory mitigation.	• Habitat improvement/restoration (e.g. habitat treatments, weed removal, mowing projects, well projects, etc.). • Mitigation banking. • Inventorying and monitoring of pronghorn crucial winter range to inform appropriate compensatory mitigation during site-specific APD process. Refer to Section 4.24 (*Compensatory Mitigation*) in the NPL EIS for additional information on compensatory mitigation.
67	Wildlife – Fisheries – Colorado River Fish Species	Indirect impacts on fish and fisheries from project-related activities that increase erosion and result in increased sedimentation and salinity of surface waters downstream from the Project Area	Prohibit surface disturbance within 500 feet of surface waters, riparian areas, wetlands, and 100-year floodplains unless no practicable alternative exists (**RPM 106; 174; 175**) The BLM would consider linear crossings of 100-year floodplains on a case-by-case basis and would prohibit surface disturbance within 100-year floodplains, wetlands, and riparian areas unless there is no physically practical alternative (**RPM 173**)	Implement soil stabilization, erosion control, and reclamation measures (**RPMs 82-117; 148-153**) Construct and operate all water wells according to the requirements of the Wyoming State Engineer's Office (**RPM 184**) Assess the potential for erosion and sedimentation loading to Wyoming State Wildlife Action Plan (SWAP) Tier 1 fish species habitat in the Green River and Big Sandy River, and identify appropriate BMPs (**RPMs 243**)	Conduct successful reclamation in disturbed areas as soon as practicable (**RPMs 89; 129; 141; 143; 149; Appendix C – Reclamation Plan**) If amphibian habitat cannot be avoided, the operator will work with the BLM and WGFD to determine appropriate protection buffers, mitigation, and monitoring (**RPM 245**) Pay a depletion fee for each acre-foot of water depletion in excess	Indirect impacts on Colorado River Fish Species from project-related activities would be avoided by prohibiting surface disturbance within 500 feet of surface waters, riparian areas, wetlands, and 100-year floodplains unless no practicable alternative exists (RPM 106; 174; 175); considering linear crossings of 100-year floodplains on a case-by-case basis and would prohibit surface disturbance within 100-year floodplains, wetlands, and riparian areas unless there is no physically practical alternative (RPM 173); prohibiting surface disturbance within 100 feet of the edge of intermittent and large ephemeral drainages (RPM 176); and recording incidental observations of amphibian and reptile	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA	N/A

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			Avoid[5]	Minimize[6]	Rectify/Restore[7]			
			Prohibit surface disturbance within 100 feet of the edge of intermittent and large ephemeral drainages (**RPM 176**) Record incidental observations of amphibian and reptile species encountered during site-specific wildlife surveys during the APD process (**RPM 244**)		of 100 acre-feet from the Colorado River System (**RPM 252**)	species encountered during site-specific wildlife surveys during the APD process (RPM 244). These same impacts would be minimized by implementing soil stabilization, erosion control, and reclamation measures (RPMs 82-117; 148-153); constructing and operating all water wells according to the requirements of the Wyoming State Engineer's Office (RPM 184); and assessing the potential for erosion and sedimentation loading to Wyoming State Wildlife Action Plan (SWAP) Tier 1 fish species habitat in the Green River and Big Sandy River, and identify appropriate BMPs (RPMs 243). The impacts would be rectified/restored by conducting successful reclamation in disturbed areas as soon as practicable (RPMs 89; 129; 141; 143; 149; Appendix C – Reclamation Plan); working with the BLM and WGFD to determine appropriate protection buffers, mitigation, and monitoring if amphibian habitat cannot be avoided (RPM 245); and paying a depletion fee for each acre-foot of water depletion in excess of 100 acre-feet from the Colorado River System (RPM 252). No residual effects are anticipated.	process as warranting compensatory mitigation.	
68	Wildlife - Fisheries (including Flannelmouth Sucker)	Indirect impacts on fish and fisheries from project-related activities that increase erosion and result in increased sedimentation and salinity of surface waters downstream from the Project Area	Prohibit surface disturbance within 500 feet of surface waters, riparian areas, wetlands, and 100-year floodplains unless no practicable alternative exists (**RPM 106; 174; 175**) The BLM would consider linear crossings of 100-year floodplains on a case-by-case basis and would prohibit surface disturbance within 100-year floodplains, wetlands, and riparian areas unless there is no physically practical alternative (**RPM 173**) Prohibit surface disturbance within 100 feet of the edge of intermittent and large ephemeral drainages (**RPM 176**)	Implement soil stabilization, erosion control, and reclamation measures (**RPMs 82-117; 148-153**) Construct and operate all water wells according to the requirements of the Wyoming State Engineer's Office (**RPM 184**) Assess the potential for erosion and sediment loading to Wyoming State Wildlife Action Plan (SWAP) Tier 1 fish species habitat in the Green River and Big Sandy River, and identify appropriate BMPs (**RPMs 243**)	Conduct successful reclamation in disturbed areas as soon as practicable (**RPM 89; 129; 141; 143; 149; Appendix C – Reclamation Plan**) Pay a depletion fee for each acre-foot of water depletion in excess of 100 acre-feet from the Colorado River System (**RPM 252**)	Indirect impacts on fisheries from project-related activities would be avoided by prohibiting surface disturbance within 500 feet of surface waters, riparian areas, wetlands, and 100-year floodplains unless no practicable alternative exists (RPM 106; 174; 175); considering linear crossings of 100-year floodplains on a case-by-case basis and prohibiting surface disturbance within 100-year floodplains, wetlands, and riparian areas unless there is no physically practical alternative (RPM 173); and prohibiting surface disturbance within 100 feet of the edge of intermittent and large ephemeral drainages (RPM 176). These same impacts would be minimized by implementing oil stabilization, erosion control, and reclamation measures (RPMs 82-117; 148-153); constructing and operating all water wells according to the requirements of the Wyoming State Engineer's Office (RPM 184); and assessing the potential for erosion and sediment loading to Wyoming State Wildlife Action Plan (SWAP) Tier 1 fish species habitat in the Green River and Big Sandy River, and identify appropriate BMPs (RPMs 243). The impacts would be rectified/restored by conducting successful reclamation in disturbed areas as soon as practicable (RPM 89; 129; 141; 143; 149; Appendix C – Reclamation Plan) and paying a depletion fee for each acre-foot of water depletion in excess of 100 acre-feet from the Colorado River System (RPM 252). No residual effects are anticipated.	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	N/A

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			Avoid[5]	Minimize[6]	Rectify/Restore[7]			
69	Wildlife – Gray Wolf	Potential direct and indirect impacts to gray wolf and their habitat.				Gray wolf has not been documented and is unlikely to occur within the analysis area. As a result, there are no anticipated direct/indirect impacts or residual impacts to gray wolf.	No residual effects are anticipated. Therefore, compensatory mitigation is not warranted.	N/A
70	Wildlife – Greater Sage-Grouse	Increases in accidental mortality due to increased vehicle traffic	Avoid the construction of new local or collector roads within 1.9 miles of leks in PHMAs; prohibit all new roads within 0.6 miles of leks in PHMA (**RPM 217**)	Post appropriate road warning signs and support the enforcement of speed limits (**RPM 135**) Do not upgrade existing routes in PHMA unless the activity would minimally impact Sage-Grouse, is necessary for safety, or eliminates the need to construct a new road (**RPM 218**) Use existing roads or realignments to access federal oil and gas leases that are not yet developed in PHMA. Any new road will be constructed to the absolute minimum standard necessary (**RPM 219**) Prohibit heavy truck traffic within 2-mile Sage-Grouse lek buffers between the hours of 6:00 p.m. and 8:00 a.m. during Sage-Grouse mating season (**Mitigation Measure N-1**)		Increases in accidental mortality due to increased vehicle traffic would be avoided by avoiding the construction of new local or collector roads within 1.9 miles of leks in PHMAs and prohibiting all new roads within 0.6 miles of leks in PHMA (RPM 217). These same impacts would be minimized by posting appropriate road warning signs and support the enforcement of speed limits (RPM 135); not upgrading existing routes in PHMA unless the activity would minimally impact Sage-Grouse, is necessary for safety, or eliminates the need to construct a new road (RPM 218); using existing roads or realignments to access federal oil and gas leases that are not yet developed in PHMA and constructing any new road to the absolute minimum standard necessary (RPM 219); and prohibiting heavy truck traffic within 2-mile Sage-Grouse lek buffers between the hours of 6:00 p.m. and 8:00 a.m. during Sage-Grouse mating season (Mitigation Measure N-1). No residual effects are anticipated.	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	N/A
71	Wildlife – Greater Sage-Grouse	Increases in accidental mortality due to equipment such as tanks containing freestanding liquids, chemical tank secondary containment, and other hazards	Jonah Energy would not use any open reserve pits (**Preferred Alternative**) Implement spill prevention and cleanup measures (**RPM 36**) All new production facilities that have open-vent exhaust stacks will be equipped to prevent bird and bat entry or perching on the stack (**RPM 237**)			Increases in accidental mortality due to equipment such as tanks containing freestanding liquids, chemical tank secondary containment, and other hazards would be avoided by not using open reserve pits (Preferred Alternative), implementing spill prevention and cleanup measures (RPM 36), and equipping all new production facilities that have open-vent exhaust stacks to prevent bird and bat entry or perching on the stack (RPM 237). No residual effects are anticipated.	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	N/A
72	Wildlife – Greater Sage-Grouse	Increases in accidental mortality due to collisions or entrapment in wire exclosure fences for well pads or production facilities and associated ROWs		Minimize ROW fencing. Fence design must be approved by the WGFD and meet BLM fencing standards for facilitating wildlife movement (**RPM 202**)		Increases in accidental mortality due to collisions or entrapment in wire exclosure fences for well pads or production facilities and associated ROWs would be minimized by minimizing ROW fending and using fence designs approved by the WGFD and meet BLM fencing standards for facilitating wildlife movement (RPM 202), and working with permittees and the BLM to identify	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM	N/A

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			Avoid[5]	Minimize[6]	Rectify/Restore[7]			
				Work with permittees and the BLM to identify wildlife-friendly fencing initiatives (**RPM 203**) All fences should be wildlife friendly (**RPM 204**)		wildlife-friendly fencing initiatives (RPMs 203, 204). Note: *The BLM considered applying a mitigation measure requiring the Installation of fence markers to enhance the visibility of fences to Sage-Grouse. This potential measure was supported by research conducted by Stevens et al. (2012), which found that the use of fence markers would reduce collisions by up to 83 percent. The BLM determined that this measure was not necessary because fence design would be determined at the site-specific level pending assessment and analysis of sage-grouse impacts.*	RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	
73	Wildlife – Greater Sage-Grouse	Decrease in Sage-Grouse chick survival rates close to development and production activities		Limit of one disturbance location per 640 acres in DA1 (winter concentration area) and DA 3 (PHMA) (**Preferred Alternative**) Within Winter Concentration Areas, surface disturbance would not exceed 20 acres (5 percent) surface disturbance per 640 acres, inclusive of existing disturbance (**Preferred Alternative)** Above-ground facilities would be centralized to locations outside of Winter Concentration Areas, where technically and economically feasible (**Preferred Alternative)**. Limit of one disturbance location per 640 acres in PHMA; limit cumulative value of existing disturbances to not exceed 5 percent of suitable habitat of the DDCT area (**RPM 206)** Seasonal timing limitation from March 15 – June 30 prohibiting surface-disturbing and disruptive activities throughout PHMAs and within 2 miles of leks outside PHMAs to protect breeding, nesting, and early brood-rearing habitat (**RPMs 209; 210)** Use remote telemetry and SCADA technology to reduce vehicle trips and human presence for well monitoring and control during production activities (**RPMs 2; 121)**	Conduct successful reclamation in disturbed areas as soon as practicable (**RPMs 89; 129; 141; 143; 149; Appendix C – Reclamation Plan**)	Decreases in Sage-Grouse chick survival rates close to development and production activities would be minimized by limiting development to one disturbance location per 640 acres in DA1 (winter concentration area) and DA 3 (PHMA) (Preferred Alternative), limiting the cumulative value of disturbances to not exceed 5 percent of suitable habitat in a DDCT area (RPM 206), applying a surface disturbance threshold of 20 acres (5 percent) per 640 acres in Winter Concentration Areas (Preferred Alternative), centralizing above-ground facilities outside of Winter Concentration Areas where technically and economically feasible (Preferred Alternative), applying a seasonal timing limitation from March 15 – June 30 prohibiting surface-disturbing and disruptive activities throughout PHMAs and within 2 miles of leks outside PHMAs (RPMs 209; 210), and using remoted telemetry and SCADA technology to reduce vehicle trips and human presence for well monitoring and control during production activities (RPMs 2; 121). These same impacts would be rectified/restored by conducting successful reclamation in disturbed areas as soon as practicable (RPMs 89; 129; 141; 143; 149; Appendix C – Reclamation Plan). No residual effects are anticipated.	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	N/A
74	Wildlife – Greater Sage-Grouse	Surface disturbance, vegetation clearing, and other project-related activity during the development phase and long-term facilities that	Prohibit surface occupancy and surface-disturbing activities within 0.6 miles of occupied Sage-Grouse leks in PHMA and within 0.25 mile of leks outside PHMA (**RPMs 207; 208**)	Limit of one disturbance location per 640 acres in DA1 (winter concentration area) and DA 3 (PHMA) (**Preferred Alternative**)	Conduct successful reclamation in disturbed areas as soon as practicable (**RPMs 89; 129; 141; 143; 149; Appendix C – Reclamation Plan**)	Habitat loss and degradation in PHMA and Winter Concentration Areas would be avoided by prohibiting surface occupancy and surface-disturbing activities within 0.6 miles of occupied Sage-Grouse leks in PHMA and within 0.25 mile of leks outside PHMA (RPMs 207; 208) and	Project-related activity that decreases the quantity and quality of Sage-Grouse habitat in PHMA and Winter Concentration Areas represents a residual effect to	• Inventory and monitoring of Sage-Grouse PHMA and Winter Concentration Areas to better understand the habitat and inform appropriate compensatory

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			Avoid[5]	Minimize[6]	Rectify/Restore[7]			
		would persist throughout the duration of the production phase (e.g., RGFs) would decrease the quantity and quality of Sage-Grouse habitat in PHMA and Winter Concentration Areas in the analysis area.	New local or collector roads) will be avoided within 1.9 miles of the perimeter of occupied Sage-Grouse leks within PHMAs. All new roads will be prohibited within 0.6 miles of the perimeter of occupied Sage-Grouse leks within PHMA **(RPM 217)**	Within Winter Concentration Areas, surface disturbance would not exceed 20 acres (5 percent) surface disturbance per 640 acres, inclusive of existing disturbance (**Preferred Alternative)** Above-ground facilities would be centralized to locations outside of Winter Concentration Areas, where technically and economically feasible (**Preferred Alternative)** Within Winter Concentration Areas development would be phased from east to west (**Preferred Alternative)** Limit of one disturbance location per 640 acres in PHMA; limit cumulative value of existing disturbances to not exceed 5 percent of suitable habitat of the DDCT area (**RPM 206)** Seasonal timing limitation from March 15 – June 30 prohibiting surface-disturbing and disruptive activities throughout PHMAs and within 2 miles of leks outside of PHMAs to protect breeding, nesting, and early brood-rearing habitat (**RPMs 209; 210)** Prohibit surface-disturbing and disruptive activities in Sage-Grouse winter concentration areas from December 1 – March 14 (**RPM 211**) Use existing roads or realignments to access federal oil and gas leases that are not yet developed in PHMA. Any new road will be constructed to the absolute minimum standard necessary (**RPM 219**)		avoiding new local or collector roads) within 1.9 miles of the perimeter of occupied Sage-Grouse leks within PHMAs. All new roads will be prohibited within 0.6 miles of the perimeter of occupied Sage-Grouse leks within PHMA (RPM 217); minimized by limiting development to one disturbance location per 640 acres in DA1 (winter concentration area) and DA 3 (PHMA) (Preferred Alternative), limiting surface disturbance to not exceed 20 acres (5 percent) per 640 acres (Preferred Alternative), centralizing above-ground facilities to locations outside of Winter Concentration Areas where technically and economically feasible (Preferred Alternative), phasing development from east to west within Winter Concentration Areas (Preferred Alternative), limiting development to one disturbance location per 640 acres in PHMA, and limiting the cumulative value of disturbances in PHMA to not exceed 5 percent of suitable habitat of the DDCT area (RPM 206); prohibiting surface-disturbing and disruptive activities throughout PHMAs and within 2 miles of leks outside of PHMA from March 15 – June 30 (RPMs 209; 210), prohibiting surface-disturbing and disruptive activities in Sage-Grouse winter concentration areas from December 1 – March 14 (RPM 211), and using existing roads or realignments to access federal oil and gas leases that are not yet developed in PHMA and constructing new roads to the absolute minimum standard necessary (RPM 219); and rectified/restored by conducting successful reclamation in disturbed areas as soon as practicable (RPMs 89; 129; 141; 143; 149; Appendix C – Reclamation Plan).	a resource that is considered important, scarce, sensitive, or has a protective legal mandate that has been identified as warranting compensatory mitigation.	mitigation during site-specific permitting. • Barrier (e.g. fences) modification/removal. • Raptor perching/nesting structure modification/removal. • Highway/road crossing improvements. • Habitat improvement/restoration (e.g. habitat treatments, weed removal, mowing projects, well enhancement projects, active head-cut restoration, springs and reservoir fencing; identification of functioning reservoirs, etc.). • Mitigation banking. Refer to Section 4.24 (*Compensatory Mitigation*) in the NPL EIS for additional information on compensatory mitigation.
75	Wildlife – Greater Sage-Grouse	Surface disturbance, vegetation clearing, and other project-related activity during the development phase and project facilities that would persist during the duration of the production phase (e.g., RGFs) would decrease the quantity and quality of Sage-Grouse wintering	Prohibit surface occupancy and surface-disturbing activities within 0.25 miles of leks outside PHMA (**RPM 208**) New local or collector roads) will be avoided within 1.9 miles of the perimeter of occupied Sage-Grouse leks within PHMAs. All new roads will be prohibited within 0.6 miles of the	Limit of one disturbance location per 640 acres in DA1 (winter concentration area) and DA 3 (PHMA) (**Preferred Alternative**) Within Winter Concentration Areas, surface disturbance would not exceed 20 acres (5 percent) surface disturbance per 640 acres, inclusive of existing disturbance (**Preferred Alternative)**	Conduct successful reclamation in disturbed areas as soon as practicable (**RPMs 89; 129; 141; 143; 149; Appendix C – Reclamation Plan)**	Habitat loss and degradation in Sage Grouse wintering habitats not delineated as Winter Concentration Areas would be avoided by prohibiting surface occupancy and surface-disturbing activities within 0.25 mile of leks outside PHMA (RPM 208); minimized by protecting additional mapped winter concentration areas in GHMA if conditions warrant (RPM 211); and rectified/restored by conducting successful reclamation in disturbed	Habitat loss and degradation in Sage-Grouse wintering in areas that are outside of delineated Winter Concentration Areas, and not afforded the same protection measures as delineated Winter Concentration Areas, represents a residual effect to a resource that is considered important, scarce, sensitive, or	• Inventory and monitoring of sage-grouse wintering habitats (not currently WCA) within the RSFO and PFO to further identify and refine boundaries, in order to propose those that qualify for designation as Winter Concentration Areas.

Row #	Resource	Impact Indicator[1]	Strategy To Avoid, Minimize, And Rectify Impacts To The Resource[2]			Residual Effects[3]	Warrant Compensatory Mitigation?[4]	Compensatory Mitigation Options to be Considered at Site-Specific Level
			Avoid[5]	Minimize[6]	Rectify/Restore[7]			
		habitats not delineated as Winter Concentration Areas.	perimeter of occupied Sage-Grouse leks within PHMA **(RPM 217)**	Above-ground facilities would be centralized to locations outside of Winter Concentration Areas, where technically and economically feasible (**Preferred Alternative)** Within Winter Concentration Areas development would be phased from east to west (**Preferred Alternative)** Limit of one disturbance location per 640 acres in PHMA; limit cumulative value of existing disturbances to not exceed 5 percent of suitable habitat of the DDCT area (**RPM 206)** Seasonal timing limitation from March 15 – June 30 prohibiting surface-disturbing and disruptive activities throughout PHMAs and within 2 miles of leks outside of PHMAs to protect breeding, nesting, and early brood-rearing habitat (**RPMs 209, 210)** Prohibit surface-disturbing and disruptive activities in Sage-Grouse winter concentration areas from December 1 – March 14; protect additional mapped winter concentration areas in GHMA if conditions warrant (**RPM 211**)		areas as soon as practicable (RPMs 89; 129; 141; 143; 149; Appendix C – Reclamation Plan).	has a protective legal mandate that has been identified as warranting compensatory mitigation.	• Increased data collection (e.g., wintering flights and counts) throughout the UGRB to better understand Sage-Grouse use of wintering areas and to inform appropriate future delineation of additional Winter Concentration Areas. Refer to Section 4.24 (*Compensatory Mitigation*) in the NPL EIS for additional information on compensatory mitigation.
76	Wildlife – Greater Sage-Grouse	Due to the acreage of Sage-Grouse PHMA and Winter Concentration Areas in the Project Area, RGFs may need to be located within PHMA and Winter Concentration Areas to effectively service well pads located in these areas. Locating RGFs within Sage-Grouse PHMA and Winter Concentration Areas could result in adverse impacts to Sage-Grouse resulting from direct mortality, surface disturbance, and increased human and project-related activity associated with these facilities.	To avoid potentially significant noise impacts, locate compressor engines 2,500 feet or more from a dwelling, residence, or sage-grouse lek (**RPM 61**)	Buried pipelines would be required to transport produced water and condensate from RGFs within Winter Concentration Areas and PHMA to RGFs outside of these areas. Products would then be trucked out from RGFs outside of PHMA and Winter Concentration Areas (**Preferred Alternative)** Limit of one disturbance location per 640 acres in PHMA; limit cumulative value of existing disturbances to not exceed 5 percent of suitable habitat of the DDCT area (**RPM 206)** Prohibit surface occupancy and surface-disturbing activities within 0.6 miles of occupied Sage-Grouse leks in PHMA and within 0.25 miles of leks outside PHMA (**RPMs 207; 208**) Seasonal timing limitation from March 15 – June 30 prohibiting surface-disturbing and disruptive activities		Impacts to Sage-Grouse from locating RGFs in PHMA or Winter Concentration Areas would be avoided by locating compressor engines 2,500 feet or more from a dwelling, residence, or sage-grouse lek (RPM 61). These same impacts would be minimized by requiring the use of buried pipelines to transport produced water and condensate from RGFs within Winter Concentration Areas and PHMA to RGFs outside of these areas (Preferred Alternative); limiting development to one disturbance location per 640 acres in PHMA and limiting the cumulative value of disturbances in PHMA to not exceed 5 percent of suitable habitat of the DDCT area (RPM 206); prohibiting surface occupancy and surface-disturbing activities within 0.6 miles of occupied Sage-Grouse leks in PHMA and within 0.25 mile of leks outside PHMA (RPMs 207; 208); prohibiting surface-disturbing and disruptive activities throughout PHMAs from March 15 – June 30 (RPM 209); and limiting new project noise levels, either individual or cumulative, should not exceed 10 dBA (as measured by L50) above baseline noise at the perimeter of the lek	The BLM Wyoming Sage-Grouse RMP Amendments indicate that liquid gathering facilities should be placed outside Sage-Grouse priority areas. As a result, compensatory mitigation is warranted to conform with applicable BLM RMP resource objectives/guidance and to address residual impacts to an important resource (i.e., Sage-Grouse and their habitat).	• Application of compensatory mitigation options for decreased quantity and quality of habitat as described above. • Additional baseline noise monitoring and inventory within PHMA to better understand ambient noise levels, the existing noise/sound environment in the Project Area, and to inform appropriate development and compensatory mitigation during site-specific permitting. • Installation of noise dampening devices on facilities within PHMA and Winter Concentration Areas.

Row #	Resource	Impact Indicator[1]	Strategy To Avoid, Minimize, And Rectify Impacts To The Resource[2]			Residual Effects[3]	Warrant Compensatory Mitigation?[4]	Compensatory Mitigation Options to be Considered at Site-Specific Level
			Avoid[5]	Minimize[6]	Rectify/Restore[7]			
				throughout PHMAs to protect breeding, nesting, and early brood-rearing habitat (**RPM 209**) New project noise levels, either individual or cumulative, should not exceed 10 dBA (as measured by L50) above baseline noise at the perimeter of the lek from 6:00 p.m. to 8:00 a.m. during the breading season (March 1 – May 15) (**RPM 212**)		from 6:00 p.m. to 8:00 a.m. during the breading season (March 1 – May 15) (RPM 212).		Refer to Section 4.24 (*Compensatory Mitigation*) for additional information on compensatory mitigation.
77	Wildlife – Greater Sage-Grouse	Increased avoidance by and displacement of Sage-Grouse individuals or groups from suitable habitat proximate to development due to lighting, during both the development phase and the production phase	Prohibit surface occupancy and surface-disturbing activities within 0.6 miles of occupied Sage-Grouse leks in PHMA and within 0.25 miles of leks outside PHMA (**RPMs 207; 208**)	Limit of one disturbance location per 640 acres in DA1 (winter concentration area) and DA 3 (PHMA) (**Preferred Alternative**) Within Winter Concentration Areas, surface disturbance would not exceed 20 acres (5 percent) surface disturbance per 640 acres, inclusive of existing disturbance (**Preferred Alternative)** Above-ground facilities would be centralized to locations outside of Winter Concentration Areas, where technically and economically feasible (**Preferred Alternative)** Limit of one disturbance location per 640 acres in PHMA; limit cumulative value of existing disturbances to not exceed 5 percent of suitable habitat of the DDCT area (**RPM 206**)		Increased avoidance by and displacement of Sage-Grouse due to lighting would be avoided by prohibiting surface occupancy and surface-disturbing activities within 0.6 miles of occupied Sage-Grouse leks in PHMA and within 0.25 miles of leks outside PHMA (RPMs 207; 208); and minimized by limiting development to one disturbance location per 640 acres in DA1 (winter concentration area) and DA 3 (PHMA) (Preferred Alternative), applying a surface disturbance threshold of 20 acres (5 percent) within Winter Concentration Areas (Preferred Alternative), limiting the cumulative value of disturbances to not exceed 5 percent of suitable habitat of a DDCT area (RPM 206), and centralizing above-ground facilities outside of Winter Concentration Areas where technically and economically feasible (Preferred Alternative). No residual effects are anticipated.	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	N/A
78	Wildlife – Greater Sage-Grouse	Increased avoidance by and displacement of Sage-Grouse individuals or groups from suitable habitat proximate to development due to vibration, during both the development phase and the production phase	Prohibit surface occupancy and surface-disturbing activities within 0.6 miles of occupied Sage-Grouse leks in PHMA and within 0.25 miles of leks outside PHMA (**RPMs 207; 208**) New local or collector roads) will be avoided within 1.9 miles of the perimeter of occupied Sage-Grouse leks within PHMAs. All new roads will be prohibited within 0.6 miles of the perimeter of occupied Sage-Grouse leks within PHMA **(RPM 217)**	N/A		Increased avoidance by and displacement of Sage-Grouse due to vibration would be avoided by prohibiting surface occupancy and surface-disturbing activities within 0.6 miles of occupied Sage-Grouse leks in PHMA and within 0.25 miles of leks outside PHMA (RPMs 207; 208) and avoiding new local or collector roads) within 1.9 miles of the perimeter of occupied Sage-Grouse leks within PHMAs and prohibiting all new roads within 0.6 miles of the perimeter of occupied Sage-Grouse leks within PHMA (RPM 217). No residual effects are anticipated.	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	N/A

Row #	Resource	Impact Indicator[1]	Strategy To Avoid, Minimize, And Rectify Impacts To The Resource[2]			Residual Effects[3]	Warrant Compensatory Mitigation?[4]	Compensatory Mitigation Options to be Considered at Site-Specific Level
			Avoid[5]	Minimize[6]	Rectify/Restore[7]			
79	Wildlife – Greater Sage-Grouse	Increased avoidance by and displacement of Sage-Grouse individuals or groups from suitable habitat proximate to development due to noise, during both the development phase and the production phase	To avoid potentially significant noise impacts, Jonah Energy will locate compressor engines 2,500 feet or more from a dwelling, residence, or sage-grouse lek (**RPMs 61**) Prohibit surface occupancy and surface-disturbing activities within 0.6 miles of occupied Sage-Grouse leks in PHMA and within 0.25 miles of leks outside PHMA (**RPMs 207; 208**) New local or collector roads) will be avoided within 1.9 miles of the perimeter of occupied Sage-Grouse leks within PHMAs. All new roads will be prohibited within 0.6 miles of the perimeter of occupied Sage-Grouse leks within PHMA **(RPM 217)**	Limit of one disturbance location per 640 acres in DA1 (winter concentration area) and DA 3 (PHMA) (**Preferred Alternative**) Within Winter Concentration Areas, surface disturbance would not exceed 20 acres (5 percent) surface disturbance per 640 acres, inclusive of existing disturbance (**Preferred Alternative)** Above-ground facilities would be centralized to locations outside of Winter Concentration Areas, where technically and economically feasible **(Preferred Alternative)** Buried pipelines would be required to transport produced water and condensate from RGFs within Winter Concentration Areas and PHMA to RGFs outside of these areas. Products would then be trucked out from RGFs outside of PHMA and Winter Concentration Areas (**Preferred Alternative)** Use remote telemetry and SCADA technology to reduce vehicle trips and human presence for well monitoring and control during production activities (**RPMs 2; 121**) Limit of one disturbance location per 640 acres in PHMA; limit cumulative value of existing disturbances to not exceed 5 percent of suitable habitat of the DDCT area (**RPM 206**) New project noise levels, either individual or cumulative, should not exceed 10 dBA (as measured by L50) above baseline noise at the perimeter of the lek from 6:00 p.m. to 8:00 a.m. during the breading season (March 1 – May 15) (**RPM 212**) Prohibit heavy truck traffic within two-mile Sage-Grouse lek buffers between the hours of 6:00 p.m. and 8:00 a.m. during Sage-Grouse mating season (**Mitigation Measure N-1**) Employ noise-reducing practices during construction (**Mitigation Measure N-2**)		Increased avoidance by and displacement of Sage-Grouse due to noise would be avoided by locating compressor engines 2,500 feet or more from a dwelling, residence, or sage-grouse lek (RPMs 61); prohibiting surface occupancy and surface-disturbing activities within 0.6 miles of occupied Sage-Grouse leks in PHMA and within 0.25 miles of leks outside PHMA (RPMs 207; 208); avoiding new local or collector roads) within 1.9 miles of the perimeter of occupied Sage-Grouse leks within PHMAs and prohibiting all new roads within 0.6 miles of the perimeter of occupied Sage-Grouse leks within PHMA (RPM 217). These same impacts would be minimized by limiting development to one disturbance location per 640 acres in DA1 (winter concentration area) and DA 3 (PHMA) (Preferred Alternative), applying a surface disturbance threshold of 20 acres (5 percent) surface disturbance per 640 acres within Winter Concentration Areas (Preferred Alternative), limiting the cumulative value of disturbances to 5 percent of suitable habitat in a DDCT area (RPM 206), centralizing above-ground facilities would be centralized to locations outside of Winter Concentration Areas where technically and economically feasible (Preferred Alternative), using buried pipelines to transport produced water and condensate from RGFs within Winter Concentration Areas and PHMA to RGFs outside of these areas (Preferred Alternative), using remote telemetry and SCADA technology to reduce vehicle trips and human presence for well monitoring and control during production activities (RPMs 2; 121), limiting new project noise levels to 10 dBA (as measured by L50) above baseline noise at the perimeter of the lek from 6:00 p.m. to 8:00 a.m. during the breading season (March 1 – May 15) (RPM 212), prohibiting heavy truck traffic within two-mile Sage-Grouse lek buffers between the hours of 6:00 p.m. and 8:00 a.m. during Sage-Grouse mating season (Mitigation Measure N-1), employing noise-reducing practices during construction (Mitigation Measure N-2), employing noise-reducing practices during operation of the NPL Facility (Mitigation Measure N-3), and implementing a noise monitoring program to verify noise levels from NPL construction, operation, and truck traffic do not exceed 35 dBA L_{max} at Sage-Grouse leks during sensitive breeding hours (Mitigation Measure N-4). No residual effects are anticipated.	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	N/A

Row #	Resource	Impact Indicator[1]	Strategy To Avoid, Minimize, And Rectify Impacts To The Resource[2]			Residual Effects[3]	Warrant Compensatory Mitigation?[4]	Compensatory Mitigation Options to be Considered at Site-Specific Level
			Avoid[5]	Minimize[6]	Rectify/Restore[7]			
				Employ noise-reducing practices during operation of the NPL Facility (**Mitigation Measure N-3**) Implement a noise monitoring program to verify noise levels from NPL construction, operation, and truck traffic do not exceed 35 dBA L_{max} at Sage-Grouse leks during sensitive breeding hours (**Mitigation Measure N-4**)				
80	Wildlife – Greater Sage-Grouse	Increased avoidance by and displacement of Sage-Grouse individuals or groups from suitable habitat proximate to development due to fugitive dust, during both the development phase and the production phase	Prohibit surface occupancy and surface-disturbing activities within 0.6 miles of occupied Sage-Grouse leks in PHMA and within 0.25 miles of leks outside PHMA (**RPMs 207; 208**) New local or collector roads will be avoided within 1.9 miles of the perimeter of occupied Sage-Grouse leks within PHMAs. All new roads will be prohibited within 0.6 miles of the perimeter of occupied Sage-Grouse leks within PHMA **(RPM 217)**	Limit of one disturbance location per 640 acres in DA1 (winter concentration area) and DA 3 (PHMA) (**Preferred Alternative**) Within Winter Concentration Areas, surface disturbance would not exceed 20 acres (5 percent) surface disturbance per 640 acres, inclusive of existing disturbance (**Preferred Alternative)** Above-ground facilities would be centralized to locations outside of Winter Concentration Areas, where technically and economically feasible (**Preferred Alternative)** Buried pipelines would be required to transport produced water and condensate from RGFs within Winter Concentration Areas and PHMA to RGFs outside of these areas. Products would then be trucked out from RGFs outside of PHMA and Winter Concentration Areas (**Preferred Alternative)** Implement measures to control fugitive dust through the use of paving, gravelling, mulching, watering, and vehicle speed limits (**RPMs 4-6; 15; 127; 135**) Limit of one disturbance location per 640 acres in PHMA; limit cumulative value of existing disturbances to not exceed 5 percent of suitable habitat of the DDCT area (**RPM 206)**		Increased avoidance by and displacement of Sage-Grouse due to fugitive dust would be avoiding by prohibiting surface occupancy and surface-disturbing activities within 0.6 miles of occupied Sage-Grouse leks in PHMA and within 0.25 miles of leks outside PHMA (RPMs 207; 208), and avoiding new local or collector roads within 1.9 miles of the perimeter of occupied Sage-Grouse leks within PHMAs and prohibiting all new roads within 0.6 miles of the perimeter of occupied Sage-Grouse leks within PHMA (RPM 217); and minimized by limiting development to one disturbance location per 640 acres in DA1 (winter concentration area) and DA 3 (PHMA) (Preferred Alternative), applying a surface disturbance threshold of 20 acres (5 percent) surface disturbance per 640 acres within Winter Concentration Areas (Preferred Alternative), limiting the cumulative value of disturbances to 5 percent of suitable habitat in a DDCT area (RPM 206), centralizing above-ground facilities would be centralized to locations outside of Winter Concentration Areas where technically and economically feasible (Preferred Alternative), using buried pipelines to transport produced water and condensate from RGFs within Winter Concentration Areas and PHMA to RGFs outside of these areas (Preferred Alternative), and implementing measures to control fugitive dust (RPMs 4-6; 15; 127; 135). No residual impacts are anticipated.	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	N/A
81	Wildlife – Greater Sage-Grouse	Increased avoidance by and displacement of Sage-Grouse individuals or groups from suitable	Prohibit surface occupancy and surface-disturbing activities within 0.6 miles of occupied Sage-Grouse leks in PHMA and within 0.25 miles	Limit of one disturbance location per 640 acres in DA1 (winter concentration area) and DA 3 (PHMA) (**Preferred Alternative**)		Increased avoidance by and displacement of Sage-Grouse due to human presence would be avoided by prohibiting surface occupancy and surface-disturbing activities within 0.6 miles of	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit	N/A

Row #	Resource	Impact Indicator[1]	Strategy To Avoid, Minimize, And Rectify Impacts To The Resource[2]			Residual Effects[3]	Warrant Compensatory Mitigation?[4]	Compensatory Mitigation Options to be Considered at Site-Specific Level
			Avoid[5]	Minimize[6]	Rectify/Restore[7]			
		habitat proximate to development due to human presence, during both the development phase and the production phase	of leks outside PHMA (**RPMs 207; 208**) New local or collector roads) will be avoided within 1.9 miles of the perimeter of occupied Sage-Grouse leks within PHMAs. All new roads will be prohibited within 0.6 miles of the perimeter of occupied Sage-Grouse leks within PHMA **(RPM 217)**	Within Winter Concentration Areas, surface disturbance would not exceed 20 acres (5 percent) surface disturbance per 640 acres, inclusive of existing disturbance (**Preferred Alternative)** Above-ground facilities would be centralized to locations outside of Winter Concentration Areas, where technically and economically feasible (**Preferred Alternative)** Within Winter Concentration Areas development would be phased from east to west (**Preferred Alternative)** Buried pipelines would be required to transport produced water and condensate from RGFs within Winter Concentration Areas and PHMA to RGFs outside of these areas. Products would then be trucked out from RGFs outside of PHMA and Winter Concentration Areas (**Preferred Alternative)** Use remote telemetry and SCADA technology to reduce vehicle trips and human presence for well monitoring and control during production activities (**RPM 2; 121**) Limit of one disturbance location per 640 acres in PHMA; limit cumulative value of existing disturbances to not exceed 5 percent of suitable habitat of the DDCT area **(RPM 206)** Seasonal timing limitation from March 15 – June 30 prohibiting surface-disturbing and disruptive activities throughout PHMAs and within 2 miles of leks outside of PHMAs to protect breeding, nesting, and early brood-rearing habitat (**RPM 209; 210)** Prohibit surface-disturbing and disruptive activities in Sage-Grouse winter concentration areas from December 1 – March 14 (**RPM 211**) Use existing roads or realignments to access federal oil and gas leases that are not yet developed in PHMA. Any		occupied Sage-Grouse leks in PHMA and within 0.25 miles of leks outside PHMA (RPMs 207; 208), and avoiding new local or collector roads within 1.9 miles of the perimeter of occupied Sage-Grouse leks within PHMAs and prohibiting all new roads within 0.6 miles of the perimeter of occupied Sage-Grouse leks within PHMA (RPM 217); and minimized by limiting development to one disturbance location per 640 acres in DA1 (winter concentration area) and DA 3 (PHMA) (Preferred Alternative), applying a surface disturbance threshold of 20 acres (5 percent) surface disturbance per 640 acres within Winter Concentration Areas (Preferred Alternative), phasing development from east to west in Winter Concentration Areas (Preferred Alternative), limiting the cumulative value of disturbances to 5 percent of suitable habitat in a DDCT area (RPM 206), centralizing above-ground facilities would be centralized to locations outside of Winter Concentration Areas where technically and economically feasible (Preferred Alternative), using buried pipelines to transport produced water and condensate from RGFs within Winter Concentration Areas and PHMA to RGFs outside of these areas (Preferred Alternative), using remote telemetry and SCADA technology to reduce vehicle trips and human presence for well monitoring and control during production activities (RPM 2; 121), prohibiting surface-disturbing and disruptive activities throughout PHMAs and within 2 miles of leks outside of PHMAs from March 15 – June 30 (RPM 209; 210), prohibiting surface-disturbing and disruptive activities in Sage-Grouse winter concentration areas from December 1 – March 14 (RPM 211), and using existing roads or realignments to access federal oil and gas leases that are not yet developed in PHMA and constructing any new road to the absolute minimum standard necessary (RPM 219). No residual impacts are anticipated.	achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	

Row #	Resource	Impact Indicator[1]	Strategy To Avoid, Minimize, And Rectify Impacts To The Resource[2]			Residual Effects[3]	Warrant Compensatory Mitigation?[4]	Compensatory Mitigation Options to be Considered at Site-Specific Level
			Avoid[5]	Minimize[6]	Rectify/Restore[7]			
				new road will be constructed to the absolute minimum standard necessary (**RPM 219**)				
82	Wildlife – Greater Sage-Grouse	Development could result in Sage-Grouse avoiding areas if they perceive they are at risk from predation, such as areas under powerlines, which could also reduce total habitat available to the species and increase competition in other suitable, non-disturbed habitat areas	Bury electric distribution lines in PHMA and Winter Concentration Areas where feasible; otherwise, overhead installations would be allowed if lowest impact alternative (**RPM 214; Preferred Alternative**)	Co-locate new ROWs within or adjacent to existing ROWs where technically feasible (**RPM 213**)		Avoidance of habitat by Sage-Grouse due to perceived predation risk would be avoided by burying electric distribution lines in PHMA and Winter Concentration Areas where feasible (RPM 214; Preferred Alternative) and minimized by co-locating new ROWs within or adjacent to existing ROWs where technically feasible (RPM 213). No residual impacts are anticipated.	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	N/A
83	Wildlife – Greater Sage-Grouse	Increased fragmentation of Sage-Grouse habitat (e.g., sagebrush-steppe) resulting in barriers to movement to preferred habitat areas, more isolated populations, and a more dispersed area to fulfill life-history requirements (e.g., nesting and breeding habitat)	Prohibit surface occupancy and surface-disturbing activities within 0.6 miles of occupied Sage-Grouse leks in PHMA and within 0.25 miles of leks outside PHMA (**RPMs 207; 208**) Bury electric distribution lines in PHMA and Winter Concentration Area where feasible; otherwise, overhead installations would be allowed if lowest impact alternative (**RPM 214; Preferred Alternative**) Avoid new local or collector roads within 1.9 miles of leks in PHMAs; prohibit all new roads within 0.6 miles of leks in PHMA (**RPM 217**)	Limit of one disturbance location per 640 acres in DA1 (winter concentration area) and DA 3 (PHMA) (**Preferred Alternative**) Within Winter Concentration Areas, surface disturbance would not exceed 20 acres (5 percent) surface disturbance per 640 acres, inclusive of existing disturbance (**Preferred Alternative)** Above-ground facilities would be centralized to locations outside of Winter Concentration Areas, where technically and economically feasible (**Preferred Alternative)** Within Winter Concentration Areas development would be phased from east to west (**Preferred Alternative)** Implement soil stabilization, erosion control, and reclamation measures (**RPMs 82-117; 148-153**) Follow transportation plans to maintain the largest undisturbed blocks of habitat possible and to minimize the acres of disturbance from roads, pipelines, power lines and other facilities (**RPM 140**)	Conduct successful reclamation in disturbed areas as soon as practicable (**RPM 89; 129; 141; 143; 149; Appendix C – Reclamation Pla**n) Close and reclaim unnecessary roads to reduce fragmentation and restore habitat integrity (**RPM 141**)	Increased fragmentation of Sage-Grouse habitat would be avoided by prohibiting surface occupancy and surface-disturbing activities within 0.6 miles of occupied Sage-Grouse leks in PHMA and within 0.25 miles of leks outside PHMA (RPMs 207; 208), burying electric distribution lines in PHMA and Winter Concentration Areas where feasible (RPM 214; Preferred Alternative), and avoiding new local or collector roads within 1.9 miles of the perimeter of occupied Sage-Grouse leks within PHMAs and prohibiting all new roads within 0.6 miles of the perimeter of occupied Sage-Grouse leks within PHMA (RPM 217). These same impacts would be minimized by limiting development to one disturbance location per 640 acres in DA1 (winter concentration area) and DA 3 (PHMA) (Preferred Alternative); applying a surface disturbance threshold of 20 acres (5 percent) surface disturbance per 640 acres within Winter Concentration Areas (Preferred Alternative); phasing development from east to west in Winter Concentration Areas (Preferred Alternative); limiting the cumulative value of disturbances to 5 percent of suitable habitat in a DDCT area (RPM 206); implementing soil stabilization, erosion control, and reclamation measures (RPMs 82-117; 148-153); following transportation plans to maintain the largest undisturbed blocks of habitat possible and to minimize the acres of disturbance from roads, pipelines, power lines and other facilities (RPM 140); allowing new pipelines in PHMA only	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	N/A

Row #	Resource	Impact Indicator[1]	Strategy To Avoid, Minimize, And Rectify Impacts To The Resource[2]			Residual Effects[3]	Warrant Compensatory Mitigation?[4]	Compensatory Mitigation Options to be Considered at Site-Specific Level
			Avoid[5]	Minimize[6]	Rectify/Restore[7]			
				Limit of one disturbance location per 640 acres in PHMA; limit cumulative value of existing disturbances to not exceed 5 percent of suitable habitat of the DDCT area (**RPM 206**) Allow new pipelines in PHMA only within an RMP corridor or adjacent to existing utilities (**RPM 216**) Do not upgrade existing routes in PHMA unless it would minimally impact Sage-Grouse, is necessary for safety, or eliminates the need to construct a new road (**RPM 218**) Use existing roads or realignments to access valid existing rights that are not yet developed in PHMA. If valid existing rights cannot be accessed via existing roads, construct any new road to the absolute minimum standard necessary and add the surface disturbance to the total PHMA (**RPM 219**)		within an RMP corridor or adjacent to existing utilities (RPM 216); not upgrading existing routes in PHMA unless it would minimally impact Sage-Grouse, is necessary for safety, or eliminates the need to construct a new road (RPM 218); and using existing roads or realignments to access valid existing rights that are not yet developed in PHMA (RPM 219). The impacts would be rectified/restored by conducting successful reclamation in disturbed areas as soon as practicable (RPM 89; 129; 141; 143; 149; Appendix C – Reclamation Plan) and closing and reclaiming unnecessary roads to reduce fragmentation and restore habitat integrity (RPM 141). No residual effects are anticipated.		
84	Wildlife – Greater Sage-Grouse	Diminished health in Sage-Grouse individuals and local populations because of long-term physiological stress from exposure to varying degrees of displacement, habitat fragmentation, predation, changes in food availability and sources, and human activity	Prohibit surface occupancy and surface-disturbing activities within 0.6 miles of occupied Sage-Grouse leks in PHMA and within 0.25 miles of leks outside PHMA (**RPMs 207; 208**) Bury electric distribution lines in PHMA and Winter Concentration Areas where economically feasible; otherwise, overhead installations would be allowed if lowest impact alternative (**RPM 214; Preferred Alternative**) Avoid new local or collector roads within 1.9 miles of leks in PHMAs; prohibit all new roads within 0.6 miles of leks in PHMA (**RPM 217**)	Limit of one disturbance location per 640 acres in DA1 (winter concentration area) and DA 3 (PHMA) (**Preferred Alternative**) Within Winter Concentration Areas, surface disturbance would not exceed 20 acres (5 percent) surface disturbance per 640 acres, inclusive of existing disturbance (**Preferred Alternative)** Above-ground facilities would be centralized to locations outside of Winter Concentration Areas, where technically and economically feasible (**Preferred Alternative)** Within Winter Concentration Areas development would be phased from east to west (**Preferred Alternative)** Buried pipelines would be required to transport produced water and condensate from RGFs within Winter Concentration Areas and PHMA to RGFs outside of these areas. Products would then be trucked out from RGFs outside of PHMA and Winter Concentration Areas (**Preferred Alternative)**	Conduct successful reclamation in disturbed areas as soon as practicable (**RPM 89; 129; 141; 143; 149; Appendix C – Reclamation Plan**) Close and reclaim unnecessary roads to reduce fragmentation and restore habitat integrity (**RPM 141**)	Long-term physiological stress to Sage-Grouse would be avoided by prohibiting surface occupancy and surface-disturbing activities within 0.6 miles of occupied Sage-Grouse leks in PHMA and within 0.25 miles of leks outside PHMA (RPMs 207; 208), burying electric distribution lines in PHMA and Winter Concentration Areas where feasible (RPM 214; Preferred Alternative), and avoiding new local or collector roads within 1.9 miles of the perimeter of occupied Sage-Grouse leks within PHMAs and prohibiting all new roads within 0.6 miles of the perimeter of occupied Sage-Grouse leks within PHMA (RPM 217). These same impacts would be minimized by limiting development to one disturbance location per 640 acres in DA1 (winter concentration area) and DA 3 (PHMA) (Preferred Alternative); applying a surface disturbance threshold of 20 acres (5 percent) surface disturbance per 640 acres within Winter Concentration Areas (Preferred Alternative); phasing development from east to west in Winter Concentration Areas (Preferred Alternative); limiting the cumulative value of disturbances to 5 percent of suitable habitat in a DDCT area (RPM 206); using buried pipelines to transport produced water and condensate from RGFs within Winter Concentration Areas and PHMA to RGFs outside of these areas (Preferred Alternative); using remote telemetry and SCADA technology to reduce vehicle trips and human presence for well monitoring and control during	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	N/A

Row #	Resource	Impact Indicator[1]	Strategy To Avoid, Minimize, And Rectify Impacts To The Resource[2]			Residual Effects[3]	Warrant Compensatory Mitigation?[4]	Compensatory Mitigation Options to be Considered at Site-Specific Level
			Avoid[5]	Minimize[6]	Rectify/Restore[7]			
				Use remote telemetry and SCADA technology to reduce vehicle trips and human presence for well monitoring and control during production activities (**RPM 2; 121**) Implement soil stabilization, erosion control, and reclamation measures (**RPMs 82-117; 148-153**) Limit of one disturbance location per 640 acres in PHMA; limit cumulative value of existing disturbances to not exceed 5 percent of suitable habitat of the DDCT area (**RPM 206**) Seasonal timing limitation from March 15 – June 30 prohibiting surface-disturbing and disruptive activities throughout PHMAs and within 2 miles of leks outside of PHMAs to protect breeding, nesting, and early brood-rearing habitat (**RPM 209, 210**) Prohibit surface-disturbing and disruptive activities in Sage-Grouse winter concentration areas from December 1 – March 14 (**RPM 211**) Use existing roads or realignments to access federal oil and gas leases that are not yet developed in PHMA. Any new road will be constructed to the absolute minimum standard necessary (**RPM 219**)		production activities (RPM 2; 121); prohibiting surface-disturbing and disruptive activities throughout PHMAs and within 2 miles of leks outside of PHMAs from March 15 – June 30 (RPM 209; 210), prohibiting surface-disturbing and disruptive activities in Sage-Grouse winter concentration areas from December 1 – March 14 (RPM 211), and using existing roads or realignments to access federal oil and gas leases that are not yet developed in PHMA and constructing any new road to the absolute minimum standard necessary (RPM 219). No residual impacts are anticipated. The impacts would be rectified/restored by conducting successful reclamation in disturbed areas as soon as practicable (RPM 89; 129; 141; 143; 149; Appendix C – Reclamation Plan) and closing and reclaiming unnecessary roads to reduce fragmentation and restore habitat integrity (RPM 141). No residual effects are anticipated.		
85	Wildlife – Greater Sage-Grouse	Decreased quantity of insect species, which Sage-Grouse consume during spring and summer months, resulting from dust, noise, vibration, human presence, changes in floral species composition, and/or increased use of pesticides within the Project Area	To avoid potentially significant noise impacts, Jonah Energy will locate compressor engines 2,500 feet or more from a dwelling, residence, or sage-grouse lek (**RPMs 61**)	Implement measures to control fugitive dust through the use of paving, gravelling, mulching, watering, and vehicle speed limits (**RPMs 4-6, 15, 127, 135**) Implement soil stabilization, erosion control, and reclamation measures (**RPMs 82-117, 148-153**) Implement measures to prevent colonization or control the spread of invasive species and noxious weeds (**RPMs 95, 142-147**) Seasonal timing limitation from March 15 – June 30 prohibiting surface-disturbing and disruptive activities	Conduct successful reclamation in disturbed areas as soon as practicable (**RPM 89; 129; 141; 143; 149; Appendix C – Reclamation Plan**) Close and reclaim unnecessary roads to reduce fragmentation and restore habitat integrity (**RPM 141**)	Decreased quantity of insect species resulting from dust, noise, vibration, human presence, changes in floral species composition, and/or increased use of pesticides within the Project Area would be avoided by locating compressor engines 2,500 feet or more from a dwelling, residence, or sage-grouse lek (RPMs 61). These same impacts would be minimized by implementing measures to control fugitive dust through the use of paving, gravelling, mulching, watering, and vehicle speed limits (RPMs 4-6, 15, 127, 135); implementing soil stabilization, erosion control, and reclamation measures (RPMs 82-117, 148-153); implementing measures to prevent colonization or control the spread of invasive species and noxious weeds (RPMs 95, 142-147), prohibiting surface-disturbing and disruptive activities throughout	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	N/A

Row #	Resource	Impact Indicator[1]	Strategy To Avoid, Minimize, And Rectify Impacts To The Resource[2]			Residual Effects[3]	Warrant Compensatory Mitigation?[4]	Compensatory Mitigation Options to be Considered at Site-Specific Level
			Avoid[5]	Minimize[6]	Rectify/Restore[7]			
				throughout PHMAs and within 2 miles of leks outside of PHMAs to protect breeding, nesting, and early brood-rearing habitat (**RPMs 209, 210)** Prohibit surface-disturbing and disruptive activities in Sage-Grouse winter concentration areas from December 1 – March 14 (**RPM 211**) Use remote telemetry and SCADA technology to reduce vehicle trips and human presence for well monitoring and control during production activities (**RPM 2; 121**) New project noise levels, either individual or cumulative, should not exceed 10 dBA (as measured by L50) above baseline noise at the perimeter of the lek from 6:00 p.m. to 8:00 a.m. during the breading season (March 1 – May 15) (**RPM 212**) Prohibit heavy truck traffic within two-mile Sage-Grouse lek buffers between the hours of 6:00 p.m. and 8:00 a.m. during Sage-Grouse mating season (**Mitigation Measure N-1**) Employ noise-reducing practices during construction (**Mitigation Measure N-2**) Employ noise-reducing practices during operation of the NPL Facility (**Mitigation Measure N-3**) Implement a noise monitoring program to verify noise levels from NPL construction, operation, and truck traffic do not exceed 35 dBA L_{max} at Sage-Grouse leks during sensitive breeding hours (**Mitigation Measure N-4**)		PHMAs and within 2 miles of leks outside of PHMAs from March 15 – June 30 (RPMs 209; 210), prohibiting surface-disturbing and disruptive activities in Sage-Grouse winter concentration areas from December 1 – March 14 (RPM 211), using remote telemetry and SCADA technology to reduce vehicle trips and human presence for well monitoring and control during production activities (RPMs 2; 121), limiting new project noise levels to 10 dBA (as measured by L50) above baseline noise at the perimeter of the lek from 6:00 p.m. to 8:00 a.m. during the breading season (March 1 – May 15) (RPM 212), prohibiting heavy truck traffic within two-mile Sage-Grouse lek buffers between the hours of 6:00 p.m. and 8:00 a.m. during Sage-Grouse mating season (Mitigation Measure N-1), employing noise-reducing practices during construction (Mitigation Measure N-2), employing noise-reducing practices during operation of the NPL Facility (Mitigation Measure N-3), and implementing a noise monitoring program to verify noise levels from NPL construction, operation, and truck traffic do not exceed 35 dBA L_{max} at Sage-Grouse leks during sensitive breeding hours (Mitigation Measure N-4). The impacts would be rectified/restored by conducting successful reclamation in disturbed areas as soon as practicable (RPM 89; 129; 141; 143; 149; Appendix C – Reclamation Plan) and closing and reclaiming unnecessary roads to reduce fragmentation and restore habitat integrity (RPM 141). No residual effects are anticipated.		
86	Wildlife – Greater Sage-Grouse	Increased predation of Sage-Grouse by raptors and corvids, resulting from an increase in roosting and hunting locations for raptors and corvids (e.g., powerlines)	Prohibit surface occupancy and surface-disturbing activities within 0.6 miles of occupied Sage-Grouse leks in PHMA and within 0.25 miles of leks outside PHMA (**RPMs 207; 208**) Bury electric distribution lines in PHMA and Winter Concentration Areas where economically feasible; otherwise, overhead installations would be allowed if lowest impact	Limit of one disturbance location per 640 acres in DA1 (winter concentration area) and DA 3 (PHMA) (**Preferred Alternative**) Within Winter Concentration Areas, surface disturbance would not exceed 20 acres (5 percent) surface disturbance per 640 acres, inclusive of existing disturbance (**Preferred Alternative)**		Increased predation of Sage-Grouse by raptors and corvids would be avoided by prohibiting surface occupancy and surface-disturbing activities within 0.6 miles of occupied Sage-Grouse leks in PHMA and within 0.25 miles of leks outside PHMA (RPMs 207; 208) and burying electric distribution lines in PHMA and Winter Concentration Areas where economically feasible (RPM 214; Preferred Alternative); and minimized by limiting development to one disturbance location per 640 acres in DA1 (winter concentration area) and DA 3 (PHMA)	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a	N/A

Row #	Resource	Impact Indicator[1]	Strategy To Avoid, Minimize, And Rectify Impacts To The Resource[2]			Residual Effects[3]	Warrant Compensatory Mitigation?[4]	Compensatory Mitigation Options to be Considered at Site-Specific Level
			Avoid[5]	Minimize[6]	Rectify/Restore[7]			
			alternative (**RPM 214; Preferred Alternative**)	Above-ground facilities would be centralized to locations outside of Winter Concentration Areas, where technically and economically feasible (**Preferred Alternative)** Limit of one disturbance location per 640 acres in PHMA; limit cumulative value of existing disturbances to not exceed 5 percent of suitable habitat of the DDCT area (**RPM 206**) Design power lines to minimize wildlife-related impacts and construct to the latest APLIC standards (**RPM 215**) Install raptor perch deterrents on any above ground structures that exceed four feet in height (**RPM 234)**		(Preferred Alternative), applying a surface disturbance threshold of 20 acres (5 percent) surface disturbance per 640 acres within Winter Concentration Areas (Preferred Alternative), limiting the cumulative value of disturbances to 5 percent of suitable habitat in a DDCT area (RPM 206), designing power lines to minimize wildlife-related impacts and construct to the latest APLIC standards (RPM 215), and installing raptor perch deterrents on any above ground structures that exceed four feet in height (RPM 234). No residual effects are anticipated.	protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	
87	Wildlife – Greater Sage-Grouse	Increase in Sage-Grouse predation by raptor, corvid, and mammalian species due to more developed areas and less vegetative cover. Reduced vegetative cover can limit escape options and opportunities for Sage-Grouse resulting in increased vulnerability to predation.	Prohibit surface occupancy and surface-disturbing activities within 0.6 miles of occupied Sage-Grouse leks in PHMA and within 0.25 miles of leks outside PHMA (**RPMs 207; 208**)	Limit of one disturbance location per 640 acres in DA1 (winter concentration area) and DA 3 (PHMA) (**Preferred Alternative**) Within Winter Concentration Areas, surface disturbance would not exceed 20 acres (5 percent) surface disturbance per 640 acres, inclusive of existing disturbance (**Preferred Alternative)** Above-ground facilities would be centralized to locations outside of Winter Concentration Areas, where technically and economically feasible (**Preferred Alternative)** Within Winter Concentration Areas development would be phased from east to west (**Preferred Alternative)** Implement soil stabilization, erosion control, and reclamation measures (**RPMs 82-117, 148-153**) Limit of one disturbance location per 640 acres; limit cumulative value of existing disturbances to not exceed 5 percent of suitable habitat of the DDCT area (**RPM 206)**	Conduct successful reclamation in disturbed areas as soon as practicable (**RPM 89; 129; 141; 143; 149; Appendix C – Reclamation Plan**) Close and reclaim unnecessary roads to reduce fragmentation and restore habitat integrity (**RPM 141**)	Increases in Sage-Grouse predation would be avoided by prohibiting surface occupancy and surface-disturbing activities within 0.6 miles of occupied Sage-Grouse leks in PHMA and within 0.25 miles of leks outside PHMA (RPMs 207; 208). These same impacts would be minimized by limiting development to one disturbance location per 640 acres in DA1 (winter concentration area) and DA 3 (PHMA) (Preferred Alternative); applying a surface disturbance threshold of 20 acres (5 percent) surface disturbance per 640 acres within Winter Concentration Areas (Preferred Alternative); limiting the cumulative value of disturbances to 5 percent of suitable habitat in a DDCT area (RPM 206); centralizing above-ground facilities outside of Winter Concentration Areas where technically and economically feasible (Preferred Alternative); phasing development from east to west in Winter Concentration Areas (Preferred Alternative); and implementing soil stabilization, erosion control, and reclamation measures (RPMs 82-117, 148-153). No residual effects are anticipated.	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	N/A
88	Wildlife – Greater Sage-Grouse	Potential increase in impacts to Sage-Grouse from West Nile Virus due to	Jonah Energy does not propose the use open reserve pits, onsite evaporation ponds, or			Potential increases in impacts to Sage-Grouse from West Nile Virus would be avoided by not using open reserve pits, onsite evaporation	No. There are no anticipated residual effects that warrant compensatory mitigation. The	N/A

Row #	Resource	Impact Indicator[1]	Strategy To Avoid, Minimize, And Rectify Impacts To The Resource[2]			Residual Effects[3]	Warrant Compensatory Mitigation?[4]	Compensatory Mitigation Options to be Considered at Site-Specific Level
			Avoid[5]	Minimize[6]	Rectify/Restore[7]			
		the creation of mosquito breeding areas	impoundments (**Preferred Alternative**)			ponds, or impoundments (**Preferred Alternative**).	project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	
89	Wildlife – Long-eared Myotis	Increased risk of mortalities from vehicle collisions due to the development of new access roads and increased traffic		Use remote telemetry and SCADA technology to reduce vehicle trips and human presence for well monitoring and control during production activities (**RPM 2; 121**) Post appropriate road warning signs and support the enforcement of speed limits (**RPM 135**)	Close and reclaim unnecessary roads to reduce fragmentation and restore habitat integrity (**RPM 141**)	Increased risk of mortalities from vehicle collisions would be minimized by using remote telemetry and SCADA technology to reduce vehicle trips and human presence for well monitoring and control during production activities (RPM 2; 121) and posting appropriate road warning signs and supporting the enforcement of speed limits (RPM 135); and rectified/restored by closing and reclaiming unnecessary roads to reduce fragmentation and restore habitat integrity (RPM 141).	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	N/A
90	Wildlife – Long-eared Myotis	Increases in accidental mortality due to equipment such as tanks containing freestanding liquids, chemical tank secondary containment, and other hazards.	Jonah Energy would not use any open reserve pits (**Preferred Alternative**) All new production facilities that have open-vent exhaust stacks will be equipped to prevent bird and bat entry or perching on the stack (**RPM 237**)	Implement spill prevention and cleanup measures (**RPM 36**)		Increases in accidental mortality due to equipment such as tanks containing freestanding liquids, chemical tank secondary containment, and other hazards would be avoided by not using open reserve pits (Preferred Alternative) and equipping all new production facilities that have open-vent exhaust stacks to prevent bird and bat entry or perching on the stack (RPM 237); and minimized by implementing spill prevention and cleanup measures (RPM 36). No residual effects are anticipated.	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	N/A
91	Wildlife – Long-eared Myotis	Increases in accidental mortality due to collisions or entrapment in wire exclosure fences for well pads or production facilities and associated ROWs.		Minimize ROW fencing. Fence design must be approved by the WGFD and meet BLM fencing standards for facilitating wildlife movement (**RPM 202**)		Increases in accidental mortality due to collisions or entrapment in wire exclosure fences would be minimized by minimizing ROW fencing and using fence designs approved by the WGFD and meeting BLM fencing standards for facilitating wildlife movement (RPM 202), and working with permittees and the BLM to identify	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM	N/A

Row #	Resource	Impact Indicator[1]	Strategy To Avoid, Minimize, And Rectify Impacts To The Resource[2]			Residual Effects[3]	Warrant Compensatory Mitigation?[4]	Compensatory Mitigation Options to be Considered at Site-Specific Level
			Avoid[5]	Minimize[6]	Rectify/Restore[7]			
				Work with permittees and the BLM to identify wildlife-friendly fencing initiatives (**RPM 203**) All fences should be wildlife friendly (**RPM 204**)		wildlife-friendly fencing initiatives (RPMs 203, 204). No residual effects are anticipated.	RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	
92	Wildlife – Long-eared Myotis	Direct loss or avoidance of suitable nesting and foraging habitat due to project activities	Characterize special status species habitat and populations within the Project Area and include appropriate avoidance and minimization measures (**RPM 246**)		Conduct successful reclamation in disturbed areas as soon as practicable (**RPMs 89; 129; 141; 143; 149; Appendix C – Reclamation Plan**)	Direct loss or avoidance of suitable nesting and foraging habitat would be avoided by characterizing special status species habitat and populations within the Project Area and include appropriate avoidance and minimization measures (RPM 246), and rectified/restored by conducting successful reclamation in disturbed areas as soon as practicable (RPMs 89; 129; 141; 143; 149; Appendix C – Reclamation Plan). No residual effects are anticipated.	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	N/A
93	Wildlife – Long-eared Myotis	Increased risk of mortalities from vehicle collisions due to the development of new access roads and increased traffic		Use remote telemetry and SCADA technology to reduce vehicle trips and human presence for well monitoring and control during production activities (**RPM 2; 121**) Post appropriate road warning signs and support the enforcement of speed limits (**RPM 135**)	Close and reclaim unnecessary roads to reduce fragmentation and restore habitat integrity (**RPM 141**)	Increased risk of mortalities from vehicle collisions would be minimized by using remote telemetry and SCADA technology to reduce vehicle trips and human presence for well monitoring and control during production activities (RPM 2; 121) and posting appropriate road warning signs and supporting the enforcement of speed limits (RPM 135); and rectified/restored by closing and reclaiming unnecessary roads to reduce fragmentation and restore habitat integrity (RPM 141).	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	N/A
94	Wildlife – Moose	Disruption of unidentified migration routes, if present	Prohibit surface disturbance within 500 feet of surface water and/or riparian areas (**RPMs 106; 175**) Preservation of migration corridors through coordination between Jonah Energy, BLM, WGFD, and other stakeholders, and avoidance of activities and facilities that create		Conduct successful reclamation in disturbed areas as soon as practicable (**RPM 89; 129; 141; 143; 149; Appendix C – Reclamation Plan**)	No impacts to moose are anticipated because there are no designated moose crucial winter range or migration routes in the analysis area, and moose rarely occur within the Project Area. Potential impacts would be avoided by preserving moose migration routes, if determined to be present (RPMs 194; 195) and prohibiting disturbance in riparian areas, where moose would be most likely to occur (RPMs 106; 175), and rectified/restored by conducting	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM RMPs. Additionally, there would be no residual impacts	N/A

Row #	Resource	Impact Indicator[1]	Strategy To Avoid, Minimize, And Rectify Impacts To The Resource[2]			Residual Effects[3]	Warrant Compensatory Mitigation?[4]	Compensatory Mitigation Options to be Considered at Site-Specific Level
			Avoid[5]	Minimize[6]	Rectify/Restore[7]			
			barriers to big game movement (**RPMs 194; 195**)			successful reclamation in disturbed areas as soon as practicable (RPM 89; 129; 141; 143; 149; Appendix C – Reclamation Plan).	considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	
95	Wildlife – Mountain Plover	Direct loss or avoidance of suitable habitat due to project activities	Conduct surveys to determine presence/absence of mountain plover and nest density (**RPM 226**) Characterize special status species habitat and populations within the Project Area and include appropriate avoidance and minimization measures (**RPM 246**)		Conduct successful reclamation in disturbed areas as soon as practicable (**RPM 89; 129; 141; 143; 149; Appendix C – Reclamation Plan**)	Direct loss or avoidance of suitable habitat due to project activities would be minimized by conducting surveys to determine presence/absence of mountain plover and nest density (RPM 226) and characterizing special status species habitat and populations within the Project Area and including appropriate avoidance and minimization measures (RPM 246); and rectified/restored by conducting successful reclamation in disturbed areas as soon as practicable (RPM 89; 129; 141; 143; 149; Appendix C – Reclamation Plan). No residual effects are anticipated.	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	N/A
96	Wildlife – Mule Deer	Direct loss or avoidance of suitable mule deer habitat and disruption of unidentified migration routes, if present	Preservation of migration corridors through coordination between Jonah Energy, BLM, WGFD, and other stakeholders, and avoidance of activities and facilities that create barriers to big game movement (**RPMs 194; 195**)	Implement soil stabilization, erosion control, and reclamation measures (**RPMs 82-117, 148-153**) Limit of one disturbance location per 640 acres in DA1 (winter concentration area) and DA 3 (PHMA) (**Preferred Alternative**) Within Winter Concentration Areas, surface disturbance would not exceed 20 acres (5 percent) surface disturbance per 640 acres, inclusive of existing disturbance (**Preferred Alternative)** Above-ground facilities would be centralized to locations outside of Winter Concentration Areas, where technically and economically feasible (**Preferred Alternative)** Within Winter Concentration Areas development would be phased from east to west (**Preferred Alternative)** Limit of one disturbance location per 640 acres in PHMA; limit cumulative value of existing disturbances to not exceed 5 percent of suitable habitat of the DDCT area (**RPM 206)**	Conduct successful reclamation in disturbed areas as soon as practicable (**RPM 89; 129; 141; 143; 149; Appendix C – Reclamation Plan**)	Direct loss or avoidance of suitable mule deer habitat and disruption of migration routes would be avoided by preserving migration corridors through coordination between Jonah Energy, BLM, WGFD, and other stakeholders, and avoiding activities and facilities that create barriers to big game movement (RPMs 194; 195). These same impacts would be minimized by implementing oil stabilization, erosion control, and reclamation measures (RPMs 82-117, 148-153), limiting development to one disturbance location per 640 acres in DA1 (winter concentration area) and DA 3 (PHMA) (Preferred Alternative), applying a surface disturbance threshold of 20 acres (5 percent) per 640 acres in Winter Concentration Areas (Preferred Alternative), limiting the cumulative value of disturbance to 5 percent of suitable habitat in a DDCT area (RPM 206), centralizing above-ground facilities outside of Winter Concentration Areas where technically and economically feasible (Preferred Alternative), phasing development from east to west within Winter Concentration Areas (Preferred Alternative), prohibiting surface-disturbing and disruptive activities in Sage-Grouse winter concentration areas from December 1 – March 14, and protecting additional mapped winter concentration areas in GHMA if conditions warrant (RPM 211); and rectified restored by conducting successful reclamation in disturbed areas as soon as practicable (RPM 89; 129; 141;	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	N/A

Row #	Resource	Impact Indicator[1]	Strategy To Avoid, Minimize, And Rectify Impacts To The Resource[2]			Residual Effects[3]	Warrant Compensatory Mitigation?[4]	Compensatory Mitigation Options to be Considered at Site-Specific Level
			Avoid[5]	Minimize[6]	Rectify/Restore[7]			
				Prohibit surface-disturbing and disruptive activities in Sage-Grouse winter concentration areas from December 1 – March 14; protect additional mapped winter concentration areas in GHMA if conditions warrant (**RPM 211**)		143; 149; Appendix C – Reclamation Plan). No residual effects are anticipated.		
97	Wildlife – Other Avian Special Status Species	Direct loss or avoidance of suitable habitat due to project activities	Prohibit development in areas of DA 1 containing greater than 5 percent sagebrush canopy cover, except where technically and economically infeasible (**RPM 156**)	Within Winter Concentration Areas, surface disturbance would not exceed 20 acres (5 percent) surface disturbance per 640 acres, inclusive of existing disturbance (**Preferred Alternative**) Above-ground facilities would be centralized to locations outside of Winter Concentration Areas, where technically and economically feasible (**Preferred Alternative**) Limit of one disturbance location per 640 acres in DA1 (winter concentration area) and DA 3 (PHMA) (**Preferred Alternative**) Implement soil stabilization, erosion control, and reclamation measures (**RPMs 82-117; 148-153**) Follow transportation plans to maintain the largest undisturbed blocks of habitat possible and to minimize the acres of disturbance from roads, pipelines, power lines and other facilities (**RPM 140**) Minimize the disturbance of Gardner's saltbush (*Atriplex gardneri*), winterfat (*Krascheninnikovia lanata*), and bud sagebrush (*Artemisia spinescens*) (**RPM 155**) Protect trees, shrubs, and groundcover in areas not cleared for construction (**RPM 157**) Limit of one disturbance location per 640 acres in PHMA; limit cumulative value of existing disturbances to not exceed 5 percent of suitable habitat of the DDCT area (**RPM 206)**	Conduct successful reclamation in disturbed areas as soon as practicable (**RPM 89; 129; 141; 143; 149; Appendix C – Reclamation Plan**) Close and reclaim unnecessary roads to reduce fragmentation and restore habitat integrity (**RPM 141**)	Most other avian special status species are sagebrush-obligate or shrub-nesting avian species. Direct loss or avoidance of suitable habitat due to project activities would be avoided by prohibiting development in areas of DA 1 containing greater than 5 percent sagebrush canopy cover, except where technically and economically infeasible (RPM 156). These same impacts would be minimized by applying a surface disturbance threshold of 20 acres (5 percent) per 640 acres within Winter Concentration Areas) (Preferred Alternative); limiting cumulative disturbances to not exceed 5 percent of suitable habitat in a DDCT area (RPM 206); centralizing above-ground facilities outside of Winter Concentration Areas where technically and economically feasible (Preferred Alternative); limiting development to one disturbance location per 640 acres in DA1 (winter concentration area) and DA 3 (PHMA) (Preferred Alternative); following transportation plans to maintain the largest undisturbed blocks of habitat possible and to minimize the acres of disturbance from roads, pipelines, power lines and other facilities (RPM 140); minimizing the disturbance of Gardner's saltbush (*Atriplex gardneri*), winterfat (*Krascheninnikovia lanata*), and bud sagebrush (*Artemisia spinescens*) (RPM 155); protecting trees, shrubs, and groundcover in areas not cleared for construction (RPM 157); not upgrading existing routes in PHMA unless it would minimally impact Sage-Grouse, is necessary for safety, or eliminates the need to construct a new road (RPM 218), and using existing roads or realignments to access valid existing rights that are not yet developed in PHMA and constructing any new road to the absolute minimum standard necessary and add the surface disturbance to the total PHMA (RPM 219). These same impacts would be rectified/restored by conducting successful reclamation in disturbed areas as soon as practicable (RPMs 89; 129; 141; 143; 149; Appendix C – Reclamation Plan), and closing and reclaiming unnecessary roads to reduce fragmentation and restore habitat integrity	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	N/A

Row #	Resource	Impact Indicator[1]	Strategy To Avoid, Minimize, And Rectify Impacts To The Resource[2]			Residual Effects[3]	Warrant Compensatory Mitigation?[4]	Compensatory Mitigation Options to be Considered at Site-Specific Level
			Avoid[5]	Minimize[6]	Rectify/Restore[7]			
				Do not upgrade existing routes in PHMA unless it would minimally impact Sage-Grouse, is necessary for safety, or eliminates the need to construct a new road (**RPM 218**) Use existing roads or realignments to access valid existing rights that are not yet developed in PHMA. If valid existing rights cannot be accessed via existing roads, construct any new road to the absolute minimum standard necessary and add the surface disturbance to the total PHMA (**RPM 219**)		(RPM 141). Mitigation strategies listed under Sage Grouse would also apply. No residual effects are anticipated.		
98	Wildlife – Other Birds (including Long-billed Curlew)	Increased risk of mortalities from vehicle collisions due to the development of new access roads and increased traffic		Post appropriate road warning signs and support the enforcement of speed limits (**RPM 135**) Use remote telemetry and SCADA technology to reduce vehicle trips and human presence for well monitoring and control during production activities (**RPM 2; 121**)	Close and reclaim unnecessary roads to reduce fragmentation and restore habitat integrity (**RPM 141**)	Increased risk of mortalities from vehicle collisions would be minimized by using remote telemetry and SCADA technology to reduce vehicle trips and human presence for well monitoring and control during production activities (RPM 2; 121) and posting appropriate road warning signs and supporting the enforcement of speed limits (RPM 135); and rectified/restored by closing and reclaiming unnecessary roads to reduce fragmentation and restore habitat integrity (RPM 141).	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	N/A
99	Wildlife – Other Birds (including Long-billed Curlew)	Increases in accidental mortality due to equipment such as tanks containing freestanding liquids, chemical tank secondary containment, and other hazards	Jonah Energy would not use any open reserve pits (**Preferred Alternative**) All new production facilities that have open-vent exhaust stacks will be equipped to prevent bird and bat entry or perching on the stack (**RPM 237**)	Implement spill prevention and cleanup measures (**RPM 36**)		Increases in accidental mortality due to equipment such as tanks containing freestanding liquids, chemical tank secondary containment, and other hazards would be avoided by not using open reserve pits (Preferred Alternative) and equipping all new production facilities that have open-vent exhaust stacks to prevent bird and bat entry or perching on the stack (RPM 237); and minimized by implementing spill prevention and cleanup measures (RPM 36). No residual effects are anticipated.	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	N/A
100	Wildlife – Other Birds (including Long-billed Curlew)	Increases in accidental mortality due to collisions or entrapment in wire exclosure fences for well pads or production facilities and associated ROWs.		Minimize ROW fencing. Fence design must be approved by the WGFD and meet BLM fencing standards for facilitating wildlife movement (**RPM 202**)		Increases in accidental mortality due to collisions or entrapment in wire exclosure fences would be minimized by minimizing ROW fencing and using fence designs approved by the WGFD and meeting BLM fencing standards for facilitating wildlife movement (RPM 202), and working with permittees and the BLM to identify wildlife-	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM	N/A

Row #	Resource	Impact Indicator[1]	Strategy To Avoid, Minimize, And Rectify Impacts To The Resource[2]			Residual Effects[3]	Warrant Compensatory Mitigation?[4]	Compensatory Mitigation Options to be Considered at Site-Specific Level
			Avoid[5]	Minimize[6]	Rectify/Restore[7]			
				Work with permittees and the BLM to identify wildlife-friendly fencing initiatives (**RPM 203**) All fences should be wildlife friendly (**RPM 204**)		friendly fencing initiatives (RPMs 203, 204). No residual effects are anticipated.	RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	
101	Wildlife – Other Birds (including Long-billed Curlew)	Direct loss or avoidance of suitable nesting and foraging habitat due to project activities	Do not conduct any activities or surface use from March 15 to August 15 for the protection of migratory bird nests (**RPM 224**)	Implement soil stabilization, erosion control, and reclamation measures (**RPMs 82-117, 148-153**)	Conduct successful reclamation in disturbed areas as soon as practicable (**RPM 89; 129; 141; 143; 149; Appendix C – Reclamation Plan**)	Direct loss or avoidance of suitable nesting and foraging habitat would be avoided by prohibiting activities and surface use from March 15 to August 15 for the protection of migratory bird nests (RPM 224); minimized by implementing soil stabilization, erosion control, and reclamation measures (RPMs 82-117, 148-153); and rectified/restored by conducting successful reclamation in disturbed areas as soon as practicable (RPM 89; 129; 141; 143; 149; Appendix C – Reclamation Plan). No residual effects are anticipated.	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	N/A
102	Wildlife – Other Mammals	Direct loss or avoidance of suitable habitat due to project activities		Implement soil stabilization, erosion control, and reclamation measures (**RPMs 82-117; 148-153**)	Conduct successful reclamation in disturbed areas as soon as practicable (**RPM 89; 129; 141; 143; 149; Appendix C – Reclamation Plan**)	Direct loss or avoidance of suitable habitat would be minimized by implementing soil stabilization, erosion control, and reclamation measures (RPMs 82-117, 148-153) and rectified/restored by conducting successful reclamation in disturbed areas as soon as practicable (RPM 89; 129; 141; 143; 149; Appendix C – Reclamation Plan). No residual effects are anticipated.	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	N/A
103	Wildlife – Other Mammals	Surface disturbance and habitat fragmentation could result in changes in floral species composition and an increase in invasive species that affects the quality and quantity of habitat for other mammals		Implement measures to prevent colonization or control the spread of invasive species and noxious weeds (**RPMs 95, 142-147**)	Conduct successful reclamation in disturbed areas as soon as practicable (**RPM 89; 129; 141; 143; 149; Appendix C – Reclamation Plan**)	Surface disturbance and habitat fragmentation affecting habitat for other mammals would be minimized by implementing measures to prevent colonization or control the spread of invasive species and noxious weeds (RPMs 95, 142-147) and rectified/restored by conducting successful reclamation in disturbed areas as soon as practicable (RPM 89; 129; 141; 143; 149; Appendix C – Reclamation Plan). No residual effects are anticipated.	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM RMPs. Additionally, there would be no residual impacts	N/A

Row #	Resource	Impact Indicator[1]	Strategy To Avoid, Minimize, And Rectify Impacts To The Resource[2]			Residual Effects[3]	Warrant Compensatory Mitigation?[4]	Compensatory Mitigation Options to be Considered at Site-Specific Level
			Avoid[5]	Minimize[6]	Rectify/Restore[7]			
							considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	
104	Wildlife – Other Mammals	Increased risk of mortalities from vehicle collisions due to the development of new access roads and increased traffic		Use remote telemetry and SCADA technology to reduce vehicle trips and human presence for well monitoring and control during production activities (**RPM 2; 121**) Post appropriate road warning signs and support the enforcement of speed limits (**RPM 135**)	Close and reclaim unnecessary roads to reduce fragmentation and restore habitat integrity (**RPM 141**)	Increased risk of mortalities from vehicle collisions would be minimized by using remote telemetry and SCADA technology to reduce vehicle trips and human presence for well monitoring and control during production activities (RPM 2; 121) and posting appropriate road warning signs and supporting the enforcement of speed limits (RPM 135); and rectified/restored by closing and reclaiming unnecessary roads to reduce fragmentation and restore habitat integrity (RPM 141).	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	N/A
105	Wildlife – Other Mammals	Exposure to or incidental ingestion of the various hazardous and non-hazardous materials associated with the project	Jonah Energy would not use any open reserve pits (**Preferred Alternative**)	Implement spill prevention and cleanup measures (**RPM 36**) Install well pad perimeter fencing (**RPM 39**) Work with permittees and the BLM to identify wildlife-friendly fencing initiatives (**RPM 203**) All fences should be wildlife friendly (**RPM 204**)		Exposure to or incidental ingestion of the various hazardous and non-hazardous materials associated with the project would be avoided by not using open reserve pits (Preferred Alternative); and minimized by implementing spill prevention and cleanup measures (RPM 36), installing well pad perimeter fencing (RPM 39); and working with permittees and the BLM to identify wildlife-friendly fencing initiatives (RPMs 203, 204). No residual impacts are anticipated.	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	N/A
106	Wildlife – Other Mammals	Predation of small mammals due to reduced ground cover and increased perching opportunities for raptors		Install raptor perch deterrents on any above ground structures that exceed four feet in height (**RPM 234**)		Predation of small mammals would be minimized by installing raptor perch deterrents on any above ground structures that exceed four feet in height (RPM 234). No residual effects are anticipated.	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA	N/A

Row #	Resource	Impact Indicator[1]	Strategy To Avoid, Minimize, And Rectify Impacts To The Resource[2]			Residual Effects[3]	Warrant Compensatory Mitigation?[4]	Compensatory Mitigation Options to be Considered at Site-Specific Level
			Avoid[5]	Minimize[6]	Rectify/Restore[7]			
							process as warranting compensatory mitigation.	
107	Wildlife – Pygmy Rabbit	Direct loss of suitable habitat	Conduct surveys during site-specific permitting for activities between April 10 and July 10 (**RPM 229**) Characterize special status species habitat and populations within the Project Area and include appropriate avoidance and minimization measures (**RPM 246**)	If suitable pygmy rabbit habitat is found during site-specific surveys, surface disturbance must not exceed 3 percent of mapped or modeled habitat in DA2 (**RPM 230)** Development must avoid entirely cutting off or bisecting suitable pygmy rabbit habitat; roads and pipelines in these areas must meet specific design requirements (**RPM 231**)	Conduct successful reclamation in disturbed areas as soon as practicable (**RPM 89; 129; 141; 143; 149; Appendix C – Reclamation Plan**) Initiate formal consultation with USFWS if substantial unanticipated environmental effects to listed, proposed, or candidate species are observed (**RPM 247**)	Direct loss of suitable habitat would be avoided by conducting surveys during site-specific permitting for activities between April 10 and July 10 (RPM 229) and characterizing special status species habitat and populations within the Project Area and including appropriate avoidance and minimization measures (RPM 246). These same impacts would be minimized by limiting surface disturbance to 3 percent of mapped or modeled pygmy rabbit habitat in DA 2 (RPM 230), avoiding entirely cutting off or bisecting suitable pygmy rabbit habitat with roads and pipelines and meeting specific design requirements (RPM 231); and rectified/restored by conducting successful reclamation in disturbed areas as soon as practicable (RPM 89; 129; 141; 143; 149; Appendix C – Reclamation Plan) and initiating formal consultation with USFWS if substantial unanticipated environmental effects to listed, proposed, or candidate species are observed (RPM 247). No residual impacts are anticipated.	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	N/A
108	Wildlife – Raptors (including special status species)	Increased risk of mortalities from vehicle collisions due to the development of new access roads and increased traffic		Limit development to one disturbance location per 640 acres in DA 1 and DA 3 (Preferred Alternative) Post appropriate road warning signs and support the enforcement of speed limits (**RPM 135**) Use remote telemetry and SCADA technology to reduce vehicle trips and human presence for well monitoring and control during production activities (**RPM 2; 121**)	Close and reclaim unnecessary roads to reduce fragmentation and restore habitat integrity (**RPM 141**)	Increased risk of mortalities from vehicle collisions would be minimized by limiting development to one disturbance location per 640 acres in DA 1 and DA 3 (Preferred Alternative), using remote telemetry and SCADA technology to reduce vehicle trips and human presence for well monitoring and control during production activities (RPM 2; 121), and posting appropriate road warning signs and supporting the enforcement of speed limits (RPM 135); and rectified/restored by closing and reclaiming unnecessary roads to reduce fragmentation and restore habitat integrity (RPM 141).	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	N/A
109	Wildlife – Raptors (including special status species)	Increases in accidental mortality due to equipment such as tanks containing freestanding liquids, chemical tank secondary containment, and other hazards	Jonah Energy would not use any open reserve pits (**Preferred Alternative**) All new production facilities that have open-vent exhaust stacks will be equipped to prevent bird and bat entry or perching on the stack (**RPM 237**)	Implement spill prevention and cleanup measures (**RPM 36**)		Increases in accidental mortality due to equipment such as tanks containing freestanding liquids, chemical tank secondary containment, and other hazards would be avoided by not using open reserve pits (Preferred Alternative) and equipping all new production facilities that have open-vent exhaust stacks to prevent bird and bat entry or perching on the stack (RPM 237); and minimized by implementing spill prevention and cleanup measures (RPM 36). No residual effects are anticipated.	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a	N/A

Row #	Resource	Impact Indicator[1]	Strategy To Avoid, Minimize, And Rectify Impacts To The Resource[2]			Residual Effects[3]	Warrant Compensatory Mitigation?[4]	Compensatory Mitigation Options to be Considered at Site-Specific Level
			Avoid[5]	Minimize[6]	Rectify/Restore[7]			
							protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	
110	Wildlife – Raptors (including special status species)	Increases in accidental mortality due to collisions or entrapment in wire exclosure fences for well pads or production facilities and associated ROWs		Minimize ROW fencing. Fence design must be approved by the WGFD and meet BLM fencing standards for facilitating wildlife movement (**RPM 202**) Work with permittees and the BLM to identify wildlife-friendly fencing initiatives (**RPM 203**) All fences should be wildlife friendly (**RPM 204**)		Increases in accidental mortality due to collisions or entrapment in wire exclosure fences would be minimized by minimizing ROW fencing and using fence designs approved by the WGFD and meeting BLM fencing standards for facilitating wildlife movement (RPM 202), and working with permittees and the BLM to identify wildlife-friendly fencing initiatives (RPMs 203, 204). No residual effects are anticipated.	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	N/A
111	Wildlife – Raptors (including special status species)	Increased risk of collision or electrocution from new powerlines	Bury electric distribution lines in PHMA and Winter Concentration Areas where feasible; otherwise, overhead installations would be allowed if lowest impact alternative (**RPM 214; Preferred Alternative**)	Limit development to one disturbance location per 640 acres in DA1 and DA 3 (**Preferred Alternative**) Design power lines to minimize wildlife-related impacts and construct to the latest APLIC standards (**RPM 215**)		Increased risk of collision or electrocution from new powerlines would be avoided by burying electric distribution lines in PHMA and Winter Concentration Areas where feasible (RPM 214; Preferred Alternative); and minimized by limiting development to one disturbance location per 640 acres in DA1 and DA 3 (Preferred Alternative) and designing power lines to minimize wildlife-related impacts and construct to the latest APLIC standards (RPM 215).	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	N/A
112	Wildlife – Raptors (including special status species)	Direct loss or avoidance of suitable nesting and foraging habitat due to project activities	Do not construct permanent and high profile structures and maintain adequate setbacks for human activity within specified distances of active raptor nests and during seasonal activity periods (**RPMs 232, 233, 238-241**) Apply seasonal protective buffers for identified raptor nests (**RPMs 238-241**) Conduct surveys of raptor nests within a 0.5 to 1.0 proposed surface use or activity areas (**RPM 235**)	Limit development to one disturbance location per 640 acres in DA1 and DA 3 (**Preferred Alternative**) Implement soil stabilization, erosion control, and reclamation measures (**RPMs 82-117; 148-153**)	Conduct successful reclamation in disturbed areas as soon as practicable (**RPM 89; 129; 141; 143; 149; Appendix C – Reclamation Plan**) The BLM will conduct USFWS and WGFD consultation for all mitigation activities relating to raptors and T&E species and their habitats; Jonah Energy will pursue and all permits required for movement, removal, and/or establishment of raptor nests (**RPMs 247, 248**)	Direct loss or avoidance of suitable nesting and foraging habitat due to project activities would be avoided by not constructing permanent and high profile structures and maintaining adequate setbacks for human activity within specified distances of active raptor nests and during seasonal activity periods (RPMs 232, 233, 238-241), applying seasonal protective buffers for identified raptor nests (RPMs 238-241), conducting surveys of raptor nests within a 0.5 to 1.0 proposed surface use or activity areas (RPM 235), and prohibiting actions that prevent raptors from successfully fledging offspring (RPM 236). These same impacts would be minimized by limiting development to one disturbance location per 640 acres in DA1 and DA 3 (Preferred Alternative) and implementing	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	N/A

Row #	Resource	Impact Indicator[1]	Strategy To Avoid, Minimize, And Rectify Impacts To The Resource[2]			Residual Effects[3]	Warrant Compensatory Mitigation?[4]	Compensatory Mitigation Options to be Considered at Site-Specific Level
			Avoid[5]	Minimize[6]	Rectify/Restore[7]			
			Prohibit actions that prevent raptors from successfully fledging offspring (**RPM 236**)			soil stabilization, erosion control, and reclamation measures (RPMs 82-117; 148-153); and rectified/restored by conducting successful reclamation in disturbed areas as soon as practicable (RPM 89; 129; 141; 143; 149; Appendix C – Reclamation Plan), conducting USFWS and WGFD consultation for all mitigation activities relating to raptors and T&E species and their habitats, and pursuing appropriate permits (RPMs 247, 248). No residual effects are anticipated.		
113	Wildlife – White-tailed Prairie Dog	Direct loss or avoidance of suitable habitat due to project activities	Characterize special status species habitat and populations within the Project Area and include appropriate avoidance and minimization measures (**RPM 246**) Conduct preconstruction surveys to confirm the presence or absence of prairie dog colonies (**RPM 251**)	Soil stabilization, erosion control, and reclamation measures (**RPMs 82-117; 148-153**)	Conduct successful reclamation in disturbed areas as soon as practicable (**RPM 89; 129; 141; 143; 149; Appendix C – Reclamation Plan**)	Direct loss or avoidance of suitable habitat due to project activities would be avoided by characterizing special status species habitat and populations within the Project Area and including appropriate avoidance and minimization measures (RPM 246), and conducting preconstruction surveys to confirm the presence or absence of prairie dog colonies (RPM 251); minimized by implementing soil stabilization, erosion control, and reclamation measures (RPMs 82-117; 148-153); and rectified/restored by conducting successful reclamation in disturbed areas as soon as practicable (RPM 89; 129; 141; 143; 149; Appendix C – Reclamation Plan). No residual effects are anticipated.	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	N/A
114	Wildlife – White-tailed Prairie Dog	Surface disturbance and habitat fragmentation could result in changes in floral species composition and an increase in invasive species that affects the quality and quantity of habitat for other mammals		Implement measures to prevent colonization or control the spread of invasive species and noxious weeds (**RPMs 95; 142-147**)	Conduct successful reclamation in disturbed areas as soon as practicable (**RPM 89; 129; 141; 143; 149; Appendix C – Reclamation Plan)**	Surface disturbance and habitat fragmentation affecting habitat for white-tailed prairie dog would be minimized by implementing measures to prevent colonization or control the spread of invasive species and noxious weeds (RPMs 95, 142-147) and rectified/restored by conducting successful reclamation in disturbed areas as soon as practicable (RPM 89; 129; 141; 143; 149; Appendix C – Reclamation Plan). No residual effects are anticipated.	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	N/A
115	Wildlife – White-tailed Prairie Dog	Increased risk of mortalities from vehicle collisions due to the development of new access roads and increased traffic		Use remote telemetry and SCADA technology to reduce vehicle trips and human presence for well monitoring and control during production activities (**RPM 2; 121**)	Close and reclaim unnecessary roads to reduce fragmentation and restore habitat integrity (**RPM 141**)	Increased risk of mortalities from vehicle collisions would be minimized by using remote telemetry and SCADA technology to reduce vehicle trips and human presence for well monitoring and control during production activities (RPM 2; 121) and posting appropriate road warning signs and supporting the enforcement of speed limits (RPM 135); and	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM	N/A

Row #	Resource	Impact Indicator[1]	Strategy To Avoid, Minimize, And Rectify Impacts To The Resource[2]			Residual Effects[3]	Warrant Compensatory Mitigation?[4]	Compensatory Mitigation Options to be Considered at Site-Specific Level
			Avoid[5]	Minimize[6]	Rectify/Restore[7]			
				Post appropriate road warning signs and support the enforcement of speed limits (**RPM 135**)		rectified/restored by closing and reclaiming unnecessary roads to reduce fragmentation and restore habitat integrity (RPM 141).	RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	
116	Wildlife – White-tailed Prairie Dog	Exposure to or incidental ingestion of the various hazardous and non-hazardous materials associated with the project	Jonah Energy would not use any open reserve pits (**Preferred Alternative**)	Implement spill prevention and cleanup measures (**RPM 36**) Install well pad perimeter fencing (**RPM 39**) Work with permittees and the BLM to identify wildlife-friendly fencing initiatives (**RPM 203**) All fences should be wildlife friendly (**RPM 204**)		Exposure to or incidental ingestion of the various hazardous and non-hazardous materials associated with the project would be avoided by not using open reserve pits (Preferred Alternative); and minimized by implementing spill prevention and cleanup measures (RPM 36), installing well pad perimeter fencing (RPM 39); and working with permittees and the BLM to identify wildlife-friendly fencing initiatives (RPMs 203, 204). No residual impacts are anticipated.	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	N/A
117	Wildlife – White-tailed Prairie Dog	Predation of small mammals due to reduced ground cover and increased perching opportunities for raptors		Install raptor perch deterrents on any above ground structures that exceed four feet in height (**RPM 234**)		Predation of small mammals would be minimized by installing raptor perch deterrents on any above ground structures that exceed four feet in height (RPM 234).	No. There are no anticipated residual effects that warrant compensatory mitigation. The project would not inhibit achieving compliance with laws, regulations, and/or policies or identified resource objectives in applicable BLM RMPs. Additionally, there would be no residual impacts considered as important, scarce, sensitive, or having a protective legal mandate that was previously identified in a mitigation strategy or NEPA process as warranting compensatory mitigation.	N/A