Oil Spill Risk Analysis for the Kobuk-Seward Peninsula Planning Area

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Introduction

This section summarizes the probability, behavior, and potential impacts that might result from a variety of oil spill scenarios. The spill scenarios used in this draft RMP/EIS, especially for larger volume spills, are likely to overestimate, in some cases substantially, the probability of a spill and/or the potential impacts. The probability of and impacts from oil spills in Alaska have received extensive analysis and review in several recent environmental documents. Though the details differ among several of the documents, the basic data and conclusions are generally similar. We incorporate these documents by reference and summarize the key points in this document.

The Reasonably Foreseeable Development Scenario (RFD) developed for the Kobuk-Seward planning area indicates that the entire planning area has either no potential for development or low potential for development. The RFD does, however, describe a hypothetical scenario of exploration and development in the area of high oil and gas occurrence potential in the northern portion of the planning area. This risk analysis for oil spills addresses the potential and severity of oil spills that would occur should this hypothetical scenario of exploration and development occur.

Spills could occur from pipelines, production and exploration pads, airstrips, and roads. Spills that leave the pads and roadbeds could reach one or more of several habitat types, including wet and dry tundra, tundra ponds, lakes, flowing creeks and rivers, and potentially the adjacent nearshore Chukchi Sea. Spills could occur anytime during the year.

Rules and Regulations

Oil and gas well drilling on Federal lands requires the lessee to submit an application for permit to drill (APD). APD's are approved consistent with the requirements in Onshore Oil and Gas Order No. 2 which requires all drilling operations to have well control of sufficient strength to control all anticipated well pressures. The equipment must be installed properly and tested before drilling begins. In order to explore and develop within the KSPPA, a lessee would also be required to have an "Oil Spill Contingency Plan" that describes how the lessee would respond to a spill incident. The plan must include location and type of equipment, estimated response times, and availability of trained personnel. An activity site would be an exploration site, drilling site, or production site, each with its ancillary facilities. Lessees would be required to submit their oil spill contingency plans with their exploration and development proposals. These contingency plans and their effectiveness would be evaluated during the

environmental review and assessment of the exploration and development proposal. (TAPS FEIS)

Section 19.70.020 of the North Slope Borough Planning and Zoning Policies states that all area wide policies set forth in this section (including all development and uses) must comply with each of the applicable established policies as described. This includes being in compliance with the Native American Graves Protection and Repatriation Act of 1990 (25 USC 3001 – 3119). Proposed development and use of North Slope lands must not be within recognized sites logged with the National Register of Historic Places, the National Register, the Commission on Inupiat History, Language and Culture or the State Historic Preservation Office (Borough Planning and Zoning Policies, 19.70).

BLM and the State of Alaska Oil and Gas Conservation Commission (AOGCC) regulations require an operator to maintain well control at all times during drilling and production. If control of the well is lost (blowout), the BLM oversees all actions needed to bring the well under control. If there is a spill or release of petroleum, drilling fluids or other chemicals used in the petroleum industry, BLM has the authority to direct the operator to clean up the spill and perform remedial action. Cleanup and remediation would be conducted in cooperation with other Federal or State agencies.

BLM requires that all spills or other undesirable events be reported to the authorized officer (AO) within 24 hours of the event. The BLM oversees the work of the lessee or operator to ensure that all spills or undesirable events are appropriately cleaned up in accordance with all applicable laws and regulations. Undesirable events are defined in Notice to Lessees No. 3A (NTL-3A) as spills or releases of petroleum fluids or chemicals used in the petroleum industry. The State of Alaska also has requirements for reporting spills of oil and hazardous substances. Those requirements are found in 18 AAC 75.300.

Alaska Statutes Title 46, Chapters 3 and 4 provide the Alaska Department of Environmental Conservation (ADEC), with authority to prevent and respond to oil pollution. In addition, AS 46.03 and 46.04 provide ADEC with civil, criminal, and administrative enforcement authorities. The ADEC regulations that apply to oil spill prevention, contingency planning, and response are found in Alaska Administrative Codes, Title 18, Chapter 75 (18 AAC 75). (TAPS FEIS)

A spill response plan must include an action plan and a list of contacts in State and Federal agencies with direct responsibilities in the event of a spill and private companies that can be called on for further information or assistance. The environmental obligations of operators on a federal onshore lease are described in BLM regulations in 43 CFR 3160, Oil and Gas Operating Rules. In addition, parts or all of several Onshore Oil and Gas Orders may apply, as necessary.

The ADEC is responsible as the On-Scene Coordinator (OSC) for spills on most lands within the State. The U.S. Environmental Protection Agency (EPA) serves as the OSC for spills that reach inland waters. The USCG is responsible for directing spill cleanup in tidewater areas and on the seas. The OSC must ensure compliance with all Federal and State laws. The intent of the applicable laws and regulations is to prevent, as much as possible, hazardous materials from entering water and to ensure the rapid removal of these substances from areas where there is a danger of contaminating water. The OSC, in coordination with the surface-land manager, monitors and documents the operator's actions and determines when the cleanup is satisfactory. The OSC instructs those responsible for the spill as to what additional measures are to be taken.

An exploration or production facility operator is required to include plans for the control and containment of spills, including blowouts, in their ADEC-approved contingency plan. The ADEC requires that all oil-spill prevention and contingency plans rely on control, containment, and cleanup of spills as the primary response tools. In situ burning is a spill response technique that would be considered and may be used, upon approval, in appropriate circumstances.

Alaska statutes and ADEC regulations require that an operator of an oil exploration or production facility, a terminal facility (storing 5,000 bbl of crude oil or 10,000 bbl of noncrude oil), an oil tank vessel or oil barges, a nontank vessel of more than 400 gross tons, or a crude oil pipeline have an oil discharge prevention and contingency plan approved by ADEC before beginning operations (AS 46.06.030 and 18 AAC 75.400). The ADEC also requires operators of facilities that must have an approved contingency plan and operators who drill for shallow natural gas (3,000 ft below ground surface or less) to provide acceptable proof of financial responsibility for the cleanup of oil spills. Facilities that must have an ADEC-approved contingency plan must meet oil pollution prevention requirements found in 18 AAC 75.005 - 75.090. Under these State requirements, operators must plan to contain or control an oil spill within 72 hours and to clean up a spill in the shortest possible time, consistent with minimizing damage to the environment. Two measures to reduce the potential for oil spills that the State has employed in the past are winter-only drilling and seasonal drilling restrictions. (TAPS FEIS)

Equipment available

Some emergency spill response equipment is located in the Alpine and Prudhoe Bay areas, roughly 350 miles east of the planning area. A limited supply of spill response equipment is also available at the North Slope Borough's Point Hope Fuel Storage Facility, which is managed by the North Slope Borough Public Works Department. Supplies contained in the stationary connexes include sorbent pads, 1000 feet of boom, a mop machine w/a rope mop, a variety of skimmers, a compressor, hoses, shovels, buoys, rebar and driver, trash pump, a wide variety of tools, a 2400 gallon fast tank, VHF radios, pipe fittings, HAZMAT PPE and some survival gear (North Slope Borough, 11/30/05). Alaska Clean

Seas has an extensive amount of similar spill response equipment located mainly at the Prudhoe Bay facility, with some additional equipment at the Alpine facility.

Upon securing an oil and gas production lease, the lessee would normally join the ACS co-op. ACS would then deploy equipment to the site based on worst case scenario situations. Available equipment would range from a recovery arm boom to skimmers to sorbant pads to hand tools. Clean up methodologies used for different scenarios are outlined in the ACS Technical Manual under "Recovery Tactics." Since releases to the tundra would tend to volatize rapidly and migrate slowly, spill response equipment could be located in a centralized facility, with trucks and qualified personnel readily available to mobilize when a release occurs.

Potential Areas of contamination

Most spills would occur in close association with the oilfield infrastructure. For convenience, the locations are classified as follows:

• gravel pads for drilling, production and processing facilities
• gravel roads (including culverts)
• gravel airstrips
• temporary ice roads and ice pads
• pipelines (including the VSM and bridges that support the pipelines)

Only in a rare and unusual circumstance (e.g., aircraft crash) would the source of a spill occur any distance from one of these structures. Most spills, except from pipelines, occur and are contained on the ice or gravel pads, roads, and airstrips, and they are promptly cleaned up as required by federal, state, and borough regulations before they reach the tundra or water bodies. Pipeline spills could occur at some distance from the nearest road or pad.

Estimated time to get equipment to spill sites

Estimated response times would vary based on weather conditions, congestion on the ice road, location of spill event relative to available response equipment and readily available personnel. Alaska Clean Seas main focus would be to isolate released product downhill from creek drainages and /or watersheds to keep released product from reaching the ocean. (phone conversation with ACS representative, Jim Nevells, 12/27/2005)

For example, a produced water spill occurred near Kuparuk on the 2H drilling pad in 2005. It took work crews 4 hours to establish a perimeter, set up a decontamination zone, and dispatch equipment to the site. Spill response equipment was located approximately 12 miles away from the spill site. Travel times are based on ADEC regulated speed limits of 35 mph on land, 5 knots per hour on water. For the 2H Pad produced water spill near Kuparuk, it took

inspectors approximately ½ hour to arrive on site for a preliminary inspection (phone conversation with Lee Majors of ACS, 12/30/05) Travel times for each tactical response are outlined in the ACS Technical Manual in table format following the general descriptions of each response tactic.

Disposal methods of collected spill materials

When establishing the production pads and central processing facility, industry would be best served for treating drilling or other wastes by both drilling one or more AOGCC or EPA approved underground injection disposal wells for drilling and other associated production wastes. A buffer storage reservoir and an oil water separator should be fixtures in the proposed central processing facility to accommodate down times in production, and for reprocessing treatable, reusable waste product. (phone conversation with AOGCC representative, Jim Regg, 1/5/06)

Alaska Clean Seas (ACS) has a variety of cleanup methodologies for various types of releases (spills to the tundra, spills on snow, embedded oil in ice, trapped oil under ice, etc) that they implement when a release occurs in the field (Alaska Clean Seas Technical Manual).

For example, should there be a release of crude oil to snow and ice covered tundra, spilled materials would be isolated, contaminated snow and ice would be scraped up and containerized, melted down and injected into an Alaska Oil and Gas Conservation commission (AOGCC) approved underground injection disposal well. The isolated affected areas would be flushed with hot water to loosen and capture any remaining hydrocarbons by using vacuum trucks to suction the contaminated melt water off of the tundra. Other spill scenarios similar to the aforementioned are outlined thoroughly in the Alaska Clean Seas Technical Manual.

Historical Large Crude Oil Spill Rates

No Alaska North Slope facility or pipeline spills greater than or equal to 1,000 bbl from Alaska North Slope production have occurred since 1985. No documentation for crude oil spills greater than or equal to 100 bbl occurring prior to 1985 was found, but spill records dated prior to 1985 have not been validated as complete because of missing or incomplete documentation.

Five facility spills and one pipeline spill are documented from 1985 to 2000. Total Alaska North Slope production was estimated to be 9.36 billion barrels (Bbbl) of crude oil and condensate (Alyeska Pipeline Service Company 2001, McMaines 2001). Anderson and LaBelle (2000) calculated Alaska North Slope spill rates from 1985 to 1998, hence they are slightly different from the spill rates calculated, using the 1985 to 2000 information. The spill rate of 0.53 large spills per Bbbl handled was calculated for Alaska North Slope facility spills, using the

entire record of five spills from 1985 to 2000. The BLM and MMS use the 1985 to 2000 time period because spills greater than 100 bbl have been documented since 1985. In addition, the ADEC began an electronic database of oil spills in 1985. The BLM and MMS consider the database most reliable from 1985 forward. The Alaska North Slope pipeline spill rate of 0.11 large spills per Bbbl handled was based on the record of one pipeline spill from 1985 to 2000. The combined large crude oil spill rate for facilities and pipelines is 0.64 spills per Bbbl handled.

Spill Volumes, Sizes and Areas of Contamination

Information on large oil spills is based on historical data from the North Slope. The following summarizes the assumptions used to analyze large oil spills, which are a mixture of project-specific information, modeling results, statistical analysis, and professional judgment.

Oil Spills

Predicting an oil spill is an exercise in probability, based on historic data. There is uncertainty in the location, number, and size of any spills, the chemistry of spilled oil, and the environmental conditions at the time of a spill. Over the lifetime of exploration and development in the Planning Area, the probability of small spills occurring is high, and small spills are expected to occur. The probability of a large spill occurring is substantially less. The probability of a very large spill occurring is very low and considered extremely unlikely.

The responses to a spill and amount of oil removed are variable and dependent upon the weather conditions, time of year, location, the size of the spill, and other factors. The amount of oil removed can range from none to effectively all of the oil. By assuming no cleanup, the estimated effects to the resources would tend to be overestimated, or greater than what would actually occur.

This Oil Spill Risk Analysis (OSRA) for the Kobuk Seward Peninsula Planning Area analyzes what is likely to happen in the future, using assumptions about the likely size, duration, and type of a spill to analyze the effects. To estimate these parameters, oil spills are divided into two types: crude oil and refined oil spills. Crude oil spills are divided into three size categories: small, large, and very large. Within each of these categories, generalized and specific assumptions are made.

Refined spills fall into the small spill size category. Small spills are defined as being less than or equal to 500 barrels (bbl; 1 bbl = 42 gallons); large spills range from greater than or equal to 500 bbl to less than or equal to 120,000 bbl; and very large spills are greater than 120,000 bbl. The following sections discuss the

oil spill analysis, and the assumptions used for analysis, for each of these three size categories. (Appendix K, NE-NPR-A, 2005)

Large Oil Spills

Large spill scenarios involve a 500-bbl crude spill from a pipeline or a 900-bbl crude or diesel oil spill from a gravel pad facility. A large spill from a planning area facility or pipeline could happen at any time during the year. Large Crude Oil Spills greater than or equal to 500 bbl occur at a rate of 0.64 spills per billion barrels. To estimate the mean number of spills, multiply the resource volume in billion barrels times the spill rate.

The spills are classified as follows:

Large spills are defined as greater than or equal to 500 bbl for the planning area, Alaska North Slope and Trans-Alaska Pipeline System (TAPS), and greater than or equal to 1,000 bbl for the TAPS tankers. Historical information about previous large spills on the Alaska North Slope, from TAPS and TAPS tankers was used to estimate the large spill sizes that are likely to occur in the future.

For example 0.5 Bbbl x 0.64 spills/Bbbl=0.32 spills (formula taken from NE-NPR-A IAP/FEIS, 2005). Then, for purposes of analysis, the number of spills is rounded to the nearest whole number; in this case, the nearest whole number would be one. These figures tend to be rounded up to be conservative. The following is a table estimating large crude oil spills over the production life of a KSPPA discovery:

Table 1 – Large Crude Oil Spills Estimated Over the Production Life of the Kobuk-Seward Peninsula Planning Area

Alternative	Resources (Bbbl)	Spill Rate (spills/Bbbl)	Assumed Spill Size (bbl)	Estimated Mean Number of Spills[1]	Estimated Total Volume of Spills (bbl)[2]
Crude Oil					
A	0	0	0	0	0
B	0.5	0.64	500 or 900	0.16 ≈ 1	500 or 900
C	0	0	0	0	0
D	0.5	0.64	500 or 900	0.16 ≈ 1	500 or 900

[1]The estimated mean number of oil spills is based on the estimated resource volume multiplied by the spill rate

[2]The estimated total spill volume is the total volume for all of the estimated spills for the given alternative and price of oil

Scenarios have been created, practiced and are available for reference through Alaska Clean Seas (ACS) Technical Manual. Many of these scenarios outline in

detail how different types of spills could reach any of the following environments similar to the proposed planning area:

• Gravel pad and then the tundra, snow, or ice (gravel pad not assumed to retain any oil);
• Open water (oceanfront, lagoon, lake, or river);
• Broken ice (oceanfront, lagoon, lake, or river);
• On top of or under solid ice (oceanfront, lagoon, lake, or river);
• Shoreline (oceanfront, lagoon, lake, or river); or
• Tundra or snow and ice.

Based on modeling, the large spill scenario (500 bbl) assumes that after 30 days in open water or broken ice, 23 to 40 percent of the oil evaporates, 0 to 22 percent disperses, and 38 to 77 percent of the oil remains. After 30 days under ice in a lagoon or lake, nearly 100 percent of the oil remains in place and unweathered. (USDOI BLM NE NPR-A IAP/EIS, 2005) Remaining oil would need to be extracted and containerized for future disposal in either an ADEC approved disposal well, or be pumped through an established waste pipeline leading to a disposal facility for post-processing.

The analysis of the effects of large oil spills is based on the following assumptions:

- One large spill occurs under Alternatives B and D;
- All the oil reaches the environment and the gravel pad absorbs no oil;
- The spill starts at the gravel pad or along a pipeline;
- There is no cleanup or containment;
- The oil chemistry is similar to that of Alpine Field oil;
- The spill could occur at any time of year;
- A spill under lake ice does not move substantially until the ice breaks up;
- Spill locations and dates used in the analysis are those that would result in the greatest impact.

Small Oil Spills

Small oil spills are defined as less than 500 bbl. It is assumed that:

• Small crude spills can begin anywhere on the gravel pad facilities or along the pipeline.
• Small spills on gravel pads occur in contained areas or are cleaned up and do not reach the environment.
• Small spills from pipelines are likely to reach the environment.

Onshore or offshore refined-oil spills can occur along ice roads, from barges, from helicopters, airplanes, from gravel pad facilities, or from trucks along the

road system. Most refined-oil spills are contained and cleaned up. Typical refined products spilled on the Alaskan North Slope are aviation fuel, diesel fuel, engine lube oil, fuel oil, gasoline, grease, hydraulic oil, transformer oil, and transmission oil. Diesel spills on the Alaskan North Slope are 61 percent of refined oil spills by frequency and 75 percent by volume (NE NPR-A Draft IAP/EIS, 2004). Data regarding spill history on the North Slope indicates that small spills occur at a rate of 618 spills per billion barrels of oil produced. This represents 178 crude oil spills and 440 small refined product spills. If one assumes the spill rate would be similar within the Kobuk-Seward Peninsula Planning Area, 89 small crude oil spills and 220 small refined product spills would be predicted should oil development occur.

Because this analysis of crude oil spills was performed collectively for all Alaska North Slope facilities, pipelines, and flow lines, the pattern that emerged was one of numerous small spills. Of the crude oil spills that occurred between 1989 and 2000, the ADEC database indicates that:

- 18 percent were less than or equal to 1 gallon;
- 54 percent were less than or equal to 5 gallons; and
- 99 percent were less than 25 bbl.

The small spill sizes in the database range from less than 1 gallon to 425 bbl. The mean crude oil spill size on the Alaska North Slope is 2.7 bbl, and the median spill size is 5 gallons. For purposes of the oil spill analysis in the Kobuk-Seward Peninsula Planning Area, a mean crude oil-spill size of 3 bbl is assumed for small spills. The database indicates that the causes of small crude oil spills on the Alaska North Slope, in decreasing order of frequency, are:

- leaks
- faulty valves/gauges
- vent discharges
- faulty connections
- ruptured lines
- seal failures
- human error
- explosions

Approximately 30 percent of the spills in the database do not include information on the causes. The estimated small crude oil spill rate for the Alaska North Slope is 178 spills per Bbbl produced. The mean number, size, and total volume of small spills for each of the alternatives are shown in Table 2. For this oil spill analysis, the mean number of small spills is used as the assumed number of spills. The assumed size distribution of those spills for each of the alternatives is shown in Table 3.

The following tables outline small crude oil spills over the production life of the Kobuk-Seward Peninsula Planning Area. These numbers were derived from an ADEC report consolidating all spills that occurred on the North Slope between 1989 and 2000. (Appendix K, NE-NPR-A Final Amended IAP/EIS)

Table 2 – Small Crude Oil Spills Estimated Over the Production Life of the Kobuk-Seward Peninsula Planning Area

Alternative	Resources (Bbbl)	Spill Rate (spills/Bbbl)	Assumed Spill Size (bbl)	Estimated Mean Number of Spills[1]	Estimated Total Volume of Spills (bbl)[2]
Crude Oil					
A	0.5	0	0	0	0
B	0.5	178	3	89	267
C	0.5	0	0	0	0
D	0.5	178	3	89	267

[1]The estimated mean number of oil spills is based on the estimated resource volume multiplied by the spill rate

[2]The estimated total spill volume is the total volume for all of the estimated spills for the given alternative and price of oil

Table 3 – Assumed Size Distribution for Small Crude Oil Spills for the Production Life of the Kobuk-Seward Peninsula Planning Area

Spill Size Range[1]	Estimated Number of Spills Under Each Alternative[2,3]			
	Alternative A	Alternative B	Alternative C	Alternative D
<1 bbl				
≤ 1 gal	0	19	0	19
> 1 gal and ≤ 5 gal	0	31	0	31
> 5 gal and < 1 bbl	0	17	0	17
Total spills < 1 bbl	**0**	**67**	**0**	**67**
≥ 1 bbl and < 500 bbl				
> 1 bbl and ≤ 5 bbl	0	17	0	17
> 5 bbl and ≤ 25 bbl	0	4	0	4
> 25 bbl and < 500 bbl	0	1	0	1
Total spills > 1bbl and < 500bbl	**0**	**22**	**0**	**22**
Total number of spills	**0**	**89**	**0**	**89**

[1]Spill-size distribution is allocated by multiplying the total estimated number of spills by the fraction of spills in that size category from the ADEC database

[2] Estimated number of spills is rounded to the nearest whole number.

[3] The integers are presented as the estimated number of spills at the predicted activity level with $33/bbl oil.

Historical Small Refined Oil Spill Rates and Types of Spills on the North Slope

Typical refined products spilled are aviation fuel, diesel fuel, engine lube, fuel oil, gasoline, grease, hydraulic oil, transformer oil, and transmission oil. On the Alaska North Slope, diesel spills represent 61 percent of refined oil spills by frequency and 75 percent by volume. Engine lube oil spills are 10 percent by frequency and 3 percent by volume. Hydraulic oil spills are 26 percent by frequency and 10 percent by volume. All other categories of spills are less than 1 percent by frequency and volume. Refined oil spills occur in conjunction with oil exploration and production, and correlate to the volume of Alaska North Slope crude oil produced. As production of crude oil has declined, so has the number of refined oil spills. However, this apparent relationship could be coincidental, as emphasis on pollution prevention has also increased in the last several years. From 1989 to 2000, the spill rate for refined oil was 440 spills per Bbbl produced.

The mean number of refined oil spills during the lifetime of the alternatives is shown in Table 4:

Table 4 – Small Refined Oil Spills <500 bbl Estimated Over the Production Life of the Kobuk-Seward Peninsula Planning Area

Alternative	Resources (Bbbl)	Spill Rate (Spills/Bbbl)	Assumed Spill Size (bbl)[1]	Estimated Mean Number of Spills[2,3]	Estimated Total Spill Volume (bbl)
A	0.5 Bbbl	0	0	0	0
B	0.5 Bbbl	440	0.7	220	154
C	0.5 Bbbl	0	0	0	0
D	0.5 Bbbl	440	0.7	220	154

[1] The mean spill size for refined spills on the Alaska North Slope from 1989 – 2000; equivalent to 29 gal.
[2] The fractional estimated mean spill number and volume are rounded to the nearest whole number.
[3] The integers represent the estimated number of spills at the produced activity level with $33/bbl oil.

Probability of a Very Large Oil Spill - Greater Than or Equal to 120,000 Barrels

Size assumptions for very large spills for Planning Area facilities and pipelines are based on response planning standards and discharge estimates for the Alpine oil field (ARCO Alaska 1999, Phillips 2001). Blowouts are unlikely events. While blowouts are often equated with catastrophic spills, very few blowout events have resulted in spilled oil, and the volumes that are spilled are often small.

Fate and Behavior of Oil Spills

This section describes the properties and behaviors of spilled oil that are important to the evaluation of the potential effects that the spilled oil may have in the various environments that occur in the planning area.

Fate and Behavior

The primary processes that affect the fate of spilled oil are spreading, evaporation, dispersion, dissolution, and emulsification (Payne et al., 1987; Boehm, 1987; Lehr, 2001). These processes--called weathering--dominate during the first few days to weeks of a spill, and, except for dissolution, can dramatically change the nature of the oil. A number of longer-term processes also occur, including photo- and biodegradation, auto-oxidation, and sedimentation. These longer-term processes are less important than the five listed above for the initial fate of spilled oil. Longer-term processes are more important in the later stages of weathering and usually determine the ultimate fate of the spilled oil. (USDOI/BLM NW-NPR-A FEIS, 2003)

The chemical and physical composition of oil changes with weathering. Some oils weather rapidly and undergo extensive changes in physical and chemical composition, whereas others remain relatively unchanged over long periods of time. As a result of evaporation, the effects of weathering are generally rapid (1 to 2 days) for hydrocarbons with lower molecular weights. Degradation of the higher weight fractions is slower and occurs primarily through microbial degradation and chemical oxidation. The weathering or fate of spilled oil depends on the oil properties and on environmental conditions. It is important to recognize the dynamic nature of spilled oil and the fact that the properties of spilled oil can change over time.

Spreading reduces the bulk quantity of oil present in the vicinity of the spill but increases the spatial area over which adverse effects from oil may occur. Thus, oil in flowing systems (as opposed to contained systems) will be less concentrated in any given location, but may cause impacts over a much larger area. Spreading and thinning of spilled oil also increase the surface area of the slick, enhancing surface-dependent fate processes such as evaporation, degradation, and dissolution.

Evaporation is the primary mechanism for loss of low molecular weight constituents and light oil products. As lighter components evaporate, the remaining petroleum product becomes denser and more viscous. Evaporation tends to reduce oil toxicity but enhance persistence. Hydrocarbons that volatilize into the atmosphere are broken down by sunlight into smaller compounds. This process, referred to as photodegradation, occurs rapidly in air, and the rate of photodegradation increases as molecular weight increases.

Dispersion of oil increases with increasing surface turbulence. The dispersion of oil into water may serve to increase the surface area of oil susceptible to

dissolution and degradation processes and thereby limit the potential for physical impacts.

Dissolution of oil in water is not a significant process controlling the oil's fate in the environment. It is one of the primary processes affecting the toxic effects of a spill, especially in confined water bodies. Dissolution increases with 1) decreasing molecular weight, 2) increasing temperature, 3) decreasing salinity, and 4) increasing concentration of dissolved organic matter.

Emulsification is the incorporation of water into oil and is the opposite of dispersion. Small drops of water become surrounded by oil. External energy from wave action is needed to emulsify oil. In general, heavier oils emulsify more rapidly than lighter oils. The oil may remain in a slick, which can contain as much as 70 percent water by weight and can have a viscosity a hundred to a thousand times greater than the original oil. Water-in-oil emulsions often are referred to as "mousse."

Photodegradation of oil increases with greater solar intensity. It can be a significant factor controlling the disappearance of a slick, especially of lighter products and constituents; but it will be less important during cloudy days and may be nonexistent in winter months in the planning area. Photodegraded petroleum product constituents tend to be more soluble and more toxic than parent compounds. Extensive photodegradation, like dissolution, may thus increase the biological impacts of a spill event.

In the immediate aftermath of a spill, natural biodegradation of oil will not tend to be a significant process controlling the fate of oil in water bodies previously unexposed to oil. Microbial populations must become established before biodegradation can proceed at any appreciable rate.

Overall, the environmental fate of released oil is controlled by many factors and persistence is difficult to predict with great accuracy. Major factors affecting the environmental fate include the type of product, spill volume, spill rate, temperature of the oil, terrain, receiving environment, time of year, and weather. Crude oil will weather differently from diesel or refined oil in that both diesel and refined oil will evaporate at a significantly faster rate than crude oil.

The characteristics of the receiving environment, such as type of land, the surface gradient, marine or freshwater, surface or subsurface, spring ice overflow, summer open water, winter under ice, or winter broken ice, will affect how the spill behaves. In ice-covered waters, many of the same weathering processes are in effect as with open water; however, the ice changes the rates and relative importance of these processes (Payne, et al. 1991).

The time of year that a spill occurs has a significant effect on the fate of the crude oil. The time of year controls climatic factors such as temperature of the air, water or soil; depth of snow cover; whether there is ice or open water; and the

depth of the active layer. During winter the air temperature can be so cold as to modify the viscosity of the oil so it will spread less and may even cause it to solidify. The lower the ambient temperature, the less crude oil evaporates. Both Prudhoe Bay and Endicott crudes have experimentally followed this pattern (Fingas, 1996). Frozen ground will limit the depth of penetration of any spill. Ice will act as a barrier to penetration until it melts.

Spills on Tundra

Oil movement over the ground surface follows the topography of the land (oil flows downhill). In general, oil will flow until it reaches a surface water body or a depression, or until absorption prevents further movement. Oil flowing over land can infiltrate vegetation cover, soil and snow. The rate of oil movement and depth of penetration are dependent on a variety of factors. If released onto tundra, oil can penetrate the soil as a result of the effects of gravity and capillary action. The rate of penetration will depend on the season, nature of the soil and the type of petroleum product. In summer, spills penetrate the active layer and then spread laterally on the frozen subsurface, accumulating in local downturns. From there the oil can penetrate into the permafrost (Collins, et al. 1993). Precipitation may increase penetration into thawed soils (Solntseva, 1998 as cited in Chuvilin et al., 2001). If groundwater becomes contaminated, contaminants generally remain concentrated in plumes. Because ground water moves relatively slowly, contaminants do not mix or spread rapidly. Contaminated ground water may eventually migrate and appear in surface waters.

In winter spreading is controlled by the snow cover or frozen soil. Snow cover can act as an absorbent, slowing the spread of oil or preventing the spill from reaching the tundra surface. During winter, oil spreads on the surface of the frozen soil and penetration of oil into the soil is generally limited. Pore space in the soils that is not filled with ice may allow spilled oil to move into the frozen soil (Yershov et al., 1997; Chuvilin et al., 2001).

Tundra relief on the coastal plain of the North Slope is low enough to severely limit the spread of spills. During summer, flat coastal tundra develops a dead-storage capacity averaging 0.5 to 2.3 inches deep (Miller, et al. 1980), which would retain 300 to 1,500 bbl of oil per acre. Even at high-water levels, the tundra vegetation tends to act as a boom, with both vegetation and peat functioning as sorbents that allow water to filter through, trapping the more viscous oil (Barsdate et al., 1980) and also making recovery of the oil more difficult. On the other hand, even small spills can be spread over large areas if the spill event includes aerial, pressured discharge. With the high-velocity, bi-directional winds on the North Slope, oil can be misted miles downwind of a leak. For example, in December 1993, an ARCO drill site line failed, and 1 to 4 bbl of crude oil misted over an estimated 100 to 145 acres (Ott, 1997).

Spills into Marine or Fresh Water

The aforementioned sections ("Spills on Tundra" and "Fate and Behavior of Oil Spills – Fate and Behavior") and the following statements under the heading "Spills into Marine or Fresh Water" have been taken from the Northwest NPR-A Final Integrated Activity Plan/Environmental Impact Statement.

Weathering processes generally would be similar in the proposed planning area's freshwater and coastal marine regimes. Seasonal ice cover can greatly slow weathering in both regimes. Oil spreading on the water surface (but not necessarily the transport of oil by moving water) would be restricted in most of the planning area's waters. Because of the increased viscosity of oil in cold water, oil spills in the planning area's lake, river, and marine waters would spread less than in temperate fresh or marine waters. The exception to this would be a spill in shallow, marshy or ponded tundra or flooded lake margins in summer, which could spread similarly to a temperate spill. The exception is possible because these shallower waters can reach temperatures up to 18 ° F-- warmer than other tundra waters (Miller, et al. 1980), and warm enough to lower oil slick viscosity.

Oil spills spread less in cold water than in temperate water because of the increased oil viscosity. This property will reduce spreading. An oil spill in broken ice would spread less and would spread between ice floes into any gaps greater than about 8 to 15 centimeters (cm) (Free, et al. 1982).

An oil spill under ice would follow the general manner described below:

1. The oil will rise to the under-ice surface and spread laterally, accumulating in the under-ice cavities (Glaeser and Vance 1971; NORCOR Engineering Research, 1975; Martin, 1979; Comfort et al., 1983).

2. For spills that occur when the ice sheet is still growing, the pooled oil will be encapsulated in the growing ice sheet (NORCOR Engineering Research, 1975; Keevil and Ramseier, 1975; Buist and Dickens, 1983; Comfort et al., 1983).

3. In the spring, as the ice begins to deteriorate, the encapsulated oil will rise to the surface through brine channels in the ice (NORCOR Engineering Research, 1975; Purves, 1978; Martin, 1979; Kisil, 1981; Dickins and Buist, 1981; Comfort et al., 1983).

The spread of oil under the ice may be affected by the presence of currents, if the magnitude of those currents is large enough. A field study near Cape Parry in the Northwest Territories reported currents up to 10 cm/sec were present. This current was insufficient to strip oil from under the ice sheet after the oil had

ceased to spread (NORCOR Engineering Research, 1975). Laboratory tests have shown that currents in excess of 15 to 25 cm/sec are required to strip oil from under-ice depressions (Cammaert, 1980; Cox et al., 1980). Current speeds in the nearshore Beaufort generally are less than 10 cm/sec during the winter (Weingartner and Okkonen, 2001). The area of contamination for oil under ice could increase if the ice were to move. Because the nearshore Beaufort is in the landfast ice area, the spread of oil due to ice movement would not be anticipated until spring breakup. Similar results could be expected for such under ice scenarios in the planning area adjacent to the Chukcki Sea.

Evaporation of oil generally correlates to temperature (Fingas, 1996). The lower the temperature, the slower crude oil evaporates. Both Prudhoe Bay and Endicott crudes have this pattern (Fingas, 1996). Oil between or on ice is subject to normal evaporation. Oil that is frozen into the underside of ice is unlikely to undergo any evaporation until its release in spring. In spring as the multi-year ice deteriorates, the encapsulated oil will rise to the surface through brine channels in the ice. As oil is released to the surface, evaporation will occur. Because freshwater and first year ice do not have enough salts to form brine channels, the oil would be released only as the ice surface ablated to the level of the encapsulated oil. For freshwater ice, this would be when the ice became porous within about 2 weeks of meltout, from May to July, depending on weather, ice thickness, and location of the oil in the ice. In multi-year ice, surfacing of the oil probably would not occur until August, and some oil would not be released until the following summer.

Dispersion of oil spills occurs from wind, waves, currents, or ice. Any waves within the ice pack tend to pump oil onto the ice. Some additional oil dispersion occurs in dense, broken ice through floe-grinding action. More viscous and/or weathered crudes may adhere to porous ice floes, essentially concentrating oil within the floe field and limiting the oil dispersion. Alaska North Slope crude oil will readily emulsify to form stable emulsions. Emulsification of some crude oils is increased in the presence of ice. With floe grinding, Prudhoe Bay crude forms a mousse within a few hours--an order of magnitude more rapidly than in open water.

The weathering processes acting on oil in and along streams or rivers are in most cases similar to those described above for freshwater or marine spills. The dynamics of a river or stream environment, however, have additional effects on the fate and behavior of spilled oil. Oil entering rivers and streams will begin to spread as in freshwater or marine spills, but the spreading motion will be rapidly overcome by the surface current, at which point an elongated slick will form. The oil will flow downstream at the speed of the current in the absence of wind effects. In general, oil will tend to accumulate in areas of quiet water or eddies at the inside of river bends on a meandering river or stream, or in other pools where velocities are slower. Pools of oil may also accumulate behind log or debris jams. Water near the center of a stream channel will flow faster than water near the

banks or bottom of the channel where the retarding forces of friction with the channel are greater. This difference in current speed and the resulting shearing forces between water layers is typically the major mixing mechanism that spreads a slick out as it moves downstream. The resulting shearing of the oil distribution along the axis of flow controls the plume shape and size, and the distance over which the oil concentration will remain above a particular level of concern. The leading edge of the slick may move as a relatively sharp front (at the mid-channel current speed) however, mixing will continuously exchange water and oil between the slower, near-bank regions and the faster-flowing, center regions of the river. From a practical point of view, this means that, although it might be possible to predict the initial arrival of oil at a point along the river, it will be considerably more difficult to estimate when the threat is past, since the areas of slower currents may continue to supply oil to the main stream channel, even after the leading edge is past (Overstreet and Galt, 1995).

Shear-dominated flows cause another effect that characterizes river spills. Shear in currents along the banks and river bottom is typically the major source of turbulence in rivers, in contrast to surface-wave activity in oceans. Mixing and dispersion caused by the interaction of the shear and the turbulence can move significant amounts of oil below the surface (particularly if it is relatively dense, or if it is finely distributed as droplets). The shear-dominated river regimes tend to produce spill distributions having higher subsurface oil concentrations than would be expected in marine spills (Overstreet and Galt, 1995). This turbulence increases with increased velocity of flow and bed roughness.

The NPR-A Oil Experiment

The following was incorporated from the Northwest NPR-A Final IAP/EIS to illustrate how crude oil behaves in an Arctic climate under varying conditions.

On July 16, 1970, 5 bbl of Prudhoe Bay crude was experimentally spilled in a 0.07-acre tundra Pond E in the NPR-A near Barrow (Miller, et al. 1978; Barsdate et al., 1980; Hobbie, 1982). The general behavior of this experimental spill is instructive about what to expect for a small spill in the Planning Area during the summer or for a winter spill that melts out during thaw.

In this experimental spill, the oil spread over the water surface within a few hours to a 0.06-inch thickness. Within 24 hours, the slick thickened, as lighter hydrocarbons evaporated, and shrank into a 10- to 16-ft band on the downwind side of the pond. For about a month, the oil moved back and forth across the pond, shifting sides with changes in wind direction. Gradually, the oil worked part way into the pond's vegetated margins. By the end of summer, all of the oil was trapped along the pond margins either on the water's surface or on the bottom. No oil left the pond during the next spring runoff, despite significant water

throughflow. Half of the oil was estimated to have evaporated or degraded within a year, but the rest of the oil remained with little change for at least 5 years.

The Caribou-Poker Creeks Research Watershed Experiment

A small experimental oil spill was conducted in an open black spruce forest within the Caribou-Poker Creeks Research Watershed (CPCRW), 48 km north of Fairbanks, AK in the winter of 1976. This experiment was designed to examine the effects of crude oil spills in permafrost terrain. No clean-up was attempted, and the site now provides an opportunity to follow the natural weathering of spilled oil under these conditions. In summer 2001, more than 25 years after the spill, Joan Braddock, Jon Lindstrom and Roger Prince sampled soils from the spill plot and a nearby reference plot to determine how the oil had weathered, and to assess microbial populations and activity. All of their collected samples from the oiled plot contained substantial amounts of methylene chloride extractable oil (4% - 66% by weight). It was determined through extraction and analysis that while some of the heavily oiled samples were almost unchanged since the spill, others had lost more than 80% of their initial hydrocarbon.

Evaporation, biodegradation and photooxidation all seem to have played important roles in this process, but to varying degrees in different samples. Various analytical assays indicate that the microbial population in the oiled soils has remained acclimated to degrade hydrocarbons. We conclude that natural weathering processes will eventually lead to the removal of much of the hydrocarbon from these heavily oiled subarctic soils. Oil residue within the study area will remain for decades to come based on the low rates of nutrient turnover, short thaw seasons, and high hydrocarbon concentrations. There is still a need to find an environmentally appropriate cleanup technology for sites similar to the aforementioned (Braddock, et. al, 2002).

Spill Volumes and Damage to Tundra Calculated by Alternative

Assumptions about oil spills are used to analyze the effects of oil spills. These assumptions pertain to the type of oil, the source of an oil spill, the general location and size of a spill, the chemistry of the oil, how the oil will weather, how long the oil will remain, and where the oil will go. Project-specific information, statistical analysis, and professional judgment support the assumptions. Based on these assumptions, a scenario is created to reflect a spill, and the effects of such a spill are analyzed. These steps constitute a “what if a spill occurs” analysis.

This oil spill analysis considers the entire production life of the Planning Area, and assumes that commercial quantities of hydrocarbons are present in the Planning Area and that these hydrocarbons will be developed and produced at the estimated resource levels presented in the DRMP/EIS. Uncertainties exist,

such as 1) the actual resource levels, 2) the actual size of a crude or refined oil spill, 3) the approximate location of oil assumed to be produced, and 4) whether production would occur at all. If no hydrocarbons exist, there is no chance of a crude oil spill occurring in the Planning Area. (NE-NPR-A Final amendment, 2005)

Most small spills are generally less than one gallon per spill event. This being the case, much of the produced waste would be scraped up off of the ice pad, containerized for later disposal into an ADEC approved waste well located on site. This Oil Spill Risk Analysis assumes that all production will occur on-shore, thus all spill events are assumed to occur on-shore as well. The following table was created by referencing compiled historical spill data contained within the NE-NPR-A Final Amended IAP/EIS, Appendix K:

Table 5 – Oil Spill Scenario Assumptions for the Alternatives

Source of Spill	Type of Oil	Size of Spill (bbl)	Assumed Number of Spills Under Each Alternative				Receiving Environment
			A	B	C	D	
Small Spills (<500 bbl) Onshore and Offshore							
Operational spills from all sources	Diesel or Crude	3	0	89	0	89	Ice, tundra, snow, gravel pad, and water
	Refined	0.7	0	220	0	220	
Large Spills (≥ 500 bbl) Onshore or Offshore							
Pipeline	Crude	500	0	1	0	1	Ice, tundra, snow, gravel pad, and water
Platform/ Gravel Pad	Crude	900					
Storage Tank Gravel Pad	Diesel	900					
Very Large Spills (≥ 120,000 bbl)							
Well Blowout	Crude	120,000	0	0	0	0	Ice, tundra, snow, gravel pad and water

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