Glamis Gold Inc.
Glamis Marigold Mining Company

Sulfide Waste Management Plan
(N26-88-005P)

(Revised)
March 23, 2000

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GLAMIS GOLD, INC.
GLAMIS MARIGOLD MINE
SULFIDE MATERIAL WASTE MANAGEMENT PLAN

1.0 INTRODUCTION

Glamis Gold, Inc. (GGI) currently operates the Glamis Marigold Mine facility under the existing Plan of Operations/Reclamation Plan (POO/RP) No. 26-88-005P. The project consists of multiple open-pits and precious metal processing facilities which are located approximately three miles south of the town of Valmy in eastern Humboldt County, Nevada. The project area encompasses approximately 19,000 acres of private and public land. The project has been in commercial operation since 1988.

Open pit mining at Marigold requires the removal of overburden to expose the gold-bearing rock. Classification of rock as ore or waste is based on the presence or absence of gold and the economic feasibility of recovering the gold from the rock. Rock with low gold content or low recovery potential may be uneconomical to mine, and is then classified as waste. This waste may be stockpiled for processing at some undetermined later time when the economics of processing are more favorable. Rock without economically retrievable gold is permanently stockpiled in the overburden storage facilities. Rock with recoverable gold content is classified as ore and is processed by heap leaching or milling.

Development of the various ore bodies requires that millions of tons of overburden and waste be removed to expose the gold-bearing rock. As described below, several geologic units exist in the region. Depending on the type of material encountered and the geologic processes to which the rock was subjected, the various units may have some limited potential to contain sulfidic material (pyritic sulfur) or other compounds. The excavation and associated fracturing of the various rock units, and subsequent disposal of the waste, provide an opportunity for meteoric water to interact with any sulfide material that may be present. If the material does have a sulfide component, then the meteoric water could result in the generation of acid rock drainage.

To date, the waste characterization data have indicated very little potential for acid generation due to the minimal amount of sulfidic material and the abundance of limestone and waste with excess acid neutralizing potential. However, GGI has proposed to mine deeper and to use the waste generated from mining existing or proposed open pits to backfill some of the existing or planned open pits. Therefore the BLM has requested that the issue of waste characterization be re-evaluated and a plan for managing sulfide waste, if any is encountered, be developed.

In an effort to avoid any environmental contamination impacts that could occur from the exposure of any sulfidic material to meteoric water, GGI has developed a plan for detecting and managing any sulfidic material that may be present. The plan as described below uses additional analysis of blast hole cuttings for sulfidic material detection and the existing permit-required sampling for continued waste characterization. Management of the material consists of blending or encapsulation, depending on the circumstances at the time the material is encountered.

1.1 Geology

In addition to Quaternary alluvium, there are three major sequences or bedrock units present within the areas to be mined. They include the Ordovician Valmy Formation, the Pennsylvanian to Permian Antler or Overlap Sequence, and the Mississippian to Permian Havallah sequence. All three are oxide in character. It is anticipated that little to no sulfidic materials will be encountered during mining. The rock types are described below:

Havallah Sequence. This Pennsylvanian to Permian aged unit consists of bedded chert, siltstone, sandstone, and mudstone. Mafic to intermediate volcanic flows occur randomly throughout this unit. The chert-siltstone-sandstone sequence can have a calcareous matrix, but this is not present throughout the unit. Some minor limestone is also present. This unit has been thrust into the region along the Golconda thrust and emplaced above the Antler Sequence or the Valmy Formation. Thickness of this unit varies from zero to several thousand feet.

Antler Sequence. Pennsylvanian to Permian in age, this unit has also been called the overlap assemblage. It consists of interbedded siltstone, sandstone, mudstone, conglomerate, and limestone. This unit varies from 200 feet to 700 feet in thickness within the property area and rests unconformably on the Ordivician Valmy Formation. Locally this sequence consists of the Battle Formation, the Antler Peak Limestone, and the Edna Mountain Formation. The Battle Formation typically contains conglomerate beds resting on eroded Valmy Formation, along with some local beds of sandstone and shale. The basal part of this formation is typically composed of coarse chert and meta-quartzarenite cobble conglomerate. A distinctive shale unit is found just above the conglomerate in some places. A coarse siliceous sandstone with interbedded conglomerate may also be part of this formation. The Antler Peak Limestone, a late Pennsylvanian and early Permian unit, overlies the Battle Formation. The Antler Peak Limestone is a massive to well bedded, gray, micritic limestone. The Edna Mountain Formation overlies the Antler Peak Limestone. The lower member consists mostly of coarse, very poorly sorted debris flows containing chert and meta-quartzarenite fragments. The upper unit of the Edna Mountain Formation consists of a thick, brown, or gray siltstone.

Valmy Formation. Ordovician in age, this formation consists of bedded to massive dark gray to black chert and siltstone, quartzite, and argillite. The quartzites are light to dark gray, with interbeds of white, purple, or green argillite. Zones have been sheared and boudined to pods of isoclinally folded forms in outcrops. Quartzite and argillite form the bulk of this rock unit in the mine area.

1.2 Rock Characterization

Waste characterization sampling has been conducted at the Marigold Mine property since 1991, in accordance with the *Waste Rock and Overburden Evaluation Guidelines* (NDEP 1990), to determine the potential for acid generation. The sampling and reporting of the results are required by MMC's Nevada Water Pollution Control Permit (WPC Permit). A chronology of the waste characterization is included in Appendix A.

Acid/Base Accounting procedures were conducted on composite samples from the East Hill, Red Rock, and Top Zone Pits in mid-December 1996 through early January 1997. Results from these tests are presented in Table 1-1.

The Acid Generating Potential (AGP) and Acid Neutralizing Potential (ANP) of these samples were determined and the results indicate that these composites have a very low potential to generate acid. Total sulfur content, in the form of sulfide minerals or pyrite, were less than 0.03% of the sample. State guidelines indicate that material with an ANP:AGP ratio of greater than 1.2:1 can be considered non-acid producing. These sample results reveal an ANP:AGP ratios ranging from 14.3:1 to 89.3:1; therefore these composites can be considered non-acid producing.

GGI has reviewed all the historic ANP/AGP and Meteoric Water Mobility Procedure data to further evaluate the potential for sulfidic materials to be present in sufficient quantities to create acid rock drainage (ARD) problems.

Table 1-1. Results of Meteoric Water Mobility Tests and Acid/Base Accounting for Composite Samples Representing Three Pits, 1996.

Constituent[1]	Drinking Water Standards	East Hill Pit Composite	Red Rock Pit Composite	Top Zone Pit Composite
Alkalinity Total	-	48.9	76.6	40.2
Aluminum	0.05-0.2	0.911	2.15	2.36
Antimony	0.006	<0.003*	<0.003*	<0.003
Arsenic	0.05	0.07	<0.04	0.1
Barium	2	0.258	0.095	0.319
Beryllium	0.004	<0.001	<0.001	<0.001
Bismuth	-	<0.077	<0.077	<0.077
Cadmium	0.005	<0.0024	<0.0024	<0.0024
Calcium	-	10.6	17.8	10.8
Chloride	250-400	1.32	0.8	4.46
Chromium (total)	0.1	<0.005	0.007	<0.005
Cobalt	-	<0.005	<0.005	<0.005
Copper	1.3	<0.003	0.006	0.004
Fluoride	2.0-4.0	0.77	0.74	0.49
Gallium	-	<0.031	<0.031	<0.031
Iron	0.3-0.6	0.091	0.496	0.4
Lead	0.015	<0.001	<0.001	<0.001
Lithium	-	0.02	0.009	0.017
Magnesium	125-150	2.99	4.84	2.59
Manganese	0.05-0.10	<0.002	0.005	<0.002

Constituent[1]	Drinking Water Standards	East Hill Pit Composite	Red Rock Pit Composite	Top Zone Pit Composite
Mercury	0.002	0.0006	0.0003	<0.0002
Molybdenum	-	<0.014	<0.014	<0.014
Nickel	0.1	<0.017	<0.017	<0.017
Nitrate, N	10	0.35	0.31	0.44
Nitrite, N	1			
pH final (S.U.)	6.5-8.5	7.66	8	7.44
Phosphorous	-	<0.18	0.21	<0.18
Potassium	-	2.87	3.76	6.62
Scandium	-	<0.001	<0.001	<0.001
Selenium	0.05	<0.04	<0.04	<0.04
Silver	0.1	0.005	0.004	<0.003
Sodium	-	10.5	10.2	9.32
Strontium	-	0.0098	0.095	0.088
Sulfate	250-500	9.08	4.18	13.5
Thallium	0.002	<0.001	<0.001	<0.001
Tin	-	<0.046	<0.046	<0.046
Titanium	-	0.011	0.038	0.033
TDS	500-1000	73	103	77
Vanadium	-	<0.004	0.006	<0.004
WAD Cyanide		<0.01	<0.01	<0.01
Zinc	5	0.016	0.012	0.019
Acid/Base Accounting				
AGP [2]	-	<0.3	<0.3	0.3
ANP [2]	-	5	26.8	4.3
ABP [2]	-	5	26.8	4
ANP/AGP	-	16.7	89.3	14.3
Sulfur Forms				
Total Sulfur	-	0.02%	0.02%	0.03%
Pyritic	-	<0.01%	<0.01%	0.01%
Sulfate	-	0.02%	0.02%	0.02%

* Elevated detection limit due to matrix interference
[1] -Units are mg/l unless otherwise specified
[2] -Tons $CaCO_3$ / kTons Material
Source: SVL Analytical, Inc.
Reference: Hepworth, 1997

1.3 Potential for Acid Generation

To date, the ANP/AGP testing indicates that the potential to encounter sulfidic material is low and that if present, it is likely to occur in isolated pods of small quantities. The geologic units of concern are in the Valmy formation, especially the siltstone within this formation, but only when they contain observable pyrite. To date, pyritic sulfur has been less than 0.045 percent of the waste rock sampled. The pH from these samples has ranged from 7.44 to 9.12 (neutral to basic pH, i.e., non-acid generating).

Between 1988 and 1997 approximately 81,756,000 tons of waste rock were excavated and stockpiled at the Marigold Mine. Of this total 33,123,000 tons (40.8 percent) consisted of Valmy Formation material. Alluvium was the only other geologic unit that exceeded 20 percent of the total waste volume. Because this is the Valmy rock type has the greatest potential for containing sulfidic material, it is the unit of primary focus.

2.0 PROPOSED SAMPLING

The first step in the sulfide waste management plan is detection of sulfidic material. Currently, waste characterization required by the WPC Permit occurs after the waste material has been removed from the pit and placed in the waste storage facilities. Although the data from this sampling provides useful information, it is not available at the time decisions are needed regarding disposition of the waste. The WPC Permit-required waste characterization would be continued with at least one static test for every one million tons of waste material mined.

2.1 Sampling Plan

GGI proposes to use the blast hole drill cutting materials to qualitatively analyze those zones of rock that may have potential to contain sulfidic material. All blast hole cuttings are collected and recorded by drill hole location. The cuttings are then separated into subsamples for testing by fire assay and atomic absorption (AA). The fire assay result determines the total gold content of the sample. The AA result approximates the amount of gold that is recoverable by the cyanide process. The two assay results combined with the fire-to-AA assay ratio are used to determine which rock material is mill grade, leach grade, or waste. The ore control geologist uses these data to generate mining plans for ore and waste blocks in the pit.

If the fire-to-AA assay ratio is high (i.e., fire result indicates high gold content and the AA result indicates low recovery potential), then one of three conditions may be the cause:

- The gold may be trapped chemically by "preg-robbing carbon." A high active carbon content can indicate unoxidized ore and the cyanide process is not favorable for processing this type of ore. This condition has not been encountered at Marigold.

- The gold may be encapsulated in silica. This condition is a result of the geothermal transport of the gold into the host rock units. If the geothermal solution had a high silica content, then the sub-microscopic gold becomes encapsulated during deposition. Silca encapsulated ore requires fine pulverization of the sample to expose the gold to the cyanide. This condition is not common at Marigold.

- The rock could have high sulfide content (pyritic sulfur or other reduced sulfur compounds).

GGI proposes to use the fire-to-AA assay ratio to flag samples that need further evaluation. Because the data are routinely entered into the computer system, and because the data is reviewed prior removal of material from the pit, this data is appropriate for the sulfide waste management process. An ore control geologist is on staff full time to flag ore and waste, and visually examine the material.

The computer will be programmed to flag any samples with a fire-to-AA assay ratio greater than 1.45:1 (i.e., AA assay is 69 percent of the fire assay result). Flagged data will be reviewed by the ore control geologist. A volume screen will be conducted, and then a follow up field visual inspection will be undertaken, as needed. During the field visual inspection, if the presence of sulfur or pyrite is confirmed, then the material would be subject to special handling as described in Section 3.0, below. Flagged samples with fire-to-AA assay ratios greater than 1.75:1 (i.e., AA assay is 57 percent or less of the fire assay result) will be subject to static tests to evaluate the results of the flagging, volume screen, and field inspection. The time required to conduct the static test analysis will not allow the static test results to be included in the waste handling decision, but will be conducted to evaluate the screening process. The material for the static test would be collected from the location of the flagged sample. Insufficient material would be available for the static testing from the blast hole drill cuttings, therefore, the ore geologist would monitor the pit development and collect a sample of sufficient quantity for static testing from the area represented by the flagged drill hole.

- If the visual inspection does not indicate the presence of sulfide sulfur or pyrite, then the material will be handled as normal waste.

- If the visual inspection does indicate the presence of sulfur or pyrite, then the volume of AGP material could be estimated by the number of samples flagged by the computer and confirmed to contain sulfidic material. Each blast hole represents approximately 300 tons of material. Thus, the samples will indicate where the material is located, allow determination of the amount of AGP, and provide an estimate of the volume of material present.

- The flagged data and the subsequent determination of the presence of sulfide sulfur/pyrite (including selected static test analysis results) will be compiled annually and reported to the BLM in addition to the presently required reports.

2.2 Sampling Rationale

- <u>Data Set Description</u>

  Three data sets have been analyzed:

  1. the 5280 level of the East Hill South pit, Valmy Formation material;

2. the project-to-date East Hill South pit, excluding the test pit, Valmy Formation material; and

3. the East Hill North pit, level 4780 to 4720, specifically the Valmy Formation.

Each data set was tabulated and analyzed, assuming that the data represent a normal distribution. The mean fire-to-AA assay ratio, plus two standard deviations were applied to distinguish anomalous from non-anomalous samples (e.g., "the data ratio flag"). See Appendix B for the statistical analysis results.

- <u>Flagging Process</u>
  All AA samples below the lower limit of confidence (LLC) of 0.015 opt, (i.e., sampling error is greater below this level) were not considered to reduce the flagging process to a manageable level without missing samples containing sulfur compounds. This is based on the fact that rock types inherent in the Marigold area must be somewhat mineralized to contain sulfur compounds. Rock with AA results below the LLC have very little mineralization, and therefore, are unlikely to contain significant quantities of sulfur compounds. The average fire-to-AA ratio from the three data sets of 1.45:1 has been selected for screening assay data.

  In other words, all waste samples exhibiting a fire to AA assay ratio of less than 1.45:1 are considered oxidized and non-ARD. Samples with ratios greater than 1.45:1 have some ARD potential. Sample with ratios greater than 1.75:1 would be subjected to static tests.

  <u>Volume Estimates</u>
  Using results from the computer flagging process, the ore control geologist will evaluate the flagged samples in each blast hole pattern. The average blast hole pattern at Marigold is approximately 150 holes representing 45k tons (or approximately 530 truck loads). If greater than 20 percent of the blast hole pattern tons are flagged by the computer, a spatial/geometric evaluation will be completed. This evaluation is conducted to ascertain the basic continuity of flagged samples. Should the flagged samples exhibit continuity which can be practically separated in the mining process, a field visit and visual evaluation will follow.

- <u>Visual Evaluation</u>
  During the field visit cuttings from a representative sample of all flagged holes will be examined with a hand lens. Consistent, visible pyrite in the cuttings will trigger special material handling.

2.3 Sampling Reporting

GGI will provide BLM with annual reports to include the fire-to-AA assay ratios, static test results from the WPC Permit-required sampling, and the static test results from samples with fire-to-AA assay ratios greater than 1.75:1. The annual reports would be submitted before April 15 each year.

3.0 WASTE MATERIAL HANDLING

The waste material from open pit operations is generally placed in the waste disposal area nearest to the pit to minimize haul distances. When needed, waste material is diverted to berm construction or other construction use. Because GGI is currently using waste to backfill or partially backfill open pits, it is important that sulfide waste, if found to occur, is minimized as backfill.

The grade cutoff at Glamis Marigold Mine between ore and waste is 0.01 ounces of gold/ton of rock. Rock that has less than 0.01 ounces of gold/ton of rock is considered waste and would be evaluated by the procedure outlined above. If the fire-to-AA assay ratio does not result in a flagged data point, then the material will go to the waste disposal area for which it was originally planned (i.e., surface disposal or pit backfill). No special handling will be required.

3.1 Sulfide Material Management

If the fire-to-AA assay ratio results in a flagged data point and visual inspection does not detect the presence of sulfur or pyrite, then the material will go to the waste disposal area for which it was originally planned (i.e., surface disposal or pit backfill). No special handling will be required.

If the fire-to-AA assay ratio results in a flagged data point and further analysis reveals the presence of sulfur or pyrite, and volume estimates indicate that separation during the mining process is practical, then the disposal of the material would be as follows:

1. If originally planned for use as pit backfill material, the waste would be diverted to an active, above ground disposal area. Disposal would be as described in 2 or 3 below.

2. <u>Small Quantities</u>: The quantity of material would be determined in relationship to the current construction stage of the disposal area. For small volumes of material (i.e., less than 20 percent of the blast volume or 20,000 tons, whichever is greater, for a dilution ratio of 5:1), determine:

   a. if the material can be dumped near the center of the lift that is currently being constructed. If so, such placement away from the final lift face will result in the potentially AGP material being encapsulated by ANP waste on the remaining portion of the lift and eventually above the potentially AGP material on the next lift.

   b. if the material would normally be placed near the final face of the lift that is currently being constructed. If so, then divert the placement of the potentially AGP material to the interior of the next lift. This will result in the potentially AGP material being encapsulated by ANP waste that is placed around and eventually above the AGP material on the next lift.

c. if the material is scheduled to be placed on the final lift. If so, then it may be necessary to spread the material and cover with ANP material. This situation may also require additional growth medium to cap the lift, and grading to shed runoff, rather than to encourage infiltration of meteoric water. A capillary break composed of coarse material could also be placed between the AGP material and the growth medium cap to prevent plant root penetration of the AGP pocket.

3. Large Quantities: The quantity of material would be determined in relationship to the current construction stage of the disposal area. For large volumes of material (i.e., greater than 50 percent of the blast volume or 25k tons, whichever is greater, for a dilution ratio of 2:1), determine:

   a. if the material is scheduled to be placed on any lift other than the final lift. If so, then spread the waste over the surface of the lift, but at least 50 feet from the designed lift face. This will produce a thin veneer, which when covered with ANP material, would be blended and encapsulated. This will reduce the amount of acid released in any one location and allow for sufficient material to neutralize any acid that may be generated.

   b. if the material is scheduled to be placed on the final lift and cannot be covered with sufficient ANP material. In this situation, consider placement on an alternative waste disposal area and cover with alluvium and waste which has ANP.

Unless the material is placed in the final lift, the encapsulation would include at least 20 feet of oxide material. This is a function of the 20-foot lift heights used in the construction of the waste dumps. If the sulfide material is to be placed in the final lift, then it would be spread within the interior of the lift, graded, and covered with oxide material. A minimum ratio of 3:1 ANP to AGP material would be achieved. The minimum depth would be in excess of 15 feet; more likely 18 feet. As stated above, the sulfide material would not be placed within 50 feet of the lift face.

3.2 Sulfide Waste Disposal Reporting

GGI would provide BLM with annual reports which include the disposition of all materials identified for special handling. The report would include pit, bench level, approximate tonnage, and geologic formation from which the material originated, as well as the waste rock facility and approximate placement (i.e., which bench and where in the bench) of the disposed material.

4.0 SUMMARY

Although the volume of ANP material at the Glamis Marigold Mine is great and the potential for encountering sulfidic material is low, a system of detection, handling, and storage has been proposed that will prevent any environmental degradation in the event that sulfidic material is encountered. The system provides determination of the presence of sulfides, the location of the material, and an estimate of the volume of material present before it is removed from the pit.

Once the volume is compared to the space available at the waste disposal site, a decision can be made concerning the placement of the material on the existing lift, or as the initial construction of the subsequent lift. This would allow for adequate encapsulation. For small quantities, material could be placed in the final lift if sufficient ANP is available. A cap of ANP material should be placed over the AGP material, and additional coarse material should be placed over the ANP cap to create a capillary break. The surface should be contoured to promote runoff rather than allow infiltration. For large quantities, a combination of encapsulation and blending would spread the material out to reduce the potential for meteoric water to contact the AGP material and provide sufficient ANP material to buffer any acid drainage. If the only area available for storage is the final lift of the active disposal area, then consideration can be given to using stockpiled alluvial material in the 8-South Dump as a cover or cap.

Appendix C includes flow charts summarizing the ongoing waste characterization program, computer flagging, volume estimates, visual confirmation, and material handling procedures for small and large quantities of sulfidic material. Appendix D contains additional sample test results from recent drill holes, channel samples, and blast holes. This information indicates that the waste material either has acid neutralizing potential or very low sulfide content.