ENVIRONMENTAL ASSESSMENT

for

Golden Sunlight Mining, Inc.
Application for Amendment

State Operating Permit No. 00065
and
Federal Plan of Operations

Stage IV and V Mining
Operating and Reclamation Plan

prepared by
Montana Department of State Lands
and
U.S. Department of Interior
Bureau of Land Management

pursuant to the

Montana Environmental Polict Act
and the
National Environmental Policy Act

May 30, 1990

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CHAPTER I - INTRODUCTION

A. Purpose and Need

This environmental assessment (EA) has been prepared by the Montana Department of State Lands (DSL) and the Bureau of Land Management (BLM), Butte District Office, in response to an application received from Golden Sunlight Mines, Inc. (GSM). The application was submitted in order to allow GSM to continue mining gold reserves in Jefferson County (Figure 1). This EA analyzes the impacts of approval of the proposed expanded operation and reclamation plan and its alternatives, cumulative impacts of past, present, and future mining, and comments received in response to the EA issued in July 1989.

Under approved amendments 001 through 007, GSM intends to complete stage III of its mining plan by the end of 1993. At the end of stage III, 90 million tons of waste rock and 20 million tons of ore will have been mined. As presently permitted, GSM is the second-largest mine in Montana in terms of permitted area, disturbed area, and volume of waste rock handled. It moves almost one-third more material per day (140,000 tons) than the largest metal mine in the state, Montana Resources, Inc. (MRI) Butte operations (Table 1). Approval of stages IV and V would make Golden Sunlight mine over two and one-half times larger than the third largest, the Zortman-Landusky complex. The Golden Sunlight Mine through stage V would have a total disturbed area of over 4.5 square miles. GSM would remain the second largest mine in disturbed acreage, behind MRI, if this amendment were approved. It would become the largest Montana gold mine in terms of waste rock handled and acres disturbed (Table 1). The scale of this operation in conjunction with the proposed reclamation of steep slopes and the reactive nature of the waste materials adds new dimensions to an already large reclamation undertaking. The success of reclamation here is critical.

The agencies received the original application from GSM on March 11, 1988. The application was determined complete on January 13, 1989, and the draft EA was prepared. Draft EAs were published in March, May, and July 1989, with 30-day comment periods. During the last comment period, a public meeting was held in Whitehall, on July 31, 1989, with approximately 600 people in attendance. A summary of comments received at the hearing and letters of comment as well as responses, are presented in Chapter X of this document.

The most significant issues identified by the agencies and through the public review during the environmental assessment process include (1) adequacy of proposed reclamation, (2) timing of reclamation, (3) degradation of water quality, (4) perpetual treatment of long-term discharge, (5) reactive nature of the ore and waste rock, (6) minimization of long-term acid-producing potential, (7) proximity to the Jefferson River, (8) visibility of the project from offsite, and (9) employment.

Since the close of the comment period the agencies have been collecting additional data from GSM and other sources to complete this document. The additional information

Figure 1. General Location Map

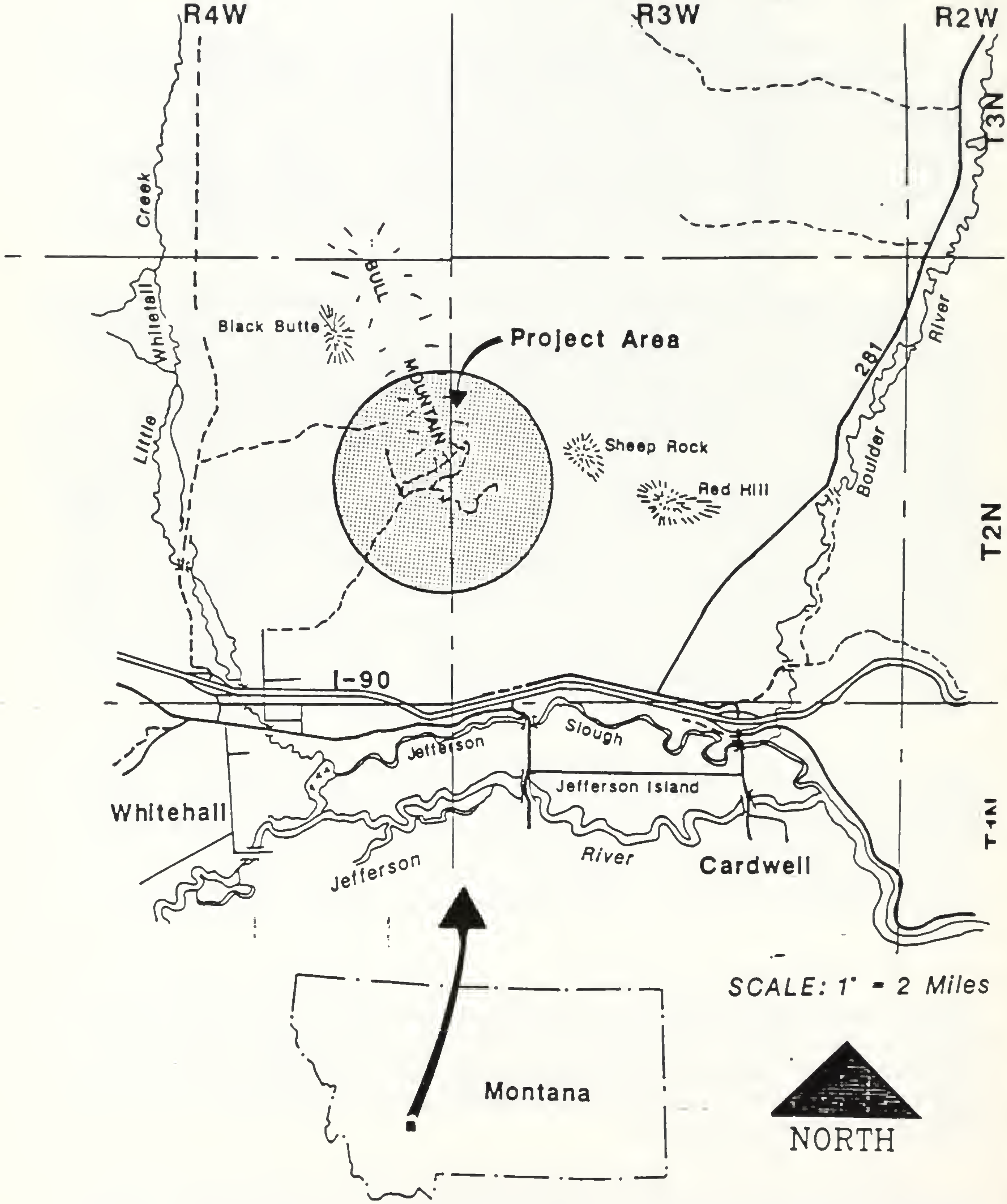


Table 1. The Thirteen Largest Existing and Proposed Metal Mines in Montana

Name	Facility	Production Tn/day	Metals Produced Tons or Ozs/Year	Permit Acres	Disturbed Acres	Pit Acres	Waste Rock Acres	Waste Rock in Million Tons	Heap/Tailing Acres	Heap/Tailing Million Tons	Life of Mine /Yrs	Employs
Montana Resources, Inc.***	Open pit H2SO4 Heap Floatation	100,000	Cu 53,00tn Mo 7,050tn	5103	5103	800	485		1600		25	330
PROPOSED Golden Sunlight Stage IV&V	Open pit Cyanide Vat	140,000	Au 100,000oz	4113	2601	210	770	300 Mil	450	50 Mil	13	250
Golden Sunlight	Open pit Cyanide Vat	140,000	Au 100,000oz	4113	1751	140	320	90 Mil	200	20 Mil	3	250
ASARCO	Underground Floatation	8,500	Cu 20,000tn Ag 4.2Mil.oz	2741	1000	-0-	0	0	385	245 Mil	4	340
Montana Tunnels	Open pit Floatation	70,000	Au 75,000 oz	1549	965	235	421	211 Mil	245	52 Mil	12	245
PROPOSED Basin Creek Amend 005	Open pit Cyanide Heap	5,000	Au 42,500oz	1323	386	118	29	25 Mil	117	16 Mil	8	90
PROPOSED Landusky Life of Mine	Open pit Cyanide Heap	75,000	Au 130,000oz Ag 260,000oz	1287	814	215	105	120 Mil	285	120 Mil	10	80
Kendall	Open pit Cyanide Heap	11,000	Au 50,000oz	1198	538	162	240	48 Mil	91	12 Mil	8	67
Beal Mountain	Open pit Cyanide Heap	12,000	Au 30,000oz	1182	370	37	29	9 Mil	91	10 Mil	10	65
Stillwater Mining	Underground Floatation	1,000	Pt 40,000oz Pd 125,000oz	1165	235	0	0	0	70	3.6 Mil	25	450
Zortman Landusky	Open Pit Cyanide Heap	75,000	Au 130,000oz Ag 260,000oz	1001	613	167			175	60 Mil	1	80
Zortman Mining, Inc.	Open pit Cyanide Heap	See Zortman Landsky	See Zortman Landusky	961	401	97	33	20 Mil	116	20 Mil	5	80
Basin Creek	Open pit Cyanide Heap	5,000	Au 42,500oz	580	225	81	29		28	3 Mil	8	90

*** Includes historic mining disturbances includes: the Dollhopf (1989), SHB (1989), SHB (1990), and Hydrometrics (1990 a, b) reports and is presented in detail in Chapters IV, V, and VI. Letter and menu references listed throughout this document are compiled chronologically in Appendix A at the end of this document.

B. Permitting History

GSM, a wholly owned subsidiary of Placer Dome U.S. Inc. of San Francisco, California, is operating an open pit gold mine in Jefferson County, Montana. The mine is located in the Bull Mountains approximately six miles northeast of Whitehall, Montana, on Mineral Hill (Figure 1) and employs 254 people. Operating Permit No. 00065 for this project was granted by the Montana Department of State Lands (DSL) and the U.S. Bureau of Land Management (BLM) in 1975. An Environmental Impact Statement (EIS) was prepared for amendment 001 in 1981 (DSL, 1981). Subsequent Preliminary Environmental Reviews (PER) and Environmental Assessments (EA) written as a result of the amendment applications are incorporated by reference into this Environmental Assessment.

The present operating permit and amendments allow GSM to mine through stage III (Figure 2) within a permit area of 4,113 acres, with 1,371 acres bonded for disturbance. When stage III is completed in 1993, the pit would measure 140 acres, the waste rock dumps 320 acres, and the tailings impoundment (Impoundment I) 198 acres. Approximately 20 million tons of tailings (1.75 million tons annually), and 90 million tons of waste rock (11.37 million tons annually), would be produced through stage III. Ore is trucked from the pit to the mill where it is crushed and vat leached using conventional carbon-in-pulp cyanide leach technology. Recoveries are enhanced through a sand tailings retreatment facility while a pre-aeration process reduces operation costs. The leached waste material (tailings) is subsequently slurried to tailing impoundment I.

C. Summary of Proposed Amendment

GSM proposes to expand mine production from stage III to stage V (Figure 3), extending the life of the operation to the year 2005. The amendment application was submitted to DSL on March 11, 1988 (GSM, 1988). Mining through stage V would result in cumulative production of 50 million tons of tailings and 300 million tons of waste rock (Table 2). The mining, milling and metallurgical processes would not change. Expansion of the mine would create a pit approximately 209 acres in size, daylighting the east flank of the Bull Mountains at an elevation of 5,350 feet (Figure 4). A second tailings impoundment (Impoundment II) would be needed for the stage IV and V expansion and would be constructed east of the existing tailings impoundment I. Impoundment II would be designed to hold the 30 million tons of additional tailings which would be up to 250 feet deep. Impoundment II would cover 250 acres and have an embankment height of 150 feet. Impoundment II, unlike impoundment I, would be constructed with a synthetic liner. Centerline construction of the embankment using cycloned sand tailings as in impoundment I is proposed. The existing waste rock dumps would be expanded to cover approximately 770 acres. Waste

Figure 2. Present Property Layout

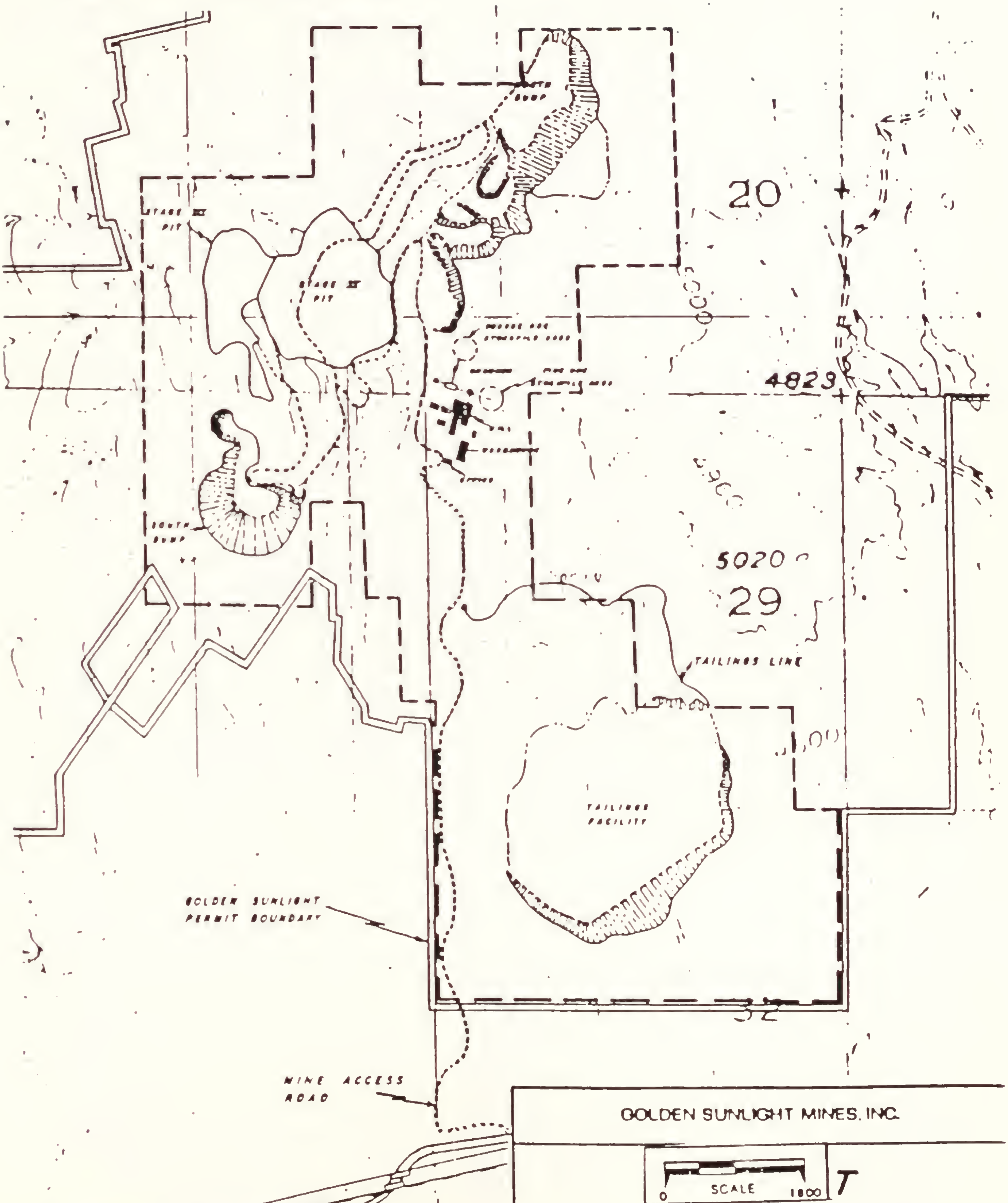


Figure 3. Plan of Pit Stages

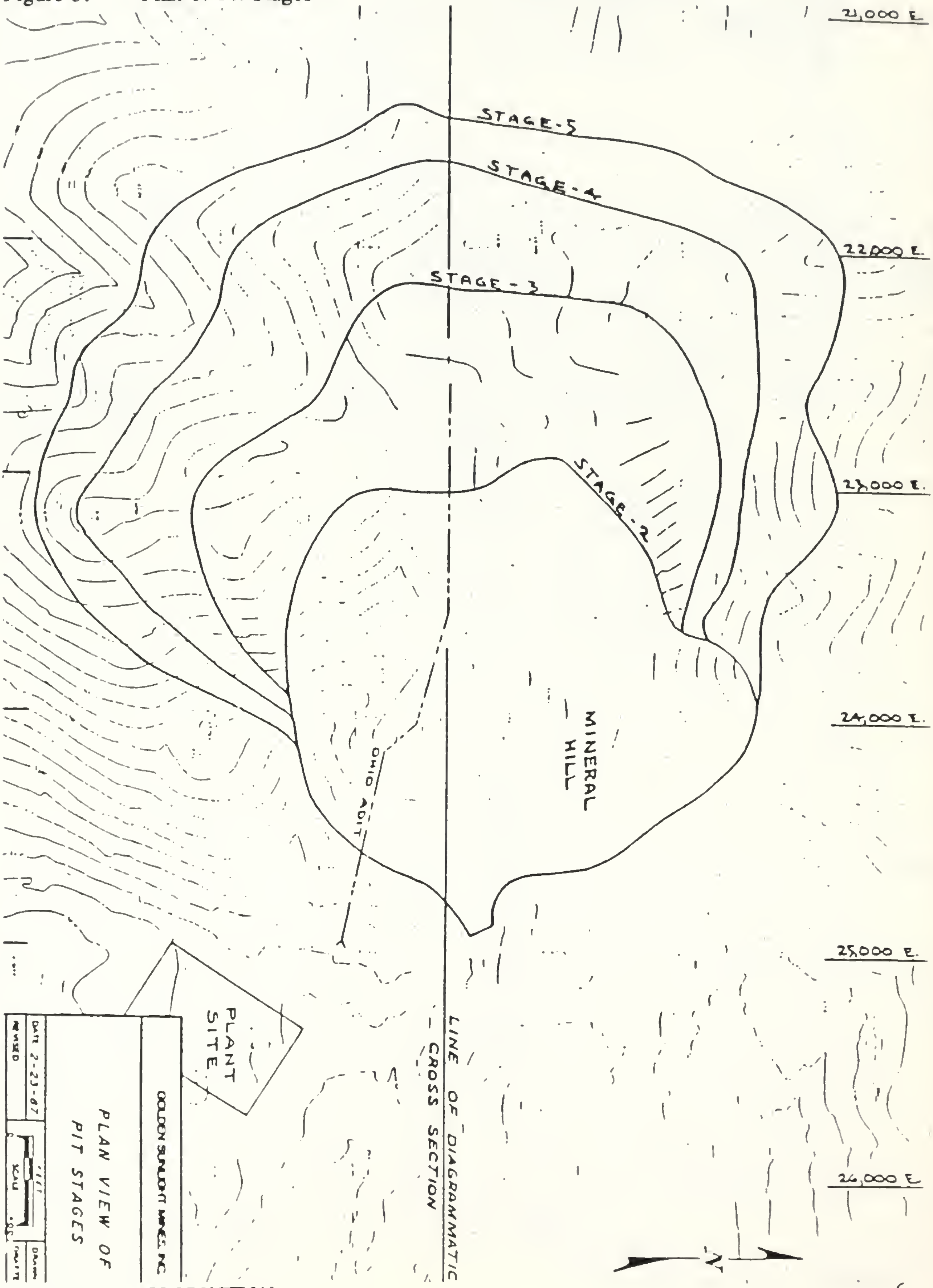
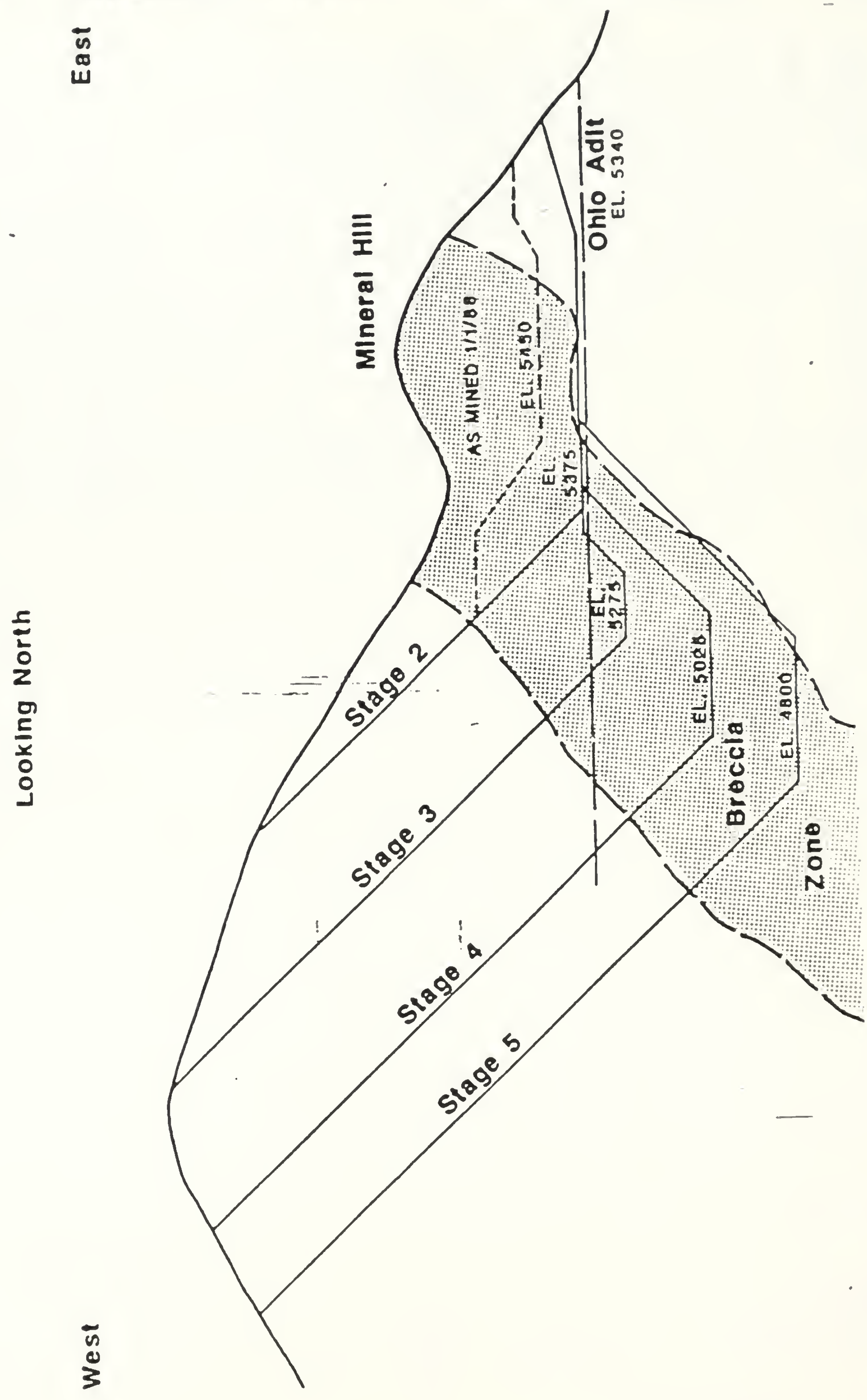


Table 2. Proposed Mine Schedule

Year	Stage 1 Tons x 1000 Bench	Stage 1 Ore	Stage 1 Waste	Stage 2 Tons x 1000 Bench	Stage 2 Ore	Stage 2 Waste	Stage 3 Tons x 1000 Bench	Stage 3 Ore	Stage 3 Waste	Stage 4 Tons x 1000 Bench	Stage 4 Ore	Stage 4 Waste	Stage 5 Tons x 1000 Bench	Stage 5 Ore	Stage 5 Waste	Tons x 1000 Total Ore	Tons x 1000 Total Waste	Strip Ratio
1987	5475-5450	663	100	5725-5625	1,785	4,719	6400-6167	---	7,146							2,448	11,965	4.9:1
1988				5625-5550	2,448	940	6167-5967	---	14,292							2,448	15,232	6.2:1
1989				5550-5475	2,448	391	5967-5800	---	14,292							2,448	14,583	6.0:1
1990				5475-5375	1,207	501	5800-5600	641	14,290	6400-6233	---	5,770				2,448	20,561	8.4:1
1991							5600-5500	2,448	3,303	6233-6000	---	23,073				2,448	26,087	10.7:1
1992							5500-5425	2,448	1,539	6000-5833	---	23,079				2,448	24,768	10.1:1
1993							5425-5350	2,448	1,596	5833-5650	---	23,077				2,448	24,563	10.1:1
1994							5350-5300	1,146	249	5650-5400	1,302	23,292				2,448	23,331	9.5:1
1995										5400-5325	2,448	4,225	6300-6000	---	20,575	2,448	24,781	10.1:1
1996										5325-5275	2,448	1,522	6000-5933	---	20,575	2,448	22,197	9.1:1
1997										5275-5225	2,448	1,143	5933-5700	---	20,575	2,448	21,718	8.9:1
1998										5225-5150	2,448	355	5700-5525	---	20,575	2,448	20,933	8.5:1
1999										5150-5050	2,225	89	5525-5325	223	20,556	2,448	20,555	8.4:1
2000													5325-5150	2,448	11,345	2,448	11,345	4.7:1
2001													5150-5075	2,448	2,543	2,448	2,543	1.0:1
2002													5075-5025	2,448	1,596	2,448	1,595	0.7:1
2003													5025-4950	2,448	1,012	2,448	1,012	0.4:1
2004													4950-4850	2,448	691	2,448	691	0.3:1
2005													4850-4800	434	50	434	50	0.1:1
Total		663	100		8,183	6,551		9,131	56,552		13,204	105,305		12,912	120,203	44,498	288,311	6.5:1

Figure 4. Diagrammatic Cross Section



rock dump expansion would occur to the northeast, south and west of the existing pit. Disturbance under this amendment would bring the total disturbance within the existing 4,113-acre permit area to 2,601 acres.

D. Location and Land Ownership

The permit area is located in portions of Sections 19, 20, 29, 30 and 32 of Township 2 North, Range 3 West, MPM. GSM controls the surface and mineral ownership of these lands by a combination of fee simple ownership, patented claims, and unpatented claims which the company either owns or leases. In 1983 the Bureau of Land Management patented 12 claims totalling 171.387 acres, covering much of the central area of the pit. In 1989 another 13 claims totaling 196.63 acres were patented for a total patented acreage of 368.02 acres. Lands owned by the State of Montana within the permit area have been exchanged for other lands owned by GSM. The state-owned mineral lease area has been examined by condemnation drilling. No mineral values were found and the lease was canceled, allowing GSM to propose to use the surface for waste rock disposal in this amendment.

E. Environmental Analysis History

Three draft environmental assessments, (EA), were prepared by BLM and DSL (DSL, 1989) using information on pit water discharge, waste rock quality, and cumulative water quality impacts from the amendment application (GSM, 1988). The regulatory agencies concluded that to approve GSM's reclamation plan as originally proposed (Chapter III) would produce significant environmental impacts and require either preparation of an environmental impact statement (EIS) and/or denial of the permit. Consultation with GSM led to supplemental commitments by the company in order to reduce the impacts of the company's proposed plan. Chapter IV of this EA analyzes the effects of the company's proposal and supplemental commitments. However, additional information now suggests that concerns over reclamation water quality, acid production and aesthetics would not be adequately resolved by the supplemental commitments to the company's proposed plan. Therefore additional modifications have been proposed and analyzed in Chapter V.

Since July 1989, additional information has been supplied by GSM on waste rock quality (Dollhopf, 1989) and pit water quality (SHB 1989, 1990) and overall water quality impacts (Hydrometrics, 1990 a, b). Based on the additional information, this EA has been prepared by DSL and the BLM in order to re-evaluate the impacts of approving the amendment as proposed with supplemental commitments.

This EA addresses cumulative impacts of mining to date, in conjunction with the proposed mine expansion. The original amendments were approved with a reclamation plan that was to be finalized as the mine tested various methodologies of reclamation during mine life.

In addition to evaluating the original amendment application (Chapter III - The Company's Proposed Plan) and denial of the permit amendment (Chapter VI - Denial of the

Amendment), DSL and BLM have evaluated two additional alternatives to address the potential impacts of mine expansion. The first alternative (Chapter IV - The Company's Proposed Plan with Supplemental Commitments) addresses approval of the proposed amendment with supplemental commitments based on the large amount of additional information supplied by GSM since July 1989 (Dollhopf 1989; SHB 1989, 1990; Hydrometrics 1990 a, b). These supplemental commitments may reduce the potential impacts below the level of significance.

The second alternative (Chapter V - The Company's Proposed Plan with Supplemental Commitments And Additional Modifications) (Preferred Alternative) recommends additional modifications to the proposed plan with supplemental commitments. These modifications are needed to increase the chances of overall reclamation success by limiting oxygen and water available for development of acid seeps.

F. Related Actions

There are no other significant non-mining activities in the immediate area proposed by adjacent landowners or the BLM. Any additional mining beyond the stage V pit would be by underground mining methods. Additional reserves have been located to the north of the mine by current exploration activities conducted by the mining company. Any additional activities beyond stage V would require another mine permit application and environmental assessment.

The closest mining related impacts to the west are in Butte, Montana. To the north, exploration and mine development plans continue in the Elkhorn Mountains. To the south, the closest proposed mining activities are gold mining and milling in the Pony, Montana, area and chlorite mining north of Twin Bridges, Montana.

G. Agency Responsibilities

1. Department of State Lands

The Commissioner of State Lands must decide whether to: (1) approve the amendment as applied for, (2) approve the GSM proposal modified by supplemental commitments, (3) approve the modified proposal subject to additional stipulations, or (4) deny the amendment, consistent with the requirements of the Montana Metal Mine Reclamation Act (MMRA) (Title 82, Chapter 4, Part 3, MCA).

DSL administers MMRA. The purpose of the act is to recognize and protect the usefulness, productivity and scenic values of the lands and waters within the state and to reclaim to beneficial use the lands used for mining. The act and its regulations (ARM 26.4.101 et seq.) set forth the steps to be taken in the issuance of an operating permit for and the reclamation of the applicant's proposed mine expansion. The act applies to all lands within Montana.

DSL's rules (ARM 26.2.601 et seq.) implementing the Montana Environmental Policy Act (MEPA) (Title 75, Chapter 1, MCA) also require preparation of an environmental assessment. The environmental assessment (EA) has several purposes:

- It serves to ensure that the agency uses the natural and social sciences in the environmental design arts in planning and decision-making;
- It assists in the evaluation of reasonable alternatives and the development of conditions, stipulations or modifications to be made a part of the proposed action;
- It determines the need to prepare an EIS through an initial evaluation and determination of the significance of impacts associated with a proposed action;
- It ensures the fullest appropriate opportunity for public review and comment on proposed actions, including alternatives and planned mitigation, where the residual impacts do not warrant an EIS; and
- It examines and documents the effects of a proposed action on the quality of the human environment, and provides the basis for public review and comment.

2. Bureau of Land Management

The Bureau of Land Management is responsible for preventing unnecessary or undue degradation of federal lands under regulatory provisions in 43 CFR 3809. Federal regulations 43 CFR 3809.3-1 provide for a joint federal-state regulatory program. Such a program was initiated on April 30, 1984, by a Memorandum of Understanding (MOU) between the BLM and DSL. Per the MOU, both agencies have participated in the review of this amendment.

3. Other State Agencies

a. State Historic Preservation Office

The State Historic Preservation Office has the responsibility of cooperating with and advising DSL and the BLM when potentially valuable historical, archeological, or other cultural resources are located within a project area (Montana Antiquities Act MCA 22-3-401 through 22-3-442 and the National Historical Preservation Act PL 89-665 as amended and reauthorized E.O. 11593). Advice given may include comments on an applicant's plan for impact mitigation of sites eligible for nomination to the National Register of Historic Places. The office also reviews the environmental document to ensure compliance with cultural resource regulations. During mine operation, DSL and BLM are responsible for monitoring compliance with cultural resource laws and monitoring plans.

b. Department of Health and Environmental Sciences

i. Air Quality Bureau

The Air Quality Bureau of DHES administers the Clean Air Act of Montana (Title 75, Chapter 2 MCA). Any proposed project with potential to emit more than 25 tons per year of any pollutant must obtain an air quality permit prior to construction. The applicant must apply Best Available Control Technology to each emission source. The applicant must also demonstrate that the project would not violate Montana or Federal Ambient Air Quality Standards.

ii. Water Quality Bureau (WQB)

The Water Quality Bureau of DHES is responsible for administration of the Montana Water Quality Act (Title 75, Chapter 5 MCA) providing for the classification of surface water, establishing surface water quality standards, and instigating permit programs to control the discharge of pollutants into state waters. A Montana Pollutant Discharge Elimination System permit must be obtained before any discharge to surface water may occur. This permit contains water quality limitations and requires self monitoring of effluent by the permittee. WQB administers Montana groundwater standards and regulates compliance with these standards.

c. Department of Natural Resources and Conservation (DNRC)

DNRC administers two acts that are applicable to mining development. These are The Montana Major Facility Siting Act (Title 75, Chapter 2 MCA) and the Montana Water Use Act (Title 85, Chapter 2 MCA). Any electrical transmission line that exceeds 69 kV or 10 miles in length requires state approval. A water rights permit is required for any surface water diversion or groundwater withdrawal exceeding 100 gallons per minute.

d. Hard-Rock Mining Impact Board

The Hard-Rock Mining Impact Board, created by the passage of the Hard Rock Impact Act (Title 90, Chapter 6, Part 3, MCA) is attached to the Montana Department of Commerce for administrative purposes. A quasi-judicial board, it is intended to act as a referee in hearing disputes between local government and large scale mineral developers over the impact mitigation plan. The impact mitigation plan identifies the increased public sector costs associated with the mineral development and commits to pay, according to a specified time schedule, all increased capital and net operating cost to local government resulting from development. With a projected workforce over 250 employees, Golden Sunlight's mine would have met the definition of a large scale mineral developer, however, it was permitted prior to the effective date of the act and was grandfathered from compliance.

A. Geology

The Golden Sunlight gold-silver deposit is located at the southern end of the Bull Mountains, in the Whitehall mining district, Jefferson County, Montana. The project area is located within an upthrown fault block that exposes Belt Supergroup rocks overlain by Paleozoic rocks and Mesozoic volcanics, which are intruded by Tertiary igneous rocks. (Porter, 1983).

Two major northerly trending high angle normal faults, the St. Paul fault to the west and Golden Sunlight fault to the east of the pit, form a horst within which the project area is located. It is a continuous structure striking north-south and then, south of the pit, bending to the southwest. Minor east-west normal and reverse faults transect the horst and cut the Golden Sunlight and St. Paul faults. Two sets of fractures are evident in the area. One set parallels the Golden Sunlight fault and the other trends northeast to southwest. A siliceous breccia pipe, approximately 700 feet in diameter, occurs within the horst and is the primary host for gold mineralization (Porter and Ripley, 1985; Smolik, Ziesing, and Loros, 1984).

The oldest exposed rocks in the project area include the LaHood, Newland and Greyson Formations, of the Belt Supergroup. The LaHood Formation is a coarse arkosic sandstone and argillic shale. The Newland Formation contains calcareous shales, black limestones and thin bedded calcareous, sometimes weakly silicified, siltstones. The Greyson Formation is a silty shale and argillite. The Newland and LaHood Formations are ore hosts and become silicified toward the breccia pipe (Porter and Ripley, 1985).

Paleozoic rocks include the Flathead Quartzite, Wolsey, and Meagher Formations. The Flathead Quartzite is a fine grain sandstone or orthoquartzite. The Wolsey Formation is a sandy shale containing interbedded sandstones and thin bedded limestones. The Meagher Formation is a thin bedded, finely crystalline limestone, containing shaly interbeds.

The youngest rocks belong to the Bozeman Group which in this area are broken into a basal breccia, conglomerates, sandstones, shales, calcareous siltstones and an upper series of fined grained arkosic rocks (Porter and Ripley, 1985). The coarse-grained lower units belong to the Climbing Arrow Formation and the upper units are in the Dunbar Formation. The proposed tailings impoundment II would be constructed on the Bozeman Group rocks.

Igneous rocks in the immediate vicinity of the Golden Sunlight mine fall into three main categories: Elkhorn volcanics, latite porphyry and lamprophyre intrusives. The Elkhorn volcanics consist of andesite, andesite porphyry flows, tuffs and agglomerates. The latite porphyry is the most abundant igneous rock present in the area. It is tan to cream colored, and is comprised of 50 percent feldspar-biotite matrix and 50 percent plagioclase and orthoclase phenocrysts which are often altered to clay minerals (Porter and Ripley, 1985). The ore host breccia crosscuts the latite porphyry. The lamprophyre intrusives are andestic to basaltic dikes and sills. They consist of a dark biotite-augite-plagioclase groundmass with biotite and augite phenocrysts. The lamprophyres are altered but lack sulfide mineralization (Porter and Ripley, 1985).

The mine is centered on a siliceous breccia pipe which contains disseminated mineralization that extends more than 100 feet into the wallrock in silicified fractures. The pipe is an irregular oval, approximately 700 feet in diameter, which plunges 35 degrees to the west. Individual breccia fragments may be greater than 30 feet in size and consist of all rock types except for the lamprophyres. Alteration consists of pyritization, silicification and decarbonization with an alteration mineral assemblage containing silica, pyrite, barite, sericite, chalcopyrite, galena, sphalerite, and molybdenite. Gold occurs as disseminated particles associated with the pyrite in the breccia matrix, auriferous pyrite, and minor telluride minerals. Superimposed across the breccia pipe and into the surrounding wall rock are northeast trending gold-quartz veins that may contain pyrite, galena, sphalerite, and barite (Porter and Ripley, 1985). The existing pit wall rock is composed primarily of Tertiary latite porphyry, and Greyson and Newland Formations of the Belt Supergroup.

Waste rock contains 1 to 5 percent sulfides, of which 99 percent is pyrite with minor amounts of chalcocite, chalcopyrite, bornite, galena, sphalerite and barite (Porter and Ripley, 1985; Dollhopf, 1989). Waste rock material is non-cohesive, angular, and relatively large with few fines. Waste rock dump complexes to the south and west are competently founded on arkosic quartzites and argillites of the Lahood Formation. The north waste rock dump complex is being constructed on Greyson and Newland Formation alluvium that overlies Bozeman Group sediments. Oxidation of waste rock follows surface topography and is generally limited to within 50 to 100 feet of the surface (GSM Memo, January 24, 1990). Waste rock includes sulfide bearing mudrock, arkose and latite as well as their oxidized equivalents within 100 feet of the surface. The existing tailings impoundment I is constructed on Quaternary alluvium and Bozeman Group rocks.

B. Soils

1. Soil Developmental Setting

a. Parent Material/Geology

Bedrock geology maps of the area indicate the presence of volcanic and sedimentary rocks with a wide variety of ages. Precambrian Greyson and LaHood Formations are the dominant bedrock type in the expansion area west of the mountains. Tertiary age volcanic intrusive rocks occur in the bedrock of the proposed waste rock dump sites on both sides of the Bull Mountains. Soft sedimentary rocks of Tertiary age are the bedrock in most of the proposed tailings impoundment II area and lower slopes of the north waste rock dump expansion area. Overlying the Tertiary valley fill are Quaternary alluvial and colluvial deposits that covered the valley fill before drainages were dissected. Benches that formed after drainages cut through the area were covered with Pleistocene age, wind-blown, loess deposits. The most recent surficial deposits in the area include colluvial and alluvial fans on terraces near toe slopes, and alluvium along drainageways.

b. Other Soil Forming Influences

Soils are relatively young, having formed in the geologic materials over the last 10,000 years since the retreat of the glaciers. Soils have developed slowly in the semiarid continental climate. Precipitation varies from ten inches in the lowest elevations, in the rain shadow on the east side of the mountains, up to 20 inches in the upper elevations on the west side of the mountains. Effective precipitation is modified by slope, aspect, snow drifting and effects of runon and runoff moisture when rainfall intensity exceeds soil infiltration rates or when the ground is frozen.

Slopes vary from zero to over 75 percent on all aspects. Elevations in the proposed permit boundary range from 4,400 to 6,600 feet.

2. Existing Soils

Soils of the proposed expansion areas were identified, characterized and mapped into nineteen soil type/association units (Table 3). The major soils were described in each of the three proposed disturbance areas. Data presented has been interpreted from the soil survey data provided by GSM (Prodgers, 1988) and the Jefferson County USDA-SCS office in Whitehall, Montana. Emphasis has been placed on those soils that would constitute a significant portion of soil salvaged for use in reclamation.

a. Proposed Tailing Impoundment II Area

Nine soil mapping units were identified in the 271 acres of disturbance for the proposed tailings impoundment II (Table 4). An abundance of soil exists in the area for salvage with three soil types (Units 3BC, 3CD, 5CD) representing over 65 percent of the total disturbance area and over 84 percent of the total soil volume available for salvage. The dominant soils are deep, well-drained, loamy, and on slopes from zero to 15 percent. Elevations range from 4,600 to 4,800 feet.

Possible limitations to use of the soils reviewed by GSM and DSL to calculate salvageable depths include: steepness; calcium carbonate, sodium (Na), and coarse fragment content (percentage) in the lower profile; rough broken topography; sand and clay soil horizons; and the presence of rock outcrop. Dominant soils were listed as having fair salvage volumes up to 60 inches in depth in the soil survey (Prodgers, 1988). GSM proposes to salvage 10 to 19 inches of these dominant soils.

b. North Waste Rock Dump Area

Eight soil types in the proposed expansion area covering almost 224 acres would be disturbed by the ultimate north waste rock dump (Table 5). Three soil types (Units 1BC, 1CD, 6DE) represent 74 percent of the total disturbance area and 66 to 89 percent of the total salvageable volume. The dominant soils are moderately deep to deep, well-drained, loamy soils on slopes from 2 to 30 percent. Elevation of the proposed expansion area ranges from 4,900 to 6,000 feet.

Table 3. Summary of the Major Properties of the soils in the expansion areas at Golden Sunlight Mines - Relative Abundance in Expansion Area

UNITS	SOIL TYPES	SLOPE%	DEPTH/ DRAINAGE	PHYSIO- GRAPHIC POSITION	PARENT MATERIALS	ELEVATION	VEGETATION	TAILINGS	NORTH DUMPS	WEST DUMPS
1BC, 1CD (1BCST	Aridic Argiboroll and Borollic Haplargid Loamy Skeletal mixed (stony phase)	2-15	deep, well-drained	flat terraces fans, rolling fans	colluvial sedimentary rocks	5000 - 5500 ft.	big sagebrush/ blue grama	--	Major	--
2BC	Ustic Torriorthent coarse silty - coarse loamy mixed, frigid	2-8	Deep, well-drained	terraces, benches	loess over colluvial and alluvial sediments	4600 - 5100 ft.	needle-and-thread, blue grama	Minor	Minor	--
3BC, 3CD	Borollic/Ustollic Haplargids coarse to fine loamy mixed, frigid	2-15	deep well-drained	toe slopes/ narrow swales and drainages	alluvial and colluvial soft sandy Tertiary valley fill	4500 - 4800 ft.	big sagebrush western wheat-grass/blue grama	Major	--	--
4BC, 4CD	Borollic Calciorthids loamy skeletal mixed	2-15	deep, well-drained	benches	alluvium from volcanic and sedimentary rocks	4700 - 5200 ft.	big sagebrush western wheat-grass/blue grama	Minor	Minor	--
5CD (5FG on steep slopes)	Ustic Torriorthent fine to coarse loamy mixed, frigid	4-60	deep, well-drained	upper slopes to midslope fans and swales	residual and colluvial soft sandy, Tertiary fill	4600 - 4800 ft.	blue grama/ needle-and-thread, big sagebrush	Major (Minor)	--	--
6DE	Ustic Torriorthent/Cumulic Udic Haploboroll fine loamy mixed	8-30	deep, well-drained	mid toeslopes	Loess and colluvium from sedimentary rocks over Tertiary valley fill	4500 - 5200 ft.	needle-and-thread/blue grama/western wheatgrass, big sagebrush	--	Major	--
	Borollic Calciorthids fine loamy mixed	8-30	deep, well-drained	mid toeslopes	Loess and colluvium from sedimentary rocks over Tertiary valley fill	4500 - 5200 ft.	needle-and-thread/blue grama/western wheatgrass, big sagebrush	--	Major	--

Table 3 continued

UNITS	SOIL TYPES	SLOPE%	DEPTH/ DRAINAGE	PHYSIO-GRAPHIC POSITION	PARENT MATERIALS	ELEVATION	VEGETATION	TAILINGS	NORTH DUMPS	WEST DUMPS
7BC, 8FG, 8GF, 93F, 10G	Minor soils east of the mountains; Fluvents, Argids-borolls; Orthents; streambanks and dissected uplands	2-75	shallow to deep well-drained sideslopes of dissect-ed terraces and uplands mountain slopes	floodplains of ephemeral streams, channel banks	Alluvium, colluvium, residuum, eolium, Tertiary valley fill, volcanic and meta-sedimentary rock	4500 - 6000 ft.	mixed shrub steppe, grass-lands, and conifers	Minor	Minor	--
11EF	Typic/Aridic Ustochrepts/ Udic Haploborolls loamy skeletal-to-coarse loamy mixed	15-45	deep, well-drained	toeslopes and fans	colluvium from meta-sediment-ary rocks	5000 - 5500 ft.	big sage-brush/blue-bunch wheatgrass/idaho fescue	--	--	Major
12F	Typic Ustochrepts	30-45	deep, well-drained	lower moun-tain slopes	colluvial meta-sedimentary rocks	5200 - 5800 ft	bluebunch wheatgrass/idaho fescue	--	--	Major
12G	Aridic Ustochrepts and argi/haploborolls ; loamy skeletal mixed	45-75	moderately deep, well-drained	shallow to steep mountain sideslopes	colluvium and residuum from Greyson and Lahood argillites and quartzites	5000 - 6500 ft.	bluebunch wheatgrass/ idaho fescue/ douglas fir/limber pine	--	--	Major
13DE	Lithic Typic Ustochrepts/ lithic Haplo-borolls loamy skeletal mixed to fine loamy	8-30	shallow to moderately deep, well-drained	mountain ridges	colluvium and residuum from Greyson and Lahood argillites and quartzites	5300 - 6500 ft.	douglas fir/limber pine/idaho fescue/bluebunch wheatgrass	--	--	Major

Table 4. Proposed Tailings Impoundment II Area Soils

Unit	Acres %	Major Soils	Proposed Total	Proposed Salvageable	Total Salvage Depths (inches) GSM	Total Salvage Depths (inches) DSL	Differences in Interpretations Salvage Volumes (BCY) GSM	Differences in Interpretations Salvage Volumes (BCY) DSL	Of soil Salvage Criteria
3BC	55%	Borollic Haplargid coarse loamy mixed frigid	22	22	19	60	56,200	177,400	Textural Constraints GSM: Percent Sand, Clay DSL: No limits due to mixing
	30%	Borollic/Ustollic Haplargid fine loamy mixed							Carbonates in lower profile used by GSM DSL: No limits, carbonates beneficial
3CD	65%	Borollic Haplargid loamy mixed	68	68	18	60	164,500	548,500	Carbonates in lower Coarse profile used by GSM DSL: No limits, carbonates beneficial
	20%	Borollic Haplargid fine loamy mixed							
5CD	40%	Ustic Torriorthent fine loamy mixed	87	87	10	60	116,900	701,800	Textural Constraints GSM: clay loam DSL: no limits due to mixing
	60%	Ustic Torriorthent coarse loamy mixed, frigid							
		MINOR SOILS (6)	94	51	*	*	53,000	270,900	Same differences as above, plus coarse fragments: GSM: 35%; DSL 50%
		TOTALS	271	228			390,600	1,698,600	
		DEPTH OF SOIL AVAILABLE FOR REPLACEMENT ON 271 ACRES (VOLUME ÷ ACRES)					14 INCHES	46 INCHES	

* Salvage depth of soils varies from 0-60 inches

Table 5. North Waste Dump Expansion Area Soils

Unit	(-----Acres------) %	Major Soils	(------Proposed------) Total	Salvageable	(------Total------) Salvage Depths (inches) GSM	DSL	Differences in Interpretations Salvage Volumes (BCY) GSM	DSL	Of soil Salvage Criteria
1BC	60%	Aridic Argiboroll loamy skeletal mixed, frigid	78	78	9	54	94,200	565,500	Coarse Fragments GSM: 35%; DSL: 50%
	25%	Borollic Haplargid loamy skeletal mixed							
1CD	40%	Aridic Argiboroll loamy skeletal mixed	41	41	8	49	44,400	272,000	Coarse Fragments GSM: 35%; DSL: 50%
	50%	Borollic Haplargid loamy skeletal mixed							
6DE	40%	Ustic Torriorthent fine loamy mixed	47	47	7	60	44,000	377,500	Coarse Fragments GSM: 35%; DSL: 50% Textural Constraints GSM: Clay Percentage DSL: No limits due to mixing
	15%	Cumulic Udic Haploboroll fine lomy mixed							
		MINOR SOILS (5)	58	40	*	*	93,500	145,200	
		TOTALS	224	206			276,100	1,360,200	
		SOIL IN EXISTING STOCKPILES					160,000	160,000	
		TOTAL REPLACEMENT VOLUME					436,100	1,520,200	

36 INCHES DEPTH OF SOIL AVAILABLE FOR REPLACEMENT ON 309 ACRES INCHES (VOLUME ÷ ACRES)

* SALVAGE DEPTH OF 5 SOILS VARIES FROM 0 - 60 INCHES

Possible limitations to use of these soils used by GSM and DSL to calculate salvageable depths include: slope steepness, coarse fragment, calcium carbonate, and sodium (Na) content (percentage), and sandy soil textures in the lower profiles, clay content in various horizons and the presence of rock outcrop. The soils were listed as having fair salvage value up to 19 to 31 inches in depth in the soil survey. GSM proposes to salvage 7 to 9 inches.

c. West and South Waste Rock Dump Areas

GSM proposes to salvage soil on 47 percent, or 228 out of a total of 487 acres to be disturbed on the west side of the mountains. Four soil types (11EF, 12F, 12G, 13DE) were identified (Table 6). Elevations range from 4,900 to 6,600 feet. The four soil types are variable, being shallow to deep, well-drained loamy soils on slopes from 8 to 75 percent. Salvage depths vary from 6 to 60 inches, depending on slope steepness, rock content, and depth to bedrock. GSM proposes to salvage 7 to 13 inches on 228 acres. Major factors limiting salvage are slope steepness and coarse fragment content.

C. Water Resources

1. Surface Water

The major perennial surface water resources in the area are the Boulder River, which flows north to south approximately 1.3 miles to the east of the proposed permit boundary, and the Jefferson River, which flows west to east approximately 1.4 miles to the south of the permit boundary. The mine area straddles the drainage divide between these two rivers which meet just east of the mine area.

The Jefferson River begins at the confluence of the Beaverhead and Ruby Rivers, approximately 25 miles to the southwest (upstream) from the Golden Sunlight mine area. East of the mine area (downstream), the Jefferson River is joined by the Boulder River and goes on to combine with the Gallatin and Madison Rivers to form the Missouri River near the town of Three Forks, Montana. The Jefferson and Beaverhead Rivers currently are heavily used for irrigation. A U.S. Geological Survey (USGS) water monitoring station on the Jefferson River at Three Forks, approximately 25 miles downstream, has been maintained since 1978. Records for this station indicate a drainage basin area of 9,532 square miles, an average flow of 2,421 cubic feet per second (cfs), a maximum recorded flow for the period of record of 15,900 cfs and a minimum recorded flow of 250 cfs. Water quality on the Jefferson River indicates that it is an alkaline water of medium hardness, with calcium carbonate forming the dominant alkaline component (Montana Department of Fish, Wildlife and Parks, 1988).

The Boulder River forms where the Little Boulder River combines with several channels in the vicinity of Boulder, Montana, approximately 30 miles upstream of the proposed amendment area. From Boulder, the Boulder River flows in a southeast and then southerly direction, joining with the Jefferson River east of the proposed mine expansion area. A USGS gaging station has been maintained on the Boulder River at Boulder,

Table 6. Soils in Waste Rock Dump Expansion Area South and West of the Mountains

Unit	(-----Acres------) %	Major Soils	(------Proposed------) Total	Salvageable	(------Total------) Salvage Depths (inches) GSM	DSL	Differences in Interpretations Salvage Volumes (BCY) GSM	DSL	Of soil Salvage Criteria
11EF	35%	Typic/Aridic Ustochrept loamy skeletal mixed	38	31	13	27	54,000	112,100	Coarse Fragments GSM: 35%; DSL: 50%
	25%	Typic Ustochrept coarse loamy mixed							
	30%	Udic Haploboroll loamy skeletal mixed							
12F	100%	Typic Ustochrept coarse loamy mixed	95	68	0	60	0	545,300	Coarse Fragments GSM: 35%, DSL: 50%
12G	35%	Aridic Ustochrept loamy skeletal mixed	284	70	6	20	56,400	188,200	Coarse Fragments GSM: 35%; DSL: 50%
	30%	Aridic Haploboroll loamy skeletal mixed							
	35%	Aridic Argiboroll loamy skeletal mixed frigid							
13DE	30%	Typic/Aridic Ustochrept loamy skeletal mixed frigid	70	59	7	7	55,900	55,900	
	35%	Lithic Haploboroll fine loamy mixed							
	35%	Lithic Ustochrept loamy skeletal mixed							
		TOTALS	487	228			166,300	901,500	
		EXISTING SOIL IN STOCKPILES					180,000	180,000	
		TOTAL REPLACEMENT VOLUME					346,300	1,081,500	
		DEPTH OF SOIL AVAILABLE FOR REPLACEMENT ON 416 ACRES (VOLUME + ACRES)					19 INCHES		

Montana, intermittently since 1924. These records indicate a drainage basin area of 380 square miles for the site, with an average flow of 120 cfs, a maximum recorded flow of 7,000 cfs, and a minimum recorded flow of 0 cfs. Water quality in the Boulder River drainage is neutral to alkaline with variable metal concentrations, frequently as a result of previous mining activity in the area (Montana Department of Fish, Wildlife and Parks, 1988).

There are no perennial surface water flows within the permit boundary. The ephemeral drainages characteristic of the mine area contain water only in response to snowmelt and precipitation events. Average annual precipitation of the area is approximately 14 inches.

The area of the proposed waste rock dumps on the Bull Mountains is drained by a number of small ephemeral channels. These channels coalesce on the west side of the Bull Mountains to form St. Paul Gulch, an ephemeral contributor to the Jefferson Slough. Other channels drain the south and north dumps to the east and south and are also ephemeral contributors to the Jefferson Slough. Contributing slopes are steep, about 2.5h:1v. Runoff values were predicted to vary from 1.15 to 4.15 acre-feet in the drainages (100-year, 24-hour storm of 2.9 inches of Type II rainfall).

Waste material in the north dump would extend eastward from the east side of the Bull Mountains. One major and two minor ephemeral drainages, which would be covered with waste rock, contribute to an unnamed drainage which courses just south of Sheep Rock, then southeasterly to the Jefferson Slough. The slopes of the major drainage above the dump are very steep, while the slopes of all drainages under the proposed dumps are moderate. The drainages range from 1.4 to 3.3 acres in size. Runoff values varied from 0 to 4.67 acre-feet in the drainages (100-year, 24-hour storm of 2.9 inches of Type II rainfall).

The area of the proposed tailing impoundments I and II is drained by ephemeral channels that flow southward to the Jefferson Slough. The 100-year, 24-hour precipitation event is 2.8 inches (SHB, 1988). Tailing impoundment I is contained within a watershed of 1,043 acres and tailing impoundment II's watershed is approximately 320 acres (SHB 1982, 1988). GSM calculated the probable maximum flood (PMF) for tailing impoundment II at 9.0 inches (SHB, 1988). The completed stage V pit would have an undisturbed watershed of approximately 62 acres and a surface expression of 209 acres (SHB 1989). Runoff was calculated for areas of 42 and 65 acres above impoundment II. Runoff from 42 and 65 acres totalled 6.39 and 3.15 acre-feet respectively.

2. Groundwater

Since the original operating permit application was submitted by GSM in 1975 and the EIS prepared by DSL in 1980, numerous hydrologic reports and supporting data have been submitted by GSM and their consultants in support of the various amendments to the permit. These reports are available at the DSL office in Helena and include SHB 1980; SHB 1982; SHB 1983; SHB 1985; SHB 1987; SHB 1988; SHB 1989; SHB 1990; Hydrometrics 1990; Hydrometrics 1990.

Groundwater movement in the proposed amendment area occurs in several distinct aquifers. These can be generally classed as a bedrock system, a less inundated Tertiary system in the Bozeman group and an alluvial system composed of quaternary surficial deposits and of the Jefferson Valley aquifer.

(a) Bedrock Aquifer

Groundwater occurrences in the area of the proposed mine pit are controlled by water movement in the PreCambrian LaHood, Newland, and Greyson formations of the Belt Supergroup and the Tertiary igneous intrusives which host the ore body. Water movement in these formations is in response to the development of secondary fracture permeabilities since the formations themselves are generally tight. This system is expected to have little sustained water production capability although the recharge area to the north and west would increase as the pit expands, capturing additional groundwater. Porosities were estimated by GSM to range from 0.01 to 0.005 and specific yield to range from 0.001 to 0.002 (SHB 1989). Hydraulic conductivities are highly variable depending on the number and nature of the fracture intercepted. Conductivities have been measured between 10^{-3} and 10^{-7} cm/sec. Groundwater gradients as high as 0.3 to 0.1 were reported by GSM. Groundwater quality may be poor due to the presence of sulfide minerals in the host rock and ore body which produce low pH water with elevated metals. Acidity values for water exiting the Ohio adit (approximately 10 gpm) have been reported to be in the pH 2-3 range, with metal values that exceed water quality standards for cadmium, copper, iron, nickel, and zinc (Table 7). A description of the Ohio adit is on page 20.

A potentiometric map of the bedrock system is not practicable due to the ambiguities in the fractured system and the limited continuous data base from in-pit monitoring. Groundwater elevations vary from 5,810 feet to 5,193 feet within the proposed pit. Groundwater elevations along fault zones appear to be higher as would be expected in such a system. The Ohio adit with extensive drill development does not appear to influence groundwater levels substantially. The majority of groundwater elevations, from approximately 32 drill holes within the proposed pit, range from 5,300 to 5,470 feet. Drill data indicates that groundwater follows the bedrock topography to the east and south below the pit, however southwest movement within the major fracture set is also possible.

(b) Bozeman Group Aquifer

The Tertiary Bozeman Group aquifer is composed of the lower Climbing Arrow and upper Dunbar formations, east of the Golden Sunlight fault which separates it from the bedrock aquifer of the Bull Mountains. The land surface slopes gently to the south-southwest and groundwater follows the topography. Depth to groundwater is generally less than 100 feet. A line of springs to the north of tailing impoundment I is interpreted as a discharge point for a perched system within the Dunbar on top of the Climbing Arrow Formation. The springs are of poor quality and may represent natural leaching of the deposit to the west as previously stated. These springs recharge the surficial alluvial aquifer in Golden Sunlight Gulch, (SHB 1982). Another spring exists within a landslide deposit which is presently being reactivated by the expansion of the north waste rock dump. This stratigraphy may or may

Table 7. Ohio Adit Water Compared to Water Quality Standards

Parameter (1)	Montana: Chronic Aquatic-Life Criteria	Montana: Acute Aquatic-Life Criteria	Montana: Groundwater Quality Standard	Ohio Adit: Water Quality Average	Ohio Adit: No. of Samples
Ammonia (2)	2.1	10.9	--	0.3	1
Nitrate	--	--	10	1.31	5
Arsenic	0.19 **		0.36 **	0.012	3
Barium	--	--	1	<0.1	1
Cadmium	0.00227 **	0.010638 **	0.01	0.1267 *	3
Chromium (3)	0.011	0.016	0.05	<0.02	1
Copper	0.02518 **	0.04079 **	--	33.08 *	3
Cyanide	0.0052	0.022	--	--	--
Iron	1	1	--	14.1	4
Lead	0.00976 **	0.251758 **	0.05	0.0075 *	2
Mercury	0.000012	0.0021	0.002	<.001	2
Nickel	0.33323 **	2.99751 **	--	1.65 *	2
Selenium	0.035	0.26	0.01	0.00625	2
Silver	0.00012 ++	0.018585 ++	0.05	<0.005	2
Zinc	0.22428 **	0.247615 **	--	19.25 *	3
pH	--	--	--	2.68	5

(1) Metals and nutrients contained in table are primary drinking water quality standards and aquatic-life criteria for available water quality data.

(2) Ammonia aquatic-life criteria are temperature and pH dependent. Value shown is calculated based on pH of 7.75 and 10 degrees celsius. Value is for total ammonia.

(3) Aquatic-life criteria is for hexavalent chromium, groundwater quality limit is for total of all forms of chromium.

-- No aquatic life criteria or MCL exists.

** Aquatic life values are hardness dependent. Value shown is calculated based on average hardness of 242.2 mg/l in the Jefferson Slough.

++ No standard. This is lowest observed effective level on aquatic life (Quality Criteria For Water, USEPA, 1986).

not be part of the Bozeman Group material but the spring, of poor quality, may represent natural leaching from the bedrock aquifer immediately to the west.

The predominant lithology of the Bozeman Group is shale and minor, probably discontinuous, lenses of sandstone. Hydraulic conductivities in these stratigraphies range from 1.7×10^{-5} to 2.9×10^{-8} cm/sec for the shale and 4.4×10^{-5} to 6.7×10^{-6} cm/sec for the sandstone lenses (SHB, 1987). Earlier studies placed the hydraulic conductivity within the perched Dunbar aquifer at between 4.2 to 5.7×10^{-4} cm/sec (SHB, 1982). Exploration drilling exposed minor aquifers yielding 3 to 5 gpm in 15 holes drilled under the proposed waste rock dumps.

Recharge to the Bozeman Group hydrologic system is inferred to flow from the Bull Mountains to the west with additional upgradient flow from the north. Direct precipitation and infiltration in he mine area also supplement recharge.

(c) Quaternary Aquifer

Quaternary alluvial-colluvial deposits mantle the area under study, and form aquifers in the gullies cutting northward from the Jefferson valley into the Bozeman Formation. The alluvial system in Golden Sunlight Gulch extends just northward of tailing impoundment I. A second alluvial system extends under the proposed tailing impoundment II in a gulch to the east. The silt, sands, and gravels range from 0 to 60 feet thick, of which the lower 10 feet are generally saturated. The perched aquifer rests on the relatively less permeable Bozeman Group. The channels are connected and transmit and store water. Hydraulic conductivities have been measured from 4×10^{-3} to 4×10^{-6} cm/sec (SHB, 1989, and 1982). A 1985 study of the downgradient hydrology from tailing impoundment I calculated the conductivity between 1.8×10^{-2} and 5.5×10^{-3} cm/sec. The flow within the channels prior to mining is estimated at a minimum of 5 gpm at the location of the present slurry cut-off wall. This assumes a hydraulic conductivity of 5.5×10^{-3}, a hydraulic gradient of 0.061 (SHB, 1985), and a cross-sectional area of 1,000 ft^2 (the 10-foot lower saturated zone x 100-foot cross-sectional distance). To the east, underlying the proposed tailing impoundment II, the alluvial sediments are thinner, less than 40 feet, and appear to be richer in clays (SHB, 1988). The maximum saturated thickness is approximately 6 to 7 feet.

(d) Jefferson Valley Aquifer

The Jefferson valley aquifer occupies the area to the south of the project area and consists of unconsolidated permeable alluvium of the river flood plain and flanking terrace deposits. Here the topography makes a transition from moderate to steep slopes to the north into the gently dipping inner valley of the Jefferson River. The alluvium is between 35 and 100 feet thick, and is underlain by rocks of the Bozeman Group. The alluvium typically consists of interbedded coarse sands to gravels; however, some clay and fine sand units are also encountered. The saturated thickness of the alluvium generally does not exceed 20 feet. The predominant direction of groundwater flow is from the west to the east, following the downstream direction of the Jefferson River. Water table gradients are estimated to be 0.002.

Water within the Jefferson River aquifer is assumed to be recharged by two major sources: 1) flux along the longitudinal axis of the aquifer, and 2) surface water and groundwater discharges from the washes containing alluvial material and the Bozeman Group to the north.

Historic mining in the area accessed the ore body through a horizontal opening or shaft called the Ohio adit. High sulfate water characteristic of the Ohio adit is reflected in the Mark Steppen spring, approximately one mile south of the pit along the Golden Sunlight fault and in two drill holes at the south end of the Bull Mountains. Low pH waters with elevated metals, also indicative of the Ohio adit, were sampled from two springs (the Bunkhouse and North Borrow Springs) above tailing impoundment I, within the Bozeman formation. An oxidized or ferrocreate area, possibly developed by natural leaching of metals from the deposit and precipitation by adsorption on the Bozeman clays, exists to the southeast of the mine. These geochemical patterns suggest groundwater flows, from the pit area, east out into the Bozeman formation and south to southwest through the bedrock system and into channel alluvium of the Bozeman formation and Jefferson Valley aquifer at the south end of the Bull Mountains.

3. Water Rights

A review of the current filed water rights claims for the area around the Golden Sunlight mine's proposed expansion indicates 28 filed claims are on record. Approximately half of these are listed as groundwater appropriations with flow rates of between 10 to 500 gpm, for various water uses. Surface diversions in the area range from 2 to 12 cfs with diversions from both the Jefferson River and the Boulder River.

D. Vegetation

Vegetation is dominated by the grasses typical of the mixed grass prairies and shrub steppes, particularly in the lower elevations on the east side of the mountains. In the foothills closer to the mountains, vegetation is dominated by the grasses and shrubs characteristic of the foothill mountain grasslands, interspersed with varying amounts of coniferous trees including rocky mountain juniper, limber pine, and douglas fir.

1. Plant Community Development

The plant communities existing at GSM today have developed in response to the semiarid continental climate, modified parent materials and new soils that have evolved in the area since the retreat of the Pleistocene glaciers 10,000 years ago (Ottersburg, 1988).

The resultant communities are diverse due to the extreme variations in elevation, precipitation, slope and exposure, wind, evaporation, and soil characteristics found on the site across relatively short distances. Elevations in the area range from 4,400-6,600 feet. Estimated precipitation varies from as little as 10 inches in the lower elevations in the rain shadow on the east side of the mountains to up to 20 inches at the higher elevations on the west side. In addition, effective precipitation is altered by: drifting snow in the winter;

redistribution of moisture from rainfall and runoff events that exceed soil infiltration capacities or that occur on frozen ground; and by the effect of varying slopes and exposures. Slopes range from zero to over 75 percent and occur on predominantly southerly aspects.

The most important soil characteristics affecting plant communities include reaction (pH), depth, drainage, texture, calcium carbonate content, coarse fragment content, salinity and sodium (Na) content in lower soil profiles.

In addition to the natural influences on plant community development, in the last one hundred years plant communities in the area have been altered by livestock grazing and other agricultural activities, road and highway construction, and more recently from the current mining operation. GSM had disturbed over 833 acres from 1975 to the end of 1988. Only 45 acres have been revegetated because of continued expansion of the mine.

Grazing livestock have had an important but often more subtle effect on plant communities. Rangeland water developments, herbicide use to control shrubs, plowing and seeding to create improved dryland pastures, and fencing have altered plant communities (Prodgers, 1988). Many of the existing plant communities are seral and vary from the potential communities that would exist on the site without livestock grazing.

Local vegetation communities have also been changed by historic mining and mineral exploration disturbances; tree removal for mining timbers, fencing, and firewood; man-caused fires and suppression of wild fires; and introduction of non-native vegetation including several noxious weeds which have spread along roadways, around construction sites and around rangeland water sources in the area.

2. Existing Plant Communities

Existing plant communities are described for the three main disturbance areas (Table 7). Data presented has been interpreted by DSL and BLM from the vegetation and soil survey provided by GSM (Prodgers, 1988 and Ottersberg, 1988).

a. Proposed Tailing Impoundment II Area

On relatively level benches, fans, and southerly exposures in the lower elevations, existing communities are dominated by short and midgrasses (and a sedge) characteristic of the mixed prairie grassland and big sagebrush-steppe. Shrubs, including big sagebrush and rabbitbrush, are also present (Table 8). The coulee banks and rocky areas have the same plant communities, but also contain varying quantities of bluebunch wheatgrass, rocky mountain juniper and limber pine. The presence of shrubs and trees creates the characteristic shrub-steppe appearance found in the area. North exposures have species more characteristic of the mountain foothill grasslands including idaho fescue and douglas fir. A dryland pasture seeded to crested wheatgrass has been established in a part of the proposed impoundment II area.

Table 8. Characterization of existing plant communities in the proposed expansion area, Golden Sunlight Mine

Table 8. Characterization of Existing Plant Communities in the Proposed Expansion Areas, Golden Sunlight Mine

Existing Plant Community	Slope	Percent Plant Cover	Aspect	Physical Setting	Relative Distribution in Expansion Area		
					Tailings	North	West
GRASSLAND COMMUNITIES							
Threadleaf Sedge	37%	69	S to W	Straight to undulating midslopes or coulee banks	common	limited	--
Blue grama/western wheatgrass	25%	58	All	Straight to concave midslopes on coulee banks and edges	common	--	--
Broom snakeweed bluebunch wheatgrass	56%	35	Warm	straight, midslopes or coulee banks	--	--	common
blue grama	8%	80	SE-SW	straight, lower slopes on terraces	common	common	--
western wheatgrass/ blue grama	9%	70	E-NE	concave to straight, lower slopes and runin areas	common	common	--
threadleaf sedge	Variable	71	Variable	convex sandy knolls knolls	common	--	--
needle-and-thread/blue grama/threadleaf sedge	9%	77	SE	straight midslopes on wet drainage benches	limited	common	--
idaho fescue/ bluebunch wheatgrass	40-50%	84 W, NW	Cool	straight or convex upper slopes	--	--	common
broom snakeweed	27%	59	W, N	straight to concave mid-slopes, overgrazed mountain foothill grasslands	--	--	common
SHRUB/GRASSLAND COMMUNITIES							
big sagebrush bluebunch wheatgrass	37%	71	S to E	straight, mid-to upper slopes, mountain foothills	--	common	common
big sagebrush/ idaho fescue	46%	92	E, W	straight, upper slopes on moutainsides	--	--	common
big sagebrush/ western wheatgrass	12%	92	E, S, W	concave, straight to undulating, lower to midslopes on flat uplands and swales, and coulee banks	common	limited	--

Table 8. Continued

Existing Plant Community	Slope	Percent Plant Cover	Aspect	Physical Setting	Relative Distribution in Expansion Area: Tailings	North	West
big sagebrush/ needle-and-thread-red threeawn	7%	76	E	straight, midslopes, on pediments with sandy soils	limited	--	--
mountain mahogany	44%	42	S, SW	straight, midslopes on chalky soil, limestone substrates	--	limited	--
rocky mountain juniper/bluebunch wheatgrass	38%	50	S to W	concave-slightly convex mid- to upper slopes, overgrazed western foothills	limited	--	common
rocky mountain juniper/blue grama/ threadleaf sedge	variable 5-60%	86	variable	concave, mid to lower coulee bottoms and side slopes	limited	limited	--
OTHER MISCELLANEOUS COMMUNITIES							
douglas fir	52%	70	N to W	straight, mid- to upper forested mountainsides	--	limited	common
limber pine	52%	47	SW	convex, undulating to straight, midslopes on mountain foothills and coulee banks	limited	--	common
douglas fir/scree and forested rock outcrops	variable		variable	mountain ridges and and outcrops	---	---	--
bare ground or rock or rock	variable		variable	mountain ridges and outcrops	--	--	--

b. North Waste Rock Dump Area

Although the soils and plant communities in the north waste rock dump area are considerably different than the tailing impoundment II area, the dominant plant species are essentially the same (Table 8). The foothill mountain grassland communities are more important and there is an increase in the quantity of trees with the increased moisture in the area. Species such as threadleaf sedge, blue grama, and needle-and-thread are reduced. Idaho fescue, bluebunch wheatgrass, western wheatgrass, limber pine, and douglas fir are increased. The area still has the appearance of a shrub-steppe but the mountains are closer and dominate the setting.

c. West and South Waste Rock Dump Areas

Soils on the west and south side of the mountains vary considerable from the north and east side of the mountains. Slopes are steepest on the west side of the mountains and are in excess of 45 percent on half of the proposed expansion area. Dominance by the grasses characteristic of the mixed grass prairies have given way to dominance by grasses more characteristic of mountain foothill grasslands (Table 9). Because of the increased moisture on the west side, trees are more common on the higher elevations primarily on the northerly aspects.

3. Productivity

a. Range Condition/Productivity/Stocking Rate

Range condition is generally fair to good depending on distance to livestock water (Table 10). The estimated production of non-woody vegetation varies from 0 to 1,000 kilograms/hectare (kg/ha) with 500 kg/ha being a reasonable average. Plant canopy coverage varies from 35 to 92 percent, with 70 percent being a reasonable average (Table 8). Estimates of animal unit months (AUM) of forage for livestock per acre varied from 0 to 0.40 AUM/acre. A reasonable average would be 0.15 to 0.20 AUM/acre (Table 9). The BLM has set an allotment of 19 acres per AUM for four months as the maximum livestock grazing allowed each year in the amendment area.

b. Utilization by Livestock/Wildlife

The grass dominant character of the plant communities favors cattle and horse use over sheep. Antelope use in the area is more extensive than deer. Deer utilize the area more in wintertime, especially the big sagebrush communities. There is an edaphic plant community that is dominated by mountain mahogany north of the tailings impoundment II area on limestone parent materials and chalk soils derived from limestone. This plant community receives extensive winter use by deer. Deer may use the timbered coulees and ephemeral drainages more for shelter and access to the adjacent irrigated alfalfa fields south of the impoundment II area, than for forage.

Table 9. Major Species in Proposed Expansion Areas and Relative Reestablishment Potential in Revegetated Communities (DSL Interpretation)

Table 9. Major species in Proposed Expansion Areas and Relative Reestablishment Potential in Revegetated Communities (DSL Interpretation)

Dominant Species	Presence of Species in Existing Communities			Relative Reestablishment Potential	
Dominant Species	Tailings	North Dump	West and South Dumps	Seed Availability	Observed Reestablishment Potential
threadleaf sedge	x	x	x	none	low
blue grama	x	x		low	low
needle-and-thread	x	x		low	moderate
western wheatgrass	x	x		good	good
big sagebrush	x	x	x	low	low-moderate
bluebunch wheatgrass	x	x	x	moderate	moderate to good
fringed sagewort	x	x		undesirable	--
clubmoss	x	x	x	undesirable	--
rabbitbrush	x	x	x	low	moderate
prickly pear cactus	x	x		undesirable	--
prairie junegrass	x	x	x	low	low
idaho fescue	x	x	x	low	low to moderate
rocky mountain juniper	x	x	x	stock	low to moderate
kentucky bluegrass (non-native)	x	x		good	good
limber pine	x	x	x	stock	low
skunkbush	x			stock	low to moderate
red threeawn	x			undesirable	low to moderate
douglas fir	x	x	x	stock	moderate
crested wheatgrass (non-native)	x			good	good
broom snakeweed			x	undesirable	--
mountain mahogany			x	stock	low

Table 10. Relative Productivity in Existing Plant Communities at Golden Sunlight Mine

Table 10. Relative productivity in Existing Plant Communities at Golden Sunlight Mine

RELATIVE PRODUCTIVITY

GRASSLAND COMMUNITIES	PRODUCTIVITY	RANGE CONDITION	STOCKING RATE
threadleaf sedge	550 kg/ha	fair	0.15 AUM/A
blue grama/western wheatgrass	400 kg/ha	fair	0.15 aum/a
broom snakeweed/bluebunch wheatgrass	300 kg/ha	good	0.10 aum/a
blue grama	350 kg/ha	fair	0.15 aum/a
western wheatgrass/blue grama	600 kg/ha	good	0.25 aum/a
threadleaf sedge	350 kg/ha	fair	0.15 aum/a
needle-and-thread/blue grama/ threadleaf sedge	500 kg/ha	good-fair	0.20 aum/a
idaho fescue/bluebunch wheatgrass	1,000 kg/ha	good	0.40 aum/a
broom snakeweed	--	poor	-.--
SHRUB/GRASSLAND COMMUNITIES			
big sagebrush/bluebunch wheatgrass	900 kg/ha	good	0.2-0.25 aum/a
big sagebrush/idaho fescue	1,000 kg/ha	good	0.40 aum/a
big sagebrush/western wheatgrass	600 kg/ha	fair-good	0.20 aum/a
big sagebrush/needle-and-thread-red threeawn	800 kg/ha	fair-good	0.2 aum/a
mountain mahogany	500 kg/ha	--	-.--
rocky mountain juniper/bluebunch wheatgrass	500 kg/ha	fair-good	-.--
rocky mountain juniper/blue grama/ threadleaf sedge	300 kg/ha	--	0.15 aum/a
OTHER MISCELLANEOUS COMMUNITIES			
douglas fir	250 kg/ha	--	-.--
limber pine	--	--	-.--
douglas fir/scree and forested rock outcrops	--	--	-.--
bare ground or rock	--	--	-.--

4. Noxious Weeds

Noxious weeds are not a major problem in the proposed new disturbance areas (R. Prodgers, 1988, written communication). Four weeds in the present permit boundary are considered noxious by the Madison-Jefferson County Weed Control Board. The four weeds in order of decreasing priority of control are: spotted knapweed, whitetop, leafy spurge and canada thistle.

GSM has been trying to control noxious weeds in the area since 1984 (GSM Noxious Weed Report to DSL, 1988).

5. Species Listing

The number of species found in the study areas during the vegetation survey totaled 152. Of particular importance, the total number of forbs and subshrubs reported was 112. The shrub/grassland communities were particularly forb rich.

No rare and endangered species were found in the 1988 survey of the proposed expansion areas (R. Prodgers, 1988, written communication).

E. Wildlife

The southern Bull Mountains support a small elk herd. Survey information indicates that approximately 50 elk winter in the vicinity of Black Canyon and a lesser and more variable number are found around Black Butte. These areas are two to four miles north of the proposed disturbance. Hunting season reports have placed elk in the Conrow drainage and just north of the Electronic site in section 18 (T. Carlson, 1989, written communication). But elk use during other seasons has not been adequately documented.

Mule deer use in the mine area has not been quantified, although the habitat is considered suitable for the species. The sagebrush-grassland over much of the area provides good winter range and the rough, broken country at higher elevations is good habitat during other seasons (T. Carlson, 1989, written communication). A mountain mahogany-dominated plant community north of proposed tailing impoundment II receives extensive winter use by deer (see Vegetation, Section 3 d).

Antelope winter range is located south of Red Hill. There have also been 20 to 30 head reported summering south of Red Hill in sections 27 and 28.

Smaller mammals which are common on the proposed disturbance area include the snowshoe hare, white tailed jackrabbit, two species of chipmunk, the columbian ground squirrel, red squirrel, wood rat, two species of mice, three species of voles, porcupine and striped skunk. Coyotes and bobcats are common predators in the area. Twenty-one species of passerine birds potentially nest in the area, and two species of snakes, the prairie rattler and bull snake, are common.

Although quantified information of waterfowl use of the nearby Jefferson and Boulder Rivers is not available, waterfowl use of these rivers in the vicinity of the mine is substantial. Local breeding populations of Canada geese associated with the Jefferson River and Boulder River have increased in recent years as they have throughout most of their range. This area is also a major migration corridor for swans and snow geese (T. Carlson, 1989, written communication).

Fisheries include the Jefferson and Boulder rivers. The Jefferson River between Big Pipestone Creek and the mouth has been designated a high value sports fishery, providing 1,401 fisherman days/year/10 km. Rainbow trout are common, whereas brown trout and whitefish are abundant (Trout, 1988). A three-year average population survey estimates 293 adult (3 years +) brown trout/mile below the mine site (Willow Creek to Three Forks) and 350 adult brown trout/mile above the mine site (Hells Canyon Creek section). This population experiences unusually high adult mortality, probably related to summer dewatering and severe winter icing in some sections of the river (DFWP, 1988). The Boulder River near the mine has been designated a substantial sports fishery for the stretch from Cottonwood Creek to the Jefferson River (Trout, 1988). The lower Boulder River is used for spawning by brown trout.

There is no known occupied habitat of any of the four listed terrestrial, threatened or endangered species in the vicinity of the mine. Two avian listed species, the bald eagle and the peregrine falcon, are likely to occur in suitable habitat in the general area.

Bald eagles prefer to nest near open water, hence it is very unlikely that this species would occur in the mine area. Bald eagles are likely to occur on the Jefferson River and Boulder River during the winter. Similarly, peregrine falcons are not likely to find nesting cliffs on the mine. The Jefferson River does contain used peregrine habitat, so they may occasionally occur in the mine vicinity.

F. Land Use

Lands within the permit boundary were historically used for hunting and gathering by prehistoric man. In the last 100 years, wildlife habitat, seasonal livestock grazing, and mineral extraction have been the most important uses. During mine life, wildlife use of the disturbed areas, particularly the impoundment area, would be displaced. Wildlife use of undisturbed areas within the permit boundary during big-game hunting seasons is increased because of hunting restrictions by the mining company. During mine life, livestock use within the permit boundary would be postponed.

The primary uses of land surrounding the mine are agricultural, recreational and tourism. Several farms and ranches are located along the Jefferson River Valley south of the mine. The river flows from west to east near the mine area and attracts fishermen and recreational floaters.

Lewis and Clark State Park is located approximately seven miles east of the mine site. This summer tourist attraction is popular with many visitors in the area. Also becoming somewhat of a tourist attraction is the Golden Sunlight Mine. Many people traveling through the area request a tour. GSM does not have a formal tour plan but tries to accommodate as many visitors as possible without disturbing its normal operating schedule.

G. Air Quality and Climate

GSM has monitored air quality around the existing operation for the last nine years as part of their MDHES-AQB Permit No. 1689A. Total suspended particulate (TSP) concentrations have been well below Montana and federal ambient air quality standards. The following table summarizes the TSP data collected over the last six years. (Table 11).

Table 11. Annual Total Suspended Particulate Concentrations, Golden Sunlight Mine (micrograms/cubic meter) 1984-1989

	Upwind Site			Downwind Site		
Year	Max.	Second Highest	Mean	Max.	Second Highest	Mean
1984	32	27	10	56	37	17
1985	57	49	15	78	74	21
1986	51	50	17	89	73	26
1987	96	39	21	120	64	24
1988	86	85	21	392	63	24
1989	83	56	20	170	56	17

The basis of the particulate standards has recently been changed from TSP to PM-10 (particulate matter with a diameter less than 10 microns). The following is a listing of both the old and new standards (Table 12).

Table 12. Montana and Federal Particulate Standards

Standard Pollutant	Montana Standard	Federal Primary Standard	Federal Secondary Standard
TSP annual	75 ug/m^3 annual average	75 ug/m^3 annual geometric mean	60 ug/m^3 annual geometric mean
24-hour average	200 ug/m^3	260 ug/m^3	150 ug/m^3
PM-10 annual average	50 ug/m^3	50 ug/m^3	None
24-hour average	150 ug/m^3	150 ug/m^3	None

Current air pollution sources in the area include the existing mining activities (haul road traffic, blasting, drilling, ore and waste handling, and wind erosion of exposed areas) other vehicle traffic, and agricultural activities.

The climate of the area is classified as semi-arid intermountain and is typical of southwestern Montana. The continental climate characteristics of the region are modified by the local ranges of the Rocky Mountains. Pacific Ocean air masses, drainage of cooler mountain air into the valleys, and the shielding effect of the mountains reduce the temperature changes typical of a true continental climate.

Annual precipitation ranges from 10 to 20 inches with peak amounts occurring in May and June. Pan evaporation has averaged about 45 inches per year in the May 1 to September 30 period over the last nine years. Heaviest precipitation occurs on the western or windward slopes of the mountains.

The average annual temperature is about 45 degrees F. Temperatures range from about minus 40 degrees F to 100 degrees F. Freezing temperatures can occur as late as mid-June and as early as September. The growing season is short, between 90 and 120 days.

Prevailing winds are from the west. The wind direction is from the west-southwest through west-northwest over 47 percent of the time. The westerly winds also have the highest average wind speed at 13.6 miles per hour. Highest wind speeds normally occur in January and the lowest in May and June.

H. Transportation

Interstate 90 is the main east-west transportation corridor across Montana. Whitehall is located on Interstate 90 between Butte and Bozeman, Montana. The Golden Sunlight Mine is located approximately five air miles northeast from the city of Whitehall, Montana. Interstate 90 is located 2.5 miles south of the Golden Sunlight mine and mill complex and one-half mile from the toe of the proposed tailing impoundment II system. Vehicle access to the interstate is via the Cardwell interchange, four miles east of the mine, or through Whitehall, five miles west of the Golden Sunlight access road. A frontage road paralleling I-90, Montana Highway 2 (formerly U.S. Highway 10) is the main highway leading to the mine site access road. Local access to ranches to the west of the mine is provided by gravel county roads which connect to the frontage road. The mine access road is not used for local ranch access.

Two miles east of the Golden Sunlight mine access, Montana Highway 69 branches north from Montana Highway 2, toward Boulder and Interstate 15; to the south, Montana Highways 55 and 41 connect Whitehall with Dillon and Interstate 15.

The Golden Sunlight mine access road intersects Montana Highway 2 about two miles south of its plant site complex. The road is gravel and provides good year-round access to the mine. During the periods of dry weather, the mine access road is treated with a dust suppressant to retard fugitive dust.

I. Noise

Noise from existing mine activities include blasting, heavy equipment, and migratory bird and wildlife protection. Noise from blasting and heavy equipment may be higher than background. Various measures are used to scare waterfowl and wildlife from using cyanidated water in the tailing impoundment I. These include rock music, rifles and propane poppers. These noise levels are also above background.

Sound surveys have not been conducted in the study area. The project area, though rural in character, is situated close to a railroad and a major interstate highway, as well as several well-traveled state and county roads. The dominant local noise source is wind and freeway traffic. The proposed expanded project should not result in noise complaints since all residences are located more than one mile from the active mining/tailing areas and relatively close to active highways.

J. Socioeconomic and Human Environment

1. Jefferson County

a. Employment and Income

The major source of basic employment in Jefferson County is the mining industry with five firms employing approximately 525 persons and comprising nearly 18 percent of the work force. Other major sources of employment in Jefferson County are state government (500 persons) and local government (325 persons). Together, these three sectors make up 45 percent of all employment in the county. The mining industry is also among the leaders in high-paying jobs with an average salary of $33,228 in 1989 and a total payroll of nearly $17 million, or over 30 percent of all wages and salaries paid in Jefferson County in 1989.

The civilian labor force in Jefferson County has grown from 3,081 persons in 1980 to 5,542 in 1989, representing an average annual increase of 6.7 percent. This growth rate is much higher than the statewide rate of 1 percent over the same time period. A large portion of the labor force in Jefferson County live in the highly developed northern portion of the county and work in Lewis and Clark County.

The unemployment rate in Jefferson County has varied from a high of 11.2 percent in 1983 to a low of 3.3 percent in 1989, which was approximately one-half the state rate. The principal reason that the current unemployment rate is low is due to mining activity -- primarily, the start-up of the Montana Tunnels Mine near Jefferson City in 1987.

Projections of employment and income for Jefferson County indicate little growth over the next 20 years. The National Planning Association has projected that total employment would grow from 3,200 persons in 1990 to 4,200 by the year 2010, representing an annual growth rate of 1.4 percent. Personal income is projected to grow from $105.3 million in 1990 to $223.8 million by 2010 (1982 dollars). Both of these trends are similar to the state projection trends over the same time period.

b. Government Finances

In 1989, the taxable valuation of Jefferson County was $22.5 million, up nearly 10 percent from the 1988 valuation. Over $5.0 million, or approximately 25 percent of the valuation, is attributable to the valuation of mines or gross proceeds taxes from mines. The current millage in Jefferson County is around 60 mills, including 20 mills for the general fund and 8 mills for roads. The general fund budget for 1989-90 was $1.7 million, which included $436,114 from property taxes and $335,000 from operating reserves.

Unlike the county valuation, the taxable valuation of Whitehall has remained very stable at slightly over $800,000. Whitehall has an all-purpose levy of 65 mills and a 1989-90 general fund budget of $179,400, of which $56,700 comes from property taxes.

The Golden Sunlight Mine is located in the Cardwell Elementary School District and the Whitehall High School District. Because of the few number of students at Cardwell (1989 fall enrollment was 41 students) and the high taxable valuation on the mine and gross proceeds, the mill levy for the Cardwell School District has been one of the lowest in the state (4.38 mills for general fund in 1988-89). The school has a capacity for 85 students.

Whitehall High School (Grades 9-12) has a present enrollment of 206 and its capacity is 300 without the need for added facilities. The Whitehall Grade School (Grades K-8) enrollment is 339 and it has a capacity of 450 students. Over the past six years, area school populations (Jefferson County Superintendent of Schools, 1989) have been:

School	1984	1985	1986	1987	1988	1989
Cardwell (1-8)	52	46	45	39	44	42
Whitehall (K-8)	391	417	378	390	357	339
Whitehall (9-12)	256	255	236	215	223	206

This survey confirms that over the past few years of operation at Golden Sunlight, area school enrollment has been declining. School administrators have stated that additional student enrollment would be necessary to maintain their present staff teaching levels. Unfortunately, GSM's expansion would probably not provide those students.

c. Social Life

Social structure and interaction in the Whitehall/Cardwell area have been primarily shaped by an economy based on agriculture. The physical demands and economic risk associated with agriculture have necessitated the adoption of such personal attributes as self-reliance, frugality, and conservatism. Many residents of the area come from long-established families who generally place a high value on family life.

Social well-being of a community is a subjective concept based upon individuals' perceptions of how their lives compare with their expectations of themselves and the community in which they reside. Indicators of social well-being include the incidence and rate of certain behaviors such as crime, divorce, suicide, family violence, alcohol/drug abuse, welfare rates, school dropouts, and unemployment. Except for the suicide rate in Jefferson County, most of these social indicators are below the state average.

d. Community Services

Community services are generally viewed by local residents as fair or good. Although recommendation to the City Council would be made by the mayor for upgrading municipal wastewater and fresh water systems, the services and facilities are reported to be adequate to serve the people of the area.

e. Housing

A 1981 survey of the Townsite of Whitehall indicated that 20 single-family residences were for sale. Today, seven years later, a recent survey of the same area indicates that more than 34 residences are for sale.

It can be concluded that existing Golden Sunlight operations have not influenced the housing market in the Whitehall area. Since 1983, some employees have upgraded their housing by building or buying new homes. This has been done in a gradual manner without causing any disturbance in the housing market. It should be noted that the price range for single-family residences has tended to follow state and national trends, and is not influenced by speculation on Golden Sunlight activities.

2. Golden Sunlight Mining, Inc.

a. Employment and Income

GSM has been in operation since 1975. The last major expansion of the mine, in 1981, occurred during shut-down activities of Anaconda Copper Company properties in Butte and Anaconda. The expansion took place prior to the enactment of the Hard Rock Impact Act and no Impact Plan was required. According to correspondence with local government officials and school personnel, increased mine employment posed no threat to existing local services and no deleterious impacts were anticipated as the mine expanded to its current, permitted size. Both Cardwell and Whitehall school districts have operated well below the capacity of the elementary and high school facilities since GSM received its current expansion plan in 1981.

GSM employs approximately 300 workers in a variety of technical, administrative, and mining jobs. In addition, another 30 contract jobs and 16 temporary jobs are supported by the mine. Furthermore, an estimated 100 to 150 secondary jobs have been created to satisfy the demands for goods and services from the mine and the employees of the mine. Thus, the Golden Sunlight Mine is directly responsible for approximately 13 percent of all employment in Jefferson County.

The annual payroll of the Golden Sunlight Mine, including pay to contractors, is approximately $10 million per year. Additionally, approximately $1.5 million is generated from secondary employee jobs for a total income generation of $11.5 million. This direct and indirect income due to the Golden Sunlight Mine represented approximately 10 percent of total personal income generated in Jefferson County in 1989.

In addition, the Golden Sunlight Mine further contributes to the state and local economies through local purchases. Company officials estimate that, in 1989, the mine purchased $17.9 million worth of goods and services in Montana.

A large portion of the economic benefit of the Golden Sunlight Mine is felt in the Whitehall area. Approximately 80 percent of the mine employees live within the northern portion of Jefferson County, in Whitehall and Cardwell, in the area around Butte, in Silver Bow County, or in Silver Star and Harrison, in Madison County. Since GSM employees comprise a significant percentage of the local populations, GSM is the major contributor to Whitehall's economy. Further economic benefits are derived in the Bozeman and the Butte areas, where the remaining 20 percent of the employees reside and make local purchases.

b. Government Finances

During the time the mine has been in existence, federal, state and local taxes have been paid. In addition to federal and state income taxes paid on an annual payroll of almost $10 million, GSM pays five separate state taxes. Over the past three years, GSM has paid an average of $730,000 per year in property taxes, including the Gross Proceeds Tax. Of this amount, approximately $168,000 went for county operations and $562,000 to support state and local schools. Over this period, the Cardwell Elementary School District realized approximately $296,000 per year from property taxation on the mine, or approximately $6,600 of property taxes paid per student. As a result of tax revenues paid by the mine, the Cardwell Elementary School District has one of the lowest mill levies in the state.

The Whitehall High School District received approximately $164,000 per year from taxation on the mine and the state of Montana received approximately $87,500 per year. In addition, commercial establishments, which are operating due to the mine, and mine employees both contributed property taxes to local governments including the community of Whitehall.

GSM also the Corporate License Tax. In 1988, the mine paid over $600,000 for the Metalliferous Mines Tax, and approximately $139,000 to the Resource Indemnity Trust Tax. Sixty-seven percent of the Metalliferous Mines Tax goes to the state general fund, while 33 percent goes to a Hard Rock Mining Impact Fund for local governments in the mine area. By the end of 1987, GSM had contributed a total of $600,000 to the Hard Rock Mining Impact Fund.

Keyed to production and property values, these taxes have been paid on approximately 450,000 ounces of gold produced since 1983. The tax classification of the lands disturbed under this amendment would change from agricultural to industrial for assessment purposes, thereby increasing the taxable valuation of the land and, ultimately, taxes paid by Golden Sunlight.

Additional equipment that would be required to carry on the expansion would also add tax revenue to the local government. Off-road ore haulers are assessed at 16 percent of their market value, the highest of any tax classification in Montana. Approximately five new vehicles of that classification would be necessary in the expansion. These new ore haulers and other associated equipment would be classed as personal property and would contribute more to the county tax base than at the present time.

c. Social Life

The Golden Sunlight Mine has provided additional employment opportunities for community residents, especially at the time of initial construction of the mine in 1981, when the Anaconda Copper Company's (ACC) facilities in Butte and Anaconda were closing. Many Whitehall residents commuted to Butte to work at the ACC mine, and additional employment at the Golden Sunlight Mine allowed these individuals to find employment and thus continue to reside in their home town. By remaining in Whitehall, families and their associated traditions and value systems have been maintained.

d. Community Services

Taxation and gross proceeds from the Golden Sunlight Mine assist Whitehall and Jefferson County governments in providing adequate community services to local residents. In addition, in a survey of local officials, the Golden Sunlight Mine was described as a community-minded operation, often times contributing to local schools and organizations.

K. Cultural Resources

1. Prehistoric Activities

Portions of the mine area were surveyed for cultural resources in 1980 (Steere, 1980). In 1985, the investigation was broadened to include all or portions of Section 17, 20, 23, 28, 29, 32, and 33, Township 2 North, Range 3 West, M.P.M. (Herbort, 1985). As a result of this investigation in 1985, seven prehistoric sites and twenty-three minimal activity locales (MALs) were identified in the project area. Site types included open occupation sites, material procurement sites, and stone circle sites. None of these sites are eligible for listing on the National Register of Historic Places, however one site may be potentially eligible.

2. Historic Activities

The Golden Sunlight Mine area has been the site of periodic mining activity since the 1890's when the first claim was staked (Steere, 1980). Ore was processed in a series of mills, including a 40-ton cyanide mill constructed in 1906. For the period from 1890 to 1950, the estimated gross value of mine production (including gold, silver and copper) exceeded $3 million. No historic sites were located within the permit boundary.

L. Aesthetics

The project area is situated within a mining district which has been prospected, explored and developed since the 1890's. Numerous prospect pits, underground workings, mine dumps and roadcuts exist throughout the area. The Golden Sunlight open pit mine has been in operation since 1982.

The setting is dominated by the proximity of the mountains. The natural landscape varies from rugged, sparsely vegetated rocky foothills with some scattered pine and juniper trees to rangegrass-covered foreland areas. Elevations of disturbed areas range from 6,600 feet on the west to 4,400 feet on the east. The highest elevation disturbances are the unoxidized northeast pit wall surfaces. The pit wall is bare and varies from a rusty brown to grey color.

Currently, waste rock dumps and the tailings impoundment I facility stand in contrast against the land forms and colors of the natural landscape. The waste rock dumps are constructed at the angle of repose (1.5h:1v) with flat tops. Slope distances are presently less than 600 feet with heights under 400 feet. The waste rock is off-white to grey to rusty brown in color, and completely uniform in textural appearance.

Waste rock dumps are expanding onto the west slopes where they are visible from Whitehall. Tailing impoundment I and the north waste rock dumps are visible from Interstate 90 and Montana State Highway 69. The south waste rock dump is visible from Interstate 90 and to the south almost all the way to the junction of Montana Highway 41 and Montana Highway 55, 12 miles south of Whitehall.

The proposed expansion to the project would affect an additional 986 acres around the existing operation. Portions of the project would become increasingly visible from State Highway 69 to the east, from Interstate 90 to the south, and from the gravel Whitetail road to the west, as well as from the towns of Whitehall and Cardwell.

M. Energy

Major utility corridors have already been established in the area of this application. No additional energy requirements are needed as part of the company's proposed plan.

There would also be a requirement to relocate a power line in the northeast due to the expansion of the north waste dump. The power line would be moved east approximately one-half mile and relocated on GSM's property with minimal disruption of service and with the assistance of its owner, Montana Power Company.

CHAPTER III - THE COMPANY'S PROPOSED ACTION

A. General Permit History and Explanation of Operations

The original operating permit was issued in June 1975; 300 acres of the 4,113 acres permitted were bonded for reclamation of mining disturbances. The mining plan involved open-pit mining and heap leaching of oxidized surface ores, and, eventually open-pit and underground production and mill processing of unoxidized sulfides from the mineralized breccia pipe. Proposed reclamation included (1) revegetation of haul road berms; (2) placement of alluvial borrow material on and revegetation of pit benches; (3) reduction of slopes on waste rock dumps, heap leach pads and mill tailing to 6.7h:1v, followed by soil replacement and revegetation. Impoundment I was to be built with a 100-year flood spillway. Water treatment of pit water and mill tailing effluent was anticipated and committed to by GSM.

Amendment 001 was issued in April 1981. The revised mining plan incorporated open-pit production, a cyanide vat leach metallurgical extraction process, and construction of tailing impoundment I. The completed project would produce 20 million tons of ore and impounded tailing, and approximately 90.0 million tons of waste rock. An additional 722 acres were estimated to be disturbed, bringing the area bonded for reclamation performance to 1022 acres. Proposed reclamation of the mining disturbances under amendment 001 were revised to reflect changes in the mining plan. Waste rock dumps were to be constructed to contain contour benches, and reclaimed slopes would be reduced to less than 2.5h:1v prior to soil replacement and revegetation. No pit reclamation was proposed. Haul road berms would be rounded and graded into topography; road surfaces would be ripped, water-barred, and revegetated. The mill site, utility corridors and support facilities were to be removed, and the disturbance areas recontoured and revegetated. The tailing impoundment I dike faces would be recontoured and revegetated. The tailing surface was proposed to be soiled "to the extent possible." Mill tailing test plots were to be established to evaluate different revegetation techniques and to determine the feasibility of reclaiming the tailing surface. To prevent tailing effluent from contaminating area groundwater, a bentonite slurry cut-off wall was incorporated into the impoundment I design to provide an impermeable barrier and to prevent tailing effluent solutions from seeping into and mixing with groundwater. A seepage collection pond would be constructed between the slurry cut-off well and the embankment toe to collect tailing effluents for pumpback and evaporation. Monitoring wells were to be placed downgradient of impoundment I and the slurry cut-off wall to detect any tailings effluent by passing the containment system. Long term and detailed analyses of foundation and embankment seepage were proposed to further define reclamation water treatment requirements, and diversion structures upstream of reclaimed impoundment I. The diversion structures were to minimize precipitation recharge of the tailing and subsequent effluent seepage by limiting the drainage area above the impoundment.

An environmental impact statement (EIS) prepared by the DSL prior to issuance of amendment 001 concluded that the potential threat of hazardous substances entering the surface and groundwater systems of the area was an unavoidable adverse impact (DSL, 1981).

Amendment 002 was issued in October 1981 to provide an access road, water, and telephone line corridor. Six additional acres were permitted for disturbance and the total area bonded for reclamation performance was increased to 1,028 acres.

In February 1982, at the request of GSM, the DSL agreed to accept design changes that varied from the proposed and permitted tailing impoundment I design of amendment 001. The impoundment blanket drain system, which was intended to drain tailing effluent and control the phreatic surface, was replaced by a less extensive but functionally similar finger drain system. The operational diversion system above impoundment I was eliminated in favor of maintaining sufficient impoundment capacity to retain a 100-year precipitation event. Upon decommissioning, a permanent diversion system would be constructed if determined necessary for the success of final reclamation.

Amendment 003 was issued in April 1983 to extend the north waste dumps. Seventy additional acres were estimated for disturbance bringing the total project area bonded for reclamation performance to 1,098 acres. No reclamation changes were proposed and the project reclamation was permitted in accordance with the procedures defined in amendment 001.

Amendment 004 was issued in March 1984, for the proposed south waste rock dump. The additional dumping area disturbance was estimated to be 120 acres bringing the total project area bonded for reclamation performance to 1,218 acres. Reclamation of the south dump area was proposed and permitted to include benching, with reclaimed slopes reduced to less than 2h:1v. A test plot was to be established on the south dump to evaluate the proposed waste rock dump reclamation plan.

Amendment 005 was issued in July 1984, to allow construction of pumpback wells and an additional tailing slurry pipeline from the mill to the impoundment. Elevated cyanide levels were identified downgradient in monitoring wells. The elevated levels resulted from failure of the slurry cut-off wall to function as designed because of improper installation. Pumpback wells were required to minimize further contamination of the area groundwater. Under this amendment an additional 23.4 acres were disturbed, and the total area bonded for reclamation was increased to 1,241 acres. Reclamation of the tailing slurry pipeline corridor was to be "in accordance with previous applications", with the addition that gully fill would be removed to restore natural drainages following mine shut down.

The operating permit was again revised in October 1985, for construction of a wing dike extension in the north portion of tailing impoundment I. No changes in the reclamation plan or area bonded for reclamation performance resulted from this revision.

The operating permit was revised in August 1987, to allow for a buffer zone west of the pit and for continued expansion of the north waste rock dumps. An additional 130 acres were to be disturbed, and the total area bonded for reclamation performance was increased to 1,371 acres. No reclamation changes were proposed or permitted with the revision.

The operating permit was revised in May 1988, to provide expansion room for the south waste rock dump. No changes in the reclamation of the project were proposed, and no adjustment of reclamation performance bond was made.

Amendment 006 was issued in December 1988, to allow additional area for expansion of the north, south and west waste rock dump complexes (DSL, 1988). The interim waste rock disposal area was needed to accommodate the 60 million tons of waste rock that remained to be produced from the mining stage III plan that was proposed and permitted with amendment 001 in April 1981. The disturbance area for the interim waste rock disposal expansion was 379 acres, bringing the total area bonded for reclamation performance to 1,750 acres. Reclamation proposals for the waste rock dumps and associated project roads were revised with the amendment. Waste rock dump slopes were to be built at the angle of repose and reduced to 2h:1v for reclamation. Waste rock dump tops were to be ripped and graded, and dump tops and slopes would be soiled and revegetated. Road berms and some fill material would be placed against the cut slope to control drainage, and road surfaces would be ripped and water-barred prior to revegetation.

In addition to the reclamation procedures proposed by GSM, the agencies included two stipulations on the permit.

1. A detailed evaluation of the acid-producing potential of the pit, and waste rock, and the toxicity of the pit water must be conducted in order to evaluate the need for additional reclamation requirements. Sufficient number of samples would be collected to fully characterize the pit, waste rock, and pit water. Within 60 days of approval, GSM would submit a plan for evaluating the acid-generating potential of the pit, and waste rock, and the toxicity of the pit water. GSM would also monitor the existing seep at the toe of the north dump and any new seeps which appear during operations.

B. Present Operating and Reclamation Plan

The present operating and reclamation plan has evolved from the original operating permit no. 00065 and the seven amendments described above. The project is permitted to operate through mining stage III, which would result in the deposition of 20 million tons of mill tailing and 90 million tons of waste rock on 1,750 acres bonded for reclamation. Reclamation would require an unknown number of years.

1. Operating Plan

Under the current plan, overburden removal and ore production are accomplished by conventional open pit mining techniques. Ore and waste material are drilled and blasted, loaded onto haul trucks, and transported to the mill and waste rock dumps. In plan section, the present pit edge encompasses approximately 100 acres. At the completion of stage III mining, the pit is anticipated to have a surface expression of 140 acres, be 600 feet deep at the center, and have a 1,600-foot highwall to the west.

Waste rock is extracted from pit benches and hauled to corresponding dump elevations at waste rock dump complexes to the north, south and west of the pit. At present, approximately 30.0 million tons, or one-third of the eventual waste rock production from stage III mining, is deposited in the dumps. Waste rock dumps are constructed by end-dumping material from haul trucks. Waste rock dump tops and edges are dressed with dozers to create relatively smooth, level surfaces with safety berms at dumping points. Waste rock dump slopes are at the natural angle of repose for the material, about 36 degrees from the horizontal. By 1993, when stage III mining is scheduled to be nearing completion, the waste rock dumps would cover approximately 320 acres, with vertical heights of 400 to 600 feet, and slope lengths commonly 1,000 feet long. The waste rock dumps would ring the southern tip of the Bull Mountains, and bury drainages and natural landforms below the 6,400-foot elevation on the west, the 6,000-foot elevation on the south and the 5,600-foot elevation on the east.

Ore is trucked from the pit to the mill where it is crushed to 64 percent minus 100 mesh and is vat leached with sodium cyanide solution to extract gold. Approximately 5,000 - 6,700 tons of ore per day are processed to produce about 0.05 troy ounces of gold per ton. The resulting tailing is slurried to impoundment I at about 50 percent solids by weight.

Solution required for operation of the mill is recirculated from the tailing impoundment I pond. Water that is lost to evaporation or held within the impoundment tailing is replaced by pumping makeup water from the Jefferson Slough at a rate of 446 gpm.

Tailing impoundment I is situated in a small drainage; the impoundment embankment is horseshoe shaped, with the largest section of the embankment in the drainage bottom and smaller wing dikes connecting to ridges to the east and west of the drainage. Ultimately, tailing in impoundment I would cover 198 acres to a depth of up to 135 feet. The embankment is constructed by the centerline method and would eventually be 150 feet high. Slurried mill tailing is cycloned on the embankment crest. Cyclone underflow, or sand-sized particles, are discharged directly on the dam crest, continually raising the embankment above the starter dam, and extending the downstream toe. Cyclone overflow consists of the finer fraction of mill tailing, and these slimes are spigoted into impoundment I. Depositional characteristics of the slimes result in a particle size distribution from coarse to fine from the embankment crest to the upstream end of impoundment I. A gradient is also created that causes slurry solution to pond at the back (upstream end) of the impoundment. The ponded slurry solution is pumped from a floating barge to the mill for recirculation.

Impoundment I facility was designed to be a closed circuit system with zero ground water or surface water discharge. Impoundment I has an underdrain system which allows water to seep beneath the dam where it is collected in a lined pond and pumped back to the impoundment. The underdrain was originally designed to be a layered gravel blanket drain placed beneath the dam and extending under the cycloned sands. Two finger drains extend around the perimeter to insure that no water seeps laterally through the perimeter ridges. The blanket drain was replaced in the final design with a series of finger drains beneath the dam (J. Smolik, written communication February 3, 1982). These drains are constructed of coarse gravel 2 feet thick and 8 feet wide (SHB, 1982). Approximately 40 gpm discharges from the drain system while another 300 gpm reaches the pumpback wells above the slurry cutoff wall through the alluvium (SHB, 1988). Currently, about 400 gpm are pumped back into impoundment I. This water is probably both natural ground water and process water which has seeped through the floor of impoundment I and into the alluvium. The finger drains are encased in a Typar filter fabric to ensure free drainage during operation. This fabric is expected to deteriorate sometime after abandonment and the drains would function at a reduced capacity (SHB, 1981).

A 540-foot long, 2.5- to 4-foot wide bentonite slurry cutoff wall was located across the drainage below the lined drain water reclaim pond. This wall, extending to bedrock or impervious clay formations at a maximum depth of 58.8 feet, was constructed to ensure that no leachate escaped from the impoundment I area.

2. Monitoring Plan

Five groundwater monitoring wells were originally proposed and constructed. These wells were to be monitored quarterly to ensure that impoundment I was functioning properly (SHB, 1982). Presently there are 22 monitoring wells peripheral to the impoundment and 14 pumpback wells. The seven wells located above the slurry cutoff wall pump an estimated 300 gpm from a channel aquifer at a depth of between 50 and 70 feet. The pumpback wells below the cutoff wall pump a minimal amount of water (approximately 15 gpm) from the same aquifer to ensure that no groundwater contamination leaves the permit boundary (J. Arrigo, WQB and D. Sharf, GSM, personal communication, 1989).

A permanent collection and evaporation pond was proposed at the base of impoundment I to collect drainage from the underdrain system. Additionally, GSM would complete a more definitive estimate of post-operational seepage from the underdrain. This study would be completed upon final design of the impoundment (SHB, 1981).

3. Reclamation Plan

a. Tailing Impoundment I

The present tailing impoundment I would be filled to capacity by 1992, at which time surface reclamation could begin. The current reclamation plan states the reclamation objectives are to "... prevent contamination of water and soil through erosion of tailing by wind and water, and to accelerate the re-establishment of a self-sustaining ecosystem" (DSL, 1981). To meet these objectives, the impoundment is designed to hold the 100-year precipitation event. Impoundment I dike faces would be contoured slightly and left at 2.5h:1v and revegetated, the tailing would be covered with 3 to 6 inches of soil to the extent possible. If needed, permanent diversions would be built around the impoundment. Additional diversions, as needed, could be built during final reclamation to further reduce surface flow onto impoundment I and to reduce recharge of the tailing. A spring above impoundment I would also be diverted. These diversions, if installed, would reduce the watershed draining into tailing impoundment I from 1,043 acres to 138 acres. According to the company, this would eliminate the possibility of water discharge from under impoundment I even during a 100-year storm event. Diversions would be riprapped to minimize erosion. The surface would be graded and gently sloped to eliminate any ponding on the surface (DSL, 1981; SHB, 1981; SHB, 1982). Diversions would not be necessary if reclamation of the tailing and nondegradation of water could be achieved without them.

The specific seed mixtures and revegetation techniques were not defined in the reclamation plan for amendment 001. Instead it was proposed that test plots be established within two years to evaluate a number of reclamation procedures. These procedures were to include different seed mixtures, fertilizer applications, mulching procedures, and soil application methods. The results of this program would be evaluated on an annual basis to produce the most acceptable method of reclaiming tailing impoundment I (GSM, 1980).

Twelve 30-foot by 80-foot subplots were constructed of whole mill tailing in the spring of 1984. All the plots were treated with 600 pounds per acre of fertilizer and a sulfur amendment rototilled into the top 6 inches of tailing. Four reclamation strategies were attempted: 1) four inches of soil; 2) bare tailing with the addition of five tons per acre of calcium hydroxide (Ca(OH)) plus 350 cubic yards per acre of woodchips; 3) bare tailing with five tons of calcium hydroxide plus 15 tons of hay per acre; and 4) bare tailing alone. Evaluations began in 1985 and were completed in 1989 (Western Reclamation, Inc. and GSM, Inc. 1989). Results are summarized in Chapter III, Section Db Revegetation trials.

b. Waste Rock Dumps

All waste rock dumps would be constructed with slopes at the angle of repose (1.5h:1v). At completion, waste rock dump slopes would be reduced to 2h:1v. Runoff would be diverted off the top of the waste rock dumps until final reclamation is complete. Compacted areas on waste rock dump tops would be ripped prior to soil placement. Soil would be placed on waste rock dump slopes. Before seeding or planting trees, a minimum of six inches of soil material would be redistributed depending on the soil volumes salvaged. It was estimated that enough soil was salvaged to cover approximately 75 percent of the 2h:1v slopes on the waste rock dumps.

Preference for soil replacement and revegetation efforts would be given to those waste rock dump slopes which would be most visible from Montana State Highway 69, Interstate 90, and the community of Whitehall.

Replacement of available soil on the waste rock dump slopes would require construction of access roads. Access road widths would be 14 feet without berms, or 20 feet with berms. Grades are anticipated to be 8 to 15 percent. Soil material would be hauled and dumped near the road crest edges, then dozers would spread the material downslope. Soil redistribution would begin on the lower slopes and progress upward. Access roads on the dump faces would be left intact and utilized for broadcast seeding of the prepared seedbed. Small low areas, suitable for tree planting, would have greater depths of soil material placed on them. Most waste rock dump slopes would be seeded by broadcast seeding. Waste rock dump tops and slopes less than 3h:1v, which are free of rocks, would be drill seeded. Wood fiber mulch, crimped straw, and fertilizer would be applied to reduce erosion and promote plant growth. The proposed seed mixture contains both grasses and forbs which are predominantly of native species.

Weathered and oxidized non-acid producing waste rock segregated from unoxidized waste rock would be used to supplement soil replacement, either as subsoil or alone. This mixture may be used to resoil the tops of dumps. First priority for placement of soil or oxidized waste rock would be those areas which would be unable to support vegetation without it. Placement depth would reflect field conditions necessary to support vegetation. Waste rock dump tops would be planted with douglas fir, rocky mountain juniper, and big sagebrush at various densities of seedlings per acre depending on species. Waste rock dump slopes would be planted with douglas fir and rocky mountain juniper, as well as other shrubs such as antelope bitterbrush and rubber rabbitbrush.

c. Pit Reclamation

Pit benches would be covered with alluvial borrow materials and revegetated. If necessary, perimeter berm and possibly a fence would be constructed around the edge of the pit. (DSL, 1981).

d. Miscellaneous Facilities

Cut slopes for roads within the mine complex would be less than 1.5h:1v in unconsolidated materials and close to vertical in bedrock. Fill slopes would be constructed at the angle of repose. Berms and some of the downslope material would be shaped back towards the cut faces with backhoes and dozers. Outside crests would be rounded and shaped. Flat sections would be ripped and waterbarred. Mulch would be applied and approved seed mixtures with both grassland/forb mixtures and tree/shrub species would be planted (DSL, 1988). The mill complex and utility corridor would be recontoured and seeded. The facilities would be dismantled upon completion of mining (DSL, 1981).

C. Proposed Plan of Operations and Reclamation Plan

This section describes GSM's current proposal for continued mining and expansion as it existed prior to the June 1989 draft EA.

1. Operating Plan

GSM submitted an application to amend their operating permit and expand the operation on March 11, 1988. Under the proposed plan, GSM would expand mine production from stage III to stage V, and extend the life of the mine to approximately the year 2005. Mining through stage V would produce a cumulative total of 300 million tons of waste and 50 million tons of ore.

Pit production, waste rock disposal and ore processing methods, using existing facilities would not change. Stage V development of the pit would create a surface expression of about 209 acres. The proposed pit would remove the ridge top and east flank of the mountain, and would result in a 2,000-foot highwall on the west. The east rim of the pit would be at elevation 5,350 feet. The pit bottom would be at elevation 4,800 feet, which is 1,200 feet below the existing hillside, and 225 feet below the existing groundwater table elevation.

Existing waste rock dump complexes would be expanded to contain 300 million tons, and cover approximately 772 acres. Compared to the present waste rock dump volume and area (approximately 30.0 million tons covering 125 acres) the stage V dumps would be 10 times the volume and would disturb about six times the disturbed surface area.

The proposal to expand the project through stage V mining would not alter the milling and metallurgical extraction processes; but would require another tailing impoundment to contain the additional milling wastes. The project is currently permitted through stage III, which would result in approximately 20 million tons of tailing in impoundment I; expansion through stage V would require an additional 30 million tons of tailing in impoundment II.

The proposed tailing impoundment II would be located immediately to the east of the existing permitted impoundment I. Impoundment II would ultimately cover 250 acres and have tailing to a depth of up to 150 feet. Impoundment I is estimated to reach maximum capacity in January 1993, requiring completion of first phase construction on impoundment II by October 1992.

Impoundment II embankment alignment was selected to abut the eastern wing dike of the existing facility, and minimize the drainage area above the proposed impoundment II. Diversions to route upstream runoff around the impoundment are not proposed, although these diversions were recommended to connect with the reclamation diversion channels that were to be placed around the existing impoundment I (SHB, 1988).

As with existing impoundment I, centerline construction of the embankment is proposed. Initial construction would include a toe dike, starter dam and wing dikes constructed with homogenous predominately granular fill, taken from borrow areas within the permit boundary or from the floor of impoundment II. Cycloned sands would continually raise the embankment crest and extend the downstream toe from the starter dam. Wing dike extensions would be constructed in stages using alluvial borrow materials. The proposed impoundment II design requires that a minimum freeboard of 10-12 feet be maintained to allow for containment of a 6-hour PMF precipitation runoff and room for placement of a reclamation cover.

A 60-mil HDPE synthetic liner placed over a prepared surface is being proposed for impoundment II. The synthetic liner would cover the impoundment II basin, and extend beneath the embankment starter dam, toe dike, and effluent reclaim ponds. A 5-foot layer of cycloned sands is proposed, both to cover the synthetic liner beneath the starter dam, the final dam and the toe dike for protection of the liner during construction, and to provide a blanket drain beneath the main embankment. Gravel finger drains encased in geotextile would be constructed throughout the impoundment II basin, and would connect to and pass through the cycloned sand blanket drain, the embankment and toe dike surfacing in two tailing effluent reclaim ponds. The drain system and reclaim ponds are designed for a 400 gpm capacity. These ponds would be double-lined and incorporate a leak detection system.

The proposed groundwater monitoring system would be designed to detect changes in groundwater levels or chemistry that would indicate seepage from impoundment II. The array of pumpback wells to the east of impoundment I have been replaced by wells through the impoundment I east wing dike in order to replace wells that would be buried under impoundment II. The monitoring program would use five existing wells and four new wells.

The new wells include one upgradient and three downgradient of the proposed impoundment II. The proposed groundwater monitoring program includes water table elevation measurements and water quality analyses.

2. Reclamation Plan

a. Waste Rock Dumps

No change in waste rock dump reclamation has been proposed under this amendment. The waste rock dumps would continue to be constructed and reclaimed as previously described for amendment 006, (DSL,1988) and summarized in Section B.3.b. of this chapter.

b. Tailing Impoundment II

Under this amendment, no changes to the impoundment I reclamation plan are proposed. The reclamation objectives for the proposed tailing impoundment II are similar to the original facility "... to establish a self-sustaining ecosystem which would minimize contamination of water and erosion of tailing and soils." These objectives would be met by temporary stabilization techniques, concurrent reclamation during mining, final reclamation, and monitoring with possible remedial action.

i. Temporary Stabilization

Prior to construction, soil would be stripped from all disturbances including dike construction borrow locations using scrapers or dozers and trucks. Removal depths would vary according to soil inventory reports, however, enough soil would be available to place a minimum of 6 to 12 inches over the final tailing impoundment II. Soil stockpiles and dike construction borrow areas which would remain for longer than two years would be contoured and drill seeded at a rate of 16.5 pounds per acre or broadcast seeded at a rate of 33 pounds per acre with an approved seed mix specified in the amendment application. Areas and stockpiles which are short-lived, less than 2 years, would be seeded with a cover crop such as barley.

ii. Concurrent Reclamation

The embankment top and outer surface of the dam would be reclaimed after it reached its ultimate height. One-half to one foot of soil would be placed over these areas. The flanks at 2.5h:1v would not be reduced prior to soil placement and broadcast seeding. A tackifier and wood fiber mulch, at 2,000 pounds per acre, would be hydromulched over the seeded area to reduce erosion and promote seedling establishment. The embankment top would be drill seeded. The specific seed mix and soil amendment techniques would be determined after future test plot evaluations.

Borrow areas would be soiled, if necessary, and seeded. Slopes less than 3h:1v would be drill seeded while steeper slopes would be broadcast seeded and mulched. All areas would be fertilized after the first growing season or before the spring rains.

During operation, wind erosion would be mitigated by compacting the surface of the downstream earthen fill and by applying suppressant chemicals on the sand surfaces of impoundment II. Most of the fines in the main body of impoundment II would remain wet and, therefore, not susceptible to wind erosion.

iii. Final Closure

Upon final closure of the impoundment II facility, the reclamation procedures would include: (1) flattening the tailing surface and sloping the top away from the embankment, (2) dewatering the tailing rapidly, (3) rock cap the surface of the tailing, (4) soiling and revegetating the tailing, and (5) reclaiming the underdrain ponds.

Flattening the tailing surface would fill the low areas at the upstream end of impoundment II, bringing the final grade to less than 0.6 percent. Coarser sand material, which is a better working medium, would be placed over the finer slime fraction of the tailing and the top of the dam and wing dikes would be rounded off. Impoundment II would still have enough freeboard to contain the 6-hour PMF storm event.

Surface water, several inches deep, would be dewatered as quickly as possible. This water would be dissipated by evaporation and/or by decanting to a sprinkling system on the tailing surface. The water remaining in the tailing would drain through the finger drain system to the lined reclaim ponds below the facility where it would than be pumped to the sprinkler system to hasten evaporation. The sandier portions of impoundment II, nearer the downstream end and closest to the dam, are expected to be dried within the first year or two of closure. Reclamation efforts would start there.

A 2-foot minimum thickness of random mine rock cover (waste rock cap) would be placed over the surface of the tailing to function as a textural break to prevent the upward migration of moisture containing acid, metals, and salts into the waste rock cap and soils. If revegetation fails, the waste rock cap would eliminate potential wind erosion of tailing. This procedure, starting from the drier areas and working inward, is expected to begin within the first year of reclamation and to take up to five years to complete. Care would be taken so that the rock would not be shoved downward into the wet tailing which would destroy the effectiveness of the rock cap.

Riprap of very coarse neutral mine rock would be placed at the mouth of the intermittent drainages above the tailing to prevent headward erosion. These drainages are expected to discharge water into impoundment II only during 100-year storm events. The area drained by these gullies is less than one-half the area of impoundment II itself.

One-half to one foot of soil or alluvial borrow would be placed over the waste rock cap utilizing scrapers or end-dump trucks and graders. Berms would be created periodically to segment or terrace the surface to prevent precipitation from collecting in isolated low spots. This procedure is expected to enhance plant uptake of water and inhibit recharge of the tailing by ponding the water more evenly over the surface of impoundment II.

A final seed mixture has not yet been determined. However, the mix must be a perennial, self-sustaining mixture. Information developed from the test plots and from reclamation experience gained from impoundment I would be used to finalize the reclamation effort.

GSM anticipates that very little water would discharge from the underdrain system after the first couple of years. This water would be monitored and pumped from the reclaim ponds to the sprinkler system on the impoundment II surface. If acceptable water quality standards are reached, a MPDES discharge permit would be obtained and the water allowed to overflow the ponds. If the quality doesn't improve, the water would be treated and remedial action taken. If the flow decreases or stops, the liner would be removed and, if necessary, one foot of soil would be placed over the side slopes and bottom. The pond area would then be broadcast seeded and mulched.

iv. Monitoring and Remedial Action

Surface and groundwater monitoring efforts would not be reduced at the time of closure of impoundment II. Presently, it is proposed that 11 groundwater monitoring wells would be monitored monthly for water level, pH, specific conductance, temperature, alkalinity, total dissolved solids, cyanide concentration, and nitrate/nitrite levels. Quarterly measurements would include: potassium, sodium, calcium, magnesium, chloride, fluoride, sulfate, ammonium, bicarbonate, and carbonate. Yearly measurements would include all of the above plus, common heavy metals as well as sulfide and thiocyanate. This level of monitoring is proposed to continue for one year after final shut down. If no problems occur, the level of monitoring would be reduced after year one by 66 percent, after year three by 84 percent, and would eventually be discontinued or monitored once a year after year six. If problems are noted, monitoring frequency and intensity would be modified.

Monitoring during final reclamation would involve qualitative visual evaluation of plant communities as well as quantitative counts of species and productivity.

All water discharge must meet state and federal regulations. If degradation occurs, water would be collected and treated or evaporated on site. Treatments may include the addition of hydrogen peroxide or hypochlorite and reverse osmosis techniques with pH modification and sludge removal prior to irrigation, evaporation or discharge.

When reclamation and monitoring efforts are deemed complete, the pumpback wells and monitoring wells would be abandoned in such a manner as to prevent crossflow between any multiple aquifers. This would include the removal of all surface facilities and underground pumps, pipes, and filter packs. The holes would then be filled with an expanding sealant from bottom to top.

Remedial action would focus on excessive wind blown dust, poor revegetation success and water contamination. These actions may involve additional surface preparation for areas that have not revegetated, including: mulching, soil stabilization, rock surfacing, additional plantings, and irrigation.

c. Pit Reclamation

The pit would eventually deepen to the 4,800-foot elevation, leaving a 2,000-foot benched highwall on the western edge. The northern and southern sides would slope to a 575-foot benched highwall on the eastern edge of the pit. The pit would be roughly circular in shape, approximately 2,000 feet in diameter, covering 209 acres.

Water would be encountered at the 5,025-foot elevation. This water would be pumped to the mill as makeup water during active mining. Upon abandonment, water would be allowed to collect in the pit bottom, creating a "lake" approximately 52 acres in size and 225 feet deep. The east high wall would be 325 feet above the water level. There are no adits below the lake surface that could experience increased discharge. The lake water is expected to be of poor quality similar to that presently discharging from the Ohio adit, which has pH levels close to 2.4 with elevated metal contents particularly for cadmium, iron, copper, zinc, and nickel, which exceeds drinking water standards (Table 7). No surface discharge of water was expected in the original application. If it did discharge it would be treated. No treatment scenario was presented by the company. The only pit reclamation proposed is that the pit perimeter would be bermed and possibly fenced for safety (DSL, 1981).

d. Miscellaneous Facilities

Under the proposed amendment, the only new facilities would be more pipelines, utility corridors, and haul roads. Approximately 5,000 feet of additional twelve-inch pipe would be laid in a fifteen-foot wide prepared bed to slurry tailing to the proposed impoundment II. This disturbed area, as well as other utility corridors including freshwater and electrical power, would be reclaimed by removal of surface facilities and regrading, contouring, and revegetation.

All haul roads would be reshaped. Operational safety berms on haul roads and some downslope roadfill material would be brought back towards the haul road cut slopes. Haul road fill slopes would then be rounded and revegetated. Revegetation of roads would include both grassland/forb and trees/shrub mixtures.

D. Consequences of the Company's Proposed Plan

1. Geology

a. Waste Rock Dump Stability

Waste rock dump expansion through mining stage V would continue with deposition in existing dump complexes, and development of additional dumping elevations on the west side of the mountain. Geologic information indicates that all foundations, with the exception of the Midas Slump, are competent. Most of the waste rock dumps in the north complex are stable, but foundation failure and creep has occurred where alluvium has been covered and mixed with a substantial Quaternary landslide deposit known locally as the Midas Slump

(DSL, 1988). A small seep issues from this area and is believed to originate within the landslide material and not from waste rock dump seepage.

Foundation failure in the north waste rock dump complex develops from overloading soft clays within the Midas Slump, resulting in deep circular shearing, tension cracks in the dump top and face, and upheaval of slump material ahead of the waste rock dump toe. Deformation is through slow creep that responds to waste rock loading rates, and is primarily an operational concern. GSM has implemented monitoring and mitigation programs that include soil salvage in advance of deformation below the dump toe, regular surveys to determine creep rates and response to waste rock dumping sequence, and geologic mapping to establish the extent of the Midas Slump landslide material. In addition, proposed expansion of the north waste rock dump complex is to incorporate a dumping scheme that would surround the Midas Slump material and form abutments along the flanks and toe prior to deposition of additional waste rock on the landslide.

Stability of the Midas Slump area should be further enhanced by reduction of waste rock dump slopes to 2h:1v during reclamation. The effects on reclamation may be inconsequential if operational containment of the Midas Slump is successful. In the event that the project does not go to scheduled completion, stabilization of the waste rock dump surface may require considerable time and reclamation effort. The most serious environmental consequences would occur if the extent of the Midas Slump material or the degree of creep is misinterpreted, causing potential flow into and plugging of the Sheep Rock drainage immediately to the north and east of the proposed north waste rock dump limits. Subsequent erosion and sedimentation of acid producing materials would result where runoff water cut through the slump toe in the drainage.

b. Tailing Impoundment II Stability

The centerline method of raised embankment construction is being used on impoundment I, and would be employed on the proposed impoundment II. Centerline construction is well suited for reactive tailing material, for which controlled drainage of tailing effluent is necessary. Control of saturation levels and compaction of embankment lifts in centerline dams provide stable static conditions and generally good seismic resistance. Centerline embankments cannot be used to permanently store water or totally saturated material, but can handle temporary flooding or fluctuations in phreatic surfaces. Although impounded tailing slimes are at or very near saturation during the depositional life of the project, internal drains and pervious materials in the main embankment control phreatic levels and maintain stability during operations. During operations, this drainage can cause problems with seepage as it did at GSM from impoundment I. Eventual drain failure can lead to post-operational problems with stability if drain failure is not considered in the reclamation plan.

GSM proposes that both the existing and proposed impoundments I and II permanently capture direct precipitation and upstream runoff for reclamation. Because of the small size of tailing particles and the effects of surface tension, tailing slimes would retain enough interstitial fluid to be near saturation. Periodic recharge during storm runon is expected to create fluctuating levels of saturation within the tailing deposit, and subsequent discharge through the drain systems.

Reclamation diversion systems to minimize flow into the impoundment basins, and to prevent runon and tailing recharge, were originally recommended by the design consultants for both impoundments (SHB, 1980; SHB,1987). They were discarded in 1982 (letter from DSL to GSM, February 1982). In addition, the impoundment drain systems were neither designed nor built to function permanently (SHB, 1981). In the existing impoundment I, a recommended blanket drain system was replaced by less extensive finger drains in February 1982 (DSL letter to GSM, February 1982). Present drain discharge of 40 gpm is much less than what is estimated to be seeping through the clay liner, indicating that drain function may already be diminished. As drain function decreases or ceases, it is assumed that a driving head would increase uncontrolled flow through the foundation. In the proposed impoundment II, installation of a synthetic liner would likely increase dependence on drain function for post-operational stability until the liner ceased to function.

Stability analyses for both impoundments assume that the phreatic surface is minimized in the embankment. In the existing impoundment I, an adequate design factor of safety is sensitive to elevation of the phreatic surface; however, operational monitoring of piezometer wells in the embankment toe indicate that phreatic levels are being controlled by foundation seepage. Even with complete drain failure, it is felt that sufficient uncontrolled seepage through the foundation would preclude embankment saturation and mass instability. Phreatic surfaces and pore pressures within impoundment I are controlled by the finger drains and seepage through the clay liner. A natural alluvial channel 50 feet beneath impoundment I, in the Climbing Arrow Formation, and pumpback wells to the south and east of impoundment I prevent foundation saturation. The minimum static factor of safety has been analyzed at 1.58. The minimum pseudostatic factor of safety, assuming a design peak particle acceleration of twenty percent of gravity, has been analyzed at 0.91. This means that the impoundment would be stable in case of an earthquake using the intensity earthquake selected for the analyses.

The proposed impoundment II is to incorporate a blanket drain of cycloned sands beneath the main embankment to facilitate finger drain function. In addition, the drainage area above impoundment II is considerably less than that above the existing impoundment I. Reduced runon potential and pervious material in the embankment is expected to result in moderate and temporary fluctuations in phreatic surfaces.

Mass instability is not anticipated to be a significant consequence of the proposal for reclaiming the tailing impoundments. Should revegetation and natural encapsulation of the tailing surface fail, as predicted, periodic recharge and decreased drain function would likely result in uncontrolled seepage, piping and erosion in the embankments' toes and wing dikes. If revegetation of the cycloned sands in the center portion of the impoundment II embankment were to fail, it could result in massive erosion of the 2.5h:1v slopes and lead to eventual stability problems. Probability of erosion and revegetation failure are discussed under the soils and vegetation sections, D.2. & D.4.e. of this chapter.

c. Pit Stability

Though considerable deformation has occurred, the conventional benched configuration of the pit and silicified wall rock result in operational stability. Pit expansion through stage V would produce an expansive and oversteepened benched scarp in the mountain. The 2,000-foot highwall on the west would probably experience some minor sloughing and structural wedge failure over time. However, rock falls from the pit wall should be contained in the depression of the pit bottom, relieve wall rock stress concentrations, and eventually result in a flatter, more stable configuration. As the pit enlarges, monitoring may result in altered pit configurations to alleviate potential failures, especially on the west wall of the pit. The company has modified the west pit wall as part of the stage III laydown because of stability problems. This is controlled by monitoring to meet Mining Safety and Health Administration (MSHA) standards.

d. Waste Rock Characterization

Analysis of a single "highwall composite" sample documented the potential for waste rock to be acid producing (B.C. Research, 1988). The exact sample and locations used to fashion the "highwall composite" is unknown. Consequently, the sample result may not be representative of the waste rock GSM proposes to place on the existing dumps. The test conducted to determine acid-producing potential was performed on finely ground material, -400 mesh. It was thought that this does not portray the actual waste rock dump material, which is much coarser; however, rapid weathering of waste rock may indeed make this a realistic model.

i. Acid Potential Studies

As a result of active oxidation observed on the waste rock dumps (DSL Memo, March 1989), 22 samples of both ore and waste rock from the Golden Sunlight Mine were analyzed to determine potential acid-producing characteristics (i.e., the production of acid from sulfide minerals) (DSL, 1988). Studies found unoxidized waste rock contained 1-5 percent sulfide, whereas oxidized waste rock contained 0.1 to 0.3 percent sulfide (Dollhopf, 1989). All rock types to be mined were included in the analyses. Analyses of each rock type included active and potential acidity, neutralization, weathering, mineral size and morphology, and toxic metals concentration (EP Toxicity). EP toxicity is used to determine the presence of suspect toxic levels of metals such as arsenic, barium, cadmium, chromium, lead, mercury, selenium and silver. The potential consequences of sulfuric acid production include acidification of water resources and heavy metals contamination, and possible prevention of successful plant growth during reclamation.

Active venting of water vapor, heat and sulfur dioxide and unknown sulfur compounds caused by the oxidation of pyrite in the waste rock dumps was observed during the waste rock dump reduction test in March 1989, (DSL Memo, March 1989). Concerns developed over the possible effects of this phenomenon on reclamation. The oxidation of pyrite and subsequent development of acid mine drainage is common in ore bodies which contain pyrite. One of the factors that governs the speed at which this reaction progresses is the size range of the pyrite present in the ore body. This factor is probably at least as important as the actual percentage of pyrite present.

Some of the most detailed work on acid mine drainage and oxidation of pyrite has been done in Australia at the Rum Jungle Project in the Northern Territory (Ritchie, 1985).

The Rum Jungle Mine was a copper/uranium mine mined between the years of 1954 and 1971. At Rum Jungle, mining had been completed in 1971 and no reclamation had been performed. This led to long-term environmental degradation of ground and surface waters in the area. A survey conducted in 1973-74 showed the major source of the pollution to be the waste rock piles and an old heap leach pile.

The Rum Jungle site was reclaimed between 1983-1986 by the Northern Territory Department of Mines and Energy at a cost of $(Aust.) 18.6 million. At Rum Jungle, research had disclosed temperatures over 50° C in the waste rock dump caused by the release of heat where oxidation of pyrite was taking place. Research indicated that an important aspect of reclamation on the waste dumps would be to reduce both the amount of oxygen and water available to drive the reaction.

The oxidation reaction gives off heat. This exothermic reaction causes heat and water vapor to rise which creates a "chimney" effect pulling oxygen into the dump. The most porous portion of the waste rock dumps is the lower dump slopes. This is because of the natural sorting that occurs from end dumping off the top of the dump surface, therefore, an important aspect of reclaiming the dump complex was reclamation of dump slopes, as the slopes were an important avenue for the intake of oxygen into the dumps.

The reclamation strategy involved a three-layer cover up to 0.75 meter thick, engineered runoff channels and erosion control features. The waste rock dump tops were covered with an impermeable layer (compacted clay cap). Then a textural break was placed before the top layer of soil was applied. On the reduced 3h:1v waste rock dump slopes, the compacted clay layer was applied followed by the textural break as on the waste rock dump tops. On the slopes, soil was not applied; however a rock cap layer was applied to reduce the erosion potential.

There are important environmental differences between Golden Sunlight and the Rum Jungle mines, Rum Jungle being in a tropical climate while Golden Sunlight is in a semi-arid environment. However, both projects involve ores which contain 1-4 percent sulfide sulfur and similar reclamation concerns. Therefore, it will be important to eliminate or limit oxygen and water by using effective cover layers over the reactive waste rock to prevent the continued oxidation of pyrite, heat production and subsequent vegetative failure.

(a) Acidity

The mean pH value for waste rock was 4.2. The amount of active acidity in 1989 for oxidized as well as unoxidized arkose and mudrock was very small (Dollhopf, 1989). However, potential acidity is as, or more, important than actual acidity.

In order to determine potential acidity, sulfur fractionation procedures were used to separate total sulfur into non-acid forming sulfates, hydrogen-chloride (HCl)-soluble acid-forming sulfates, nitric acid-soluble sulfides, and residual sulfides not digested by nitric acid. Of these four categories, nitric acid-soluble sulfides have the greatest potential for acid production. The six samples of oxidized arkose and mudrock had either no potential acidity or a very small amount of potential acidity. Unoxidized arkose samples located near or away from the breccia ore body were classified as potential acid producers. Similarly, unoxidized mudrock samples located near to and away from the breccia zone were classified as potential acid producers. The breccia ore which would be impounded as tailing was also classified as a potential acid producer. As the mine expands the quantity of potential acid producers would increase.

(b) Neutralization

The Shoemaker, McLean, Pratt (SMP) lime requirement test was used to quantify the amount of calcium carbonate ($CaCO_3$) needed to neutralize active and potential acidity in the various waste rock and ore samples analyzed. The laboratory results reported values of acid-producing potential in tons of calcium carbonate needed to neutralize acid production per 1,000 tons of ore or waste rock. The range of values of acid production potential are as shown in Table 13.

Table 13. Neutralization Potentials For Rock Types at GSM (Dollhopf, 1989).

Rock Type	Minimum	Maximum
Unoxidized arkose (away from breccia)	-3.9	-71.6
Unoxidized arkose (near the breccia)	-59.9	-132.0
Waste rock	-15.2	-168.0
Unoxidized mudrock (away from breccia)	-14.2	-78.0
Unoxidized mudrock (near the breccia)	-21.4	-136.2
Oxidized mudrock	-14.3	+10.2
Oxidized arkose	-1.3	-6.5
Breccia ore	-100.2	

Negative values indicate the need for lime amendments to neutralize acid-production potential. For example, 3.0 to 71.6 tons of $CaCO_3$ would be needed to neutralize unoxidized arkose that is located away from the breccia ore. Again, these figures represent the complete acid production potential, which in the case of GSM may not be reached under natural weathering (Dollhopf, personal communication, 1990).

All of the rock types discussed above would be placed in the waste rock dump except for the breccia ore which would be impounded. It is obvious that certain portions of the waste rock dump surface would be acid-producing. It is also obvious that the oxidized waste rock types may be used as a neutral waste rock cap if GSM can separate rock type visually.

A waste rock dump revegetation test was established as part of Amendment 004 in 1984 (GSM, 1984). The test was established on the south dump in 1985 and evaluated in 1986. The test failed. No further explanation was given by GSM (GSM Annual Report, 1987).

(c) Weathering

Laboratory weathering is used to understand whether sulfides would produce acid in the natural environment. All samples of waste rock produced acid during laboratory weathering. One fresh waste rock sample produced more acid during laboratory weathering than any other sample. However, another sample of fresh waste rock showed 30 times less acid produced during weathering than the first sample. Both unoxidized and oxidized arkose (future waste rock) produced little or no acid during laboratory weathering. All samples of unoxidized mudrock near the breccia ore body produced acid upon laboratory weathering. Only one of three samples of unoxidized mudrock away from the breccia produced acid during weathering. All samples of oxidized mudrock produced acid upon laboratory weathering.

(d) Mineral Size and Morphology Examination

Mineral size and morphology of waste rocks were examined with the scanning electron microscope (SEM) and energy dispersive analysis of x-rays (EDAX). Mineral size and morphology of waste rock pertains to acid-producing characteristics in the following ways. It is believed that the larger the total exposed surface area of the pyrite (sulfide), the more acid would be produced in a given time. Most studies suggest that particles less than 0.5 micrometers have rapid and complete acid production,whereas, particles greater than o.5 micrometers have slower rates of production. Particles over 100 micrometers in diameter can be classified as inert. Although many references disagree about the size limits, most agree that for rapid and complete acid production, particle sizes of less than 0.5 micrometers are required. The work done on the Golden Sunlight mine samples showed no particle sizes less than 0.5 micrometers. The pyrite at Golden Sunlight is reported to occur as euhedral to subhedral grains ranging from 500 to 2,000 micrometers in size (Porter and Ripley, 1985).

The data suggest that the majority of pyrite particles at GSM are large and may not be acid producing in the natural environment, although they produced acid during sulfur defractionation test work. In addition, active pyrite oxidation has been observed at the mine (DSL Dump Test Memo, March 1989). Rapidly weathering of waste rock caused by the exothermic oxidation of pyrite observed at GSM is suspected by the agencies. If this is so, then the total amount of pyrite exposed for reaction would increase as weathering continued to expose fresh surfaces. Conversely, this indicates that at some point the reaction may shut itself off as weathering at the surface limits oxygen and water available to drive the reaction.

ii. Toxic metal Concentrations

Toxic metal concentration analyses of waste rock types at GSM (unoxidized arkose and murdrock) showed below-suspect levels of toxicity for both rock types in a neutral (pH=7) sampling spectrum. However, acidity increases availability of heavy metals. That is why, acid mine drainage has been observed in the Ohio adit with elevated levels of cadmium, iron, zinc, nickel, and copper (Table 7). Therefore, the results of EP toxicity analyses at GSM cannot be used to evaluate potential metal problems.

e. Tailing Characterization

i. Acid Production Potential

A single composite leached pulp sample was determined to be a potential acid producer (B.C. Research, 1988). This has partially been confirmed by overburden analyses of tailing which reveals three samples having net acid producing potential of -59 to -72 (Western Reclamation, Inc., and GSM 1987). These samples would need 59 to 72 tons of $CaCO_3$ per 1000 tons of tailing material to neutralize them.

Analyses of tailing material and leachate are found in Table 14. The pH of the tailing varied between 6.66 to 8.50 with a cyanide concentration of 51.2 mg/l. The textural composition of 12 tailing samples contained 54.5 percent sand, 24.3 percent silt, and 21.2 percent clay. After four years in the tailing study plot, the pH values ranged from 2.2 - 7.5, indicating the inherent ability of the tailing to generate acid (Western Reclamation, Inc. and GSM, 1989).

The breccia pipe ore body was sampled by GSM as part of the waste rock analyses stipulated in Amendment 006 in 1988 (Dollhopf, 1989). The breccia ore samples had sulfide sulfur values of 2.81 and a net acid-producing potential of -100 (tons of $CaCO_3$ equivalent needed to neutralize 1000 tons of ore). The tailing study concluded that additional measures were needed to cover or neutralize the tailing before reclamation was possible (Western Reclamation, Inc. and GSM, 1989).

If reclamation does not eliminate the availability of oxygen and water, the tailing may eventually acidify. Replaced neutral or calcareous soil covers over acidic tailing can eventually acidify in several ways. Without a textural break between soil and acid tailing capillary rise of acid can occur especially in arid environments. On slopes, soil can acidify from lateral seepage of acid water downslope into the soil. Finally, the agencies suspect that the active oxidation of pyrite can produce enough heat and sulfur dioxide as well as other sulfur compounds that the replaced soil can be acidified from below. This is possible by convection and diffusion of sulfur in the water vapor given off by the reaction into the soil layer where it could be converted into sulfuric acid. This phenomenon is probably less of a factor over reactive tailing than over reactive waste rock.

Because of the many unknowns, unless complete and long-term neutralization of the tailing can be guaranteed, an application of neutral waste rock over the amended tailing would be desirable before soil is reapplied. A waste rock cap proposed as a textural break and/or reactive tailing would not prevent replaced soil from eventually acidification due to convection and diffusion of sulfur compounds from below. But, at least with a waste rock cap in place, if revegetation failed and the replaced soil eroded away, the tailing would not be exposed to wind and water erosion.

Table 14. Tailing and Leachate Analyses.

	Tailing (ppm)		Leachate (mg/l)	
	(1)	(2)	(1)	(3)
Element				
Al	34.0	---	0.712	---
Ba	19.9	---	0.074	---
Ca	20.0	---	89.0	---
Cd	---	0.010	0.003	<0.01
Cu	---	14.2	65.3	14.21
Fe	530.0	12.7	0.311	12.72
Pb	0.580	0.180	0.045	0.181
Mg	14.8		0.215	---
Mn	2.75	0.300	0.065	0.301
Na	50.0		1,168.0	---
Ni	9.50	0.660	0.304	0.708
Se	1.10	0.010	---	<0.01
Zn	1.75	0.350	1.95	0.352

(1) B.C. Research, 1988, based on one sample
(2) Western Reclamation, Inc., and GSM, 1987, based on an average of 12 samples
(3) Multitech, 1989 written communication, based on an average of 12 samples

ii. Other Tailings Characteristics

The proposed amendment would continue to produce tailing with similar characteristics to those presently being impounded. The tailing which report to the sand cyclone and other spigots into impoundment I are high in pyritic sulfides, a function of the character of the ore. They have a particle size of 64% less than 100 mesh from the milling circuits. Initially, the tailing have relatively high pH (8.0+) values as a result of lime additions in the leaching circuit. Concentrations of several elements have been reported including: aluminum, 34.0 ppm; iron, 530.0 ppm; barium, 19.8 ppm; copper, 25.41 ppm; lead, 0.11 - 0.25 ppm; magnesium, 14.75 ppm; calcium 20.0 ppm; and sodium, 50.0 ppm. Of these, only aluminum shows concentrations in excess of reported plant toxicity levels, which is 14 ppm for aluminum (Gough, et al., 1979). Cycloning of the tailing separates the sand fraction, which is used for center embankment construction, sending the remaining slimes into tailing impoundment I. The proposed reclamation plan for impoundment II calls for depositing whole mill tailing at the rear of impoundment II as final closure is approached, leading to the development of a veneer of unknown thickness of whole mill tails overlying the clayey "slime" mass.

f. Summary

This section summarizes the geologic factors that would influence the consequences of mining under this alternative. Discussions of waste rock dump, pit and tailing impoundment stability and acid production potential of waste rock and tailing materials are condensed for ease of understanding.

i. Structure Stability

All waste rock dump sites, except a part of the north dump complex, have competent foundations. Deposits of the north waste rock dump that are on a landslide area known locally as Midas Slump are subject to potential creepage. Uncontrolled movement of those deposits could eventually partially plug Sheep Rock drainage resulting in erosion and sedimentation of acid-producing materials. Corrective actions proposed for expansion of the north dump complex include a dumping scheme to surround the Midas Slump materials and form abutments along the flanks and toe of the dump and a slope reduction of 2h:1v. These actions should stabilize the Midas Slump area.

The west highwall of the pit would probably experience some sloughing and structural wedge failure over time. Some alterations in pit configurations may be needed during pit enlargement to alleviate potential failures.

Mass instability of tailing impoundments is not expected. Centerline construction is suited to reactive tailing material because it allows controlled drainage of tailing effluent. Although impounded tailing slimes are saturated or nearly so during deposition, internal drains and pervious embankment materials maintain stability. GSM proposed capture of precipitation, direct and upstream runoff, to enhance impoundment reclamation. This would result in periodic recharge of tailing deposits and cause fluctuating levels of saturation and subsequent discharge through the finger drain system and embankment faces. Fluctuations of phreatic levels would be less and for a shorter time in impoundment II because it has an improved drain system and a small run off drainage area compared to impoundment I. Reclamation of tailing impoundments is predicted to fail under this alternative (see Soil and Vegetation sections D.2., D.4.), and stability of the impoundments could be threatened eventually by seepage, piping and erosion in the embankment's toes and wing dike. This is especially true on the sand tailings portion of the embankment.

ii. Acid Producing Potential

Active venting of water vapor, heat, sulfur dioxide, and other unknown sulfur compounds caused by oxidation of pyrite was observed during a waste rock reduction test (DSL Memo, March 1989). At GSM, 22 samples of both ore and waste rock were analyzed to determine acid producing potential.

Waste rock was determined to be acidic showing a mean pH value of 4.2. Sulfur fractionation procedures suggested that unoxidized arkose and mudrock materials located near the breccia pipe were potential acid producers. The breccia material that would be impounded as tailing was also classified as a potential acid producer.

Neutralization (by CACO3) values indicated that most of rock types tested (Table 13) had some level of acid production potential. Therefore, certain portions of the waste rock dump surface would be acid producing. Laboratory weathering results indicate that waste rock, unoxidized mudrock near the breccia pipe and oxidized mudrock could produce acid in the natural environment. One of the factors that governs the speed at which oxidation of pyrite progresses is the size range of the pyrite present in the ore body. This factor may be at least as important as the actual percentage of pyrite present. Mineral size and morphology examinations suggest that pyrite particles at GSM are large and may not be acid producing in the natural environment, although active oxidation can be observed on the waste rock dumps.

Research on a completed copper/uranium mine in Australia indicated that a key aspect of reclamation in order to minimize oxidation of potential acid producing material is to reduce the oxygen and water available to drive the reaction (Ritchie, 1985). Based on available research information in Australia that is pertinent to situations at GSM, requirements for successful reclamation would include use of a neutral waste rock cap and/or an impermeable layer to cut off oxygen and water between the reactive mine wastes and the soil cover.

2. Soils

The results of the waste rock analyses (Dollhopf, 1989) and the tailing study plots (Western Reclamation, Inc., and GSM, 1989) indicate that in less than four years, the reclamation plan as proposed by GSM could fail. The minimal layer of 3 to 6 inches of soil salvaged under impoundment I was totally inadequate. The 6 to 12 inches proposed for salvage under new disturbances in this amendment would not be enough to ensure reclamation of the waste rock dumps or impoundment II without additional measures to prevent acidification of the replaced soils. Additional soil resources, neutral or lime rock materials, or neutralizing amendments for the tailing and waste rock would be needed.

a. Soil Salvage Overview

The agencies consider soil salvage at a particular mine site on a case by case basis. The use of the soil resource must be addressed. At Golden Sunlight, the major problem with mining is exposing unoxidized mining wastes to a weathering environment. Salvage programs at GSM must be designed to set aside enough oxidized layers of materials suitable for a growth medium when mining is completed.

Soil salvage operations and soil storage have several unavoidable, usually deleterious effects. Soil handling destroys horizon development and structure, and homogenizes soil horizons and soil types. Handling operations cause compaction and loss of tilth. Long term storage further reduces soil viability by causing the death of soil microorganisms and plant propagules.

To maximize salvage operations, Table 15 compares GSM's soil salvage criteria with criteria used by the agencies. Salvageable soils at GSM have no major textural limitations for use in reclamation, although several horizons are identified by GSM as having limited

Table 15. Comparison of Soil Salvage Criteria Used by Golden Sunlight Mine (GSM)[1] And The Department Of State Lands (DSL)[2]

SOIL CHARACTERISTICS		SALVAGE VALUE: GOOD	FAIR	POOR
SOIL TEXTURE CLASSES	GSM:	very fine sandy loam fine sandy loam, loam sandy loam silt loam	loamy fine sand loamy sand clay loam sandy clay loam silty clay loam	sand clay sandy clay silty clay loam
	DSL:	textural constraints are limited to a small percentage of total profile based on soil survey data; no limits proposed because of mixing inherent in salvage and replacement programs		
COARSE FRAGMENT PERCENTAGE ((+) 2mm)	GSM:	(-)15%**	15-35%	(+)35%
	DSL:	(depends on availability of soil resource)		(+)50%
SLOPE PERCENTAGE	GSM:			(+)2:1 (45%)
	DSL:			(+)2:1 (50%)
CARBONATE CONTENT[3] ($CaCO_3$)	GSM:	proposed carbonate content as limiting in subsoils		
	DSL:	no limits proposed based on soil survey data presented and need for the soil resource; in this instance, $CaCO_3$ is desirable as an additional soil buffer to potential acidification from the tailings and/or waste rock.		
SOIL REACTION (pH)	GSM:	5.6-7.8	4.5-5.6;7.8-8.4	(-)4.5; (+)8.4
	DSL:	no limits because of mixing		
ESP	GSM:	0-5%	5-15%	(+)15
	DSL:	0-5%	5-15%	(+)15

1 Criteria proposed by GSM based on Schafer, W.M. 1979.

2 DSL criteria based on soil data presented and interpreted by staff for each site and land use.

3 Carbonate content proposed as limiting factor by GSM soil survey, although not used by Schafer (1979).

** (+) denotes greater than
(-) denotes less than

utility because of inherent erosiveness of sandy soils or high bulk densities due to increased clay content. These would be mixed in salvage and replacement operations to a degree acceptable to the agencies for use as a growth medium, especially when used on potentially acid producing materials.

GSM has proposed salvage of soils with up to 35 percent coarse fragments. The agencies ask for salvage of soils with up to 50 percent coarse fragments. Again, the use of this marginal soil is called for in this application over acid producing materials.

Slopes of 2h:1v (50 percent) are commonly accepted as being the limit of safe operation. The agencies and GSM are in agreement on this practice.

Calcium carbonate (CaCO3) content can be a limiting factor in certain soils, because excessive calcium ties up phosphorus and inhibits water absorption, resulting in less fertile and droughty soil. Calcium carbonate also buffers soil from potential contamination from acid producing materials. Fertilizer can remedy the negative effects. Calcium carbonate content was judged by the agencies to be a desirable factor in this particular mining application.

Extremes in soil reaction (ph) are commonly viewed as unacceptable in soils used for reclamation. Mixing during soil salvage and replacement operations would reduce the effects to a degree acceptable in the proposed use at GSM. In addition, the high pH values are valuable buffers in the soil being placed over acid producing materials.

Based on the reviews of soil resources in the area and the proposed use over acid producing materials, the agencies have decided to insist on salvage of all soil material on slopes up to 50 percent, and with coarse fragment contents up to 50 percent. This would provide the largest possible buffer to future acid production in the replacement soil layers. As a result of the agencies review, the GSM proposed salvage plan was inadequate and must be supplemented before implementation.

b. Revegetation Trials

Impoundment I, as approved, was to be reclaimed with 3-6 inches of soils materials. GSM subsequently conducted soils and revegetation trials on the tailing impoundment I from 1985-1988 (Western Reclamation, Inc., and GSM, 1989). A small (120-by 240-by 4-foot) tailing pond was constructed above the level of the active tailing disposal area to serve as a revegetation study plot. The pond was filled with tailing during four days between January 30, and March 30, 1984. The study plot design consisted of four tailing treatments. The entire study plot was fertilized and amended with sulfur (100,250,200 and 50 pounds per acre of potassium chloride, potash (phosphorus), elemental sulfur, and ammonium sulfate, respectively) which were worked into the top six inches of tailings. Treatment 1 used the fertilizer and sulfur amended tailing only. Treatment 2 added 5 tons per acre of calcium hydroxide to the top six inches of fertilizer and sulfur amended tailing, and covered the surface with 4 inches of soil. Treatment 3 added 5 tons of calcium hydroxide to the top six inches of sulfur and fertilizer amended tailings and then 350 cubic yards per acre of woodchips were worked into the tailings. No soil was applied. Treatment 4 was treated the same as Treatment 3 except that 15 tons per acre of hay was substituted for woodchips.

Fertilizer was added as recommended by standard soil analyses to improve fertility. Elemental sulfur was added to improve the tailings physical properties. High sodium levels in the tailings would result in limited movement of water through the tailings. An addition of sulfur would increase the ability of the tailings to leach salts down through the tailings growth medium profile. Sulfur would also react to produce a lowering of the pH immediately giving an initial flush of growth by making growth nutrients more available to the plants. The calcium hydroxide was added to minimize the production of acid in the pyritic tailings. This would help develop soil structure, increase the formation of organic compounds in the tailing, and eventually might provide a substitute for a soil addition to the tailing.

Soil capped tailings showed the best results after four years. Results of the revegetation trials showed that a thicker layer of soil was needed to reclaim the tailing. The four-inch layer of soil proved to be an inadequate growth medium for plants because it limited soil moisture, provided inadequate fertility, and provided an inadequate barrier over the pyritic acidifying tailing. Although initial plant establishment over four inches of soil appeared satisfactory, within four years plant production and canopy cover declined and plant mortality was evident (Western Reclamation, Inc., and GSM, 1989).

Acidification of the tailing in the test plots by chemical and bacterial oxidation of the pyrite occurred in a period of four years with resultant lowering of pH values below those suitable for plant growth. Reported pH values at the end of the trials ranged from 2.2 to 7.5. Highest values occurred under soil treated plots. Salts in the tailings from the mill process had leached downward. Hydrogen ion concentrations (pH) decreased with depth, and electrical conductivities (EC), sodium absorption ratios (SARs), and total sulfur and sulfate sulfur concentrations increased with depth (Western Reclamation Inc., and GSM, 1989).

Test plot research completed on impoundment I, however, does not replicate reclamation plans proposed by GSM for impoundment I or II. For example, GSM initially treated all plots with 200 pounds per acre of elemental sulfur and a mixture of fertilizers which are not proposed in GSM's current amendment reclamation plan. The sulfur and fertilizer alter soil chemistry and affect pH. Additionally, the four feet of whole tailing used in the test plots may not necessarily replicate final conditions within impoundment II. Although GSM would use whole tailing to fill low areas at reclamation, the proposed depths are unspecified in the reclamation plan and are unknown.

GSM's final report (Western Reclamation, Inc., and GSM, 1989) concludes that the surface twelve inches or more of tailing should be neutralized with adequate quantities of lime to try and make the tailings a suitable growth medium. Lime would be applied before soil is applied. Further test plots should be studied.

The revegetation trails also concluded, and the agencies concur, that a greater depth and quality of growth medium is needed to successfully establish vegetation on the tailing than was examined in the test plot studies (Western Reclamation Inc., and GSM, 1989). Soil surveys in the area generally describe the rooting zone as limited to 60 inches or less.

Chemical amendments of the tailing were also recommended. Although sufficient neutralization of the tailing may allow them to support growth, neutralization of tailing should not be relied on exclusively at the expense of adequate soil salvage. GSM has proposed salvaging 390,600 bank cubic yards (bcy) from the 271-acre tailing impoundment II area for reclamation of the impoundment using 6 to 12 inches of soil. Twelve inches of soils would not inhibit acidification any better than four inches because no textural break is proposed. Further the proposed plan is to use a range of 6 to 12 inches of soils. Therefore, at the shallower depths the same results exhibited by the test plots would occur.

As the tailing test plots revealed, without adequate neutralization of the tailing, plant vigor and diversity following revegetation could be substantially impaired within four years by acidification of four inches of soil. Another factor to consider is that the four feet of whole mill tailing which were deposited for the test plot study contained a much higher sand fraction than would be expected in the surface four feet of tailing in impoundment II. GSM, however, has committed to placing whole tailing on the surface of impoundment II at the end of mining. Nevertheless, it is unknown how thick the final layer of whole tailing would be or if it is possible to evenly cover the entire impoundment II surface. The sandy clay loam texture of the whole tailing may inhibit plant growth and root development by promoting capillary rise of acid from the tailing upward into replaced soil layers. This is especially important if the layer is shallow and underlain by the clayey, slimy tailing within the potential rooting zone. Despite the observed downward movement of salts and acid in the test plots, both textural classes exhibited by the tailing have the potential for capillary rise of toxic solutions of metals, salts, and acid which could alter the physical and chemical characteristics of the replaced soil. Furthermore, the elemental sulfur, fertilizer, and calcium hydroxide amendments incorporated into the test plots, which are not included in GSM's tailing reclamation plan, may have been responsible for altering the pH, mobilizing sodium, and inhibiting sodic horizon formation during the short term of the test plots.

c. Tailing Impoundments Soils Salvage Plans

The cycloned sandy tailing in the impoundment II dike face must also be treated as the impoundment II surface. However, the reclamation plan proposed for the impoundment II surface is bound to fail because of acidification of the soils by the tailing over time through the inadequate soil replacement layer.

Reclamation of the original tailing impoundment I, as permitted, would entail placing approximately 97,000 bcy of salvaged soil over the 200-acre impoundment area, achieving a replacement depth of between three and six inches of soil over tailing. Based on the tailing study plots, the replaced soil would ultimately be impacted by acidification, or upward migration of salts and sodium from the unamended tailing. This change in soil chemistry would first inhibit and ultimately prevent plant growth. Ultimate revegetation failure on tailing impoundment I is assumed, with resulting blowing of contaminated soil and tailing. The impoundment I dike face created by cycloning sandy tailing, is also bound to reclamation failure for the same reasons. Additional soil salvage, use of textural breaks to isolate the tailing from replaced soils, geofabric, and tailing amendments are needed and are discussed in Chapters IV and V.

d. Waste Rock Dumps Soil Salvage Plans

There would be two types of surfaces to be reclaimed on the waste rock dumps, flat tops and benches, and 2h:1v slopes. The underlying material would be coarse waste rock, with size gradations varying from fine soil particles to gravel to boulders in size. Chemical characteristics have been described previously under geology, section D.1.

The physical limitations to plant growth of the waste rock dumps created by the rock content can be effectively overcome by placement of an adequate thickness of soil over the rock to enable a self-sustaining vegetative community to establish. Soil salvage plans would cover the waste rock with an effective depth between 6 and 12 inches. This is a minimal layer of growth medium and therefore establishment of vegetation would be severely limited. In addition, the waste rock is acid producing. Active oxidation of pyrite is occurring during the mine life. The agencies have no data on how much soil would be needed to prevent acidification of replaced soil from occurring on the waste rock dumps as was observed on the tailings revegetation trials. The agencies must assume the same thickness of soil would be needed on the waste rock dumps as on the tailings impoundments.

The waste rock dumps north and east of the pit would cover approximately 309 acres after final slope reduction to 2h:1v. Approximately 160,000 bcy of soil material has been salvaged from the north waste rock dump area at the time of amendment application. GSM has proposed salvaging soil in this area to an average depth of eight inches, salvaging 276,100 additional bcy of soil. Salvaged soil, together with that material already stockpiled, would allow for the replacement of 10 inches of soil over approximately 309 acres of waste rock dump on the north side. This would provide for a minimal rooting depth for plant growth and would be marginally adequate to sustain adapted species.

The waste rock dumps south and west of the pit would cover approximately 416 acres after final slope reduction to 2h:1v. Approximately 180,000 bcy of soil material have been salvaged from the area of the south waste rock dump. GSM has proposed salvaging soil in this area to an average depth of eight inches, which would produce 166,300 additional bcy of soil. Soil to be salvaged, together with the material already stockpiled, would allow for the replacement of six inches of soil over approximately 416 acres of waste rock dump on the south and west side. This would provide an absolute minimum rooting depth for revegetation on these harsh exposures for all but the most drought-resistant species. The test plots established on the south dump in 1985 failed because of a suspected lack of soil (GSM Annual Report, 1987). This indicates several potential problems.

The waste rock analyses showed that same waste rock types are acid-generating (Dollhopf, 1989). If acidification of the replaced soil occurs, ultimate revegetation failure can be assumed. Neutralizing amendments, and/or a rock cap, textural breaks, or other reclamation strategies would be necessary to prevent acidification of the soil cover. These are discussed in Chapter IV. More soil salvage is needed in addition to amendments of waste rock dump surfaces and/or use of a textural break of cap rock layer to prevent acidification of the replaced soil layers.

3. Water Resources

a. Pit Water

The proposed mine plan expand the mine pit to approximately 209 acres and extend mining down to an elevation of 4,800 feet. This elevation is approximately 225 feet below the estimated groundwater table elevation. Snowmelt, precipitation and groundwater inflows in excess of evaporation would result in a body of water being created in the mine pit at the end of mine life. The reclamation plan proposed by the company suggested that inflows of 90 gpm could form a lake in the mine pit which would be 225 feet deep with a surface area of 52 acres. This estimate is based primarily on the position of the inferred water table in the mine pit area.

Sustained surface water outflow from the pit would eventually discharge through the Ohio adit. In addition, either the fluctuating or the static lake may result in seepage through fractures in the pit walls and floors. The specific flow rates, paths, and directions of this seepage are unknown at the present time. However, it is likely that this water would flow from the mine pit toward the Jefferson River on either the southwestern or the northeastern fracture/fault systems.

The ultimate quality of water in the mine pit is uncertain but both the quality of water draining from the Ohio Adit (Table 7), and the leachate analysis from the highwall sample suggests that the water would have low pH, elevated levels of metals, nitrates, and high salt concentrations (Table 14). The pH, metals, nitrates and salt contents of this water are expected to be in excess of the natural groundwater conditions due to the oxidizing conditions in both the Ohio adit and the mine pit. Nitrates would be elevated due to blasting residues. Water seeping from the pit would be modified by a variety of unquantifiable geochemical processes. However, it is likely that this flow into the fractured bedrock aquifer would reduce the quality of the receiving water below water quality standards. (WQB Letter, December 20, 1990)

GSM has not proposed any reclamation within the mine pit this permit amendment.

The Montana Metal Mine Reclamation Act addresses reclamation in 82-4-336(5) and (7) MCA. Specific requirements include:

> "(5) Where mining has left an open pit exceeding 2 acres of surface area and the composition of the floor or walls of the pit are likely to cause formation of acid, toxic, or otherwise pollutive solutions (hereinafter "objectionable effluents") on exposure to moisture, the reclamation plan shall include provisions which adequately provide for:
>
> (a) insulation of all faces from moisture or water contact by covering to a depth of 2 feet or more with material or fill not susceptible itself to generation of objectionable effluents;

(b) processing of any objectionable effluents in the pit before their being allowed to flow or be pumped out of it to reduce toxic or other objectionable ratios to a level considered safe to humans and the environment by the board;

(c) drainage of any objectionable effluents to settling or treatment basins when the objectionable effluents must be reduced to levels considered safe by the board before release from the settling basin; or

(d) adsorption or evaporation of objectionable effluents in the open pit itself; and

(e) prevention of entrance into the open pit by persons or livestock lawfully upon adjacent lands by fencing, warning signs, and such other devices as may reasonably be required by the board...

(7) The reclamation plan shall provide for the reclamation of all disturbed land. Proposed reclamation shall provide for the reclamation of disturbed land to comparable utility and stability as that of adjacent areas, except for open pits and rock faces which may not be feasible to reclaim."

The Rules and Regulations governing the Montana Metal Mine Reclamation Act discuss pit reclamation in ARM 26.4.109, and require:

"(1) Section 9, Part F, concerns abandoned open pits greater than two (2) acres in size and gives the board the responsibility of setting levels of objectionable effluents safe to humans and the environment that may flow or be pumped out of the pit, with or without treatment.

(2) The board rules that subject reclamation plans must provide that all discharges from such abandoned pits must be consistent with provisions of the Montana Water Pollution Control Act, sections 75-5-102, 75-5-306, 75-5-631 to 635 as amended.

(3) Effluents from a subject abandoned pit must meet the water quality standards adopted by the Montana Water Pollution Control Council, October 5, 1967, or any future revisions of these standards in effect at the time of pit abandonment. In accordance with criteria for other materials exhibiting a residual life exceeding 30 days in water, no heavy metals or heavy metal compounds shall be pumped or allowed to flow from subject open pits in concentrations exceeding 1/100th of the median

tolerance limit (TLm 96) for game fish present in the receiving water."

To address the requirements of the Montana Metal Mine Reclamation Act, GSM has committed to treat any discharge from the mine pit. No treatment scenarios or alternate reclamation strategies were discussed either in this application or the draft EA (DSL, 1989). Treatment in perpetuity has never been addressed by the regulatory agencies. For further discussion see Chapters IV and V.

b. Waste Rock Dumps Seepage

The development of the proposed waste rock dumps would affect local runoff patterns. The waste rock material would alter the local rainfall interception and runoff and may affect localized aquifer recharge. The areas proposed for waste rock disposal are recharge areas, but only contribute substantial surface flows in the area during 100-year precipitation events and snowmelt when the ground is frozen.

Rainfall infiltrating the waste rock dumps would either be stored interstitially in the waste rock dump material or would flow through as seepage. The current waste rock dumps have not shown a tendency to seep or affect groundwater in the area to date. However, the free-draining nature (size gradation) of the waste material would maximize infiltration and minimize the effect of high evaporation in the area. The development of the waste rock dumps would affect the local surface and groundwater quality to a minor degree depending on the success of revegetation in minimizing recharge into the dumps. Revegetation under the proposed plan is assumed to fail. The waste rock dump reduction test showed water had infiltrated into the dumps to at least 10 to 15-foot depths (DSL Memo, March 1989).

Currently permitted mining has impacted a number of the ephemeral drainages in the area. The deposition of waste rock in these areas has probably influenced the runoff/infiltration relationships for these areas, and has probably altered some local hydrologic parameters such as lag time and time of concentration. However, these changes have not had a discernable impact on the hydrology of either the Boulder River or the Jefferson River to date. The EIS prepared for GSM amendment 001 concluded incorrectly that there is no evidence of acid mine drainage in the area (DSL, 1981). A stipulation attached to amendment 006 requested more information on the potential for seeps from the waste rock dumps (DSL, 1988). GSM has committed to treat seeps from dumps if necessary in the amendment approving mining through stage III (DSL, 1981). No treatment scenario was proposed for evaluation.

Waste rock dump reclamation as proposed by GSM would increase the potential for revegetation failure because slopes are long and steep, soil replacement is less than 12 inches and has considerable coarse fragments. No treatments proposed to reduce the potential acidity of the waste rock. If revegetation fails, soil would be lost by wind and water erosion, and rainfall infiltration would be maximized which would increase the potential for eventual seep development from the waste rock dumps.

Decreasing the waste rock dump slopes, increasing the replacement soil depths, and isolating the potentially acidic waste rock from the soil by use of a textural break or cap rock layer would increase the revegetation potential and decrease the potential for seepage. This would provide more water for potential use in evapotranspiration by plants in the rooting zone.

c. Tailing Impoundment Seepage

i. Impoundment II

The development of impoundment II would alter the hydrologic character of the area. Runoff that formerly flowed from the drainage area would be captured by the proposed structure and diverted to the mill. The drainage basin has an area of approximately 320 acres. The loss of these ephemeral water courses is expected to have only very localized effects and is not anticipated to influence either the alluvium recharge or surface flow in the Jefferson River. Impoundment II may reduce local aquifer recharge by sealing off areas or by capturing runoff that recharged the local groundwater system. The relatively small size of the disturbed area compared to the total groundwater recharge system suggests that this impact would be minimal.

Construction of impoundment II would necessitate installation of new pumpback wells on the crest of the wing dike on the east side of impoundment I. This array may depress the phreatic surface in areas previously not affected by the present pumpback system. These effects are expected to be localized and would not extend to any currently claimed groundwater sources or other beneficial uses.

Construction of impoundment II is not expected to affect water quality downgradient of the impoundment during operations since seepage would be controlled by the liner and seepage collection system. No surface discharge of tailing fluid from the embankment face is expected to occur during the operational life of the mine.

Interstitial water within the tailing is expected to drain downward as tailing impoundment II is decommissioned. This gravity drainage would lower the moisture content of the tailing from saturation (approximately 28 percent) to specific retention (field capacity) which is estimated at 20 percent based on the estimated size gradation of the tailing. The rate of water movement through the tailing when moisture content is below saturation is a complex process dependent on a number of factors including material properties, anisotropies and inhomogeneities in the system. Physical properties of the tailing has been described under Geology, section D.1. However, it is anticipated that the unsaturated hydraulic conductivity of the tailing would be less than the estimated saturated hydraulic conductivity (10^{-5} cm/sec). Given the estimated size gradation of the tailing material and the estimated hydraulic conductivity of the system, it is estimated that evaporation would have a limited influence on the moisture content of the tailing mass, especially at depth. A moisture content close to specific retention implies that all water reaching impoundment II would eventually seep out through the impoundment base, especially since the reclamation plan as proposed, without supplemental commitments or modifications, would ultimately fail. See Vegetation and Soils, sections D.2. and D.4.

The rate at which water would seep from impoundment II is a function of physical and hydrologic variables in the tailing. Modeling of the rate of seepage from impoundment II would be inappropriate due to the limited amount of data. However, lack of data to model seepage rates does not alter the results of a mass balance calculations calculated for the impoundments (Appendix B). The potential seepage rates may be reflected by the current seepage through and under impoundment I. The rate for both underflow and flow through the tailing is approximately 400 gpm.

The results of the mass balance calculation are presented in Figure 5. They suggest that recharge of the tailing can be anticipated under a variety of potential storm events greater than the 10 year 24-hour event. If significant recharge of tailing impoundment II occurs, increased seepage from the impoundment can be anticipated.

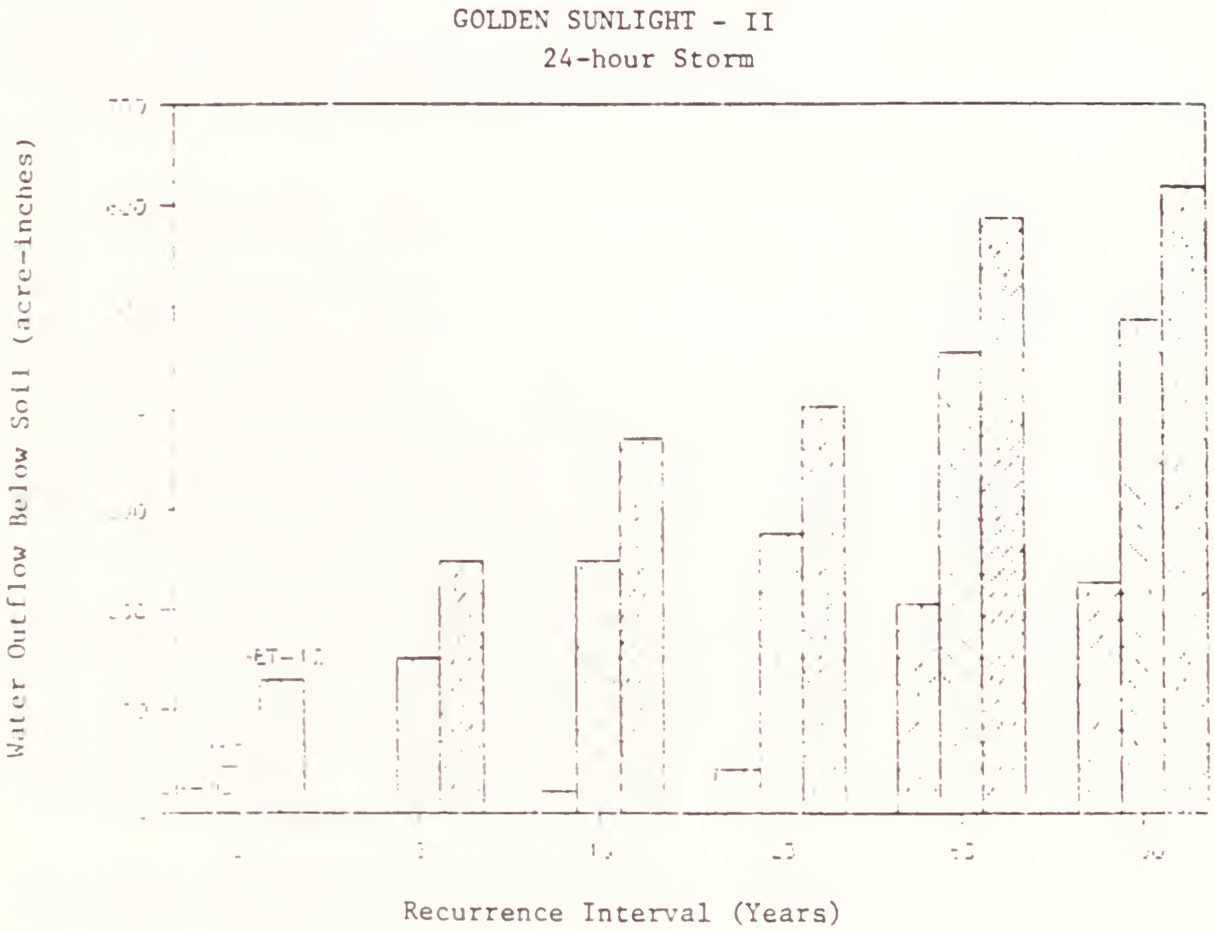
The tailing has a proven ability to generate acid, based on the results of the tailing reclamation studies conducted on impoundment I and the quality of water currently draining from the Ohio adit (Table 7). Limited information is available on the expected quality of the potential water seeping from the proposed impoundment II. Results of a variety of extraction analyses on the tailing are presented in Table 14. The results of the 1980 and 1984 analyses were used to predict the water quality of seepage from impoundment II. The 1984 data were collected using the DTPA metal analyses procedure. This method uses a pH (7.8) and probably underestimates metals values in an acidic environment. The 1980 data were obtained from a test sample using a 1.3 percent weight to volume acid leach. The exact methodology and the nature of the acid used were not known. The 1980 data appear to represent a set of reasonable metals values in an acidic environment. Based on this limited information, water seeping from impoundment II is estimated to be as low as pH 2.4 (based on the Ohio adit water samples). In this pH range, metals would be expected to mobilize and the final seepage water quality is expected to be close to extract values.

The proposal for impoundment II includes the use of a synthetic liner, and a plumbing system to transport fluids through the embankment face to the seepage collection system. This system controls the phreatic surface within the impoundment. It is anticipated that the effectiveness of the plumbing system would decrease in time, and result in a raising of the phreatic surface that would cause drainage through the embankment face. This uncontrolled seepage through the embankment face would be a function of the potential recharge of the tailing. If substantial recharge of the tailing takes place, uncontrolled seepage is anticipated. This is aggravated by the assumed failure of the reclamation plan as proposed.

ii. Impoundment I

The proposed tailing impoundment II would lie adjacent to the currently permitted impoundment I. The current impoundment I is designed to contain all of the runoff from the drainage area above the impoundment. The removal of this runoff contribution are has likely influenced the "normal" hydrologic condition in the area. However, no discernable impacts to flow in the Jefferson River has resulted from this change.

Figure 5. Mass Balance Calculations



The results of the mass balance calculations for proposed reclamation plan for impoundment II. The labels "AV-12", "DR-12", and "WET-12" refer to antecedent conditions of average, wet and drought. The value 12 corresponds to a replaced soil horizon thickness of 12 inches.

The operation of the currently permitted tailing impoundment I has influenced both the quality and quantity of local groundwater. Improper installation and the resultant failure of a slurry cut-off wall to contain impoundment I seepage early in the impoundment life has led to the presence of cyanide in domestic and monitoring wells over a mile away. Remediation of potential leakage problems from impoundment I has required continuous pumping from two separate arrays of pumpback wells. These two pumpback well arrays are operating in addition to the pumpback well array located between impoundment I and the slurry cut-off wall. The sustained pumping by all three of these arrays has altered the water table configuration in the impoundment I area. No beneficial use has been impacted since GSM bought out the owners of the contaminated wells. Currently over 40 pumpback wells are in operation to contain impoundment I seepage (D. Scharf, personal communication, April 27, 1990).

Impoundment I was designed with an amended soil liner. A piping system was installed above this liner to carry tailing seepage through the embankment face to a collection system. This seepage is currently being returned to the mill circuit. It is anticipated that the majority of the seepage from impoundment I would intercept the slurry cut-off wall. When pumpback is discontinued, both underflow and seepage would create a groundwater mound upgradient of the cut-off wall. Overtopping of the slurry wall would eventually occur if seepage is significant. It is also anticipated that seepage to the east and south may occur. In time, a decrease in the effectiveness of the plumbing system for impoundment I is expected. This decrease in efficiency may result in a rise of phreatic levels within impoundment I and drainage through the impoundment bottom or through the embankment face.

Hydraulic conductivities in the alluvium were estimated by GSM to be 580 feet per day. A pumpback test showed the hydraulic conductivity to be 650 to 750 feet per day in the alluvium (Appendix C). These flow rates were fast enough that the cyanide and other metals were not attenuated completely. Seepage from impoundment I would apparently reach the Jefferson Slough and/or other beneficial users before attenuation of cyanide and metals can occur. The same could be predicted for the proposed tailings impoundment II.

Operation of the currently permitted tailing impoundment I has influenced the local groundwater quality, flow direction and quantity. Unanticipated site conditions during construction led to two distinct seepage problems for impoundment I. The first problem stemmed from the improper construction of a bentonite slurry cut-off wall, located downgradient of the impoundment. This led to the escape of tailing effluent from the impoundment and the contamination of several downgradient wells with cyanide in 1983. (Appendix C). GSM's commitment, with approval of the appropriate agencies, included repair of the cut-off wall, installation of a series of pumpback wells downgradient to the cut-off wall (in addition to the originally permitted wells between the impoundment dike and the slurry cut-off wall) and if installation of several additional monitoring wells and the replacement of the affected domestic water supplies. Replacement water came from an unaffected spring in the area and is being treated with a reverse osmosis unit. To mitigate the impact to beneficial use, GSM bought out the impacted landowners.

The second problem with impoundment I stemmed from the escape of impoundment fluids to the east of the impoundment. These fluids appeared to be migrating within a relatively thin zone of fine sands within the more impermeable Bozeman Group rocks. In this instance, no water supplies were affected. GSM's response again included the installation of additional monitoring wells and the installation of a series of pumpback wells to contain the fluid migration.

Numerous documents by GSM, their consultants and the state have been prepared during the investigation and remediation of these problems (Appendix C). Data analysis of cyanide and static water levels in the downgradient wells indicates that the current remediation program is effective in controlling additional tailing effluent losses. Investigations by the appropriate state agencies indicates that the current water replacement system is adequate and effective. Continued data collection concerning this contamination and remediation is required, and periodic review of the effectiveness of the system is an ongoing process.

iii. Total Impoundment Seepage

The proposed tailing impoundment II would be constructed adjacent to the current impoundment I. The estimated impacts for the operation and reclamation of the current impoundment is the basis of the impact analysis below.

The potential for seepage from impoundment I was analyzed using the same methodology as for impoundment II. The results of a mass balance calculation (Appendix B) for impoundment I are shown in Figure 6. These results suggest that recharge of the tailing is possible under a variety of antecedent conditions. The actual seepage rates were not calculated as part of this analysis. It is anticipated that seepage through the soil horizon would result in recharge of the tailing and eventual seepage from impoundment I.

Under the proposed reclamation plans for both impoundments, it is probable that seepage would take place. The addition of seepage from impoundment II to the seepage from impoundment I would substantially increase the probability of pollutant migration offsite. Assuming a combined seepage rate of 200 gpm based on mass balance calculation (Appendix B) and water quality similar to that presented in Table 7, it is likely that local beneficial uses would be impaired.

Leachate exiting the impoundments would be subjected to a number of geochemical processes including precipitation, co-precipitation and dilution. Overtime, as the tailings seepage becomes acidic, these processes would generally serve to reduce the concentration of the contaminants. The exact volumes, rates, and constituents of the final leachate would depend on a number of unquantifiable conditions.

The potential for seepage from impoundments I and II to impact the Jefferson River system is dependent on the volumes, rates, timing and constituents of the seepage fluid released and on the geochemical pathway the fluid takes from the impoundments to the Jefferson River. To evaluate the potential for this seepage to impact the Jefferson River, a simple loading calculation using a worst case approach was performed. This approach assumes that no precipitation or dilution takes place between impoundments I and II and the Jefferson River. Copper was selected as the parameter to be analyzed due to the high levels of copper in the tailing leachate and the similarity of copper migration with other metals. This loading analysis assumed a combined impoundment seepage of 200 gpm with 65 ppm copper (see Table 14). Data from the Jefferson River at Three Forks, was used to evaluate the impacts of this loading function. Data available from the Water Quality Bureau suggest that the mean concentration of copper in the Jefferson River at Three Forks, is 0.16 mg/l. Results of this analysis suggest that under the proposed and existing reclamation plan, the standard for the protection of fresh water aquatic organisms against acute copper toxicity would be exceeded 10 percent of the time.

d. Water Rights

Degradation of the ground water claimed for beneficial use (28 water rights filed) could occur if impoundment I develops high uncontrolled seepage rates of objectionable water as a result of reclamation failure.

There are a number of filed water rights claims in area. Approximately half of the claims are for groundwater. It is anticipated that degradation of groundwater, currently claimed, may occur if Impoundment II seeps high rates of polluted water.

4. Vegetation

a. Plant Community Diversity

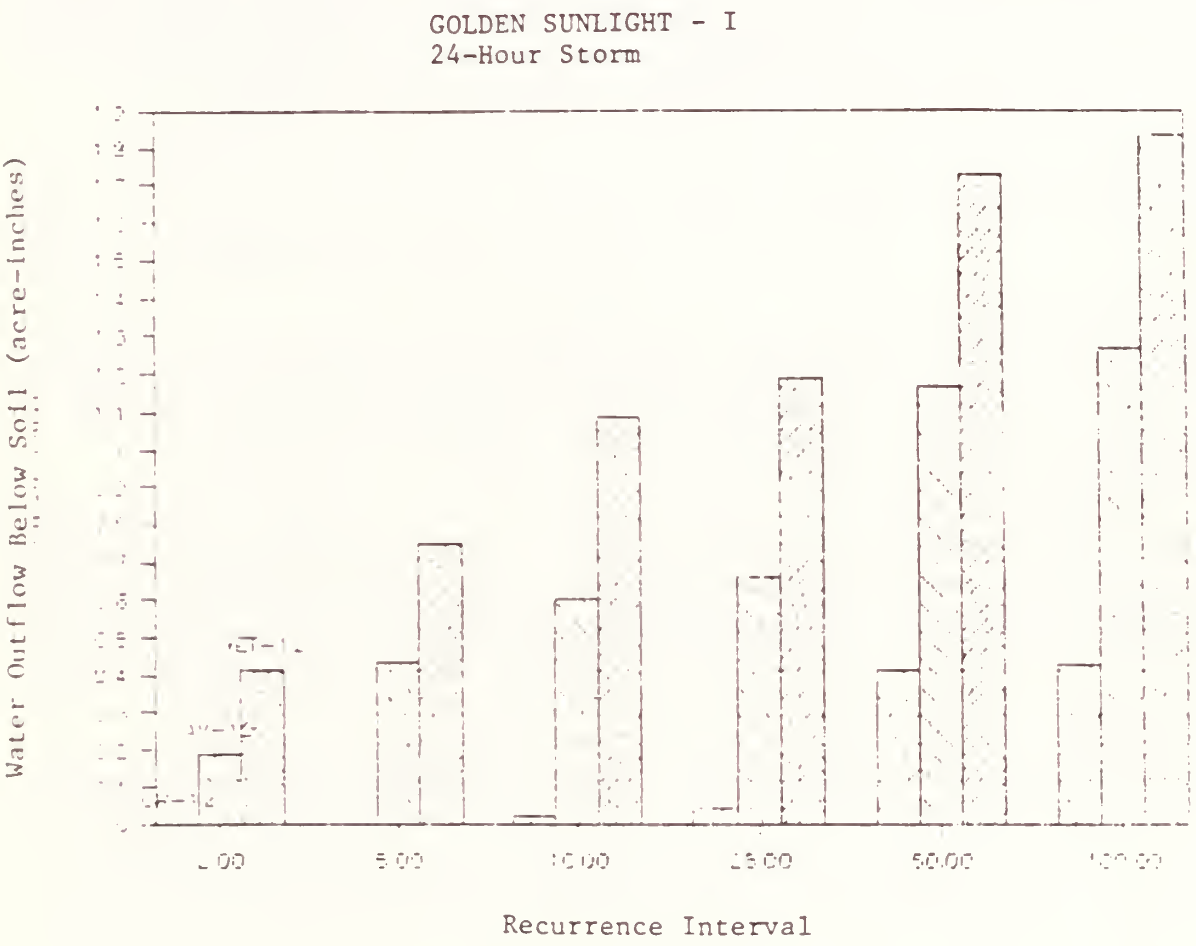
In the proposed expansion area, another 300 acres of vegetation could be destroyed, affecting fourteen to sixteen of the existing plant communities that were identified in the expansion areas inventories. The number of acres of vegetation to be destroyed could total over 1,500 acres.

Simplification of the physiography and homogenization of the replacement soils would limit the number of plant communities that can be reestablished. The reclamation plan does not address re-creation of community diversity. However, the potential does exist to create new communities because of the new substrates, re-created soils and plant species available for reclamation seeding.

b. Plant Species Diversity

Diversity would be decreased for many years after reclamation. It would increase over time but may never approach pre-mining levels. Many of the existing plant species identified in the expansion study areas are difficult and costly to reestablish (Table 9). Soil salvage programs would ensure that plant regenerative parts are stockpiled for future replacement on reclaimed sites. But, the potential for most species to regenerate from long-term storage in soil stockpiles is minimal. Over 150 species were found in the vegetation survey. Approximately ten are to be reseeded or replanted. The availability of forb and subshrub seed is limiting.

Figure 6. The Results Of The Mass Balance Calculations For Proposed Reclamation Plan For Impoundment I. The Labels "AV-12", "DR-12", and "WET-12" Refer To Antecedent Conditions Of Average, Wet And Drought. The Value 12 Corresponds To A Replaced Soil Horizon Thickness Of 12 Inches.



i. Noxious Weeds

The proposed expansion area disturbances would be susceptible to noxious weed invasion from existing sources in the mine area and/or new seed sources introduced during mine life. Eradication may be impossible. An aggressive weed control program has been implemented but as the size of the disturbance increases, effectiveness diminishes.

Weed control programs to control the aggressive species found on the mine site result in the destruction of many native forbs and shrubs susceptible to the control method used.

In combination, the weed control program, introduction of aggressive, new species, (particularly with the noxious weeds) and operating in the absence of natural plant predators and pathogens, have the potential to displace native species and eventually produce a disclimax. The number of forb and shrub species would be especially limited.

c. Plant Forage and Shelter for Livestock and Wildlife

The continued expansion of the mine would displace livestock and wildlife that used the expansion areas for food and shelter. Eventual revegetation of the disturbed acres would lessen the long term impact. Fortunately, only a small acreage of the mountain mahogany type which is an important deer winter range would be disturbed by the proposed impoundment II.

Revegetated communities on mines can typically return to pre-mine productivity levels but plant diversity is decreased, limiting the utilization by certain classes of livestock and/or wildlife (DePuit, 1988). But, GSM has proposed replacing only 6 to 12 inches of soil on tailing impoundment II. This would result in lowered productivity of the reclaimed impoundment because the majority of the original soils that exist under the proposed impoundment II site are much deeper and well drained. GSM proposes to replace even less soil over the impoundment I reclaimed surface. Vegetation production potential is reduced even more than on impoundment II, unless the tailing are amended sufficiently to reduce acidification and other chemical and potential physical limitations. More soil could be salvaged and a neutral waste rock cap or textural break could be used to improve vegetation success which would enhance animal use.

d. Revegetation Potential

Over the entire mine site, some acres may not revegetate in the short term due to rock content and a lack of cover soil. Conversely, revegetation of waste rock dumps and/or tailing impoundments may subsequently fail in the long term due to potential acidification or to limiting physical and chemical properties in the waste rock or tailing.

In the proposed permit amendment, the potential for acidification of the oxygenated areas of the waste rock dumps could not be evaluated because of insufficient data. However, additional analyses were stipulated and GSM developed acid-base data for the waste rock types (Dollhopf, 1989). Total potential acidification is estimated to be less for the waste rock dumps than for the tailing impoundments because of the reduced surface area exposed due to rock content of the waste rock dumps. However, oxidation of the waste rock and the associated heat generation have been observed in the north waste rock dump by DSL inspectors, indicating that acidification exists to some degree (DSL Memo, March 1989).

The tailing reclamation test plots established in 1985 indicate that revegetation is possible in the short term on tailing with replaced soil. Fertilization with nitrogen, phosphorus and potassium and amendment with elemental sulfur initially increased fertility and reduced the reaction (pH) and sodium (Na) hazard inherent in fresh tailing. The final report on the tailing study plot indicated that reclamation methods tested to date would fail in the long term due to acidification of the reactive tailing (Western Reclamation, Inc. and GSM) and to potential acidification of waste rock (Dollhopf, 1989).

GSM proposes to reclaim waste rock dumps at 2h:1v which would limit the potential for even distribution of soil and increase the risk of loss of soil to erosion from wind and water on 320 acres of dump slopes. Seeding and other treatments are limited to application by dozers, broadcast seeders, and by hand.

e. Erosion Potential

i. Erosion During Operations

The additional acres to be disturbed would increase the potential for wind and water erosion during the mine life. Dust would coat vegetation in the surrounding plant communities, especially those close to access and haul roads. Various techniques have been used at the mine to limit dust problems and ensure compliance with their air quality permit. Increased waste to ore stripping ratios from 3.1:1 in stage III to 6.5:1 in stage V, and increased hauling distances would increase dust production.

As the size of the disturbances increases, especially in critical drainageways and off major haulroads, the runoff hazard increases and Best Management Practices (BMP's) to reduce erosion and disperse runoff (e.g., culvert sizing and need for diversions) must be reevaluated. Settling ponds may be needed to prevent sediment-laden water from leaving the site as the mine approaches the permit boundaries. GSM has committed to constructing sediment ponds to coal-mine specifications if needed.

ii. Post-mine Erosion Potential

The greatest potential for long term impact of wind erosion would occur if, after implementation of impoundment I reclamation plans, the reestablished vegetation died, subjecting the minimal cover soil and tailing to wind and water erosion. This is particularly significant on the cycloned sands embankment face. Erosion by wind and water of the sand tailings embankment faces must be minimized to guarantee long term stability of the embankment (2.5h:1v slopes). Impoundment II has this potential problem only on the 2.5h:1v embankment sand tailings face, because the rest of the impoundment surface would be capped with waste rock.

No water or wind erosion should occur in the mine pit that would influence other reclaimed areas.

Runoff above major disturbance areas should be diverted around the disturbed site or routed across it via an armored channel. GSM has committed to diverting runoff off the waste rock dump tops until reclamation is complete. As the mine enlarges and as the reclamation programs begin, the need for diversions, water bars, energy dissipators, armored channels, etc., must be continually reviewed, especially along major haul roads and around the mine facilities area.

The waste rock dump slopes and tailing embankment faces present the largest potential for erosion because of the steep slopes being used to reclaim them. The long, steep (2h:1v) reclaimed waste rock dump slopes present an additional challenge to soil stabilization and revegetation efforts. Steep, long, and largely southerly aspect waste rock dump slopes would be subject to water erosion and to the unsheltered effects of strong winds. These would be particularly harsh sites to reclaim and success would be limited without adequate soil replacement and erosion control measures.

Although there would be some wind erosion, water erosion on the steep 2h:1v side slopes of the waste rock dumps is a major concern. To evaluate the potential erosion from the waste rock dump slopes, the agencies conducted a comparison of erosion from different slope angles in Chapter IV (Supplemental Commitments) using the Universal Soil Loss Equation (USLE)[1] (Wischmeier and Smith, 1960). Based on the evaluation, the volumes of soil lost off the 2h:1v slopes could not be reduced to the assumed acceptable limits of soil loss per year, regardless of the extra conservation practices or Best Management Practices (BMPs) applied in the formulas.

Acidification of the replaced soil from contact with acid-producing waste rock is assumed from the tailing test plot studies (Western Reclamation, Inc. and GSM, 1989) and the waste rock analyses conducted by GSM (Dollhopf, 1989). This would result in a loss of vegetative cover, increased erosion and loss of the replaced soil. Some replaced soil would be lost into voids in the waste rock. Wind erosion would likely be a more significant factor on the exposed slopes of the west side. If acidification proves to be a problem, the waste rock dumps could ultimately become bare rock with scattered pockets of acidified soil. Most of the contaminated soil would blow or wash away onto adjacent areas. Slopes would remain bare for an unknown length of time, until oxidation and weathering of surface horizons has been completed.

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[1]The USLE is a tool that is used to predict the reduction of soil loss through changes made in cultural or management practices. It provides an estimate of local soil loss that can be used to compare erosion control methodologies. Reduced soil losses result in improved water quality as a result of less runoff, more effective use of available precipitation, and less leaching of undesirable salts and metals to underground water tables. For a detailed description of USLE, see Appendix D.

f. Aesthetic Impacts

Vegetation tends to soften the appearance of unweathered rock. The destruction of vegetation would adversely affect the visual quality of the mountain setting from Whitehall, Cardwell, and the major highways in the area. Approximately 7,000 cars pass by the mine on Interstate 90 on an average day (MT Dept. of Highways, Personal communication, 1990).

The visibility of the pit highwall could be largely mitigated by revegetating the upper pit benches. GSM originally proposed revegetating the pit benches in the original application for operating permit no. 00065. The commitment to revegetate the pit benches was dropped in amendment 001 (DSL, 1981).

Major haul roads would be revegetated between the pit and the waste rock dumps and facilities area. These road cuts are very visible and preference should be given to revegetation with trees and shrubs to increase the degree of blending possible.

The tailing embankments and waste rock dump slopes would be the impacts most visible to the majority of travelers and to residents of Whitehall. The majority of the natural slopes in the ultimate dump toe areas are less than 2h:1v. GSM has proposed reclamation of these slopes at 2.5h:1v slopes for the tailing embankments and 2h:1v for the waste rock dump slopes. Revegetation of these slopes is certainly feasible to some degree, but revegetation potential could be enhanced by reduction of slopes to 3h:1v. Slope reduction to 3h:1v would allow use of farming-type equipment and would match the native slopes in the areas of the proposed disturbance. Slope reduction to 3h:1v would enhance the ultimate use of vegetation to minimize aesthetic impacts of the mining operation.

A substantial portion of the mine waste rock dumps could begin to be reclaimed on the west and south side of the mountains as early as 1994 (GSM memo, 1989). This aggressive concurrent reclamation program would substantially reduce the total aesthetic impacts by beginning to revegetate a large portion of the mine before mine shutdown.

5. Wildlife

The local elk herd would be impacted to some degree by the expansion of waste rock dumps and the construction of tailing impoundment II. The mining expansion which occurred in 1981 dislocated wintering elk northward. It is possible that some summer use areas nearer the mine may become insecure to individual animals. Further impacts are considered minor.

Mule deer which have become acclimated to the mining operation nearby would be physically displaced by the advancing waste rock dumps and by construction of tailing impoundment II. These animals would move to less desirable habitat or to areas already occupied. This displacement would be gradual and major population fluctuations would probably not be observable. Deer would probably continue to frequent the edges of the operation. Occasional loss of a deer in tailing impoundments I and II is a possibility. One deer has been lost to date in impoundment I. Since that time, GSM has constructed a wildlife enclosure fence around impoundment I to reduce the potential of further losses. Deer impacts should be minimal in the future.

The antelope which winter south of Red Hill, and the 20 to 30 animals which summer in this vicinity would be affected by a direct loss of forage as a consequence of construction of tailing impoundment II.

It is unlikely that the loss of approximately 500 acres would materially diminish the forage base for these animals. Displacement to adjacent areas is likely if tailing impoundment II construction results in loss of important habitat components or disturbance.

Most of the individual small mammals occurring in the expansion areas are incapable of making rapid, long distance moves. Hence, those chipmunks, mice, voles, ground squirrels and other small species which are in the path of advancing waste rock dumps or earthmoving equipment would be covered by soil and debris or be caught under machinery. Coyotes, bobcats and other species capable of long-distance flight would probably escape and attempt to relocate in other areas. These populations are not unique to the disturbed acres, hence their loss would have no effect on adjacent areas or on population numbers as a whole.

Proposed mine pit expansion would have no direct effect on waterfowl until the mine pit fills with water after mine shutdown. Any waterfowl landing in the pit would be lost. Construction of tailing impoundment II would more than double tailing acreage and would increase the potential of loss of birds which settle on the ponds during operations. Three swans died in 1988 on tailing impoundment I despite the deterrent efforts of GSM.

GSM has been using a combination of propane cannons and loud rock and roll music to discourage waterfowl from using tailing impoundment I. Just recently, GSM has hired a full-time person to patrol impoundment I during the migratory seasons using a rifle to scare waterfowl away (D. Scharf, personal communication, April 27, 1990).

Under the reclamation plan proposed by the company, acid tailing leachate may reach the Jefferson River. A worst case calculation is presented in the Water Resources section D.3.c. and Appendix D. The results of this analysis indicate that the fresh water aquatic standards, especially for copper, may be exceeded under the existing and proposed reclamation plan. Exceedances of these standards may cause fish mortality.

If reclamation of the waste rock dumps is ultimately unsuccessful due to acidification and erosion off 2h:1v slopes, then they would provide little usable habitat for any wildlife species, except on the oxidized portions that don't acidify or erode.

Impoundment I reclamation presents some special problems. Initially, it would be a toxic, slimy pond creating a hazard for mammals and waterfowl. After drying, the tailing would no longer be a hazard to waterfowl. Reclamation of the existing tailing impoundment I would fail as presently proposed. The dry blowing tails would not be usable for any wildlife species.

Threatened and endangered species are not expected to be impacted by the proposal. The possibility of eagles feeding on killed waterfowl on the tailing ponds is remote, given the efforts of GSM to prevent waterfowl from landing on the ponds during operations.

6. Land Use

Before GSM operations, land use of the expansion area included seasonal grazing by livestock, wildlife habitat and recreation. Mining activities have precluded these uses because of destruction of and interference with the habitat. Post-mining uses would be dependant upon the success of reclamation, particularly revegetation, which might once again allow grazing and some wildlife utilization. No agricultural use is foreseen and should be discouraged on the tailing impoundments in particular.

Table 16. Particulate Emission Inventory

Source	Tons/Year Uncontrolled	Controlled	Control Measures
Pit Operations			
Soil Handling	21.0	9.0	Revegetation
Drilling	19.5	2.0	Water Injection
Blasting	8.8	8.8	Min. Area & Overshoot
Ore and Waste Removal	196.0	196.0	Min. Fall Distance
Hauling	2197.2	1098.6	Watering
Ore and Waste Dumping	196.0	196.0	Min. Fall Distance
Equipment Exhaust	13.4	13.4	None
Disturbed Areas	27.6	27.6	None
Exposed Tailing	32.5	8.1	Chem. Stabilization
Access Road Traffic	41.3	6.2	Chem. Stabilization
Primary Crushing	25.0	0.3	Wet Scrubber
Secondary Crushing	31.3	0.3	Wet Scrubber
Tertiary Crushing	18.8	0.2	Wet Scrubber
Coarse Ore Conveying and Reclaiming	6.5	0.1	Water Spray
Coarse Ore Stockpile Discharge	6.3	3.1	Water Spray
Fine Ore Stockpile Discharge	12.5	6.3	Water Spray
Refining Furnace Scrubber Stack	1.9	0.4	Wet Scrubber
TOTAL	2,855.6	1,576.4	

Table 17. Estimated gaseous pollutant emissions from Golden Sunlight Mine.

Source	Tons/Year Controlled
Equipment Exhaust	
SO_2 (Sulfur Dioxide)	23.5
CO (Carbon Monoxide)	93.3
HC (Hydrocarbons)	15.7
NO_x (Nitrogen Oxides)	216.6
Blasting	
SO_2	9.5
CO	317.3
NO_x	80.5

7. Air Quality and Climate

a. Direct

The primary air pollutant of concern with the expanded project are particulate matter (dust) and gaseous emissions. The following tables list the estimated emissions for the project based on GSM's current air quality permit (No. 1689A), and their application for an alteration to the permit for the proposed expansion (Tables 16 and 17).

The emission control practices used by GSM have been determined to represent Best Available Control Technology (BACT) for this project by the Montana Air Quality Bureau.

b. Indirect

There would be a slight increase in air pollution levels associated with any population increase in the area. This results from increased vehicle traffic and home heating. See section D 10.

c. Total

The GSM mining operation is the only large industrial source of air pollutant emissions in the area currently and no others are anticipated in the near future. The additive impact of these emissions with the existing or possible future minor sources in the area should be minimal. Concentrations of all air pollutants should remain well below ambient air quality standards.

In general, particulate emissions would increase with time as the mine expands. This is related to increased haul distances and exposed areas (disturbance areas and tailing). At the conclusion of mining, corresponding air pollution sources would no longer exist if reclamation of the tailing impoundment and waste rock dumps is successful.

Within the waste dumps, oxidation of sulfide minerals may generate sulfur dioxide. the more commonly identified environmental impact of this process is acid drainage; however, there is a potential for the formation and emission of gaseous sulfur dioxide. Movement of oxygen through the pore spaces within the dump can occur by diffusion, convection, and advection. The amount of sulfur dioxide which may be emitted under such a scenario is very difficult to quantify. It is assumed that ambient sulfur dioxide concentrations would be well below ambient air quality standards, but there would possibly be a potential for adverse impacts to vegetation of surface areas where the gas exits. Successful revegetation of the waste dumps would be necessary to minimize oxygen and water infiltration to the dumps, which would reduce acid and sulfur dioxide formation.

If reclamation was not successful, the potential for on-going wind erosion would be substantial. This would be most significant with the tailings area but would also be a factor on any disturbed area.

8. Transportation

Vehicular access to the mine would not be affected by the proposed expansion of the waste rock dumps and construction of tailing impoundment II. Access from the Interstate would continue to be via the Cardwell interchange, through Whitehall on Highway 2, or from Highway 2 and Highway 69 toward Boulder and Helena. The increase of approximately ten workers per shift is not anticipated to result in a noticeable increase of traffic on local, state or federal highways.

It is anticipated that increased travel on roadways in the vicinity of Golden Sunlight would be minimal. Increased employment levels amount to only about ten people per shift. Construction of another tailing facility may add another 10 to 20 vehicles per day, limited to the construction period.

9. Noise

The frontage road and Interstate 90 are 3.5 to 4.0 miles from the mining activity. The noise level at residences along the frontage road is not known, but is high enough above background that three area residents have complained. The complaints are about the rock music used for discouraging the birds and wildlife from using the cyanidated tailing water.

10. Socioeconomics

The proposed expansion would increase the work force by 25 to 35 additional employees. GSM has committed to hire as many local, qualified people as possible and has approximately 400 job applications from the local (Whitehall, Cardwell and Silver Star) area. Continued impacts would occur until 2005.

The proposed disturbance areas would result in a change in land classification from agricultural to industrial and a higher county property tax bracket. Along with increasing the taxable valuation of the land, GSM would increase the number of off-road ore haulers used at the mine by five. These vehicles would be taxed as personal property by Jefferson County and would increase the amount of tax paid by the company.

11. Cultural Resources

In 1985, GSM and the State of Montana exchanged 1,642.56 acres of state-owned land for a similarly-sized tract of privately-owned land. The state-owned land exchange site was included in the second, extensive cultural resource survey. As a result of the findings of this survey and as a condition of the exchange, GSM and the State of Montana entered into a Memorandum of Understanding (MOU).

The conditions of the MOU included annual DSL inspection of the Sheep Rock site (24JF292), a "significant antiquities site", notification of the State Historical Preservation Office (SHPO) by DSL if any adverse impact to the site has occurred, and a commitment that, should any mine-related disturbance of the site be proposed, appropriate mitigation measures would be promptly conducted (full documentation of the site) by GSM.

Expansion of the waste rock dump would include portions of the west half of Section 20, T2N, R3W. The disturbance area would not extend to the site of 24JF292 on Sheep Rock. The cultural materials exposed by the cut face in the road to the spring have been protected by burial as a result of the annual inspection in 1988 conducted by DSL personnel. A layer of plastic sheeting was anchored to the site, and it was covered by talus from an adjacent location. As a result, expansion of the waste dump to the west side of the drainage should pose no threat of direct or indirect impact to the site. Should GSM, at a future time, propose to disturb the site, full mitigation measures would be required in accordance with the conditions of the MOU.

The Coulee Ring Site (24JF766) would be obliterated by construction of the proposed tailing impoundment II dam, either by the dam itself or by being located in borrow areas utilized for dam construction. The site has been photographed, mapped, and recorded and no further work was recommended.

12. Aesthetics

Visual effects of the project would consist of the gradual covering of affected portions of the original landscape by permanent waste dumps and the tailing storage facility. Smooth, regularly-shaped landforms would replace irregular natural topography and vegetation.

During the active mining operation, the enlarged pit, proposed waste rock dumps and tailing impoundment II would contrast with the natural landscape in both form and color. There is no way to develop a mine of this size without substantially affecting the visual resource. The mine would be visible from the communities of Whitehall and Cardwell, as well as Interstate 90, and local highways 69, 41, and 55.

Concurrent reclamation, by reclaiming impoundment I and all the waste rock dumps on the west and south side beginning in 1994, would help to moderate the total number of disturbed unreclaimed acres.

No pit reclamation is proposed. As weathering reduces the lighter color of exposed rock on the pit wall and waste rock dump surfaces, the predominant color would fade from light grey to rusty brown.

After reclamation, contrast with form and color would continue. The geometric form of the reclaimed waste rock dumps and dam, and the artificial flatness of the tailing impoundment surface would continue to contrast with the steep natural topography of the surrounding area.

As vegetation becomes established, the color of reclaimed surfaces may blend with nearby undisturbed habitats, particularly in early spring before droughty conditions of replaced soil accelerate vegetative curing. With adequate revegetation of the most visible, reclaimable portions of the mine area (dump slopes, haul roads cuts, and embankment faces) eventual blending would occur. However, the reclamation as proposed would fail and aesthetic impacts would persist indefinitely.

Although emissions fall within air quality standards, there would be substantial increases in particulate emissions from the expanded operations and transportation, especially the access road. Some new facilities are planned within one mile of Interstate 90. Dust from these facilities would reduce the visual resource of the valley. Successful revegetation of the millsite tailing dump, impoundments, roads, etc. would reduce these impacts to short term after mine life. However, the reclamation plan as proposed would fail on the tailing impoundment and sand tailing embankment faces, waste rock dumps, and haul road cuts through unoxidized rock.

Concerning reclamation, the [illegible] and [illegible] on the west and south side [illegible] disturbed unvegetated [illegible].

No [illegible] reclamation is proposed [illegible] rock on the [illegible].

After reclamation, [illegible] of the reclaimed [illegible] rock [illegible] topography [illegible] surrounding area.

As described [illegible] nearby [illegible] replaced [illegible] reclamation [illegible] [illegible] would [illegible].

[illegible] increase [illegible] the [illegible] However, the [illegible] relatively unweathered rock.

CHAPTER IV - COMPANY'S PROPOSED PLAN WITH SUPPLEMENTAL COMMITMENTS

A. Introduction and Description of the Issues

Following the release of the draft EA in June 1989, several additional aspects of the proposed reclamation plan were identified as issues. As discussed in Chapter III of this document, the central issue is water quality and quantity, specifically the potential for ground or surface water pollution from seepage from the abandoned pit, tailing impoundments and waste rock dumps. Reclamation feasibility is closely linked to the water quality and quantity issue, because without adequate reclamation, cumulative seepage through the waste rock dumps, tailing impoundments, and abandoned pit would increase the probability that water quality standards could not be met. The company's proposed plan evaluated in the draft EA (DSL, June 1989) and chapter III of this document, is inadequate to assure reclamation success. Others issues central to the proposed mine expansion are the proximity of the Jefferson River, visibility of the mine from major highways, concurrent reclamation during the mine life, and economic importance of the mine to the local communities.

Supplemental commitments have been made by GSM since the completeness determination in January 1989 and publication of the draft EA. This chapter summarizes and analyzes impacts of the company's proposed plan with the supplemental commitments specific to reclamation and water quality and quantity. This alternative does not involve changes in the proposed disturbance; therefore only those issues which are impacted (reclamation and water quality and quantity) are discussed in the environmental consequences section of this chapter.

DSL stipulated, in the approval of amendment 006 and subsequent letters to the company, that GSM would have to characterize the nature of the waste rock types and ore to determine the potential for acid production (DSL, 1988; DSL letter to GSM, December 9, 1988; DSL letter to GSM, August 16, 1989). This information, submitted in October 1989 confirmed the potential for acid production (Dollhopf, 1989).

The agencies also required more information on the relationship between the pit water and local groundwater systems as a part of the information requests listed above. This information was submitted November 20, 1989 (SHB, 1989b). However, several water quality and quantity concerns were stilled unresolved (WQB letter, December 20, 1989). Additional requests (DSL letter to GSM, December 20, 1989; SHB letter to GSM, February 2, 1989) generated information which focused on water quality and quantity and proposed water treatment alternatives (Hydrometrics, 1990 a,b; SHB, 1990).

GSM committed to a major concurrent reclamation program in order to limit bonding obligations (GSM memo February 7, 1990). This concurrent reclamation plan could result in major reductions to aesthetic impacts, potential soil erosion, and amount of water infiltrating the waste rock dumps.

Memos and letters detailing commitments and standards are compiled, chronologically, in Appendix A.

B. Reclamation Plan

This section summarizes the proposed reclamation plans with supplemental commitments.

1. Waste Rock Dumps

The reclamation plan described in this chapter, for the waste rock dumps, is based on GSM's report (Hydrometrics, 1990a) and represents the most current update of applicable supplemental reclamation commitments made by GSM since the draft EA was issued in June 1989. These commitments include surface treatments for reclamation of the waste rock dumps originally were proposed by the agencies in order to:

1) isolate untreated, potentially acid-producing, unoxidized waste rock from the replaced soil cover;

2) treat the oxidized waste rock cap placed over the unoxidized waste rock surface to ensure it is not acid/producing;

3) increase revegetation potential to the point that the replaced plant community can effectively utilize soil available moisture from all but the major precipitation events; and

4) reduce potential surface water recharge into the waste rock dump, which would ultimately result in less potential for seepage of acid mine drainage into groundwater and surface water resources.

Waste rock dumps would be reclaimed as follows:

Slope reduction: Angle-of-repose (1.5h:1v) slopes would be reduced to 2h:1v. This remains the same as the original company's proposed plan.

Waste Rock Cap: As a supplemental commitment, GSM agreed to place 2-3 feet of oxidized waste rock (cap) over the waste rock dump tops and reduced slopes to cover the exposed unoxidized acid-producing waste rock.

Liming: As a supplemental commitment GSM agreed to add/incorporate lime as necessary to neutralize to the replaced oxidized rock cap before soil placement.

Soil Placement: As a supplemental commitment GSM agreed to increase the placement of soil over the limed/oxidized waste rock cap to 24 inches on the north waste rock dumps and 19 inches on the west and south waste rock dumps.

Revegetation: Revegetation species and rates to be seeded and/or planted remain the same as the company's proposed plan. Seeding, planting, mulching, and fertilizing methods are the same as the company's proposed plan.

Seepage: GSM had committed to treatment, as needed, of any acid mine drainage from the waste rock dumps in their existing permit (GSM Permit Application, 1974). Their commitment was withdrawn from this amendment application as discussed under seepage/water treatment for the waste rock dumps.

a. Slope Reduction

The agencies evaluated 2h:1v versus 3h:1v waste rock dump slope reduction with the company. GSM committed to testing and evaluating 2h:1v slope reclamation on the waste rock dumps while submitting a bond for 3h:1v slopes (BLM Letter to DSL, March 2, 1990). A reclamation test plot is to be established on one of the waste rock dumps using reclamation plan methodologies currently permitted. If reclamation attempts fail, GSM has committed to reducing the slopes to 3h:1v. During the life of the mine, GSM would develop a more detailed reclamation plan based on reclamation test plot results. The agencies and the mining company have agreed on reclamation success parameters to be used to evaluate the waste rock dump test results proposed by GSM (Prodgers, 1990; Schafer and Associates, 1990) (DSL memo, May 1, 1990). These parameters include comparisons of erosion, soil loss, and vegetation success between the reclamation test plots on the waste rock dump slopes and native reference areas. The uniformity of application of the cap rock and topsoil will also be evaluated. Vegetation success criteria would consider canopy cover as it affects productivity and erosion control (DSL memo, May 1, 1990).

b. Waste Rock Cap

GSM has committed to placing two to three feet of oxidized waste rock over the waste rock dump tops and recontoured 2h:1v waste rock dump slopes. GSM has started to develop oxidized waste rock stockpiles on the waste rock dumps. Selection of oxidized waste rock for stockpiling is based on color and proximity to the original land surface. GSM is stockpiling the upper 50 feet of the mountain as oxidized materials rather than the 100 feet GSM originally believed to be oxidized (GSM Memo, January 24, 1990). GSM evaluated and verified that they had the volumes of oxidized waste rock needed to cover the acreage involved (GSM Memo, January 24, 1990). Oxidized waste rock would be placed by either direct pushing with dozers from the stockpiles and/or by rehandling and hauling to the application area.

Waste rock analyses indicated the acid-producing potential of oxidized waste rock was minimal (Dollhopf, 1989). However, limited data is available to indicate that the actual material being stockpiled for use as rock cap would be neutral and non-acid producing.

Acid-producing waste rock or tailing can potentially destroy replaced soil covers and cause revegetation failure. This was indicated in the revegetation trials conducted by the company (Western Reclamation Inc. and GSM, 1989). In order to isolate the replaced soil rooting zone from the potential acid-producing unoxidized waste rock, a two-foot layer of coarse, neutral waste rock would be used to provide a textural break and/or effective waste rock cap to separate the replaced soil from the acid-producing rock. Two feet of material was selected, based on the provisions in the Act, 82-4-336(5a), MCA, for preventing the production of objectional effluent in mine pits which have proven acid-generating materials.

As further justification, the rock layer would prevent erosion of acid-producing materials off the steep slopes if revegetation eventually fails and the replaced soil erodes.

c. Liming

GSM has committed to liming, if necessary, after placing the rock cap over the waste rock dump top and recontoured 2h:1v slopes. The need for liming would be based on testing of the waste rock cap after placement. No method of lime placement and incorporation was proposed; the method would have to be determined during the reclamation test studies.

d. Soil Placement

GSM originally proposed 6 to 12 inches of oxidized rock materials and/or soil placement on the reclaimed waste rock dumps. A portion of the south waste rock dump was prepared as a reclamation plot to meet company commitments made in Amendment 004 (GSM, 1984). The angle of repose slope was reduced with dozers, probably to 2h:1v. Half of the reduced slope was covered with oxidized waste rock and some soil and the other half of the slope was left untreated. The entire area was broadcast seeded, mulched and a hydroseeder was used to apply tackifier to hold the seed in place (GSM Annual Report, 1986). In 1986 GSM concluded that the waste rock dump test had failed because of the lack of fine soil particles in the oxidized rock cover (GSM Annual Report, 1987). No research was conducted to determine if the failure had been the result of acidification of the enplaced material or lack of moisture or nutrients. No further analyses have been conducted on the waste rock dumps to date (DSL Memo, February 21, 1990).

Mass balance calculations on the tailing impoundments indicated that two feet of soil would be needed by reclaimed plant communities to utilize the volume of moisture produced by 10-year, 24-hour storm events and to prevent seepage out of the reclaimed impoundments. (Appendix B). Therefore, it is assumed by the agencies that at least that much soil would be needed to create the same effect on the reclaimed waste rock dumps. As a result, soil salvage proposals were reevaluated by the agencies (Chapter III, Section D.2.a. and Tables 4, 5, 6, and 15). Additional soils could be recovered from the proposed disturbance areas for stage IV and V waste rock dump expansion. Replacement soil depth could be increased from 6 to 12 inches to 19 to 24 inches on the south and west waste rock dump complex, and 24 inches on the north waste rock dump complex. As a result of the soil salvage overview, GSM has committed to placing 19-24 inches of soils on the south and west, and 24 inches on the north waste rock dumps, respectively (Hydrometrics, 1990a).

e. Revegetation

The revegetation plan as described in Chapter III would likely succeed, if overriding complications with slope reduction and isolation of the rooting medium from acid-producing waste rock were successfully avoided. GSM has committed to continually evaluate revegetation practices during the interim between proposed testing and conclusion of waste rock dump reclamation (Prodgers, 1990 and Schafer and Associates, 1990). Parameters to be evaluated include erosion control, soil loss and revegetation success (DSL Memo, May 1, 1990).

GSM has also committed to concurrent reclamation on waste rock dumps as they are decommissioned, in order to save on bonding obligations (GSM Memo, February 7, 1990). Concurrent reclamation would utilize the most current methods and species that are applicable. All reclamation will be continually monitored to evaluate the suitability of technology and of seeding mixtures.

f. Seepage/Water Treatment

GSM committed to treatment of any acid mine drainage from the waste dumps if necessary, in their original application in 1975 (GSM Application for an Operating Permit, 1975). That commitment was dropped based on the company's analysis of water quality impacts (Hydrometrics, 1990 a) which showed relatively minor quantities of seepage from the waste rock dumps.

2. Tailing Impoundments

a. Reclamation Objectives

Reclamation objectives for the tailing impoundments are to establish a self-sustaining ecosystem which; (1) increases revegetation potential, (2) minimizes contamination of water from acid mine drainage and (3) minimizes erosion of soils and tailing. The impoundment I reclamation plan was tested in the tailing revegetation trials and failed (Western Reclamation Inc., and GSM, 1989). Based on the acid-producing potential of tailing materials, it is likely that the proposed reclamation plan for impoundment II would also fail.

The replaced soil cover proposed for both impoundments, under the company's proposed plan would be increased to improve revegetation potential and minimize seepage potential. Mass balance calculations indicated that 24 inches of soil and diversions of upslope runoff could limit potential seepage from all 10-year, 24-hour storm events (Tables 5-8 and Appendix B). The soil surveys were reviewed (Otterbsberg, 1988; USDA-SCS, 1989) and enough soil was identified under impoundment II to cover both impoundments with 24 inches of soil materials that meet DSL's soil salvage criteria (Chapter III, Section D.2.a. and Tables 4, 5, 6 and 15).

GSM's supplemental commitments (Hydrometrics, 1990a) which apply to the tailing impoundments include embankment reclamation, impoundment surface reclamation, surface preparation, dewatering, capping, liming, soiling and revegetation and treatment of seepage from the impoundment. These commitments are summarized below.

b. Embankment Reclamation Plan

The company's proposed plan called for the top of the embankment and the wing dikes to be rounded off; however, impoundment I would have better capacity to hold the 100-year, 24-hour precipitation event and impoundment II would still hold the 6-hour probable maximum flood (PMF). The 2.5h:1v embankment faces would be reclaimed during the mine life as soon as the design capacity is met. The sand tailing on the main embankment face would be covered with two feet of neutral oxidized waste rock before applying 24 inches of cover soil and revegetating. Wing dikes, would be revegetated directly on the untreated construction material which is alluvial borrow. No soil cover, capping, liming, or mulching are proposed over the alluvial material.

c. Impoundment Surface Reclamation Plan

Surface preparation: In the company's proposed plan , GSM would flatten the final tailing surface on both impoundments to less than a 0.6 percent grade sloping toward the back of the impoundments. Whole mill tailing, containing the sand fraction, would be used to cap the final impoundment surfaces. An undefined thickness of whole mill tailing would be placed over the more clayey slime fraction of the tailing during final spigoting. Final grading using tracked dozers would be necessary.

Dewatering: GSM would drain the tailing as quickly as possible, especially at the surface by evaporation or decanting to a sprinkling system. Chemical stabilization would be used to prevent wind erosion during dewatering until surface cover treatments can be applied. This dewatering plan has not been modified from the company's proposed plan.

Rock Cap: As a supplemental commitment, GSM would deposit a two-foot layer of neutral oxidized waste rock (rock cap) over the whole-tailing cap. The waste rock would act as a textural break over the tailing, isolating the cover soil from potential upward migration of acid, and would prevent wind erosion of tailing in the event reclamation ultimately fails.

Liming: As a supplemental commitment, GSM would treat the waste rock cap with lime before the soil cover is placed if testing shows it to be an acid-producing material.

Soil Placement: As a supplemental commitment, GSM would spread two feet of cover soil in two lifts on the rock cap. Subsoil would be placed first under the topsoil, on the oxidized/limed rock cap, then the topsoil would be replaced.

Revegetation: GSM would revegetate the tailing impoundments with a self-sustaining vegetation community. No changes were made in the proposed revegetation practices proposed by GSM in the original proposed plan.

d. Seepage/Water Treatment

As a supplemental commitment, based on mass balance calculations, GSM would construct permanent diversions to divert all runon moisture around the two impoundments to minimize potential seepage through the tailing. (DSL EA, 1989; Chapter III, D.3.c; and Appendix B). Impoundment II, as noted in Chapter III, includes the use of a synthetic liner and a plumbing system to transport fluids through the embankment face to the seepage collection system. GSM committed to treatment of any discharge from tailing impoundment II in the original proposed plan. Any treatment facility would treat objectionable effluent pumped from the pit and tailing impoundments.

To supplement the proposed plan, GSM has committed to treat seepage from impoundment II in perpetuity. Also, GSM has committed to treat seepage from impoundment I until it meets applicable water quality standards. Pumpback wells would continue to capture impoundment I leaks until the seepage could meet water quality standards. After impoundment II is reclaimed, GSM would apply for a discharge permit and treat seepage from impoundment II to meet water quality standards. Water would then be discharged pursuant to a WQB discharge (MPDES) permit. GSM would reclaim the underdrain ponds located below the two tailing embankments when water quality standards are achieved. The slurry cut-off wall could then be breached and pumpback and treatment discontinued after monitoring indicates water quality standards are assured. Reclamation of monitoring wells and other sites are specified in the company's proposed plan in Chapter III.

3. Pit Reclamation

a. Reclamation Plan

Under the current approved plans through amendment 007, GSM would cover the pit benches with alluvial borrow material and revegetate. In addition, the company would build a perimeter berm, and if necessary, fence the pit perimeter. Under the company's proposed plan (Chapter III), there is no commitment to reclaim pit benches. No supplemental commitments to the proposed plan for revegetation of the pit have been made.

b. Seepage/Water Treatment

The Metal Mine Reclamation Act deals specifically with pits that produce objectionable effluent (Chapter III, D.3.a). However, GSM has provided supplemental detail on their commitment to treat pit water, if necessary, in perpetuity. The Montana Water Quality Bureau has characterized GSM's mine pit discharges as a potential point source of water pollution(WQB Letter,December 1989 and Hydrometrics 1990a). GSM has proposed to treat a conservative postreclamation discharge estimate of 8 gpm of water they predicted would seep from tailing impoundment II as well as 6 gpm of pit water if and when necessary.

GSM's supplemental commitments for the treatment of effluent from the pit and tailing impoundments would include a combination of reverse osmosis, activated carbon treatment, and evaporation. Reverse osmosis is a common water treatment technology which could effectively improve water quality of the expected effluent.

Pit water and tailing seepage would be pumped to a water treatment facility downgradient of the proposed tailing impoundments. To meet dischargeable water quality levels, a series of membranes would be used including recycling a brine water back through the membranes to decrease the volume of brine. Treated water (14 gpm) would be pumped to a one-acre percolation pond or the ephemeral stream downgradient of the proposed tailing impoundment. Water treatment would continue indefinitely until discharge water from the pit and tailing impoundments meet discharge water quality standards. Brine water (1-2 gpm) would be evaporated in a separate lined impoundment divided into cells. The area required to evaporate the 1 to 2 gpm flow rate would be approximately 1.8 acres, assuming an evaporation rate of 1.75 feet per year (SHB, 1990). Evaporation could be enhanced by enclosing the final cells with a structure similar to that of a greenhouse with a ventilation system to eliminate precipitation input and increase net evaporation. In addition to enhancing evaporation, the enclosure would eliminate the potential for wind-blown salts which could otherwise become a problem.

Brine evaporation would result in 60 tons or 56 cubic yards of solids precipitated per year. A 7.5-foot deep, 10-acre landfill with 2-acre lined impoundments and 2h:1v slopes would be capable of holding enough material for about 2,500 years of operation (with each impoundment capable of holding enough material for about 500 years of operation). As part of the impoundment is filled it would be capped to prevent water from infiltrating and reclaimed with a soil and vegetation cover.

Solids resulting from brine evaporation would likely constitute "hazardous waste" and be subject to RCRA Subtitle C regulation. GSM proposes to dispose of these materials in a 10-acre landfill on the site. This facility would have to be constructed to meet RCRA requirements for hazardous waste disposal in effect at the time. A groundwater monitoring program for the landfill would be developed prior to mine closure after a site is selected for the landfill.

4. Miscellaneous Facilities Reclamation

The reclamation plan for miscellaneous facilities has not been supplemented since the proposed plan was determined complete in January 1989. Proposed reclamation measures are discussed in Chapter III.

C. Consequences of the Company's Proposed Plan With Supplemental Commitments.

This section addresses impacts by issue. All other impacts remain as identified in Chapter III.

1. Waste Rock Dumps Reclamation

a. Slope reduction

Reclamation success of the almost 800 acres and 300 million tons of waste rock is necessary to minimize potential impacts to water quality and aesthetics from erosion, revegetation failure and seepage, and impacts to water quantity. Observed oxidation of pyritic sulfur (DSL Memo, April 1989) and the acid production potential of the waste rock (Dollhopf, 1989) makes reclamation success even more critical. Staff expertise, literature review and discussions with reclamation specialists suggest that reclamation of the long, steep extensive 2h:1v slopes would be difficult under normal conditions. Given the nature of the waste rock, the need to uniformly apply cap rock and soil, and the potential need for application of other amendments, as well as routine revegetation practices, reclamation of the 2h:1v waste rock dump slopes at Golden Sunlight would be even more difficult to achieve. (BLM Letter to DSL, December 12, 1980; DSL Memo, February 6, 1990).

Slope reduction to 3h:1v was recommended by the regulatory agencies because of erosion potential on long, steep slopes. In order to quantify the difficulties of reclamation on 2h:1v slopes, the Universal Soil Loss Equation (USLE) was used to predict soil erosion (BLM, USLE memo, January 8, 1990) (Appendix D). The USLE was developed to estimate soil loss resulting from cultural practices, principally for agricultural uses. It was not designed for rangeland applications, however, in practice it has been found to be a useful tool for predicting soil loss in many situations. In the agencies evaluation, soil loss on 2h:1v slopes could not be reduced to levels presumed acceptable (i.e. soil regeneration approximates soil loss over time) regardless of the degree of cultural practices (Best Management Practices) applied. In contrast, soil losses were reduced to acceptable limits on 3h:1v slopes when combined with several additional agricultural practices which can't be implemented on 2h:1v slopes. Loss from water erosion was predicted to be approximately doubled on a 2h:1v slope when compared with 3h:1v slopes at GSM. Soil loss on an undisturbed 2h:1v slope was calculated to be less than five tons per acre per year.

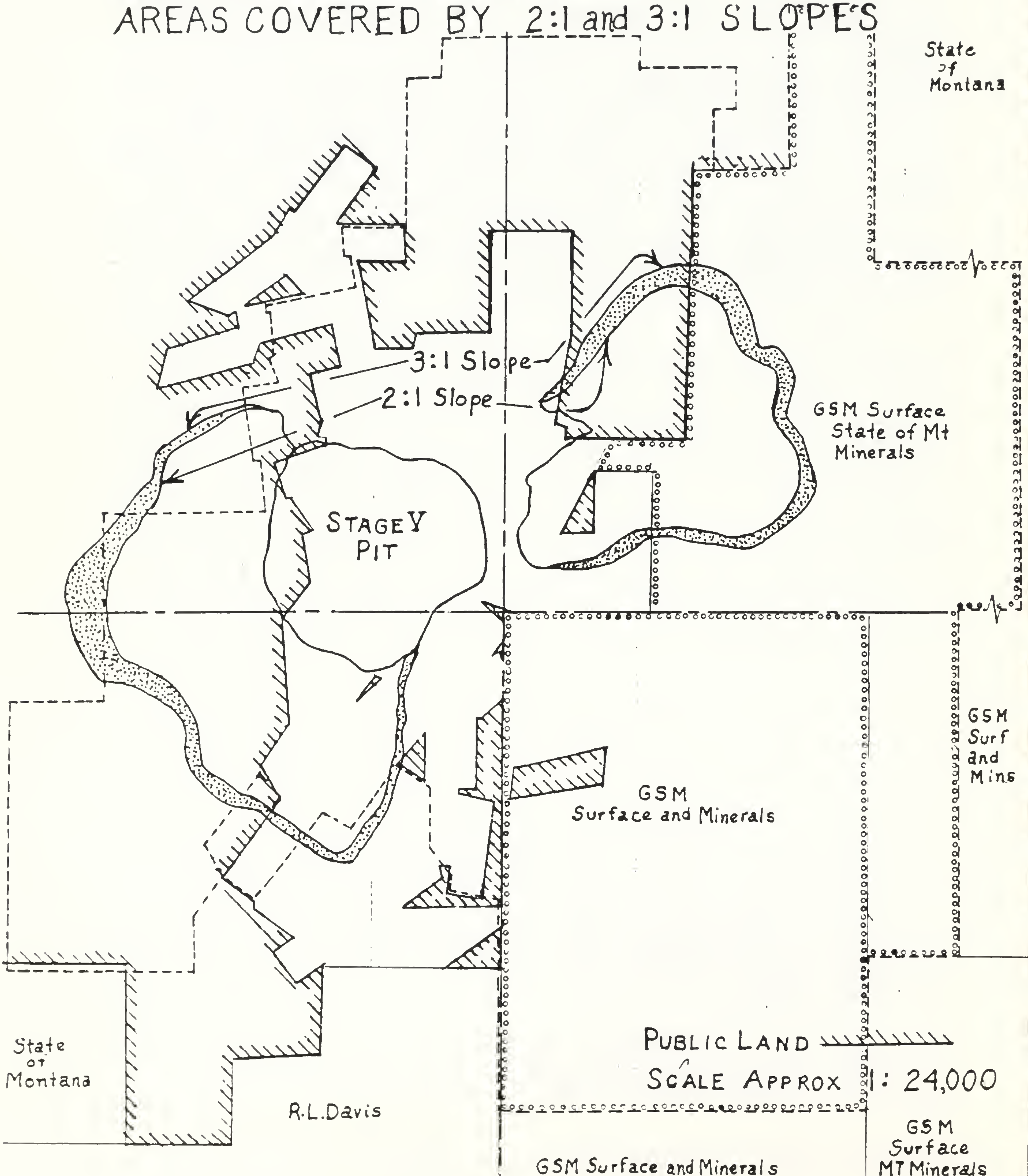
In addition to higher erosion rates, 2h:1v slope reduction would provide marginal opportunities for reclamation success on potentially acid producing materials because of equipment limitations. Equipment used for reclamation would be limited to tracked dozers operating perpendicular to the contour of the slope uniform application of the waste rock cap and soils) is difficult to accomplish with tracked dozers on 2h:1v slopes. Reduction to 3h:1v would allow the efficient use of scrapers which would ensure a more even distribution of the oxidized rock cap, lime application and in corporation if needed, and soil. Without uniform application of these materials reclamation success is questionable because contact between the soil cover and acid producing material could occur. In addition, regular farming equipment, which can not be used on the steeper slopes, could be used on 3h:1v slopes to prepare the soil surface for erosion control measures and revegetation. Finally, 3h:1v slope reduction would increase revegetation potential and provide more complete water use which would, in turn, decrease the potential for long-term acid mine drainage from the reclaimed waste rock dumps.

GSM insisted that they could successfully reclaim 2h:1v waste rock dump slopes with tracked dozers and control erosion and drainage. Also, GSM argued that the disadvantage of 3h:1v slopes is that an additional 180 acres of land would be disturbed. (GSM Letters to DSL, January 22, 1990 (2), GSM Memo, February 7, 1990).

The agencies agreed that slope reduction to 3h:1v would disturb more acreage than 2h:1v (Figure 7). Figure 7 indicates, at 1:24,000 scale, that as much as 110 additional acres could be disturbed. The agencies also evaluated the implications of additional soil salvage on the extra acres. Evaluation on a larger-scale base map shows only 87 acres would be disturbed by a 3h:1v slope reduction. Soil salvage replacement depths would be increased by 1 to 1.5 inches over replacement depths projected from acres disturbed by 2h:1v slope reduction (Appendix E).

The GSM testing of reclamation on the waste rock dump would include a comparison of 3h:1v and 2h:1v reclamation success. Uniformity of application of the rock cap and soil would also be evaluated. In order to be determined successful, the test must meet the

Figure 7. Comparison of 3h:1v and 2h:1v slopes



parameters for erosion control, soil loss, and vegetation success (DSL Memo, May 1, 1990). If 2h:1v waste rock dump slope fails to meet criteria established by the agencies, 3h:1v reclamation would be implemented immediately and no effects on concurrent reclamation would result.

However, major impacts to the proposed concurrent reclamation commitments could result if the waste rock dump test succeeds in some degree. If the reclamation on the waste rock dump slopes is marginally successful, then concurrent reclamation on waste rock dumps could be postponed indefinitely. The test could continue for up to 10 years. The waste rock dump test would monitor soluble sulfate changes over time, which would indicate potential long-term acidification in the waste rock dump. The waste rock dump test does not measure heat or oxygen relations in the dump which would indicate the effectiveness of the replaced rock cap and soil in shutting off the oxidation of pyrite. Development of the oxidation reaction could progress slowly after reclamation is implemented, thereby delaying the acidification of the soil cover and development of acid mine drainage until years after final reclamation is completed.

GSM has committed to extensive concurrent reclamation of waste rock dumps as they are decommissioned to save on bonding obligations (GSM Memo, February 7, 1990). GSM has indicated that up to $4.5 million dollars would be spent on waste rock dump reclamation alone, and reclamation of 563 acres out of 800 (primarily on the south and west side of the mine complex) could be achieved by the end of mine life. Concurrent reclamation would minimize the cumulative effects of erosion, sedimentation and visual contrast. Furthermore, precipitation that might eventually discharge as waste dump seepage could be utilized in the replaced soil cover and enhance revegetation rather than seeping into the unreclaimed waste rock dump for the life of the dump test. Another benefit of concurrent reclamation would be an improved potential for direct hauling of the oxidized waste rock cap to the dumps rather than having to stockpile and rehandle it.

An additional impact which would occur in the event the 3h:1v test plot on the south dump was not successful, is the reduced likelihood of any eventual reclamation on the south waste rock dump. It would be extremely difficult to salvage reclamation on the large waste rock dump if testing demonstrated that a 2h:1v reduction is too steep because soil resources would have been lost and/or contaminated by acid producing waste rock. The south dump occupies approximately 65 acres or 8 percent of the waste rock dump complex and is one of the most visible of the waste rock dumps.

b. Waste Rock Cap

The waste rock cap on the dump would isolate or separate the replaced soil from the underlying waste rock, thus preventing erosion of the acid-producing waste rock in the event reclamation failed on either the dump tops or the reclaimed 2h:1v slopes. The two- to three-foot layer would provide a textural break between the waste rock and the replaced soil and act to minimize the potential for capillary rise of acidified soil moisture from the underlying waste rock layers. However, the rock cap cannot stop the oxidation of the pyrite and nor does it prevent acidification of replaced soil if lateral seeps develop in the lower waste rock dump slopes. Furthermore the waste rock cap layer itself has not been shown to be neutral and no testing program has been proposed.

c. Liming

Liming would be applied to the replaced cap rock, if testing revealed the waste rock cap material was not neutral. Placement of a minimal layer of lime and incorporation into the rock cap using dozers on 2h:1v slopes has not been addressed and would be hard to achieve.

d. Soil Placement

The effectiveness of soil in reducing seepage into the waste rock dump from major storm events has been inferred from mass balance calculations performed on the tailing impoundments (Appendix B). No data has been generated on the effectiveness of the replaced soil layer in stopping the oxidation of pyrite. The increased soil depth over the neutral waste rock cap increases the chances of long term revegetation success by locating the upper soil layer at a greater distance from the acid producing waste rock. Increased soil depth should also slow down the oxidation rate but no monitoring is proposed in this alternative.

Soil resources would be completely utilized in the first attempt at reclamation and subsequent reclamation attempts to correct deficiencies would have to rely on treatments that try to make a growing medium out of alternate materials.

Salvage of existing subsoils in the area would be preferable to amending waste rock alone. At abandoned mines, for example, soil salvage may not be practicable without disturbing large areas of additional ground. At GSM, however, large acreages that would be disturbed with future expansion are currently available for additional soil salvage. Another possibility is that various portions of the oxidized waste rock may be a suitable growth medium or could be used as a barrier to prevent contamination of replaced soils over acidifying waste rock.

e. Revegetation

No supplemental commitments were proposed by GSM which would change the analysis of the revegetation plan presented in Chapter III. However, the additional rock cap, liming, and soil depth proposed by GSM under this alternative would increase the likelihood that revegetation would be successful in the long term as discussed above.

Revegetation is proposed to, in part, utilize moisture from precipitation events in order to minimize the potential for acid mine drainage. Because of the acid-producing potential of almost 300 million tons of waste rock limiting oxygen and moisture penetration into the waste rock dumps is essential. Revegetation could be initially successful as it was on the tailing impoundment I. However, if the oxygen and water supply is not effectively stopped, subsequent active oxidation of the waste rock could potentially kill the reclaimed plant community, which would increase the potential for eventual acid mine seepage. No documentation has been provided that the supplemental commitments (additional rock cap, liming, etc.) would stop the oxidation of pyrite.

f. Seepage/Water Treatment

The waste rock dumps have been established as non-point sources of water pollution as defined in ARM 16.20.701-705 and are thus exempt from the nondegradation criteria in Montana Water Quality Act if all reasonable land, soil, and water management or conservation practices (Best Management Practices) have been applied (Hydrometrics 1990a). Best Management Practices have been defined as 3h:1v for slope reduction at placer mines (Entrix, 1988). However no standards have been set for other mines in Montana (Larry Brown, WQB Personal communication. May 22, 1990).

The effect of water percolating through the 772 acres of reclaimed waste rock dumps was modeled by GSM using the EPA "HELP" model (SHB, 1989). The HELP model is not an ideal model to use for predictive purposes, however, in some cases it may provide order of magnitude accuracy and so does have some utility (P. Bierbach, Personal communication, 1990; and PRC, 1990). Its use for the purpose of calculating seepage from the waste rock dumps is probably outside the capabilities of the model.

The HELP model predictions vary from 1 gpm for the "anticipated conditions" (poor to fair vegetation on 19 to 24 inches of soil over a 24-inch layer of oxidized cap rock and no substantial erosion) to 41 gpm under the worst-case scenario (no vegetation with a compacted 6 inch soil cover). The "anticipated conditions" used in the model are unrealistic. Poor to fair vegetation on a 2h:1v slope would result in substantial erosion and increase the impacts.

Alternate calculations using water infiltration and mass balance calculations provide worst-case scenarios ranging from 25 gpm to 140 gpm. The total impact of the potential waste rock dump seepage when added to potential seepage from impoundments and pits on the east side of the mountains could be substantial.

The water quality of the waste rock leachate was assumed to be roughly comparable to the water draining from the Ohio adit (Table 7). The water would be acidic (Ph from 2.3 - 4.0) and could be high in nitrate, ammonia, nickel, cadmium, copper, iron and zinc.

In the event reclamation of the 772 acres of waste rock is not successful, impacts to groundwater could be limited by the attenuation characteristics of the geologic and calcareous soil material underlying and downgradient of the waste rock dumps. Column testing show the clays of the Bozeman group to be effective at attenuating a variety of metals present in the leachate (Table 18). (Hydrometrics, 1990 a). However, the sediments used for column testing have low hydraulic conductivity and any seepage may travel through sand lenses or horizons in the Bozeman group, or in channel alluvial deposits above the Bozeman group. These would be substantially less effective at attenuating the elevated metals content. The actual attenuation characteristics of these units in place has not been determined, nor is it known how long the units might continue to be effective at attenuating the elevated metals content.

Table 18. Summary of Ohio Adit Water and Column Leachate Analysis

SITE NAME	OHIO ADIT	SOIL EFFLUENT	SOIL EFFLUENT	SOIL EFFLUENT	SOIL EFFLUENT
SAMPLE DATE	01/15/90	01/26/90	01/26/90	01/26/90	01/26/90
DESCRIPTION		SOIL 1	SOIL 1	SOIL 2	SOIL 2
LAB	EL	EL	EL	EL	EL
REMARKS		PORE VOL.	PORE VOL.	PORE VOL.	PORE VOL.
REMARKS		1&2	3&4	1&2	3&4
PHYSICAL PARAMETERS					
SPEC. COND. (UMHOS/CM) LAB	2070	2140	2290	1970	1930
PH LAB	3.0	6.8	6.3	5.8	4.6
TDS MEAS. @ 180 DEG. C	1530	1740	1920	1720	1700
COMMON IONS					
TOTAL HARDNESS AS CACO3	835	814	872	1110	1090
CALCIUM (CA)	114	183	196	259	259
MAGNESIUM (MG)	131	87	93	112	108
SODIUM (NA)	41	207	146	66	55
POTASSIUM (K)	7	17	17	22	18
ACIDITY TO pH 9		0	0	0	3.39
ACIDITY AS CACO3	40.7				
ALKALINITY AS CACO3 (LAB)	<1	36	14	9	2
BICARBONATE (HCO3) (LAB)	<1	43	17	11	2
CARBONATE AS CO3 (LAB)	0	0	0	0	0
SULFATE (SO4)	1110	1160	1450	1230	1160
CHLORIDE (CL)	11	25	10	17	11
NUTRIENTS					
NITRATE + NITRITE AS N	0.21	0.59	0.38	0.97	0.40
AMMONIA (NH3 AS N)	<.3	<0.1	0.1	0.2	0.2
TRACE ELEMENTS					
ALUMINUM (AL) DISS	24.0	<0.1	<0.1	0.6	2.9
ALUMINUM (AL) TOTAL REC.	24.0				
ARSENIC (AS) DISS	<0.005	0.007	<0.005	<0.005	<0.005
ARSENIC (AS) TOTAL REC.	0.007				
BARIUM (BA) DISS	<0.1	<0.1	<0.1	0.2	0.1
BARIUM (BA) TOTAL REC.	<0.1				
BERYLLIUM (BE) DISS	<0.005	<0.005	<0.005	<0.005	<0.005
BERYLLIUM (BE) TOTAL REC.	<0.005				
BORON (B) DISS	<0.1	<0.1	<0.1	<0.1	<0.1
BORON (B) TOTAL REC.	<0.1				
CADMIUM (CD) DISS	0.038	<0.001	0.001	0.005	0.003
CADMIUM (CD) TOTAL REC.	0.038				
CHROMIUM (CR) DISS	<0.02	<0.02	<0.02	<0.02	<0.02
CHROMIUM (CR) TOTAL REC.	<0.02				
COBALT (CO) DISS	0.21	<0.01	<0.01	0.03	0.02
COBALT (CO) TOTAL REC.	0.21				

All quantities in milligrams per liter unless otherwise noted. Blank line indicates parameter not tested. (Hydrometrics, 1990a).

Table 18.--Continued

SITE NAME	OHIO ADIT	SOIL EFFLUENT	SOIL EFFLUENT	SOIL EFFLUENT	SOIL EFFLUENT
SAMPLE DATE	01/15/90	01/26/90	01/26/90	01/26/90	01/26/90
TRACE ELEMENTS					
COPPER (CU) DISS	6.84	0.15	<0.01	0.45	0.92
COPPER (CU) TOTAL REC.	6.91				
IRON (FE) DISS	14.1	<0.03	<0.03	0.04	0.05
IRON (FE) TOTAL REC.	23.2				
LEAD (PB) DISS	<0.01	0.03	<0.01	0.01	0.02
LEAD (PB) TOTAL REC.	<0.01				
LITHIUM (LI) DISS	<0.1	<0.1	<0.1	<0.1	<0.1
LITHIUM (LI) TOTAL REC.	<0.1				
MANGANESE (MN) DISS	1.21	<0.02	<0.02	0.13	0.18
MANGANESE (MN) TOTAL REC.	1.21				
MERCURY (HG) DISS	<0.001	<0.001	<0.001	<0.001	<0.001
MERCURY (HG) TOTAL REC.	<0.001				
MOLYBDENUM (MO) DISS	<0.005	0.041	0.012	<0.005	<0.005
MOLYBDENUM (MO) TOTAL REC.	<0.005				
NICKEL (NI) DISS	0.43	<0.03	<0.03	0.05	0.07
NICKEL (NI) TOTAL REC.	0.43				
SELENIUM (SE) DISS	<0.005	<0.005	<0.005	<0.005	<0.005
SELENIUM (SE) TOTAL REC.	<0.005				
SILVER (AG) DISS	<0.005	<0.005	<0.005	<0.005	<0.005
SILVER (AG) TOTAL REC.	<0.005				
VANADIUM (V) DISS	<0.10	<0.10	<0.10	<0.10	<0.10
VANADIUM (V) TOTAL REC.	<0.10				
ZINC (ZN) DISS	6.04	0.03	0.01	0.77	1.01
ZINC (ZN) TOTAL REC.	6.04				

All quantities in milligrams per liter unless otherwise noted. Blank line indicates parameter not tested. (Hydrometics, 1990a).

Depending on the methods used for slope reduction, there may be compacted layer which develop in the waste rock dump, regardless of ultimate slope angle, which would act as barriers to the downward migration of water in the dumps. These layers could lead to the development of seeps on the side slopes which could contribute to areas with revegetation failure, increased erosion and mass failure of replaced soil layers. The waste rock dump test slope for reclamation developed as part of the supplemental commitments would be crucial for determining what levels of reclamation are possible on the 2h:1v slopes. If the test shows that effective reclamation of the waste dump slopes at 2h:1v is not practical, then GSM would modify the reclamation to whatever slope angle is suitable based on results from the reclamation test plots. There would be no long slopes available for use as test plots until 1993 or 1994. Eventual seepage rates from any 2h:1v waste rock dump test slopes may not be conclusive at the time final reclamation plans are implemented in 2005. Eventual reduction of slopes to 3h:1v, if the dump test fails, would result in loss of all replaced soil on the slopes.

2. Tailing Impoundments

a. Embankment Reclamation Plan

Reclamation of the wing dikes as proposed in the application for amendment is evaluated in chapter III and has not been modified. GSM's supplemental commitments to cap the 2.5h:1v reclaimed slopes on the sand tailing embankment face with two feet of rock and two feet of soil would not eliminate oxygen in the sand tailing portions of the central embankment structure.

The goal of the reclamation plan for tailing impoundments with acid-producing tailing should be to limit oxygen and water availability (US Bureau of Mines, 1989). By eliminating oxygen and water, the production of acid is limited as well. Generally, to limit oxygen and water to the tailing requires the use of some restrictive layer such as a liner, clay cap, cementitious materials, etc. The use of a restrictive layer to limit oxygen also limits potential recharge of the tailing and therefore, potential seepage as well. This ultimately minimizes water treatment needed in perpetuity.

The tailing have a proven ability to generate acid based on tailing reclamation trials conducted on impoundment I, the quality of water draining from the Ohio adit (Table 7), and results of extraction analyses (Table 19). An estimate of seepage water quality and relevant state and federal water quality standards is included in Table 19.

The agencies have no data to indicate the effectiveness of the revised reclamation plan in limiting the availability of oxygen. In addition, there is some question about the predicted seepage volume. Therefore, the potential for lateral acid seep development downslope on the embankment face is a possibility from precipitation alone. In addition, if the underdrain system eventually fails, phreatic buildup in the impoundments could force lateral seeps out the wing dikes or sand tailing embankment faces as well.

Table 19. Results of various extraction analyses on the Golden Sunlight tailing material

Parameter	1980*	1984**	EPA+ Acute	EPA+ Chronic	State ++ Water Supply	St.Irri-gation
Cadmium	0.003	0.00	0.003	0.001	0.01	0.05
Copper	65.2	14.2	0.05	0.03	---	5.0
Lead	0.045	0.33	0.01	---	0.05	10.0
Nickel	0.30	0.71	0.22	4.25	---	2.0
Zinc	1.95	0.35	0.00	0.80	---	10.0
Selenium	1.10	0.01	---	---	0.01	0.02

*DSL, 1981. Draft EIS, Appendix F
**Multitech, Letter to GSM August 28, 2984
+EPA, 1986. Quality Criteria for Water; (EPA 440-5-86-001).
++State Public Water Supply and Irrigation: Montana WQB, 1984. prepared by Water Quality Bureau, Environmental Sciences Division, Department of Health and Environmental Sciences, 305(b) Report, October 1984, 19p.

It is probably not possible to apply a restrictive layer on 2.5h:1v slopes. The tailing slopes could be cemented in place and left as is, or a replacement soil layer could be placed on top which would probably slump. If a restrictive layer could not be applied and oxygen and water infiltration could not be eliminated, eventual reclamation failure on portions of the embankment face can be assumed. The rock cap should prevent any erosion of tailing off the embankment face and maintain embankment stability even if revegetation fails. The waste rock cap may need to be limed if it is not neutral based on testing.

b. Impoundment Surface Reclamation Plan

i. Surface Preparation and Dewatering

Preparation of impoundment surfaces has not been changed by GSM supplemental commitments. Therefore the evaluation in chapter III would remain unchanged.

ii. Waste Rock Cap

The neutral waste rock cap would be placed as soon as the tailing impoundment surfaces begin to dry. The rock cap is a supplemental commitment designed to provide a textural break between the replaced soil cover and the acid producing tailing, and to guarantee that if ultimate revegetation failed and the soil was lost, that the tailing would not be re-exposed to wind and water erosion. The waste rock cap was not designed to eliminate oxygen from the tailing surfaces.

The back portions of the impoundments may not dry as well as the sandier portions near the front of the impoundments. If GSM cannot operate equipment on the surface, the surface cannot be reduced. A geofabric, more waste rock, or other measures may be needed to provide a working surface for the equipment placing the rock cap. The geofabric, however, would not limit oxygen and water from getting into the tailing materials.

iii. Liming

The need to lime the waste rock cap would not change under this alternative. If other alternative cover materials are selected, the need to lime them may need to be evaluated,as well.

iv. Soil Placement

The increased soil depth commitment from 6-12 inches to 24 inches was based on the available soil left to be salvaged under impoundment II. No data is available on the effectiveness of the replaced soil and waste rock cap in limiting the availability of oxygen and water to the tailing surface. No analysis was conducted on the borrow materials used to build the wing dikes to determine its suitability as an alternate soil/subsoil source and its influence on oxygen and water elimination.

v. Revegetation

GSM has not proposed any supplemental changes to the revegetation plan under this alternative.

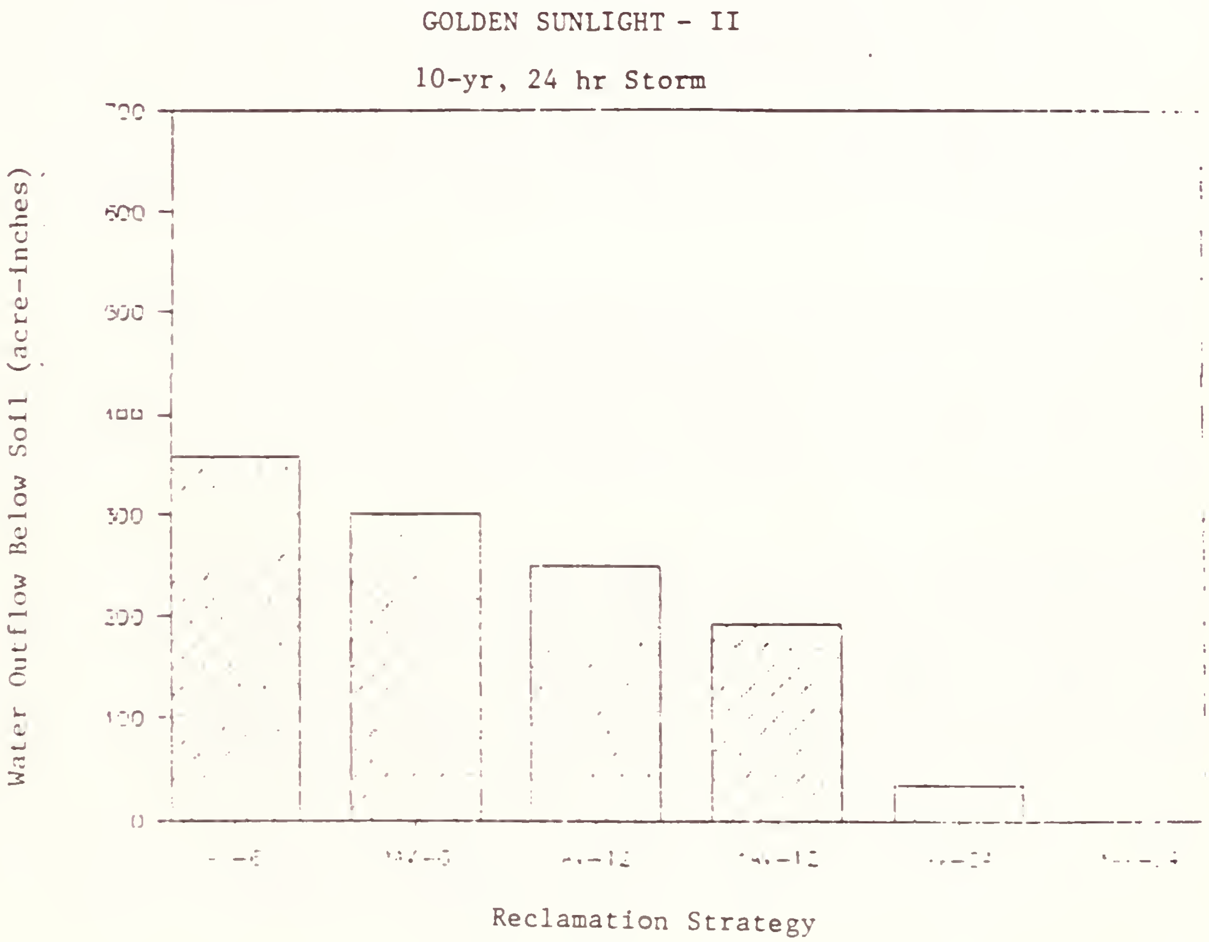
c. Seepage/Water Treatment

GSM's proposal to construct diversions, under this alternative, would divert runon moisture around the impoundments. If the diversions were adequately sized, there would be little chance of subsequent failure. However, if diversions were under sized eventual chances of runon moisture reaching the impoundment surface and creating the potential for increased seepage could occur.

In the Draft EA prepared in July 1989, the agencies prepared mass balance calculations for the tailing impoundments (Appendix B). These calculations were prepared for specific storm events and show outflow from tailing impoundment II varying from 0 to 31 gpm averaged over a year, depending on alternative reclamation strategies and the storm recurrence interval (Figure 8). Mass balance calculations for a 10-year, 24-hour storm event on tailing impoundment II with the proposed soil cover show outflows of 5.2 gpm when averaged over an entire year. The calculations did not include any allowance for annual precipitation. An increase in soil cover reduced the amount of seepage regardless of the storm recurrence interval (DSL, 1989).

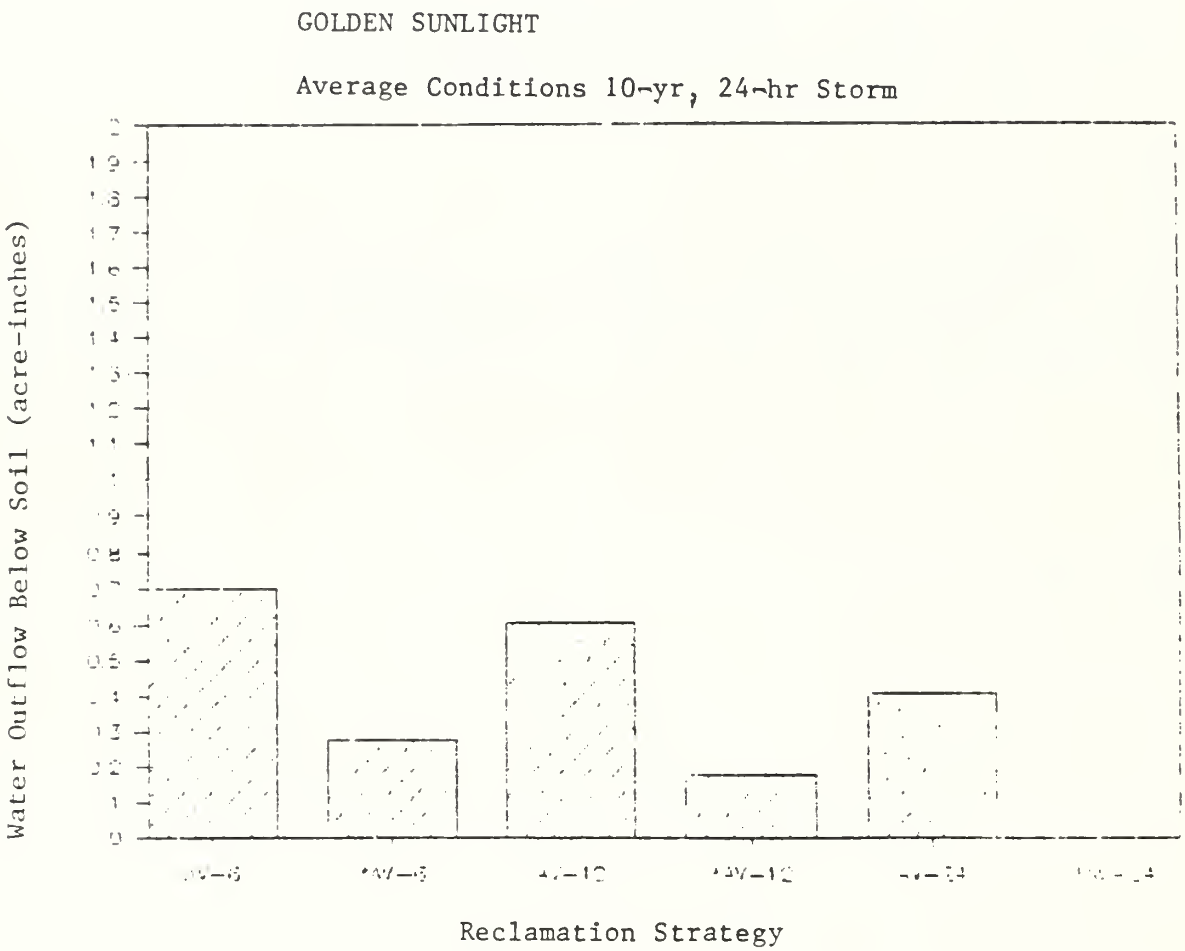
Mass balance calculations for impoundment I showed the relationships among various topsoil depths and 10-yr, 24-hr storm event runon (Figure 9). Impoundment I was designed with a slurry cutoff wall. Pumpback wells were installed discovering that the slurry cutoff

Figure 8. The results of the mass balance calculations for proposed reclamtion plan for impoundment II using average antecedent values



The results of some alternative reclamation strategies for impoundment II using average antecedent values (AV). The values following the "AV" are the replaced topsoil depths (6, 12, or 24 inches). Labels with a preceeding asteric indicate diversion of all upslope runon, values without a preceeding asteric assume no diversion.

Figure 9. The results of the mass balance calculations for proposed reclamation plan for impoundment I using average antecedent values



The results of some alternative reclamation strategies for impoundment I using average antecedent values (AV). The values following the "AV" are the replaced topsoil depths (6, 12, or 24 inches). Labels with a preceeding asteric indicate diversion of all upslope runon, values without an asteric assume no diversion.

wall was not functioning as planned and seepage was migrating eastward. The pumpback wells are currently returning approximately 400 gpm to impoundment I. The majority of seepage for impoundment I will intercept the slurry cutoff wall. When the pumpback is discontinued, underflow and seepage through the impoundment may accumulate behind the cutoff wall. This groundwater may overtop the cutoff wall and develop seeps.

Over time a decrease in the efficiency of the plumbing system in Impoundment I may result in a rise of phreatic levels within the impoundment and drainage through the impoundment I bottom or the embankment face. Impoundment II uses a synthetic liner and incorporates a plumbing system to transport fluids through the embankment face to a collection system. As is the case with impoundment I, over time the efficiency of the plumbing system of impoundment II may decrease and result in increased drainage through the embankment face if recharge is sufficient. Nothing can be done to maintain the interdrain plumbing system in perpetuity.

After shutdown, seepage from tailing impoundment I would be basic at first. This water could not be buffered and would constitute degradation. This water would have to be pumped to the proposed treatment facility through the existing pumpback system. This operation would be more maintenance-intensive and costlier than the system on tailing impoundment II. After the water acidifies from pyrite oxidation, it would begin to buffer to some degree.

Because of the unknown quantities and qualities of the potential leachate, the agencies requested that GSM conduct a seepage analysis. GSM undertook this analysis and employed the HELP model discussed earlier (SHB 1989, SHB, 1990). The model was designed for landfills employing relatively flat caps. (The agencies believe this comparative model is not an ideal model for predicting seepage. It may provide order of magnitude estimates, and so does have some utility). GSM concluded that a maximum of 12.1 gpm could seep from tailing impoundment II during a 100-year, 24-hour storm event (SHB, 1989: Table 2). GSM used the wettest year of the three years of on-site monitoring data. These three years were all below average precipitation years for the area (PRC, 1990). The agencies evaluation of GSM's analyses is summarized as follow:

* GSM Report No. 2 (SHB, 1990) assumes the impoundment cover design includes a 14-inch thick loam vegetative layer, a thick compacted loam vertical percolation layer, a 24-inch thick layer of tailing slimes. These design assumptions are not reflected in information contained in the text of GSM's report submitted to DSL. For example, the test does not propose an impoundment over design that would incorporate lateral drainage collection systems or compaction of the loam soil cover. Using the HELP model, the agencies performed a sensitivity analysis by varying landfill design input data to model the stated GSM cover design (PRC, 1990). This sensitivity analysis suggests the percolation rate through a 24-inch revegetated loam cap above a 24-inch waste rock vertical percolation layer may be 12.8 gal-

lons per minute (gpm) higher than the percolation rate suggested by GSM (SHB, 1990).

* The agencies analyzed the annual precipitation for the period of record (1917 to 1988) (PRC, 1990). The climatological information indicates that 1987 precipitation data presented by GSM are average or below average compared with precipitation data for the 1917 to 1988 period of record. In addition, the climatological information indicates that precipitation in year 1975 was above average.

* The agencies developed a reasonable worst-case analysis using 1975 precipitation data (PRC 1990). Initial soil water content was set at field capacity. Results suggest the rate of percolation through the impoundment cover using 1975 precipitation data may be between 12.9 and 24.9 gpm depending on model assumptions for landfill design. Percolation rates using 1975 data are slightly higher than percolation rates prediction in the GSM worst case analysis (Table 20).

* The agencies assume seepage for an average year to approach 15 gpm through tailing impoundment II with the supplemental covers proposed (PRC , 1990). Additionally, the agencies believe that tailing impoundment I would also seep approximately 15 gpm on an average year. This seepage would mix with the natural flow in the alluvial channel estimated at 5 gpm and flow to the slurry cut-off wall. These waters would be of poor quality, initially basic and high in cyanide and metal-cyanide complexes (350 ppm), eventually turning acidic (Ph 3) with chemistries similar to the Ohio adit (Table 7). The agencies have proposed further mitigations in Chapter V to handle this situation.

* HELP model results presented by GSM are considered to be adequate "order of magnitude estimates" of percolation through the proposed tailing impoundment cover. A reasonable worst case analysis suggests percolation through a 48-inch thick cover may approach a maximum rate of 24.9 gpm in extremely wet years (PRC, 1990).

Table 20. Summary of HELP computer simulations to estimate percolation from the Golden Sunlight Mine tailing disposal facility.

Computer Run No.	Reference[1]	Annual Precipitation	Annual Volume Precipitation (inches)	Assumed Cover Design[2] 1:2:3:4	HELP Simulation Results Percolation from lowest layer (assumes poor vegetation) (acre-feet per year)	(gallons per minute)
1	SHB	1987, no storms	14.8	V:V:L:B	1.5	0.9
2	SHB	1987 + 2yr-24hr storm	15.9	V:V:L:B	1.5	0.9
3	SHB	1987 + 5yr-24hr storm	16.3	V:V:L:B	5.1	3.2
4	SHB	1987 + 10yr-24hr storm	16.7	V:V:L:B	10.5	6.5
5	SHB	1987 + 25yr-24hr storm	16.8	V:V:L:B	11.7	7.3
6	SHB	1987 + 50yr-24hr storm	17.4	V:V:L:B	18.3	11.4
7	SHB	1987 + 100yr-24hr storm	17.5	V:V:L:B	19.3	12.1
8	PRC	1987, no storms	14.8	V:V	22.2	13.8
9	PRC	1975, no storms	20.9	V:V:L:B	20.8	12.9
10	PRC	1975, no storms	20.9	V:V	40.1	24.9

[1] SHB= Sergent, Hauskins & Beckwith Report No. 2
PRC= Planning Research Corporation technical memorandum

[2] Cover design modeled as either 2 or 4 layers as described below:
V:V:L:B = Assumes the design includes a 14-inch loam vegetative layer, a 10 inch compacted loam vertical percolation layer, a 24-inch thick lateral drainage layer, and a 24-inch thick layer of tailings slimes.
V:V = Assumes the design includes a 24-inch loam vegetative cover, and a 24-inch waste rock vertical percolation layer.

GSM's option for treatment of seepage is viable; however, our analysis of increased seepage necessitates that the numbers proposed be revised. This additional mitigation is considered in Chapter V.

3. Pit Reclamation

a. Reclamation Plan

The pit walls may not be feasibly reclaimed as is allowed in the Act, 82.4-336(5), MCA. No analysis of the feasibility of any pit reclamation has been performed to date.

b. Seepage/Water Treatment

There will be no reclamation in the pit. GSM has committed to the treatment of waste water from the pit in order to avoid pollution of either groundwater or surface water. In the company's proposed plan GSM estimated 90 gpm would enter the pit through stage V.

In response to the agencies' request, GSM gathered more data on the pit hydrology and ultimate fate of the effluent (SHB, 1990). GSM concluded that a steady-state condition would develop after 400 years and maintain a lake of 40 acres at the 5,270-foot elevation with a seepage of 2 gpm (SHB, 1990). GSM contends that no groundwater would seep through the pit walls for the first 75 to 150 years. These conclusions were based on a mass-balance approach. This approach calculates the inflow parameters minus the outflow parameters to calculate the amount of storage until steady-state conditions are reached. Hydraulic conductivity was calculated as 2.2×10^{-6} cm/sec, from an analysis of the Ohio adit discharge. Hydraulic gradients were considered as high as 0.3 to 0.1. The inflow-outflow parameters considered were as follows:

Inflows

+ Runoff from outside the pit. (62 acres)
+ Direct precipitation (100 percent to the accumulated water within the pit).
+ Runoff and groundwater inflows within the pit (20 percent of precipitation [HELP Model, Method of Miller, 1982])(see SHB, 1990)
+ Groundwater from outside the pit. (5 - 10 percent of precipitation [Method of Miller, 1982])

Outflows

+ Evaporation (from the accumulated water within the pit). (35 inches, 100 percent)
+ Groundwater (2-6 gpm from Darcy's Law $K= 2 \times 10^{-6}$ cm/sec from Ohio Adit and a hydraulic gradient of 0.036 calculated from the pit rim to the Bozeman aquifer)

Table 21 estimates the changes needed in these conditions to effect the worst-case condition; i.e., discharge at the 5350 elevation. GSM concluded seepage would not take

Table 21. Estimated Changes of Water Balance Parameters Required to Produce Worst-Case Conditions

Water Balance Component	Projected Steady State Conditions* (from Table 5)		Worst Case Conditions**		Change in Steady State Conditions Required to Produce Worst Case Conditions (Percent)
	Unit Rate (acre-feet acre/year)	Volume (acre-feet/year)	Unit Rate (acre-feet acre/year)	Volume (acre-feet/year)	
Runoff from Outside the Pit	+0.09	+6	+0.59	+39	+650
Runoff from Within the Pit	+0.23	+38	+0.45	+68	+100
Direct Precipitation	+1.12	+47	+1.67	+99	+50
Groundwater Inflows	+0.12	+32	+0.24	+65	+100
Evaporation	-2.92	-123	-2.35	-139	-20

*Inflow/outflow parameters are in balance at 123 acre-feet/year. Steady state accumulated water surface is about 5,270 feet.

**Surface water outflows are projected to occur when water levels within the pit rise over the 5350 spill elevation. A 33 acre-feet/year minimum increase in net pit inflows, when compared with the projected steady state conditions, is estimated to produce surface water outflows from the pit. To determine parameter sensitivity, each parameter is varied to account for the entire 33 acre-feet/year imbalance while the other parameters are held at levels.

place until the water level in the pit is above the water table peripheral to the pit wall, i.e., Bozeman aquifer east of the Golden Sunlight fault, approximately the 5150-foot level.

Groundwater seepage is predicted to be of a quality comparable to the Ohio adit (Table 7). In column leach tests (Hydrometrics, 1990a), GSM calculated the attenuation of metals from a 6 gpm discharge (assumes water level in pit at the 5,350-foot level) in the Bozeman Group formation to be acceptable (lower than primary drinking water standards) (Table 18). Actual attenuation in the Bozeman Group is not known. Even with their analysis, GSM has chosen to treat the pit discharge as described in the previous section.

The agencies disagree that several of the input parameters used by GSM are conservative estimates and that individual methods are applicable. GSM has based much of its input data on calculations from the Ohio adit discharge and on inflow calculations using Miller's 1982 method for seepage at a slope face. Miller's analysis of seepage at a slope face does not take into account the rising elevation of a lake in a pit and is not applicable to GSM's situation (Dr. Miller, Personal communication, 1990). Goodman's equation used for the analysis of hydraulic conductivity from the Ohio adit assumes isotropic and homogeneous conditions and as stated by Freeze - Cherry (1979: page 491) "may be suitable for order-of-magnitude design-inflow estimates,..." It is believed, taking all the hydraulic conductivity tests performed by GSM into account, and the fact that the zone around the mine would be artificially fractured by blasting and depressured by excavating, that the calculated hydraulic conductivity could be low by an order of magnitude. Furthermore, GSM's contention that no vertical component of flow would exist beneath the pit or that flow would not travel south through the fractured bedrock is not substantiated by data.

A review of Table 21 reveals that a reasonably foreseeable change in a number of parameters is sufficient to take the water balance towards the worst case. For example, a change in pit wall runoff of only twice the amount calculated, or 45 percent of direct precipitation, would tip the balance to a worst case scenario, as would twice the inflow from groundwater or a 20 percent drop in the 100 percent calculated evaporation rate from the lake. Given that the pit walls would be bare, highly fractured, and in shadow most of the day, it is easy to conceive of increased runoff as well as decreased evaporation in a pit protected from wind and direct sunlight much of the time. Furthermore, an order of magnitude or one-half order of magnitude increase in the hydraulic conductivity would more than allow enough water to inflow from the northern Bull Mountains. This cone of depression or groundwater catchment area would expand indefinitely in response to increased mine pumping.

Given these concerns, the inflow calculations could be low by an order of magnitude and that the pit could likely produce up to 60 gpm and seepage may commence sooner than anticipated. Furthermore, the possibility of eventual surface discharge at the 5,350-foot level exists. For this reason, the agencies would bond for water treatment at a minimum of 60 gpm pit seepage and stipulate further mitigations of monitoring and data acquisition, and pit reclamation, as outlined in Chapter V.

The consequences of treatment of approximately 60 gpm from the pit and 35 gpm from the two tailing impoundments would be substantially larger treatment facilities than anticipated. While the size of the actual treatment facility might change very little, the evaporation pond required to evaporate the brine water would be approximately 9 acres. Brine evaporation at these treatment rates would generate approximately 430 tons of precipitated solids per year. The proposed landfill disposal facility would need to be about 70 acres rather than the ten acres proposed.

4. Miscellaneous Facilities

The potential for acid production around other miscellaneous facilities has not been addressed. A potential for haul roads to be cut through or contaminated by unoxidized rock types exists but was not addressed in the reclamation plan. The areas around the mill would be acid-producing from ore hauling and crushing activities, if left untested and untreated at the end of mine life. The borrow areas reclamation plan has not been modified.

CHAPTER V - COMPANY'S PROPOSED PLAN WITH SUPPLEMENTAL COMMITMENTS AND ADDITIONAL MODIFICATIONS (PREFERRED ALTERNATIVE)

A. Introduction and Description of Issues

The major issues which have been identified through the draft EA released in July 1989 have been discussed above. Several additional modifications have been developed by the Montana Department of State Lands and the Bureau of Land Management in response to the draft EA and the subsequent information supplied by GSM (Dollhopf, 1989; SHB, 1989 and 1990; and Hydrometrics, 199(Additional information has indicated the key to successful reclamation of reactive mine w .es is elimination of oxygen and water available to the reactive materials.

The company's proposed plan and supplemental commitments have not addressed minimizing oxygen and water available to the reactive mine wastes. The following additional modifications have been developed to reduce oxygen and water available to the reactive materials. The total amount of eventual seepage out of the waste rock dumps, tailing impoundments, and mine is unknown, although projections have been made in Chapters III and IV. The implementation of the following modifications would further limit the amount of water that would need to be treated in perpetuity.

Modifications are specific to reclamation issues; ther. . those resources such as wildlife or transportation not affected are not discussed.

B. Reclamation Plan

1. Waste Rock Dumps

The objective of the waste rock dump reclamation plan is to minimize the introduction of oxygen and water into the dumps to improve the likelihood of long-term reclamation success.

a. Slope Reduction

Additional modifications which would help ensure rec' on potential of the extensive areas of steep dump slopes and mitigate the consequences on concurrent reclamation of the proposed 2h:1v dump test include:

- Concurrent reclamation of all portions of dump tops not needed for vehicular traffic or proposed for future slope reduction.

- Additional monitoring and research for dump slopes undergoing concurrent reclamation in order to determine the effectiveness of reclamation in limiting the oxidation of pyrite in the dumps. Likely parameters to measure include: air permeability, oxygen, carbon dioxide and sulfur dioxide concentrations, temperature and moisture content.

- Further evaluation of benching or other slope breaks to minimize the total effective slope length.

b. Rock Capping

No changes are proposed in the waste rock cap.

c. Liming

Two modifications are proposed with regard to liming:

- Lime would be incorporated into the rock cap horizon, the amount and method of application would be based on field testing developed during the reclamation tests, and

- Monitoring of the potential acid-producing characteristics of all waste rock, including the oxidized cap rock as the material is placed on the dumps would be implemented.

d. Soil Placement

Additional soil requirements would include:

- Testing of replaced soil to evaluate the effectiveness of amendments in correcting physical or chemical deficiencies which may be inherent in the additional subsoils which would be salvaged.

e. Revegetation

No changes are proposed in the revegetation plan.

f. Seepage/Water Treatment

Two modifications are also proposed with regard to the potential for seepage or water treatment impacts. These modifications are:

- Diversion of water around the tops of the reclaimed dumps and also off the top of the reclaimed dumps via engineered drainageway systems sized to handle a 100-year, 24-hour precipitation event, and

- Construction of drainage or seepage barriers beneath the waste rock dumps made of calcareous subsoils and constructed on the contour of the slope.

2. Tailing Impoundments

a. Reclamation Objectives

The proposed reclamation objectives for the tailing impoundments include measures to minimize the introduction of oxygen and water into the impoundments in order to improve the likelihood of long-term reclamation success and to reduce the amount of seepage which might ultimately need to be treated in perpetuity.

b. Embankment Reclamation

Two additional modifications are proposed for embankment reclamation, as follows:

- In order to mitigate the potential seepage and subsequent impacts to impoundment stability and to improve the likelihood of successful reclamation on the embankment face, a wedge of net neutralizing material, either waste rock or calcareous borrow material, should be applied to the front of the embankment face to bring the overall slope of the embankment face to 3h:1v. This material would form a "wedge" ranging from several feet at the base to 24 inches at the crest, and

- The sand tailing reclamation test plot discussed in the current amendment should be initiated as soon as practical.

c. Impoundment Surface

Additional modifications proposed for the reclamation of the impoundment surfaces include:

- Requiring a layer of 18 inches compacted clay (hydraulic conductivity 1×10^{-7}) to be placed in two 9-inch lifts in the cover layer, or other method of limiting the availability of oxygen and water which would prevent the continued oxidation of pyritic tailing material. The actual amount of clay would be determined by additional research or testing. Any combination of cover materials which can be shown to achieve an equivalent reduction in oxygen and water infiltration would be acceptable. The impermeable cover layer would be applied to the entire impoundment surface and carried to the crest of the embankment.

d. Seepage/Water Treatment

In order to quantify impacts as well as to minimize seepage, the following would be required:

- Monitoring of the reclamation of impoundment I to quantify the amount of seepage and effectiveness of reclamation in limiting oxygen and water. The monitoring should continue until applicable water quality standards are met. Monitoring should include phreatic water level in the impoundment soluble sulfate production, heat, oxygen reactions, and other measures for evaluating the effectiveness of reclamation in stopping the reaction, and

- The pumpback wells would continue to operate and discharge into impoundment II during mine life. If monitoring reveals seepage calculations to be substantially different from forecasts, GSM should revise treatment plans and areas accordingly.

3. Pit Reclamation

a. Reclamation Plan

The agencies would add the requirement that:

- Reclamation of benches or talus slopes within the pit using tree plantings on oxidized materials or amended unoxidized materials in order to reduce visual impacts and increase the consumption of water. Total reclamation of pit benches is not feasible due to the friability of the benches.

b. Seepage/Water Treatment

Three additional modifications are being proposed to monitor flows associated with the pit. These include:

- Monitoring of water balance in the pit throughout the remainder of the mine life and report inflow calculations yearly. This data would be used to fine tune the calculations and adjust water treatment volumes and costs as necessary. Treatment facilities to be adjusted accordingly.

- Diversion of water around pit perimeters via an engineered drainageway system.

- Analysis of the potential for vertical flow beneath the pit and fracture flow to the south and any inflow to the pit from the east. This data would be used to determine if water would be allowed to accumulate in the pit and to what level. A review of treatment techniques would be required at closure based on the information accumulated during the remaining mine life. These may include: sealing the bottom of the pit in order to let water accumulate during the winter months to be treated during the summer when evaporation would be most effective, the development of a well or series of wells to prevent accumulation of water in the pit or alkaline flooding of the pit.

4. Miscellaneous Facilities

All areas which have the potential for the production of acid mine drainage at the conclusion of operations would be required, as an additional modification, to be tested and measures taken to either cover and revegetate the areas or channel drainage to areas subject to treatment.

5. Additional Measures for Consideration

The measures identified below may have some utility in improving reclamation success. They are included as measures which may warrant further consideration by the company as additional information is developed during the remainder of the mine life. They would not be additional modifications or stipulations, but rather may be considered as alternate methods for improving the reclamation.

- Use of a bactericide on some or all slopes prior to seeding,
- Use of a filter fabric or geotextile membrane to prevent tailing mixing with cap rock in areas of the impoundment which may be slow to dewater,
- Placement of a clay cap on the dump tops if monitoring indicates other measures to limit oxygen and water availability have been ineffective,
- Reduction of slopes from 2h:1v to 3h:1v or less with concurrent reclamation,
- The use of surplus oxidized waste rock on all reactive mine wastes based on priorities identified by monitoring of concurrent reclamation dur[illegible] the remainder of mine life, and/or
- Consideration of a clay cap extending down the embankment face on impoundment II, based on monitoring of the reclamation at impoundment I.

C. Consequences of Additional Mitigating Measures

1. Waste Rock Dump Reclamation

a. Slope Reduction

Concurrent reclamation of all dump tops which are (1) at final elevation, (2) not needed for vehicular traffic, and (3) not subject to removal during future slope reduction operations, would allow reclamation of approximately 50 percent of all dump tops, or 125 acres, prior to cessation of operations. This reclamation, in conjunction with the proposed monitoring of the oxidation of pyrites, would provide important information on the effectiveness of the reclamation both on reducing the oxidation reaction, and on the effect of the oxidation on the reclamation efforts. This information would be used to supplement and modify the existing reclamation plan.

Additional breaks in slope length may help to minimize erosion on the waste rock dump slopes.

b. Waste Rock Cap

There would be no changes from the consequences discussed in Chapter IV.

c. Liming

The use of lime would act to decrease the potential for future acidification of the soil. Testing on the reclamation slopes may show it to be unnecessary.

Monitoring of waste rock would make certain cap rock is in fact neutral. If the cap rock is not neutral, this information would be used to calculate lime application rates.

d. Soil Placement

There would be no changes from the impacts discussed in Chapter IV.

e. Revegetation

There would be no changes from the impacts discussed in Chapter IV.

f. Seepage/Water Treatment

Diversion of water around and off the tops of the reclaimed dump slopes during major storm events would reduce the amount of waterflow over the tops of the dumps and subsequent erosion.

Drainage or seepage barriers may help to prevent surface seepage at the toe of the waste rock dumps.

2. Tailing Impoundments

a. Embankment Reclamation

Covering the face of the embankments with a wedge of net neutralizing material would take the place of the rock cap. This would act to neutralize any seeps which might develop in the face of the embankment as the engineered drainageways become less efficient over time. Because seeps are more likely to develop at the base of the impoundment if the phreatic water level rises, the thicker layer of material at the base would have the capability to neutralize material for a longer time. If the phreatic water level rises, the wedge of material would also act to improve the stability of the embankment. This would likely require some modification to the reclaim pond below the embankment.

Initiation of the sand tailing test plot may help to determine the effectiveness of alternative treatments on the embankment.

b. Impoundment Surface

The use of a horizon of clay would act to further isolate the acid tailing material from water and oxygen, thus increasing the chance of successful reclamation and potentially reducing the amount of water which might ultimately need to be treated in perpetuity. This proposal may prove to be difficult to accomplish due to geotechnical considerations of working on the dewatered tailing impoundment.

c. Seepage/Water Treatment

The proposed monitoring would enable GSM to anticipate any needed changes in the reclamation and treatment plan based on the results of ongoing reclamation at tailing impoundment I.

Pumping into impoundment II would probably require rearranging the existing pumpback circuit. This would eliminate the need to treat any seepage from impoundment I during the remainder of the mine life. Pumping into lined impoundment II would further reduce the potential for unregulated seepage during the remainder of the mine life.

3. Pit Reclamation

a. Reclamation Plan

Reclamation of the pit benches or talus slopes and diversion of water around the perimeter of the pit would both act to reduce the amount of runoff into the pit which might eventually need to be treated. Reclamation may also serve to reduce the visual impacts of the pit.

b. Seepage/Water Treatment

The environmental consequences of the proposed plan for seepage and water treatment are not certain because data on the amount of water ultimately needing treatment is limited. The environmental consequences of the GSM proposal are addressed in Chapter IV. The proposals for additional modifications do not substantially alter the nature of those consequences. However, if the proposed measures are effective at reducing the volume of water to be treated, then the scope of the consequences can be substantially reduced.

4. Miscellaneous Facilities

The proposals to either cover and revegetate areas with the potential for acid mine drainage or to channel any drainage to areas which would be treated would limit unregulated seepage or discharge from these areas.

5. Additional Measures for Consideration

Use of a bactericide prior to seeding or during operations has been shown to be effective at reducing the rate of oxidation of pyrite during operations and thus improving the likelihood of successful revegetation. The use of a filter fabric, geotextile membrane, or additional waste rock would prevent mixing of the cap rock with the underlying acid tailing material. Any mixing of the acid tailing material and the neutral cap rock may act to increase the likelihood of future soil acidification and subsequent vegetative failure. This may only be a problem on those portions of the tailing impoundments which are not fully dried prior to the initiation of reclamation.

The placement of a clay cap on the dump tops would act to further reduce the infiltration of water into the waste rock dumps. The monitoring wells might show this to be an effective alternative reclamation strategy.

The consequences of the proposed additional mitigating measures would be the disturbance of approximately 150 additional acres and the subsequent loss of this existing vegetative community and related wildlife resource values. Soil salvage on these additional acres would offer an opportunity to increase the total amount of soil available for reclamation and marginally increase the average depth of replaced soil on both the north and south and west dump complexes. On the north dump area additional slope reduction would offer the opportunity to salvage 140,225 bcy of additional soil. This would increase the possible average redistribution depth from 36 to 36.5 inches. On the west and south dump complex additional slope reduction would salvage an additional 234,470 bcy which would increase the possible average redistribution depth from 19 to 20.6 inches. This increased soil depth is available because as the dump is expanded onto shallower slopes, the depth of soil available for salvage increases. The chief benefit of the increased soil depth would be to increase available rooting depth and water available to plants.

There is a general consensus in the reclamation community that 3h:1v or less is preferable for effective reclamation, both from the standpoint of soil loss, vegetation and efficient use of equipment. Steeper slopes generally require more intense erosion control measures, and result in less efficient use of machinery. Because a 3h:1v slope would allow for use of equipment on the contours, some of the reclamation tactics utilizing erosion and surface runoff control features would become available for reclamation. Use of features such as dozer basins has proven effective on slopes up to an slightly steeper than 3h:1v. At the reduced slope angle the use of agricultural equipment becomes feasible, which ensures a more effective seed bed preparation and also more effective seeding, fertilization and mulching. Because the application of lime often utilizes agricultural equipment for spreading and harrowing lime into the soil, the efficiency of lime application would also be increased. Together these would substantially increase the likelihood of successful revegetation. The lower slope angle would also provide for easier access for the purpose of placing the cap rock layer. This should make it substantially easier to ensure that construction standards for the different horizons are more easily met. The improved likelihood of vegetative success and lower slope angle would somewhat reduce the visual impacts. The improved vegetative cover would help to limit the infiltration of water and oxygen into the waste rock. This would act to limit adverse impacts to groundwater primarily by limiting the quantity of water available for the oxidation of pyrite in the waste rock. It is not certain if the reclamation measures proposed would eliminate the oxidation reaction in the waste dumps.

The use of any surplus oxidized waste rock on reactive material would act to further isolate the material and improve the likelihood of reclamation objectives. A clay cap on the embankment face would serve to limit infiltration into the embankment. It would likely require an embankment slope of 3h:1v or less. Monitoring of the reclamation on impoundment I may show it to be unnecessary or to have potential adverse effects.

A. Introduction And Description of the Issues

Montana law (82-4-351 and -352, MCA) provides for permit denial if the reclamation requirements of the Montana Metal Mine Reclamation Act (MMRA) can not be met with reclamation as proposed. The proposal may be modified by the proponent and resubmitted. Denial of the proposed expansion through stage V means that GSM would not be allowed to proceed beyond the completion of stage III, (scheduled for completion in 1993). It also means that only the reclamation and water treatments described in the existing permit and approved amendments would be binding on the company. GSM could then either decide to resubmit the proposal with modifications or terminate mining upon reaching the ultimate stage III limits. Denial of the permit would cause immediate hardships because GSM plans to begin stripping topsoil for impoundment II during the summer of 1990. Application approval would provide for continued mining through 2005. While there are environmental consequences with permit denial at the conclusion of stage III mining, the central issue of permit denial is the economic impact to the community and surrounding areas.

B. Reclamation Plan

Reclamation under the existing permit could create the impacts identified below, based on information developed since June 1989. Due to the accumulation of additional data from previous analysis, many of these impacts have not been previously identified. To the extent possible, these impacts would be mitigated by requiring GSM to submit an updated reclamation plan pursuant to 82-4-337, MCA.

1. Waste Rock Dumps

Termination of mining following the completion of stage III would leave 90 million tons of waste rock to be reclaimed.

a. Slope Reduction

The reclamation plan calls for dump slopes to be reduced to 2h:1v as discussed in Chapter III.

b. Waste Rock Cap

No waste rock cap would be placed on the dumps.

c. Liming

No liming is proposed for the waste rock dumps.

d. Soil Placement

Compacted areas would be ripped prior to soil replacement. Approximately 75 percent of the slopes would be covered with approximately 6 inches of topsoil. Preference for topsoil and revegetation would be given to those slopes visible from Montana Highway 69, Interstate 90 and the community of Whitehall.

e. Revegetation

No changes in the revegetation plan are proposed. Most waste dumps would be broadcast seeded. Slopes 3h:1v or less would be drill seeded. Wood fiber mulch, crimped straw, and fertilizer would be applied to reduce erosion and promote plant growth. The proposed seed mixture contains both grasses and forbs and is composed of predominantly native species. Dump tops would also be planted with a variety of brush species as well as douglas fir trees.

f. Seepage/Water Treatment

Upslope runoff would be diverted around the dump tops prior to final reclamation. The dump tops would be graded to assure maximum drainage. Any seepage from the waste rock dumps would be treated as described in the permit with approved amendments.

2. Tailing Impoundment

a. Reclamation Objectives

A series of test plots proposed to determine the best method for reclamation of the tailing impoundment were implemented. The results concluded reclamation failure under the characteristics with which the testing was conducted.

b. Embankment Reclamation

Slope reduction would be 2.5h:1v and a 3- to 6-inch soil cover would be placed on the impoundment embankments. The impoundment dikes would be recontoured and revegetated.

c. Impoundment Surface

The tailing would be topsoiled to the extent possible, with 97,000 bcy of salvaged soil (3 to 6 inches in depth) being proposed. Upon final reclamation, the tailing system would be isolated from both surface and groundwater flows. There would be no rock cap placed on the impoundment surface to buffer the soil cover.

d. Seepage/Water Treatment

GSM would maintain enough capacity in the impoundment (freeboard) upon final reclamation to provide for retention of the 100-year precipitation event. GSM would install a diversion system if it is found necessary to do so in order to protect reclamation efforts. Any permanent seepage would be handled by evaporation from a permanent collection structure. (See existing permit with approved amendments).

3. Pit Reclamation

a. Reclamation Plan

Benches within the pit are to covered with "lake bed" material and seeded. A perimeter berm would be constructed around the pit edges, if the berm was found to be unsatisfactory, the pit perimeter would be fenced and signed.

b. Seepage/Water Treatment

Water treatment of pit water committed to in the original operating permit would be required. Any water released would have to meet quality standards.

4. Miscellaneous Facilities

Reclamation of miscellaneous facilities associated with the mine would be adhered to as described in the existing permit with approved amendments. However, specifics pertaining to the proposed reclamation are limited.

5. Aesthetics

Aesthetics have not been adequately addressed in any past documents.

B. Consequences of Application Denial

Several impacts discussed in Chapter III (proposed action, GSM's proposal) would not take place. Denial of the permit would mean that no disturbance beyond that authorized under previous amendments would take place. All environmental consequences discussed in Chapter III which specifically relate to the additional acreage that would be disturbed by the proposed amendment would be avoided with denial of the permit.

1. Waste Rock Dump Reclamation

a. Slope Reduction

Slopes would be reduced to 2h:1v as provided for under the approved permit and amendments. There is limited information regarding the successful reclamation of steep dump slopes with high potential for the generation of acid mine drainage. Therefore long-term stability and productivity of reclamation would be questionable.

b. Waste Rock Cap

The lack of a neutral waste rock cap would likely cause acidification of the soil by the underlying acidic waste rock and result in a loss of any established vegetative cover. This would ultimately lead to extensive erosion and loss of the replaced soils. The overall result would be failure of the reclamation on the waste rock dumps. The dump slopes would ultimately become exposed acidic waste rock with scattered pockets of acidified soil. There would be little, if any, vegetation present on the slopes.

c. Liming

Without lime application the occurrence of the impacts described above would be even more likely.

d. Soil Placement

The depth of soil replacement proposed for the waste rock dumps ranges from six inches on the west side dumps to ten inches on the north dump. These soil depths are only adequate to support marginal vegetation. Uniform distribution of 6 to 10 inches of soil would be unlikely on a 2h:1v slope. Consequently, soil acidification and reclamation failure would be an even greater concern.

e. Revegetation

The predicted acidification of the soil by the underlying acidic waste rock would preclude long-term establishment of a vegetative cover.

f. Seepage/Water Treatment

The commitment to treat any potential seepage would limit impacts to water quality.

2. Tailing Impoundment

a. Embankment Reclamation

Reclamation of the embankments under the existing permit as amended would not be successful due to a lack of topsoil and the underlying acidic tailing material.

b. Impoundment Surface

Reclamation of tailing impoundment I would entail placing approximately 3 to 6 inches of soil on the impoundment. This soil horizon would likely become acidified by the underlying acidic tailing. This would inhibit or ultimately prevent plant growth. The lack of vegetation would result in the tailing impoundment developing into an area with extensive wind and water erosion and resultant blowing of contaminated soil and tailing.

c. Seepage/Water Treatment

The commitment to treat any seepage from the impoundment I would likely limit impacts to water resources.

3. Pit Reclamation

a. Reclamation Plan

The proposed reclamation consisting of covering the benches with "lakebed material" and seeding with grasses leaves the ultimate fate of the reclamation uncertain. The lack of any information regarding depth of material makes it impossible to predict whether reclamation will succeed or fail. If soil depths are adequate to support vegetation, there will be some improvement in the aesthetic appearance of the pit. If the soil depths are not adequate to support vegetation, then the lakebed material will erode into the pit, and the vegetation will fail.

b. Seepage/Water Treatment

The termination of mining at the conclusion of stage III would leave the pit bottom an elevation of 5,275 feet, which is above the anticipated water table. Termination at stage III would avoid the impacts of the pit to the local ground and surface water systems. Adverse impacts to any water resources are unlikely.

4. Miscellaneous Facilities

The proposed reclamation is inadequate to assure reclamation of all areas occupied by miscellaneous facilities.

5. Socioeconomic and Human Environment

a. Employment and Income

The mine would begin a gradual slowdown in 1991 until closure in 1993. Initial layoffs could begin as early as 1990 consisting of employees who would have been used in pre-impoundment II stripping operations. Additional work on reclamation would probably continue for three to five years. Ultimately about 300 direct mine jobs would be lost with the economic impact felt from Butte to Bozeman. The most damaging social and economic affects would be to the community of Whitehall and to Jefferson County. In addition to the estimated payroll of $11.5 million, annual purchases of $17.9 million would also be lost. Considering the proposed life of the mine through stage V, loss of income would amount to $323.0 million in 1989 dollars.

b. Government Finances

With closure of the mine, Jefferson County government would lose approximately $168,000 per year in tax revenue, or approximately 10 percent of the general fund for county operations. The community of Whitehall also would be impacted as people moved away from the area and businesses closed. The tax base for the city of Whitehall would likely deteriorate, making budgeting for services provided by the city increasingly difficult. Both the Cardwell Elementary School District and the Whitehall High School District would be severely impacted by the mine closure. The elementary district would lose approximately $296,000 per year in tax revenue, while the high school would lose approximately $164,000 per year.

Montana state government would also lose revenue at mine closure. The mine pays approximately $600,000 per year in Metal Mines Tax, yielding approximately $400,000 per year to the state general fund. Over the projected life of the mine, this loss in revenue would total approximately $4.4 million (in 1989 dollars). In addition, GSM also pays a Corporate License Tax, 64 percent of which is deposited in the state general fund. GSM employees pay state income taxes on the approximately $11.5 million in annual salary.

c. Social Life

Mine closure would increase the unemployment in Jefferson County significantly. A decrease in the employment base would adversely affect young people entering the job market seeking local employment in order to remain close to family and friends. Migration of people would of the Whitehall area would likely occur. With a decreasing population base, businesses may be forced to close for lack of retail trade.

d. Community Services

The expected migration out of the Whitehall area because of a lack of employment opportunities would impact community services. Residents of Whitehall would be forced to either pay higher per capita rates to maintain the current level of services (water, sewer, police and fire protection and other community facilities and programs), or the level of services available would have to be reduced. Unemployed people choosing to remain in the area may be forced to rely on government aid programs.

e. Survey of Local Officials

An informal telephone survey of local officials was conducted to solicit their views on the adequacy of community services in Whitehall and potential impacts from closure of the Golden Sunlight Mine (Appendix 5). Local officials interviewed included James Frazer (Mayor), Francine Giono (City Council member), Joyce Janacaro (Jefferson County Commissioner), Harold Piazzola (acting president, Whitehall State Bank), Frank Marble (supervising teacher, Cardwell Elementary School District), Bill Barringer (Superintendent, Whitehall School District), and Ron Robertson (acting director of Public Works).

In general, all informants believed that the community services (e.g., water, wastewater treatment, and police and fire protection) were adequate to meet the demands of the community. Informants reported that the community, as a whole, supported the Golden Sunlight Mine and considered them to be a good neighbor. One informant added that opposition to the mine was from people outside of the community of Whitehall.

Informants concurred that adverse impacts would be realized if the Golden Sunlight Mine were to close. Potential impacts mentioned by informants included a decrease in population, economic hardships on local businesses, a decline in taxable valuation and tax revenues, and a change from the school system Class B status to Class C. As one informant reported, "Golden Sunlight Mine is a gold mine for Whitehall."

CHAPTER VII - RELATED ACTIONS AND CUMULATIVE IMPACTS

A. Related Actions

The long-term plans of GSM beyond stage V are not known at this time. Additional exploration work has detailed areas of interest to the northwest of the existing pit. The ore body continues at depth and the possibility of underground mining does exist. Any additional proposals would require the submittal of a permit application for the agencies review. No other related actions are discussed in this EA because no additional activities are proposed by any of the adjacent landowners.

B. Cumulative Impacts

This section identifies the cumulative impacts from implementation of alternatives identified in Chapters III, IV, V, and VI - the proposed plan, the proposed plan with supplemental commitments, the plan with commitments and additional modifications, and denial, respectively.

1. Company's Proposed Plan

The company's proposed plan involves extensive disturbance covering nearly 2600 acres. Approximately 800 acres of waste rock dumps, 500 acres of tailing impoundments and a variety of ancillary facilities and disturbance. The discussions in Chapter III, D-Environmental Consequences, covers the impacts to a variety of affected resources. Impacts to geology, vegetation, wildlife, land use, air quality and climate, transportation, noise and cultural resources do not vary appreciably in their cumulative impacts from one alternative to the next. The impacts to these resources are addressed in Chapter III. There are important differences in the cumulative impacts to other resources which are discussed below.

a. Soils

Recovery of only 27 percent of the soil available for salvage and subsequent reclamation under the proposed plan would have a substantial impact on the likelihood of successful reclamation. The reduced amount of soil available for reclamation makes it unlikely reclamation would succeed.

b. Water Resources

The company's proposed plan could lead to violations of water quality standards for copper in the Jefferson River approximately 10 percent of the time under a worst-case scenario. A more likely scenario is for intermittent violations of the groundwater quality standards. The actual amount of seepage into the groundwater system in the area from the waste rock dumps, tailing impoundments and pit is not known with any certainty. This is true for all four alternatives. Additionally, erosion of the waste dumps may impact either surface waters or adjacent lands through the deposition of material eroded off the waste rock dumps or sediment laden water reaching surface waters.

c. Socioeconomic

The company's proposal would have no adverse impacts on the range of social and economic considerations discussed earlier. Mining activity and subsequent reclamation work would continue to 2005 and beyond.

d. Aesthetics

Overall failure of the proposed reclamation would leave an extensively disturbed area of several hundred acres visible from I-90, the major east-west travel route in Montana.

2. Company's Proposed Plan with Supplemental Commitments

a. Soils

The commitment to salvage all available topsoil for reclamation dramatically improves the likelihood of successful reclamation; however, it is still likely there would be extensive area where reclamation may fail in the long term.

b. Water Resources

The supplemental commitment to treat discharge water from the tailing impoundments and pit in perpetuity would likely limit pollution of groundwater to only seepage from the waste rock dumps. Seepage from the waste rock dump is not expected to violate state groundwater quality standards.

Impoundment and pit discharges may amount to 2 to 140 gpm of low quality water into the existing groundwater systems east and west of the mine.

c. Socioeconomic

The company's proposal with supplemental commitments would have no adverse impact on the range of social and economic considerations discussed earlier. Mining activity and subsequent reclamation work would continue to 2005 and beyond.

d. Aesthetics

The likelihood of successful reclamation is substantially improved with this alternative; however, it is still likely there would be extensive areas where reclamation would ultimately fail, particularly in the long term. The visual impact to travelers on I-90 would remain dominant in the area.

3. Company's Plan with Supplemental Commitments and Additional Modifications

a. Soil

The commitment to increase soil salvage to include all he available topsoil dramatically improves the likelihood of successful reclamation. The test plots for the 2h:1v slopes would leave virtually all waste rock dump slopes unreclaimed until nearly the end of mine life (about 12 years). Approximately 125 acres of dump tops would be reclaimed prior to the end of mine life. Delayed reclamation may increase the potential for seepage from the waste rock dumps, as explained in Chapter V.

b. Water Resources

The proposed company plan with supplemental commitments and additional modifications should reduce the amount of water to be treated. These reductions in the amount of water to be treated may enable the company to substantially reduce the scale of the proposed treatment facility. The likelihood of any violations to Montana groundwater standards is further reduced by this alternative.

c. Socioeconomic

The socioeconomic impacts of this alternative are not known. The proposed additional modifications would add substantially to the total reclamation cost. If projected reclamation costs exceed GSM's allowable operating budget, the mine may be closed at the end of stage III (1993). The potential for employment at the mine would be shortened by 12 years.

d. Aesthetics

The proposed additional modifications would reduce the visual impacts of the mine in the lo: term though the mine would remain dominant in the landscape.

4. Denial Alternative

a. Soils

The proposed soil salvage for the current reclamation plan is not adequate to provide for reclamation if the proposed amendment were to be denied. Mining would terminate at the stage III pit. Ultimate surface disturbance would be less than one-half that of the proposed plan with supplemental commitments (Chapter IV) and with additional modifications (Chapter V). Reclamation on the approximately 600 acres of tailing impoundment and waste rock dump would likely fail.

b. Water Resources

Because mining would terminate above the water table, impacts to water resources from pit seepage would be reduced. Approximately 15-20 gpm seepage of poor quality water would be treated from impoundment I. Discharge to groundwater from the waste rock dumps would be reduced because of the reduced acreage in the waste rock dumps.

The waste rock dumps would discharge 80 to 90 gpm of poor quality water into the groundwater systems east and west of the mine. This seepage is not expected to violate groundwater quality standards.

c. Socioeconomic

Denial of the amendment application would have immediate negative impacts on the Whitehall area, as workers not needed for topsoil stripping would be laid off. As operations decline near the original proposed end of mine life at stage III, additional workers would be laid off and the economic impacts would begin to affect the Whitehall area.

d. Aesthetics

The impacts of denial would be similar to the impacts of the proposed plan; however, considerably fewer acres would be disturbed, thus the cumulative impact would be commensurately less.

CHAPTER VIII - SUMMARY AND CONCLUSIONS

A. Reclamation of Reactive Wastes

Weathering of sulfide-bearing wastes produces sulfuric acid, which lowers the pH and increases the solubility of residual heavy metals. Acid formation is controlled by mineralogy, oxygen availability, water in and moving through the wastes, bacterial growth, and particle-size distribution. Acidic leachate, or acid mine drainage (AMD), may be produced that is both deleterious to ground and surface waters and toxic to vegetation (CANMET, 1988).

Sulfide-bearing wastes that are acid generating can be successfully revegetated and acidic leachates controlled by limiting oxygen penetration and water movement through the waste materials. Additional measures can include the use of a bactericide to prevent the formation of acid mine drainage. Diversions are used to limit overland flow and water accumulation on the reclaimed surface. Establishment of vigorous vegetation and an adequate rooting zone prevents the recharge of waste material by eliminating the potential for water moving through the plant growth medium in all but major moisture events. The reclaimed surface may be modified to avoid concentration of water on any one area on the reclaimed surface. Neutralization of reactive waste or construction of a capillary break, or other barrier prevents contact of rooting vegetation with acid-generating materials. In some cases reactive wastes can be amended to produce an effective plant growth medium; however, this is usually done when an alternative growth medium is not available. If reactive waste materials are not isolated from the growth medium through the use of a cover system, the soils may eventually acidify and the vegetative cover could fail.

1. Tailings Reclamation

Reclamation of tailing impoundments associated with mining and milling operations typically include dewatering, stabilization, diversion of offsite water, revegetation of the surface and seepage control. When the tailings exhibit toxicity to vegetation, measures must be taken to assure the vegetative cover and its supporting growing medium are isolated or amended in order to avoid failure of the vegetation due to transport of toxic materials in the tailings. If the tailings include sulfides, the reclamation plan should minimize the availability of oxygen and water to the tails in order to reduce or eliminate the oxidation of the sulfides and resultant potential for acid mine drainage.

2. Waste Rock Dump Reclamation

Reclamation of the overburden or waste rock removed during mining operations normally involves redistribution of the waste rock to a stable configuration which can be treated and revegetated. The nature of the treatment depends on the characteristics of the material. If the material is benign, reshaping, topsoiling and seeding may be all that is needed. If the material is reactive and exhibits potential toxicity to vegetation, then a more sophisticated reclamation plan would need to be developed. Reclamation involving reactive waste rock must attempt to minimize the availability of oxygen and water to the waste rock as discussed above. Reclamation plans should include provisions for rapid removal of intense precipitation events off the surface, a cover design which isolates waste rock, and an effective revegetation plan. In some cases it may be necessary to chemically amend the surface with neutralizing agents to further guard against acidification of the soil and subsequent vegetation failure.

3. Acidic Leachate Treatment

During the mine life, acid mine drainage problems are often resolved by water control through pumping or other collection methods. At mine closure, these methods are often no longer appropriate for long-term control of acid mine drainage. Long-term water treatment methods evaluated by the company include lime neutralization, sodium hydroxide and sulfide precipitation, ion exchange, reverse osmosis, evaporation, development of wetlands and other methods or a combination of several of the above. The method of treatment selected by the company and analyzed in this document was a combination of reverse osmosis and evaporation. The sludges produced can pose serious disposal problems. Almost all treatment methods require long-term maintenance which can be a considerable expense.

B. Impact Summaries and Permit Conditions

The original submittal by GSM does not include measures which would adequately insure reclamation and meet the requirements of the MMRA and the Federal Land Policy and Management Act. This proposal would have significant impacts on the environment.

The company's proposed plan with supplemental commitments includes a variety of additional commitments based on impact analyses and supplemental data. These include commitments to:

- place a two- to three-foot cap of oxidized waste rock on the tailing impoundment and waste rock dumps.
- place additional soil on the tailing impoundments and waste rock dumps, and
- treat the anticipated seepage from the pit and the impoundments.

Treatment of seepage would involve construction of a facility below the impoundments which would disturb between 15 and 75 acres. GSM would also test the feasibility of reclamation on the waste rock dumps at a slope of 2h:1v using criteria established by the agencies and GSM to establish success or failure of the test. While this alternative substantially improves the likelihood of successful reclamation of reactive wastes, the possibility of potentially significant impact remains (see Chapter IV).

Modifications of the company's proposed plan and supplemental commitments would further improve the likelihood of successful reclamation of reactive wastes. These modifications include measures to further isolate the reactive waste rock and tailings from oxygen and water, additional monitoring of both the oxidation rates in the waste dumps and and groundwater systems in the area, concurrent reclamation of waste rock dump tops, and some potential reclamation of the mine pit. This alternative further improves the likelihood of successful reclamation, reduces the amount of acid seepage which would require treatment in perpetuity and reduces the overall impact to other resources addressed in the EA. If this alternative is selected, the additional modifications in Chapter V would be stipulated in the permit. Although impacts to the environment have been further reduced by this alternative, the agencies cannot categorically state that long-term cumulative impacts would or would not be significant.

If the permit were to be denied, this would be the least environmentally desirable of the alternatives at this time. The reclamation plan would revert back to the plan existing prior to the application for this amendment. This plan is not adequate to prevent significant adverse impacts to the environment, based on the data now available. If this alternative were to be selected, the agencies would require an immediate updating of the existing reclamation plan in order to mitigate impacts, based on data now available. This would be done pursuant to 82-4-227, MCA, which gives DSL the authority to require amendments to existing approved permits.

CHAPTER IX - CONSULTATION AND CO(:DINATION

This document was prepared by the agencies, DSL and BLM. This chapter identifies public involvement, consultation, and coordinator, distribution and review of this document, and SIS preparers.

A. Public Involvement

Previous drafts of this EA have been distributed. A public meeting was held, as described in Chapter I, and comments were received. Comments are responded to in Chapter X.

B. Consultation and Coordination

The following agencies, companies, and organizations provided information to the DSL and the BLM, which was used in preparation of this EA.

-Golden Sunlight Mines, Inc.
-PRC Environmental Management, Inc.
-Sergent, Hauskins, & Beckwith
-Hydrometrics
-State Historic Preservation Office
-U. S. Forest Service
-U. S. Bureau of Mines
-Montana Bureau of Mines & Geology
-Montana Department of Fish Wildlife and Parks
-Montana Department of Health and Environmental Sciences
-Montana Department of Natural Resources and Conservation
-Montana Department of Commerce
-Montana State University Reclamation Research Unit

C. Distribution and Review of this EA

Copies of this EA are being provided to about 150 persons, groups, local governments, and agencies which have expressed an interest in this Golden Sunlight Amendment. The mailing list was compiled using the names and addresses of:

-parties who have requested copies of the EA
-parties who have submitted written comments
-agencies and groups consulted during the EA preparation
-agencies, governments, and companies potentially affected by the proposed operation.

A copy of this EA can be reviewed at the following locations:

Agencies
- Montana Department of State Lands
  1625 Eleventh Ave., Helena, MT
- U. S. Bureau of Land Management
  106 North Parkmont, Butte, MT

Libraries
- Bozeman Public Library
- Butte Public Library
- Boulder Community Library
- John Gregory Memorial Library

Copies of this document are also available on request from:

Montana Department of State Lands
Capitol Station
Helena, MT 59620
(406-444-2074)

Bureau of Land Management
P. O. Box 3388
Butte, MT 59702
(406-494-5059)

D. EA Preparers

This document was prepared by the following members of the Department of State Lands and the Bureau of Land Management.

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CHAPTER X - GOLDEN SUNLIGHT RESPONSES TO PUBLIC COMMENT

This chapter summarizes comments received on the revised draft EA (July 1989) and provides a response or reference to appropriate sections of this EA where additional information may be found. Page numbers cited in the comments refer to specific pages in the July 1989 EA. Comments have been identified by the specific commentor if comments were written. Technical oral comments tended to duplicate written comments and therefore specific individuals have not been identified.

Comment 1.

Now that synthetic liners are available, will there be any possibility of potential hazardous substances entering the surface and ground water of the area? A bentonite slurry cutoff trench should be constructed to ensure that no leachate escaped from beyond the impoundment area. What was the reasoning behind not changing the reclamation plan, or increasing the reclamation bond? What safeguards are there to prevent future problems with the existing pond and at the proposed new pond. (Montana Wildlife Federation (MWF), Northern Plains Resource Council (NPRC)).

Response

The second tailing impoundment would utilize an impervious liner. It iunlikely a slurry cutoff trench would be needed as proper construction of the impoundment liner will limit the potential for leakage. The reclamation plan has been changed (Chapters IV and V) and the reclamation bond would be increased. The slurry cutoff wall and pump backs and proposed changes to the impoundment I reclamation plan should limit future problems with the existing impoundment. The liner, monitoring, and reclamation plans for impoundment II would limit the potential for problems with the new pond.

Comment 2.

What recourse do people have should reclamation procedures fail, or not be fully carried out? Will the new bond be adequate if the worst case scenario in DSL's recommendations develop? Reclamation of lands disturbed during the taking of natural resources is mandated. Bond amounts should be adequate to assure reclamation if the project is closed prematurely. (MWF, M. Tebay, NWF)

Response

GSM is responsible for the performance of reclamation; however, in the event reclamation is not successful, the entire reclamation plan would be covered by bond adequate to insure reclamation.

Comment 3.

Interagency monitoring of reclamation procedures and of test plots should be a requirement of approval. The EA should include a projection of potential impact and should require a contingency plan and groundwater monitoring plan be developed earlier than "prior to final closure" as indicated. The DSL and GSM should prepare and present additional information as to the adequacy of the proposed plans based on prior reclamation programs as well as site-specific studies. (MWF, T. Mulligan, National Wildlife Federation (NWF)).

Response

The EA recommends extensive monitoring of a variety of tests necessary to adequately resolve future reclamation concerns. Additional information is presented in Chapters IV and V.

Comment 4.

Are the proposed replanted trees native species? (MWF).

Response

Any replanted trees would be native species.

Comment 5.

What is the water source for irrigating the replanted vegetation? (MWF).

Response

No irrigation is proposed in the reclamation plan.

Comment 6.

It is stated that GSM would monitor the existing seep at the toe of the north dump. What is being done to cement this seep? What are the impacts of the seep? Page 45. If the Midas slump slipped into the adjacent drainages the cost of reclamation would be substantially greater. Is GSM going to be bonded sufficiently to cover this increased cost? (MWF).

Response

The existing seep at the toe of the north dump will be buried under the north dump as it expands. The impacts of seepage are discussed in this EA in Chapter III, D.1.a. Burial under the expanding dump is expected to stabilize the slump. Seepage would likely be contained in the dump or channel into shallow groundwater aquifers.

Comment 7.

Stage V dumps would be ten times the volume and cover six times the disturbed surface area. With this in mind how can an expansion of this magnitude not warrant an EIS? On page 77, it is stated that "Regardless of GSM's commitments to monitor and take appropriate remedial actions, reclamation will fail, particularly for the mine as a whole". This warrants the preparation of a complete EIS to further study the potential impacts of the mine expansion, particularly given the admission of the high potential for unavoidable significant impacts. Why is mining allowed to obtain permitting with an EA and not required to submit a full EIS? The NWF intends to exercise its legal right to a review of the expansion through an EIS. Stage V would require an additional tailings impoundment. If an EIS was required for the first tailings impoundment, why not for the new one? (MWF, Stan Senechal, NWF)

Response

The EA with the additional modifications to the company's proal with supplemental commitments may reduce the impacts below the level that would require an EIS under the current MEPA and NEPA regulations.

Comment 8.

Who is responsible for groundwater monitoring? Does the public have access to the results of these tests? (MWF).

Response

GSM is responsible for groundwater monitoring. These results are available at the Department of State Lands in Helena and the Bureau of Land Management in Butte.

Comment 9.

Does GSM have any plans for off-site improvements or mitigation measures to compensate for the loss of wildlife habitat at the site and disturbance of surface waters? The DSL should consider requiring bond to be used to purchase habitat comparable to that lost through any reclamation failure on public lands within the permit area. Consideration should be given to requiring GSM to purchase water or lease rights to the Jefferson river which could be used to augment instream flow levels. (MWF, NWF).

Response

There are no plans for offsite mitigation.

Comment 10.

Page 18: Compared to the work down by Pegasus at German Gulch, why is GSM not held to the same standards? (MWF).

Response

GSM has been held to the standards required by the Metal Mine Reclamation Act and the Federal Land Policy and Management Act.

Comment 11.

Are test plots being prepared to determine the future success of reclamation procedures? Goals for reclamation procedures cannot be determined unless test plots are being developed. (MWF)

Response

Test plots would be used to verify that the reclamation proposed by GSM would be successful. See Chapters IV and V of this document.

Comment 12.

Page 19: What does "Dewater the tailings as quickly as possible" really mean? (MWF).

Response

Final spigotting onto the tailing impoundment will result in a slight gradient that would aid in the dewatering process. The sooner tails are dewatered the sooner reclamation can begin in order to minimize impacts from dust and potential acid mine drainage. See Chapters III-V.

Comment 13.

Page 19: Clarify the statement "GSM anticipates that very little water would discharge from the underdrain system after the first couple of years" (MWF).

Response

See EA, Chapters IV and V, discussions on impoundment hydrology.

Comment 14.

Only native species should be planted as part of reclamation procedures. The diversity of plants would be reduced. (MWF).

Response

Species would be selected primarily on the need for effective long-term revegetation which meets all of the reclamation goals.

Comment 15.

What is the reclamation procedure for the pit water, which will be of a poor quality with Ph level of about 2.4? There is no definite proposal regarding disposal of the problem generated by the pit water. There should be a plan to test various methods for intercepting and treating pit waters and for gaining a better understanding of the pit hydrology. How much and where will the pit water which leaks out end up? (MWF, A. R. Graesser, NWF, G. Hirschenberger).

Response

See EA, Chapters IV and V, discussion of treatment of pit water.

Comment 16.

What procedures would GSM take in regard to noxious weed control? (MWF).

Response

See EA, Chapter III, discussion of revegetation.

Comment 17.

Page 47: There are discrepancies between the DSL and GSM concerning the suitability of soil salvage for reclamation use. Who will resolve these discrepancies? DSL standards must be strictly enforced in such a fragile environment. Will GSM be required to revise the plan to reflect the topsoil salvage available for reclamation? Where is the topsoil they will need? (MWF, T. Mulligan, N. Hirschenberger).

Response

See EA, Chapter IV, discussion of soil salvage. GSM would be required to recover soils consistent with DSL criteria.

Comment 18.

Page 50: Revegetation trials show that a thicker layer of soil is needed to reclaim tailings. (MWF).

Response

See EA, Chapter IV, discussion of soil salvage and placement.

Comment 19.

What agency is responsible for monitoring the mitigation measures listed throughout the EA? What is the duration of the monitoring program? Who funds the monitoring program? Would the public have access to the progress of implementation of mitigation measures? Testing levels should be maintained until the tailings impoundments are dewatered. Who will oversee the reclamation? (MWF,NWF, N. Hirschenberger)

Response

The Bureau of Land Management and the Montana Department of State Lands are responsible for assuring GSM's compliance with the permit stipulations and applicable statutes. Monitoring would continue past the completion of reclamation by GSM, with agency oversight until monitoring results indicate compliance with statutes has been achieved. The results of monitoring would be available to the public. Reclamation would be conducted by GSM and inspected for compliance by the agencies.

Comment 20.

Page 74: If "successful long-term reclamation of tailings impoundment 1 is unlikely", what mitigation measures should GSM implement to help offset this development? (MWF).

Response

See EA, Chapters IV and V, discussions of impoundment reclamation.

Comment 21.

GSM should be required to develop a water quality monitoring program throughout the region. More discussion is necessary concerning current seepage during operation, and if the expansion is granted. On page 66, how was the time factor for acidic leachate travel arrived at? What are the volumes and toxicity levels at this time and in the future. Have the location of the various aquifers been identified and the flow established? (MWF, T. Mulligan, P. Mulligan).

Response

See EA, Chapter IV and V, discussions of hydrology.

Comment 22.

What guarantees are there that the mitigation measures listed on Page 74 would be more successful in mitigating damages than those implemented for tailings impoundment 1? (MWF).

Response

See EA, Chapter IV and V, discussion of reclamation on the impoundments.

Comment 23.

Noise pollution has not been addressed, even though loud rock music is played at the existing tailings facility in the early morning hours. (S. Senechal).

Response

Further abatement of the noise hazing for waterfowl is undergoing current review.

Comment 24.

No alternatives to the proposed action were described or analyzed. There were no alternatives presented. (G. Hirschenberger).

Response

The current EA includes alternatives as required by the most recent revisions to the Montana Environmental Policy Act regulations and consistent with NEPA.

Comment 25.

Since contamination of the tributaries of the Missouri river would be a disaster, the mining expansion should either eliminate the pit development or include lining of the pit to prevent leakage. If this is economically infeasible there should be a complete EIS prepared due to the water problems which are known and unknown. (E. H. Likes).

Response

The EA addresses a range of modifications and monitoring to avoid this possibility.

Comment 26.

A promise to reclaim is not equivalent to a reclamation plan. Neither the DSL nor GSM has demonstrated that DSL's proposed reclamation requirements will succeed, or that they are economically or technologically feasible. (NWF).

Response

The reclamation and monitoring plans, presented in Chapters IV and V, and bonding requirements are intended to assure the success of reclamation.

Comment 27.

Expansion should only be permitted through phase 4, which would allow excavation to the projected level of ground water. (NWF).

Response

See EA, Chapter IV, discussion of all aspects of pit hydrology.

Comment 28.

Phase 5 should be subjected to a second review, with permitting contingent upon development of adequate plans for disposing of pit waters, and satisfactory results of model neutralization and revegetation programs. (NWF).

Response

Current plans for pit water are discussed in Chapters IV and V. The objective of these plans is to define a permitting scenario that prevents significant impact.

Comment 29.

A better public information effort should be implemented, which will be aimed at disclosing the potential hazards of groundwater contamination. (NWF).

Response

All information available to the agencies is available for public review.

Comment 30.

Seepage from the tailings impoundments has the potential to impact the water quality of the Jefferson river and cause the standard for acute copper toxicity for aquatic organisms to be exceeded as much as 10% of the time. (NWF).

Response

See EA, Chapter IV and V, discussions of impoundment hydrology.

Comment 31.

Is the cost of maintaining the monitoring and pumpback wells included in the reclamation bond? (NWF).

Response

The cost of any treatment facilities would be included in the bond. The treatment bond would be held until monitoring documented that treatment was no longer necessary to assure compliance with the Water Quality Act and the Metal Mine Reclamation Act.

Comment 32.

Concerns about current and future water contamination; the effect this water has on the surrounding farms, ranches and residences and the effect of contamination as it pertains to wildlife and fisheries. (N. Tebay).

Response

The EA covers the range of potential impacts to the water resources of the area.

Comment 33.

Will the synthetic liner last as long as the toxicity of the tailings impounded? (M. Tebay).

Response

The manufacturers of synthetic liners typically warranty the liner for 30 years. There would likely be cyanide compounds in the tailings considerably longer than that. There is little information on the life expectancy of synthetic liners in practice.

Comment 34.

Page 10a. Since the "unavoidable adverse impact" actually occurred in the first impoundment, will the "worst case scenario" also occur? (M. Tebay).

Response

The agencies believe the proposed modifications, discussed in Chapters Iv and V, will avoid a worst-case scenario.

Comment 35.

If there is a power failure will the leak detection system also fail? Will a leak be detected before the aquifer is polluted? (M. Tebay).

Response

The mine has an emergency power supply available in the event of interruptions in service.

Comment 36.

Page 14-15. What are the results of the plot tests? (M. Tebay).

Response

See EA, Chapter III, D.2.b, discussion of revegetation trials.

Comment 37.

Page 16. Why does GSM have to wait until a permit is granted before submitting plans for evaluation of the acid generating potential and toxicity of the pit, waste rock and pit water? (M. Tebay).

Response

This information has been submitted and was used in the preparation of this document.

Comment 38.

What protection is there from the elevated metal seepage into the groundwater after mine abandonment? Is there the possibility that an aquifer will be sealed off? Does this aquifer serve as a major source of irrigation and recreational use? Is the possible seepage going to create the same situation for the Tebay Ranch and the Jefferson river as is now in the Berkeley pit, Clark Fork River and Travonia mine in Butte? (M. Tebay).

Response

See EA, discussions of groundwater systems in the area and impacts are discussed in Chapters III, IV, and V. The additional modifications proposed in the EA, in conjunction with extensive monitoring, are designed to avoid adverse impacts to both ground and surface waters. It is unlikely any aquifers would be sealed off. The aquifers in the area are not major sources of irrigation or recreational waters. However, as discussed in the EA, they do eventually provide water recharge to the Boulder and Jefferson Rivers.

Comment 39.

Osprey have nested on property less than 1 mile from the existing tailings impoundment. With the death of other birds in the area after landing on, and feeding, on the tailings impoundment would it be possible to place a cover over these areas? (M. Tebay).

Response

The current plans do not call for covering the impoundments. In the event future problems arise, this is subject to reexamination.

Comment 40.

Seismic stability is a concern, since people live below the impoundment. (M. Tebay).

Response

See EA, Chapter III,D.1.b, discussion of impoundment stability.

Comment 41.

Page 75-3a: Since we are on a fault line, could a seismic disturbance cause a break in the waste rock site. (M. Tebay).

Response

Faults in the area do not show evidence of recent movement. It is unlikely seismic activity would cause more than minor problems with the waste rock dumps.

Comment 42.

Appendix C, Page 2: Were soil samples taken from other alfalfa fields surrounding this area to determine the nitrate levels in the Jefferson alluvium? (M. Tebay).

Response

No samples were taken from other alfalfa fields in the area.

Comment 43.

Page 4: Could the elevated nitrate levels be due to blasting activity? (M. Tebay).

Response

See Appendix C, report on the leakage from impoundment I.

Comment 44.

We are concerned about cyanide pollution in the air and want monitoring of this substance as well as to know what the present level of contamination is. (M. Mackin).

Response

Cyanide, as hydrogen cyanide (HCN) gas, can represent an occupational hazard for workers at the plant if operational controls are not followed. It is unlikely as an atmospheric pollutant based on the characteristics of HCN gas.

Comment 45.

The price of land in the area has decreased by 50% because of the mine's contamination. Now it is going to expand to within a few hundred feet of our sons's property. (E. Tebay).

Response

The expansion would be consistent with applicable statutes and regulations.

Comment 46.

Page 12: There is a reference to the "detailed evaluation of acid-producing potential and toxicity." I cannot find this information. (NPRC).

Response

See EA, Chapter III and IV, discussion of acid production potential.

Comment 47.

I can find no specific information regarding the exact location of test wells. In addition, there is no specific information about the leak detection system, other than pipe specs. Can leaks be detected every few feet in the liner, or is detection by section? (NPRC).

Response

Leaks in the liner can generally not be pinpointed by the leak detection system.

Comment 48.

I am concerned about the visual impact of a 400 million ton waste rock pile. (G. Hirschenberger).

Response

The visual impacts are one of the concerns identified in the EA.

Comment 49.

It is difficult to tell what areas would be buried by the waste rock. An appropriate scale map with sections delineated by topographic lines would help. (G. Hirschenberger).

Response

The waste rock dump proposals, on a topographic base at an appropriate scale, are available at the BLM office in Butte and the DSL office in Helena and are open to public review.

Comment 50.

Is the pumping of the ground water below the tailings pond depleting the aquifer? If it is how long before it is depleted? How long will the pumping continue? (G. Hirschenberger).

Response

Most of the water being pumped is from the impoundment. Pumping would continue until applicable water quality standards can be met.

Comment 51.

How much cyanide is used by GSM annually? What is the fate of cyanide in the ground and surface water? (G. Hirschenberger).

Response

GSM uses approximately 4.5 million pounds of sodium cyanide annually. During the operation life of the mine much of the cyanide is degraded through the milling and recovery processes. At the completion of operations, a portion of the cyanide in the tailing impoundment will be complexed with metals. As the tailing begins to acidify over time, the cyanide would degrade through the formation of cyanate compounds, volatilization, oxidation, and biodegradation. The efficiency of natural degradation in the reclaimed tailing impoundments is not known, but it is likely that there would be residual cyanide present for an extended time. The impoundments would be pumped to a treatment facility as discussed in the EA.

Comment 52.

Where does the affected ground water recharge? (G. Hirschenberger).

Response

See EA, Chapter III and IV discussion of hydrology.

Comment 53.

How fast and in what direction would a plume of cyanide spread if another leak should develop? (G. Hirschenberger).

Response

It is likely that any leak from either impoundment would follow more or less the same path followed by the 1983 leak. That is generally to the southeast and towards the Jefferson slough. See Appendix C of this document.

Comment 54.

Is there any plan for pit reclamation besides putting up a fence? (G. Hirschenberger).

Response

See EA, Chapters IV and V for a discussion of pit reclamation concerns.

Comment 55.

How will GSM reduce the present waste rock slopes of 36 degrees plus to 2:1 slopes, taking into consideration that this is on loose rock? (G. Hirschenberger).

Response

The conceptual plan developed by GSM involves bulldozers working behind the face of the waste rock dumps, reducing the slope by continually reworking material down the slope until the ultimate slope design is reached.

Comment 56.

It was stated that the St. Paul Gulch is east of the GSM and drains into the Boulder river. It is west of the GSM and drains into the Jefferson sloughs. (G. Hirschenberger).

Response

The text has been modified.

Comment 57.

Page 42: It is stated that this is the northern part of Jefferson county, when it is the southern. (G. Hirschenberger).

Response

Text has been modified.

Comment 58.

How was the bond calculated? (G. Hirschenberger).

Response

The bond is calculated based on estimates of the actual cost, to the agencies , of performing reclamation. Costs include such factors as materials volumes, hauling distances, treatment costs, revegetation costs and others.

Comment 59.

Steps must be taken to control seepage from impoundment 1. (P. Mulligan).

Response

Seepage from impoundment I is currently being returned to impoundment I by a pumpback system. This would continue until monitoring documents that water quality standards are met.

Comment 60.

GSM should be required to cover the impoundments. (P. Mulligan).

Response

The current plans do not call for covering the impoundments. In the event future problems arise, this is subject to reexamination.

Comment 61.

The source of the nitrates in the ground water needs to be determined, especially when there is the future possibility of high cyanide levels and or acids with metals in solution. (G. Preston).

Response

See EA, Appendix E. The conclusion of a report prepared by the DSL in July 1988 was that elevated levels of nitrates are caused by agricultural practices.

Comments 62.

The list of metals is incomplete, and should include arsenic. (G. Preston).

Response

Arsenic levels in the Ohio adit waters do not exceed water quality standards.

Comment 63.

Was the expected probability during the EIS process identified? (T. Mulligan).

Response

The EA attempts to address all reasonably foreseeable impacts from a range of alternatives.

Comment 64.

Has the operating history been consistent with the EIS projections? (T. Mulligan).

Response

There have been extensive modifications to the project after the development of the original EIS. These have been addressed in supplemental environmental assessments as well as cumulatively in this assessment.

Comment 65.

What is the current seepage rate and quantity? What is the concentration level and migration pathway? What is the projected continued impact? What is the impact on the neighbors? (T. Mulligan).

Response

See EA, Appendix B, for a discussion of the 1983 leak from impoundment I.

Comment 66.

Diversions around the impoundment is needed to minimize seepage. (T. Mulligan).

Response

A diversion around the impoundments is included in the reclamation plan. See Chapter IV.

Comment 67.

What is the basis for the assumption that problems won't occur until after reclamation efforts have begun? (T. Mulligan).

Response

Conclusion on the likely problems are based on staff experience and expertise, literature research, and discussions with a variety of specialists. Acid mine drainage is a result of processes, described in Chapter III, which take time to develop and which are minimized by the exclusion of air and water.

Comment 68.

What kind of liner material and detection system will be used? (T. Mulligan).

Response

See EA, Chapter III for a discussion of the proposed liner system.

Comment 69.

What is the plan of action if seepage is detected between the liners? (T. Mulligan).

Response

The likely response will depend on the amount of seepage. Responses could range from no action to the development of an extensive network of pumpback wells such as exist for impoundment I. This would require a modification to the existing plan.

Comment 70.

Is there any stability concern for the waste rock dumps during the 15 years of operation? (T. Mulligan).

Response

See EA, Chapter III, D.1.a, for a discussion of waste rock stability.

Comment 71.

How can the expansion be granted without the knowledge required to ensure successful revegetation and long term water management? The evaluation of acid producing potential and toxicity and the resultant reclamation and water management requirements should be part of the EA and made available for public comment. (T. Mulligan).

Response

These concerns are addressed in the current EA. See Chapters IV and V.

Comment 72.

What is the plan to reclaim the aquifer? (P. Mulligan).

Response

There are no plans to reclaim the aquifer impacted by seepage from impoundment I. Seepage would continue to be pumped to impoundment II during the life of mine; following the completion of mining operations, seepage would be treated until applicable water quality standards can be met.

Comment 73.

Has there been a study on the engineering strength of the tailings ponds structures, current and proposed? What point of the richter scale are they designed to withstand? (P. Mulligan).

Response

See EA, Chapter III, D.1.b, discussion of impoundment stability.

Comment 74.

How many gallons of cyanide solution would be spilled in the event of an earthquake? (P. Mulligan).

Response

See EA, Chapter III, D.1.b, discussion of impoundment stability.

Comment 75.

Potential sources of pollution that is not mentioned are: rupturing pipelines, leaks in pipes carrying tailings water and trucks hauling cyanide. (P. Mulligan).

Response

These are unlikely to be more minor and temporary than any other sources of pollution. Any ruptures in pipes or pipelines at the minesite would be confined to the minesite and temporary in nature. Cyanide hauled in trucks is in solid form (NaCN) and poses little risk unless ingested or spilled into water. Transport is rigidly regulated by the US Department of Transportation.

Comment 76.

What efforts are being taken to keep wildlife and waterfowl away from existing impoundments and future impoundments? (MWF).

Response

GSM has fenced the impoundment and has developed an extensive hazing program to discourage waterfowl use. (MWF).

Comment 77.

Would GSM help pay for the cost of road maintenance in the area due to increased traffic from mining operations? (MWF).

Response

GSM makes no direct payments which address increased traffic; however, taxes paid to Jefferson County and the State may indirectly be used for road maintenance.

Comment 78.

What is being done to preserve the prehistoric site, Sheep Rock, from operations? (MWF).

Response

See Chapter III, Cultural Resources. Impact/mitigation to Sheep Rock would be done consistent with the Historic Preservation Act of 1966, as amended, and related Executive Orders.

Comment 79.

Will GSM pay for the cost of studying and excavating any prehistoric sites disturbed by the operations? (MWF).

Response

As a part of their responsibilities under the Historic Preservation Act of 1966, as amended, GSM is responsible for both identification of and mitigation of cultural resource sites.

Comment 80.

What remedial actions have been taken to control seepage through the existing impoundment? (MWF).

Response

The present slurry cutoff wall and battery of pumpback wells effectively captures and returns seepage from the impoundment. Modifications to the reclamation plan for impoundment I, as described in Chapters IV and V, are intended to limit seepage for the long term.

Comment 81.

The potential levels of cyanide concentrations and the impact on landowners was not evaluated. (T. Mulligan).

Response

Potential levels of cyanide concentrations, and their effect on landowners, was not evaluated specifically, except to note that seepage entering the groundwater system could potentially threaten nearby wells and surface water systems. Two additional Appendices, C and E have been added to this EA. These appendices outline the effect of impoundment leaks on downgradient wells. In addition, uncontrolled leakage from impoundment I could cause elevated levels of copper in the Jefferson River. However, continued pumpback and treatment of this leakage, as described in Chapters IV and V, are expected to prevent significant impacts to the Jefferson.

Comment 82.

Does GSM currently have a MPDES permit allowing seepage from impoundment 1? Are they under any type of compliance action as a result of the seepage? If so, would the conditions of the permit or compliance action affect, or be affected by, the proposed action? (T. Mulligan).

Response

GSM does not currently have an MPDES permit. An MPDES permit is required for surface water discharges. The Montana Water Quality Act does not require GSM to hold a Groundwater Pollutant Discharge Elimination System (GWPDES) permit because it operates under the Montana Metal Mine Reclamation

Act. GSM is presently in compliance with both the Montana Metal Mine Reclamation Act and the Montana Water Quality Act.

Comment 83.

Page 21 stated that no surface discharge is expected and that there are no adits below the lake surface that could experience increased discharge. What is the basis for these projections? (T. Mulligan).

Response

The pit would daylight at an elevation higher than the inferred water table. Further, supplemental commitments to minimize the amount of water needing treatment would minimize the potential for any surface discharge. See response to comment 84.

Comment 84.

Are there other adits besides the Ohio? What is the projected outflow from the pit? (T. Mulligan).

Response

The Ohio Adit is the only known adit in the area. Projected outflow from the pit is discussed in Chapters IV and V.

Comment 85.

How and when will GSM know if there is any danger of migration, or if migration has already begun? What directions would the migration go? Are there any groundwater monitoring wells? (T. Mulligan).

Response

Available data suggest that any seepage from impoundment II would follow the same general path and travel at the same rate as seepage from impoundment I (see also Appendix C). The liner and drain system and ground water monitoring wells described in Chapters III, IV, and V, are expected to function effectively over the operation of stage IV and V mining. In addition GSM has made a commitment to abate any uncontrolled seepage that may occur during operations. The alternative reclamation plan with additional capping, soils and diversion of runoff would limit recharge and seepage from the impoundments. The underdrains are designed to provide a means of identifying any seepage that would occur.

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APPENDIX A - DOCUMENTATION OF EXISTING AND PROPOSED PLANS AND SUPPLEMENT COMMITMENTS FROM GOLDEN SUNLIGHT MINES WHICH ARE NOT CONTAINED IN THE PERMIT APPLICATION

DATE	SOURCE
February 18, 1982	DSL to Placer Amax
May 28, 1986	GSM 1985-86 Annual Report
December 20, 1989	WQB to GSM
January 22, 1990	GSM to DSL: Slope Considerations
January 24, 1990	GSM Memo: Oxide Stockpile
February 7, 1990	GSM Memo: Conceptual Dump Reclamation
May 2, 1990	GSM to DSL: Success Criteria

6-14-2-6

DEPARTMENT OF STATE LANDS

TED SCHWINDEN GOVERNOR

CAPITOL STATION

STATE OF MONTANA

(406) 449-2074
(406) 449-4560 RECLAMATION DIVISION

1625 ELEVENTH AVENUE
HELENA, MONTANA 59620

February 18, 1982

Placer Amex, Inc.
P.O. Box 678
Whitehall, MT 59769

ATTN: Mr. T. J. Smolik

Re: Operating Permit #00065

Dear Mr. Smolik:

After making a review of volumes I and II of SHB Job No. E81-41, it appears that the final tailing pond design is as good or better than the design submitted for Amendment 001 to Operating Permit #00065. Of particular importance is the elimination of the up-slope runoff diversion system. It is understood that Placer Amex, Inc. will:

1). Maintain enough dam freeboard during operations and upon final reclamation to provide for retention of the 100 year precipitation event.

2). Install the diversion system if it is found necessary to do so to protect the dam from failure or protect reclamation efforts.

Placer Amex, Inc. may consider condition number three of amendment 001 satisfied.

Sincerely,

Steve Anderson

Steve Anderson, Chief
Hard Rock Bureau
Reclamation Division

Enclosure

cc: Brace Hayden

SA:ds

GOLDEN SUNLIGHT MINES, INC.

May 28, 1986

State of Montana
Department of State Lands
Reclamation Division
1625 Eleventh Ave.
Helena, Montana 59620

RECEIVED
MAY 2 9 1986
STATE LANDS

21706

Attn: Terry Grotbo
Chief, Hard Rock Bureau

Dear Mr. Grotbo:

Attached please find the annual report covering our operating permit No. 00065 for 1985-86, and the $25.00 annual fee.

Should you have any questions, please contact us. Thank you.

Sincerely,

Donald E. Jenkins

Donald E. Jenkins
Administrative Superintendent

DEJ:bls

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MAY 2 9 1986
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ATTACHMENT A
Reclamation Progress

Mine Area

Most haulroads, waste dumps, and pit areas in the mine were active in 1985 and therefore were not conducive to permanent reclamation. However, fill slopes of the Phase II access road were seeded in the fall with the regular seed mix. This was the second seeding of this 2-3 acre area because dry conditions during the normal growing season prevented good establishment from the fall, 1984 seeding.

A portion of the south waste dump face was prepared as a reclamation demonstration site. The angle of repose slope was lessened with a dozer. Half of the slope had peripheral weathered burden material (including topsoil) spread on it while the other half was left as is. The entire area was broadcast seeded with the standard mixture at a rate of about 30 lbs/acre. Wood fiber mulch with a tackifier was hydrosprayed over the entire area at a rate of about 2000 lb/acre.

Tailings Area

The east tailings area corridor cut and fill slopes were broadcast seeded with the regular seed mix in the spring of 1985. Establishment as noted this spring is fair to good.

The tailings reclamation test site was reseeded in the fall of 1985. Some seedlings emerged in the spring (late April, 1986) only to perish from unusual drouth conditions in May and June. Additional emergencies occurred in late summer and fall after fair precipitation was received in late August and early September. It was felt these late emergers would winterkill due to a lack of a good root system. The three plots with surface topsoil were not reseeded because of fair establishment of most species. Seedling counts were done in the spring and fall. No definite conclusions can be reached from this data other than crested wheatgrass seemed to do the best in all plots.

Attached is a map depicting the present bonded area in relation to our operation, updated water monitoring data summary and some pictures of reclamation endeavors.

GOLDEN SUNLIGHT MINES, INC.

May 15, 1987

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State of Montana
Department of State Lands
Reclamation Division
1625 Eleventh Ave.
Helena, Montana 59620

Attn: Kit Walther
Chief, Hard Rock Bureau

Attached please find the Annual Report covering Golden Sunlight Mines, Inc. Operating Permit No. 00065 and its annual fee of $25.00 for year 1986-1987.

Should you have any questions concerning this report, please contact us. Thank you.

Sincerely,

Donald E. Jenkins

Donald E. Jenkins
Administrative Superintendent

cc: Files

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MAY 18 1987
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ATTACHMENT A

RECLAMATION

Previous

The access road cut and fill slopes which were hydro-seeded Fall, 1983 and Fall, 1984 are supporting vegetative cover. On the fill slopes the cover is more dense than on the cut slopes. Shrubs such as four-wing saltbush and big sagebrush are taking hold.

The Phase 3 access road fill slope which was hydro-seeded with the regular seed mixture plus yellow sweetclover in the Fall of 1985, has responded to some extent. Most of the slope is rocky with interspersed areas of finer material where the grasses and clover have grown.

The East tailings line corridor which was hand broadcast seeded Spring, 1985 with the regular seed mixture overall has good growth with some small steep cut slopes which have little.

1986/1987

The mine and waste dumps are active with no areas ready for permanent reclamation.

During the year weathered surface and edge material and topsoil from the steep slopes of the Phase 2 pit have been segregated in the waste dumps. This material will be used for future reclamation.

Topsoil has been removed from the future active areas of the Phase 3 pit. This removal is not complete and is currently on-going.

Small secondary containment dams were constructed in some of the small drainages by the East and West tailing lines to catch solutions in the event of a pipeline leak. The small dams were hand broadcast seeded in the Fall, 1986.

A tailing dam borrow area northwest of the impoundment area was seeded this Spring. Peripheral sideslopes which had been flattened and contoured with a small dozer were broadcast seeded with the regular seed mixture and fertilized. The interior flat portion of the borrow area was drill seeded with barley at the rate of 30 lb/acre and fertilized with 40 lb/acre of 16-12-8-8. Total area of this borrow was approximately 5 acres. In the late Fall of 1987 the regular seed mixture will be drill seeded within the dried barley area.

Spotted knapweed infested areas around the mine and tailings impoundment on adjacent company owned land were sprayed with 2, 4-D and Tordon. An evaluation early this Spring indicated control was about 95%.

Reclamation Research

Vegetative density and production in the tailing reclamation test site plots has been evaluated in the Spring and Fall of 1985 and in the Summer of 1986. A report on the evaluation prepared by Western Reclamation, Inc. of Bozeman is included as Attachment D.

A portion of the south waste dump face which was prepared as a reclamation demonstration site (see 1986 Annual Report) was not successful. Apparently, the fine weathered material which was placed over the sloped rock surface worked too far down in the Winter and Spring of 85/86. Without any medium to retain moisture or nutrients the broadcast seed did not emerge.

Water Monitoring

Monitoring of water quality as outlined in approved plans has continued. A data summary was recently submitted to the Department of State Lands.

DEPARTMENT OF
HEALTH AND ENVIRONMENTAL SCIENCES

STAN STEPHENS, GOVERNOR

COGSWELL BUILDING

STATE OF MONTANA

FAX # (406) 444-2606

HELENA, MONTANA 59620

December 20, 1989

Mr. Donald D. Jenkins
Golden Sunlight Mines Inc.
P. O. Box 678
Whitehall, MT 59759

Dear Mr Jenkins:

Our review of your application for an amendment of your operating permit for your project near Whitehall indicates that operation of your project would cause violations of the Montana Water Quality Act's nondegradation provisions (Section 75-5-303, MCA) and the rules which implement this law, ARM 16.20.701 et seq., the nondegradation rules, and ARM 16.20.1001 et seq., the Montana Groundwater Pollution Control System.

Specifically, seepage from the tailing impoundment, the pit and the waste rock piles will cause violations of section 16.20.1011 ARM by causing increases in the concentration of nitrate, and metals such as cadmium in the ground water beyond your property boundary. In addition, this seepage water may cause increases in the concentration of toxic and deleterious substances in the Jefferson River which will constitute violations of ARM 16.20.702 et seq.

This determination by the Department may be appealed to the Board of Health and Environmental Sciences using the procedures given in ARM 16.20.704 et seq., If you have questions or comments regarding this determination or the procedures for appealing this determination please contact me or Abe Horpestad of my staff at (406) 444-2406.

Very truly yours,

Steven L. Pilcher

Steven L. Pilcher, Chief
Water Quality Bureau
Environmental Sciences Division

SLP:AH:dd/Goldensun
cc: Dennis Casey, DSL
Sandy Olsen, DSL
Gary Amestoy, DSL
David Williams, BLM
John McKay, BLM

GOLDEN SUNLIGHT MINES, INC.

January 22, 1990

Ms. Sandra Olsen, Bureau Chief
Montana Department of State Lands
Hard Rock Mining Bureau
Capitol Station
Helena, MT 59620

Dear Ms. Olsen:

In reply to your letter dated December 20, 1989, the following comments are provided for justification of 2H:1V final waste dump slopes at the Golden Sunlight Mine.

The principal concerns outlined in your letter were understood to be:

1. Erosion potential with eventual exposure of acid producing waste rock, and

2. The capability of equipment to operate on a 2:1 slope.

First, the difference for acid production potential from waste rock under reclaimed surfaces on either 3H:1V or 2H:1V is probably slight. Intuitively, the infiltration amount through any given cap/topsoil configuration would be less for a steeper slope for two reasons:

a. Steeper slopes have less equivalent precipitation per unit area. With less water, the chance for infiltration to unoxidized waste rock and acid production is reduced.

b. Steeper slopes effectively increase the neutralization cap material/topsoil thickness when the vertical infiltration distance is considered.

The principal negative aspects of 3H:1V slopes are:

a. Additional disturbance of approximately 180 acres.

b. Slope reduction in some areas on the west side would require additional "mining" because with the steep existing topography, crests of 3H:1V slopes would extend back into the original ground. In effect, flattening the slopes this much would amount to mountain "leveling".

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Reclamation of the waste dumps will in some respects duplicate natural conditions. Many of the natural slopes in the mine area are steeper than 2H:1V. The average slope determined by map measurements and surveys is slightly flatter than 2H:1V. Slopes reduced from angle of repose to 2H:1V will, as much as practicable, have the natural convex(crest)/concave(toe) profile. Oxidized waste rock will be placed over rock surfaces which have acid producing potential. Much of the topsoil in the waste dump areas, especially on the west side, has a high rock fragment content. This material will be placed over the cap material or unreactive waste rock to depths specified in the Environmental Assessment. The high rock content in this replaced topsoil will help minimize erosion because of greater infiltration capacities and a greater runoff shear force is required to move particles. This is evident on existing natural slopes.

Measures will be taken to minimize erosion. Irregularities will be left in the final slope surfaces to catch runoff and decrease runoff distances. Also, tractor dozers will be used for final topsoil placement which will create horizontal cleat depressions on the slope. These small depressions are very effective for holding broadcasted seed and reducing runoff. Most seeding will be done by hydro-broadcasting followed with a covering of a tackified wood fiber mulch. If necessary, biodegradable erosion control nets alone or with an incorporated mulch may be used.

Drainage control will be established to insure that gully erosion is minimized. Major runoff areas on the dump tops will be diverted, where feasible, to the ends where natural undisturbed ground exists. Here or at dump faces where spill-over would occur, energy dissipating features will be constructed.

Second, you state "....further slope reduction is necessitated in order to cap or lime the dump surfaces. Slope reduction is required to allow safe and effective equipment operation...."

Golden Sunlight successfully demonstrated to your Bureau, March 20 and 21, 1989, that the proposed dump slope reduction can be achieved with our personnel and equipment. Our proposed method of reduction was demonstrated to be safe and effective. Dozer productivity increases with steeper downhill grades but the limiting factor is being able to back-up the slope which was accomplished on a 2:1 slope with un-modified D8N dozers. To increase productivity, the following is recommended:

1. New or oversized grousers should be used during dump slope reduction work. This would substantially increase traction on the loose dump materials which would help the dozers to operate better on the 2:1 slopes.

2. Wide tracks should be used. This would also help increase traction and would stabilize the dozer in sidehill situations.

3. Weight should be added to the rear of the dozers to help counter-balance the offset weight due to operation on the steep slopes. This can be accomplished by either attaching steel plates to the rear of the dozers or by replacing the single tooth rippers by double or triple tooth rippers.

4. The dozers didn't have any trouble pushing full loads with the standard size u blades. Oversize blades could be used which would increase production substantially.

Track equipment can be modified to accommodate any phase of the dump reclamation process. The optimum method will be subject to trial and error. However, when considering these modifications and past equipment successes, the described method is applicable.

Golden Sunlight hopes the information in this letter addresses your concerns.

Sincerely,

Darrell Scharf

Darrell Scharf
Environmental Engineer

cc: Dennis Casey
Gary Amestoy
Cole McFarland
Alan Joscelyn
Don Wilson
Don Jenkins
File

GOLDEN SUNLIGHT MINES, INC.

January 24, 1990

Memo To: T.A. Jensen

From: J.S. Freeman

Subject: Oxide Stockpile

I have reviewed the oxide stockpile locations for the remainder of the mine life. Don Wilson requested that I use the map which was originally drafted on May 22, 1988, and subsequently, given to the DSL. This map will be revised this year when the new pit design is finalized. I have shown the oxide stockpile locations as near as possible to the areas which we will dump relative to the new design (see attached drawing). The exact locations will be determined by August, 1990.

Upon reviewing the locations and volumes, I noticed that an error had been made in calculating the to-date oxide tonnage (January, 1989 to July, 1989). The conversion factor used to change tons to cubic yards was incorrect and resulted in an overestimation of over 13,000,000 CY of as-mined oxide material for the period.

The remaining oxide to be mined was originally estimated to average 100 feet thick. Upon reviewing the actual thickness of material on the west, north and south lobes, the thickness would probably be closer to 50 feet.

I have revised the remaining oxide estimate accordingly. The results are given below.

	Oxidized Rock (Cubic Yards)		
	West Dump Complex	North Dump Complex	Total
Stockpiled to Date	6,005,700	1,225,600	7,231,300
To be Stockpiled	4,691,000	2,526,000	7,217,000
Total	**10,696,700**	**3,751,600**	**14,448,300**

John S. Freeman
Chief Engineer

JSF/lw

Attachments
cc: Al Storey
File

GOLDEN SUNLIGHT MINES, INC.

Memo To: D. J. Wilson

From: T. A. Jensen

Date: February 7, 1990

Subject: Conceptual Dump Reclamation

Per your request, a conceptual explanation of dump reclamation is provided in this memorandum. The intent is not to provide a specific dump reclamation design; but instead, provide a general explanation of how dumps will be reduced to 2:1 slopes, capped with brown-oxidized rock (when applicable) and topsoiled.

Through the mine life, dumps will be constructed in a manner that will enhance slope reduction. Where feasible, the dumps will be stair-stepped and interior slopes will be blended to reduce the slope reduction requirements. Currently, few dumps in the west complex mingle. However, as Stage IV and V material is mined, gaps between the dumps will be minimized.

Dump reduction will correspond to the method successfully tested at Golden Sunlight in March of 1989. Large dozers, modified for slope reduction, will reduce the dumps by working on an optimum slope while carrying a final back-slope of 2:1 (see Figure 1). This will minimize push distances and the amount of maneuvering on the 2:1 slope. The optimum working slope will be a function of productivity and equipment wear.

Placement of the oxidized rock will be completed by two methods; direct push with dozers and/or re-mine, haul and place. In several areas, oxidized rock will be stockpiled behind the 2:1 slope reduction line which will allow direct pushing with dozers. In other areas, oxidized stockpiles may be drifted across reduced slopes.

The second placement method will be used for both oxidized rock and topsoil. Three techniques are proposed at this time. Each will involve constructing haulroads in the dump faces to gain access from the stockpiles to the point of application.

The three techniques are:

1. Direct Placement Via Scrapers - Scrapers will pick up stockpiled material and haul it to the appropriate 2:1 slope. Scrapers will be assisted by a large dozer equipped with a bail hook for holdback purposes. Scrapers will then spread the stockpiled material along the fall line on the 2:1 slope. Local contractors question the need for a holdback dozer. Once experience is gained, the dozer may not be needed.

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2. Haul, Dump and Dozer Placement - Cover material will be hauled by truck or scraper to the reduced dump crests, and a mini-dump will be constructed. The mini-dump will consist of a calculated volume equivalent to the required amount for the appropriate depth of cover. This mini-dump will then be reduced utilizing methods described for the initial dump slope reduction. Should a dump slope face be too long to allow economical dozing or hauling, a road will be cut into the face of the reduced dump. The same type of mini-dump will be constructed off of the cut crest and then reduced by dozers. (See Figure 2.)

3. Benched Slope Reduction, Dump and Dozer Placement - This method is similar to technique No. 2 above. To minimize the dozing and/or haulage distances, long slopes may be reduced in a stair-step method. This would require a significant amount of extra dozing during initial slope reduction. However, the overall economics may justify this work. (See Figure 3.)

These methodologies are not definitive. Perhaps a combination of ideas or entirely new concepts will ultimately prove successful. Certainly, experience will yield the most productive and economical reclamation system. Golden Sunlight will have the opportunity to test its theories in the near future. Reclamation of the uppermost dumps is scheduled in the mid-1990's and will continue intermittently throughout mine life. This will allow the methodology to be modified well before bulk reclamation near mine closure.

T. A. Jensen
Mine Superintendent

TAJ/bls

cc: J. S. Freeman
File

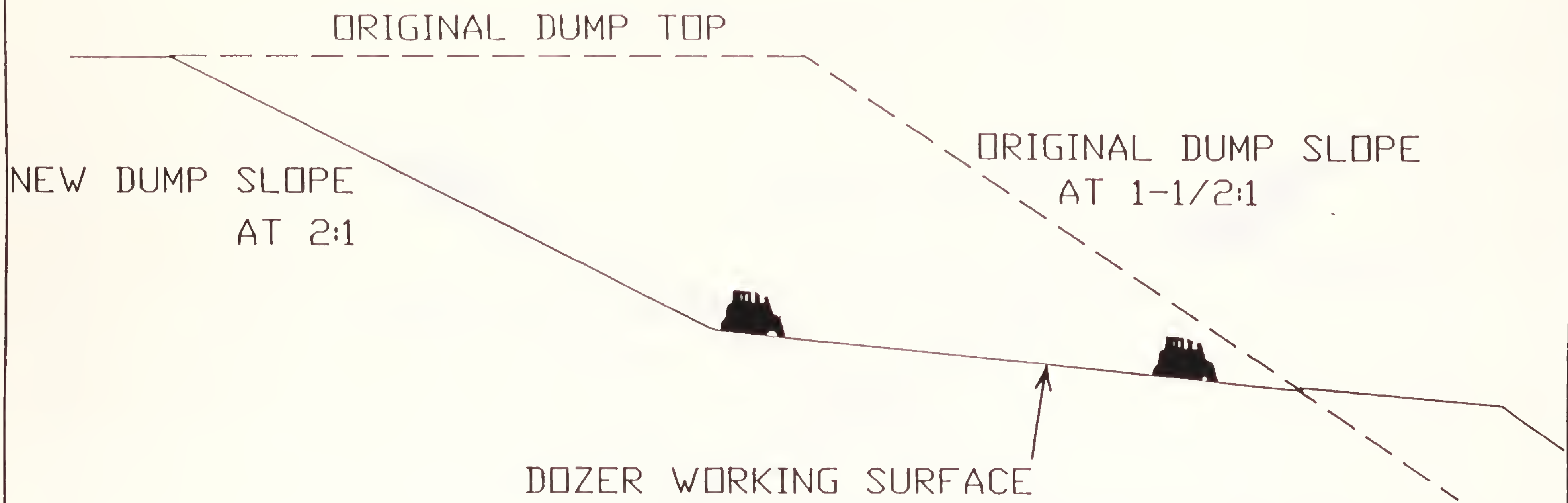

FIGURE 1

GSM METHOD OF DUMP REDUCTION

FEBUARY 1, 1990

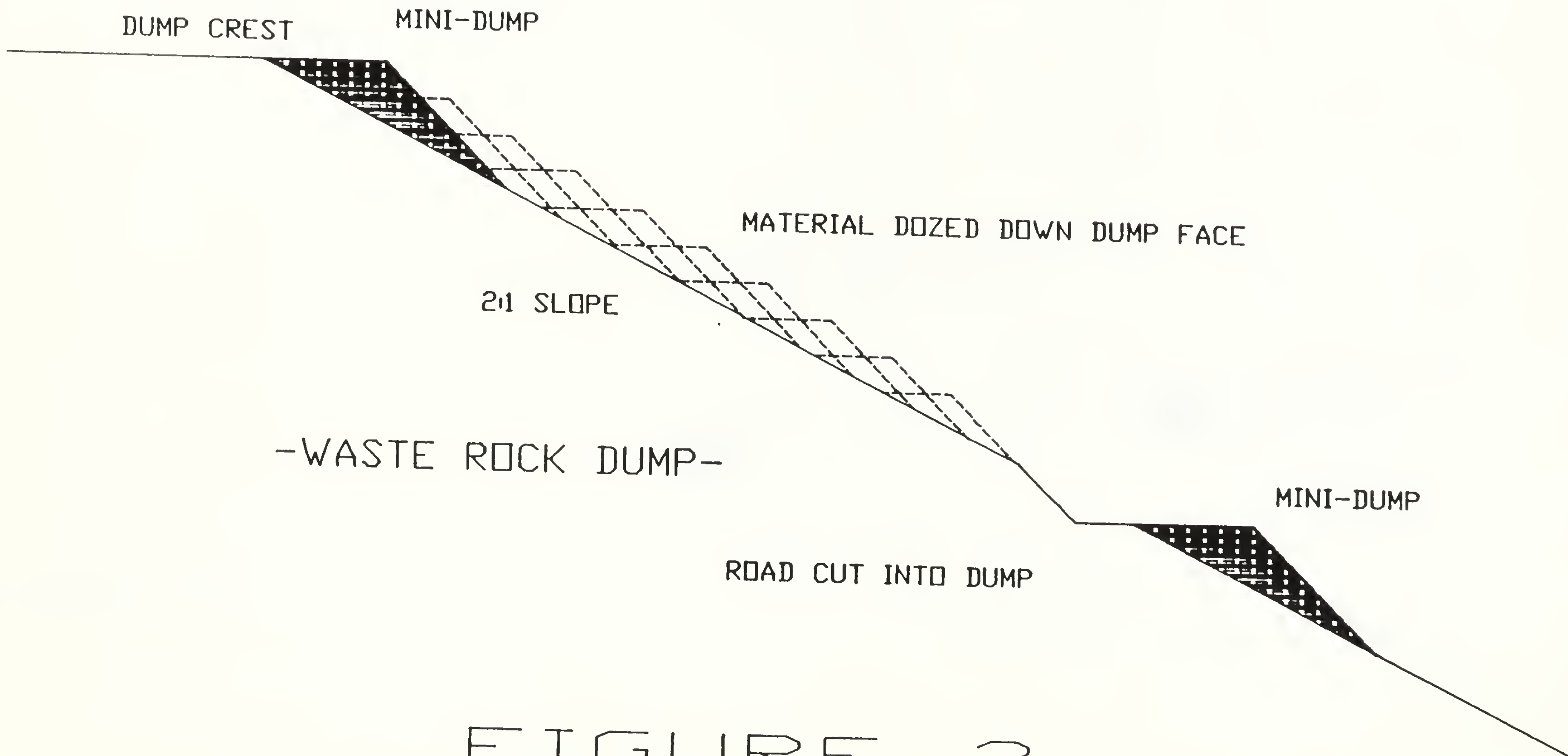

FIGURE 2

OXIDIZED ROCK PLACEMENT

FEBUARY 1, 1990

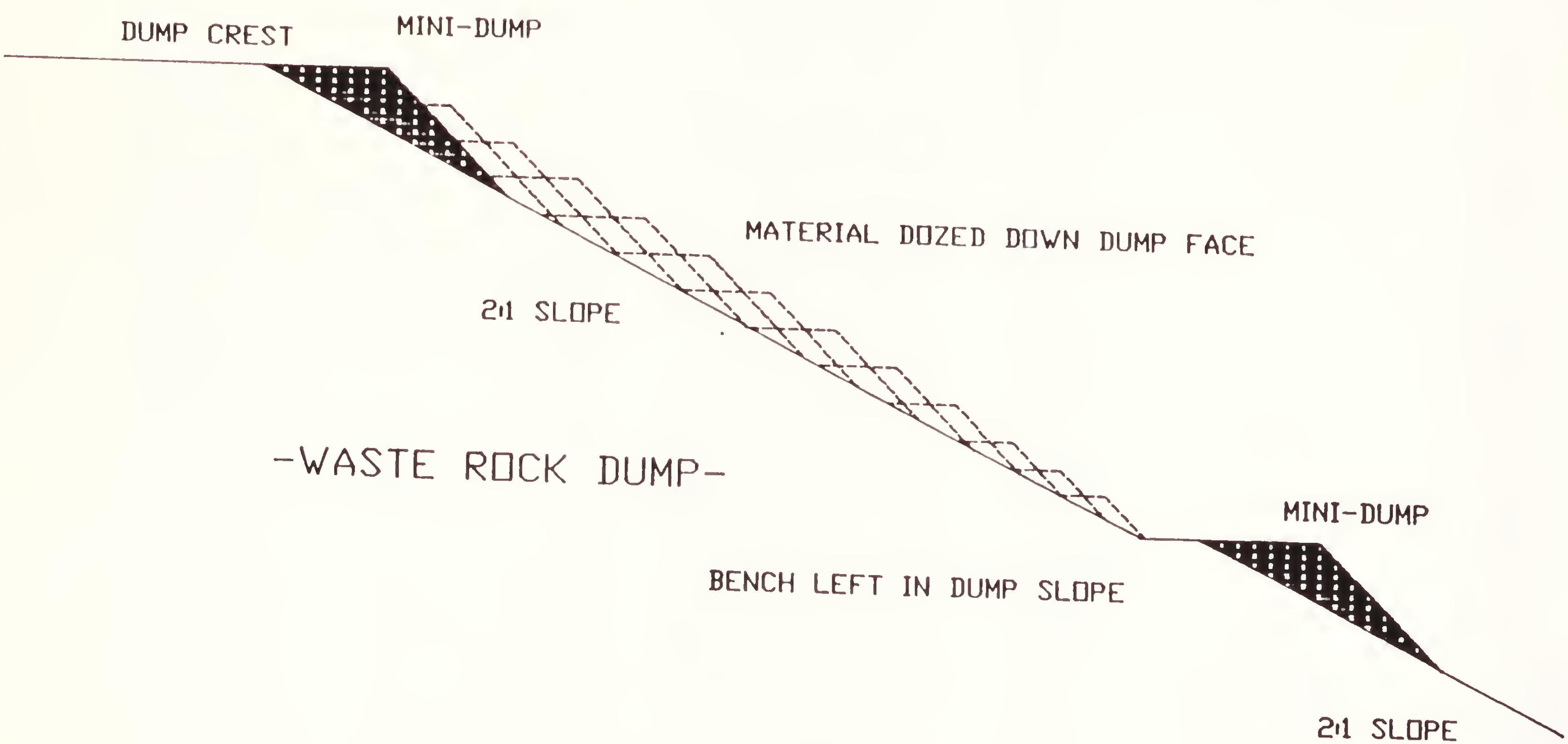

FIGURE 3

OXIDIZED ROCK PLACEMENT

FEBUARY 1, 1990

GOLDEN SUNLIGHT MINES, INC.

RECEIVED
MAY 4 '90
STATE LANDS

May 2, 1990

Mr. Pete Strazdas
Montana Department of State Lands
Hard Rock Mining Bureau
Capitol Station
Helena, MT 59620

Dear Pete:

After review of your notes for the April 19 meeting on reclamation success criteria and conversations with other individuals who were there, GSM agrees with everything but two items in your meeting notes.

First, with respect to erosion in item 2 of your notes, it was never agreed rills 3 inches wide and deep would be percentage compared to those on reference slopes. The only agreement was for a quantitative assessment without any size measurement. After examining the reference slopes April 27 which have no rills, you will probably agree it is unrealistic to establish success by a percentage variation. This point is well explained in the attached summary of the April 27 field trip meeting by R. Prodgers. GSM agrees it is more important to measure the sediment accumulation which will also account for any rill development.

Second, there was no postponement on the decision for success criteria for the depth of neutral waste rock. According to Bill Schafer and my recollection, it was decided to have:

. at least 90% of the design thickness on 50% or more of the sampling sites or transect locations

. at least 75% of the design thickness measured at 90% or more of the sampling sites or transect locations, and

. minimum of 12 inches on any area.

The above criteria were accepted unless a literature review by DSL revealed a minimum of 24" was absolutely necessary. This is explained in more detail in the memorandum from Bill Schafer which was attached to my April 19 meeting notes sent to Pat Plantenburg on April 24.

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In closing it is good that GSM, DSL and the BLM have agreed on criteria, methods, and reference areas for evaluation of reclamation success on the dump slopes. Please incorporate these in the EA and/or permit stipulations you are preparing as agreed upon.

Sincerely,

Darrell Scharf

Darrell Scharf
Environmental Engineer

DS/lw

cc: D.J. Wilson
D.E. Jenkins
Alan Joscelyn
File

BIGHORN ENVIRONMENTAL QUALITY CONTROL

April 30, 1990

Dear Mr. Scharf:

Enclosed is a summary of our meeting (4-27-90) and agreement with DSL concerning evaluation of revegetation and erosion control success on 2:1 slopes.

I would like to recommend that we delete the measurement of rills from the evaluation of erosion control success. This was not in my initial outline because the sediment troughs will measure net transported material leaving the slope. The contribution of any rills, if present, will be included in the sediment load. Any appreciable amount of sediment resulting from rill erosion will result in far more than 110% of reference area erosional deposition. So I think that the sediment troughs will summarize contributions from all sources of erosion, and further measurement of components will only complicate the evaluation.

Second, I have never been confident that the proposed rill measurement is more than a semi-quantified estimate. For example, would a second observer evaluating rills along approximately the same transects get the same results? If not, any comparison is useless and the likely subject of disagreement. We sure don't need measurements or estimates that are, in themselves, points of contention.

Third, and very important, the reference areas have no rills that I have seen. Therefore, whether the success criteria allows for 110% or 125% or whatever percentage of rills on the reference areas is immaterial. If you have zero rills on the reference area and one on the revegetated slope, that is an infinite increase.

In summary, I think GSM's reclamation can achieve 110% of erosional deposition from reference areas. But I cannot advise you to agree to a standard of no rills at all, nor do I think this provision is necessary given our primary technique of evaluating erosion control.

Sincerely,

Richard A. Prodgers

Richard A. Prodgers

305 West Mercury • Butte, MT 59701 • (406) 723-4061 • FAX 723-5345

GOLDEN SUNLIGHT 2:1 SLOPE RECLAMATION

SUMMARY OF MEETING AND AGREEMENT 4-27-90

SOIL EROSION AND REVEGETATION EVALUATION CRITERIA

by R. A. Prodgers

This meeting occurred at the mine and was attended by representatives of GSM, DSL, BLM and Bighorn Environmental. All parties agreed upon two candidate reference areas proposed by GSM. These reference areas will be used to evaluate erosion and revegetation at the low-grade ore dump and south dump sites.

VEGETATIONAL COMPARISONS

All parties agreed that in order to be "successful", canopy-coverage of revegetated slopes must be at least 90% of canopy-coverage in reference communities (see below). Revegetation success will be evaluated by measuring canopy-coverage on revegetated slopes and reference communities. Canopy-coverage measurements will be taken annually in the same locations to compare plant abundance in reference and revegetated areas, evaluate the success of species seeded into the reclaimed areas, and provide a temporal picture of plant community dynamics.

Canopy-coverage estimates will be taken along 10 systematically located transects in each treatment area and corresponding reference area. Each transect will consist of five nested 2 x 5 decimeter frames or plots. Initially, each treatment and reference area will be sampled with a total of 50 2 x 5 decimeter plots. If warranted, the number of transects and/or size of plots can be modified in later years based on results from the low-grade ore dump evaluation.

Each transect will be oriented cross-slope, with plots (frames) spaced one meter apart. The endpoints of each transect will be permanently marked with metal spikes that can be located with a metal detector if necessary. The sample grid will be diagrammed. At the perimeters of the test areas, steel fence posts will reference the locations of transects. Care will be taken to avoid trampling damage to the areas where revegetation will be measured. This caution applies to investigators conducting concurrent studies and other personnel observing revegetated slopes.

Within each frame, each vascular plant species will be identified and canopy-coverage estimated. When summarized, these data will provide average canopy-coverage and frequency information for each treatment and reference area. Color photographs will be taken of each 2 x 5 decimeter plot to document estimates and perhaps resolve anomalies in the data that often crop up in long-term studies.

Canopy-coverage from the reference and revegetated plant communities will be compared using a paired t-test, in which coverage data are paired by years. Canopy-coverage on revegetated slopes will be compared to 90% of coverage in reference areas. If canopy-coverage of revegetated slopes and 90% of canopy-coverage in reference areas do not differ at the 90% significance level during the final years of comparison, then revegetation will be considered successful. Noxious weeds (Jefferson County list) will not count toward vegetational cover in either the reference or revegetated areas.

SOIL EROSION COMPARISONS

The same two reference areas used for vegetational comparisons will be used to compare erosional deposition. The proposed soil erosion evaluation will measure the end result of erosion and sedimentation. In short, deposition from test slopes will be measured and compared to deposition from reference slopes.

Sediment troughs will be constructed or installed at the toe of reclaimed slopes and situated to evaluate similar slope lengths on reference slopes. Troughs will be permanently anchored and also tied into the upslope soil so overland flow does not cut around the trough. Each trough will have drains covered with geotextile material that allow passage of water but not soil particles of sand size or larger. After the geotextile material is covered with sediment, few if any soil particles will be lost through the drains.

Troughs will be sampled annually and after high-intensity precipitation events. The amount of sediment will be estimated volumetrically. Samples of bulk density will allow conversion to units of mass. Troughs will be cleaned when sediment accumulation appreciably reduces trough capacity.

The length of sedimentation sampling troughs will be proposed by GSM to DSL when construction details are more firm, but they will be at least 30' long at reference areas.

The amount of sediment collected in troughs at reference areas and reclaimed slopes will be compared using a paired t-test, in which sedimentation will be paired by years. Sedimentation from reclaimed slopes will be compared to 110% of sedimentation from reference areas. If the amount of sediment collected from reclaimed slopes and 110% of the sediment collected from reference areas do not differ at the 90% probability level during the final years of comparison, then erosion control will be considered successful.

APPENDIX B. MASS BALANCE MODEL DESCRIPTION

Recharge of both the replaced soil, the waste rock cap and the tailings material is expected to be controlled more by specific storm intensities and volumes than by mean annual values. Water entering the impoundment during a precipitation event will either infiltrate into the soil/tails system or will be held in temporary surface storage (filling of small ponds and depressions). Water recharging the soil system is not readily evaporated. Water that is stored in temporary and permanent surface storage and water that is located in the upper surface horizons is available for evaporation. This model assumes that all water entering the impoundment is used to recharge the soil system and that no surface detention occurs. Model inputs are identified in Tables 1 and 2.

The long-term effectiveness of evaporation as a water removal mechanism will be a function of the unsaturated hydraulic conductivity of the material and the amount of tension the evaporative system is able to produce. For a highly evaporative system such as Golden Sunlight, evaporative losses will be limited by the ability of the tailings material to move water (hydraulic conductivity). The hydraulic conductivity of the Golden Sunlight tails is estimated to be low. Therefore, it is anticipated that evaporation will be active in the upper foot or less of material. Below this zone, water movement upward in response to evaporation will be very slow, and the rate of water removal is expected to be very low. It is therefore anticipated that the majority of the tails have a moisture content at or near the specific retention value.

At closure, intersticial water within the tails can be expected to drain downward. This gravity drainage will lower the moisture content of the tails from saturation (approximately 28%) to a water content of specific retention (field capacity)(estimated at 20% based on estimated size gradation of the tails). The rate of water movement at moisture contents below saturation is a complex process and is dependent on a number of factors, including material properties and inhomogeneities in the system. Specific information on the physical properties of the Golden Sunlight tails was not provided in the application. However, it is anticipated that the unsaturated hydraulic conductivity of the Golden Sunlight tailings material will be less than the estimated saturated hydraulic conductivity (10^{-5} cm/sec).

Water entering the impoundment comes from two sources, runoff from the upstream catchment area and direct precipitation on the impoundment surface. Upstream runoff volumes reaching the impoundment surface were developed using an upstream catchment area of 113 acre (application, SHB addendum, job E88-1, volume 2,p.9). An SCS curve number of 80 corresponding to poor condition range was used to compute runoff values from rainfall values for the upstream catchment area. Direct precipitation on the impoundment was calculated using an ultimate impoundment surface are of 214 acres (application, SHB addendum, job E88-1, volume 2,p.9). All water falling on the impoundment surface was used in the mass balance calculation.

A certain volume of water entering the impoundment will be used to raise the moisture content of the soil material to allow or enhance water movement. For ease of calculation, it was assumed that no water movement in the soil matrix would take place until specific retention values were achieved. The use of this simplification is not thought to compromise the usefulness of the model. The amount of water needed to raise the moisture content of the soil to specific retention is dependent on the antecedent soil conditions. In addition, the amount of runoff entering the impoundment from the upslope source is also a function of the antecedent condition. In order to span a range of potential scenarios, three different antecedent conditions were used. For drought conditions, the volume of water to be added to the soil system prior to drainage can be represented as the difference in moisture content between the wilting point of the soil and the specific retention value. This has been estimated at 1.8 inches. In addition, the volume of runoff entering the impoundment from the storm events was calculated using the SCS antecedent condition 1 numbers. Under wetter conditions, the amount water would needed to raise the moisture content to specific retention has been estimated at 0.7 inches, and an antecedent condition III was used to calculate the runoff. An average soil moisture requirement is estimated at 1.0 inches, and runoff was calculated using an SCS antecedent condition II. It should be noted that the soil moisture requirement values appear to agree extremely well with values developed by use of the SCS curve number analysis.

Water seeping out of the soil horizon would flow through a waste rock cap layer approximately 2 feet thick. The nature of water movement for this cap is highly dependent on the size distribution of the voids between the clasts. Since this information is difficult to obtain, it is assumed that all water seeping from the soil system will be available for recharge of the tails.

Some water exiting the waste rock cap and entering the tails may be used to raise the moisture content level of the tails to at least specific retention values. However, as mentioned above, it is anticipated that the majority of the tailings mass will have a moisture content value close to specific retention values. Therefore, it is assumed that the water used to raise the moisture level of the tailings mass is insignificant and that the balance of the water seeping through the waste rock cap will be available for recharge of the tails.

Tables 3, 4, 5, and 6 indicate that at least 24 inches of replaced soils are necessary to minimize outflow under the expected conditions.

Table 1. Model Soil and Tailing Inputs

<u>Replaced Soil Material Properties</u>

Based on an average available soil classification of silty sand to silty clay, the following parameters were estimated:

Condition	Gravimetric Water Content
Wilting Point (15 Bar suction)	10%
Field Capacity (1/3 Bar Suction)	20%

Dry Density: 1.3 g/cc

Water required to raise moisture content from wilting point to field capacity:
1.5-1.8 inches/foot of soil depth

<u>Estimated Tailings Material Properties</u>

Size Gradation:
sand: 36% silt: 34% clay: 30%

Soil Classification: clay loam

Measured Moisture Content at Saturation: 28%

Specific Retention (field capacity): 22% (based on classification)

Dry Density: 1.5 g/cc

Estimated Permeability: 10-5 cm/sec

Table 2. Model Hydrologic Inputs (from SCS, 1970)

Storm Duration	Recurrence Interval	Amount (inches)	Storm Duration	Recurrence Interval	Amount (inches)
6 hrs	2 yr	.70	24 hrs	2 yr	1.10
6 hrs	5 yr	.90	24 hrs	5 yr	1.50
6 hrs	10 yr	1.00	24 hrs	10 yr	1.90
6 hrs	25 yr	1.30	24 hrs	25 yr	2.00
6 hrs	50 yr	1.4	24 hrs	50 yr	2.60
6 hrs	100 yr	1.5	24 hrs	100 yr	2.70

Table 3. Volume of water expected to exit the bottom of the soil profile (in acre inches of water) for impoundment II assuming a 24-hour storm duration of variable intensity, 12 inches of replaced soils and no diversion of upslope runon.

	Intensity		
Recurrence Interval (years)	DR-12[1] (acre in)[4]	AV-12[2] (acre in)	WET-12[3] (acre in)
2	0.0	44.0	130.8
5	0.0	152.2	250.3
10	21.4	249.1	369.8
25	42.8	276.2	402.5
50	205.1	455.4	587.4
100	226.5	488.1	620.15

[1] The volume of water expected from storms during dry years (below average)

[2] The volume of water expected from storms during years of average precipitation.

[3] The volume of water expected from storms during years of above average previpitation.

[4] Acre-inches of water expected for 12 inches of replaced soils.

Table 4. Volume of water expected to exit the bottom of the soil profile (in acre in of water) for impoundment II using a different replaced soil depths, with and without diversions of upslope runon.

No diversion:

Recurrence Interval (years)	AV-6[1] (acre in)[4]	AV-12[2] (acre in)	AV-24[3] (acre in)
2	151.0	44.0	0.0
5	259.2	152.2	0.0
10	356.1	249.1	35.1
25	383.2	276.2	62.2
50	562.4	455.4	241.4
100	595.1	488.1	274.1

Diversions in place:

Recurrence Interval (years)	AV-6[1] (acre in)	AV-12[2] (acre in)	AV-24[3] (acre in)
2	128.4	21.4	0.0
5	214.0	107.0	0.0
10	299.6	192.6	0.0
25	321.0	214.0	0.0
50	449.4	342.4	128.4
100	470.8	363.8	149.8

[1] Volume of water expected from an average rainfall event, with 6 inches of replaced soils.

[2] Volume of water expected from an average rainfall event, with 12 inches of replaced soils.

[3] Volume of water expected from an average rainfall event, with 24 inches of replaced soils.

[4] Acre-inches of water.

Table 5. Volume of water expected to exit the bottom of the soil profile (in acre in of water) for impoundment I assuming a 24 hour storm intensity, 12 inches of replaced soils and no diversion of upslope runon.

Recurrence Interval (years)	DR-12[1] (acre in)[4]	AV-12[2] (acre in)	WET-12[3] (acre in)
2	0.0	188.8	417.2
5	0.0	437.0	749.9
10	19.8	600.7	1082.6
25	39.6	662.75	1186.9
50	411.9	1161.8	1728.2
100	431.7	1266.1	1832.5

Table 6. Volume of water expected to exit the bottom of the soil profile (in acre in of water) for impoundment I using a different replaced soil depths without and with diversion of upslope runon.

<u>No Diversion of Upslope Runon:</u>

Recurrence Interval (years)	AV-6 (acre in)	AV-12 (acre in)	AV-24 (acre in)
2	287.8	188.8	0.0
5	536.0	437.0	239.0
10	699.7	600.7	402.8
25	761.8	662.75	464.8
50	1260.8	1161.8	963.8
100	1365.1	1266.1	1068.1

[1] The volume of water expected from storms during dry years (below average).

[2] The volume of water expected from storms during years of average precipitation.

[3] The volume of water expected from storms during years of above-average precipitation.

[4] Acre-inches of water expected for 12 inches of replaced soils.

Table 6. Volume of water expected to exit the bottom of the soil profile (in acre in of water) for impoundment I using a different replaced soil depths without and with diversion of upslope runon.--Continued

Diversion of Upslope Runon:

Recurrence Interval (years)	AV-6[1] (acre in)[4]	AV-12[2] (acre in)	AV-24[3] (acre in)
2	118.8	19.8	0.0
5	198.0	99.0	0.0
10	277.2	178.2	0.0
25	297.0	198.0	0.0
50	336.6	316.8	118.8
100	365.4	336.6	138.6

[1] Volume of water expected from an average railrall event, with 6 inches of replaced soils.

[2] Volume of water expected from an average rainfall event, with 12 inches of replaced soils.

[3] Volume of water expected from an average rainfall event, with 24 inches of replaced soils.

[4] Acre-inches of water.

INVESTIGATION OF GOLDEN SUNLIGHT MINES' TAILINGS POND LEAK AND ALLEGED IMPACT TO DOWNGRADIENT DOMESTIC WATER SUPPLIES

by

HARDROCK BUREAU

DEPARTMENT OF STATE LANDS

MAY 15, 1987

Table A6. Volume of water expected to exit the bottom of the soil profile (in acre inchs of water for impoundment II using a different replaced soil depths. Table A indicates the soil outflow with no diversion, Table B shows the outflow with diversion.

I. INTRODUCTION

In 1983, Golden Sunlight Mines incurred a water loss through their tailings pond slurry cut-off wall into the alluvium of a small drainage and ultimately into the alluvium of the Jefferson River near Cardwell. Subsequently, two downgradient landowners, Stan Senechal and Ray McCafferty, filed suit alleging loss of water quality due to the pond leakage. District Judge Frank Davis issued a stay order of the proceedings so that the Department of State Lands could prepare administrative findings pursuant to statute 82-4-355 MCA. Earl Griffith, Physical Sciences Coordinator for the Facility Siting Bureau of DNRC, was retained by DSL to complete these findings.

Only two questions are addressed in this determination:

1. Did the release of the tailings water ultimately contaminate the Senechal and McCafferty wells with cyanide? and
2. Did the release of tailings water contaminate the Senechal and McCafferty wells with Nitrate?

In order to address the second question, well data from other wells, including the Grace and Kebs wells (owned by How[illegible] Mulligan), were analyzed. Possible sources of the high nitrate levels in these wells and others are presented.

II. INVESTIGATION PROCESS

This report is based on the following:

A) Initial meeting with Department of State Lands Reclamation Division personnel on February 18, 1987.

B) Personal interviews with Golden Sunlight Mines' staff on March 6, 1987, and GSM staff and hydrologic consultant, Ralph Weeks, on March 12, 1987.

C) Field sampling of affected domestic wells with GSM hydrologist, Darrell Scharf, on April 13, 1987.

D) Phone interviews with Darrell Scharf on April 10, April 13, April 15, April 17, April 23, and April 24, 1987.

E) Phone interviews with Ralph Weeks of Sergent, Hauskins, and Beckwith on April 2, April 5, April 10, April 16, and April 24, 1987.

F) Phone interviews and personal conversations with John Standish, Chief Chemist of Energy Labs, on April 10, April 15, and April 24, 1987.

G) A file containing DSL notes and correspondence and copies of the stay order is presented as Exhibit 1.

H) Plates 1A and 1B from SHB report on hydrogeology are attached as Exhibit 2.

I) SHB report titled "Hydrogeologic Evaluation - Tailings Disposal Facility, Golden Sunlight Project, Whitehall, MT" is attached as Exhibit 3.

J) SHB report titled "Hydrogeologic Evaluation Report - Tailings Disposal Facility, Golden Sunlight Project, Whitehall, MT" is attached as Exhibit 4.

K) SHB report on the Grace well is attached as Exhibit 5.

L) SHB report on the tailings pond pump-back system is attached as Exhibit 6.

M) Water quality summary data sheets for wells, springs, and surface water sites are attached as Exhibit 7.

N) Lithologic descriptions for relevant wells near the tailings pond and downgradient are attached as Exhibit 8.

O) Well logs for all domestic and stock wells in the area on file with DNRC are attached as Exhibit 9.

P) Soil nitrate analysis of core material from well OW-2 is attached as Exhibit 10.

Q) SHB report on groundwater flow and solute transport is attached as Exhibit 11.

R) Photocopies of journal articles on nitrate occurrence, isotope analysis, leaching, and relationship to soil/water parameters are attached as Exhibit 12.

S) Aquifer test - data and analysis from Darrell Scharf for the Grace - Kebs area is attached as Exhibit 13.

GSM, Sergent, Hauskins and Beckwith (SHB), and Energy Labs have given their total cooperation throughout this investigation. All water quality data, maps, pertinent reports, and mathematical analyses were made available upon request. **THESE REPORTS, MAPS, DATA, AND ANALYSES ARE ON FIL AND ARE NOT REPRODUCED IN THIS APPENDIX.**

III. HYDROGEOLOGIC CONDITIONS

An extensive review of the local groundwater systems near the pond is found in Exhibit 4. Initial studies of the Jefferson River aquifer are outlined in Exhibit 3, pages 25-29. Pump test data for the Grace - Kebs area are in Exhibit 13.

Basically, three distinct groundwater units control groundwater movement from the tailings pond to the wells in question. These are the channel alluvium, Jefferson River alluvium, and the underlying Bozeman Group rocks (Exhibit 11, Sheet 1). First, the Tertiary age Bozeman Group, consisting of four distinct lithologic units, underlies the tailings pond, channel alluvium, and Jefferson River alluvium. These tightly cemented or fine-grained materials behave as a barrier to vertical groundwater movement.

Second, the channel alluvium of Quaternary age reaches a maximum thickness of about 60 feet and is connected with older terrace deposits and the Jefferson River alluvium (Exhibit 11, sheet 1, cross sections A-A' and B-B'). The hydraulic conductivity of these alluvial materials is calculated to be about 50 feet a day (Exhibit 4, pages 5-6).

Finally, regional groundwater is controlled by the Jefferson River alluvium. The vast majority of its flow is from alluvial underflow from the west with minor contributions from small tributary channels and the Bozeman Group (Exhibit 3, page 23). Estimates of hydraulic conductivity based on a long-term pump test (Exhibit 13) range from 650-750 feet per day. SHB used a value of about 580 feet a day in their report modeling the groundwater flow and solute transport (Exhibit 11). This value, along with other hydraulic parameters characteristic of the Jefferson River alluvium, was used by SHB to show that a contaminant plume could travel from the pond to the Senechal - McCafferty wells in the time period indicated by changes in cyanide values (Exhibit 11). Thus, based on the hydraulic characteristics of the two main aquifers in question, the contamination of the Senechal - McCafferty wells by cyanide was probably due to tailings pond seepage.

IV. WATER CHEMISTRY

A. Cyanide

Golden Sunlight Mines has been monitoring the upper alluvial channel at well GW-2A since December 1982 -- well before the leak. This well provided the first indication of a problem in 1983 and allowed GSM to track the movement of the cyanide plume through the channel alluvial system. A combination of new wells and existing wells were used to monitor water quality downgradient in the alluvial channel and Jefferson aquifer. The Grace well showed elevated cyanide in May 1985 (0.031 mg/l) (Exhibit 7, page 8). The Kebs well showed cyanide at 0.023 mg/l on June 27, 1985 (Exhibit 7, page 9). The McCafferty well began a steady climb in cyanide beginning May 15, 1986 at 0.012 mg/l (Exhibit 7, page 11). Finally, the veterinary Clinic, downgradient from Senechal and McCafferty, showed a possible beginning of cyanide contamination in December 1986 at 0.013 mg/l (Exhibit 7, page 13). In all cases, the water analyses show a change in baseline quality reflecting the arrival and continued influence of cyanide-contaminated water.

B. Nitrate

Water analyses for nitrate were not started until some time after the cyanide release and were generally confined to the domestic water supplies. Nitrate levels in the tailings pond are normally in the range of 4 - 5 mg/l (Darrell Scharf, personal communication). Possible sources of nitrate around the mine include the tailings pond (4 - 5 mg/l) and ammonium nitrate from blasting. Data from mine area wells do not indicate any impact from the blasting agent (Exhibit 3, page 25).

Monitoring well GW-2A just below the tailings pond shows nitrate levels ranging from 0.005 mg/l up to a maximum of 2.5 mg/l in January 1987 (Exhibit 7, page 2). Well GW-5, about 200 feet due east of GW-2A, was monitored for nitrate at the same time as GW-2A beginning in July 1986. Concentrations have ranged from 2.1 mg/l to 5.6 mg/l in January 1987 (Exhibit 7, page 4). Well OW-4 showed 7.3 mg/l nitrate in November 1985 at the peak of cyanide contamination and has risen steadily to 15.8 mg/l in January 1987 (Exhibit 7, page 5). The source of higher levels of nitrate in OW-4 are not known but could be attributable to agricultural practices. Well OW-3 east of and downgradient from OW-4 about 1800 feet shows nitrate levels of 1.3 to 2.0 mg/l. Thus, any effort to point to the mine as the source of nitrates is confounded by the low levels of nitrate in mine process waters and the relatively low levels (with the exception of OW-4) of nitrate in wells close to the mine.

Grace - Kebs area wells: The much higher levels of nitrate appearing in well OW-2 and in the Grace - Kebs wells are so much higher than surrounding wells it is probably not a problem attributable to the mine. Several reasons account for this.

1. Adding tailings nitrate values and cyanide degraded to nitrate values together doesn't add up to the very high values seen in OW-2 and the Grace - Kebs wells (5 mg/l nitrate in tailings water plus 3 mg/l nitrate from cyanide, assuming a 1:1 HCNO to NH_3 reaction by oxidation or biodegradation should account for slight increases in nitrate levels concurrent with cyanide arrival (Exhibit 7, pages 4, 5, 7, and 9)). Nitrate values from OW-2, Grace and Kebs, however, are 10 to 12 times those that would be chemically possible from a tailings water plume. Even if the background levels were 25 to 35 mg/l (Exhibit 7, pages 8 and 9), adding on the tailings water can't give the high levels shown by OW-2 and the Grace - Kebs wells.

2. Solute transport in a plume should not result in significantly different arrival times and subsequent increases or decreases in contaminants. At the Grace well, cyanide began appearing in May 1985 (0.031 mg/l) and reached a peak in May 1986 (0.27 mg/l). Nitrate started being analyzed in June 1985 (32.0 mg/l and remained relatively steady through March 1986 (31.0 mg/l) when it began to climb. From May 1986 to February 1987, cyanide was quite variable but nitrate rose to a maximum of 107 mg/l. At this same time, TDS increased from 1300 mg/l to 2160 mg/l in the Grace well, a change which didn't occur in well GW-2A with its varying cyanide. Thus, the extreme changes in nitrate concentrations at OW-2, Grace and Kebs, do not appear to be tied to the tailings pond.

3. An analysis of core material from well OW-2 (Exhibits 8 and 10) show two depths where high nitrate occurs -- from 29 to 34 feet (17 mg/l) and from 70 to 79 feet (12.0 mg/l) at the top of the Bozeman Group. It is very unlikely that tailings water would be found at the 29 to 34-foot level due to gradient

and head characteristics and the relation of the channel alluvium to the Jefferson River alluvium (Exhibit 11, sheet 1, cross sections A-A' and C-C').

The source of high nitrate in OW-2 and the Grace - Kebs wells is unknown, but several factors could be contributing to it.

1. The irrigated alfalfa field was used for dryland small grains until 1977 (Howard Mulligan, personal communication). Changes in cropping from dryland to irrigated have been known to result in nitrate leaching (Exhibit 12A).

2. The nitrate could be coming from the soil itself as a result of its inherent soil chemistry, textural characteristics, history of fertilization of dryland crops, and leaching from irrigation (Exhibits 12A, 12D, 12G, and 12H).

3. The Grace - Kebs wells could be picking up nitrates from old septic systems, now abandoned at the sites (Exhibits 12B and 12C). The age of the casings (Kebs well 1961, Grace 1965) and potential casing/packing deterioration could be allowing inter-aquifer mixing of waters (Exhibit 9, pages 1 and 2).

4. The sandy/gravelly units in the top 30 feet of the alfalfa field would have allowed rapid leaching of soluble nitrates. The siltstone from 29 to 34 feet would have retained some soluble nitrates and slowed the leaching process. However, once the nitrates reached the 44 to 60-foot section (the saturated part of the Jefferson Alluvium), mobility is unrestricted (Exhibit 8, page 2). The nitrate values given in Exhibit 10 are very likely low because the soil samples tested were over 18 months old. Normally, tests for nitrate-nitrogen are performed as soon after sampling as possible so that the analysis is accurate. Any biochemical changes over time would increase organic nitrogen and decrease nitrate.

Senechal - McCafferty wells: The Senechal and McCafferty wells show fairly consistent nitrate levels up to the time of the arrival of cyanide when the Senechal well nitrate level increased 1-2 mg/l and the McCafferty well shoed increases up to 4+ mg/l (See Exhibit 7, pages 11 and 12). These increases are appropriate given the amount of nitrate in the tailings water. More importantly are those data which precede cyanide (and thus nitrate) arrival (Senechal well, July 1986, McCafferty well, May 1986). The McCafferty well from May 20, 1985 to May 15, 1986 averaged 12.2 mg/l nitrate while the senechal well averaged 10.8 mg/l from August 12, 1985 to July 20, 1986. Thus, the nitrate levels were already above the drinking water standard before the influence of the tailings water was noted.

There are several possible sources of nitrate for these two wells. First, the land are above the Senechal - McCafferty property is used as a winter feeding area for several hundred cows and cow-calf pairs. As a result, the area is overgrazed, and has a great deal of nitrogen-rich manure o the surface, and few plants to utilize the available nitrogen. Much of this manure decomposes with its constituents going into the coulee above the Senechal - McCafferty property. It is very possible that some of the nitrate is migrating down through the channel alluvial gravels and entering the alluvial unit supplying water to these wells (Exhibits 12A, 12B, and 12E).

A second but more remote possibility is the influence of septic tank contamination. The vertical distance of the water-bearing unit from the septic drain fields (about 60 feet) would require a direct, driving head/well drawdown connection -- something which doesn't appear to exist at the properties in question. Finally, the existence of high nitrate in the Grace - Kebs wells beginning with analysis for nitrate in June 1985 could mean that the high levels had existed for some time. Unfortunately, there are no data on nitrate which precede the cyanide analysis for these wells. If a Grace - Kebs, Senechal - McCafferty well connection exists, then the McCafferty - Senechal nitrate problem could be related to the Grace - Kebs nitrate levels, and over time could be expected to increase over present levels.

V. CONCLUSIONS

* Based on analyses of domestic well water (Exhibit 7) and the groundwater/ solute transport model prepared by SHB (Exhibit 11), it appears that the cyanide seepage through the slurry cut-off wall is responsible for the cyanide concentrations at Grace - Kebs, Senechal - McCafferty, and surrounding wells.

* As stated in the SHB report (Exhibit 11), there may be a prolonged duration of low cyanide concentrations at these wells.

* The extremely high nitrate levels occurring in the Kebs - Grace wells do not appear attributable to the seepage from the tailings pond.

* The nitrate concentrations in the Senechal and McCafferty wells also do not appear related to the seepage from the tailings pond.

VI. RECOMMENDATIONS

* Whereas the source of the nitrate concentrations in the Grace - Kebs and McCafferty - Senechal wells cannot, with present data, be clearly attributable to the pond leakage, Golden Sunlight Mines should utilize the procedures developed by Charles Kreitler (Exhibits 12A, 12B, and 12C) to determine the possible source(s) of the nitrate in the domestic wells and compare them to the known source of the tailings pond.

* With respect to replacement water supplies, GSM has done a very timely and credible job and has just recently installed a reverse osmosis filter to the replacement water supply. Nothing further appears to be necessary with respect to replacement water to satisfy existing rules, other than maintaining the present system.

* GSM should continue to monitor water quality at its pump-back wells, wells into the Jefferson aquifer, and the affected domestic supplies. If it is determined that the

source of the nitrates is not from the tailings pond and future cyanide levels drop to a level acceptable to all parties, the maintenance of SH-2 alternative water supply and filter system might appropriately be borne by both the landowners and GSM. The landowners could also elect to again use their old wells, eliminating the need for the alternative system, or keep the system operating and use their own wells for lawn and garden watering.

APPENDIX D. GOLDEN SUNLIGHT MINE SOIL LOSS CALCULATIONS

The analyses in this appendix compare soil loss, and some of the factors affecting soil loss, on 2:1 slopes versus 3:1 slopes. The following assumptions were used in the comparison.

1. Although there will be some wind erosion, water erosion on the steep sideslopes of the waste rock dump and the tailings impoundment is the main concern with regard to reclamation and revegetation. The universal soil loss equation (USLE), for this reason, was used to estimate erosion from runoff (sheet and rill erosion).

2. Four soils from the Order 1 soil survey completed by Golden Sunlight Mine (GSM) were used to in this example. All of these soils were rated as good topsoil by the GSM.

3. The reclaimed soils on the waste rock dump sites and tailings impoundments, because of the depth of the top soil, are considered very shallow or shallow soils. A conservative tolerable soil loss value (T) of 2 tons/acre/year was considered the allowable soil loss for the reclaimed soils at the mine site.

To make the comparison, the Universal Soil Loss Equation[1]

The USLE is: $A = R\ K\ (LS)\ C\ P$

A = The soil loss in tons/acre. This value is obtained by multiplying the R, K, (LS), C, and P factors.

R = The average annual rainfall factor and snowmelt factor. This value is obtained from the R factor map (SCS field Office, Whitehall, MT.). An R value of 15 was used to make comparisons of different slopes and conservation practices.

K = The soil erodibility factor. This value indicates the ease with which soil particles are detached and floated away by raindrop impact and surface water movement. The soil structure for this example was considered to be massive or platy because all the structure would be destroyed in the hauling and stockpiling process. Permeability was increased for increased coarse fragments.

L = The length of slope. A slope length of 200 feet was used for the purpose of making a comparison. The soil loss increases as the length of the slope increases.

[1] Information used in these calculations is from the Soi Conservation Service Field Office Technical Guides, Whitehall, MT

S = Slope gradient in percent. This was calculated using slopes of 2:1 (50 percent slope) and 3:1 (33 percent slope) where this is a ratio of horizontal length to vertical rise. The soil loss increases as the percent slope increases.

(LS) = Topographic factor. The steepness and length of slope substantially affect the rate of erosion. These two factors have been evaluated separately in research. In field application, the two are combined into the topographic factor (LS) for convenience. This comes from a topographic factor chart. The soil loss increases as the (LS) factor increases.

C = Cover and management factors. Cover and management factors for rangeland, native pasture, and idle land were used for these calculations. It was assumed that the cover at the surface would be grass with a 20 percent ground cover. This is probably a reasonable estimate for the percent ground cover in the early stages of the reclamation process. The soil loss decreases as the percent ground cover increases.

P = Supportive practice factors. These are natural topographic features or range conservation practices that slow runoff to vary degrees. These practices that slow runoff to varying degrees. These practices are considered to be 1.0 where uniform slope, smooth surface water flow is not restricted on rangeland. Soil loss decreases as the slopes change from a uniform slope to a convex or concave slope and from a smooth surface to a moderately rough or rough surface.

T = Tolerable soil loss (T). If (A) is smaller than (T) the erosion loss is acceptable. If it is greater than (T), then either the practices will have to be applied at a higher intensity or additional practices will have to be applied. Six to twelve inches of topsoil over the tailings impoundments and waste rock dumps appears to be the range in depth of topsoil that will be applied in the reclamation by GSM. This, as pointed out in the environmental assessment, is a very shallow or shallow soil. The allowable soil loss for a very shallow or shallow soil is 1 or 2 tons/acre/year respectively. An optimistic value of 2 tons/ac/yr is used for this example.

Table 1. Soil Losses On 2h:1v Slopes.

SLOPE	SOIL	SURFACE TEXTURE	(R)	(K)	L ft.	S %	(LS)	(P)	(C)	A t/a/yr[1]	T
2:1	Argiboroll (1BC)	GR-1	15	.37	200	50	25.2	1	.2	28.0	2
2:1	Torriorthent (2BC)	Sil	15	.43	200	50	25.2	1	.2	32.5	2
2:1	Haplargid (3BC)	L	15	.43	200	50	25.2	1	.2	32.5	2
2:1	Haplargid (3BC)	CL	15	.37	200	50	25.2	1	.2	28.0	2

1. t/a/yr is defined as tons per acre per year.

Table 2. Soil Losses On 3h:1v Slopes With All Other Factors Remaining Constant.

SLOPE	SOIL	SURFACE TEXTURE	(R)	(K)	L ft.	S %	(LS)	(P)	(C)	A t/a/yr[1]	T
3:1	Argiboroll (1BC)	GR-1	15	.37	200	33	13.3	1	.2	14.7	2
3:1	Torriorthent (2BC)	Sil	15	.43	200	33	13.3	1	.2	17.1	2
3:1	Haplargid (3BC)	L	15	.43	200	33	13.3	1	.2	17.1	2
3:1	Haplargid (3BC)	CL	15	.37	200	33	13.3	1	.2	14.7	2

1. t/a/yr is defined as tons per acre per year.

The percent reduction in soil loss, throughout the remainder of this example, will be calculated to illustrate that a reduction in soil loss and the resulting reclamation of this site can be attained through the use of common conservation practices. The percent reduction in soil loss in considered the percent reduction when applying a specific conservation practice to that of the original 2:1 slopes with minimal conservation practices. This value is obtained by subtracting the two soil loss values (A) and dividing this difference by the larger value. The larger value, in all cases, will be the (A) value on 2:1 slopes.

Changing the slopes from 2:1 to 3:1 results in a 48 percent reduction of soil loss. However, this is still greater than the tolerable soil loss for a very shallow or shallow soil. With this in mind, some other conservation practices were applied to the 3:1 slopes in an attempt to reduce the soil loss to a tolerable level.

Improved "C" Values. A very shallow range site, in excellent condition, in the foothills and mountains, 10-to 14-inch precipitation zone can be expected to have a 35 percent ground cover. A shallow range site in excellent condition, in the foothills and mountains, 10-to-14 inch precipitation zone can be expected to have a 70 percent ground cover. Assuming the reclaimed soils will vary in depth between very shallow and shallow and that excellent range site conditions are possible on these reclaimed soils, a percent ground cover (including rocks) of 50 percent could be attained. This would result in a "C" factor of 0.07. The following "A" values could be obtained using a "C" factor of 0.07:

Table 3. Soil Losses on 3h:1v Slopes With Increasing Ground Cover

SLOPE	SOIL	SURFACE TEXTURE	(R)	(K)	L ft.	S %	(LS)	(P)	(C)	A t/a/yr[1]	T t/a/yr[1]
3:1	Argiboroll (1BC)	GR-1	15	.37	200	30	13.3	1	.07	5.1	2
3:1	Torriorthent (2BC)	Sil	15	.43	200	30	13.3	1	.07	6.0	2
3:1	Haplargid (3BC)	L	15	.43	200	30	13.3	1	.07	6.0	2
3:1	Haplargid (3BC)	CL	15	.37	200	30	13.3	1	.07	5.1	2

1. t/a/yr is defined as tons per acre per year.

Changing the slopes from 2:1 to 3:1 and changing the "C" value to 0.07 (50 percent ground cover) results in a 82 percent reduction of soil loss. These "A" values are still greater than the allowable "T" value of 2 tons/ac/yr. Adding a straw mulch could also increase the percent ground cover, decrease the "C" value, and reduce the "T" value. If 1.0 to 1.5 tons/acre of straw mulch were applied to the surface and crimped in with a disk or cultipacker, a percent ground cover of approximately 85 percent could possibly be attained. This could result in a "C" factor of 0.01. The following "A" values could be obtained using a "C" factor of 0.01:

Table 4. Soil Losses on 3h:1v Slopes With Additional Mulching

SLOPE	SOIL	SURFACE	(R)	(K)	L	S	(LS)	(P)	(C)	A	T
		TEXTURE			ft.	%				t/a/yr[1]	
3:1	Argiboroll (1BC)	GR-1	15	.37	200	33	13.3	1	.01	0.74	2
3:1	Torriorthent (2BC)	Sil	15	.43	200	33	13.3	1	.01	0.86	2
3:1	Haplargid (3BC)	L	15	.43	200	33	13.3	1	.01	0.86	2
3:1	Haplargid (3BC)	CL	15	.37	200	33	13.3	1	.01	0.86	2

1. t/a/yr is defined as tons per acre per year.

Changing the slopes from 2:1 to 3:1 and changing the "C" value to 0.01 (85% ground cover) results in a 97% reduction of soil loss. As this illustrates, a soil loss of less than 2 tons/acre/year is possible with 3:1 slopes and conservation practices that reduce the "C" value by increasing the percent ground cover. Other conservation practices can also help to reduce the soil loss to tolerable limits.

Improved "P" Values. Changing the slopes from uniform slopes with smooth surfaces and unrestricted flow to convex or concave slopes that are moderately rough to rough (mounds, hummocks, heaving, slipping, or "terracing" from trails, etc.) can decrease the P value from 1.0 to 0.3. This assumes that water flow will be somewhat restricted causing some deposition to occur but not enough to impede water flow down the slope. Supportive factor values between 0.3 and 1.0 can be obtained depending on the slope and roughness factor achieved by the specific conservation practice. Table 5 illustrates the reduction in soil loss that could possible be achieved by decreasing the P value to 0.3 on 3:1 slopes with a C value of 0.2

Table 5. Soil Losses on 3h:1v Slopes Using Moderate And Increased Roughness And Configuring of Slopes

SLOPE	SOIL	SURFACE TEXTURE	(R)	(K)	L ft.	S %	(LS)	(P)	(C)	A t/a/yr[1]	T t/a/yr[1]
3:1	Argiboroll (1BC)	GR-1	15	.37	200	33	13.3	.3	.2	4.4	2
3:1	Torriorthent (2BC)	Sil	15	.43	200	33	13.3	.3	.2	5.1	2
3:1	Haplargid (3BC)	L	15	.43	200	33	13.3	.3	.2	5.1	2
3:1	Haplargid (3BC)	CL	15	.37	200	33	13.3	.3	.2	4.4	2

1. t/a/yr is defined as tons per acre per year.

Changing the slopes from 2:1 to 3:1 and changing the P value to 0.3 results in an 84 percent reduction of soil loss. This soil loss (T) is greater than the tolerable soil loss using minimal C values (0.2).

An acceptable T value of less than 2 t/ac/yr can be achieved, in this example, if the C value is decreased by increasing the percent ground cover. It is not unreasonable to assume that 50 percent ground cover could be achieved and maintained during the reclamation of the GSM lands. Table 6 illustrates the reduction in soil loss that could possibly be achieved by decreasing the P value to 0.3 on 3:1 slopes with a C value of 0.07.

[1] t/a/yr is defined as tons per acre per year.

Table 6. Soil Losses On 3h:1v Slopes With Roughness, Without Mulching

SLOPE	SOIL	SURFACE TEXTURE	(R)	(K)	L ft.	S %	(LS)	(P)	(C)	A t/a/yr[1]	T t/a/yr[1]
3:1	Argiboroll (1BC)	GR-1	15	.37	200	33	13.3	.3	.07	1.6	2
3:1	Torriorthent (2BC)	Sil	15	.43	200	33	13.3	.3	.072	1.8	2
3:1	Haplargid (3BC)	L	15	.43	200	33	13.3	.3	.07	1.8	2
3:1	Haplargid (3BC)	CL	15	.37	200	33	13.3	.3	.07	1.6	2

1. t/a/yr is defined as tons per acre per year.

These practices result in a 94 percent reduction in soil loss and an acceptable A value that is less than the T value of 2 t/acre/yr. These are realistic conservation practices that could be applied in the reclamation of these lands.

Table 7 shows losses on native 2h:1v slopes for the purpose of comparison.

Table 7. Native 2:1 Slopes With Moderate Ground Cover

SLOPE	SOIL	SURFACE TEXTURE	(R)	(K)	L ft.	S %	(LS)	(P)	(C)	A t/a/yr[1]	T t/a/yr[1]
2:1	Argiboroll (1BC)	GR-1	15	.37	200	50	25.2	1	.035	4.9	5
2:1	Torriorthent (2BC)	Sil	15	.43	200	50	25.2	1	.035	5.7	5
2:1	Haplargid (3BC)	L	15	.43	200	50	25.2	1	.035	5.7	5
2:1	Haplargid (3BC)	CL	15	.37	200	50	25.2	1	.035	4.9	5

1. t/a/yr is defined as tons per acre per year.

The USLE is a tool that is used to estimate reduction of soil loss through changes made in cultural or management practices. It provides an estimate of local soil loss that can be used to evaluate erosion control needs. The examples illustrated in the results above should illustrate that a minimum slope of 3:1 as well as some other conservation practices would probably be necessary if a reduction of soil losses is to occur on the reclaimed surfaces at the GSM. These reduced soil losses, as a result of effective conservation practices, should result in the successful reclamation of the GSM. Successful reclamation of these lands should result in improved water quality as a result of less runoff, more effective use of available precipitation, and less leaching of undesirable salts and metals to underground water tables.

APPENDIX E - SOIL SALVAGE EVALUATION ON ACRES DISTURBED BY 3H:1V SLOPE REDUCTION OF WASTE ROCK DUMPS

Reduction of the waste rock dumps to slopes of 3h:1v would disturb more land surface than reduction to 2h:1v because the toe of the dumps would be pushed out onto undisturbed ground. In the north dump area approximately 29 acres of land would be covered by waste rock would remain undisturbed if slopes were reduced to 2h:1v. In the south and west dump areas this figure is 58 acres, for a total of approximately 87 additional acres disturbed by slope reduction to 3h:1v.

Soil salvage on these additional acres would offer an opportunity to increase the total amount of soil available for reclamation and marginally increase the average depth of soil on the entire dump complex. On the north dump area, additional slope reduction would offer the opportunity to salvage 140,225 bcy of additional soil which would increase the possible redistribution depth from 36 inches to 36.5 inches. On the west and south dump areas, additional slope reduction would salvage an additional 234,470 bcy of additional soil which would increase the possible average redistribution depth from 19 inches to 20.6 inches. The increased soil salvage is possible because as the dump slopes are reduced the dumps extend onto areas of deeper soil.

Additional slope reduction from 2h:1v to 3h:1v would marginally increase replacement soil depths on both the north and south and west dumps, thereby increasing available rooting depth and plant available water and reclamation success. The principle benefit of additional slope reduction would come from reduced soil erosion and improved vegetative establishment on 3h:1v slopes compared to 2h:1v slopes.

Table 1. GSM - Additional Soil Available for Salvage from 3h:1v slope reduction.

West Side:

Soil Type	Acres	Rounded Acres	Depth (in.)	Cubic Yards
13DE	6.14	6	7	5,647
12G	14.37	14	20	37,644
12F	11.66	12	60	96,800
11EF	26.14	26	27	94,380
TOTAL.....................		58 acres		234,471

North Dump:

Soil Type	Acres	Rounded Acres	Depth (in.)	Cubic Yards
6DE	7.57	8	60	64,533
8FG	7.04	7	0	0
1BC	5.20	5	54	36,300
4BC	3.39	3	13	5,243
2BC	1.76	2	60	16,133
1CD	2.31	2	49	13,176
9EF	0.82	1	25	3,361
10G	0.60	1	11	1,479
TOTAL.....................		29 acres		140,225

APPENDIX F

RESULTS OF AN INVESTIGATION OF THE HIGH NITRATE VALUES IN WELLS SURROUNDING THE GOLDEN SUNLIGHT MINE, WHITEHALL, MONTANA

Prepared by: Montana Department of State Lands

July 20, 1988

INTRODUCTION

In May 1987, the Department of State Lands (DSL) issued a report describing the impact of Golden Sunlight's tailings impoundment leak on downgradient domestic water supplies. The report concluded that cyanide from the tailings pond appeared to have contaminated the Grace - Kebs and Senechal - McCafferty wells. Elevated nitrate levels in these wells and others did not appear related to mining activities. However, a clear nitrate source was not discovered. Rising nitrate levels in the Senechal, McCafferty, and Veterinary Clinic wells led to a formal complaint to the DSL by Stan Senechal. The DSL contracted Earl Griffith of DNRC to investigate the nitrate source. This report presents the results and conclusions of that study.

INVESTIGATION PROCESS

This report is based on the following:

1. Phone interviews with Darrell Scharf of GSM and Dr. Charles Kreitler of the Bureau of Economic Geology at the University of Texas, Austin, during March and April 1988, and with landowner Howard Mulligan and Dr. Roy Spaulding of Hydro-Trace, Inc. in April 1988.

2. Complete water quality data to date on wells OW-2, OW-3, OW-4, OW-5, OW-7, OW-10, Grace, Kebs, Senechal, McCafferty, and Veterinary (Exhibit 1).

3. Plots of total cyanide and nitrate values through time for wells OW-2, OW-4, Grace, Senechal, McCafferty, and Veterinary Clinic (Exhibits 2a-2f).

4. Letter and data from Dr. Roy Spaulding (nitrate isotope analysis) to GSM dated August 10, 1987 (Exhibit 3).

5. Additional data and letter from Dr. Spaulding to GSM dated September 16, 1987, (Exhibit 4).

6. Copies of borehole logs for holes BH-1 and BH-2 (Exhibit 5).

7. Lithologic description of well OW-2 from GSM (Exhibit 6).

8. Soil analyses showing nitrate levels for well OW-2 (May 11, 1987) and BH-1 and BH-2 (March 21, 1988) from Energy Labs (Exhibit 7a). Plot of nitrate versus soil depth for hole BH-1 and BH-2 (Exhibit 7b).

9. Map of area, showing cultural practices and well locations (Exhibit 8).

10. A discussion of many of the preliminary results, assumptions, and conclusions for this study is presented in the department's first report (May 15, 1987, Exhibit 9).

RESULTS

WATER CHEMISTRY

A detailed description of the plots of total cyanide and nitrate values through time until May 1987 for the area wells is presented in the 1987 report. Exhibits 2a-2f show plots of both total cyanide and nitrate through time until the current date. The following changes have taken place since the issuance of the May 1987 report.

OW-4 (Exhibit 2a) - Cyanide values have dropped since May 1987 with the exception of a spike in July 1987 and a slight rise in March 1988. Nitrate levels have steadily risen since May 1987, with a drop in March 1988.

OW-2 (Exhibit 2b) - Cyanide values rose from May to November 1987, and then dropped in March 1988. Nitrate levels during eh same period showed a steady decline.

Grace Well (Exhibit 2c) - Since May 1987, cyanide values rose to approximately 0.25 mg/l, then dropped to 0.10 mg/l in February 1988, and then rose again in March. Nitrate levels during the same period rose steadily until February 1988 and then dropped in March.

Senechal Well (Exhibit 2d) - Nitrate levels exhibited a steady rise from May 1987 to March 1988 with cyanide values during the same period showing a slight rise and a spike in February 1988.

McCafferty Well (Exhibit 2e) - Nitrate values showed a steady rise since May 1987 with a drop in February 1988. The cyanide values have shown a fluctuating nature during the same time period.

Jefferson Veterinary Clinic Well (Exhibit 2f) - The nitrate values showed a steady rise since May 1987 with the cyanide values rising steadily, followed by a drop in March 1988.

SOIL NITRATE

The 1987 report suggests that the mine was probably not responsible for increased nitrate levels in the local wells. This conclusion is based, in part, on the fact that no clear relationship exists between the timing and the magnitude of the rise in nitrate and cyanide values in the wells near the tailings impoundment. Further, combining the tailings liquid nitrate values with the amount of nitrate expected to be generated by the breakdown of cyanide is an order of magnitude less than the values recorded in several of the area wells. In addition, soil samples taken from well OW-2 indicate a high nitrate horizon approximately 20 feet above the water table in the Jefferson alluvium.

In an effort to confirm the presence of a high nitrate horizon above the water table in the Jefferson alluvium, soil core samples from two boreholes were collected on March 2, 1988 for immediate nitrogen species analysis. BH-1 was less than 10 feet east of OW-2 and BH-2 was half-way between BH-1 and the Grace well (Exhibit 9). The analyses (Exhibit 6) provide evidence that both nitrate (NO_3 nitrogen) and Kjeldahl nitrogen (Ammonia compounds, amino compounds, and all other organically immobilized nitrogen) are very high in certain parts of the soil/subsoil profile, especially in the fine-grained fractions (See Figures 1 and 2).

Nitrogen Isotope

An isotope analyses on OW-2, OW-4, and McCafferty well water gave N^{15} ratios of +5.3, +4.4, and +5.4 respectively (see Exhibit 2). Samples collected from the tailings impoundment had N^{15} values of +1.4, while the nitrogen portion of the cyanide in the impoundment had values of approximately -1.4. In addition, a sample of leachate from a commercial fertilizer spill had values of -15.4 for the nitrate portion and -14.6 for the ammonia portion.

DISCUSSION

The source of the nitrate may best be determined by following the historic land use. Prior to being broken up for small grains in the 1960's, the "east" field between Highway 69 and the first major drainage to the west was used as a day pasture for a dairy herd (Mulligan, personal communication 1988). It was then used for alternate year, crop-fallow farming of small grains with little or no fertilization up to 1974 (Mulligan, personal communication 1988). From 1974-79 the field remained fallow (with attendant weeds), was then seeded to alfalfa, and remains so today. With this use history, the source of nitrate and the nitrate-producing process could have proceeded as follows:

First, the breakup of virgin soils to cultivated land "is often accompanied by a decrease in organic material content to a new stable level over a period of decades" (Johnston and Mattingly, 1978), "during which time significant quantities of nitrate are released by microbial activity" (Reinborn and Aunimelech, 1974; Smith and Young, 1975; Meints, Kurtz, Melsted, and Peck, 1977) in Young (1983). A grassland soil on alluvial materials in a region of 10-14 inches precipitation (semi-arid) could have between 2400 and 3200 pounds of nitrogen per acre - furrow-slice (a layer of soil 6 inches deep by 1 acre in extent -- about 2 million pounds of soil) (Brady, 1974). This amount does not include nitrogen from manure or any other source. Assuming that 50 percent was oxidized into nitrates would provide between 1200 and 1600 pounds per acre-furrow slice or concentrations between 600 and 800 ppm. The actual amount available for leaching is affected by plant uptake and the amount held on soil exchange sites. Nonetheless, there appears to be sufficient available nitrogen to produce the nitrate levels noted in the soil analyses (Figure 1).

Kreitler (1975) in his study of nitrate contamination in Runnels County, Texas, found the nitrate concentrations in turnrow soils to be high because there was no nutrient uptake by plants in these equipment roads. The study also [illegible]wed that the N^{15} ratio in these soils when compared to a standard ranged between +3 and [illegible] percent. The isotope analyses on OW-2, OW-4, and McCafferty well water gave N^{15} ratios of +5.3, +4.4, and +5.4, respectively (see Exhibit 2). Even though the initial tests by Hydro-Trace in August 1987 seemed to indicate a fertilizer or synthetic nitrate source based in part on speculative land/fertilizer use, the ratios are possible through natural nitrification. Drs. Kreitler and Spaulding confirmed this possibility through phone conversations on April 20, 1988. Dr. Spaulding also noted that one of the problems with isotope ratios in this range was that the products of natural nitrification gave nearly the same N^{15} ratio as commercial fertilizer. The high ratio from OW-2 cuttings (Exhibit 2) probably is due to nitrogen fractionation from the long (18-month) storage at extreme temperatures (well below freezing to above 100°F). The latest core material was not analyzed for isotope ratios.

Second, crop-fallow farming increases moisture in the soil profile during a period of no-plant growth. Also during this fallow period, nitrogen is being oxidized and very probably leached out of the root zone. The continuous fallow period (1974-1979 only would exacerbate the nitrogen oxidizing/leaching problem in the area's well-drained soils.

Finally, the change to irrigated alfalfa could increase the available nitrogen at depth as root/nodule systems sloughed off (Brady, 1974), as well as increase leaching through irrigation. The movement of the nitrate through the subsoils is a function of nitrate concentration in soil water below the alfalfa root zone and driving head due to irrigation (Robbins, 1980). Excess soil water and excess nitrate would, over time, find its way to the water table and water supplies as shown in Figures 3-8.

CONCLUSIONS

* Separate cyanide and nitrate sources are clearly indicated by plots of cyanide and nitrate through time for wells OW-2, OW-4, and the Grace well. In addition, separate cyanide and nitrate sources may be less clearly indicated in other analyzed wells.

* Soil analysis indicates a high nitrate reservoir in the subsoil. This nitrate reservoir appears to be due to natural nitrification of both existing soil organic matter and pre-existing nitrogen, coupled with fallow farming and irrigation practices.

* The nitrate isotope ratios of well water from OW-2, OW-4 and McCafferty are within the range of values expected from a natural nitrification source.

* Irrigation and fallow farming on the permeable soils in the area appear to have leached the accumulated nitrate out of the subsoil into the groundwater system. It is estimated that this nitrate source is sufficient to cause the elevated nitrate values seen in the downgradient wells. Therefore, it is unlikely that either mining practices or excessive fertilizer use are the nitrogen sources responsible for elevated nitrate values in wells downstream of the Golden Sunlight's tailings impoundment.

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