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Bunker Hill Mine Water Management Remedial Investigation/Feasibility Study

April 2001

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in association with
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Acronyms and Abbreviations

AAC	acceptable ambient concentration
AHPA	Archaeological and Historic Preservation Act
AMD	acid mine drainage
ARAR	applicable or relevant and appropriate requirement
ARPA	Archaeological Resources Protection Act
ATSDR	Agency for Toxic Substances and Disease Registry
AWQC	ambient water quality criteria
BAT	best available technology
BCF	bioaccumulation factor
BCT	best conventional technology
BHSS	Bunker Hill Superfund Site
BLP	Bunker Limited Partnership
BPT	best practicable technology
CAA	Clean Air Act
CDC	Centers for Disease Control
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CFR	Code of Federal Regulations
CIA	Central Impoundment Area
COC	contaminant of concern
CTP	Central Treatment Plant
CWA	Clean Water Act
DEQ	U.S. Department of Environmental Quality
DOT	U.S. Department of Transportation
EPA	U.S. Environmental Protection Agency
ERA	ecological risk assessment
ESA	Endangered Species Act

FMEA	failure modes and effects analysis
FR	*Federal Register*
gpm	gallons per minute
HAZMAT	hazardous materials
HDPE	high-density polyethylene
HDS	high-density sludge
HHRA	human health risk assessment
HMI	human-machine interface
HMTA	Hazardous Material
IDAPA	Idaho Administrati
IDEQ	Idaho Department of Environmental Quality
IDHW	Idaho Department of Health and Welfare
KT	Kellogg Tunnel
LDR	Land Disposal Restriction
LDS	low-density sludge
LHIP	Lead Health Intervention Program
MCL	maximum contaminant level
msl	mean sea level
MSWLF	municipal solid waste landfill
NAAQS	National Ambient Air Quality Standards
NAGPRA	Native American Graves Protection and Repatriation Act
NBHMC	New Bunker Hill Mining Company
NCP	National Contingency Plan
NHPA	National Historic Preservation Act
NMFS	National Marine Fisheries Service
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
NRHP	National Registry of Historic Places
NRWQC	National Recommended Water Quality Criteria

NSPS	new source performance standards
NTR	National Toxics Rule
O&M	operation and maintenance
OU	operable unit
PCB	polychlorinated biphenyl
PLC	programmable logic controller
ppm	parts per million
PRP	potentially responsible party
PTM	principal threat material
RAO	remedial action objective
RCRA	Resource Conservation and Recovery Act
RI/FS	remedial investigation/feasibility study
ROD	Record of Decision
ROW	right-of-way
SAIC	Science Applications International Corporation
SFCdA	South Fork Coeur d'Alene (River)
SSC	site-specific criteria
TBC	to-be-considered (guidance, criteria, and advisories)
TCLP	toxicity characteristic leaching procedure
TMDL	total maximum daily load
TSDF	treatment, storage, and disposal facilities
TSS	total suspended solids
U.S.C.	U.S. Code
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
UST	underground storage tank
WY	water year
WQS	water quality standard

Glossary of Frequently Used Mining Terms

Adit: A horizontal mine opening.

Bedding: Geologic arrangement of sedimentary rocks in strata.

Bedding Plane: The surface that separates ones stratum, layer, or bed of stratified rock from another. Individual layers of deposition found within sedimentary rock.

Chute: An inclined channel, as a trough, tube, or shaft, for conveying water, grain, coal, etc., to a lower level.

Conductivity: The conductivity of a solution is a measure of its ability to carry an electrical current, and varies both with the number and type of ions the solution contains.

Crosscut: A horizontal opening driven at right angles to the strike of a vein or rock formation.

Diamond Drill Hole: A small diameter boring whereby a rock core is extracted for the entire length of drilling and used in the exploration for ore.

Drift: An approximately horizontal passageway in underground mining that follows an ore vein.

Filtrate: Water that drains from the raw sludge from onsite disposal beds.

Flotation Tailings: The waste produced from the concentrating process of froth flotation. The mineralized particles will adhere to air bubbles and rise to the top of the slurry. The waste product will sink to the bottom.

Flume: A widely used device for measuring the flow rate in open channels.

Gob: A waste material containing zinc, lead, and iron sulfides.

Grouting: The process of sealing off a water flow in rocks by forcing thin cement slurry, or other chemicals, into the crevices; usually done through a diamond drill hole.

Jig Tailings: The waste product from the concentrating process of jigging. Jigging relied on the specific gravity of the mineralization to separate the ore from the waste. Fines and any lighter ores such as zinc ores (sphalrite) were not effectively recoverable by jigging.

Level: Term used to differentiate the elevations in a mine. For example, the first adit may be called the 100 Level and next adit driven below may be called the 200 Level.

Mill: The plant where the mineralization and waste rock are separated. Mills are also called concentrators. The products of a mill are the concentrate and tailings.

Mine Waste: The rock that comes out of the mine that does not contain enough mineralization to be considered ore. Many times, the waste is non-mineralized from development drifts to reach the ore bodies.

Ore: The material from the mine that contained mineralization with a grade high enough to be profitable.

pH: The negative logarithm of the hydrogen ion concentration.

Portal: The opening of an adit that is at the surface. Quite often, the portal is made of concrete to keep it open.

Raise: A shaft excavated upward from below. An inclined opening from one level to another and used for accessing an ore body.

Shaft: A vertical or sloping passageway leading to the surface used for hoisting or lowering of men or materials as well as hoisting or ore or waste.

Stope: Any excavation made in a mine, especially from a steeply inclined vein, to remove the ore that had been rendered accessible by the shafts and drifts.

Tailings Pile: An uncontained pile of waste material from a mill. Generally, the tailings piles are composed of jig tailings and have a particle size of less than 0.5 inch.

Tailings Pond: A contained impoundment of waste material from a mill. The material is generally composed of flotation tailings and is deposited in the pond as a slurry. The pond's purpose was to allow the liquid to be decanted from the slurry.

Upper Country: 9 Level and above.

Yellow Boy: Iron hydroxide ($Fe(OH)_3$) precipitate that forms as a result of ferric iron (Fe^{3+}) hydroxylation (i.e., ferric iron reacting with H_2O molecules). Iron hydroxide precipitated out of acidic water and accumulated within the flow paths of water within the mine.

Waste Pile: A pile of mine rock that did not meet the minimum grade for ore. May or may not contain mineralization of the type(s) found in ore. Mine waste generally has not been crushed and as such has a particle size that can be up to one foot or greater. The majority of the particles will be less than 1 foot in size.

Winze: An internal shaft within a mine.

Workings: Any mine excavation or operating areas.

Executive Summary

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Purpose

This focused Bunker Hill Mine Water Management Remedial Investigation and Feasibility Study (RI/FS) identifies and evaluates remedial alternatives in accordance with the requirements of the National Contingency Plan (NCP). It addresses the discharge of acid mine drainage (AMD) from the Bunker Hill Mine, located within the Bunker Hill Mining and Metallurgical Superfund site near Kellogg, Idaho.

In February 1998, the U.S. Environmental Protection Agency (EPA) and the Idaho Department of Environmental Quality (IDEQ) released a jointly prepared memorandum that identified the need to begin evaluations for long-term mine water management. The RI/FS process was begun in August 1998 in response to the joint IDEQ and EPA memorandum. A work group that includes representatives from both EPA and IDEQ, as well as the current mine owner, have worked together in developing this RI/FS.

Background

AMD Description

The AMD is a result of acid-forming reactions occurring within the mine among water, oxygen, sulfide minerals and bacteria. The majority of the AMD is formed within the Flood-Stanly Ore Body. Yearly spring snowmelt cycles typically increase water infiltration through the ore body, which in turn increases AMD formation. The largest area of water infiltration to the Flood-Stanly Ore Body is the West Fork Milo Creek basin, where all the creek flow is believed to enter the mine in the vicinity of the ore body.

The AMD is acidic and contains dissolved and suspended heavy metals that have demonstrated significant aquatic toxicity. The pH is typically between 2.5 and 3.5, and the constituents of primary concern are heavy metals. Discharge rates from the mine are usually between 1,000 and 2,000 gallons per minute (gpm), but have peaked at over 6,000 gpm during precipitation and snow melt events as a result of surface water infiltration to the mine workings.

Within the mine, the AMD flows through a series of workings and is collected in underground ditches. The lower portions of the mine are flooded, and pumps are used to keep the water level pumped down to about 11 Level. All the AMD converges together on the 9 Level (400 feet higher than 11 Level) of the mine, and is drained through the Kellogg Tunnel and out the Kellogg Tunnel portal, which is the main mine entrance. The Kellogg Tunnel, portal area, portions of the mine yard, underground workings, mineral rights, and much of the land surface above the mine is currently owned by the New Bunker Hill Mining Company, of which Mr. Robert Hopper is president.

At the portal the AMD enters a concrete ditch, passes through a Parshall flume for flow measurement, and then enters a buried pipeline that conveys it to a lined storage pond. A pump station is used to pump the stored AMD to the Central Treatment Plant (CTP). The CTP uses lime neutralization to remove the acidity and to precipitate the metals, which are removed by gravity settling, forming a sludge. The sludge is pumped into an unlined disposal area on top of the Central Impoundment Area (CIA). The treated water is discharged into Bunker Creek, which flows into the South Fork Coeur d'Alene (SFCdA) River. The CTP was constructed by the Bunker Hill Company and has not been significantly upgraded since it started operations in 1974. The CTP is currently operated and owned by the EPA. The EPA is also operating all mine water management systems outside the mine, consisting of the collection channel, pipeline, lined storage pond and pump station, and the sludge disposal area.

Baseline Risk Assessment

The following are the contaminants of concern (COCs) in the mine water identified in the baseline risk assessment:

- For aquatic and terrestrial receptors: aluminum, arsenic, cadmium, copper, iron, lead, manganese, mercury, selenium, silver, and zinc
- For humans: arsenic, cadmium, lead, mercury, and thallium

The AMD contains significant quantities of these COCs, much higher than in treated AMD (current CTP effluent). To put this into perspective (using zinc as an example), a 1-day release of untreated AMD is equivalent to about 1.4 years of existing CTP discharge, and about 5.6 years of discharge if the CTP were updated to achieve current federal and state water quality standards and targets. A prolonged direct release of AMD to Bunker Creek and then to the SFCdA River would result in an acutely toxic shock to the aquatic system, likely resulting in significant mortality of fish and invertebrate species.

Summary of the Problem

The mine water management problem at Bunker Hill stems from the following issues of concern:

- Release of untreated AMD to Bunker Creek results in toxic aquatic conditions in the creek and in the SFCdA River downstream of the confluence.
- The magnitude of the AMD flows, and particularly the high peak flows, results in considerable expense and effort to collect, convey, store and treat the mine water, and to dispose of the sludge.
- AMD discharge from the mine is expected to continue indefinitely. Current technology is unable to stop the formation and discharge of AMD from the mine.
- No long-term plan exists for control and management of the mine water.
- No measures are being taken to further reduce the flow rate and contaminant load of the mine water.

- Equipment at the CTP is reaching the end of its design life or it is inefficient, resulting in high operating costs. Some of the equipment is inoperative, and much of the equipment is approaching 30 years old and needs to be replaced. These conditions increase the likelihood of unplanned CTP shutdowns and the release of untreated AMD.
- The CTP cannot produce treated water that will meet the recently finalized total maximum daily load- (TMDL) based discharge levels and State of Idaho surface water quality criteria.
- The remaining sludge disposal space on the CIA will be filled in approximately 3 to 5 years and additional or replacement space is needed for continued operation of the CTP.

Remedial Action Objectives

The remedial alternatives developed and presented in this RI/FS present options for meeting the following remedial action objectives (RAOs):

- Prevent the release of untreated AMD into Bunker Creek and ultimately into the SFCdA River
- Reduce the concentrations and mass per day of metals discharged into Bunker Creek and ultimately into the SFCdA River
- Achieve the TMDL and Idaho surface water quality criteria
- Upgrade the CTP using more modern and reliable equipment to reduce unplanned shutdowns, to meet the new discharge standards, and to increase efficiency
- Provide additional sludge disposal capacity to enable ongoing operation of the CTP
- Reduce both the overall quantity of AMD generated by the mine, and the peak flows, which are the most difficult to collect and manage
- Reduce long-term AMD management costs
- Reduce the volume of sludge generated at the CTP to reduce long-term disposal costs

Technology Screening and Development of Alternatives

Remedial alternatives were developed by evaluating a variety of technologies for the following six general mine water control components:

- AMD Mitigations/Source Control
- AMD Collection
- AMD Conveyance
- AMD Storage
- AMD Treatment
- Sludge Management

The AMD mitigations/source control component pertains to actions that could reduce the volume or improve the quality of the AMD. AMD collection consists of the method used to

collect water within the mine and transport it to the mine portal. AMD conveyance consists of transporting the AMD from the portal to a treatment facility or into a storage pond. AMD storage addresses the requirement to place AMD in a temporary holding area during those periods when the discharge flow rate from the mine exceeds the capacity of the treatment plant or when the treatment plant is inoperative. AMD treatment consists of changing the chemical characteristics of the mine water such that it is suitable for discharge to Bunker Creek and the SFCdA River. Sludge management consists of dewatering and disposal of sludge generated during the treatment process. Performance monitoring is also a component of each alternative and consists of post-remedial-action monitoring and evaluation of remedy performance.

Remedial Alternatives

The remedial alternatives provide a range of approaches for managing the Bunker Hill mine water. The primary difference between the alternatives is the degree to which AMD mitigations and treatment capacity are implemented. They include a No Further Action alternative (Alternative 1), an alternative consisting of a larger treatment plant but no AMD mitigations (Alternative 2), alternatives that use a phased approach for implementing AMD mitigations and treatment capacity (Alternatives 3 and 4), and one using smaller treatment capacity and all the AMD mitigations carried through technology screening (Alternative 5).

Alternative 1—No Further Action

The NCP requires preparation and development of a “No Action” alternative. The No Action Alternative is a baseline alternative against which other alternatives are judged. For this RI/FS the No Action Alternative consists of performing no “further” actions. No additional remediation activities are undertaken for AMD control, no CTP repairs would be made, and no additional sludge disposal facilities would be constructed when the current CIA disposal area is full, which is expected to be within 3 to 5 years. At this point the CTP would be shut down because it cannot function without sludge disposal. This will result in untreated AMD being discharged into Bunker Creek. When the CTP is shut down, all other mine water management components would also be shut down.

Alternative 2—Treatment Only

Alternative 2, Treatment Only, consists of an updated and improved lime neutralization high-density sludge treatment plant with effluent media filters, but no mitigations for reducing infiltration to the mine and the volume of AMD from the Kellogg Tunnel. The treatment plant is sized to accommodate a peak inflow of 5,000 gpm, large enough to treat all previously recorded Kellogg Tunnel flows except for infrequent high peak flows. These infrequent high flows greater than 5,000 gpm would be stored either in the lined pond or in the mine pool for later extraction and treatment using the existing pump-based diversion and extraction systems. The AMD conveyance pipeline from the portal would be modified to allow direct flow to the CTP. The treatment sludge would be managed using one of the following four options:

Option A: The sludge from the CTP would be pumped into lined sludge disposal beds located on the CIA. In the beds the sludge would dewater by gravity draining and evaporation. The drained water would be collected and re-treated. One 10-year capacity bed would be constructed at a time, and would be capped when full.

Option B: The sludge would be dewatered at the CTP using mechanical equipment and then hauled offsite for disposal in a landfill.

Option C: This option is similar to Option A but the sludge disposal beds would be located on site above the smelter closure area rather than on the CIA.

Option D: In this option the sludge from the CTP would be pumped into one of two sludge drying beds located on the CIA. These would be smaller than the sludge disposal beds, but would dewater the sludge in the same manner. Use of the beds would alternate yearly. Every year the dried sludge from one bed would be removed and trucked to a sludge landfill located above the smelter closure area.

Performance monitoring would be conducted over the life of the remedy, consisting of on-going monitoring at the Kellogg Tunnel portal for AMD flow rate and chemistry, and at the CTP for discharge compliance.

Alternative 3—Phased Mitigations/Treatment

Alternative 3 would phase the implementation of mitigations and treatment plant capacity based on performance monitoring results. The treatment plant would be the same type as for Alternative 2, but would have an initial capacity of 2,500 gpm rather than 5,000 gpm. An initial set of mitigations believed to have the highest potential to be successful would be constructed (West Fork Milo Creek Diversion, Rehabilitate Phil Sheridan raises, and plug in-mine drill holes). Up to 10 years of performance monitoring and evaluation would be conducted to determine if the initial mitigations and treatment plant capacity were sufficient, or if more are needed. A decision process consisting of data analysis, conceptual model refinement, assessment of mitigation effectiveness, and a cost/benefit analysis would be used to evaluate remedy performance, and to select subsequent actions if warranted. Mine water flows in excess of 2,500 gpm would be temporarily stored in the lined pond or in the mine using a new gravity diversion system into the mine pool. A new mine pool extraction system would be installed to reduce the time needed to extract the stored water and to increase reliability. The AMD conveyance pipeline from the portal would be modified to allow direct flow to the CTP. Sludge would be disposed using one of the four sludge options listed in Alternative 2.

Alternative 4—Phased Mitigations/Treatment with Plugging of Near-Stream Workings

All components of Alternative 4 are the same as Alternative 3 except it includes two more initially constructed mitigations. These are plugging the Small Hopes Drift below Mainstem Milo Creek, and plugging the Inez Shaft in Deadwood Gulch below Deadwood Creek. This would reduce or eliminate the possibility of high stream flows eroding direct flow paths into the mine through these areas. Alternative 4 uses the same type of phased approach as Alternative 3 for monitoring performance and determining the need for additional actions.

Alternative 5—Treatment with All Mitigations

Unlike alternatives 3 and 4, Alternative 5 does not use a phased approach. It consists of implementing all the mitigations identified for Alternative 4 plus others, and construction of a treatment plant having a capacity of 2,500 gpm. Given the extensive mitigations implemented, additional treatment capacity is not expected to be necessary. The other components are similar to alternatives 3 and 4, except mitigation performance monitoring is assumed to occur for up to 5 years rather than 10.

Alternatives Evaluation

The alternatives were evaluated against seven of the nine criteria specified by the NCP. Two evaluation criteria, State Acceptance and Community Acceptance, will be evaluated by EPA following receipt of state and public comments at community meetings, agency meetings, and written comments submitted by the state and public in response to the RI/FS. The following are summary evaluations of the other seven criteria. Table ES-1 also provides a summary for each alternative.

Overall Protection of Human Health and the Environment

Alternative 1 does not protect human health and the environment. It results in the direct discharge of untreated AMD to Bunker Creek that endangers humans and results in toxic conditions for aquatic life. Alternatives 2 through 5 all use the same treatment technology. They protect human health and the environment by removing the toxicity associated with AMD to levels that achieve the TMDL discharge allocations for the CTP. Alternatives 3, 4, and 5, however, provide some additional protectiveness over Alternative 2. They include mitigations to reduce the overall volume of AMD, and upgraded diversion and pumping systems that permit more significant in-mine water storage. These additional components reduce the chance of high mine water flows exceeding the downstream capacity of the treatment plant and resulting in a release of untreated AMD to Bunker Creek. Alternative 2, which uses a larger-capacity treatment plant, does not have these additional safeguards. Alternatives 3 and 4 are believed to be somewhat more protective than Alternative 5. They employ a phased approach to implementing mitigations and treatment plant sizing. This approach allows careful consideration of the most effective ways to either reduce mine water flow or optimize treatment plant size. Alternative 5 does not use a phased approach; thus, it has no built-in flexibility to use or benefit from new information gained during installation and operation of initial mitigations, treatment capacity, or both. This lack of flexibility reduces its ability to protect as compared to Alternatives 3 and 4.

All four sludge options are expected to be protective of the community and the environment. Options A, C, and D, the onsite sludge disposal options, provide protection by using lined disposal facilities to prevent leakage to the environment. Fencing and gates would also be used to prevent public exposure to sludge. Option A, disposal in sludge beds located on the CIA, may provide somewhat higher worker protection because sludge handling is minimized. Option B, offsite disposal, provides protection by removing the sludge from the community and transporting it to a secure facility.

Compliance with ARARs

Alternative 1 will not meet chemical-specific ARARs and results in release of untreated AMD to Bunker Creek. All other alternatives are expected to achieve the TMDL-based discharge allocation for the CTP, and be in compliance with most Idaho surface water discharge criteria. Performance monitoring of the upgraded CTP is needed to further assess compliance for Idaho surface water criteria for mercury, selenium, thallium, temperature, dissolved oxygen, and pH. Alternatives 2, 3, 4 and 5 are expected to be in compliance with other chemical-, location-, and action-specific ARARs. All four sludge management options are expected to be in compliance with all ARARs. Therefore, there is no difference between Alternatives 2 through 5 for compliance with ARARs.

Long-Term Effectiveness and Permanence

None of the alternatives will halt the acid-producing reactions occurring within the mine. Acid production and metal release is expected to continue for hundreds or thousands of years unless new technology becomes available and is used to stop the process. The alternatives, however, differ in the degree to which they reduce the quantity of AMD and the magnitude of residual risk remaining from treatment plant sludge.

Alternative 1 takes no measures to reduce the long-term release of AMD from the mine and results in increased long-term human health risk and environmental harm by direct discharge of AMD to Bunker Creek. Alternative 2 also does not reduce the long-term release of AMD from the mine, but uses improved and larger treatment systems to protect human health and the environment. Alternatives 3, 4, and 5 use mitigations to reduce both peak and average AMD flows, which reduces the long-term risk from large flows exceeding treatment capacity compared to Alternative 2. Therefore, these alternatives provide the greatest degree of long-term effectiveness and permanence. The specific effectiveness of the mitigations will not be known until they are constructed and operated for some time; thus, it is possible that the additional mitigations initially implemented in Alternative 5 may not substantially increase overall remedy effectiveness compared to Alternatives 3 and 4.

Alternatives 2 through 5 all require long-term operation, maintenance, and periodic replacement of components. The mitigation facilities of Alternatives 3, 4, and 5 must be inspected and maintained. The mitigation facilities in the West Fork Milo Creek will be difficult to access and clean during winter and spring because of snow accumulation, which increases the probability of clogging by debris and the bypass of water into the mine. However, the potential for this occurring would be minimized during design. AMD collection within the mine is the same for all alternatives. Continual and substantial effort is needed to keep the workings maintained to ensure unimpeded movement of AMD either into storage or out through the Kellogg Tunnel. The in-mine gravity storage system used in Alternatives 3, 4, and 5 will be more reliable than the pumped system of Alternative 2. Alternatives 2 through 5 all use the same treatment processes, which are expected to provide long-term protection by reducing the acid and metals to safe levels. The treatment plants are expected to be reliable and have reasonable backup systems.

Alternatives 2 through 5 all produce the same type of sludge. Compared to Alternative 2, Alternatives 3, 4, and 5 are expected to reduce long-term sludge volumes. These reductions reduce the volume of on- or offsite land required for long-term disposal, and the magnitude

of residual risk remaining from the sludge. All four sludge management options are expected to have adequate and reliable controls to prevent migration of contaminants and public exposure, although Option B (offsite disposal) is expected to produce nearly twice the sludge volumes as the other options. Sufficient sludge disposal space is available onsite for Options A, C, and D, or regionally for Option B. Long-term land use restrictions will be needed for the onsite options (A, C, and D) to prevent disturbance of the capped and closed disposal areas. Option D requires use of trucks to transport the dried sludge from the CIA drying beds to the smelter closure area landfill. About 300 to 600 truckloads would be required over a 1-month period every fall. This volume of truck traffic along McKinley Avenue will provide some community disruption.

Reduction of Toxicity, Mobility, or Volume Through Treatment

Alternative 1 results in the existing treatment plant shutting down in 3 to 5 years. This causes an increase in the toxicity, mobility, and volume of AMD contaminants compared to current conditions.

Alternatives 2 through 5 all use the same lime high-density sludge treatment process to remove dissolved metals, and the same type of media filters for removal of suspended metals. The same treatment plant effluent quality is expected from each alternative. The treatment process will remove all of the acidity and will reduce cadmium, lead, and zinc to levels that achieve the TMDLs. The process is expected to significantly reduce the toxicity, mobility, and volume of AMD contaminants by incorporating them into an alkaline sludge. The sludge is classified as a non-hazardous waste. It is expected to pass the toxicity characteristic leaching procedure test, and it is excluded from being characterized as a hazardous waste by the Bevill Amendment to the Resource Conservation and Recovery Act. Alternative 2, however, does not employ source control measures that are expected to reduce the quantity of AMD generated and volume of sludge produced. Alternatives 3, 4, and 5 all employ such measures and thus provide greater volume reductions than Alternative 2. Alternatives 3 and 4 are expected to produce about 10 percent less AMD and sludge than Alternative 2, and Alternative 5 is expected to produce 20 percent less AMD and sludge than Alternative 2.

The treatment process could be reversed if the alkaline sludge is dissolved by contact with sufficient acidity. The onsite options (A, C, and D) use low-permeability liner and cover systems to isolate the sludge from the environment and potential sources of acidity. Long-term land use restrictions are needed to prevent the covered and closed facilities from being disturbed. The offsite option will use appropriate disposal facilities to ensure that the sludge is properly managed.

Short-Term Effectiveness

Alternative 1 increases the risk posed by release of untreated AMD by halting maintenance of existing AMD management systems. Alternatives 2 through 5 are expected to provide about the same short-term protectiveness. The AMD will continue to be collected, stored, and treated using existing systems during construction of new systems. Impacts on the community during construction of Alternatives 2 through 5 are expected to be similar because they all involve AMD pipeline and CTP upgrades, and possibly sludge disposal on-

site. Worker safety is also expected to be about the same because each uses similar construction practices.

Environmental impacts associated with Alternatives 3, 4, and 5 are greater than Alternative 2 because of impacts from mitigation construction. Some of the mitigations require work in stream segments, although some of the segments have been previously disturbed by past mining activities.

Alternatives 2 through 5 will provide protection as soon as they are implemented. The implementation time is similar for each. The phased approach used for Alternatives 3, 4, and 5 may take up to 10 years to complete, but initially implemented remedial actions are expected to provide protection from untreated releases of AMD during the phasing period.

The onsite sludge options (A, C, and D) are expected to have about the same construction impacts on the community because they require similar construction methods and timeframes. Option B, the offsite option, will have minimal community construction impacts because all construction occurs at the CTP.

Implementability

Alternative 1, although technically feasible to implement, may have low administrative feasibility because of the resulting environmental consequences from untreated AMD entering Bunker Creek and the SFCdA River. Alternatives 2 through 5 all have similar implementability. All use standard technologies expected to be reliable given proper operation and maintenance, and all require materials and services available locally or regionally. None of the alternatives prevent the undertaking of additional remedial actions, if necessary. Alternatives 2 through 5 all have the same administrative feasibility, which requires agency coordination similar to that already conducted for other portions of the site. Alternatives 3, 4, and 5 require coordination with landowners to implement mitigations.

Alternatives 2 through 5 require coordination with the mine owner for AMD collection and implementation of in-mine storage. Alternatives 3, 4, and 5 require in-mine monitoring to assess the effectiveness of the mitigations. In-mine monitoring is technically feasible and requires the cooperation of the mine owner for access to underground monitoring locations. In-mine monitoring is not required for Alternative 2.

Onsite sludge options (A, C, and D) would be constructed on federally owned land and would use standard technologies. Therefore, there are no administrative impediments to locating sludge disposal beds in these areas. These areas are also currently under industrial use (waste containment / disposal) and they are anticipated to remain so in the future. There has been some community interest in reuse of the top of the CIA (such as for a golf course) once it has been capped. However, thus far there are no specific plans or agreements in place regarding what type of reuse may be appropriate. Option A, which would be located on top of the CIA, would not preclude community redevelopment of the CIA in the future because the sludge disposal beds would occupy only a limited portion of the CIA (about 10 percent over 30 years), and would be covered and capped when full. Option C will be more difficult to implement than options A and D because of the required sludge pump station and pipeline along McKinley Avenue. Reliance on the pump station and pipeline may make Option C less reliable than options A or D. Option D requires use of public roadways to

TABLE ES-1
Alternatives Evaluation Summary
Bunker Hill Mine Water RI/FS Report

Overall Protection of Human Health and the Environment	Compliance with ARARs	Long-Term Effectiveness and Permanence	Reduction of Toxicity, Mobility, or Volume through Treatment	Short-Term Effectiveness	Implementability	Cost[1] (million $)
Alternative 1—No Further Action						
Does not protect. Results in discharge of untreated AMD and aquatic toxicity in Bunker Creek and the SFCdA River.	Does not comply with ARARs.	Takes no measures to reduce the long-term release of AMD from the mine and results in increased long-term human health risk and environmental harm by direct discharge of AMD to Bunker Creek.	Results in the existing treatment plant shutting down in 3 to 5 years, increasing the toxicity, mobility, and volume of AMD contaminants compared to current conditions.	Results in increased short-term risks. Never provides protection.	Will likely have low administrative feasibility because of the resulting environmental consequences from untreated AMD entering Bunker Creek and the SFCdA River.	Capital: $0 Annual O&M: $6.36 **Total NPV: $6.4**
Alternative 2—Treatment Only						
Protects by using storage and a large enhanced treatment plant; however, AMD flows are not reduced. Thus, there is potential for peak flows to exceed storage and treatment capacity.	Expected to comply with most Idaho surface water criteria and attain TMDLs.	Does not halt AMD generation or reduce flows. Although treatment is effective, it is needed indefinitely.	Uses treatment to reduce the toxicity, mobility, and volume of contaminants to acceptable levels. Treatment sludge requires long-term management. Treatment process could be reversed if sludge is dissolved.	Alternatives 2 through 5 are expected to provide about the same short-term protectiveness. The AMD will continue to be collected, stored, and treated using existing systems during construction of new systems.	Readily implementable. Uses existing and available technologies. No administrative difficulties. Adequate sludge storage available on or off-site. Require coordination with the mine owner to implement in-mine storage.	Capital: $15.5 – $21.2 Annual O&M: $2.21 – $2.90 **Total NPV: $44.0 – $51.5** **Lowest cost alternative (other than Alternative 1)**
Alternative 3—Phased Treatment/Mitigations						
Protects by use of mitigations to reduce AMD flows, use of an enhanced in-mine storage system, and use of an enhanced treatment plant. Phased implementation of mitigations and treatment capacity provides flexibility to increase protection if needed, and should provide more overall protectiveness than Alternative 2.	Similar to Alternative 2	Reduces long-term risk compared to Alternative 2 by using mitigations to reduce AMD flows, and an enhanced in-mine storage system. Indefinite treatment is still needed. Reduces sludge volume by about 10 percent compared to Alternative 2.	Uses the same treatment and sludge disposal methods as Alternative 2, but mitigations result in about 10 percent less AMD and sludge. Further reductions will occur if more mitigations are built using the phased approach.	Environmental impacts associated with Alternatives 3, 4, and 5 are greater than Alternative 2 because of impacts from mitigation construction.	Similar to Alternative 2, but additional coordination with the mine owner is required to implement in-mine AMD monitoring. Also requires coordination with landowners to implement mitigations.	Capital: $20.8 – $26.4 Annual O&M: $2.47 – $3.11 **Total NPV: $52.6 – $59.4**
Alternative 4—Phased Treatment/Mitigations with Plugging of Near-Stream Workings						
Similar to Alternative 3, but initially more protective since two additional mitigations are constructed.	Similar to Alternative 2	Similar to Alternative 3	Similar to Alternative 3	Similar to Alternative 3	Similar to Alternative 3	Capital: $21.8 – $27.4 Annual O&M: $2.47 – $3.11 **Total NPV: $53.6 – $60.4**
Alternative 5—Treatment with All Mitigations						
Does not use a phased approach and has less flexibility compared to Alternatives 3 and 4. This lack of flexibility reduces its ability to protect as compared to Alternatives 3 and 4.	Similar to Alternative 2	Similar to Alternatives 3 and 4, but since a phased approach is not used, it is possible that the additional mitigations initially implemented may not substantially increase overall remedy effectiveness.	Similar to Alternatives 3 and 4, but mitigations result in about 20 percent less AMD and sludge than Alternative 2.	Similar to Alternative 3	Similar to Alternative 3	Capital: $27.7 – $33.2 Annual O&M: $2.54 – $3.12 **Total NPV: $60.3 – $66.4** **Highest cost alternative**
Sludge Options						
All four sludge options are expected to be protective of the community and the environment.	All four sludge management options are expected to be in compliance with all ARARs.	All four sludge management options are expected to have adequate and reliable controls to prevent migration of contaminants and public exposure. Option D requires about 300 to 600 truckloads of sludge to be hauled each fall along McKinley Avenue from the CIA drying beds to the smelter closure area landfill. Although the trucks would be decontaminated, this volume of truck traffic could be disruptive.	All three onsite options (A, C, and D) use engineering controls or land use restrictions to isolate and protect the sludge from disturbance. The offsite option (B) will use appropriate disposal facilities to ensure that the sludge is properly managed.	The onsite sludge options (A, C, and D) are expected to have about the same construction impacts on the community. Option B, the off-site option, will have minimal community construction impacts because all construction occurs at the CTP.	Onsite sludge options (A, C, and D) would be constructed on federally owned land. Option C more difficult to implement than options A and D because of the sludge pump station and pipeline along McKinley Ave. Sufficient regionally available off-site sludge disposal capacity exists for Option B.	Of the four sludge options, Option B, which uses mechanical dewatering and offsite disposal, is the most costly. Option A, which uses CIA sludge disposal beds, is the least costly. Options C and D have about the same cost.

[1]The cost of each alternative depends on which sludge option is selected. 30-year net present values use a 7 percent interest rate to convert future costs to present cost.

AMD = acid mine drainage

SFCdA = South Fork Coeur d'Alene (River)

ARAR = applicable or relevant and appropriate requirement

TMDL = total maximum daily load

transport the sludge from the CIA drying beds to the smelter closure area landfill. There is sufficient regionally available offsite sludge disposal capacity for Option B.

Cost

Table ES-2 presents estimates of the 30-year net present value costs for the alternatives. The 30-year basis is selected merely to compare the early costs of the alternatives. All of the alternatives, except Alternative 1, are expected to have costs beyond 30 years because present information shows that contaminated mine water flows are expected to continue beyond 30 years.

The 30-year net present value costs range from $6.4 million for Alternative 1 to $66.4 million for Alternative 5B. Alternatives 3 and 4 are in the middle of the cost range. Other than Alternative 1, Alternative 2 is the least costly, and Alternatives 3, 4, and 5, which all use mitigations, are more costly. Total costs generally go up as more mitigations are implemented. Annual O&M costs also go up as more mitigations are implemented.

Of the four sludge options, Option B, which uses mechanical dewatering and offsite disposal, is the most costly. Option A, which uses CIA sludge drying beds, is the least costly. Options C and D have about the same cost.

TABLE ES-2
Summary of Costs
Bunker Hill Mine Water RI/FS Report

Alternative	Capital Costs (million $)	Annual O&M Costs[1] (million $)	30-Yr NPV[2] O&M Costs (million $)	30-Yr NPV[2] Total Costs (million $)
Alternative 1—No Further Action (4-year NPV)				
1—No Further Action	0	1.88 (Yrs 1-4)	6.4	6.4
Alternative 2—Treatment Only				
2A—with CIA Sludge Disposal Beds	16.6	2.21 (Yrs 1-30)	27.4	44.0
2B—with Mechanical Sludge Dewatering and Offsite Disposal	15.5	2.90 (Yrs 1-30)	36.0	51.5
2C—with Smelter Closure Area Sludge Disposal Beds	21.2	2.23 (Yrs 1-30)	27.7	48.8
2D—with CIA Sludge Drying Beds and Smelter Closure Area Sludge Landfill	20.1	2.31 (Yrs 1-30)	28.7	48.8
Alternative 3—Phased Mitigations/Treatment				
3A—with CIA Sludge Disposal Beds	22.0	2.57 (Yrs 1-10) 2.33 (Yrs 11-30)	30.6	52.6
3B—with Mechanical Sludge Dewatering and Offsite Disposal	20.8	3.21 (Yrs 1-10) 2.97 (Yrs 11-30)	38.6	59.4
3C—with Smelter Closure Area Sludge Disposal Beds	26.4	2.60 (Yrs 1-10) 2.36 (Yrs 11-30)	30.9	57.3
3D—with CIA Sludge Drying Beds and Smelter Closure Area Sludge Landfill	25.0	2.67 (Yrs 1-10) 2.43 (Yrs 11-30)	31.8	56.8
Alternative 4—Phased Mitigations/Treatment with Plugging of Near-Stream Workings				
4A—with CIA Sludge Disposal Beds	23.0	2.57 (Yrs 1-10) 2.33 (Yrs 11-30)	30.6	53.6
4B—with Mechanical Sludge Dewatering and Offsite Disposal	21.8	3.21 (Yrs 1-10) 2.97 (Yrs 11-30)	38.6	60.4
4C—with Smelter Closure Area Sludge Disposal Beds	27.4	2.60 (Yrs 1-10) 2.36 (Yrs 11-30)	30.9	58.3
4D—with CIA Sludge Drying Beds and Smelter Closure Area Sludge Landfill	26.0	2.67 (Yrs 1-10) 2.43 (Yrs 11-30)	31.9	57.9
Alternative 5—Treatment with All Mitigations				
5A—with CIA Sludge Disposal Beds	28.8	2.70 (Yrs 1-5) 2.46 (Yrs 6-30)	31.5	60.3
5B—with Mechanical Sludge Dewatering and Offsite Disposal	27.6	3.28 (Yrs 1-5) 3.04 (Yrs 6-30)	38.7	66.4
5C—with Smelter Closure Area Sludge Disposal Beds	33.2	2.73 (Yrs 1-5) 2.48 (Yrs 6-30)	31.8	65.0
5D—with CIA Sludge Drying Beds and Smelter Closure Area Sludge Landfill	31.4	2.79 (Yrs 1-5) 2.55 (Yrs 6-30)	32.6	64.0

[1]The annual O&M costs for Alternatives 3 and 4 is higher the first ten years due to the mitigation performance monitoring assumed to be conducted the first ten years as part of the phased approach. Alternative 5 assumes only 5 years of mitigation performance monitoring.

[2]The 30-yr Net present Value (NPV) costs are calculated using a 7 percent interest rate.

SECTION 1.0

Introduction

1.0 Introduction

1.1 Purpose and Organization

This focused Bunker Hill Mine Water Management Remedial Investigation and Feasibility Study (RI/FS) identifies and evaluates remedial alternatives in accordance with the requirements of the National Contingency Plan (NCP), Part 300.430(f)(4)(ii) of the Code of Federal Regulations (CFR). It addresses the discharge of acid mine drainage (AMD) from the Bunker Hill Mine, located within the Bunker Hill Mining and Metallurgical Superfund Site near Kellogg, Idaho (see Figure 2-1 in Section 2 of this report).

This report consists of six sections:

Section 1, Introduction: Describes the purpose and organization of the RI/FS, provides introductory background and framework, summarizes the nature and extent of the AMD contamination, provides a definition of the problem, and lists the RI/FS goals and objectives.

Section 2, Characterization of the Site: Provides RI information, which includes background information, a summary of historical investigations and research, site characterization, the risk assessment, and applicable or relevant and appropriate requirements (ARARs).

Section 3, Identification and Screening of Technologies: Identifies and describes six remedy components and provides screening of technology options for each.

Section 4, Development of Alternatives: Develops and describes five alternatives for long-term management of the AMD.

Section 5, Detailed Evaluation of Alternatives: Evaluates the alternatives against the nine criteria required by the NCP.

Section 6, Works Cited: Lists the references used in the document.

This focused RI/FS was prepared using historical site-specific data and experience gained at other similar sites to streamline new data collection and remedial technology identification and screening. Historical information is summarized and referenced to augment the information presented in this report.

1.2 Background and Framework of This RI/FS

This RI/FS focuses on the AMD that discharges from the Kellogg Tunnel of the Bunker Hill Mine, which is located within the Bunker Hill Superfund site. The following text describes the relationship of this RI/FS with past and ongoing Superfund activities.

The Bunker Hill facility was placed on the National Priorities List (NPL) in 1983, pursuant to the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA),

Section 121(c), as amended. The Bunker Hill facility includes the area commonly referred to as the Bunker Hill Superfund site (BHSS). Soils, surface water, groundwater, and air within the site have been affected by contamination associated with metals mining and refining and related activities both up-gradient and within the site. Initial investigatory and cleanup actions at the facility were focused within the BHSS. This area was identified as having the most significant human health impacts.

The facility has been divided into four cleanup areas, which are also called operable units (OUs). The four operable units are: the populated areas (OU 1); the non-populated areas (OU 2); the long-term management of AMD from the Bunker Hill Mine (OU3); and mining-related contamination in the broader Coeur d'Alene River Basin (OU 4). A Record of Decision (ROD) for the populated areas was signed in 1991 (EPA, 1991). A ROD for the non-populated areas was signed in 1992 (EPA, 1992). In 1998, a RI/FS of the third OU was initiated to address the long-term management of AMD from the Bunker Hill Mine, which is the subject of this document. Also in 1998, EPA initiated a RI/FS of the fourth OU to address mining-related contamination in the greater Coeur d'Alene River Basin. A summary of the four operable units is provided below.

1.2.1 Operable Unit 1

The populated area of the BHSS (OU 1) includes residential and commercial properties, rights-of-way (ROWs), and public use areas in the towns of Kellogg, Wardner, Smelterville, Pinehurst, and several smaller unincorporated communities. Cleanup activities began in this OU because this was the area of greatest concern for human health exposure. In 1985, a Lead Health Intervention Program (LHIP) was initiated by the Centers for Disease Control (CDC) and the Agency for Toxic Substances and Disease Registry (ATSDR) to minimize blood lead levels in children through health education, parental awareness, and biological monitoring. The program is ongoing to date and is administered by the local Panhandle Health District under the Idaho Department of Health and Welfare.

In 1986, some city parks and school playgrounds were cleaned up as part of a CERCLA removal action. The yard soil removal program was initiated in 1989 as a CERCLA time-critical removal action to replace contaminated soils in yards of homes where young children at highest risk of lead poisoning lived. Since 1994, the yard soil removal program has been implemented by the potentially responsible parties (PRPs) pursuant to the 1991 populated area ROD. The PRPs are scheduled to remediate 200 residential parcels each year until all yards, commercial properties, and ROWs with lead-contaminated soils greater than or equal to 1,000 parts per million (ppm) have been remediated to achieve a community-wide average of 350 ppm lead. Completion of remedial activities in the populated area is expected by 2003.

House dust, long recognized as a primary source of lead exposure to children, is being monitored through the LHIP. If house dust lead levels remain elevated following completion of remediation, homes with dust lead concentrations greater that 1,000 ppm will be evaluated for interior remediation. A Five-Year Review of OU1 was completed in 2000. The review document further describes OU1 cleanup activities (EPA, 2000a).

1.2.2 Operable Unit 2

The non-populated area operable unit of the BHSS (OU 2) includes the former industrial complex and mine operations area, river flood plain, hillsides, various creeks and gulches, site surface water and groundwater, and the Central Impoundment Area (CIA). Site PRPs performed various removal activities pursuant to several orders prior to the 1992 ROD, including smelter stabilization efforts from 1989 to 1993, and hillside revegetation and fugitive dust control efforts from 1990 to 1992.

Following completion of the ROD in 1992, five PRPs signed a Consent Decree with the U.S. Environmental Protection Agency (EPA) to perform cleanup activities in limited areas of the site, including the Union Pacific Railroad ROW, the A-4 gypsum pond, and the Page Pond tailings repository. In 1995, EPA and the State of Idaho entered into a State Superfund Contract to perform the remaining site remedial actions. Cleanup actions addressed in the ROD included a series of source removals, surface capping, reconstruction of surface water creeks, demolition of abandoned milling and processing facilities, engineered closures for waste consolidated on site, revegetation efforts, and surface water and groundwater controls and treatment in a constructed wetlands treatment system. There has been one ROD amendment (EPA, 1996) and two Explanations of Significant Differences since the ROD was completed in 1992. A Five-Year Review of OU2 was completed in 2000. The review document further describes OU2 cleanup activities (EPA, 2000b).

In the State Superfund Contract, EPA and the State of Idaho agreed to a two-phased site implementation strategy. Phase I largely addresses source removals aimed at consolidating extensive contamination from various areas of the site. Phase I cleanup activities are estimated to be substantially completed in 2001. Phase II will address site surface water and groundwater cleanup and will be implemented following completion of source control and removal activities and evaluation of the effectiveness of these activities in meeting water quality improvement objectives.

Although Phase II water quality-related cleanup has not yet begun, a laboratory bench study was conducted by the U.S. Bureau of Mines. That study demonstrates that a technical approach for treatment using a wetlands treatment process is not able, on a year-round basis, to achieve the desired water quality. These bench-scale laboratory studies were performed to test this treatment process on contaminated surface water and groundwater, and on Bunker Hill mine water (U.S. Bureau of Mines, 1998).

1.2.3 Operable Unit 3

At the time the non-populated areas ROD was written in 1992, the Central Treatment Plant (CTP), which was built by the Bunker Hill Company in 1974 to treat the mine water and other industrial complex wastewaters, was under private ownership and was anticipated to remain so. Therefore, the 1992 ROD did not address control of AMD from the Bunker Hill Mine or operation of the CTP in any significant way. It briefly addressed the mine water by requiring that it continue to be treated in the CTP prior to discharge to a wetlands treatment system for removal of residual metals. However, the wetlands treatment system, as noted above, was found by the U.S. Bureau of Mines to be unreliable on a year-round basis.

The 1992 ROD did not contain or otherwise identify any plans for the control or long-term management of the mine water. Subsequent to the 1992 ROD, some measures were taken to

reduce mine water flows. Between December 1994 and February 1995 the New Bunker Hill Mining Company (the current mine owner/operator) plugged 72 drill holes within the mine that were discharging water. They also placed a concrete bottom in the reservoir behind the Bunker Hill Dam in mainstem Milo Creek. This was done to reduce leakage to underlying mine workings. In 1998 and 1999 a water diversion project was implemented on the mainstem of Milo Creek. The purpose of the project was to minimize contact between Milo Creek surface water and tailings/waste rock on the valley floor, and to reduce infiltration into the mine workings underlying that stretch of Milo Creek. Although, to date, the effectiveness of these measures to reduce infiltration cannot be determined, it is believed that AMD flows, and particularly the seasonal peak flows, can be significantly reduced by additional measures.

The 1992 ROD also did not address the long-term management of the treatment residuals (sludge) from the CTP, which are currently pumped into an unlined pond on the CIA. At current disposal rates it is estimated that this pond will be filled in 3 to 5 years. In addition, the 1992 ROD acknowledged that development of a total maximum daily load (TMDL) for the South Fork Coeur d'Alene (SFCdA) River, as required by the Clean Water Act (CWA), was being considered. At the time of the 1992 ROD, however, the TMDL was not developed.

In September 1996, the United States District Court for the Western District of Washington ordered EPA and the State of Idaho to develop a schedule for completion of TMDLs for all water quality impaired streams earlier identified by the state, including the Coeur d'Alene River Basin (Basin). TMDL development for the Basin was initiated in 1998. In August 2000, a TMDL for dissolved cadmium, lead, and zinc in surface waters of the Basin was jointly released by EPA and the State of Idaho. These metals were considered the highest priority for TMDL development because large portions of the Basin exceed the water quality standards for these metals. The TMDL assigned individual wasteload allocations to approximately 70 discrete sources, including the Bunker Hill CTP, that contribute metals to surface waters of the Coeur d'Alene River and its tributaries.

In February 1998, EPA and the Idaho Department of Environmental Quality (IDEQ) released a jointly prepared memorandum that described additional considerations for the long-term management of the Bunker Hill mine water (IDEQ and EPA, 1998). The joint memorandum identified the need to begin further evaluations for long-term mine water management, including achievement of the TMDL and long-term sludge disposal. With this memorandum, IDEQ and EPA jointly initiated the RI/FS process for OU3, and in response, the Bunker Hill Mine Water Management RI/FS was begun in August 1998. A joint work group including representatives from EPA, IDEQ, contractors for both agencies, and the New Bunker Hill Mining Company (NBHMC) have worked together in developing the RI/FS.

1.2.4 Operable Unit 4

At the time the 1992 non-populated areas ROD was written, it was widely recognized that mining-related contamination in North Idaho was not limited to the areas surrounding the BHSS. Actions selected in the ROD did not address sources of contamination upgradient of the site, and although selected actions were expected to have significant benefits over time to down-gradient SFCdA River water quality, active remediation of the SFCdA River was beyond the scope of the ROD. To address these and other contamination and water quality

issues in the broader Coeur d'Alene Basin, the EPA, State of Idaho, the Coeur d'Alene Tribe, and other federal, state, and local agencies formed the Coeur d'Alene Basin Restoration Project. The purpose of this project was to integrate water quality improvement programs in the Basin through coordination of the federal regulatory authorities under the CWA, CERCLA, and RCRA, and other state, local, and tribal programs.

In 1998, EPA began to look more closely at broader Basin-wide contamination issues and initiated a RI/FS for the Coeur d'Alene Basin. The Basin, as evaluated in the RI/FS, includes the watershed and flood plains and associated communities of the South Fork, North Fork, and Main Stem of the Coeur d'Alene River, Coeur d'Alene Lake, and the Spokane River that drains from Coeur d'Alene Lake and crosses from Idaho into Washington State. The TMDL, discussed above, establishes water quality-based targets for the RI/FS for cadmium, lead, and zinc in the Coeur d'Alene River and its tributaries.

The BHSS, including the Bunker Hill Mine, is located within the area being investigated as part of the Basin project. The remedial actions conducted within the non-populated areas of the site are being reviewed and considered in the Basin RI/FS process. For example, an evaluation of metals loading from all sources in the Basin, including the non-populated areas (OU 2), is included in the Basin RI/FS. It is possible that additional cleanup actions in the non-populated area may need to be considered if determined necessary to meet overall cleanup goals for the Basin. It also possible that cleanup technologies and strategies being considered for the Bunker Hill mine water, such as water treatment and sludge management, may be similar or compatible with those considered for the Basin. This overlap may provide opportunities that benefit cleanup in both OUs.

1.3 Bunker Hill Mine Water

The preceding section described the relationship of the Bunker Hill Mine Water OU (OU3) to the other three related OUs within the Coeur d'Alene Basin. This section provides an overview of the mine water and the current mine water management system. Additional mine water characterization is provided in Section 2.

1.3.1 Mine Water Characteristics

The AMD is a result of acid-forming reactions occurring within the mine between water, oxygen, sulfide minerals and bacteria. The majority of the AMD is formed within the Flood-Stanly Ore Body. Yearly spring snowmelt cycles typically increase water infiltration through the ore body, which in turn increases AMD formation. The largest area of water infiltration to the Flood-Stanly Ore Body is the West Fork Milo Creek Basin, where all the creek flow is believed to enter the mine in the vicinity of the ore body.

The AMD is acidic and contains dissolved and suspended heavy metals that have demonstrated significant aquatic toxicity. The pH is typically between 2.5 and 3.5, and the constituents of primary concern are heavy metals. Discharge rates from the mine are usually between 1,300 and 1,700 gallons per minute (gpm), but have peaked at over 6,000 gpm during precipitation and snowmelt events as a result of surface water infiltration to the mine workings. Additional mine water characterization is provided in Table 1-1 and Section 2.

As discussed in the baseline risk assessment in Section 2.5, a prolonged direct release of AMD to Bunker Creek and then to the South Fork Coeur d'Alene (SFCdA) River would result in an acutely toxic shock to the aquatic system, likely resulting in significant mortality of fish and invertebrate species. The following are the contaminants of concern (COCs) identified in the risk assessment:

- For aquatic and terrestrial receptors: aluminum, arsenic, cadmium, copper, iron, lead, manganese, mercury, selenium. silver, and zinc
- For humans: arsenic, cadmium, lead, mercury, and thallium

The AMD contains significant quantities of these COCs, much higher than in treated AMD (current CTP effluent). To put this into perspective (using zinc as an example), a 1-day release of untreated AMD is equivalent to about 1.4 years of existing CTP discharge, and about 5.6 years of discharge if the CTP was updated to achieve the TMDL and state water quality criteria.

1.3.2 Overview of the Current AMD Management System

Within the mine, the AMD flows through a series of workings and is collected in underground ditches. The lower portions of the mine are flooded, and pumps are used to keep the water level pumped down to within a specific range near 11 Level. All the AMD converges together on the 9 Level of the mine (400 feet higher than 11 Level), and is drained through the Kellogg Tunnel and out the Kellogg Tunnel portal, which is the main mine entrance. The Kellogg Tunnel, portal area, portions of the mine yard, underground workings, mineral rights, and much of the land surface above the mine is currently owned by the New Bunker Hill Mining Company, of which Mr. Robert Hopper is President.

At the portal the AMD flows into a concrete ditch, passes through a Parshall flume for flow measurement, and then enters a buried pipeline that conveys it to a lined surface impoundment (pond). The lined pond is the central collection reservoir for site waters requiring treatment. It collects the mine water, discharge from an old mine water pipeline, wash water from two vehicle decontamination stations, leachate from the smelter area principle threat material (PTM) closure, and drainage from the industrial landfill cap toe drain. The mine water flow is the largest of all these flows, on average contributing more than 90 percent of all water requiring treatment. The mine water is also the most contaminated of the site waters. On a per-gallon basis, it contains the highest concentrations of dissolved metals, requires the most treatment chemicals, and generates the most sludge. A pump station is used to pump the combined site water from the lined pond to the CTP. If not collected at the portal, the untreated AMD would flow downhill through the mine yard, across properties where public and environmental exposures would occur, and into Bunker Creek and the SFCdA River.

The CTP uses lime neutralization to remove the acidity and to precipitate the metals, which are removed by gravity settling, forming a sludge. The sludge is pumped into an unlined disposal area on top of the CIA. The treated water is discharged into Bunker Creek, which flows into the SFCdA River. The CTP was constructed by the Bunker Hill Company and has not been significantly upgraded since it started operations in 1974. The CTP is currently operated and owned by the U.S. Environmental Protection Agency (EPA). The EPA is also

operating all mine water management systems outside the mine, consisting of the collection channel, pipeline, lined storage pond and pump station, and the sludge disposal area.

1.3.3 New CTP Discharge Levels

Table 1-2 shows the typical current discharge quality from the CTP. Table 1-3 lists the current CTP operational discharge requirements. These requirements are pursuant to an expired National Pollutant Discharge and Elimination System permit (NPDES) for the CTP.

EPA and IDEQ have developed waste load allocations for individual sources, including the CTP, for cadmium, lead, and zinc as part of the TMDL for the SFCdA River, which are described in more detail in Section 2.6. The current typical effluent quality of the CTP, listed in Table 1-2, will not meet the new TMDL-based discharge levels, which are considerably more stringent than the current requirements. The current CTP effluent will also not meet all Idaho surface water criteria, which are described in Section 2-6.

1.4 Summary of the Problem

The mine water management problem at Bunker Hill stems from the following issues of concern:

- Release of untreated AMD to Bunker Creek results in toxic aquatic conditions in the creek and in the SFCdA River.
- The magnitude of the AMD flows, and particularly the high peak flows, results in considerable expense and effort to collect, convey, store, and treat the mine water.
- AMD discharge from the mine is expected to continue indefinitely. Current technology is unable to stop the formation and discharge of AMD from the mine.
- No long-term plan exists for control and management of the mine water.
- No measures are being taken to further reduce the flow rate and contaminant load of the mine water.
- Equipment at the CTP is reaching the end of its design life or it is inefficient, resulting in high operating costs. Some of the equipment is inoperative, and much of the equipment is approaching 30 years old and needs to be replaced. These conditions increase the likelihood of unplanned CTP shutdowns and the release of untreated AMD.
- The CTP cannot produce treated water that will meet the recently finalized TMDL-based discharge levels and all Idaho surface water quality criteria.
- The remaining sludge disposal space will be filled in approximately 3 to 5 years and additional or replacement space is needed for continued operation of the CTP.

1.5 Remedial Action Objectives

The goals and objectives of this RI/FS are to present alternatives for long-term management of the mine water and to address the problems identified above in Section 1.4.

The following are the remedial action objectives (RAOs):

- Prevent the release of untreated AMD into Bunker Creek and ultimately into the SFCdA River
- Reduce the concentrations and mass per day of metals discharged into Bunker Creek and ultimately into the SFCdA River
- Achieve the TMDL and Idaho surface water quality criteria
- Upgrade the CTP using more modern and reliable equipment to reduce unplanned shutdowns, to meet the new discharge standards, and to increase efficiency
- Provide additional sludge disposal capacity to enable ongoing operation of the CTP
- Reduce both the overall quantity of AMD generated by the mine, and the peak flows, which are the most difficult to collect and manage
- Reduce long-term AMD management costs
- Reduce the volume of sludge generated at the CTP to reduce long-term disposal costs

The alternatives developed and presented in Section 4 and evaluated in Section 5 of this report present options for meeting these objectives. The alternatives focus on managing the problem using the best, currently available technologies and approaches. New control methods and strategies may be developed in future years to further reduce or eliminate the long-term burden of managing the Bunker Hill mine water.

TABLE 1-1
Summary Characterization of the Bunker Hill Mine Water[1]
Bunker Hill Mine Water RI/FS Report

Parameter	(Units)	Average[1]	Range[1]	Average Load (lb/day)[2]
Flow	gpm	1,300 to 1,700	500 to 6,700	
pH		3.1	2.6 to 3.8	
Temperature	degrees C	14.5	10.6 to 18.0	
Conductivity	µmhos/cm	2,000	1,100 to 3,600	
Sulfate	mg/L	1,900	500 to 5,300	34,000 lb/day
TSS	mg/L	170	30 to 500	3,100 lb/day
Lime Demand	lb/1,000 gal	8.2	3.7 to 40	18,000 lb/day
Solids Formed	lb/1,000 gal	8.6	3.5 to 43	19,000 lb/day
Aluminum (total)	mg/L	6.7	2.0 to 38	120 lb/day
Antimony (total)	mg/L	0.003	0.002 to 0.009	0.05 lb/day
Arsenic (total)	mg/L	0.41	0.05 to 3.6	7.4 lb/day
Barium (total)	mg/L	0.031	0.019 to 0.059	0.56 lb/day
Beryllium (total)	mg/L	0.002	0.0006 to 0.008	0.04 lb/day
Cadmium (total)	mg/L	0.39	0.11 to 2.0	7.0 lb/day
Calcium (total)	mg/L	130	27 to 240	2,300 lb/day
Chromium (total)	mg/L	0.006	0.0005 to 0.022	0.11 lb/day
Cobalt (total)	mg/L	0.190	0.07 to 0.72	3.4 lb/day
Copper (total)	mg/L	0.52	0.11 to 3.9	9.4 lb/day
Iron (total)	mg/L	210	78 to 900	3,800 lb/day
Iron (dissolved ferrous)	mg/L	41	11 to 73	740 lb/day
Lead (total)	mg/L	0.75	0.33 to 2.5	13.5 lb/day
Magnesium (total)	mg/L	160	48 to 280	2,900 lb/day
Manganese (total)	mg/L	130	31 to 230	2,300 lb/day
Mercury (total)	mg/L	0.0001	0.00005 to 0.0003	0.002 lb/day
Nickel (total)	mg/L	0.16	0.07 to 0.47	2.9 lb/day
Potassium (total)	mg/L	5.3	0.99 to 11.2	95 lb/day
Selenium (total)	mg/L	0.02	0.001 to 0.055	0.36 lb/day
Silver (total)	mg/L	0.02	0.002 to 0.052	0.36 lb/day
Sodium (total)	mg/L	2.4	0.005 to 7.0	43 lb/day
Thallium (total)	mg/L	0.030	0.001 to 0.084	0.54 lb/day
Vanadium (total)	mg/L	0.003	0.0005 to 0.025	0.05 lb/day
Zinc (total)	mg/L	170	63 to 700	3,100 lb/day

[1]Chemistry is based on Kellogg Tunnel discharge monitoring data collected during the 1998/1999 monitoring program. Flow is based on historical data between 1972 and 1999.

[2]The daily load is calculated using an average flow of 1,500 gpm and the Average concentrations.

TABLE 1-2
Typical Current Central Treatment Plant Discharge Quality
Bunker Hill Mine Water RI/FS Report

Parameter	(Units)	Typical Average[1]
pH		8 to 9
Cadmium (total)	µg/L	3.0
Lead (total)	µg/L	100
Zinc (total)	µg/L	240
Total Suspended Solids	mg/L	<1 to 4

[1]From a review of the April 1999 through March 2000 discharge monitoring reports.

TABLE 1-3
Current Central Treatment Plant Operational Discharge Requirements
Bunker Hill Mine Water RI/FS Report

Parameter	Daily Average Limit[a]		Daily Maximum Limit[b]	
	µg/L	lb/day	µg/L	lb/day
pH (pH units)	The pH must be between 6.0 and 10.0			
Total Suspended Solids	20,000	985	30,000	1,907
Total Zinc	730	36.2	1,480	91.3
Total Lead	300	14.8	600	37.0
Total Cadmium	50	2.4	100	6.1
Total Copper[c]	150	7.4	300	18.6
Total Mercury[c]	1	0.05	2	0.12

[a] The total units discharged during a month divided by the number of days the plant operated that month.
[b] The maximum value attained on any day in a given monitoring month.
[c] Daily monitoring for copper and mercury not required.

SECTION 2.0

Characterization of the Site

2.0 Characterization of the Site

This section describes the site setting, the mine and mine water, ARARs, and a risk assessment. Detailed descriptions of the site setting and mine water characteristics have been presented in previous project documents. Sections 2.1 through 2.4 summarize the information in these documents and refer the reader to these sources of more detailed information.

2.1 Site Setting

2.1.1 Setting

The Bunker Hill Mine is located in the Kellogg-Wardner-Smelterville area of northern Idaho on the SFCdA River in what is known as the Coeur d'Alene Mining District. The Coeur d'Alene River basin is located in Shoshone and Kootenai Counties in northern Idaho (Figure 2-1). The Bitterroot Range forms the divide at the eastern boundary of the basin. The Coeur d'Alene Mountains form the northern boundary, and the St. Joe Mountains form the southern boundary. Most of the main ridge systems in the basin trend westward from the Bitterroot Mountains, as in the case of the St. Joe and the Coeur d'Alene Mountains (Hobbs et al., 1965).

The towns of Kellogg and Smelterville are located in the valley of the SFCdA River, known as the Silver Valley. The Silver Valley is a mountain valley that trends from east to west approximately 2,250 feet to 4,000 feet above mean sea level (msl). Tributary valleys branching north and south are generally steep-walled with v-shaped cross sections. The town of Wardner is in a smaller valley formed by Milo Creek just south of Kellogg. Milo Creek flows north into the SFCdA River at Kellogg. The Coeur d'Alene River basin has a maximum elevation of 6,848 feet and a minimum elevation of 2,125 feet. Slopes of the area are very steep, with some slopes at angles of 30 degrees or more. The valley floors are narrow, ranging in width from three-quarters of a mile along the main stem of the Coeur d'Alene to less than one-half of a mile along the SFCdA River (Ralston, 1973, and Trexler, 1975). Figure 2-2 is a map showing the local area.

The mine is located below hills just south of Kellogg. The major area of underground workings lies between Milo Creek and Deadwood Creek as depicted in Figures 2-2 and 2-3. The main entrance to the underground mine workings is through the Kellogg Tunnel portal, which opens into the valley within the town of Kellogg at an elevation of 2,360 feet. The hills above the mine rise to Wardner and Kellogg peaks, the location of the Silver Mountain Ski Resort. Kellogg Peak is slightly higher than Wardner Peak at an elevation of 6,297 feet.

2.1.2 Climate

The climate in the study area has four seasons of generally equal length. Mild temperatures are common during the summer, with highs typically in the 70s and 80s. During the winter, the highs in the Silver Valley are often in the 20s and 30s, but sub-zero temperatures are not uncommon for brief periods. The annual average precipitation in Kellogg is 33.0 inches,

based on data (1970-1999) from the Idaho State Climate Services in Moscow, Idaho. Generally, the data show that precipitation increases with elevation. Most of the precipitation is in the form of snow falling primarily during the winter. The maximum, average, and minimum snowpack amounts measured on Kellogg Peak during the past 29 years (1970-1998) equal 52.4, 29.6, and 13.6 inches of snow water equivalent, respectively, based on data from the Idaho State Climate Services. The snowpack values are based on instantaneous measurements taken roughly once per month. Snowmelt from the higher elevations collects in ephemeral and perennial streams. Snowmelt from the northwest side of Kellogg Peak and from the north side of Wardner Peak is collected by the forks of Milo Creek, which flow above the eastern end of the mine workings.

A short rainy season can usually be expected in April, May, and early June, and the latter part of September. The snow often melts in the lower western portion of the study area between storms, but accumulates at the higher elevations of Kellogg and Wardner peaks. These accumulations remain until late August if they are shaded from the sun. Snow may persist in some cirque basins throughout the year (Trexler, 1975).

Warm spells and Chinook winds occasionally occur during the winter. The Chinook winds consist of warmer air masses from the southwest that can cause rapid snowmelt, which results in elevated flows in the streams and creeks that overlie the mine. Elevated flows can also occur in the late spring or early summer as a result of warmer temperatures and rainfall.

2.1.3 Vegetation

The Bunker Hill Mine and surrounding area originally consisted of a large coniferous forest and included western hemlock, western red cedar, mountain hemlock, and subalpine larch interspersed with ponderosa pine, lodgepole pine, and Douglas fir. The principal species at higher elevations included subalpine fir, mountain hemlock, and grand fir. Western white pine, lodgepole pine, and western larch are the principal disturbance-related species that often dominate forests because of past fires (Dames and Moore, 1990). The forest has been heavily affected in low-lying areas near Bunker Hill as a result of harvesting the timber for mine timbers and fuel. Much of the timber not used in the mining operations or for fuel was burned in the forest fire of 1910 that swept through the area. Near Kellogg and Smelterville, smelter fumes have reduced the amount of vegetation on the hillsides. An effort is in progress as part of the sitewide Superfund activities to revegetate these areas as determined by the 1992 ROD.

A great variety of vegetation still exists within the basin. The conifers now present include Douglas fir, white fir, Alpine fir, western yellow pine, western white pine, lodgepole pine, mountain hemlock, Engleman spruce, and patches of western larch. Aspen groves are found on high open slopes. The brushy plants of the higher elevations include huckleberry or tall whortleberry, and deerbrush (Ralston et al., 1973).

The lower elevation of the basin contains western yellow pine and many deciduous trees. The deciduous trees are mainly species of willows and black cottonwood. The brushy plants are huckleberry or tall whortleberry, chokecherry, mountain ash, and devils club (Ralston et al., 1973).

2.1.4 Geology

The Coeur d'Alene mining district lies at the intersection of a broad arch that extends from Kimberly, British Columbia, to the St. Joe River in Idaho and the Lewis and Clark Lineament (Trexler, 1975). The Lewis and Clark Lineament is represented in the district by the Osburn Fault and related faults. The patterns of the folds and faults in the district are governed by the Osburn Fault, an extensive fault with a west-northwest strike and a large strike-slip displacement. Movement along the Osburn Fault is right lateral with a maximum displacement of 16 miles.

The faulted block of Belt sediments that includes the Bunker Hill Mine lies south of the Osburn Fault and contains several additional major faults. Major faults that intersect the Bunker Hill Mine include the Cate, Sullivan, Dull, Katherine, Buckeye, and Kruger. These faults make up the skeleton along which the ore bodies are associated. The Cate Fault is the major structure in the mine, striking northwesterly and dipping 40 to 60 degrees to the southwest. The Sullivan, Dull, and Kruger faults lie in the foot wall (northeast) of the Cate Fault. The Katherine and Buckeye faults lie in the hanging wall (southwest) of the Cate Fault. All these faults strike more westerly than the Cate, with a dip of 50 to 30 degrees to the southwest.

The principal rock types found in the Coeur d'Alene mining district belong to the Belt Supergroup of Precambrian metamorphic rocks (Riley, 1985). They are composed of fine-grained argillites and quartzites associated with smaller amounts of carbonate-bearing dolomitic rocks. The formations of the Belt Series from oldest to youngest are Prichard, Burke, Revette, St. Regis, Wallace, and Striped Peak.

The Bunker Hill Mine lies within a highly faulted block of transition rock between the Revette and St. Regis formations. The Revette formation is composed primarily of massive quartzites interlaminated and interbedded with argillites. The St. Regis formation includes argillites and argillaceous quartzite, which grade downward to the base into nearly pure quartzite.

The Bunker Hill Mine includes three general ore types classified on the basis of their mineralogy. The ore bodies occur along major faults with little dispersion into the country rocks. Trexler (1975, p. 23-24) provides the following description of the ore types:

> The Bluebird Ore contains considerable pyrite and galena, which usually exceeds or equals sphalerite in a siderite-quartz gangue. The Bunker Hill Ore consists mainly of galena in a siderite-quartz gangue. The Jersey Ore consists of galena with considerable sphalerite in a quartz-siderite gangue. The major mineralogical difference between the three ore types is the presence of large quantities of pyrite in the Bluebird Ore and the high degree of oxidation found in the Bluebird Ore areas (upper levels of the mine).

2.1.5 Mine Hydrology

The following text provides an overview of the mine hydrology. Additional detail on flow of water within the mine is provided in Section 2.3.

Water flow in and near the Bunker Hill Mine reflects the intentional and unintentional impact of mining activities on the bedrock groundwater flow system within the area of the

mine. Trexler (1975), Eckwright (1982), Hunt (1984), Erikson (1985) and Riley (1990) provide detailed information on water flow in and near the mine from a series of studies conducted by the University of Idaho. Eckwright (1982, p. 24) divides the occurrence and movement of water within the mine into two groups:

1. Water movement that occurs through man-made openings from the surface to the underground mine levels and from level to level down through the mine, and
2. Water discharged into the mine from natural fracture systems in the rock either through drill holes or directly into drifts and stopes.

Trexler (1975, p. 54) describes the development of the mine and the impacts on water flow patterns as follows:

> After the mining began in 1885, the equilibrium of the ground-water system in the mine area was disturbed. Often the stopes were worked to the surface, some even into the creek bed. This caused increased recharge through stopes and increased discharge from the portals. The Milo Creek area (Small Hope and East Reed workings) and the Deadwood Creek area (Inez, Arizona and Oakland workings) are excellent examples of such a disturbance.
>
> As the mining activity extended downward from the upper levels, a vertical zone of high permeability was developed. The porosity is secondary, formed from multilevel stopes and other interconnections, man-raises and ore passes.
>
> Block caving, used in the upper levels (4, 5 and 6) of the Bunker Hill Mine, forms another vertical zone of high permeability. The surface depression caused by the subsidence brought about by the caving creates a major surface recharge site. This surface feature channels three small intermittent tributary valleys of Milo Creek directly into the caved area where the water freely moves on down through the old workings.

The mine workings interconnect the pre-mining subregional groundwater system almost exclusively through fractures within the block caving imposed by the mining methods. Much of the water draining by gravity through the mine workings is captured on the 9 Level and drains out the Kellogg Tunnel. Water currently not captured from the upper workings and water from the lower workings is pumped up to the 9 Level to join the water from the upper workings. The pumping maintains the mine pool water level near the 11 Level. Riley (1990) indicated in the 1980s that on average about 44 percent of the Kellogg Tunnel discharge was gravity drainage, with the remaining 56 percent pumped from the lower workings. This approximately equal split between gravity and pumped water was also found during the 1998/1999 monitoring program (CH2M HILL, 2000a).

2.2 Mine Description

2.2.1 History

Mining at the Bunker Hill site began in 1885 when Noah Kellogg set out to discover gold in the Silver Valley. Kellogg staked a claim on land subsequently called Bunker Hill. A mill was built, and a small mining operation was started in 1886.

From 1887 through 1916, ore concentrate from the mine was shipped to various smelters in the west. In 1917, a smelter began operation at the mine, and in 1926 an electrolytic zinc plant was installed. An electrolytic antimony plant was constructed in 1939 but operated only a few years. A slag fuming plant was constructed in 1943 to recover zinc in blast furnace slag. In 1954, a sulfuric acid plant was added to the zinc plant to recover sulfur in the stack gases, and in 1960 a phosphoric acid plant was constructed. A second sulfuric acid plant was added to the lead plant during the 1970s.

By 1960, production for the mine included 26,500,000 tons of ore, 2,000,000 tons of lead, 321,000 tons of zinc, and 97,000,000 ounces of silver. In 1974, the mine produced about 2,500 tons of ore per day with a total production of 31,500,000 tons of ore. Development averaged about 4 miles per year of drifting and about 60,000 feet per year of diamond drill holes (Trexler, 1975).

At its peak, Bunker Hill was one of the largest lead/zinc mines in the world. The mine was part of the Bunker Hill Mining Complex that was an integrated mining, milling, and smelting operation. In addition to the mine, the complex included a milling and concentrating operation, a lead smelter, a silver refinery, an electrolytic zinc plant, a phosphoric acid and fertilizer plant, sulfuric acid plants, and a cadmium plant. The complex occupied approximately 350 acres between the towns of Kellogg and Smelterville. The Complex produced silver, corroding lead, antimonial lead, special high-grade zinc, zinc die casting alloys, cadmium, specification lead alloys, leaded zinc oxides, ore metal, super-purity antimony, sulfuric acid, and phosphoric acid.

In the 1970s, growing public concern about the environment compelled the owners of the Bunker Hill Mine to implement improvements to comply with federal air and water pollution control standards. Several pollution control systems were put in place, including AMD control. A water treatment plant (the CTP) was completed in 1974 to treat the AMD and associated complex flows.

In 1983, when the Bunker Hill site was placed on the NPL, EPA and IDEQ focused their attention on the 21-square-mile area referred to as the Bunker Hill Mining & Metallurgical Complex or “the box,” the area of most severe human health risk, historically. Starting in 1994, the milling, processing, smelting and other facilities associated with the Bunker Hill Mining Complex, that had been previously shut down by their owners, were demolished as part of a series of remedial actions under Superfund.

Bunker Limited Partnership (BLP) shut down the mine on January 17, 1991, and completed removal of pumps from all of the main pump stations within the mine by July 25, 1991. The deepest pump station prior to the shutdown was located at the 23 Level, which was the top of the mine pool at that time. Upon pulling the last pumps, all power to the mine was turned off. About August 23, 1991, an auction was held for sale of all materials at the

complex. On December 20, 1991, Robert Hopper, the current mine owner, purchased the Bunker Hill Mine from BLP to form the New Bunker Hill Mining Company (Personal Communication, 1999).

After the power to the pumps was turned off in 1991, infiltrating surface water and groundwater began to flood the mine. From the time the power was turned off until April 20, 1992, all water from the Milo Gulch side of the mine above 9 Level (Wardner water) was diverted down the No. 2 Shaft, and all other water on the 9 Level discharged out of the Kellogg Tunnel to the CTP. On April 20, Mr. Hopper diverted the Wardner water to the CTP as well. By July 15, 1992, power to the mine was reestablished. On approximately December 10, 1992, the water elevation in the mine was about 20 feet above the 18 Level. In January 1993, the first hoist restored (No. 3 Hoist) was in operation; however, a cave-in within the shaft kept access to a minimum until March. By then the water elevation was just below the 17 Level. About October 30, 1993, the mine water line to the CTP was shut down and the mine waters were diverted into the deeper underground workings. A reading during the summer of 1993 showed the water level at about 20 feet below the 16 Level, and the water level was still below the 15 Level in October 1993. In December 1994 the pumps at the 11 Level were started and all water was again discharged to the CTP for treatment. Prior to the third week of July 1995, water below the 11 Level had risen 2 feet per day; during that week, the water rose at a rate of 4 feet per day. In December 1996, the rate increased to 6 feet per day, where it stayed until the last week of November 1998, when it once again dropped back to 4 feet per day (Personal Communication, 1998a).

The mine is currently worked on a small scale using an open stoping method. Approximately 9 to 11 employees work at the mine on day shift during the week, and employees are on call for night shifts, weekends, and holidays, as necessary (Personal Communication, 1998b). Job classifications at the mine include electrician, mechanic, hoistman and laborer. The employees are non-union, and one employee is a designated foreman. The mine produces approximately 1,000 tons of ore per month.

2.2.2 Physical Layout

The Bunker Hill Mine encompasses about 561 claims with a surface area totaling about 6,500 acres. From the discovery cuts, some 3,600 feet above sea level, more than 20 major ore zones were mined to nearly 1,600 feet below sea level, a vertical distance of about 1 mile. The mine contains more than 150 miles of drifts and 6 miles of major inclined shafts, and it encompasses about 5 cubic miles of underground workings. Figure 2-3 presents an aerial photo of the site and shows the general location of the underground mine workings. The majority of the workings are bounded by Milo Gulch on the east and Deadwood Gulch on the west. Milo Gulch is the larger of the two.

Figure 2-4 shows an aerial photo of Milo Gulch. Surface water flows in Milo Gulch collect in Milo Creek, which consists of a mainstem, a south fork, and a west fork. These receive drainage from Kellogg and Wardner peaks. Deadwood Creek collects surface water in Deadwood Gulch. Deadwood Creek and all three forks of Milo Creek flow over near-surface workings of the mine and portions of the flow infiltrate the mine workings. Streamflow from West Fork Milo Creek does not reach Mainstem Milo Creek because most or all of the flow from this ephemeral stream infiltrates directly into the mine.

Between 1998 and 2000, a stream diversion and flood control system was constructed in Mainstem Milo Creek. The first inlet is downstream of the confluence with South Fork Milo Creek. This structure diverts water out of the stream channel and into a second inlet structure located lower in Milo Creek upstream of the Reed Landing Area. From this second structure, the water is piped down to the SFCdA River. The intake structures and Reed Landing Area are shown on Figure 2-4.

Figure 2-5 shows a cross section of the mine and helps convey the magnitude of the underground workings. The Bunker Hill Company originally developed this figure during the 1950s; thus, additional workings other than those depicted in this figure exist because the mine has been extended down to the 30 Level.

The mine was developed with levels on about 200-foot-elevation intervals generally following the structural features associated with the Cate Fault. Thus, the shafts are inclined, with the workings generally following a strike to the northwest and a dip of about 60 degrees to the southwest. The main entrance to the mine, the Kellogg Tunnel, extends from the valley of the SFCdA River to the underground workings on the 9 Level. Historically, mining proceeded from near the land surface on the 4 Level and above to below the 30 Level. Figures 2-6, 2-6a, and 2-7 present the 5 and 9 Level maps of the mine projected on the surface topography. These levels are readily accessible and better understood when compared to the other, less-accessible levels within the mine.

The mine is currently being worked on a small scale using an open stoping method. The areas worked in the last 7 years include the 9, 10, and 11 levels. The mine is currently kept pumped down to approximately 30 feet below 11 Level, which corresponds to about 1,970 feet above mean sea level. For reference, the elevation of the river across (north) from the Kellogg Tunnel is about 2,270 feet above mean sea level. A subsequent Unilateral Administrative Order issued by EPA requires that the mine water be kept pumped down to this level. This requirement is in place to prevent AMD from leaking into the SFCdA River, and to supply a vertical buffer separation from the mine pool and the river.

2.2.3 Mine Infrastructure

This section describes the current mine infrastructure relative to mine water management, including surface facilities, the rail system, hoisting facilities, the electrical system, ventilation systems, and shaft/level repair.

2.2.3.1 Surface Facilities

Figure 2-8 shows the layout of the surface facilities at the mine including an office building, a shop, a motor barn/change room, and maintenance shops. The buildings are generally in good condition. Some of the piping has friable asbestos, and the buildings have transite siding. There are no known underground storage tanks (USTs), and petroleum products are stored in drums and containers. The buildings and equipment have accumulations of dust from the ore crushing activities.

2.2.3.2 Rail System

A rail system is installed in the 9, 10, and 11 levels of the Bunker Hill Mine. This rail system is used for hauling ore and transporting personnel, equipment, and materials to and from

the mine. The 9 Level rail system must be maintained in order to transport personnel, equipment, and materials to and from the mine for mine water control. The majority of the operation and maintenance (O&M) activities for the rail system are focused on keeping the ditches clear of sediment buildup and debris so that water flows in the ditch. Rails and ties are replaced infrequently.

Electric locomotives are the main transport vehicles. There are four electric locomotives and one small diesel locomotive. The electric locomotives are battery powered. Battery charging stations are located in the car barn, at the 10 Level, and at the 11 Level. The track and ties for the rail system are standard gauge. Figure 2-9 presents a plan view of the underground rail system on 9 Level.

2.2.3.3 Hoisting Facilities

Hoisting facilities are necessary in order to raise or lower personnel, equipment, and materials between levels and to provide the means for escape from the mine. Hoists are installed in the No. 2 Shaft, the No. 1 Shaft, the Cherry Shaft, the Last Chance Shaft, and the No. 3 Shaft. All these hoists are operational, with the exception of the No. 1 Shaft hoist. The mine owner is in the process of rehabilitating this hoist. The hoist in the Cherry Shaft is in the process of being repaired.

All hoists are composed of steel drums and wire rope. The hoists that must be maintained for mine water control are those in the Cherry and No. 2 shafts. It is believed that the wire rope in these hoists is in good condition. The No. 2 Shaft hoist is the primary hoisting facility for the mine and provides access to the pump column. A temporary hoist in the No. 1 Shaft was installed for secondary access to the pump column. The hoist in the Cherry Shaft is used as a mandatory secondary escape route from the mine.

Typical O&M activities associated with the hoist system are inspections of the hoist systems; lubrication of the motors, pulleys, and wire rope; and replacement of motors. Periodically a specialist is brought in to do a complete inspection of the hoist ropes. If the ends of the wire rope become frayed, they are cut and resocketed.

2.2.3.4 Electrical System

The electrical distribution system consists of a main surface transmission line, substations, and distribution feeder cables inside the mine. There are four substations: a surface substation at the Cherry Shaft, and underground substations near the No. 2 Shaft, between the No. 1 and No. 2 shafts, and near the No. 3 Shaft. The main surface substation for the mine is located on the surface near the EPA Superfund Office building.

Electricity is stepped down from 13.8 kilovolts to a service use of 220 volts and 440 volts. The electrical cable inside the mine is suspended from the walls of the drifts. Reportedly, the electrical equipment at the mine does not contain regulated levels of polychlorinated biphenyls (PCBs).

Typical O&M activities related to the electrical system are primarily for the pumps and hoisting systems. Wiring harnesses, breakers, and fuses need to be replaced or fixed on an ongoing basis. The electrical cable is sometimes damaged or goes bad, and the bad section must be removed and the electrical cable spliced back together. Splicing electrical cable can take as long as a half-day to complete. There are generally sufficient spare pieces of electrical

equipment available from previous demolition of other structures. Much of the electrical equipment is quite old, and if spares are not available, it can be expensive and time-consuming to locate replacements.

2.2.3.5 Ventilation and Air Systems

The Bunker Hill Mine is naturally ventilated on the 5, 9, 10, and 11 levels. The Last Chance Shaft, located west of the Barney Switch and extending between the 9 Level and the Arizona Tunnel, is used as a fresh air ventilation shaft. There are several raises between levels that circulate the air between levels. If the mine were to be drained to below the 11 Level, air would need to be forced by fans to these lower areas because they do not naturally ventilate.

An air compressor that serves the entire mine is located on the 9 Level. This compressor is used to provide air in areas where supplemental oxygen is necessary, and to operate some of the mine equipment. Steel pipelines are used to distribute compressed air around the mine.

There are few O&M activities associated with the ventilation and air systems. The motor for the air compressor must be greased and checked regularly.

2.2.3.6 Shaft/Level Repair

Maintenance activities are necessary to keep drifts, tunnels, and raises open in the mine. These activities typically include repairing and replacing timber roof supports and roof bolts, and scaling loose rock from mine walls and roofs. Substantial effort is needed to remove cave-ins that periodically occur in the mine.

2.3 Mine Water Characterization

A substantial amount of site characterization work has been completed at the Bunker Hill Mine over the past 30 years. Most of the work was conducted during various research projects in the 1970s and 1980s through the University of Idaho and more recently by CH2M HILL as part of the remedial investigation for the Bunker Hill Mine Water Management RI/FS project. Two of the more significant investigations conducted recently include the 1998/1999 mine water sampling program and the piezometer installation and monitoring conducted in 1999 and 2000.

Some of the research done at the Bunker Hill Mine was directed toward understanding the flow paths, chemistry, and water quality of the mine and, therefore, is particularly useful in the development of the conceptual model for mine water. A review of the library database was conducted to identify these key research projects, and a summary of these key projects is provided in Appendix A. The summary identifies the study area, evaluation methods, and key observations and other relevant findings for each project.

Some of the research projects summarized in Appendix A, and the more recent investigation work, are commonly referenced in this RI/FS document and include the following:

Sources and Causes of Acid Mine Drainage (Trexler et al., 1975). Trexler measured water quality and quantity from October 1972 to February 1975 in underground and above ground locations to determine areas of recharge, acid water production, and flow paths. He used

tracer tests to evaluate the relationship between surface water and groundwater in the Milo Creek and Deadwood Creek basins.

Analysis of Recharge to an Underground Lead-Zinc Mine, Coeur d'Alene Mining District, Idaho (Hunt, 1984). Hunt investigated recharge to the groundwater flow systems in the Milo Creek area through a variety of methods including dye dilution, surface resistivity profiling, piezometer nest installation and monitoring, aerial photography, spring surveying, groundwater sampling, flow measurement, and fluorescent dye tracing.

Analysis of Water Movement in an Underground Lead-Zinc Mine, Coeur d'Alene Mining District, Idaho (Erikson, 1985). Erikson studied water quantity in the upper country (9 Level and above) between February 1983 and September 1984. He conducted hydrograph analyses to understand the source and mechanism of inflow to the mine.

Acid Water Implications for Mine Abandonment, Coeur d'Alene Mining District, Idaho (Riley, 1985). Riley measured water quality and quantity from March 1983 through September 1984 in underground locations in the upper country (9 Level and above). He identified areas that produced poor water quality, and presented an analysis of hypothetical reclamation alternatives, including Milo Creek diversions.

Analysis of Fracture-Flow Hydrogeology in an Underground Lead-Zinc Mine, Coeur d'Alene Mining District, Idaho (Lachmar, 1989). Lachmar focused on the New East Reed Drift in the mine and investigated fault orientation and location, joint and relict bedding planes, joint infilling and flow characteristics, discharge from vertical rock bolts, pressure variation in drill holes, pressure head in piezometer nests, and constant discharge flow tests on drill holes.

Near-Surface Acid Mine Water Pools and their Implications for Mine Abandonment, Coeur d'Alene Mining District, Idaho (Bretherton, 1989). Bretherton describes the temporal, physical, and chemical characteristics of the pooled water in the 3 Level Homestake Workings and discusses their importance in acid water formation relative to the overall spatial and temporal distribution of water quality in the mine.

A Comparison of Multivariate Statistical Analysis and the Use of an Indicator Ion for the Interpretation of Water Quality Data (Riley, 1990). Riley continued his research by monitoring flow and water quality through December 1985. He discusses temporal variations in water quality at many underground monitoring locations and includes detailed statistics on the sampling data.

Analysis of the Hydrogeologic Role of Geologic Structures with Application to Acid Mine Drainage Abatement (Levens, 1990). Levens provides the best quantification of the tiered hydraulic conductivity systems in the rock mass. He discusses the results of the two-phase hydraulic testing and suggests two analytical models that may be applicable to analysis of drawdown data from observation located within the producing structure.

Analysis of the Sub-Regional Influence of Geologic Structures on Ground Water Flow In Acid Producing Metamorphic Rocks (Demuth, 1991). The objectives of this research were to evaluate the influence of geologic structures on groundwater flow on subregional and local scales, and to apply the results to an analysis on a regional scale. Demuth discusses the results of the three-phase hydraulic testing using inflatable packers in flowing horizontal drillholes.

*Acid Mine Drainage – Bunker Hill Mine Water Conceptual Model (*CH2M HILL, 1999a). The conceptual model document reviews existing information on flow and quality of water within the mine, summarizes known flow paths within the mine, and identifies current known sources of AMD.

Supplement No. 1B Bunker Hill Mine Conceptual Model. Final Data Summary for 1998/1999 Monitoring Program. (CH2M HILL, 2000a). This document provides a summary of analytical and flow data regularly collected at 14 underground monitoring locations during the 1998 / 1999 mine water sampling program.

Milo Creek Piezometer Installation. (CH2M HILL, 2000b). This technical memorandum provides a description of the installation of eight piezometers in four locations within the West Fork and Mainstem Milo Creek basins. Initial water elevation data for these piezometers and two existing piezometers in the SFCdA River are included. Data collection from the piezometers is ongoing as part of long-term, site-wide monitoring. Limited data were available during preparation of this document.

*Potential for Lime and Sludge Reduction by Bunker Hill Mine Water Mitigation Measures (*CH2M HILL, 2000c, also included as Appendix B). This document provides an evaluation of whether significant reductions in acid and metals loads will result from reduced recharge to the mine. A geochemical analysis of mine water is also presented.

2.3.1 Chemistry of Acid Formation

The Bunker Hill Mine contains three general ore types based on mineralogy: Bluebird Ore, Bunker Hill Ore, and Jersey Ore (Trexler, 1975). The major mineralogical difference among the three ore types is the presence of abundant pyrite (FeS_2) in the Bluebird Ore. Pyrite is oxidized in the presence of air and water, resulting in the formation of sulfuric acid. The oxidation process occurs in three steps that are generalized in the following reactions:

Step 1: $FeS_2(s) + 7/2\ O_2 + H_2O = Fe^{2+} + 2SO_4^{2-} + 2H^+$
Step 2: $Fe^{2+} + ¼\ O_2 + H^+ = Fe^{3+} + ½\ H_20$
Step 3: $FeS_2(s) + 14Fe^{3+} + 8H_2O = 15Fe^{2+} + 2SO_4^{2-} + 16H^+$

In Step 1, pyrite is oxidized to sulfate and ferrous iron by oxygen present in the mine air. In Step 2, ferrous iron is oxidized to ferric iron. This process is commonly the rate-limited reaction, but the bacteria *Thiobacillus ferrooxidans* and possibly other species catalyzes the reaction (Riley, 1985). In Step 3, pyrite is oxidized by ferric iron from the second equation, and hydrogen ions are released.

These three general steps of acid production are presented graphically in Figure 2-10. For illustrative purposes, these reactions are shown as occurring in the water along the bottom of the drift; however, the majority of acid production most likely occurs in moist, aerobic environments within the workings in a thin film covering the exposed pyrite deposits and in deposits of pyritic muck. The acid is periodically flushed out by seasonal snowmelt-induced water flow.

An intermediate step occurs between Step 2 and Step 3 that results in the production of "yellow boy" or iron hydroxide [$Fe(OH)_3$] in the drifts:

$$Fe^{3+} + 3H_2O = Fe(OH)_3 + 3H^+$$

This reaction is reversible, and low pH conditions will force the reaction to the left. Therefore, the large amount of yellow boy in the mine drainage system acts as a reservoir for ferric iron. Figure 2-11 includes two photographs that show the yellow boy in the drifts; the yellow boy is the yellowish orange muck on the floors. Low pH conditions release ferric iron, which can then further oxidize pyrite and create more acidic water. The ferric iron that reacts with pyrite in Step 3 is reduced to ferrous iron, which can then be re-oxidized back to ferric iron in the second step. Large deposits of yellow boy occur where water containing low pH ferric iron contacts a more alkaline water and the pH is raised sufficiently to precipitate the ferric iron. When this occurs, the concentration of hydrogen ions is decreased, the pH rises, and dissolved ferric iron precipitates as ferric oxy-hydroxide. Observations at the Bunker Hill Mine suggest that this reaction occurs between a pH of 2.5 and 3.0. Above this range, iron (ferric) hydroxide is precipitated; below this range, iron hydroxide is dissolved into the mine water. Reece (1974) and Lowson (1982) present a more detailed discussion of this acid formation.

2.3.2 Acid-Producing Areas of the Mine

The major AMD source within the mine is the Flood-Stanly Ore Body. This area is depicted on the cross section shown in Figure 2-5. The Flood-Stanly Ore Body consists predominately of Bluebird Ore. Most of the ore body has been mined and has been backfilled with sulfide-rich gob, a waste material containing zinc, lead, and iron sulfides. Recovery of this waste was not economical during the early years of mining.

Mined during the 1940s and 1950s using a block caving method, the Flood-Stanly Ore Body extends from near the land surface down to an elevation near the 11 Level. Caved mineralized zones and fracturing associated with the block caving technique extend to the land surface. The major surface depression caused by the block cave mining is called the Guy Cave Area and is near the bottom of the West Fork Milo Creek drainage (see Figure 2-4). Cracking caused by the caving radiates further out than the surface expression and provides a conduit for surface water infiltration into the Flood-Stanly Ore Body. In addition, surface water infiltrates into the mine workings in much of the Milo Creek area through other mining-related conduits and the subregional groundwater system. This water source flushes acid and acid salts that have been generated and stored along the flow path to the Kellogg Tunnel and to lower portions of the mine. The water also fuels the generation of more acid water, although the natural humidity present in the mine air itself is thought to provide enough water to maintain acid production.

Because the current water elevation in the mine is roughly 30 feet below the 11 Level, most of the Flood-Stanly Ore Body is unsaturated and therefore is exposed to oxygen. The flow of air through the mine via numerous surface openings provides sufficient oxygen in the unsubmerged areas to fuel the generation of acid water in areas containing appreciable pyrite, such as the Flood-Stanly Ore Body.

The unique combination of significant quantities of pyrite, water, and oxygen within the Flood-Stanly Ore Body, together with the muck within the ore body and within the gob,

results in the production of the majority of acid water in the Bunker Hill Mine. Studies conducted at the University of Idaho in the 1970s and 1980s show that most of the acidic water containing elevated concentrations of metals originates in the area of the Flood-Stanly Ore Body (Trexler, 1975; Riley, 1985). The discharge from the Flood-Stanly Ore Body represents only about 9 percent of the mine water flow, but carries more than 90 percent of the metal load from the mine. Data collected by CH2M HILL in 1998-1999 showed that the pH ranged between 0.59 and 3.9 at monitoring stations measuring drainage from the Flood-Stanly Ore Body. Other ore bodies within the mine produce acid, but their contribution to the AMD problem is relatively minor when compared to the quality and quantity of acid water that originates in the Flood-Stanly Ore Body.

Water from the annual surface water runoff/infiltration event associated with spring snowmelt and streamflow moves through fractures and openings into the upper country mine workings (above 9 Level), dissolving acid salts from oxidizing sulfide sites, and moves ponded acid water from within the mine drifts. Most of the drainage from the upper country workings discharges on the 9 Level and drains out through the Kellogg Tunnel. The quantity that drains to the Kellogg Tunnel from the upper country workings is relatively well-documented, but an unknown portion of the water from the upper workings bypasses the 9 Level to discharge on Levels 10 and 11 and ultimately into the mine pool.

2.3.3 Mine Water Flow Paths

The Bunker Hill Mine hydrology is complicated by the evolution of the mine's history and the complex nature of the underground workings (Trexler, 1975; Eckwright, 1982; Riley, 1985). The mine was initially developed at higher elevations within the Milo Creek drainage, with shallow workings along near-surface ore bodies. The individual workings were combined into a single mine with numerous working levels (on approximately 200-foot vertical spacing) to considerable depths. Shortly after 1900, the Kellogg Tunnel was constructed from an elevation equivalent to 9 Level and the valley floor to allow more efficient transport of men and materials. The Kellogg Tunnel is the major conduit for discharge of the mine water. The mine was then developed down from the 9 Level (Kellogg Tunnel level) to the 30 Level. A tunnel was constructed on the 23 Level to connect the Bunker Hill Mine with the nearby Crescent Mine to the east. The mine workings, from about 30 feet below the 11 Level, are currently flooded, resulting in the formation of a mine pool. The water level is maintained by pumping water from the pool within the No. 2 Shaft (also referred to as the No. 2 Raise). This water was sampled during the 1998/1999 monitoring program (described below) at the 9PU monitoring station, located on the 9 Level where the water discharges into the 9 Level ditch. Figure 2-12 shows a generalized model for mine water flow in the mine.

EPA and IDEQ initiated a sampling program in October 1998, with assistance from the New Bunker Hill Mining Company and others, to verify the relationships of upper country flow paths and poor water quality sources that had been established in previous work. Sampling locations and analytical methodology were developed to identify discrepancies between current and historical data at major flow points in the mine.

The following subsections describe the gravity flow paths for water on 9 Level and above, pumped flow from submerged workings below 9 Level, and the Kellogg Tunnel flow path. A more detailed description of mine water flow paths can be found in the conceptual model

report (CH2M HILL, 1999a) and the in-mine reconnaissance report (CH2M HILL, 1999b). Details of the known surface water inflow paths are described in *Field Reconnaissance of Inflow/Recharge Mechanisms, AMD Generation Mitigations, Bunker Hill Mine Water Management Project* (CH2M HILL, 1999c). In the following discussion, references are made to flumes; these are references to the wooden cutthroat flumes temporarily placed in various locations to measure flow. These flow measurements were first made in the 1980s by various researchers from the University of Idaho, and in 1998 and 1999 by CH2M HILL.

2.3.3.1 Gravity Flow (9 Level and Above)

The following discussion on gravity flow paths is focused on 3 Level, 5 Level, and 9 Level. The water flow paths on these levels are the best researched and understood. Other levels convey flow in the mine, but access to these inactive levels is difficult or impossible because of unsafe conditions; consequently, a detailed assessment of flow paths in these other levels has not been conducted.

3 Level Flow

The 3 Level consists of the Homestake Workings and the Utz Workings, both of which are below the lower portions of the West and South forks of Milo Creek in Milo Gulch. Inflow is controlled by the Cate Fault in this area (Bretherton, 1989). The Cate Fault is recharged in part by Milo Creek in areas above these workings, and by Milo Creek and the City of Wardner water supply dam reservoir in areas below. Losses through the bottom of the reservoir had been measured at 60 gpm after the removal of a fine sediment layer (Trexler, 1975). A concrete bottom was installed in the reservoir in 1996. This area of the Homestake Workings discharges through fractures to the Cherry 4 Level (Bretherton, 1989), and to 5 Level drawpoints at the end of the Asher Drift. Figure 2-13 is a map showing the major flow paths in the Homestake Workings.

5 Level Flow

The direction and quantity of flow on 5 Level has been studied extensively by Riley, Erikson, Trexler, and Lachmar in thesis and dissertation projects at the University of Idaho. The current understanding of intra-mine flow on 5 Level is based on this work and on observations during recent site visits. Two important flumes were located on 5 Level: the Williams Flume and Becker Flume. Each is discussed below in terms of its tributaries. Figures 2-6 and 2-6a present the known 5 Level flow paths.

Williams Flume. Water enters the New East Reed Drift through the New East Reed Drill Holes (most of which are sealed) and through fractures intersected by the drift. Water flows northwest along the drift to the New East Reed Flume (a sampling location used in the 1980s) and converges with water infiltrating from the Russell Dam Reservoir. The Russell Dam was built underground on 5 Level to capture flows from the Old East Reed Drift for use as drill water. The Old East Reed Drift conveys flow from fractures, an ore chute, and drill holes along the drift. Flow continues northwest from below Russell Dam past open stopes to the west and converges with flow from the Russell Tunnel. The majority of Russell Tunnel flow comes from the Asher Drift. After converging, water flows to the Williams Flume.

From the Williams Flume, water flows down the Williams Winze (Raise) to 6 Level. It is likely that the majority of this water comes down the Van Raise to 9 Level, but access to the

7 and 8 Levels has been difficult because of the condition of the workings, and the exact flow path has not been determined.

Becker Flume. Flow at the Becker Flume originates from the west portion of the mine in the 5 Level workings. This flow is also measured upstream of the Becker Flume at the West Reed Flume. The West Reed Flume measures flow that drains from the underground greenhouse area via the Ventilation Drift and the Guy Drift, and therefore may be hydraulically connected to the surface water infiltrations through the Guy Cave Area. It also receives flow from the Motor Vein Workings. The West Motor Flume flow originates from a stope west of the flume, the extent of which is not clear. From the Becker Flume, water flows down the Becker (Mule) Raise to 6 Level. Based on reconnaissance observations, the majority of this water likely comes out on 9 Level via the Van Raise.

9 Level Flow

Water on 9 Level flows northwest on the No. 9 East Drift to the Barney Switch area, where it flows northeast out the Kellogg Tunnel. Pump discharge from the submerged workings is tributary to the No. 9 East Drift at the No. 2 (White) Raise. Figure 2-7 presents the known water flow pathways on 9 Level. The flow from the east side of 9 Level has been measured near Raise No. 2, referred to as the Cherry Flume in the 1980s studies and as the 9LA Flume in the 1998/1999 study. The flow from the west side has been measured at the Barney Switch, referred to as the Barney Switch Flume in the 1980s and as 9BS in the 1998/1999 study.

No. 9 East Drift. From the Van Raise, which is thought to convey the majority of the flow from above 9 Level, water flows northwest on the No. 9 East Drift to a confluence with the Cherry Crosscut. Water from the Cherry Crosscut originates from the Cherry Raise, the 7 Level Drain (which is no longer working), the Bailey Ore Chute, and the Bailey Drill Holes. Farthest upstream are the Bailey Drill Holes, which are currently flowing. The Bailey Ore Chute receives a majority of flow from a dam on 7 Level built to hold drill water from Diamond Drill Hole (DDH) No. 1208, which is thought to intersect the Katherine Fault within the West Fork and South Fork Milo Creek basins. Flow that comes down the Bailey Ore Chute is measured at the Bailey Flume (9BO). The Cherry Raise is tributary to the Cherry Crosscut flow. The origin of this water is not clearly understood, but it may originate from the Guy Cave Area and other discharge from the Flood-Stanly Ore Body. The Cherry Raise on 5 Level is dry. The 7 Level Drain was built to convey poor-quality water from 7 Level around the raise, but it is no longer working. It is likely the flow coming down the Cherry Raise originates in part from the 6, 7, and 8 Level workings.

From the confluence of the Cherry Crosscut and the No. 9 East Drift, water flows northwest down the No. 9 East Drift until it merges with discharge from the Stanly Crosscut. The Stanly Crosscut Flume (9SX) measures flow from the Stanly Crosscut that probably originates from the Flood-Stanly Workings and is hydraulically connected to the surface water inflow to the Guy Cave Area. The flow from the Stanly Ore Chute (9SO) merges downstream of the Stanly Crosscut Flume and is also hydraulically connected to the surface water inflow to the Guy Cave Area. After the confluence of the Stanly Crosscut, water continues northwest on the No. 9 East Drift, and is measured at the Loadout Area at 9 Level Flume (9LA), just upstream of the No. 2 Raise. Water balances conducted around 9LA in the 1980s and in 1998/1999 show that only about 50 percent of the flow can be accounted for

using the known upstream sources. The unaccounted-for flow could be miscellaneous and disperse seepage into the 9 Level East Drift along its length, but this is uncertain.

During the 1998/1999 monitoring program, large flows were observed in a second ore chute (9SO2) upstream of 9SX in the Stanly Crosscut during a May 1999 snowmelt event. Peak flows were observed coming down the ore chute at the same time that peak flows were observed in West Fork Milo Creek disappearing into the ground about 100 feet above the surface expression of the Guy Cave Area. Peak flows were also observed at 9CR, 9SO, and 9SX. The 9SO2 ore chute discharged only small flows prior to or after the peak surface water runoff event. This demonstrates that high surface water flows in the West Fork that reach the Guy Cave Area directly infiltrate the Flood-Stanly Ore Body, the largest source of acid production for the mine.

No. 9 West. From the No. 2 Raise, water continues to flow northwest until it reaches the Barney Switch (9BS), which drains the workings to the northwest. Information on the flow relationships in this western portion of the mine have not been defined as part of the RI/FS.

Mine water flow on each of these levels occurs in ditches. Maintenance is required to periodically remove yellow boy and other mine debris from the ditches to allow open channel flow. If the ditches become plugged on 9 Level, acid water will come out of the ditch and will rapidly deteriorate the steel rails and other wood and metal infrastructure components (rail ties, timber roof supports, air, water, and electrical lines, etc.). For mine levels that are currently used less frequently, such as 3 Level and 5 Level, the ditches are typically located in the center of the tunnel, and there is less infrastructure at risk. Periodic inspection is required to identify the formation of muck dams that could result in a dangerous release of mine water to downgradient flow paths within the mine, and ultimately out the Kellogg Tunnel.

2.3.3.2 Pumped Flow (Below 9 Level)

The water level in the submerged workings is maintained at about 30 feet below 11 Level with two pump systems using a series of pumps. The primary pump system is located in the No. 2 Raise. A submersible pump lifts water to 11 Level where a stationary pump boosts the water to 10 Level, and a third pump boosts water to 9 Level. The elevation of the water in the submerged workings is maintained at approximately 1,970 feet above mean sea level. The discharge from this pump system enters the 9 Level at the Loadout Area (9LA). The flow rate is fairly constant and averages between 600 and 900 gpm. A secondary pump system consists of a single stationary pump on 10 Level. This pump system is used intermittently to boost water to the 9 Level, and discharges near the No. 1 Raise.

Typical O&M activities related to the pumping system include inspection of the pump columns for leaks, cleaning intake screens, pump lubrication, and pump and pipe replacement. The specific types and sizes of the pumps and motors are not known, although most pumps are believed to be manufactured by Flygt. Typically the mine has a backup pump available. Pipe and other materials needed for the pump system are available locally.

The source of water in the submerged workings is not clearly understood. Water likely comes from fractures, faults, and bedding planes intercepted by mine workings and drill holes. In addition, water that is not intercepted by the 9 Level workings probably flows down to 11 Level and contributes to the submerged workings. This includes the water from

Deadwood Creek (west side of the mine) that may enter through the Inez Workings and descend to 11 Level, and water from the upper country that is not intercepted by the No. 9 East Drift. The Flood-Stanly Ore Body extends down to near the 11 Level (see Figure 2-12), and is likely discharging acid water to the mine pool.

Comparison of the temperature of the extracted mine pool water (9PU) with the likely geothermal gradient (Appendix B) suggests that the water diverted to the mine pool affects the 12 Level mine pool but has little impact on the mine pool water below 13 Level. This implies little mixing of the upper country water into the deeper mine pool.

The Yreka Crosscut connects the 23 Level workings of the Bunker Hill Mine to the 3100 Level of the Crescent Mine, which is about 3 miles to the east. The hydraulic relationship between the Crescent Mine and the Bunker Hill Mine is not fully understood. The elevation of the Kellogg Tunnel portal is about 300 feet below the elevation of the Hooper portal of the Crescent Mine, and about 0.5 cfs was reported to drain to the Bunker Hill Mine (Hampton, 1985). The quality of this water is unknown, but it is suspected to be acidic based on samples collected from within the mine before it was flooded (Hampton, 1985).

2.3.3.3 Kellogg Tunnel

Mine water from the east and west sides of 9 Level, including the pumped water discharging at No. 2 Raise and No. 1 Raise, combine at the Barney Switch and flow northeast for about 8,000 feet to the Kellogg Tunnel (9KT) portal. The New Caledonia Workings merge with the Kellogg Tunnel about 3,000 feet downgradient from the Barney Switch. These workings contribute about 1 to 2 percent of the total Kellogg Tunnel flow (Erikson, 1985).

The Kellogg Tunnel requires periodic inspection and cleaning to maintain ditch flow within the tunnel and to prevent the acid mine drainage from deteriorating or burying the rail system. Even with regular inspection, it is possible that flow could be blocked by yellow boy buildup, a collapse, or a combination of both. While drift and tunnel collapse is always a possibility, a collapse of the Kellogg Tunnel could block flow of mine water out of the mine. One area of poor rock condition exists at the passing track just northeast of the Caledonia Workings where the Kellogg Tunnel crosses the Osburn Fault. The tunnel in this area has been reinforced with concrete because of the poor structural quality of rock in the fault zone. Timber roof supports have been installed on both sides of the concrete portion. If a collapse occurred in this or other portions of the Kellogg Tunnel, the mine water could pond behind the blockage. Immediate action should be taken under extreme care to remove the blockage and allow the water to drain safely.

A 12-inch Parshall flume at the Kellogg Tunnel portal measures the flow of mine water from the mine. The flume and concrete channel at the portal were replaced in 1999 as part of the emergency pipeline project at the mine (described in Section 3 of this document). A new 20-inch high-density polyethylene (HDPE) pipeline was installed to convey mine water from the Kellogg Tunnel to the lined pond. Currently, mine water is pumped from the lined pond to the CTP. A tee was installed on the new pipeline to allow for the future installation of a pipeline to the CTP so that mine water can flow directly from the Kellogg Tunnel to the CTP.

2.3.4 Mine Water Quantity and Quality

The following text summarizes flow and analytical data for the locations described above. The summary primarily includes the data collected during the 1998/1999 monitoring program. A detailed analysis of how recent data compare to the substantial amount of data collected during the 1980s is provided in Supplement No. 1B of the Conceptual Model (CH2M HILL, 2000b). A brief summary is presented in Section 2.3.4.5 of this report. Generally, the data sets compare reasonably well, and therefore the 1998/1999 data provide a good overall summary of the characteristics of the mine water.

2.3.4.1 Mine Water Flows

A summary of flow data for each regularly monitored location (except for 9SO2, which was a late addition to the program) is presented in Figure 2-14. Monitoring locations that measure flow from sources hydraulically connected to surface water and snowmelt infiltration (5WR, 5BK, 5WM) exhibited an increase in flow in early March 1999. This response was likely a result of snowmelt at relatively low elevations. Other monitoring locations not directly connected to low-level surface water and snowmelt infiltration (9CR and 9SX) exhibited increased flows in early April 1999 when the snow melted at higher elevations.

A large increase at locations monitoring flow from the Flood-Stanly Ore Body was observed toward the end of May when the higher-elevation snowmelt occurred (see Figure 2-14). Flows rapidly increased several-fold at these locations (9CR, 9SX, 9S0, and 9LA) to their annual peaks. Flows at 9CR increased from 18 to 70 gpm, 9SX increased from 38 to 373 gpm, 9SO increased from 4 to 30 gpm, and the flow at 9LA, which receives tributary flow from these locations, increased from 505 to 1,190 gpm. These flow increases significantly increased the acid and metal load discharging from the mine because these areas produce the most acidic mine water measured in the mine.

The rapid flow increases were a result of higher flows in West Fork Milo Creek, which resulted in surface water reaching further down the drainage basin than had previously occurred during the spring of 1999. Surface observations made at the same time as the peak underground flows verified that the West Fork flow was disappearing into the ground below the Phil Sheridan Raise No. 2 and about 100 to 200 feet above the surface expression of the Guy Cave Area. If the raise had not been plugged with debris, it is likely that the water would have been diverted around the Guy Cave Area and out of the Phil Sheridan portal (see Figure 2-4). The Phil Sheridan drift, which circles around the Guy Cave Area, was constructed by the Bunker Hill Company in the 1950s to divert surface water away from the cave area. Two raises were constructed from the drift to the surface to intercept surface water. Raise No. 2 opens into the West Fork Milo Creek drainage, and Raise No. 1 opens into a sub-drainage located to the northwest. Over time, the raises have collapsed and become plugged with debris. They were partially cleaned out from the surface in 1999, but are still plugged to an unknown extent deeper down.

Figure 2-14 shows that the other areas of the mine did not experience the significant peaks that occurred in the areas receiving recharge from the West Milo basin. Flows from the Deadwood Creek side were measured at the 9BS monitoring station. This hydrograph increased gradually from a base flow of about 150 gpm to a high of about 290 gpm in early April, then gradually receded to base flow. There were no sudden flow increases or

dramatic peaks associated with Deadwood Creek or the west side of the mine. In a similar manner, the flow at 9VR (which likely measured flow infiltrating through the mainstem reach of Milo Creek below the South Fork confluence) was also relatively constant, indicating little seasonal increase in flow as a result of higher flows in Mainstem Milo Creek.

Most locations reached base flow conditions in late July or August, equal to flows observed as winter base flow at the beginning of the monitoring program (between November 1998 and February 1999).

The 9KT flow was measured with the 12-inch Parshall flume during the 1998/1999 mine water sampling program. The flow at 9KT includes mine water pumping rates. Two sets of pumps (9PU and 10PU) are used to dewater the mine. When 9PU and/or 10PU pumps were on, the combined pump contribution to 9KT ranged between 650 and 850 gpm. These rates were calculated by taking the 9KT flow difference when a sudden significant increase or decrease was recorded in 9KT flow readings during the sampling event period. Starting in February 1999, pumping system operations were modified to keep 9KT flows below 1,400 to 1,500 gpm because of a partially plugged mine water pipeline. Therefore, peak mine water flows toward the end of May were not observed at 9KT. This demonstrates the effect mining operations can have on the historical data collected for the mine water. Recently, a new flume of the same type and size was installed during pipeline replacement as part of the emergency upgrade to the mine water conveyance system.

In summary, the Bunker Hill Mine workings have created a large zone of drawdown in which the subregional groundwater system is dominated by unsaturated flow conditions but with numerous small perched saturated systems. Recharge occurs as a result of sub-regional groundwater flow systems and seasonal snowmelt/rainfall/recharge phenomena. The sub-regional system is generally expressed by long-term, relatively steady flows within the mine. Seasonal phenomena are expressed by short-term peaks (a few days to a few weeks) in the hydrologic record. The rising limbs of the hydrographs usually involve only a few days, but the falling limbs can take a few weeks. The peak flows observed indicate movement of water rapidly from a surface source (probably infiltrating streamflow) through the upper workings. The undisturbed rock has very low hydraulic conductivity. Thus, peak flows cannot originate from groundwater flow systems in undisturbed rock. Groundwater that discharges into the upper country (above 9 Level) mine workings flows through man-made openings (e.g., drifts, stopes, and raises) along and downward between levels. Most of the gravity drainage discharges on the 9 Level where it mixes with the water pumped from the lower levels and flows out the Kellogg Tunnel to the portal. A portion of the gravity drainage bypasses 9 Level where it contributes to the mine pool.

2.3.4.2 KT Flow Return Interval Analysis

Statistical analysis of historic Kellogg Tunnel flows was conducted to evaluate return intervals as part of the hydrologic evaluation conducted for achieving the TMDL for the CTP (CH2M HILL, 2000d). A return interval is the reciprocal of the probability of occurrence. For instance, a 25-year event for peak or average flows implies there is a 4 percent probability of peak or average flows of that magnitude occurring during any year. The period of record consisted of 21 years, from 1973 to 1999, excluding 1976, 1977, and 1991 through 1994. The period between 1991 and 1994 is when the flow out of the Kellogg Tunnel

was reduced or eliminated by diverting the water into the mine to flood the lower workings. Kellogg Tunnel flow data are not available for 1976 and 1977.

Table 2-1 summarizes the statistical flow return intervals. The statistics suggest that flows in excess of the maximum flow observed to date (estimated at 6,700 gpm) can occur. The estimated 50-year return interval flow is 7,140 gpm, and the 100-year flow is 8,320 gpm.

The estimated 6,700 gpm maximum historical flow occurred in response to a rain-on-snow event in December 1972. No in-mine flow measurements are available to describe which portions of the mine contributed to the high flow, but the majority of the infiltration likely occurred on the east side of the mine in the Milo Creek watershed. This is based on comments from previous mine workers who noted that the Milo side of the mine usually showed much more rapid and dramatic flow increases than the central or western (Deadwood Creek) side of the mine.

Between 1961 and 1991 the practice of sand filling contributed to the mine water flow out the Kellogg Tunnel. Sand filling consists of using a tailings slurry to backfill mined areas. Sand filling began at Bunker Hill in 1961 and continued until January 1991. The tailings sand from the lead and zinc flotation circuits was pumped approximately 10,000 feet into the mine in a slurry containing about 35 percent solids by weight for storage. It was then concentrated to about 65 to 70 percent solids by weight and distributed by gravity into the stopes. The water removed during concentration was placed into the 9 Level ditch system for flow back out of the mine. Between 1961 and 1974 the sand fill rate increased from 100,000 tons per year to 272,000 tons per year (Trexler, 1975). The associated flow rate of sand slurry transport water increased from about 100 gpm to 240 gpm. Sand fill rates between 1974 and 1991 are unknown, but are believed to be equal to or slightly higher than those in 1974. The transport water separated from the sand contributed to the mine water flow out the Kellogg Tunnel. Because sand filling was a near continuous operation, the flow rate contribution to the Kellogg Tunnel discharge would have been nearly constant. Currently, sand filling is not occurring, but would likely be incorporated in any future larger-scale mining operation. Subsequent sections of this RI/FS discuss historical Kellogg Tunnel flows. Flows between 1961 and January 1991 would have included a constant contribution from sand fill water.

Figure 2-15 is a plot of historical Kellogg Tunnel flows overlaid on each other. The timeline for the plot represents a water year (the period from October through September). Flows in excess of about 3,000 to 3,500 gpm are always associated with peak flow events, such as the December 1972 event discussed above. It is possible that the other peak flows were caused by similar high runoff events that rapidly infiltrated into the mine workings.

The West Fork Milo Creek drainage basin has the greatest potential for causing rapid infiltration to the mine, resulting in high Kellogg Tunnel flows, because all the flow from this drainage is believed to infiltrate the workings. West Fork Milo Creek, which is an ephemeral stream, has no outlet to Mainstem Milo Creek. The old streambed disappears into the Guy Cave Area overlaying the Flood-Stanly Ore Body, which produces high levels of acids and metals as described previously. The technical memorandum in Appendix B describes how reducing recharge in this area results in a reduction of Kellogg Tunnel flow, and in expected reductions in treatment plant lime consumption and sludge generation. The reduction of rapid infiltration within the Milo Creek watershed, particularly the West Fork

Milo Creek watershed that drains directly to the mine workings, will significantly reduce the peak mine flows.

Table 2-2 lists estimated West Fork Milo Creek flows for return intervals between 2 and 100 years. Flows are listed for rainfall-only events and for rainfall-only events with snowmelt (e.g., 2-year rainfall event with snowmelt occurring at the same time). The potential flows are very high, much higher than any documented flows out the Kellogg Tunnel. Either stream flows of this magnitude have not occurred since the Guy Cave Area has existed, or if they have, they have not completely infiltrated the mine. It is also possible that the Phil Sheridan diversion system could have directed high flows around the Guy Cave Area. Because the surface expression of the Guy Cave Area has been filled in with waste rock during the last 4 years and sloped to drain toward Milo Creek, it is possible that a large portion of the flows could be carried over the caves. However, this does not detract from the potential risk of a long-duration, high flow event from eroding and infiltrating into the underlying Flood-Stanly Ore Body. In fact, a similar yet relatively small event was documented in the spring of 1999 (see Section 2.3.4.1). Similar events may have caused the peak flows from the Kellogg Tunnel shown in Figure 2-15. However, the spring 1999 event was caused only by snowmelt, not a rain-on-snow event that would have caused much higher flows. Diversion of West Fork Basin flows around the Guy Cave Area should significantly reduce peak Kellogg Tunnel flows associated with these events.

Other known locations that have the potential for rapid mine inflow are the Small Hopes area in Mainstem Milo Creek, and currently to a lesser extent the Inez Shaft area in Deadwood Creek. The Small Hopes Workings are within 10 to 20 feet of the creek bottom (see Figures 2-2 and 2-4). In the past, stream gravel has been found in the drift below the creek indicating significant stream-bed fracturing. Currently the workings are not accessible. There is no indication of a lot of leakage into the Small Hopes Workings from the creek based on the flow rates measured at 9VR during 1998 and 1999 and as shown in Figure 2-14. Inflow to the mine from the vicinity of the Small Hopes Workings would reach 9 Level through the Van Raise, and would be indicated by the 9VR data. These data show that the flow was relatively constant at about 150 gpm, with a slight increase up to about 180 gpm in the spring. It is likely that stream sedimentation has reduced flow through the streambed into the workings. The concern is that large stream flows could erode the sedimentation and open direct flows into the Small Hopes Workings. Sealing the Small Hopes drift below the creek would reduce or eliminate this possibility, and possibly also reduce long-term seepage from the creek into the mine.

The Inez Shaft was constructed in the bottom of Deadwood Creek at about elevation 3,550 (see Figure 2-2). The shaft extends from the surface to the Arizona Tunnel, which runs east from below Deadwood Creek to the center of the mine at an elevation equal to about 5 Level West. The Inez Shaft opening is not currently apparent in Deadwood Creek, having been covered by stream sediment and alluvial debris. In the past, significant infiltration occurred through the shaft. Bryson Trexler, who studied inflow to the mine in the early 1970s, reported that miners could tell when it was raining hard by the mine water flows increasing rapidly underground as a result of inflow through the Inez Shaft. For this reason, Trexler constructed a temporary stream bypass around the shaft using metal culvert pipe. He reported that this system significantly reduced recharge from Deadwood Creek into the shaft (Trexler, 1975). Currently, there is no indication of a lot of leakage from Deadwood

Creek into the shaft. Surface observations of flow in Deadwood Creek at the Inez Shaft area could not detect loss of stream flow. This was also indicated by the flow rates measured at 9BS during 1998 and 1999 as shown in Figure 2-14. Inflow from the west side of the mine was fairly constant year-round, with no spring peaks associated with snowmelt, although the flow increased gradually from a base flow of about 150 gpm to a high of about 290 gpm in early April. Similar to the Small Hopes drift, it is likely that stream sedimentation has reduced flow through the streambed into the workings. The concern is also similar, in that large flows in the stream could erode the sedimentation and re-open direct flows into the Inez Shaft. Sealing the Inez Shaft below the creek would reduce or eliminate this possibility, and possibly also reduce long-term seepage from the creek into the mine.

Another mechanism that can rapidly increase flow within the workings and from the Kellogg Tunnel portal is mine floods. Mine floods are short-duration events caused by a rapid release of large volumes of water from somewhere in the mine, such as from collapse of man-made or yellow boy muck dams, blocked and flooded ore chutes, or other in-mine water impoundments. Because a large portion of the workings are no longer accessible or maintained, it is unknown how many of these conditions exist, their locations, and their likelihood of causing a flood. The mine owner reported three mine floods in the spring of 1997. The first flood occurred on March 23, and the second and third floods occurred three and six weeks after the first, respectively. The precise cause and source of these floods is unknown, but they originated somewhere on the east side of the mine. Each flood deposited large amounts of muck in the 9 Level east drift and in the Kellogg Tunnel, and considerable effort was required to remove the deposits. Repairs were not completed until December 15, 1997. Continued maintenance of the mine water conveyance system will reduce the potential for future floods, but will not eliminate their possibility.

In summary, the quantity of AMD and peak flows that discharge from the Kellogg Tunnel portal varies significantly from year to year, and is influenced by seasonal mine water recharge conditions such as snowpack, rainfall, rate of snowmelt runoff (including rain-on-snow events), infiltration rate to the workings, and mine floods. Infiltration to the workings occurs as a result of recharge from the groundwater system upgradient of the mine, and also from stream flow that rapidly infiltrates. Long-term base flow from the Kellogg Tunnel is a result of groundwater recharge through rock fractures and faults, and seasonal peak flows are caused by rapid stream flow infiltration through near-surface workings.

2.3.4.3 Zinc Concentration

Total zinc concentration is an indicator of mine water quality; in general, a high zinc concentration indicates poor water quality. Figure 2-16 shows the total zinc concentration (log scale) measured at each regularly monitored location. The figure shows that water from 9SO continuously exhibited the highest concentration of zinc at 0.6 to 2 percent by weight (6,000,000 to 20,000,000 µg/L) throughout the 1998/1999 monitoring program. Zinc concentrations at 9CR, 5WR, and 9SX had the next highest levels observed among all the monitoring locations. 9CR appears to have the second highest zinc concentration at 0.1 percent to 0.3 percent. 9SX and 5WR also exhibit high zinc concentrations at about 0.1 percent.

The zinc concentration in the submerged workings at 9PU is consistently higher than 3HD, 5WM, 9BS, and 9BO, respectively. 9BO consistently exhibits the lowest zinc concentrations of all monitored locations.

2.3.4.4 Lime Demand

Lime demand is a measure of how much lime is needed to neutralize the mine water (calcium hydroxide demand to a pH of 10). Samples collected from monitoring locations were analyzed for lime demand to assess the strength of AMD from different areas of the mine, and to determine the quantity of lime required to treat a unit volume.

Lime demand data for the 1998/1999 monitoring program are presented in Figure 2-17. Variations in lime demand values and the trends in the figure are very similar to what was observed for zinc concentrations. 9SO continuously exhibited the highest lime demand of all the monitoring locations, with an average of 470 lb/1,000 gallons. Other locations with high lime demand include 9CR, 5WR, 9SX, and 5BK. The reason for the large fluctuation observed at 5WR in late 1998 is not known, but a similar change was observed during the same period for zinc concentrations at 5WR.

2.3.4.5 Comparison of 1980s and 1998/1999 Data

A detailed comparison of 1980s and 1998/1999 mine water data was described in Supplement No. 1B of the Conceptual Model (CH2M HILL, 2000b). The comparison included flow and zinc loading for data obtained from the 1998/1999 AMD Monitoring Program (water year, or WY 1999), Riley's dissertation (Riley, 1990) (WY 1983, 1984, and 1985), and Bretherton's masters thesis (Bretherton, 1989) (WY 1986, 1987, and 1988). Additional comparison is made in the memorandum included in Appendix B.

The comparison shows that the base and peak flows at 5BK, 5WM, 9BS and 9BO and the timing for peak flows at 3HD and 5WR are very similar to the 1980s records. This suggests that recharge and inflow mechanisms to the mine have not changed substantially in recent years. However, the 1999 peak flows are much higher than the 1980s records for the Flood-Stanly Ore Body locations (for example, 9CR, 9SX, 9SO and 9LA). This is most likely attributed to higher surface water flows caused by snowmelt in West Fork Milo Creek in 1999 when compared to the 1980s. Peak flows through and from the Flood-Stanly Ore Body increased by a factor of 2 to 12 compared to those of the mid-1980s. Hunt (1984) reported that during field measurements in 1984, the lowest West Fork flows observed before they disappeared into the ground were 220 feet upstream from Phil Sheridan Raise No. 2. The timing of the peak flows observed in May 1999 coincides with the onset of high-elevation snowmelt and the observation of infiltration from West Fork Milo Creek below Phil Sheridan Raise No. 2 immediately above the Guy Cave Area, as described previously.

Several generalizations can be made based on the past and present mine water data. First, most of the poor-quality water originates within the upper country portion of the Flood-Stanly Ore Body. Second, flushing of the upper workings during spring recharge events causes higher metal concentrations with higher flows at the CTP. Thus, the highest metal loading from the mine occurs in the spring and early summer and is related to infiltration of snowmelt runoff and flushing of the mine workings, with the largest contributions coming from movement of West Milo Basin water through the Flood-Stanly Ore Body.

2.3.5 Mine Water Characterization Summary

The following bullets summarize key aspects of mine water characterization:

- The Bunker Hill Mine workings have created a large zone of drawdown in which the sub-regional groundwater system is dominated by unsaturated flow conditions but with numerous small perched and saturated zones.
- Recharge occurs as a result of sub-regional groundwater flow systems and seasonal snowmelt / rainfall / recharge. The sub-regional system is generally expressed by long-term, fairly steady flow within the mine. Seasonal phenomena are expressed by short-term peaks (a few days to a few weeks) in the hydrologic record. The peaks usually involve only a few days, but the falling limb of the hydrograph can take a few weeks. The peak mine water flows are a major cause of the maintenance and treatment problems posed by the mine water.
- The peak flows indicate movement of water rapidly from a surface source (probably streamflow) through the upper workings. The peak flows cannot originate from groundwater flow systems in undisturbed rock because of the rock's limited hydraulic conductivity. Groundwater collected by the upcountry mine workings predominantly moves through the workings in a series of cascading ditch flow systems. These flows converge with the extracted mine pool water and discharge from the Kellogg Tunnel, and are treated.
- Mine water flow through the in-mine workings is complex and most of the areas are inaccessible because of unsafe entry conditions. Research work since the 1970s has resulted in the identification of many of the major flow paths and metal load. However, additional flow paths exist that have not yet been defined. For instance, the 9 Level represents the most easily accessible and best understood level in the mine, yet monitoring stations placed upstream of 9LA, the station used to monitor the east side of 9 Level, account for only about 50 percent of the flow and metal load observed at 9LA.
- In general, the water pumped from the mine pool contributes about one-half of the mine water, and the gravity drainage from the upper workings accounts for the other half. However, during spring snowmelt recharge the gravity drainage proportion increases significantly, whereas the pumped portion stays more constant.
- The Flood-Stanly Ore Body is the primary source for acid and metal loading into the mine water. Discharge from the Flood-Stanly Ore Body represents only about 9 percent of the flow but carries more than 90 percent of the metal load that discharges from the mine.
- Spring snowmelt significantly increases mine water flow and metals load. This is caused by flushing of metals generated by sulfide oxidation, which includes washing of acid salts from reaction sites, flushing of acid water pools on drift floors, and breaking of yellow boy dams within the drifts. At most in-mine monitoring locations that receive drainage directly from the Flood-Stanly Ore Body (9SO, 9SX, 9CR, and 5WR), an increase in flow is accompanied by a decrease in metal concentration. This dilution effect does not exist for other locations, including locations that are further downstream of the

Flood-Stanly Ore Body such as at 9LA, where an increase in flow is accompanied by an increase in metal concentration. In both cases, the net result is an increase in metal load.

- Infiltration from West Fork Milo Creek is the largest identified contributor to seasonal flow variation. Flow from this ephemeral stream directly infiltrates the Flood-Stanly Ore Body via the area surrounding the Guy Caves.

2.4 Mine and River Hydrology Relationship

An analysis was conducted to determine if there is a relationship between the timing of peak SFCdA River surface water events and peak mine flow events. If a relationship exists, it may be possible to predict peak mine water flow events and therefore more effectively manage the mine water. Historical data for mine water flow at the Kellogg Tunnel and at 9LA were compared to surface water data for the SFCdA River, and also to Placer Creek near Wallace. 9LA was included because it receives most of its flow from gravity drainage through upper country workings. Placer Creek was included because it is situated on the south side of the Silver Valley facing north, similar to Milo Creek, and because there are no flow data available for Milo Creek.

The results of the analysis, summarized in *Hydrologic Evaluation for Bunker Hill Mine TMDL Compliance* (CH2M HILL, 2000d), show that the mine water flows and the river flows do not correlate well. Contributing reasons for this lack of correlation include historic mine water operations (dewatering efforts, the use of sand fill, etc.), orientation and size of the drainage basins, and recharge mechanisms. Therefore, it is not possible to use surface water flow data to predict either long-term or real-time mine water flows beyond the general observation that mine water flows increase during the spring and decrease to a base flow condition in the fall and winter.

2.5 Baseline Risk Assessment

This baseline risk assessment evaluates the current and future potential threat to human health and the environment as a result of potential or actual releases of hazardous substances from Bunker Hill Mine AMD. This baseline risk assessment also considers any uncertainties associated with the assessment. The results of this assessment are used to determine whether a current or potential threat to human health or the environment is of sufficient magnitude to warrant remedial action. In determining whether an exposure is associated with an unacceptable risk, a risk assessment generally evaluates the cumulative carcinogenic and non-carcinogenic site risks. This risk assessment does not conduct a quantitative assessment of carcinogenic and non-carcinogenic risks. Rather, because this RI/FS considers discharge of treated and untreated AMD to Bunker Creek and the SFCdA River, water quality criteria, standards, and targets for metals commonly found in the AMD are used to define acceptable risk levels that are considered to be protective of aquatic life and human health.

This baseline risk assessment is “qualitative” and uses the human health and ecological risk assessments and information already completed for the populated and non-populated areas of the Bunker Hill Superfund site (“the box”), and also those assessments in progress for the Coeur d’Alene Basin. A draft human health risk assessment (HHRA) (EPA, IDHW, DEQ, 2000c) and a draft ecological risk assessment (ERA) (EPA, 2000d) have been completed as part

of the ongoing Coeur d'Alene Basin Remedial Investigation and Feasibility Study process. While the Coeur d'Alene Basin RI/FS is focused on areas outside "the box," both the ecological and human health risk assessments for "the box" are also referenced because they are directly related to the potential for risk inside "the box" (SAIC, 1991; SAIC, 1992). The major findings from these studies are discussed below. Mine water was addressed in these documents as one of the contributors of metals to the SFCdA River, and as a component of basin-wide discharges of metals.

This baseline risk assessment evaluates current and future potential threats to human health and the environment in the absence of any remedial actions (i.e., the No Further Action alternative). Under the no-action scenario, it is assumed that no action is taken to upgrade the existing CTP, and that the CTP is shut down when the existing CIA sludge disposal area is full. As a result, untreated AMD would discharge into Bunker Creek and the SFCdA River. The potential for human and ecological exposures to these releases of untreated AMD is the primary focus of this risk assessment because it represents the most prominent exposure pathway.

2.5.1 Contaminants of Concern

Analytical data show that the Bunker Hill Mine is releasing large quantities of metal contaminants via AMD. The effects of metals on humans and aquatic life in the Coeur d'Alene River basin are presently being evaluated as part of the Coeur d'Alene River basin-wide RI/FS. The effects of metals on human health and the environment have also been evaluated as part of "the box" human health and ecological risk assessments.

For this risk assessment, the mine water Contaminants of Concern (COCs) were identified by comparing characterization data (summarized in Table 1-1) to the COC lists developed for surface water in "the box" and basin-wide assessments, and to risk-based benchmarks (Section 2.5.4). The following are the COCs for Bunker Hill mine water:

- For aquatic and terrestrial receptors: aluminum, arsenic, cadmium, copper, iron, lead, manganese, mercury, selenium, silver, and zinc
- For humans: arsenic, cadmium, lead, mercury, and thallium

The AMD contains significant quantities of these COCs, much higher than in treated AMD (current CTP effluent). To put this into perspective (using zinc as an example), a 1-day release of untreated AMD is equivalent to about 1.4 years of existing CTP discharge. The following section discusses the potential for exposure to untreated AMD, treated AMD (current CTP effluent), and treatment plant sludge.

Although not a COC, pH levels play a significant role in both direct toxicity (mortality to organisms exposed to low pH) and indirect toxicity (increasing bioavailability and toxicity of metals) to aquatic organisms. The pH levels in the AMD typically range from 2.5 to 3.5. These levels are extremely toxic to fish and other aquatic organisms.

2.5.2 Exposure Assessment

This section evaluates the site-specific characteristics and conditions that influence the potential for human and ecological exposures associated with the AMD, in order to identify the most important exposure pathways. Figure 2-18 shows the surface features associated

with the AMD. The AMD exits the Kellogg Tunnel portal in the mine yard and flows through an open channel (partially covered by a grate) for about 80 feet before it enters a buried pipeline that conveys it to the lined pond, where it is stored prior to treatment. The lined pond pump station pumps the AMD through a buried pipeline into the CTP. The treated AMD is discharged into Bunker Creek at the 006 Outfall. Bunker Creek flows westward, paralleling the Union Pacific Railroad bike and pedestrian path (to be open to the public), then turns northward, passing beneath Interstate 90 where it converges with the SFCdA River. CTP sludge is pumped into the unlined sludge disposal area on the CIA west of the CTP.

2.5.2.1 Fate and Transport of Contaminants

The major mechanism for onsite and offsite transport of contaminants under the no-action scenario is surface flow of untreated AMD into Bunker Creek and subsequently into the SFCdA River. Subsurface contaminant transport could occur if the mine pool elevation were to increase higher than the river level. However, this cannot occur as long as the mine pool pumping system is operated.

The major processes that appear to affect the fate of transported aluminum, cadmium, copper, lead, manganese, and zinc in surface waters are co-precipitation with iron hydroxides, or precipitation as oxy-hydroxides, oxides, or carbonates. As aluminum, cadmium, copper, lead, manganese, and zinc have a tendency to precipitate, arsenic, silver, selenium and thallium have a tendency to sorb to the iron oxy-hydroxide particles (selenium may also bind with free manganese if available). Once the metal-bound iron oxy-hydroxide particles mix with surface water, they tend to flocculate among themselves and also adhere to other solids (both suspended particles and sediments) as they are transported. Mercury has a tendency to preferentially sorb to organic matter rather than sorbing to iron oxy-hydroxide particles. Dissolved metals concentrations are further reduced as surface water pH is raised for those metals that have a tendency to precipitate, and in general for all metals as the flow is diluted by water. However, as shown in Table 2-3, even after dilution the release of untreated AMD into the SFCdA River results in downstream chronic toxic concentrations of metals. Based on the Coeur d'Alene River Basin-Wide RI/FS, it also has been documented that metals have accumulated in biota tissue via food chain concentrations.

2.5.2.2 Potential for Exposure to Untreated AMD

Although untreated AMD is accessible at the Kellogg Tunnel portal and in the lined pond, the potential for exposure in these areas is limited because these areas have controlled access. Also, access to the mine yard is controlled by the mine owner. The mine yard is an industrial facility not open to the public, and will likely remain zoned for industrial use. The 80-foot-long concrete ditch outside the portal is partially covered by a grate. The ditch walls and the grate contain the AMD to a narrow corridor, limiting access. Access to the lined pond is also controlled. The lined pond is open to the atmosphere but is enclosed with a chain-link fence about 7 feet tall. The gate is normally kept locked. The fence currently (and in the future) prevents exposure to larger animals. Small animals could burrow under or climb through the fence, and birds could fly over the fence and land in the AMD in the pond.

Public exposure to untreated AMD in the buried pipelines and at the CTP is minimal. These areas have either no, or very limited, public access. Workers could be exposed while performing pipeline or CTP maintenance, but these are industrial activities that should be conducted according to approved health and safety protocol.

In the event of CTP failure, untreated AMD would discharge into Bunker Creek downstream of the mine yard. Typical concentrations of selected COCs measured in untreated AMD are summarized in Table 2-3. Contaminant concentrations in the creek would be similar to raw AMD because of the limited dilution water present much of the year. Access along Bunker Creek is currently restricted, but in the future when the site is open to the public, recreational users of the bicycle and pedestrian path will be able to access the adjacent creek. Areas adjacent to Bunker Creek are planned for future development.

In summary, public and wildlife exposure to untreated AMD is limited by controlled access and physical barriers expected to remain in place. Removal of these would increase the potential for exposure. However, failure to effectively treat the AMD would result in raw AMD in Bunker Creek, increasing the potential for human and ecological exposure. Under this scenario, Bunker Creek would have contaminant concentrations approaching that of raw AMD, and concentrations in the SFCdA River downstream of the Bunker Creek confluence would increase to concentrations significantly higher than risk-based water quality standards (see Section 2.5.4).

2.5.2.3 Potential for Exposure to Treated AMD

When the CTP is operating, exposure to treated AMD can occur from the point of its discharge into Bunker Creek to the confluence with the SFCdA River. Also, exposure to diluted treated AMD can occur downstream of the confluence with the SFCdA River. Exposure to treated AMD at the CTP is limited to CTP workers. CTP activities are industrial and should be conducted according to approved health and safety procedures. Exposure to treated AMD in Bunker Creek is currently restricted while cleanup actions at the site are ongoing, but the potential for exposure will increase in the future when the cleanup is completed and these restrictions are removed. Although some exposure to treated AMD in Bunker Creek or the river is possible, the potential for exposure to untreated AMD is the primary focus of this risk assessment because of the significant higher contaminant concentrations.

2.5.2.4 Potential for Exposure to Treatment Plant Sludge

The treatment plant sludge, which is currently disposed in an unlined sludge pond on top of the CIA (see Figure 2-18), also contains the same metals as found in the AMD, although they are precipitated and relatively insoluble. Any filtrate (water that drains through the sludge) from that pond infiltrates through the underlying tailings, contributing to subsurface contamination. The current pond only has a few years of remaining storage capacity, after which it will be capped similar to the rest of the CIA. Capping of the current sludge pond will reduce the quantity of filtrate passing to the underlying tailings. Control of future discharges from the CIA, including the current sludge pond, is being addressed as part of the remedy for the non-populated area operable unit of the Bunker Hill Superfund site. Because public access is currently controlled and because it will be capped, the current

sludge pond is not considered to be a concern for potential future exposure or direct contact risk. Subsequent replacement sludge disposal facilities, if constructed, would also have controlled access.

2.5.2.5 Potentially Exposed Populations

The potentially exposed populations consist of aquatic life, terrestrial wildlife, and humans that have contact with either raw or diluted AMD in Bunker Creek or the SFCdA River.

Aquatic Life. If untreated, the AMD would contribute very high metal loadings to Bunker Creek and the SFCdA River. Primarily as the result of past practices, Bunker Creek is largely devoid of aquatic and benthic life. The SFCdA River is a cold-water body typical of western Idaho, containing fish as well as benthic invertebrates (e.g., crayfish, insect larvae, etc.). A more complete description of the aquatic organisms potentially at risk in the river is provided in the documents supporting the Coeur d'Alene Basin Remedial Investigation and Feasibility Study.

Terrestrial Wildlife. Terrestrial wildlife currently could contact raw AMD at the 80-foot ditch outside the mine portal, or in the lined pond, although potential for exposure here is limited as described earlier. Terrestrial wildlife could also contact raw AMD in Bunker Creek or the SFCdA River if the CTP fails or is shut down. Types of terrestrial wildlife potentially susceptible to exposure include large mammals such as deer, elk, coyotes, and foxes; waterfowl including ducks and geese; wading birds such as herons; and raptors such as eagles and ospreys. The draft Coeur d'Alene Basin Ecological Risk Assessment that is currently ongoing provides a description of the terrestrial wildlife potentially exposed to COCs in the Coeur d'Alene Basin.

Human Population. The potential for direct human exposure to the AMD once it leaves the mine is relatively small as described earlier, unless the AMD is not treated. If untreated AMD reaches Bunker Creek, there is the potential for direct exposure by people entering the creek, such as recreational users of the adjacent bike path, or people who might wade in or contact raw AMD in the upstream portions of Bunker Creek where little dilution water is available. Recreational users could also be exposed to diluted AMD by contact with the lower portions of Bunker Creek or surface water downstream from the confluence with the SFCdA River. People could also be exposed by consumption of fish taken from the river, if these fish have accumulated contaminants from the AMD.

2.5.2.6 Exposure Summary

Because of the significantly higher contaminant concentrations in untreated AMD and the potential for future exposure in the event of CTP failure or shutdown, exposure to untreated AMD in Bunker Creek and the SFCdA River is considered the primary exposure pathway of concern for this risk assessment. Future release of AMD will occur under the no-action scenario. Aquatic resources within the downstream water bodies represent the most sensitive receptors susceptible to exposure and risk; however, terrestrial wildlife and human exposures are also possible. Exposure to AMD at other upstream locations (toward the mine) or to treatment plant sludge is limited by either controlled access, physical barriers, or working procedures as described earlier. The following sections focus on the effects of untreated AMD in Bunker Creek and the SFCdA River.

2.5.3 Toxicity Assessment

This section provides brief descriptions of the types of toxic effects resulting from exposure to COCs in AMD. National Recommended Water Quality Criteria (NRWQC) for the COCs are summarized in Table 2-8.

2.5.3.1 Aquatic Toxicity Assessment

Aquatic life exposed to contaminants of concern in surface water may be adversely affected from exposure via direct ingestion, direct contact, and uptake via accumulation in prey species. Copper, selenium, and zinc are essential nutrients for aquatic life in small amounts, but are toxic in elevated concentrations. Aluminum and manganese become more soluble in acidic water and thus bioavailable to aquatic organisms. A portion of the iron in the AMD is in the reduced state, which increases toxicity to freshwater organisms. The aquatic effects of metals are discussed below. In general, divalent metals cause damage to the gill surfaces of fish and thereby interfere with respiration. The low pH, in addition to causing direct toxicity, also increases the bioavailability of toxic metals. When adsorbed into the body they can be metabolic poisons. Most aquatic species have some ability to moderate the adverse effects of metals at sublethal concentrations, but at some metabolic cost. Toxicity also depends on life stage and the specific organism that is exposed. The following presents the chemical-specific toxicity of metals to aquatic life via exposure to surface water with elevated concentrations of COCs.

Aluminum. Aluminum, which is a trivalent metal, is generally nontoxic; however, when in contact with acidic water, it becomes more soluble and available to aquatic organisms. When soluble aluminum enters buffered streams or lakes, a hydroxide floc is formed. This type of scenario is what the NRWQC for the protection of aquatic life for aluminum is based upon (see Table 2-8).

Arsenic. Arsenic occurs as two forms in ambient media: As (III), usually the most toxic, and As (V) (EPA, 1985a). The magnitude of bioavailability and toxicity is dependent on the oxidation state and temperature (McGeachy and Dixon, 1992). Toxicological tests indicate that the relative toxicity of various arsenic forms varies significantly between species. Tests conducted with several species indicate that early lifestages are more sensitive to arsenic exposure. Freshwater residue data indicate that arsenic is not highly bioaccumulative in freshwater fish, although lower forms of aquatic life (i.e., algae) may accumulate higher residue levels than fish (EPA, 1985a). Once accumulated, the arsenic is metabolized to an organic form, rendering it largely nontoxic to consumers higher on the food chain. Unlike most metals, arsenic toxicity to freshwater organisms is unaffected by the water hardness.

Cadmium. Results of many studies have identified a clear distinction in toxicity between salmonid and nonsalmonid species, with the former being considerably more sensitive to cadmium. For all species, increasing water hardness is associated with reduced toxicity. Young life stages are reported to be more susceptible than adult fish and, for both age classes, the effective concentration decreases progressively with increased exposure. Temperature can also affect the acute toxicity of cadmium, with increasing temperature decreasing the toxicity between 2- and 30-fold (Mance, 1990). Cadmium has a high to very high bioaccumulative potential for fish, mollusks, and crustacea (Bodek, et al., 1988).

Copper. The toxicity of copper to aquatic life is related primarily to activity of the cupric (Cu^{2+}) ion, and possibly to the hydroxy complexes. Aquatic invertebrates and fish exhibit reduced growth and elevated mortality when exposed to elevated concentrations of copper. Copper toxicity to aquatic life is inversely proportional to water hardness. Salmonid species tend to be highly sensitive; however, acclimation of fish to copper tends to ameliorate the toxicity. Increased temperature has the effect of decreasing the toxicity of copper (Mance, 1990). Copper has a high bioaccumulative potential in fish, mollusks, crustacea, and algae. Biomagnification of copper has been observed in aquatic plants.

Iron. Iron is an essential trace element at low concentrations. The bivalent and trivalent forms are of most concern, from a toxicity standpoint, to freshwater organisms. Iron is acutely toxic to freshwater fish and invertebrates at concentrations ranging from 0.300 mg/L to 2.0 mg/L (Train, 1979; cited in Dave, 1984). An acidic iron-containing waste water discharged into a water body will inhibit reproduction and affect survivability of *Daphnia magna* at concentrations of 0.158 mg/L and 0.256 mg/L, respectively (Dave, 1984).

Lead. In typical surface water, lead exists primary in an undissolved form, which can include colloidal particles or large undissolved particles of lead carbonate, lead oxide, or lead hydroxide. EPA (1980a) and Eisler (1988) have reviewed the aquatic toxicity of various lead compounds. Aquatic species differ significantly in their toxic response to lead (Eisler, 1988). In general, organic lead is more toxic than inorganic lead and dissolved waterborne lead is more toxic than total lead. Lead toxicity is a function of water hardness where toxicity to aquatic organisms is inversely related to hardness. Comparison of available acute toxicity data for invertebrates indicates that crustaceans are the most sensitive to lead (Mance, 1990). Lead is well-known to significantly bioconcentrate in aquatic biota; however, evidence does not support the occurrence of lead biomagnification through the aquatic food chain (Eisler, 1988). Lead does tend to bioconcentrate in aquatic organisms, with the highest lead concentrations seen in benthic organisms and algae, whereas the lowest concentrations are found in upper trophic level predators such as carnivorous fish (Eisler, 1988).

Manganese. Acute toxicity values for manganese ranged from 19.4 mg/L for *D. magna* to 33.80 mg/L for fathead minnow (Kimball, 1978). Biesinger and Christensen (1972) reported an EC50 value for reproductive impairment of 5.2 mg/L and a 3-week LC50 of 5.7 mg/L. A concentration of 1,110 mg/kg manganese is estimated to be toxic to most benthic organisms (Persaud et al., 1990). Manganese is deposited in the olfactory bulb of the brain (Rouleau et al., 1996). Calcium transport is impaired in the liver, kidney, muscle and inorganic portions of the bone (Bendell-Young and Harvey, 1986).

Mercury. Most of the mercury in the environment exists in inorganic forms (metallic mercury and inorganic mercury compounds). Inorganic mercury is strongly sorbed to particulate material. Organic forms of mercury (e.g., methyl mercury) are also favorably bonded to organic matters in soil and in the water column. Prominent biomagnification of methyl mercury has been reported for aquatic organisms. Mercury concentrations in carnivorous fish have been measured at 10,000 and 100,000 times higher than the concentrations in water (Callahan et al., 1979; EPA, 1980b; EPA, 1984, as cited in ATSDR, 1993).

Selenium. Selenium has a combination of attributes that make it an unusual pollutant (EPA, 1987a). These attributes include, but are not limited to, the following: it is an essential trace nutrient; it can occur in three oxidation states and be reduced or oxidized by various

organisms; it is a metalloid with physicochemical properties similar to sulfur, which may reduce the toxicity of selenium or be replaced by selenium in biologically important compounds; it can reduce the toxicity of several heavy metals and can have varying effects on cadmium and mercury toxicity; both water and food are important exposure pathways for aquatic biota; and there are substantial natural and anthropogenic releases to water. Selenium accumulation is quite variable and is not known to be affected by water hardness or temperature (EPA, 1987a). Nassos et al., (1980, as cited in Eisler 1985) found short-term exposure yielded bioaccumulation factors (BCFs) of 460 for the mosquitofish and 32,000 for the freshwater gastropod. As observed in long-term studies, selenium BCFs reached equilibrium and yielded lower BCF values. Although selenium is an essential nutrient for many aquatic species, it can be quite toxic.

Silver. Silver adheres strongly to clay particles found in suspended particulates and sediments. The impact of silver is most likely to occur in the soil/water interface. Silver usually occurs in low concentrations when in natural waters because of its low mobility in water. Food chain bioaccumulation of silver in aquatic systems is unlikely at normal concentrations in the environment. Algae, daphnia (water flea), freshwater mussels and *Pimephales promelas* (fathead minnow) have all been found capable of accumulating silver. However, although bioconcentration occurs in lower trophic organisms, the food chain is not an important route of silver accumulation for animals at higher tropic levels. In natural waters, sorbed and complexed silver species are at least one order of magnitude less toxic to aquatic organisms than the free silver ion. As water hardness decreases, the toxicity of silver increases.

Zinc. At low levels, zinc is an essential element needed for growth and metabolism. At higher concentrations, zinc is considered toxic and interferes with growth and causes mortality to aquatic organisms. Significant adverse effects on growth, reproduction, and survival are documented for sensitive marine and freshwater species of aquatic invertebrates and vertebrates at nominal water concentrations between 10 and 25 µg/L (Eisler, 1993). Toxic effect levels (48- or 96-hour LC_{50} or EC_{50}) for freshwater organisms range from 50 to 7,000 µg/L, 10,000 to 20,000 µg/L, and 400 to 50,000 µg/L for species of Salmonidae, Centrarchidae, and Cyprinidae, respectively (Rand and Petrocelli, 1985). The toxicity of zinc to fish has been reviewed extensively, with the common conclusions that water hardness reduces toxicity and that salmonid species are more sensitive than non-salmonid species. Temperature appears to have no effect on the toxicity of zinc to fish. Acclimation to zinc has also been reported to ameliorate zinc toxicity (Mance, 1990). Zinc can accumulate in freshwater animals from 51 to 1,130 times the concentration present in the water (EPA, 1987b).

2.5.3.2 Human Toxicity Assessment

Divalent metals are toxic to humans in various ways. The critical toxicity of arsenic and cadmium to humans is caused by their ability to cause cancer and other health effects such as skin lesions, neuropathy, gastrointestinal irritation, and kidney damage. Lead and mercury affect biochemical processes and interfere with metabolism and functioning of the central nervous system. Thallium appears to act by interfering with the normal action of potassium in important enzyme systems. The following presents the potential chemical-

specific noncarcinogenic and carcinogenic effects to humans as a result of exposure to COCs in AMD or in the surface waters of Bunker Creek and SFCdA River:

- **Arsenic**. Noncarcinogenic effects include skin lesions, neuropathy, and gastrointestinal irritation. Carcinogenic effects include skin cancer.
- **Cadmium.** Noncarcinogenic effects include kidney damage. There are insufficient data on carcinogenic effects via oral exposure.
- **Lead.** Noncarcinogenic effects include impaired neurobehavioral development, kidney damage, anemia and hypertension. Carcinogenic effects include kidney tumors. There is sufficient evidence of carcinogenicity in animals but insufficient evidence in humans.
- **Mercury.** Noncarcinogenic effects include kidney damage and neuropathy. There is inadequate evidence on carcinogenic effects to humans from exposure to mercury.
- **Thallium.** Studies in rats exposed to high levels of thallium showed adverse developmental and reproductive effects. Other effects include changes in blood chemistry, and hair loss. There is inadequate evidence on carcinogenic effects to humans from exposure to thallium.

2.5.4 Risk Characterization

The potential risks associated with aquatic, terrestrial, and human receptors are summarized in this section. Exposure to untreated AMD carries the potential for the largest risk to both human and ecological receptors. Exposure to CTP effluent carries less risk because the contaminant concentrations have been reduced significantly compared to the untreated AMD. Table 2-3 provides a comparison of typical concentrations of toxic priority pollutant COCs in untreated AMD against Idaho water quality standards (WQSs) for protection of freshwater aquatic life and human health. The table indicates that metals concentrations in untreated AMD are up to 2,200 times greater than applicable risk-based WQSs. If AMD were discharged to Bunker Creek without treatment, the concentration of contaminants in Bunker Creek would exceed protective WQSs. The concentration in Bunker Creek would be similar to the concentration in untreated AMD during dry periods of the year, and would be slightly diluted by surface water flow during wet periods of the year.

Table 2-3 also provides an evaluation of what would happen if untreated AMD was discharged from Bunker Creek to the SFCdA River, under various AMD and streamflow conditions. Contaminant concentrations in the untreated AMD would be diluted by background concentrations in the river. After mixing with background concentrations, the concentration of cadmium, lead, and zinc in the river would greatly exceed Idaho WQSs for the four potential flow conditions evaluated, and concentrations of copper would exceed Idaho WQSs for three of the four flow conditions. It should be noted that because the background concentrations of cadmium, lead, and zinc in the river currently exceed WQSs, the AMD could not be diluted below these standards regardless of the flow condition.

Table 2-4 presents typical concentrations for cadmium, lead, and zinc in treated effluent from the current Bunker Hill CTP. The table compares typical effluent concentrations to TMDLs developed for the Bunker Hill CTP for four flow conditions at Pinehurst (7Q10, 10th percentile, 50th percentile, and 90th percentile river flow). The table shows that the

concentrations in the CTP discharge exceed the TMDLs for cadmium, lead, and zinc at all four flow conditions.

Tables 2-3 and 2-4 demonstrate that discharge of untreated raw AMD will not meet WQSs, and that discharge of treated AMD by the current CTP will not meet TMDLs. As mentioned previously, access to the mine yard, AMD pipeline, lined pond, CTP, and sludge disposal bed is currently limited by existing institutional controls. The potential for exposure would increase if these controls were removed. The worst exposure scenario is direct discharge of untreated AMD into Bunker Creek. Aquatic life in the creek and the SFCdA River would be the most affected. Exposure to untreated AMD is acutely toxic to aquatic organisms. People and terrestrial wildlife would also be at considerable risk from direct contact with creek water.

2.5.4.1 Risk to Aquatic Resources

A prolonged direct release of AMD to Bunker Creek and then to the SFCdA River would result in an acutely toxic shock to the aquatic system, likely resulting in significant mortality of fish and invertebrate species. Chronic and long-term risks to aquatic life have been characterized by comparison with the NRWQC and State of Idaho WQSs, and by measuring numbers of fish and other aquatic life in various parts of the Coeur d'Alene River Basin (EPA, 2000b). In the portion of the SFCdA River that flows through "the box," concentrations of cadmium, lead, and zinc exceed the NRWQC and State of Idaho WQSs in most samples collected. Loadings of these contaminants to the SFCdA River through the AMD is a significant source of contamination even with the current treatment plant in operation. Numbers of fish and aquatic invertebrates are substantially reduced in that part of the SFCdA River compared to other streams not affected by mining waste. Based on the Coeur d'Alene Basin Draft Ecological Risk Assessment, and the concentrations of COCs in the mine water, the untreated mine water presents significant ecological risk to most ecological receptors. In addition, the existing treatment plant cannot meet the TMDLs for the SFCdA River without any upgrades (see Table 2-4).

For aquatic receptors (fish, invertebrates, and plants), exposure to metals has been confirmed by elevated concentrations of metals in the tissues of fish, invertebrates, and plants in many portions of the Basin. Metals concentrations in surface waters are at concentrations that are lethal to some aquatic life (above both the chronic and acute NRWQC). These concentrations would substantially reduce growth and reproduction of surviving aquatic life.

2.5.4.2 Risk to Terrestrial Wildlife

Terrestrial wildlife populations onsite are susceptible to direct exposure of AMD or current CTP effluent. Terrestrial wildlife may also be exposed from consumption of contaminated plants and animals that may have bioaccumulated some metals at higher concentrations. Terrestrial wildlife (e.g., birds, mammals, etc.) have been identified as being at risk from exposure to metals in the Coeur d'Alene Basin Draft Ecological Risk Assessment.

2.5.4.3 Risk to Human Populations

Individuals are at risk if they have direct contact with or ingest AMD or CTP effluent. The risk of such exposure is currently controlled by limited access to the site. Removal of the

controlled access will increase the opportunity for exposure. Children are at somewhat greater risk than adults, when considering noncancer toxicity resulting from incidental contact with AMD or diluted AMD in downstream waters. Individuals who consume fish from downstream waters are also potentially at risk, because some of the metals bioaccumulate and bioconcentrate in tissue.

2.5.5 Uncertainties

Several sources of uncertainty affect the assessment of potential risk to ecological and human receptors. These sources of uncertainty are generally associated with the reliability of the estimates of exposure (as represented by historical metals concentrations measured in treated and untreated AMD), and estimates of potential toxicity (as represented by available risk-based surface water criteria). Some specific uncertainties associated with this risk assessment include:

- Chemical concentrations in CTP effluent that are reported to exceed TMDLs (see Table 2-4) are based on total recoverable metals. Total metals concentrations may over-estimate potential bioavailability to aquatic organisms. However, for untreated AMD, measurements of soluble and total recoverable metal concentrations are similar for most metals because of its low pH. In the event of a release of AMD to Bunker Creek or the SFCdA River, elevation of pH during dilution would render some of the dissolved metal insoluble.
- Tables 2-3 and 2-4 present a range of AMD and SFCdA River flow conditions. Other combinations of AMD and SFCdA River flows exist that could create more or less toxic conditions than those shown in Tables 2-3 and 2-4.
- Highest flow rates for mine drainage occur in spring, when sensitive life-stages of aquatic organisms are present. The NRWQC are derived from toxicity data from multiple organisms, and may not necessarily protect the most sensitive life stages for all of these organisms. Therefore, risks identified throughout this assessment may underestimate potential risks to sensitive life stages during certain times of the year.

2.6 Identification of Potentially Applicable or Relevant and Appropriate Requirements

Remedial actions under CERCLA must meet or exceed any state or federal standards, requirements, criteria, or limitations that are determined to be legal “applicable or relevant and appropriate requirements” (ARARs). This section discusses ARARs for the remedial alternatives that are being evaluated for the Bunker Hill Mine Water Management RI/FS. Section 121(d) of CERCLA, 42 U.S.C. §9621(d) requires that remedial response actions selected under CERCLA attain a level or standard of control of hazardous substances that complies with ARARs of federal environmental laws and more stringent state environmental and facility siting laws.

The identification of ARARs is an iterative process throughout the RI/FS, and the final determination of ARARs will be made by EPA as part of the selection of the remedy, and will take into account public comment. Therefore, the federal and state statutes and

regulations identified in this RI/FS are identified as potential ARARs and are not intended to serve as the final determination of all ARARs for the site.

The purpose of the ARARs development and analysis is to help refine remedial goals and initially identify remedial alternatives. The remedial alternatives discussed within this RI/FS focus on the control of the discharges of AMD into Bunker Creek. Alternatives under consideration include AMD treatment, and disposal of treatment residuals (sludge). Some alternatives include stream diversions or other work that would modify stream channels.

The primary adverse impact from AMD is on surface waters, specifically to the biota that reside within them and to humans that use them for recreation or fish consumption. Secondary adverse impacts are associated with the possible upland disposal of sludge, the possible subsequent leaching from sludge to underlying groundwater, and to air (from particulate emissions during sludge drying). The ARARs development and analysis in this report focuses on requirements for discharges of AMD and treated effluent into surface waters, modifications to streams to implement surface water diversion structures, and the land disposal of sludge. ARARs concerning the cleanup of groundwater and soil were identified and addressed in the 1992 Bunker Hill Mining and Metallurgical Complex ROD (EPA, 1992) and therefore are not repeated in this analysis.

Section 2.6.1 provides general information on ARARs, including definitions and categories of ARARs. Specific ARARs information for this report is organized into three primary categories: chemical-specific, location-specific, and action-specific. These categories provide the basis for determining the objectives and goals of remedial actions and how they must be implemented. Each category is addressed in Sections 2.6.2 through 2.6.4. Within each category, the federal requirements are addressed first, followed by state and local requirements.

2.6.1 Basic ARAR Concepts

Key terms relating to ARARs are listed and defined below. Additional general information regarding ARARs may be found in EPA's *CERCLA Compliance with Other Laws Manual* (EPA, 1989). Specific ARARs issues are also discussed in the March 8, 1990, *Federal Register* notice publishing the final rule for the NCP (*Federal Register*, 1990).

ARARs. ARARs include “applicable” and “relevant and appropriate” requirements. In addition to these promulgated standards, EPA may also use guidance and health advisories as matters “to be considered.”

Applicable Requirements. Applicable requirements are those cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal or state environmental or facility siting laws that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance found at a CERCLA site. “Applicability” implies that the remedial action or the circumstances at the site satisfy all of the jurisdictional prerequisites of a requirement.

Relevant and Appropriate Requirements. Relevant and appropriate requirements are those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal environmental or state environmental or facility siting laws that, while not “applicable” to a hazardous substance,

pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site, address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well-suited to the particular site.

To-Be-Considered Guidance, Criteria, and Advisories (TBCs). TBCs are non-promulgated advisories or guidance issued by federal or state government that are not legally binding and do not have the status of potential ARARs. TBCs may be considered along with ARARs and may be useful in developing CERCLA remedies.

State Requirements as ARARs. CERCLA provides that state requirements may be used as ARARs for Superfund sites. To be considered an ARAR, the state requirement must be promulgated, it must be more stringent than federal requirements, and the state must identify the ARAR to EPA in a timely manner.

Permit Exemptions. CERCLA §121(e), 42 U.S.C. §9621(e), states that no federal, state, or local permits are required for remedial actions conducted entirely onsite. However, unless subject to a waiver, onsite remedial actions must meet the ARAR's substantive requirements. Any action that takes place offsite is subject to the full requirements of federal, state, and local regulations.

Chemical-Specific ARARs. These ARARs are usually health- or risk-based numerical values or methodologies which, when applied to site-specific conditions, result in the establishment of numeric values. These values establish the acceptable amount or concentration of a chemical that may be found in, or discharged to, the ambient environment.

Location-Specific ARARs. Location-specific ARARs are restrictions placed on the concentration of hazardous substances or the conduct of activities solely because they occur in special *locations*. Location-specific ARARs relate to the geographical or physical position of the site (e.g., presence of wetlands, endangered species, flood plains, etc.).

Action-Specific ARARs. Action-specific ARARs are usually technology- or activity-based requirements or limitations on actions taken with respect to hazardous substances.

Waiver Criteria for ARARs. CERCLA §121, 42 U.S. Code (U.S.C.) §9621, provides that under certain circumstances EPA may waive an ARAR. The waivers provided by CERCLA §121(d)(4), 42 U.S.C. §9621(d)(4) include the following criteria:

- Interim Measures
- Greater Risk to Health and the Environment
- Technical Impracticability
- Equivalent Standard of Performance
- Inconsistent Application of State Requirements
- Fund Balancing

2.6.2 Potential Chemical-Specific ARARs and TBCs

As discussed above, chemical-specific ARARs include those requirements that regulate the release to, or presence in, the environment for materials possessing certain chemical or physical characteristics or containing specified chemical compounds. These requirements

generally set health- or risk-based concentration limits or discharge limitations for specific chemicals. When a specific chemical is subject to more than one discharge or exposure limit, the more stringent of the requirements is used. Potential chemical-specific ARARs for Bunker Creek and the SFCdA River were identified on the basis of the COCs at the site. These are discussed in Section 2.5.1 and are aluminum, arsenic, cadmium, copper, iron, lead, manganese, mercury, selenium, silver, and zinc for aquatic life, and arsenic, cadmium, lead, mercury, and thallium for humans. Potential federal and state chemical-specific ARARs for the site are summarized in Table 2-5. Tables 2-6 through 2-9 provide additional details of chemical-specific ARARs by corresponding media. (Note: All tables are located at the end of this section.) Sections 2.6.2.1 and 2.6.2.2 present a discussion of potential chemical-specific ARARs for surface water and air and identify why these chemical values are potentially applicable, potentially relevant and appropriate, and/or to be considered. ARARs concerning groundwater and soil are addressed in the 1992 Bunker Hill Mining ROD.

2.6.2.1 Surface Water

Any discharge of AMD to surface waters must comply with applicable federal and state water quality criteria. EPA guidance states that federal water quality criteria for specific pollutants should generally be identified as ARARs for surface water cleanup if circumstances exist at a site that water quality criteria were specifically designed to protect, unless the state has promulgated corresponding water quality standards that apply to the water bodies at the site (see "ARARs Q's and A's: Compliance with Federal Water Quality Criteria," EPA Pub. No. 9234.2-09/FS, June 1990). Potential ARARs and TBCs for surface water include the following:

- Federal ambient water quality standards established by the Clean Water Act CWA(40 CFR 131), also known as the National Toxics Rule (NTR)
- Idaho Water Quality Standards [Idaho Administrative Procedure Act (IDAPA) 58.01.02]
- National Recommended Water Quality Criteria (NRWQC)
- Total Maximum Daily Load (TMDL) for the Coeur d'Alene River Basin
- National Pollutant Discharge Elimination System (NPDES) Regulations

Each of these are discussed below.

Federal Water Quality Standards (40 CFR 131)/NTR

In 1992 EPA established numeric water quality criteria for protection of human health and aquatic organisms for 12 states, including Idaho, that had failed to fully comply with Section 303(c)(2)(C) of the CWA. EPA withdrew the NTR for Idaho on April 12, 2000, because the state promulgated water quality criteria for specific pollutants (IDAPA 58.01.02) by adopting the NRWQC by reference. For this reason, the federal water quality standards are not applicable, but are considered potential relevant and appropriate requirements.

State of Idaho Water Quality Standards

In Idaho, the state surface water quality standards are developed based on designated beneficial uses of specific waters and on numeric and narrative criteria that are determined to be protective to humans and aquatic life. The state toxic substance criteria incorporates the NTR set forth in 40 CFR 131.36(b)(a) by reference, with the exception of arsenic. Idaho's

arsenic standard is 50 µg/L instead of the federal criteria of 0.14 µg/L (protection of human health for consumption of organisms). The state water quality standards are considered as potentially applicable requirements.

Bunker Creek, Milo Creek, and Deadwood Creek are the only surface waters located within the project area that are potentially affected by the remedial alternatives proposed in this RI/FS. These creeks are undesignated water bodies within the SFCdA River Subbasin. Remedial actions may affect Bunker Creek through the discharge of treated AMD to the creek. The other creeks may be affected by water diversion or other infiltration mitigations. Under Idaho's water quality standards, beneficial uses for undesignated water bodies include cold water biota (i.e., protection of freshwater aquatic life), and primary contact or secondary contact recreation (i.e., protection of human health for consumption of organisms) (IDAPA 58.01.02.101). Table 2-6 presents the relevant criteria for physical parameters and Table 2-7 presents the toxic pollutant criteria that have been identified as COCs for the mine water. The toxic pollutant criteria are presented as dissolved or total concentrations adjusted for hardness values. The State of Idaho has no surface water criteria for aluminum, manganese, and iron, which are identified as non-priority pollutants in the NRWQC as described in the following section.

A mixing zone for a point source wastewater discharge may or may not be applicable, depending on factors such as the size, configuration, and location of the discharge as outlined in IDAPA 58.01.02.060. The water quality within a mixing zone may exceed chronic water quality criteria so long as chronic water quality criteria are met at the boundary of any approved mixing zone. Acute water quality criteria may be exceeded within a zone of initial dilution inside the mixing zone if approved by IDEQ (IDAPA 58.01.02.060).

National Recommended Water Quality Criteria. The NRWQC were developed pursuant to Section 304(a) of the CWA. The criteria are used in implementing a number of environmental programs, including setting discharge limits in the NPDES permits. The most current criteria are published in the December 7, 1998, *Federal Register* (*Federal Register*, 1998). The criteria include priority and non-priority toxic pollutants. These criteria are updated periodically to reflect the latest scientific knowledge. (Note: A correction to these NRWQC was published in April 1999 (EPA, 1999). These criteria are not regulations, and do not impose legally binding requirements on the states. However, states are expected to adopt the new or revised numeric water quality criteria into their standards within 5 years of being published by EPA. For this reason, these criteria are considered as potentially relevant and appropriate. Table 2-8 presents the NRWQC priority and non-priority pollutants for the protection of fresh water aquatic organisms, and for the protection of human health for consumption of organisms and consumption of water and organisms.

Total Maximum Daily Load. On August 21, 2000, IDEQ and EPA jointly issued the final Total Maximum Daily Load for Dissolved Cadmium, Dissolved Lead, and Dissolved Zinc in Surface Waters of the Coeur d'Alene Basin (EPA, 2000e). The TMDL establishes allowable pollutant loadings for the Coeur d'Alene River Basin. Numeric criteria for the dissolved metals are established (in pounds per day) to assure attainment of the designated use established by the state. The TMDL specifies maximum daily loads of cadmium, lead, and zinc that can be discharged to the SFCdA River from several point sources, including the CTP. The TMDL is an important aspect of the mine water project because it contributes to

overall water quality improvements in the Coeur d'Alene Basin. The remedy will seek to achieve the load-based discharge limitations established in the TMDL. The TMDL is considered to be a TBC.

A general summary of the procedure used to allocate metals loads for the Coeur d'Alene River Basin is as follows:

- Gross allocation of allowable metal discharge load is calculated for each SFCdA River flow condition (7Q10, 10th percentile, 50th percentile, and 90th percentile) by subtracting the natural background load and upstream loads allocated to other sources from the loading capacity of the river.
- The gross allocation is divided into wasteload allocations for discrete sources (25 percent), waste piles and non-point sources (65 percent), and a margin of safety (10 percent).
- The wasteload allocation is divided into source allocations based on the ratio of the average flow at a source to the total flow from all sources.

Table 2-9 summarizes the CTP source allocation for cadmium, lead, and zinc associated with the four SFCdA River flow conditions, which will be measured at the Pinehurst gauge station. EPA will implement the TMDL based on a tiered or "step" approach. The 7Q10 source allocation would apply to river flow conditions from zero up to the 10th percentile. For flows between the 10th and 50th percentiles, the 10th percentile source allocation would apply. The 50th percentile source allocation would apply to flows between the 50th and 90th percentiles. The 90th percentile source allocation would apply for flow greater than the 90th percentile. At its discretion, EPA may allow for additional flow tiers (and associated discharge limits) to be used in establishing individual discharge requirements.

The TMDL is established to achieve the currently applicable water quality criteria for Coeur d'Alene River Basin waters in the Idaho water quality standards. EPA and the State of Idaho recognize that site-specific criteria (SSC) for lead, zinc, and cadmium may be appropriate for the SFCdA River to reflect the specific characteristics of the river and the sensitivity of the resident cold water biota. Therefore, future SSC development could affect the waste-load allocations for the CTP.

National Pollutant Discharge Elimination System Regulations. The CWA regulates the discharge of pollutants from point sources into waters of the United States. A discharge is defined as "the addition of any pollutant to navigable waters from any point source" [40 C.F.R. §401.11(h)(1)]. The discharge of metals-bearing AMD from the Bunker Hill Mine into Bunker Creek and the SFCdA River constitutes the discharge of pollutants from a point source or sources. All streams that are affected by the releases at the Bunker Hill Mine site are tributaries of the SFCdA River, a navigable waterway.

CWA controls are imposed on discharges through NPDES permits, which are issued on an individual basis in the Coeur d'Alene Basin by EPA Region 10. [In Idaho, the Idaho Department of Environmental Quality (IDEQ) has not requested NPDES permitting authority.] Because the discharges from the CTP occur onsite, no permit will be required; however, the discharge must meet the substantive requirements of the NPDES regulations.

In establishing discharge limits, the permitting agency evaluates both technology and water quality-based requirements in federal and state regulations. National technology-based limits that apply to copper and zinc mines are potentially applicable. Water quality-based limits based on the Idaho water quality standards are also potentially applicable.

The CWA's system of technology-based effluent controls establishes effluent limitations according to whether the discharge is from a new or existing source, and whether the pollutant is conventional, toxic, or a non-conventional, non-toxic pollutant. Existing sources of toxic discharges were initially required to achieve best practicable technology (BPT) and then later to achieve best available technology (BAT) that is economically achievable. Conventional pollutants are subject to best conventional technology (BCT) controls. New sources are subject to new source performance standards (NSPS).

The BPT and BAT limits on discharges from existing point sources at lead, copper, and zinc mines [40 C.F.R. §§440.102(a) and 440.103(a)] are presented in Table 2-10. These limits are considered potentially applicable.

2.6.2.2 Air

Disposal of AMD sludges will require control of particulates. Under the Clean Air Act (CAA), the EPA has set forth National Ambient Air Quality Standards (NAAQS) that define levels of air quality necessary to protect public health (40 CFR Part 50). DEQ has adopted these values (IDAPA 58.01.01.577), as well as ambient air values for carcinogens and noncarcinogens (IDAPA 58.01.01.585 and .586). Potentially relevant and appropriate to this site are the ambient air quality standards for lead and for particulates measured as equal to or less than 10 microns in diameter and less than or equal to 2.5 microns in diameter.

2.6.3 Potential Location-Specific ARARs

Location-specific ARARs are those requirements that relate to the geographical position or physical condition of the site. These requirements may limit the type of remedial action that can be implemented or may impose additional constraints on some remedial alternatives. Location-specific ARARs that could affect remedial actions are categorized and briefly described below. Potential location-specific ARARs for the site are summarized in Table 2-11.

2.6.3.1 National Historic Preservation Act, National Historic Landmarks Program, and National Register of Historic Places

The National Historic Preservation Act (NHPA), 16 U.S.C. §470, requires federal agencies to take into account the effect of any federally assisted undertaking or licensing on any district, site, building, structure, or object that is included in or eligible for inclusion in the National Register of Historic Places (NRHP). Criteria for evaluation are included in 36 CFR Part 60.4. The Bunker Hill site has not been designated as having historic value to warrant inclusion in the NRHP. If an eligible structure were encountered, the procedures for protection of historic properties set forth in Executive Order 11,593 entitled “Protection and Enhancement of the Cultural Environment” and in 36 CFR Part 800, 36 CFR Part 63, and 40 CFR Part 6.301(c) are potentially applicable.

2.6.3.2 Native American Graves Protection and Repatriation Act

Ground-disturbing activities would require that the Native American Graves Protection and Repatriation Act (NAGPRA) (25 U.S.C. §3001 et seq.) and the NHPA be followed, should remains or funerary objects or cultural resources (artifacts) be encountered onsite. NAGPRA requires that federal agencies take responsibility for damage to or loss of human burials caused by project actions, and NHPA requires that federal agencies consider the effects of their actions on properties on or eligible for the NRHP. These requirements are also potentially applicable.

2.6.3.3 Archaeological and Historic Preservation Act and Archaeological Resources Protection Act

The Archaeological and Historic Preservation Act (AHPA), 16 U.S.C. §469, and the Archaeological Resources Protection Act (ARPA), 16 U.S.C. §470, established procedures to preserve and protect archaeological resources. The first provides for preservation of historical and archaeological data that might be destroyed through alteration of terrain as a result of a federal construction project or a federally licensed activity or program. The second prescribes steps taken by investigators to preserve data. If remedial activities would cause irreparable loss or destruction of significant scientific, prehistoric, historical, or archaeological data, mandatory data recovery and preservation activities would be necessary. The implementing regulations [40 CFR 6.301(c) and 43 CFR 7] would be potentially applicable if eligible structures were identified.

2.6.3.4 Idaho Preservation of Historical Sites and Idaho State Historical Society

The Idaho Preservation of Historical Sites Act requires the state government to engage in a comprehensive program of historic preservation (Idaho Statute 67-4601, et seq.). The State is authorized to designate, establish, and declare any historic or archaeological site, monument, or point of interest in this state as an Idaho state historic site. If an eligible structure were to be designated or adversely affected, the procedures for protection of historical properties are potentially applicable.

2.6.3.5 Endangered Species Act

The Endangered Species Act (ESA), 16 U.S.C. §1531, et seq., requires consultation with the resource agencies for remedial actions that may affect these species. Section 7 of the ESA requires that federal agencies consider whether their actions will jeopardize the existence of species that are listed as threatened or endangered by the U.S. Fish and Wildlife Service (USFWS) or the National Marine Fisheries Service (NMFS). EPA is complying with the consultation provisions of the ESA, and is proposing selection of a remedial action that will provide the necessary level of protection for affected species. The ESA would be considered as potentially applicable.

2.6.3.6 Fish and Wildlife Conservation Act and Fish and Wildlife Coordination Act

The Fish and Wildlife Conservation Act, 16 U.S.C. §§2901, requires federal agencies to use their authority to conserve and promote conservation of non-game fish and wildlife. The Fish and Wildlife Coordination Act, 16 U.S.C. §§661-666, requires federal agencies involved in the control or structural modification of any natural stream or body of water to take action to protect fish and wildlife resources that may be affected by the selected remedial

action. The Fish and Wildlife Conservation Act and the Fish and Wildlife Coordination Act and their implementing regulations (50 CFR 83 and 40 CFR 6.302(g)) are potentially applicable to site remediation activities.

2.6.3.7 Idaho Classification and Protection of Wildlife

The Idaho Department of Fish and Game classifies wildlife as game, protected non-game, endangered, threatened, and species of special concern (IDAPA 13.01.06). The protected non-game, species of special concern, threatened or endangered species may not be taken or possessed, except as provided by Idaho Department of Fish and Game. These requirements are potentially applicable for any action that might affect and take designated wildlife species.

2.6.3.8 Clean Water Act (Section 404)

Section 404 of the CWA, 33 U.S.C. §1344, requires a permit for the discharge of dredged or fill material into waters of the United States. Bunker Creek, Milo Creek, and Deadwood Creek are considered "waters of the United States." Substantive CWA requirements are potentially applicable to remedial alternatives proposed in this RI/FS.

Activities associated with a selected remedy that might trigger Section 404 requirements include road construction, mine water treatment plant construction (or upgrades), and possible surface water diversions in Milo Creek and Deadwood Creek. The *Guidelines for Specification of Disposal of Sites for Dredged or Fill Material* [40 CFR Part 230, Section 404(b)(1)] define requirements that limit the discharge of dredged or fill material into the aquatic environment or aquatic ecosystems. These guidelines specify consideration of alternatives that have less adverse impacts and prohibit discharges that would result in exceedance of surface water quality standards, exceedance of toxic effluent standards, and jeopardize threatened or endangered species. Actions that can be taken to minimize potential adverse impacts of the discharge on the aquatic ecosystem are specified in Subpart H of 40 CFR 230, and include:

- Confining the discharge's effects on aquatic biota
- Avoiding disruptions of periodic water inundation patterns
- Selection of disposal site and method of discharge
- Minimizing or preventing standing pools of water

2.6.3.9 Executive Order on Floodplain Management

The Executive Order on Floodplain Management, Executive Order No. 11,988, requires that federal agencies evaluate the potential effects of actions that may take place in a floodplain to avoid, to the extent possible, adverse effects associated with direct and indirect development of a floodplain. EPA's regulations to implement this Executive Order are set forth in 40 C.F.R. §6.302(b). In addition, EPA has developed guidance entitled "*Policy on Floodplains and Wetlands Assessments for CERCLA Actions*," dated August 6, 1985 (EPA, 1985b). The proposed remedial activities, such as treatment plant construction, are not expected to affect the 100-year floodplain of Bunker Creek. However, the requirements of this regulation are potentially applicable if any remedial activities affect the floodplain.

2.6.4 Executive Order on Protection of Wetlands

The Executive Order on Protection of Wetlands, Executive Order No. 11,990, requires that federal agencies avoid, to the extent possible, adverse impacts associated with the destruction or loss of wetlands and to avoid support of new construction in wetlands if a practicable alternative exists. EPA's regulations to implement this Executive Order are set forth in 40 C.F.R. §6.302(a). In addition, EPA has developed guidance entitled "*Policy on Floodplains and Wetlands Assessments for CERCLA Actions*" (EPA, 1985b). There are no wetlands within the vicinity of the CTP that have been identified by federal or state agencies. If wetlands are encountered, these requirements would be potentially applicable.

2.6.5 Action-Specific ARARs

Action-specific ARARs are requirements that define acceptable containment, treatment, storage and disposal criteria and procedures. These ARARs generally set performance, design, or other similar action-specific controls or restrictions on particular kinds of activities. These requirements are activated by the particular remedial actions selected to accomplish a remedy. The action-specific requirements do not in themselves determine the remedial alternative; rather, they indicate how, or to what level, a selected alternative must achieve the requirements.

A preliminary list of potential action-specific ARARs is summarized in Table 2-12. These ARARs serve as a starting point. Other potential action-specific ARARs are typically developed and evaluated more closely as the selected remedy(ies) are identified and become final.

2.6.5.1 Exemption of Mining Waste from Hazardous Waste Regulations

AMD is related to the historic and current mining operations at the site. As such, it is exempted under RCRA §3001(b)(3)(A)(ii), 42 U.S.C. §6921(a)(3)(A)(ii) (also known as the "Bevill Amendment"). The Bevill exclusion, codified in 40 C.F.R. §261.4(b)(7), provides that "[s]olid waste from the extraction, beneficiation and processing of ores and minerals (including coal), including phosphate rock and overburden from the mining of uranium ore [are not hazardous wastes]." Sludge derived from the treatment of AMD is also exempted because the sludge is the direct result of "extraction" included under the Bevill Amendment. The Bevill Amendment is applicable to AMD. Therefore, the handling and disposal of sludge is not subject to RCRA Subtitle C regulations.

2.6.5.2 RCRA Subtitle C Hazardous Waste Identification and Generator Requirements

Federal hazardous waste regulations including 40 CFR Part 261 Hazardous Waste Identification, and 40 CFR Part 262 Generator Requirements specify requirements for hazardous waste generators. Under the RCRA regulations, a material is a hazardous waste if: (1) it is a solid waste; (2) it is not excluded or exempted from the regulation as a hazardous waste (i.e., "Bevill Amendment" wastes); and (3) it exhibits, on analysis, any of the characteristics of a hazardous waste, (i.e., ignitability, corrosivity, reactivity, and toxicity, as determined by TCLP).

If wastes, other than Bevill-exempt wastes, are generated at the CTP (e.g., spent laboratory chemicals or treatment additives), and they exhibit characteristics of a hazardous waste,

then the requirements of 40 CFR Part 262, generator requirements would be applicable to those wastes.

2.6.5.3 Idaho Rules and Standards for Hazardous Waste

The State of Idaho promulgated rules governing hazardous waste in March of 1993. The rules and standards for hazardous waste are found in IDAPA 58.01.05. All of 40 CFR Part 261 Identification and Listing of Hazardous Waste (including exclusions such as the Bevill Amendment) and 40 CFR Part 262 Generator Requirements are incorporated in the Idaho rules by reference. These rules and standards would be potentially applicable if hazardous waste (other than Bevill-exempt wastes) were generated by the CTP.

2.6.5.4 40 CFR Part 257 Criteria for the Classification of Solid Waste Disposal Facilities and Practices and Part 258 Criteria for Municipal Solid Waste Landfills

Subtitle D of RCRA establishes a framework for controlling the management of nonhazardous solid waste. The federal role is to provide overall regulatory direction and provide minimum nationwide standards for protecting human health and the environment. The existing Part 257 criteria is a potentially applicable requirement if the CTP sludge is disposed of on land. Under Part 257, solid waste disposal that violates criteria for any of the following poses a reasonable probability of adverse effects on health and the environment:

- Floodplains
- Endangered Species
- Surface Water
- Groundwater
- Air

Implementation of specific solid waste programs is largely a state and local function.

Under Part 258, minimum national criteria for municipal solid waste landfills (MSWLFs), including MSWLFs used for sludge disposal, are defined. These include minimum criteria for the location, design, operation, cleanup, and closure of the MSWLF units. These requirements are not applicable to the disposal of sludge from the treatment of AMD, but may be relevant and appropriate, particularly for the following considerations:

- Location restrictions
- Design criteria (including run-on and run-off controls and control of discharges to surface water and groundwater)
- Control of public access
- Closure and post-closure care
- Prohibited disposal of liquid wastes

2.6.5.5 Idaho Solid Waste Management Rules

The Idaho State Department of Water Resources adopted Solid Waste Management Rules and Standards (IDAPA 58.01.06) in December of 1992. Solid wastes will be managed whether it be during storage, collection, transfer, transport, processing, separation,

incineration, composting, treatment, reuse, recycling, or disposal, to prevent health hazards, public nuisances, or pollution of the environment. These standards are potentially applicable if sludge is disposed of on land at the site.

2.6.5.6 The Hazardous Materials Transportation Act

The Hazardous Materials Transportation Act (HMTA) regulates the transportation of hazardous materials on public highways, railways, or waterways. The HMTA is implemented by the U.S. Department of Transportation (DOT) in 49 CFR Parts 100-199. Transportation incidents involving reportable quantities of HAZMAT must be reported. DOT regulations also require specific training, communications, shipping and packaging requirements. If hazardous materials are transported offsite on public thoroughfares, these regulations will be applicable.

2.6.5.7 National Pollutant Discharge Elimination System

The NPDES program promulgated under Section 402 of the CWA establishes a comprehensive framework for addressing stormwater discharges under the NPDES program. 40 CFR 122.26 specifies requirements for point source discharge of stormwater from construction sites to surface water and provides for BMPs such as erosion control for removal and management of sediment to prevent run-on and run-off. These requirements are also potentially applicable to the discharge of treated AMD. NPDES requirements for point source discharges from treatment plants are discussed above in Section 2.6.2.1.

2.6.5.8 Idaho Non Point Source Management Plan

The Idaho Non Point Source Management Plan (December 1999) outlines the state's strategy for compliance with Section 319 of the CWA concerning the nonpoint source pollution management program. The long-term goals of the state's nonpoint source program are to restore, maintain, and protect the beneficial uses of both surface water and groundwater. The plan also outlines the roles of each federal/state agency, ways to achieve a balanced approach for cleanup of water, TMDL implementation strategy, design and implementation of BMPs for surface water and groundwater, and program management. This plan is a potential TBC for the site.

2.6.5.9 Idaho Water Quality Standards and Wastewater Treatment Requirements

Restrictions are placed on the discharge of wastewaters and on human activities that may adversely affect water quality in state waters. Under IDAPA 58.01.02.800, hazardous and deleterious materials must not be stored, disposed of, or accumulated adjacent to or in the immediate vicinity of state waters unless adequate measures and controls are provided to ensure that those materials will not enter state waters. A non-toxic chemical additive would be considered deleterious if the taste of edible fish or drinking water is tainted. These regulations are considered as potentially applicable.

2.6.5.10 Federal Clean Air Act

The federal CAA creates a national framework designed to protect ambient air quality by limiting air emissions. 40 CFR 50, NAAQS implements the CAA by establishing ambient air quality standards including particulate matter and designation of attainment, unclassifiable,

and non-attainment areas. These regulations are potentially applicable to construction activities.

2.6.5.11 Idaho Air Pollution Control Rules

The State of Idaho promulgated rules governing air pollution in May 1994 (IDAPA 58.01.01). The ambient air quality standards for specific air pollutants (IDAPA 58.01.01.578) include particulate matters. These standards are potentially applicable. Remedial activities will be designed to take all reasonable precautions to prevent particulate matter from becoming airborne including, but not limited to (as appropriate) the use of water or chemicals as dust suppressants, the covering of trucks, and the prompt removal and handling of excavated materials.

2.6.5.12 Idaho Safety of Dams Rules

The Idaho Safety of Dams Rules (IDAPA 37.03.06) establish acceptable standards for construction of a new or existing dam. Substantive requirements relevant to the Safety of Dams Rules is potentially applicable if the construction of dams is necessary during remedial activities (e.g., during stream diversions). The size classification, risk category, and relevant safety requirements of a dam are determined by the Idaho State Department of Water Resources.

2.6.5.13 Idaho Stream Channel Alteration Rules

The alteration of stream channels is regulated by the State of Idaho under IDAPA 37.03.07. Alteration must follow minimum standards set forth in the regulations that are designed to protect fish and wildlife habitat, aquatic life, and water quality. The substantive requirements of this regulation are potentially applicable to response actions that involve alteration of stream channels such as Milo Creek or Deadwood Creek.

2.6.5.14 Disposal of Dredge Material

Under Section 404(b)(1) of the CWA, *Guidelines for Specification of Disposal Sites for Dredged or Fill Material* are defined. These guidelines are intended to restore and maintain the chemical, physical, and biological integrity of waters of the United States through the control of discharges of dredged or fill material (40 CFR Part 230.1). Remedial actions involving the disposal of soil or dredge material need to consider the effects on the aquatic ecosystem, satisfy appropriate steps to minimize adverse impacts, prevent significant degradation of the water, and avoid violation of water quality standards. 40 CFR Part 230 and 33 CFR Parts 320 to 330 present these regulations. If dredging and filling occur as a result of stream alterations, then these requirements will be potentially applicable.

2.6.5.15 Idaho Land Remediation Rules

The Idaho Land Remediation Rules (IDAPA 58.01.18) have been adopted with the purpose of fostering the remediation, transfer, reuse or redevelopment of sites based on risk to human health and the environment where releases or threatened release of hazardous substances exist. Under IDAPA 58.01.18.27, institutional controls may be part of voluntary remediation under specified circumstances. Institutional controls may be needed in instances where residual concentrations of chemicals remain in excess of risk or regulatory

levels in order to reduce or eliminate contact with contaminated media. These rules are considered as potentially relevant and appropriate.

TABLE 2-1
Estimated Kellogg Tunnel Flow Return Intervals
Bunker Hill Mine Water RI/FS Report

Return Interval (years)	Probability of Occurrence In Any Year (%)	Estimated Average Annual Volume (million gallons)	Estimated Average Annual Flow (gpm)	Estimated Peak Flow (gpm)
2	50	862	1,640	2,740
5	20	1,020	1,940	3,900
10	10	1,102	2,100	4,790
50	2	1,247	2,370	7,140
100	1	1,298	2,470	8,320

TABLE 2-2
Estimated Flows for West Fork Milo Creek Drainage Basin
Bunker Hill Mine Water RI/FS Report

Return Interval (years)	Probability of Occurrence in Any Year (%)	Rainfall w/Snowmelt	Rainfall Only
2	50	6 cfs (2,700 gpm)	0 cfs (0 gpm)
5	20	17 cfs (7,600 gpm)	2 cfs (900 gpm)
10	10	34 cfs (15,300 gpm)	4 cfs (1,800 gpm)
25	2	53 cfs (23,800 gpm)	8 cfs (3,600 gpm)
100	1	86 cfs (38,600 gpm)	28 cfs (12, 600 gpm)

(From Spectrum Engineering, 1996.) Milo Gulch Flood Hydrology and Water Quality Improvement Plan. March 1996.

TABLE 2-3
Comparison of Untreated (Raw) AMD Priority Pollutants to Idaho Water Quality Standards and SFCdA River Concentrations After Mixing
Bunker Hill Mine Water Management RI/FS Report

Parameter	Average Raw AMD[1] (ug/L)	Idaho Water Quality Standards for SFCdA at Pinehurst		AMD vs. Idaho Water Quality Standards		Average Background at Pinehurst[8] (ug/L)	Concentration in SFCdA River after mixing with Raw AMD[10] (ug/L)			
		Freshwater[2] (ug/L)	Human Health[3] (ug/L)	Freshwater	Human Health		1500 gpm AMD +68 cfs SFCdA	1500 gpm AMD +97 cfs SFCdA	3500 gpm AMD +268 cfs SFCdA	6700 gpm AMD +1290 cfs SFCdA
Arsenic	413	50	50	8 X	8 X	0.63 [9]	20	14	12	5
Cadmium	389	0.8[4,5]	NA	480 X	NA	7.8	26	20	19	12
Copper	517	8.5[4,5]	NA	60 X	NA	1.08 [9]	25	18	16	7
Lead[11]	754	1.73[4,5]	NA	440 X	NA	4.7	40	30	26	13
Mercury	0.11	0.012 [5]	0.14	9 X	0.8 X	ND	0.01	0.00	0.00	0.00
Selenium	19	5 [6]	NA	4 X	NA	ND	0.9	0.6	0.5	0.2
Silver	23	1.9 [4,5,7]	NA	12 X	NA	ND	1.1	0.8	0.7	0.3
Thallium	30	NA	1.7 [6]	NA	18 X	NS	1.4	1.0	0.8	0.3
Zinc	172,200	78[4,5]	NA	2200 X	NA	1,420	9,420	7,110	6,250	3,370

1 Chemistry is based on average total recoverable metals in Kellogg Tunnel discharge monitoring data collected during the 1998/1999 monitoring program. The relative percent difference between total and dissolved concentrations in AMD for cadmium, copper, lead, silver, and zinc is less than 6.7 percent, and therefore these concentrations can be viewed as dissolved for the purposes of this table. Average flow is based on historic data between 1972 and 1999.

2 Idaho Water Quality Standards and Wastewater Treatment Requirements for Freshwater Aquatic Life Protection (Chronic). IDAPA 58.01.02.250. These reflect the criteria for toxic pollutants in 40 CFR 131.36, with the exception of arsenic which is 50 ug/L based on IDAPA 58.01.02.210.

3 Idaho Water Quality Standards and Wastewater Treatment Requirements for Human Health Protection for Consumption of Water and Organisms. IDAPA 58.01.02.250. These reflect the criteria for toxic pollutants in 40 CFR 131.36, with the exception of arsenic which is 50 ug/L based on IDAPA 58.01.02.210.

4 Criteria based on 71 mg/L hardness estimates for 50th percentile flow condition at Pinehurst as presented in the Technical Support Document for TMDLs (EPA, August 2000).

5 Expressed as dissolved metal in the water column.

6 Expressed as total recoverable metal in the water column.

7 Represents Freshwater Aquatic Life Protection for Acute conditions (Chronic criteria not available).

8 Current average dissolved background concentration at Pinehurst from Technical Support Document for TMDLs (EPA, August 2000), which includes treated effluent from CTP. Calculation of background concentration without the CTP effluent would be difficult and suspect to error, and therefore these average values are used. For cadmium and zinc, treated effluent dilutes the background concentrations in the river, but the difference in values is less than 5 percent. See note 11 for lead.

9 Average dissolved concentration from URS database for South Fork Coeur d'Alene River at Pinehurst, total of five samples.

10 Weighted average of Raw AMD and Background at Pinehurst, assumes complete mixing.

11 The relative percent difference between dissolved and total concentrations for lead in raw AMD is 5.7 percent, due to the low pH of the AMD. However, the difference in the SFCdA River is typically a factor of 2.2 (EPA, August 2000). Water quality standards and background concentrations are expressed as dissolved concentrations. Comparison of lead in raw AMD to lead in the river therefore overestimates the resulting concentration of in the river since some of the lead would precipitate out of solution.

NA not applicable ND not detected NS not sampled.

TABLE 2-4
Comparison of Treated AMD Contaminants of Concern to South Fork Coeur d'Alene River TMDLs
Bunker Hill Mine Water Management RI/FS Report

		South Fork Coeur d'Alene River TMDLs for Bunker Hill CTP[2] (ug/L)			
Parameter	**Average Bunker Hill CTP Effluent[1] (ug/L)**	**1500 gpm AMD +68 cfs SFCdA**	**1500 gpm AMD +97 cfs SFCdA**	**3500 gpm AMD +268 cfs SFCdA**	**6700 gpm AMD +1290 cfs SFCdA**
Cadmium (total)	3.0	1.3	1.7	1.6	1.3
Lead (total)	100	7.5	9.9	7.9	3.7
Zinc (total)	240	135	179	157	111

[1] From a review of the April 1999 through March 2000 discharge monitoring reports, flow is based on historical Kellogg Tunnel data between 1972 and 1999.
[2] Concentrations based on indicated AMD flow rate and Bunker Hill CTP source allocations.

TABLE 2-5
Potential Chemical-Specific ARARs and TBCs
Bunker Hill Mine Water RI/FS Report

Citation	Summary of Requirement	Evaluation
Surface Water		
Federal Water Quality Standards (40 CFR 131)	Establishes acceptable contaminant levels for ingestion of aquatic organisms by people and for exposure of aquatic organisms in surface water. Also known as National Toxics Rule.	Potentially relevant and appropriate.
Idaho Water Quality Standards and Wastewater Treatment Requirements (IDAPA 58.01.02)	The Surface Water Quality Standards designate uses for waters of the state and water quality standards protective of those uses. With the exception of arsenic, this regulation adopts the National Toxics Rule (40 CFR 131) for individual chemicals and other parameters based on protection of beneficial uses.	Potentially applicable.
National Recommended Water Quality Criteria— EPA 822-Z-99-001, April 1999	Federal criteria for 157 pollutants for protection of human health and aquatic life, developed as guidance for states. Revised on December 7, 1998 (FR Vol. 63, No. 234) to reflect the latest scientific knowledge. Republished in April 1999.	Potentially relevant and appropriate.
Total Maximum Daily Load (TMDL) August 21, 2000	TMDL establishes allowable pollutant loadings for specific water bodies. Numeric criteria for the dissolved metals including cadmium, lead, and zinc are established (in pounds per day) to assure attainment of the surface water use designated by the state.	To Be Considered.
National Pollutant Discharge Elimination System (NPDES) Regulations	Section 402 of the CWA, which establishes the NPDES permitting program (40 CFR 122) require that no pollutants be discharged to any surface water of the state from a point source, except as authorized by an individual or general permit.	Potentially applicable.
Air		
National Ambient Air Quality Standards (42 U.S.C. 7401 et seq.; 40 CFR 50)	Establishes ambient air quality standards for emissions of chemicals such as lead and particulate matter.	Potentially relevant and appropriate at the site boundary.
Idaho Toxic Air Pollutants (IDAPA 58.01.01.577, 585, 586)	Acceptable ambient concentrations (AACs) for carcinogens and noncarcinogens are provided as 24-hour averages. Ambient air quality standards for particulates and lead are provided as annual and 24-hour averages.	Potentially relevant and appropriate at the site boundary.

Notes:
ARAR – applicable or relevant and appropriate requirement
CWA – Clean Water Act
FR – Federal Register
IDAPA – Idaho Administrative Procedure Act
NPDES – National Pollutant Discharge Elimination System
CFR - Code of Federal Regulations NTR – National Toxics Rule
OSWER - Office of Solid Waste and Emergency Response
ppm - parts per million
TBC - to be considered
U.S.C. - U.S. Code

TABLE 2-6
Potential State of Idaho Physical Parameters Criteria in Surface Water
Bunker Hill Mine Water RI/FS Report

Parameter	Criteria
Cold Water Biota (IDAPA 58.01.02.250)	
pH	6.5 to 9.5 pH unit
Dissolved Oxygen	>6 mg/L
Temperature	22 °C or less with a maximum daily average of no greater than 19 °C
Total Dissolved Gas	<110% of saturation at atmospheric pressure at the point of sample collection
Turbidity	Not exceed background turbidity by more than 50 nephelometric turbidity units (NTUs) instantaneously or more than 25 NTUs for more than 10 consecutive days.

TABLE 2-7
Potential State of Idaho Chemical-Specific Surface Water ARARs for COCs (µg/L)[1]
Bunker Hill Mine Water RI/FS Report

Chemical	Freshwater Aquatic Life Protection		Human Health Protection for Consumption of:	
	Acute	Chronic	Water + Organisms	Organisms Only
Arsenic	50[2]	50[2]	50[2]	50[2]
Cadmium	16.6 [3,4]	2.9 [3,4]	NA	NA
Copper	62.8 [3,4]	37.1 [3,4]	NA	NA
Lead	281 [3,4]	10.9 [3,4]	NA	NA
Mercury	2.1	0.012 [3]	0.14	0.15
Selenium	20 [5]	5 [5]	NA	NA
Silver	37.4 [3,4]	NA	NA	NA
Thallium	NA	NA	1.7 [5]	6.3 [5]
Zinc	371 [3,4]	338 [3,4]	NA	NA

[1] Idaho Water Quality Standards and Wastewater Treatment Requirements. IDAPA 58.01.02.210. With the exception of arsenic (see Note 2), these reflect the criteria for toxic pollutants in 40 CFR 131.36.

[2] The standard for arsenic is 50 µg/L (IDAPA 58.01.02.210).

[3] Expressed in terms of the dissolved metal in the water column.

[4] Freshwater aquatic criteria for cadmium, copper, lead, silver, and zinc are expressed as a function of hardness (mg/L of $CaCO_3$) in the water column. Values above correspond to a hardness value of 400 mg/L, the maximum value allowed per 40 CFR 131.36. The expected hardness values of CTP effluent is 2000 mg/L. Values were calculated according to the following formulae:

CMC (dissolved) in µg/L = exp{mA[(ln hardness)]+bA} (CF)
CCC (dissolved) in µg/L = exp{mc[(ln hardness)]+bc} (CF)

[5] Expressed in terms of the total recoverable metal in the water column.

NA – Not applicable or not available.

Where:

Chemical	m_A	b_A	m_C	b_C	Freshwater Conversion Factors (CF)	
					Acute	Chronic
Cadmium	1.128	-3.828	0.7852	-3.490	1.136672-[(ln hardness)(0.041838)]	1.101672-[(ln hardness)(0.041838)]
Copper	0.9422	-1.464	0.8545	-1.465	0.96	0.96
Lead	1.273	-1.46	1.273	-4.705	1.46203-[(ln hardness)(0.145712)]	1.46203-[(ln hardness)(0.145712)]
Silver	1.72	-6.52	NA	NA	0.85	NA
Zinc	0.8473	0.8604	0.8473	0.7614	0.978	0.986

TABLE 2-8
Potential Federal Chemical-Specific Surface Water ARARs for COCs (µg/L) – NRWQC [1]
Bunker Hill Mine Water RI/FS Report

	Freshwater Aquatic Life Protection		Human Health Protection for Consumption of:	
Chemical	**Acute**	**Chronic**	**Water + Organisms**	**Organisms Only**
Priority Toxic Pollutants	**µg/L**	**µg/L**	**µg/L**	**µg/L**
Arsenic	340 [2]	150 [2]	0.018	0.14
Cadmium	19.1 [2,3]	6.2 [2,3]	NA	NA
Copper	49.6 [2,3]	29.3 [2,3]	1,300	NA
Lead	281 [2,3]	10.9 [2,3]	NA	NA
Mercury	1.4 [2]	0.77 [2]	0.05	0.051
Selenium	12.8 [4,5]	5 [4]	NA	NA
Silver	37.4 [2,3]	NA	NA	NA
Thallium	NA	NA	1.7	6.3
Zinc	379 [2,3]	382 [2,3]	9,100	69,000
Non Priority Pollutants	**µg/L**	**µg/L**	**µg/L**	**µg/L**
Aluminum	750[6]	87[6]	NA	NA
Iron	NA	1,000[6]	300[6]	NA
Manganese	NA	NA	50[6]	100[6]

[1] National Recommended Water Quality Criteria (NRWQC) for Priority Toxic Pollutants. U. S. EPA Office of Water. EPA 822-Z-99-001. April 1999. (Originally published on December 7, 1998, 63 FR 67548-67558.)

[2] Freshwater NRWQC for protection of aquatic life are expressed in terms of the dissolved metal in the water column.

[3] Freshwater NRWQC for cadmium, chromium III, copper, lead, nickel, silver, and zinc are expressed as a function of hardness (mg/L of CaCO3) in the water column. The values above correspond to a hardness value of 400 mg/L. The expected range of hardness values of CTP is 2000 mg/L. Values were calculated according to the following formulae:

CMC (dissolved) in µg/L = exp{mA[(ln hardness)]+bA} (CF)
CCC (dissolved) in µg/L = exp{mc[(ln hardness)]+bc} (CF)

[4] Expressed in terms of the total recoverable metal in the water column.

[5] CMC = 1/((f1/CMC1)+(f2/CMC2)) where f1 and f2 are the fractions of total selenium that are treated as selenite and selenate, respectively, and CMC1 and CMC2 are 185.9 ug/L and 12.83 ug/L, respectively. Selenate is assumed to be predominant in the discharge.

[6] National Recommended Water Quality Criteria (NRWQC) for Non Priority Toxic Pollutants. U. S. EPA Office of Water. EPA 822-Z-99-001. April 1999. (Originally published on December 7, 1998, 63 FR 67548-67558.)

ARAR – applicable or relevant and appropriate requirement

COC – contaminant of concern

NA – not applicable or not available

TABLE 2-9
TMDL—Source Allocations for Bunker Hill Central Treatment Plant* (lbs./day)
Bunker Hill Mine Water RI/FS Report

	South Fork Coeur d'Alene River Flow at Pinehurst			
Metal	**7Q10 (68 cfs)**	**10th (97 cfs)**	**50th (268 cfs)**	**90th (1,290 cfs)**
Cadmium	0.0233	0.0310	0.0659	0.103
Lead	0.135	0.178	0.334	0.297
Zinc	2.43	3.22	6.60	8.90

*Units are lb/day based on total concentrations.

TABLE 2-10
Potential Surface Water ARARs - Best Practicable Technology and Best Available Technology[1]
Bunker Hill Mine Water RI/FS Report

Parameter	Maximum for any one day (mg/L)	Average of daily values for 30 consecutive days (mg/L)
Total Suspended Solids	30	20
pH	Within the range of 6.0 to 9.0	Within the range of 6.0 to 9.0
Copper	0.30	0.15
Lead	0.6	0.3
Mercury	0.002	0.001
Zinc	1.5	0.75

[1] Best practicable technology (BPT) listed in 40 CFR 440.102(a) and Best Available Technology (BAT) listed in 40 CFR 440.103(a) are identical, with the exception of total suspended solids, which is listed as a BPT only.

TABLE 2-11
Potential Location-Specific ARARs and TBCs
Bunker Hill Mine Water RI/FS Report

Citation	Summary of Requirement	Evaluation
National Historic Preservation Act (16 U.S.C. 470 et seq.; 36 CFR Part 800; 40 CFR 6.301(b); Executive Order 11593); National Historic Landmarks Program (36 CFR Part 65); National Register of Historic Places (36 CFR Part 60)	Federal agencies must identify possible effects of proposed remedial activities on historic properties (cultural resources). If historic properties or landmarks eligible for, or included in, the National Register of Historic Places exist within remediation areas, remediation activities must be designed to minimize the effect on such properties or landmarks.	Potentially applicable.
Native American Graves Protection and Repatriation Act (25 U.S.C. 3001 et seq., 43 CFR 10)	Protects Native American burial sites and funerary objects. If Native American graves are discovered within remediation areas, project activities must cease and consultation must take place between the Department of Interior and the affected tribe.	Potentially applicable.
Archaeological and Historical Preservation Act (16 U.S.C. 469 et seq., 40 CFR 6.301(c))	Establishes procedures to provide for preservation of historical and archeological data that might be destroyed through alteration of terrain as a result of federal construction project or a federally licensed activity or program. Presence or absence of such data on the site must be verified. If historical or archaeological artifacts are present in remediation areas, the remedial actions must be designed to minimize adverse effects on the artifacts.	Potentially applicable.
Archaeological Resources Protection Act of 1979 (16 U.S.C. 470aa-ii; 43 CFR7)	Steps must be taken to protect archaeological resources and sites that are on public and Indian lands and to preserve data. Investigators of archaeological sites must fulfill professional requirements. Presence of archaeological sites are to be identified.	Potentially applicable.
Idaho Preservation of Historical Sites (Idaho Statute 67-4601 et seq.) and Idaho State Historical Society (Idaho Statute 67-4101 et seq.)	Covers historical sites and historical districts within the State of Idaho and the excavation of archaeological resources. The State Historical Society publishes the National Register of Historic Places for Idaho.	Potentially applicable.
Endangered Species Act, 16 U.S.C. 1531 et seq., 50 CFR 402; 40 CFR 6.302(h))	Protects endangered or threatened species and their habitat. If endangered or threatened species are in the vicinity of remediation work, U.S. Fish and Wildlife Service (USFWS) must be consulted and the remediation activities must be designed to conserve endangered or threatened species and habitats.	Potentially applicable.

TABLE 2-11
Potential Location-Specific ARARs and TBCs
Bunker Hill Mine Water RI/FS Report

Citation	Summary of Requirement	Evaluation
Fish and Wildlife Conservation Act (16 U.S.C. 2901 et seq. And 50 CFR 83)	Federal departments and agencies required to use their statutory and administrative authority to conserve and promote conservation of non-game fish and wildlife and their habitats. Non-game fish and wildlife are defined as fish and wildlife that are not taken for food or sport, that are not endangered or threatened, and that are not domesticated.	Potentially applicable. Site contains habitat for non-game fish and wildlife.
Fish and Wildlife Coordination Act (16 U.S.C. 661 et seq. and 40 CFR 6.302(g))	Requires consultation with USFWS (and State of Idaho Department of Fish and Game) when any federal department or agency proposes or authorizes any modification of stream or other water body greater than 10 hectares; requires adequate provisions for protection of fish and wildlife resources). Certain remedies may result in the temporary or permanent modification of naturally occurring water bodies and may require the construction of mitigated wetlands in other areas.	Potentially applicable.
Idaho Classification and Protection of Wildlife (Idaho Statute 36-201 and IDAPA 13.01.06)	The Idaho Department of Fish and Game classifies wildlife as game, protected non-game, endangered, threatened, and species of special concern. None of the protected non-game, species of special concern, threatened, or endangered species may be taken or possessed, except as provided by Idaho Fish and Game.	Potentially applicable.
Clean Water Act (Section 404) - Dredge or Fill Requirements (33 U.S.C. 1251-1376; 40 CFR 230)	Establishes requirements that limit the discharge of dredged or fill material into waters of the United States. EPA guidelines for discharge of dredged or fill materials in 40 CFR 230 specify consideration of alternatives that have less adverse impacts and prohibit discharges that would result in exceedance of surface water quality standards, exceedance of toxic effluent standards, and jeopardy of threatened or endangered species. Special consideration required for “special aquatic sites” defined to include wetlands. Portions of site encompasses “waters of the United States.” Should also be considered as an action-specific ARAR. Certain proposed alternatives may result in the constant submersion of metal-contaminated sediments.	Potentially applicable.
Protection of Floodplains (Executive Order 11988; 40 CFR 6.302(b); 40 CFR Part 6, Appendix A)	Requires federal agencies to evaluate the potential effects of action they may take in a floodplain to avoid the adverse impacts associated with direct and indirect development of a floodplain.	Potentially applicable for activities that may occur within the 100-year floodplain.

TABLE 2-11
Potential Location-Specific ARARs and TBCs
Bunker Hill Mine Water RI/FS Report

Citation	Summary of Requirement	Evaluation
Protection of Wetlands (Executive Order 11990; 40 CFR 6.302(a); 40 CFR Part 6, Appendix A)	Requires federal agencies to take action to avoid adversely affecting wetlands, to minimize wetlands destruction, and to preserve the value of wetlands.	Potentially applicable if wetlands are identified.

Notes:
ARAR – applicable or relevant and appropriate requirement
CFR – Code of Federal Regulations
FR – Federal Register
RCRA – Resource Conservation and Recovery Act
TBC - to be considered
U.S.C. - U.S. Code
USFWS - U.S. Fish and Wildlife Service
IDAPA – Idaho Administrative Procedure Act

TABLE 2-12
Potential Action-Specific ARARs and TBCs
Bunker Hill Mine Water RI/FS Report

Citation	Summary of Requirement	Evaluation
RCRA Bevill Exemption – RCRA Section 3001(b)(3)(A)(ii), 42 U.S.C. 6921(a)(3)(A)(ii), 40 CFR 261.4(b)(7)	The Bevill exclusion, codified in 40 C.F.R. §261.4(b)(7), provides that "[s]olid waste from the extraction, beneficiation and processing of ores and minerals (including coal), including phosphate rock and overburden from the mining of uranium ore [are not hazardous wastes]."	Potentially applicable to AMD and sludge generated from treatment of AMD.
RCRA Subtitle C—Hazardous Waste Identification and Listing of Hazardous Waste (40 CFR 261) and Standards Applicable to Generators of Hazardous Waste (40 CFR 262)	A solid waste is hazardous if it exhibits any of the characteristics of a hazardous waste; i.e., ignitability, corrosivity, reactivity, and toxicity as determined by a toxicity characteristic leaching procedure (TCLP). If a waste is deemed to be hazardous, then substantive requirements of 40 CFR 262 Generator Requirements are applicable.	Potentially applicable to any hazardous waste (other than Bevill-exempted waste) generated as part of the treatment plant operation.
Idaho Rules and Standards for Hazardous Waste-Management of Hazardous Waste (IDAPA 58.01.05 et. seq.)	Hazardous wastes that are generated must be managed in accordance with the applicable generation and transportation, storage, and disposal requirements. On-site actions are exempt from some requirements and permits are not required.	Potentially applicable to any hazardous waste (other than Bevill-exempted waste) generated as part of the treatment plant operation.
RCRA Subtitle D Part 257, Criteria for Classification of Solid Waste Disposal Facilities and Practices (42 U.S.C. 6901et seq; 40 CFR 257)	Maintenance of a facility at which solid waste open disposal occurs. Criteria established to determine which solid waste disposal facilities and practices pose a reasonable probability of adverse effects on human health or the environment. Requirements include the following: (1) Facility or practices shall not cause or contribute to taking of any endangered or threatened species; (2) Facility or practices shall not result in the destruction or abuse of critical habitat; (3) Facility or practice shall not cause discharge of pollutants into waters of the U.S. in violation of a NPDES permit; and (4) Facility or practices shall not cause discharge of dredged or fill material into waters of the United States.	Potentially applicable.
RCRA Subtitle D Part 258, Criteria for Municipal Solid Waste Landfills (42 U.S.C. 6901et seq; 40 CFR 258)	Establishes minimum design and operational requirements for municipal solid waste disposal facilities to ensure protection of human health and the environment.	Potentially relevant and appropriate.

TABLE 2-12
Potential Action-Specific ARARs and TBCs
Bunker Hill Mine Water RI/FS Report

Citation	Summary of Requirement	Evaluation
Idaho Solid Waste Management Rules and Standards (IDAPA 58.01.06)	Requires that all solid waste be managed to prevent human health hazards, public nuisances, or pollution of environment.	Potentially applicable.
Federal Department of Transportation Hazardous Materials Transportation Act (49 CFR Parts 171 to 180)	The movement of hazardous materials on public roadways must follow the placarding, packaging, documentation, emergency response, and other requirements of this regulation.	Potentially applicable.
Stormwater Discharge under National Pollutant Discharge Elimination System (40 CFR 122.26)	Section 402 of CWA establishes a comprehensive framework for addressing stormwater discharges under the NPDES program. Specifies requirements under 40 CFR 122.26 for point source discharge of stormwater from construction sites to surface water, and provides for BMPs such as erosion control for removal and management of sediments to prevent run-on and run-off.	Potentially applicable.
Idaho Non-Point Source Management Plan (December 1999)	Remedial activities will be consistent with the state's goal of restoration, maintenance, and protection of the beneficial uses of both surface water and groundwater. Long-term goals include design and implementation of BMPs for surface water and groundwater.	Potential TBC.
Idaho Water Quality Standards and Wastewater Treatment Requirements (IDAPA 58.01.02)	Restrictions are placed on the discharge of wastewaters and on human activities that may adversely affect water quality in state waters. Under IDAPA 58.01.02.800, hazardous and deleterious materials must not be stored, disposed of, or accumulated adjacent to or in the immediate vicinity of state waters unless adequate measures and controls are provided to ensure that those materials will not enter state waters. A non-toxic chemical additive would be considered deleterious if the taste of edible fish or drinking water are tainted.	Potentially applicable.
Federal Clean Air Act (42 U.S.C. 7401 et seq.)	Provides valuable guideline with respect to minimizing the harmful effects of fugitive dust and airborne contaminants that result from excavation, construction, and other removal activities.	Potentially applicable.
Idaho Air Pollution Control Rules (IDAPA 58.01.01)	Remedial activities will be designed to take all reasonable precautions to prevent particulate matter from becoming airborne including, but not limited to, as appropriate, the use of water or chemicals as dust suppressants, the covering of trucks, and the prompt removal and handling of excavated materials.	Potentially applicable.

TABLE 2-12
Potential Action-Specific ARARs and TBCs
Bunker Hill Mine Water RI/FS Report

Citation	Summary of Requirement	Evaluation
Idaho Safety of Dams Rules (IDAPA 37.03.06)	Requirements relevant to the Safety of Dams may be applicable if the construction of dams is necessary during remedial activities. The size classification, risk category, and related safety requirements of a dam are determined by the Department of Water Resources. Specific requirements for construction plans, drawings, and engineering specifications are detailed in the rule.	Potentially applicable for activities involving the construction or alteration of a dam as a result of stream diversions.
Idaho Stream Channel Alteration Rules (IDAPA 37.03.07)	The alteration of stream channels is regulated by the State of Idaho. Applicant is required to follow minimum standards set forth in regulations. These regulations are designed to protect fish and wildlife habitat, aquatic life, and water quality.	Potentially applicable for activities that involve the alteration of stream channels.
Disposal of Dredge Material (40 CFR Part 230 and 33 CFR Parts 320 to 330)	Disposal of soil or dredge material must determine effects on the aquatic ecosystem, satisfy appropriate steps to minimize adverse impacts, prevent significant degradation of the water, and avoid violation of water quality standards.	Potentially applicable.
Idaho Land Remediation Rules (IDAPA 58.01.18.027)	Institutional controls may be part of voluntary remediation under specified circumstances. Institutional controls may be needed in instances where residual concentrations of chemicals remain in excess of risk or regulatory levels in order to reduce or eliminate contact with contaminated media.	Potentially relevant and appropriate.

Notes:
AMD – Acid Mine Drainage
ARAR – applicable or relevant and appropriate requirement
BMPs – best management practices
CERCLA - Comprehensive Environmental Response, Compensation, and Liability Act
CFR – Code of Federal Regulations
EPA - U.S. Environmental Protection Agency
FR – Federal Register
IDAPA – Idaho Administrative Procedure Act
IDHW - Idaho Department of Health and Welfare
LDR - Land Disposal Restriction
NPDES - National Pollutant Discharge Elimination System
RCRA - Resource Conservation and Recovery Act
TBC - to be considered
TCLP - toxicity characteristic leaching procedure

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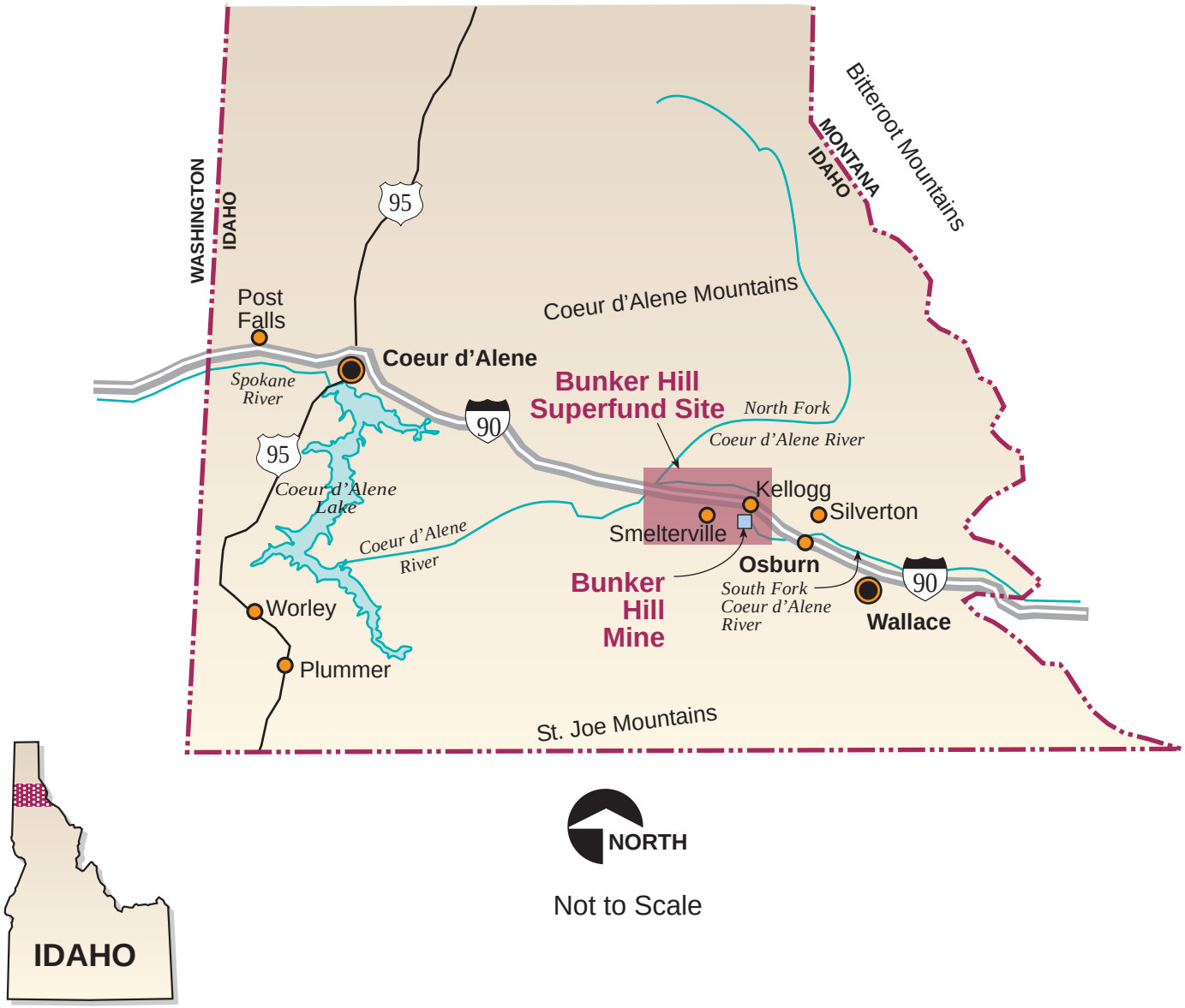
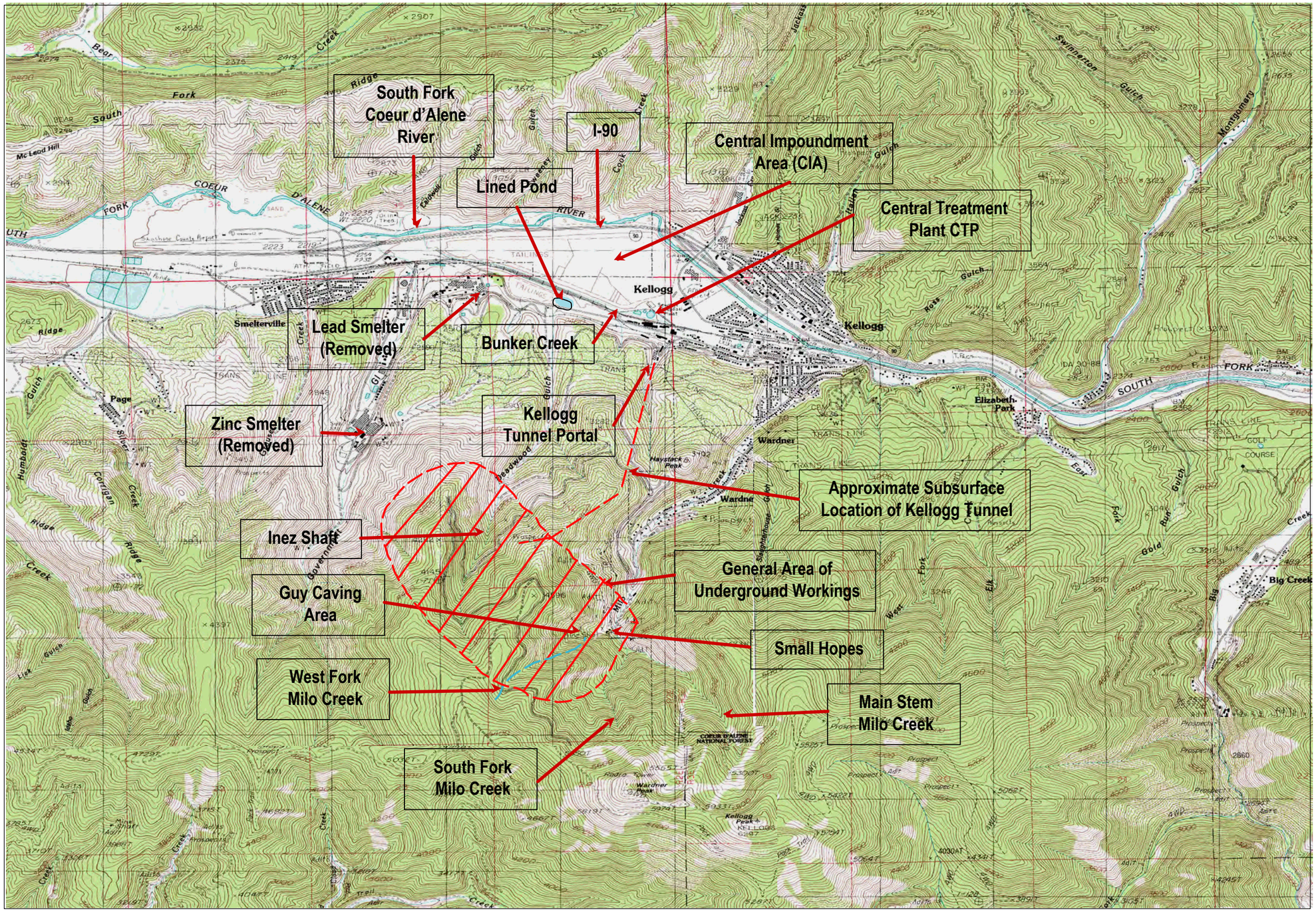


FIGURE 2-1

VICINITY OF THE BUNKER HILL MINE

BUNKER HILL MINE WATER MANAGEMENT RI/FS

CH2MHILL

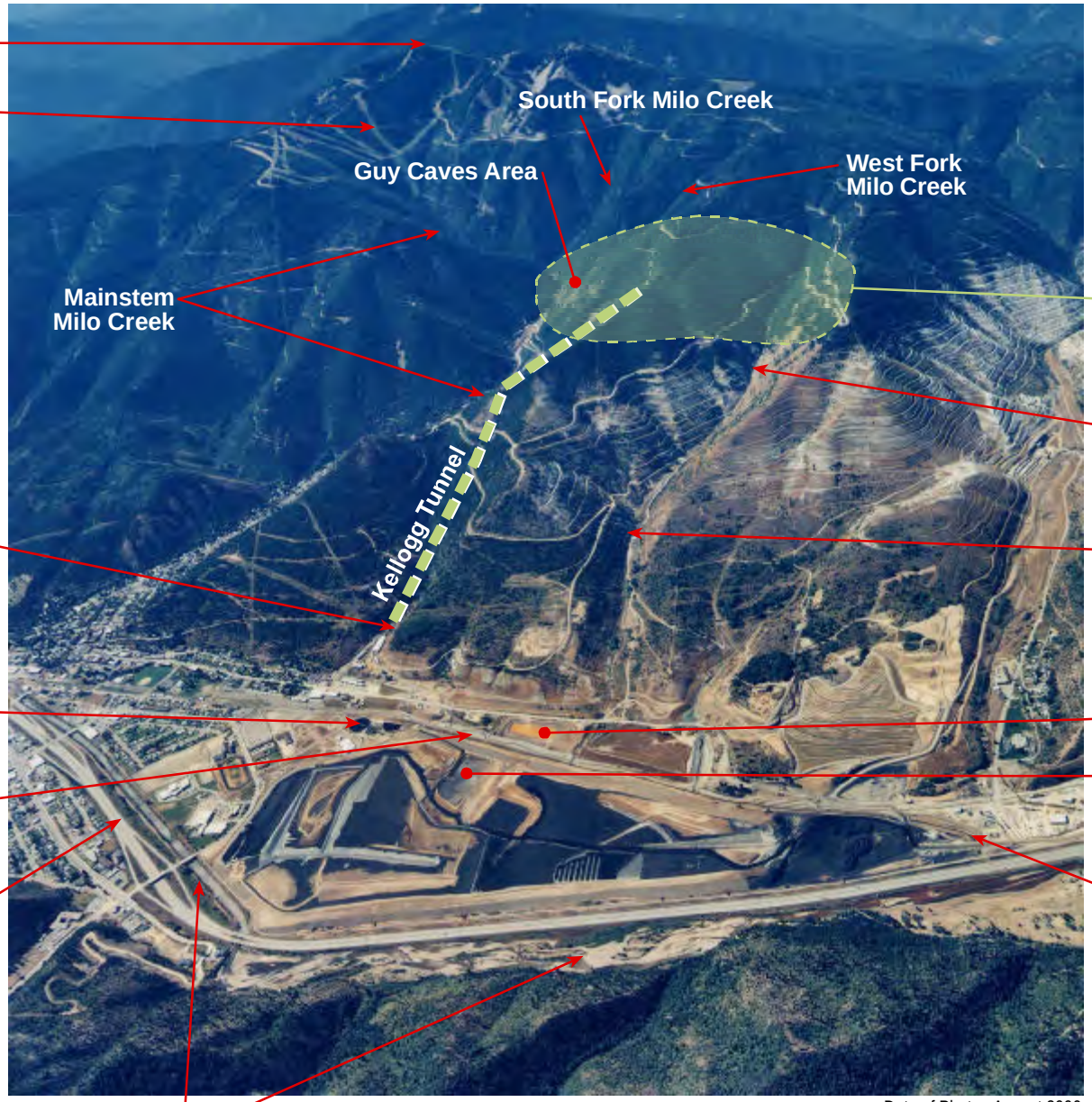


North

Approximate Scale
1" = 3000'

FIGURE 2-2
BUNKER HILL MINE AREA
BUNKER HILL MINE WATER MANAGEMENT RI/FS

CH2MHILL



Date of Photo: August 2000

NORTH

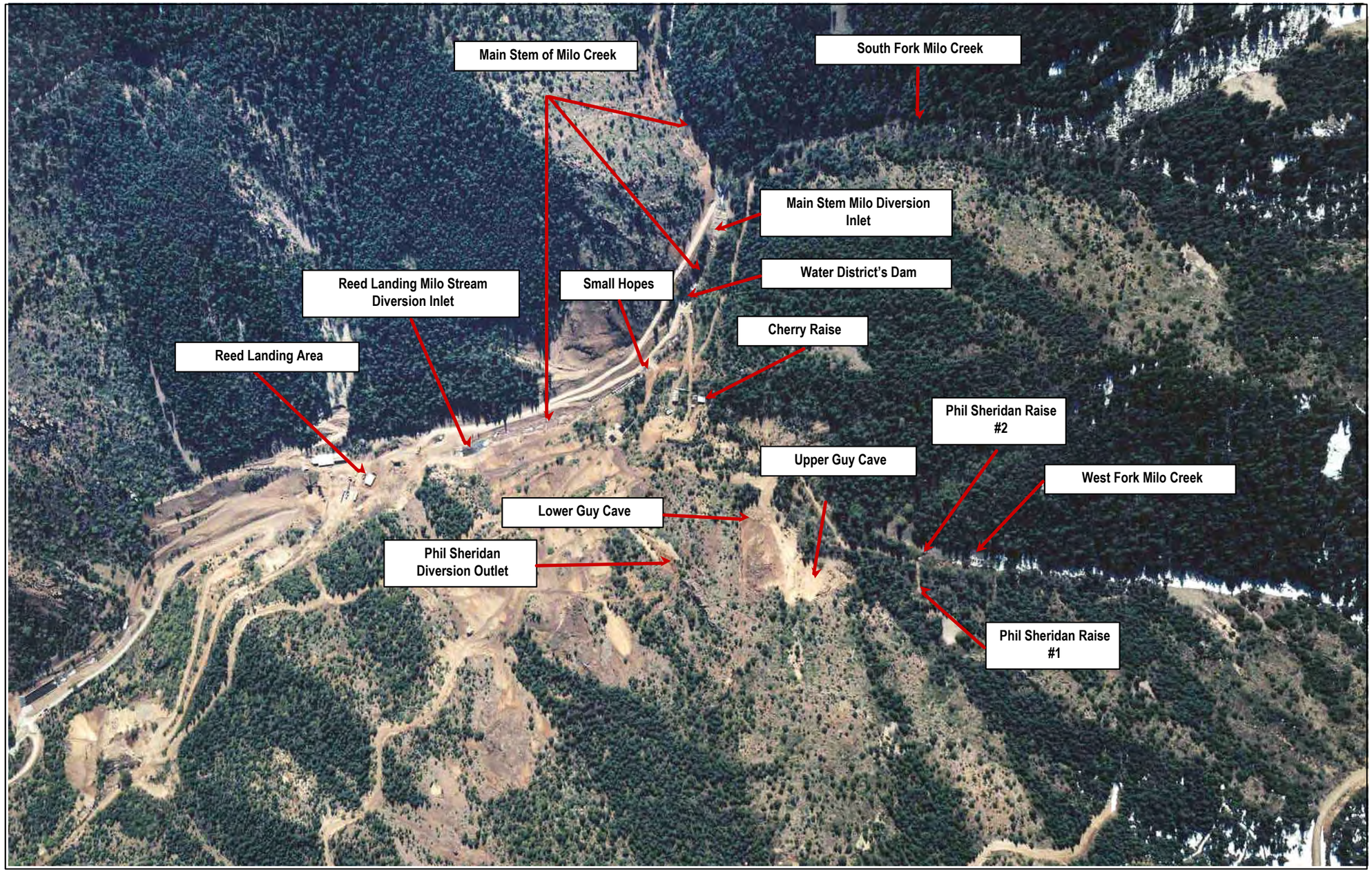
Not to Scale

FIGURE 2-3

BUNKER HILL MINE AREA

BUNKER HILL MINE WATER MANAGEMENT RI/FS

CH2MHILL



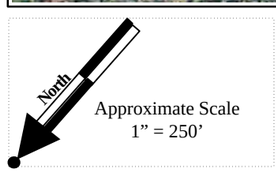
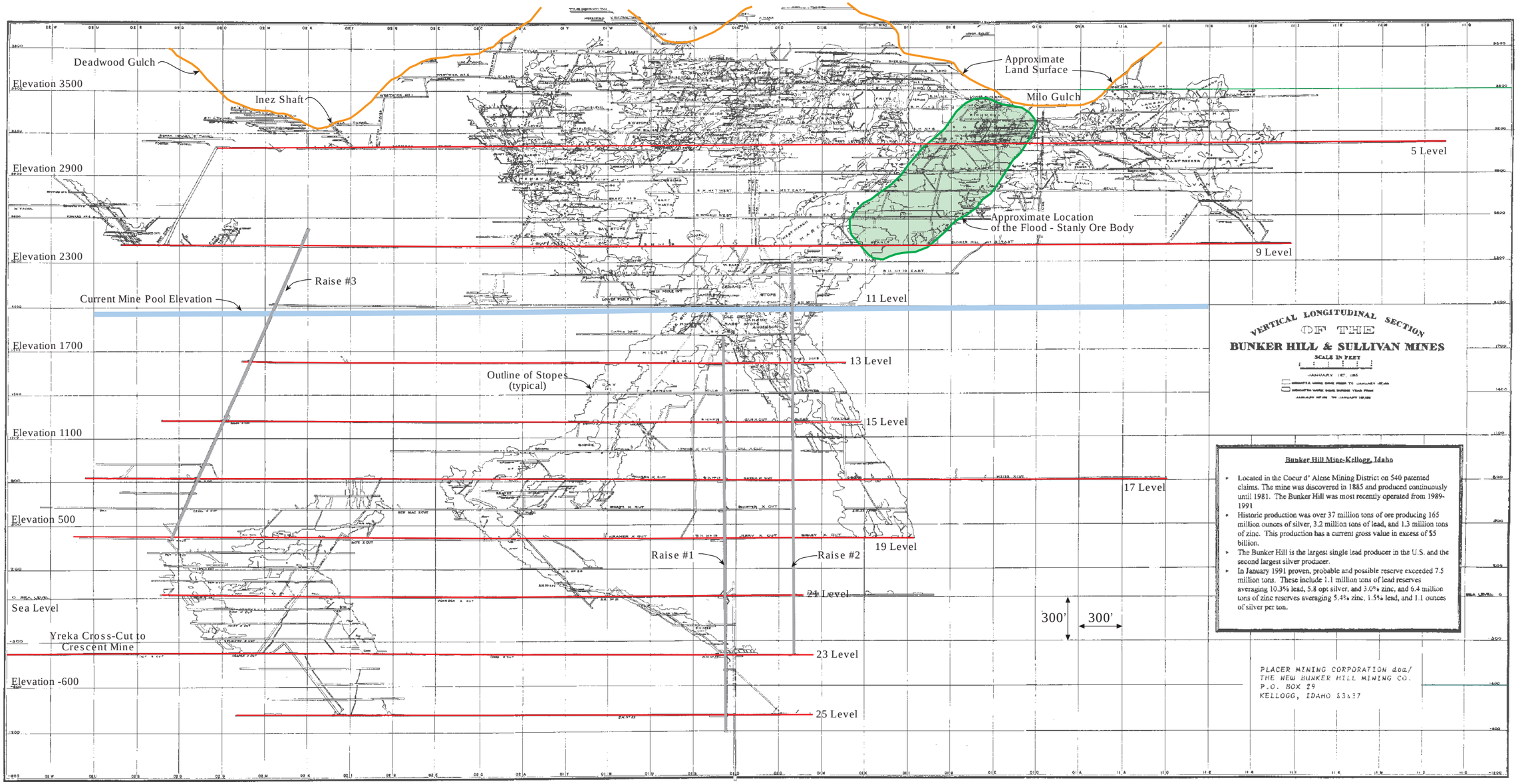


FIGURE 2-4
MAY 1999 MILO GULCH AERIAL PHOTO SHOWING CREEKS AND MINING FEATURES
BUNKER HILL MINE WATER MANAGEMENT RI/FS

CH2MHILL



NOTE:

The purpose of this figure is to convey the magnitude of the mine workings. Each square is 300 feet x 300 feet. The cross-section was prepared by the Bunker Hill Company in the 1950's. Workings were subsequently extended to the 31 level and thus are larger than depicted. The levels are about 200 feet apart and dip at about 60 degrees to the Southwest.

FIGURE 2-5
CROSS SECTION VIEW OF THE MINE
BUNKER HILL MINE WATER MANAGEMENT RI/F

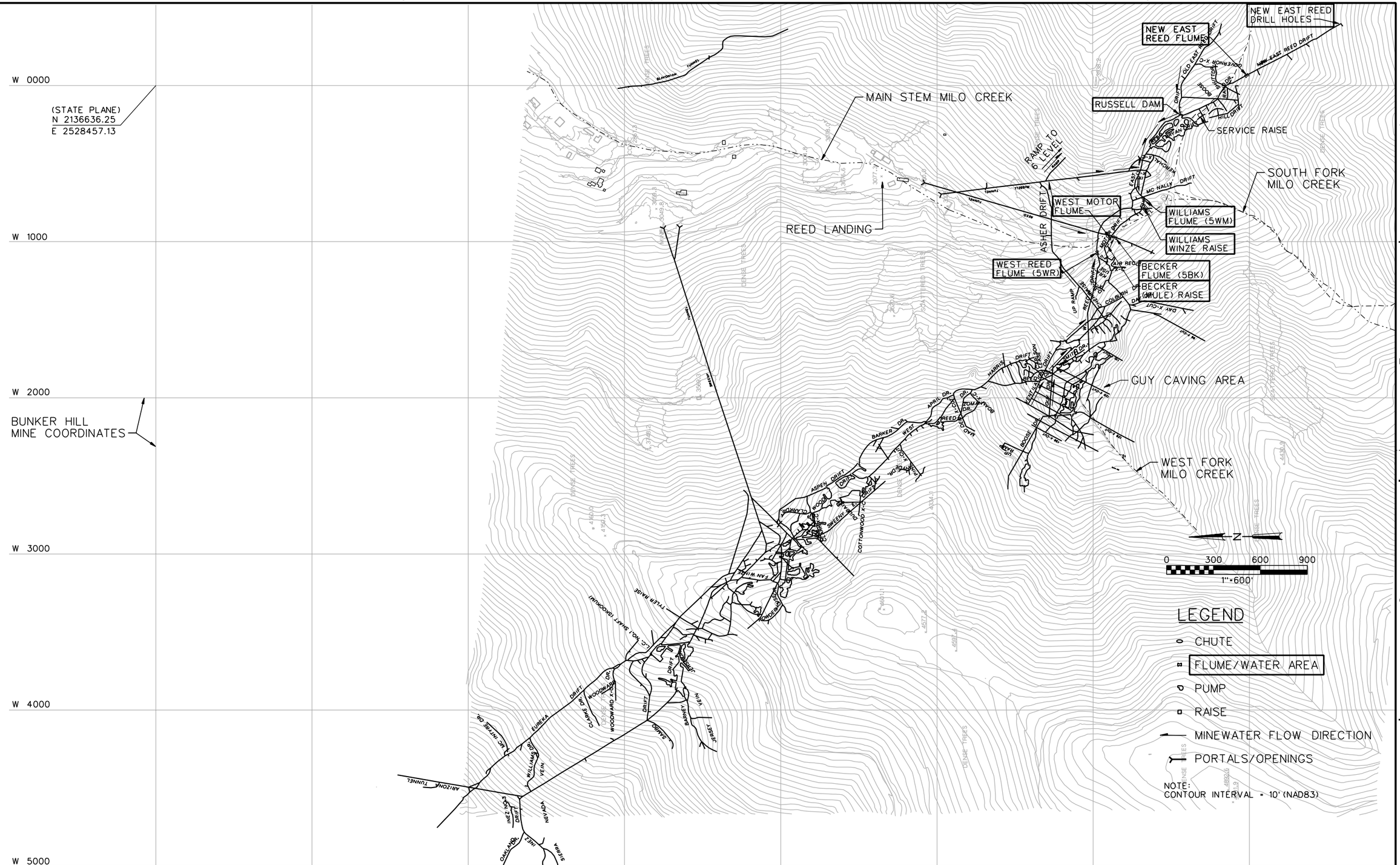


FIGURE 2-6
5 LEVEL WITH SUPERIMPOSED SURFACE CONTOURS

BUNKER HILL MINE WATER RI/FS REPORT
152215.FS.01

CH2MHILL

NDM 148562 FILE NAME: 90DXX155.DLV 10-JAN-2001

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m10:p99m002a.mst	1, 3, 5, 8-9, 11-14, 16-63	m10:p99l002.mst	1:63
m10:e01s1222.mst	1:63	d10:206xx001.dw	1:63
m10:e02s2222.mst	1:63		
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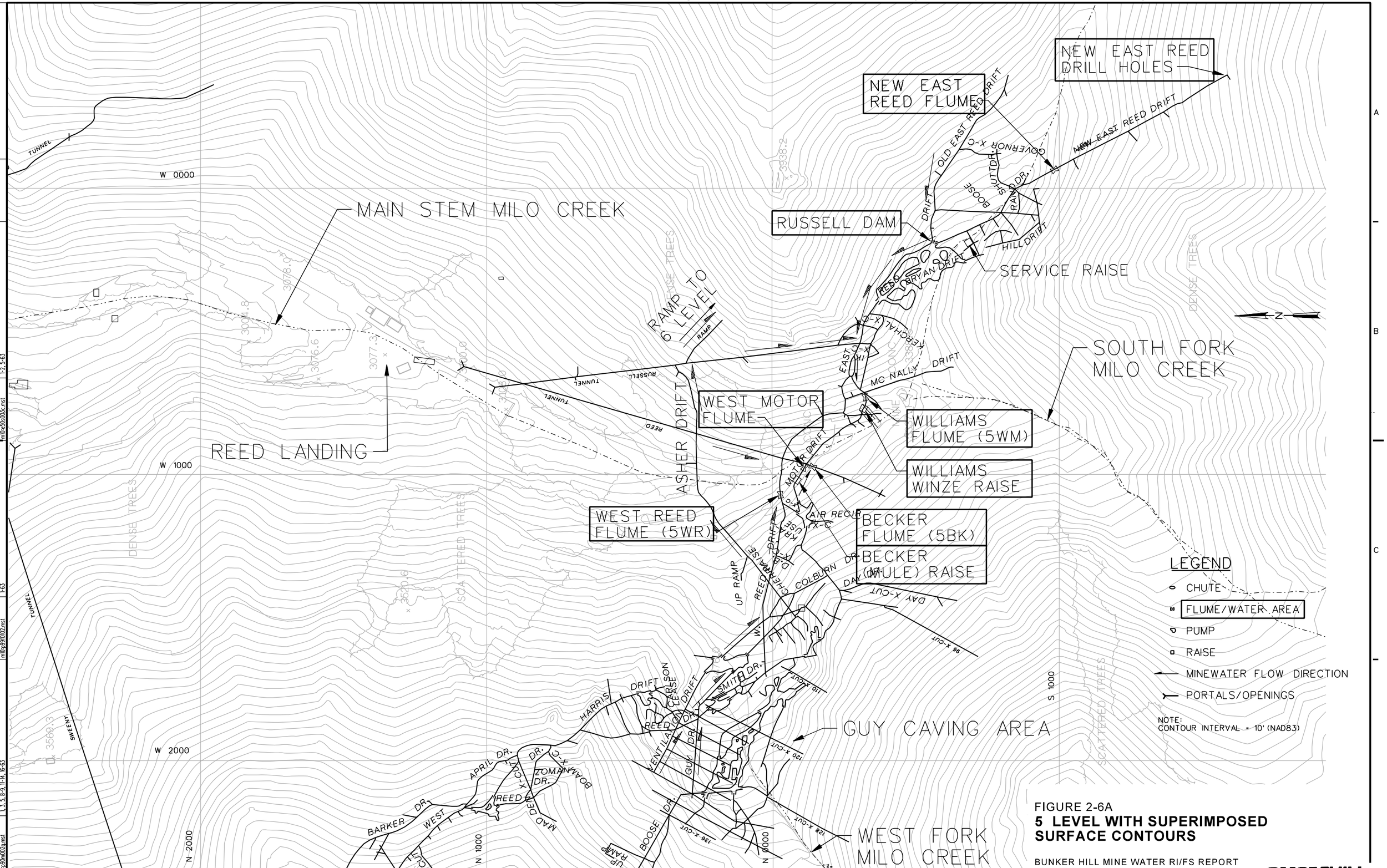

FIGURE 2-6A
5 LEVEL WITH SUPERIMPOSED SURFACE CONTOURS

BUNKER HILL MINE WATER RI/FS REPORT
152215.FS.01

FILE NAME: 90DXX157.DLV 10-JAN-2001

CH2MHILL

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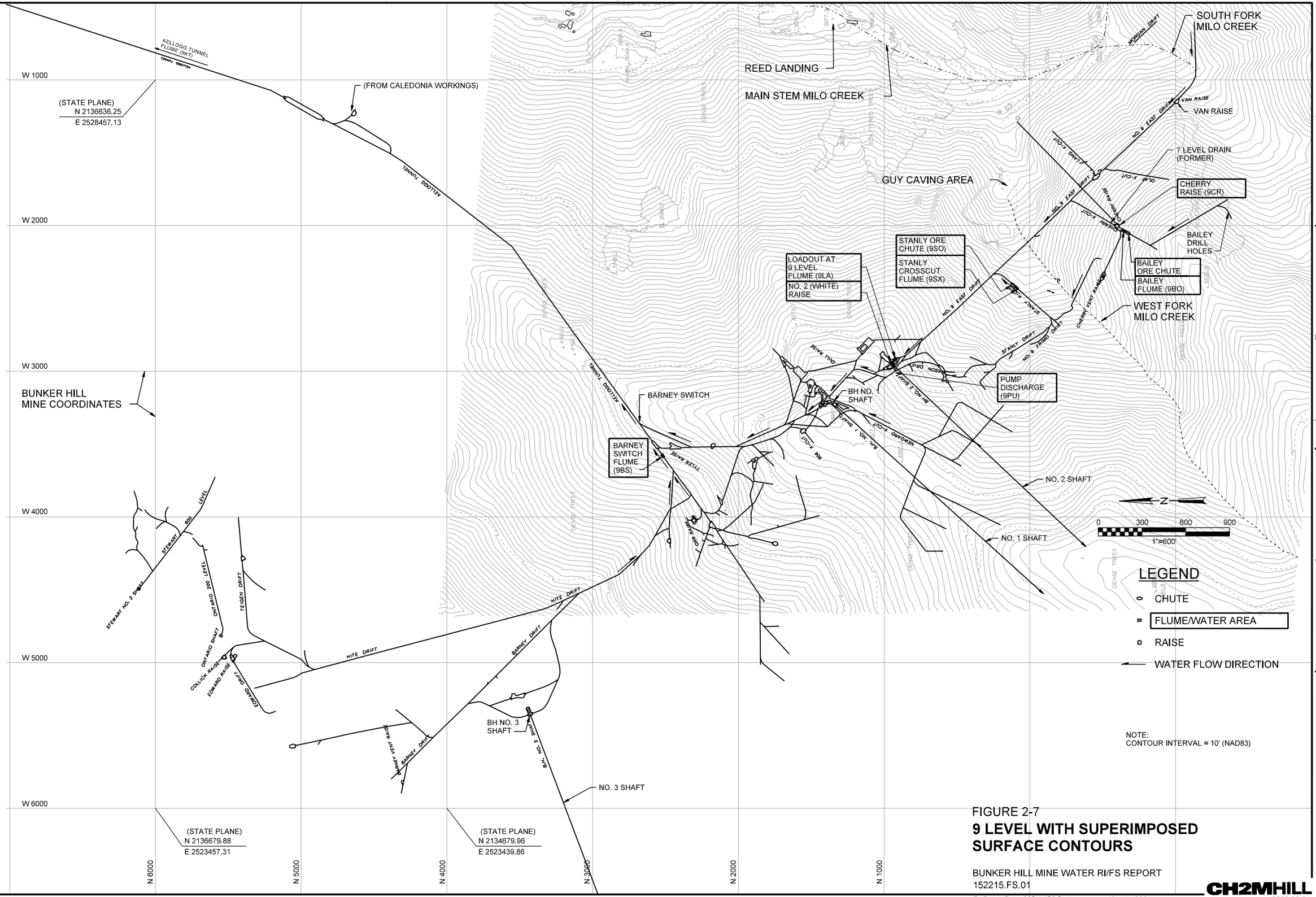

FIGURE 2-7

9 LEVEL WITH SUPERIMPOSED SURFACE CONTOURS

BUNKER HILL MINE WATER RI/FS REPORT
152215.FS.01

CH2MHILL

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m0:e01ls224.mst	1-63	
m0:gs9910002.mst	1-63	
m0:-b0ls1222.mst	1-63	
m0:-e02s2222.mst	1-63	
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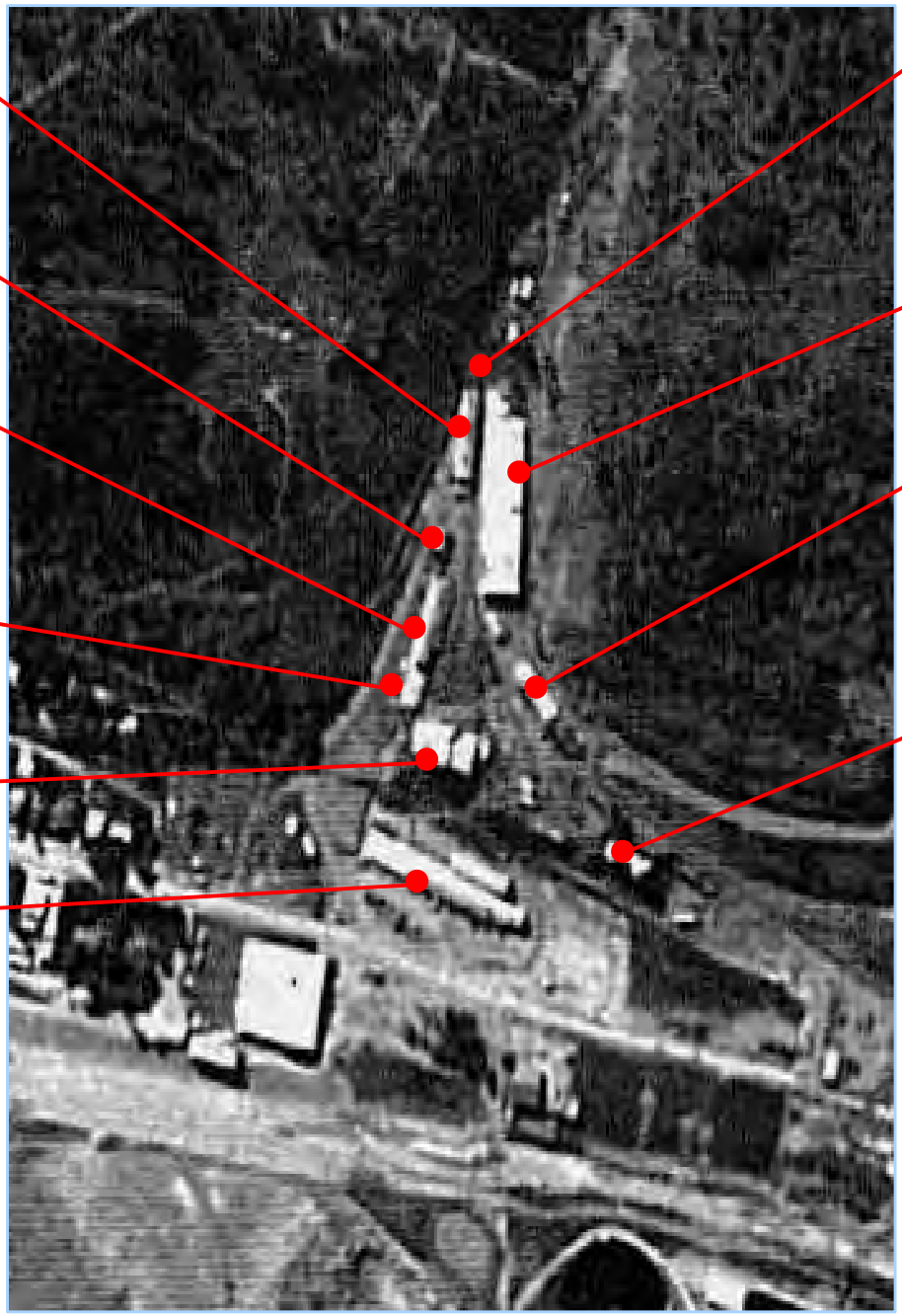

FIGURE 2-8
SURFACE FACILITIES
BUNKER HILL MINE WATER MANAGEMENT RI/FS

CH2MHILL

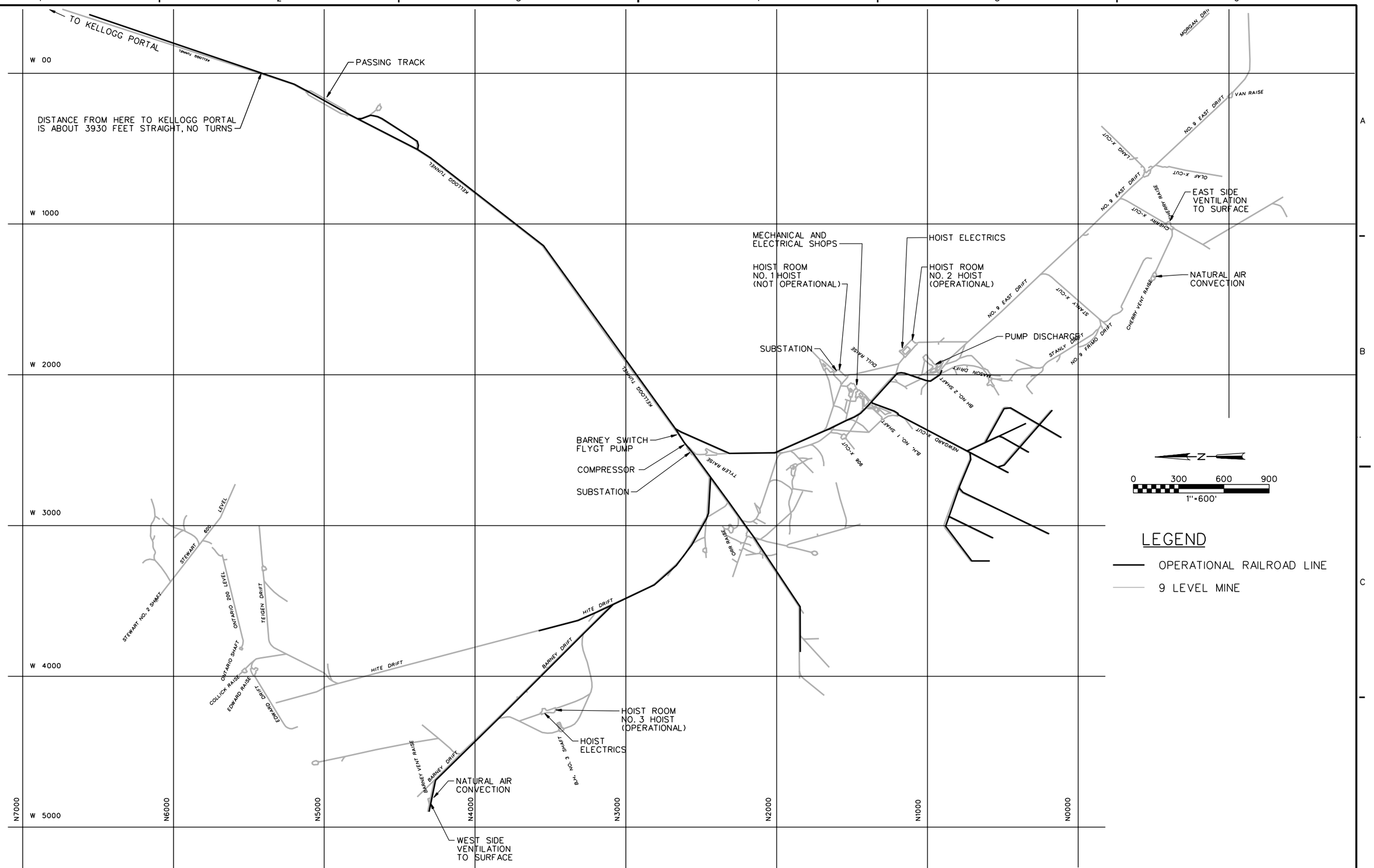

FIGURE 2-9
9 LEVEL INFRASTRUCTURE

BUNKER HILL MINE WATER RI/FS REPORT
152215.FS.01

CH2MHILL

FILE NAME: 10CXX101.DLV 10-JAN-2001

148562.02.01

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m10-e05d002c.mst	1=63	m10-e01d01219.mst	1=63
m10-p90m002p.mst	1, 3-6, 8-9, 11-14, 16-63	m10-e02d2219.mst	1=63
m10-p02d2210.mst	1=63		
m10-e05d00c.mst	1=63		

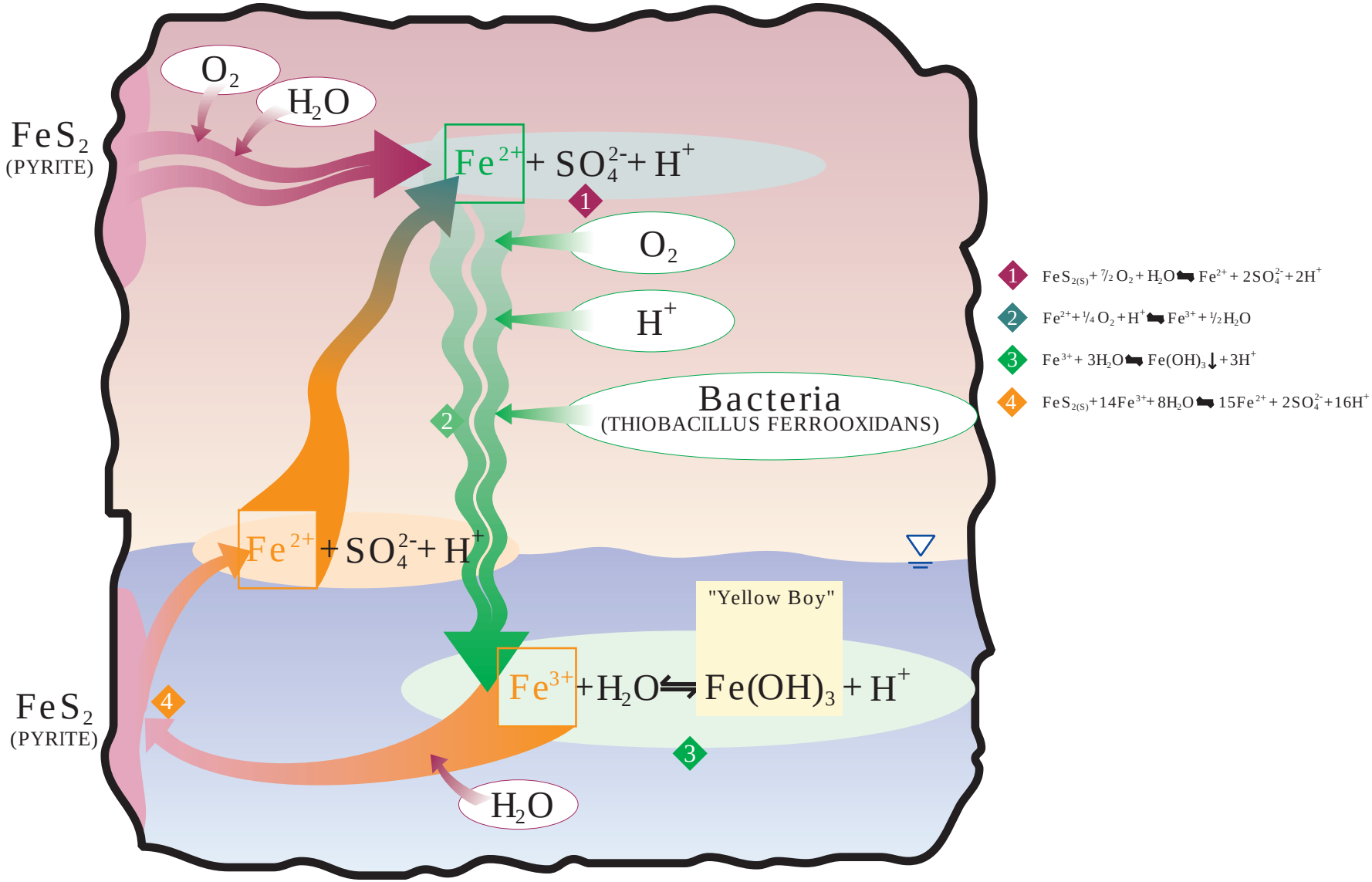

FIGURE 2-10
CHEMISTRY OF ACID PRODUCTION
BUNKER HILL MINE WATER MANAGEMENT RI/FS

CH2MHILL

5 Level: Looking upstream of the Williams Flume.

5 Level: New East Reed Drift

FIGURE 2-11
YELLOW BOY ACCUMULATION IN 5 LEVEL DRIFT
BUNKER HILL MINE WATER MANAGEMENT RI/FS

CH2MHILL

E122000003CVO 152215.FS.02 Bunker Hill *Fig 2-12.fh8 01/15/01 ams

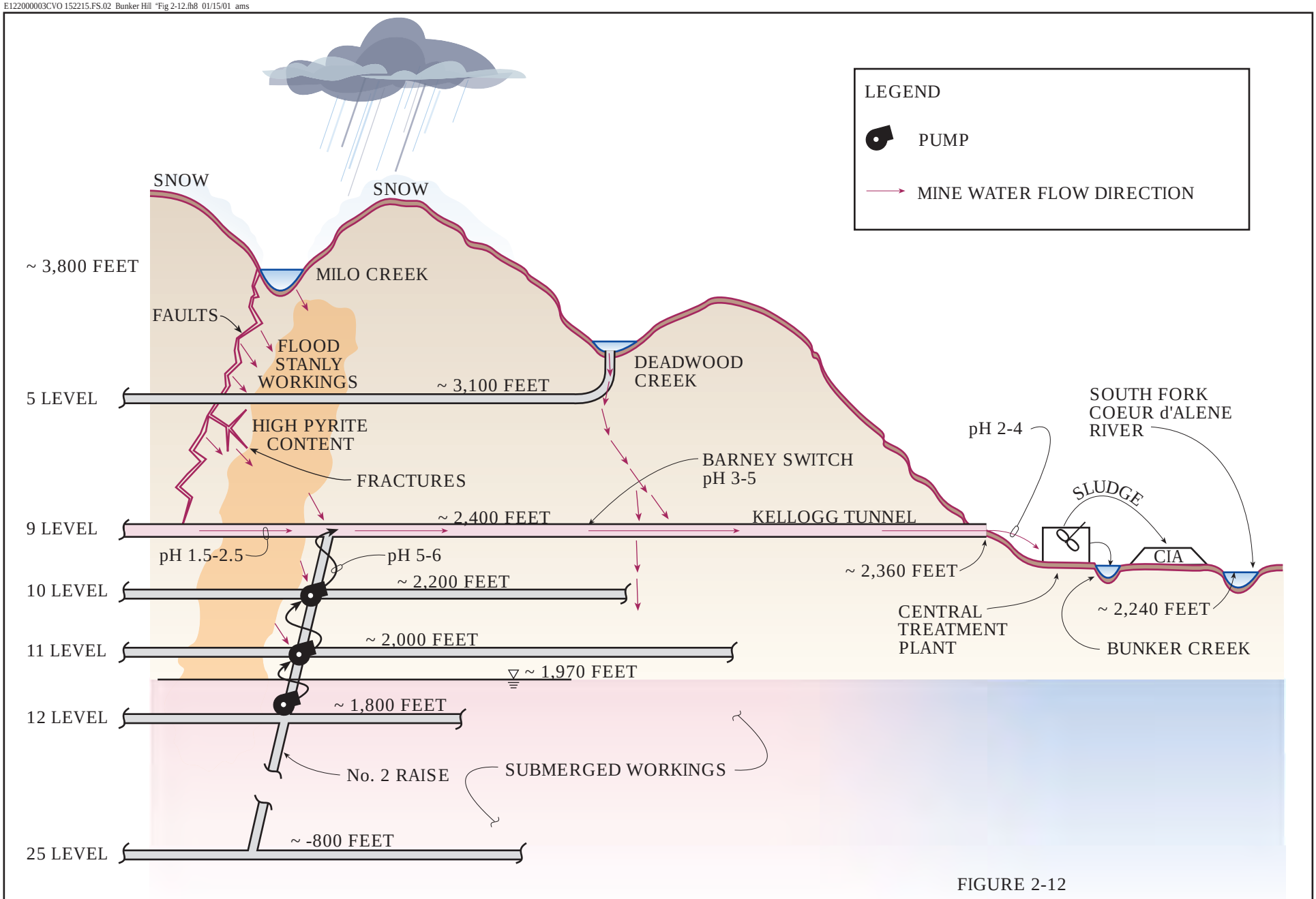

FIGURE 2-12
GENERAL FLOW MODEL
BUNKER HILL MINE WATER MANAGEMENT RI/FS

CH2MHILL

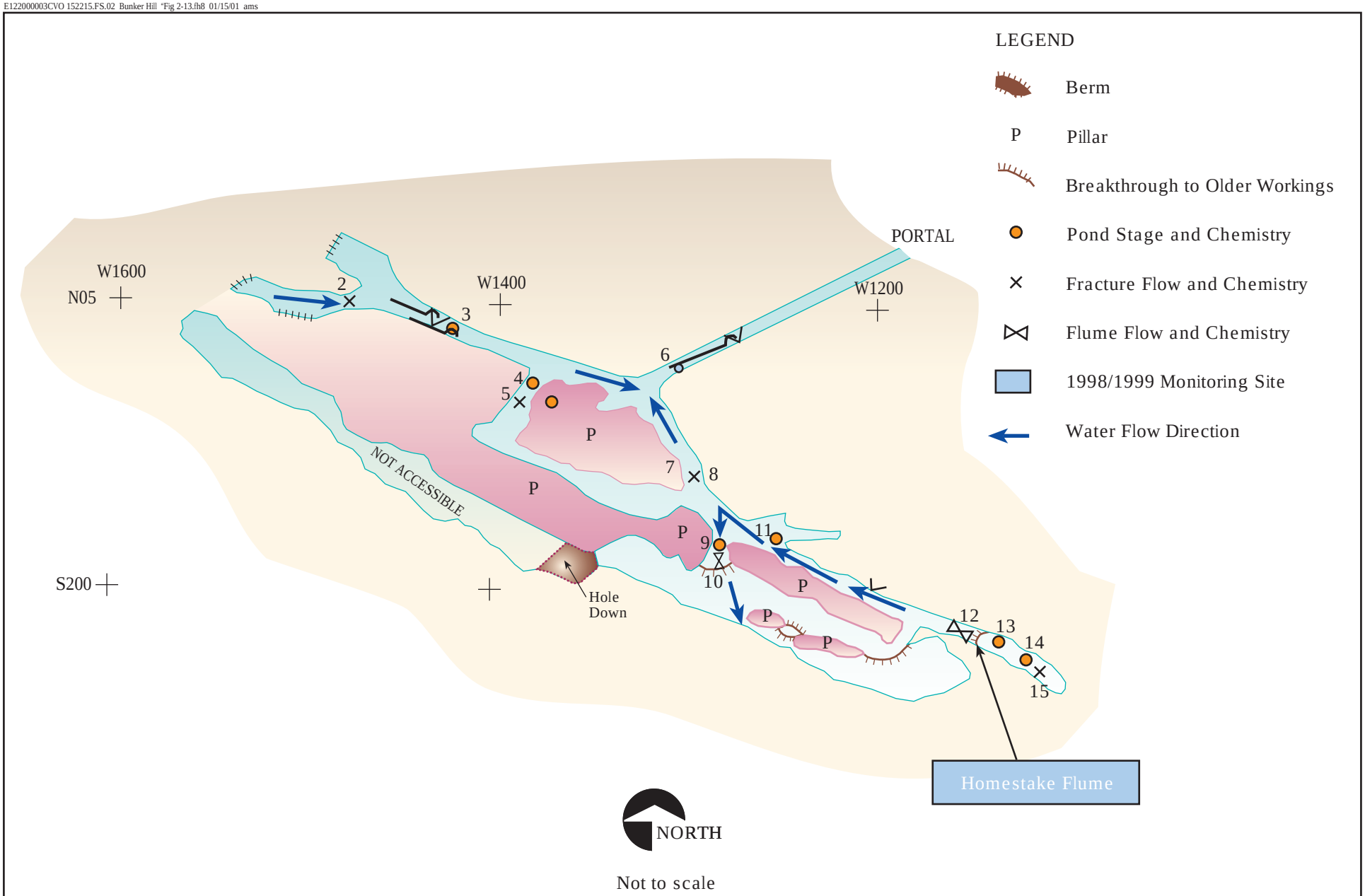

FIGURE 2-13
3 LEVEL MONITORING LOCATIONS
BUNKER HILL MINE WATER MANAGEMENT RI/FS

CH2MHILL

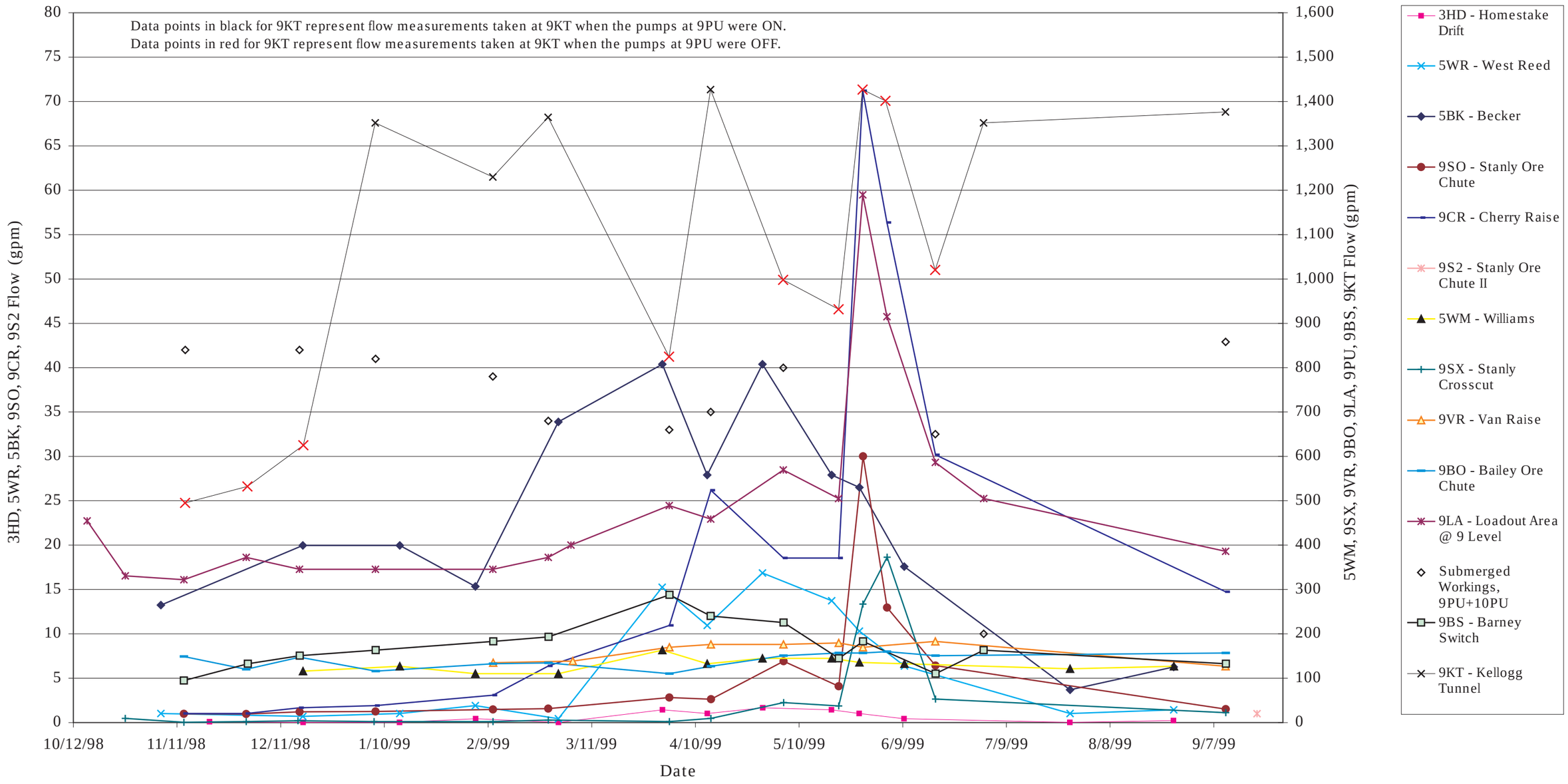

FIGURE 2-14
SUMMARY OF AMD FLOW DATA
BUNKER HILL MINE WATER MANAGEMENT RI/F

CH2MHILL

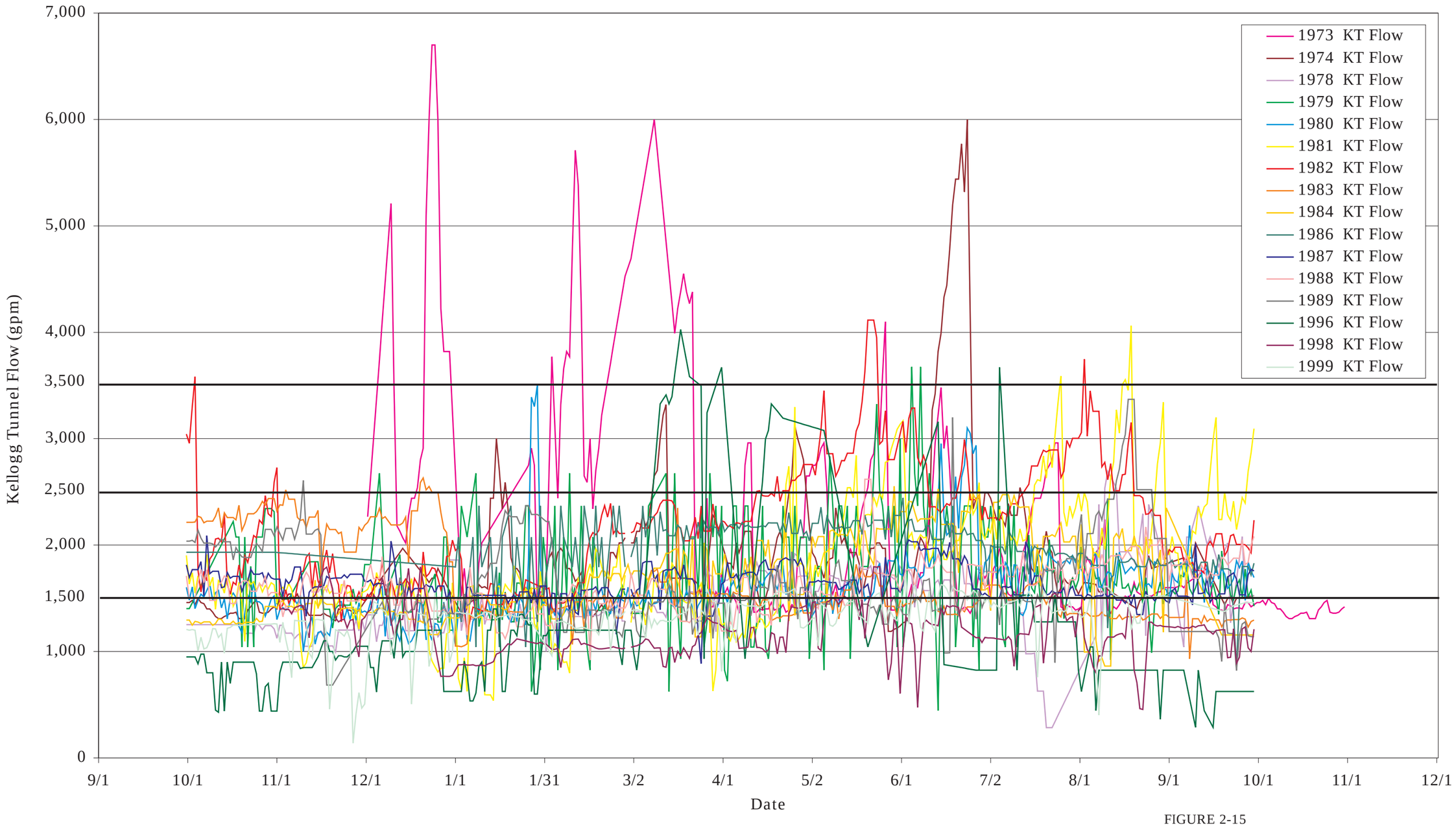

FIGURE 2-15
INTERPOLATED KELLOGG TUNNEL HYDROGRAPHS FOR ALL WATER YEARS
BUNKER HILL MINE WATER MANAGEMENT RI/F

CH2MHILL

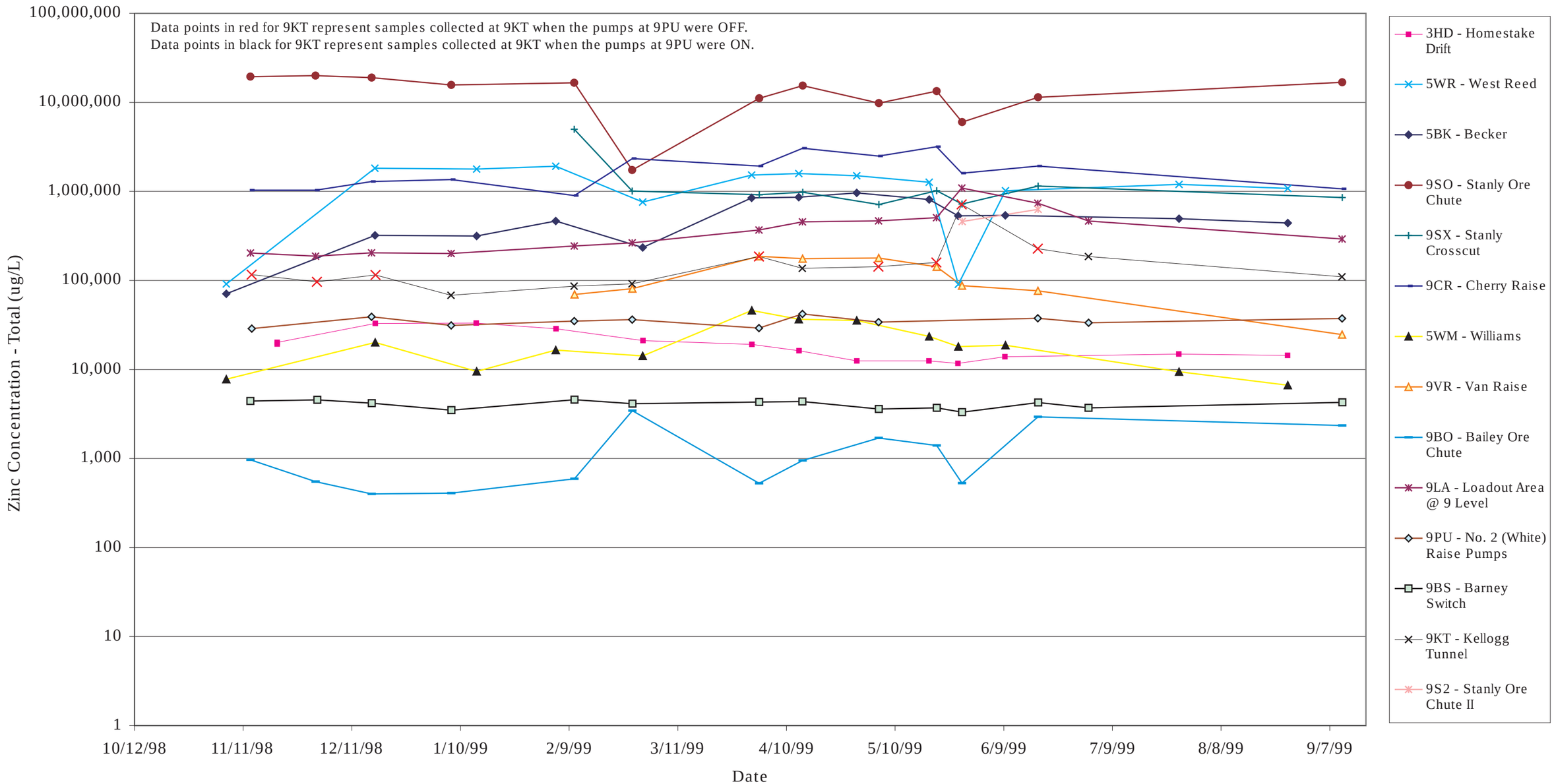

FIGURE 2-16
SUMMARY OF ANALYTICAL DATA FOR TOTAL ZINC
BUNKER HILL MINE WATER MANAGEMENT RI/F

CH2MHILL

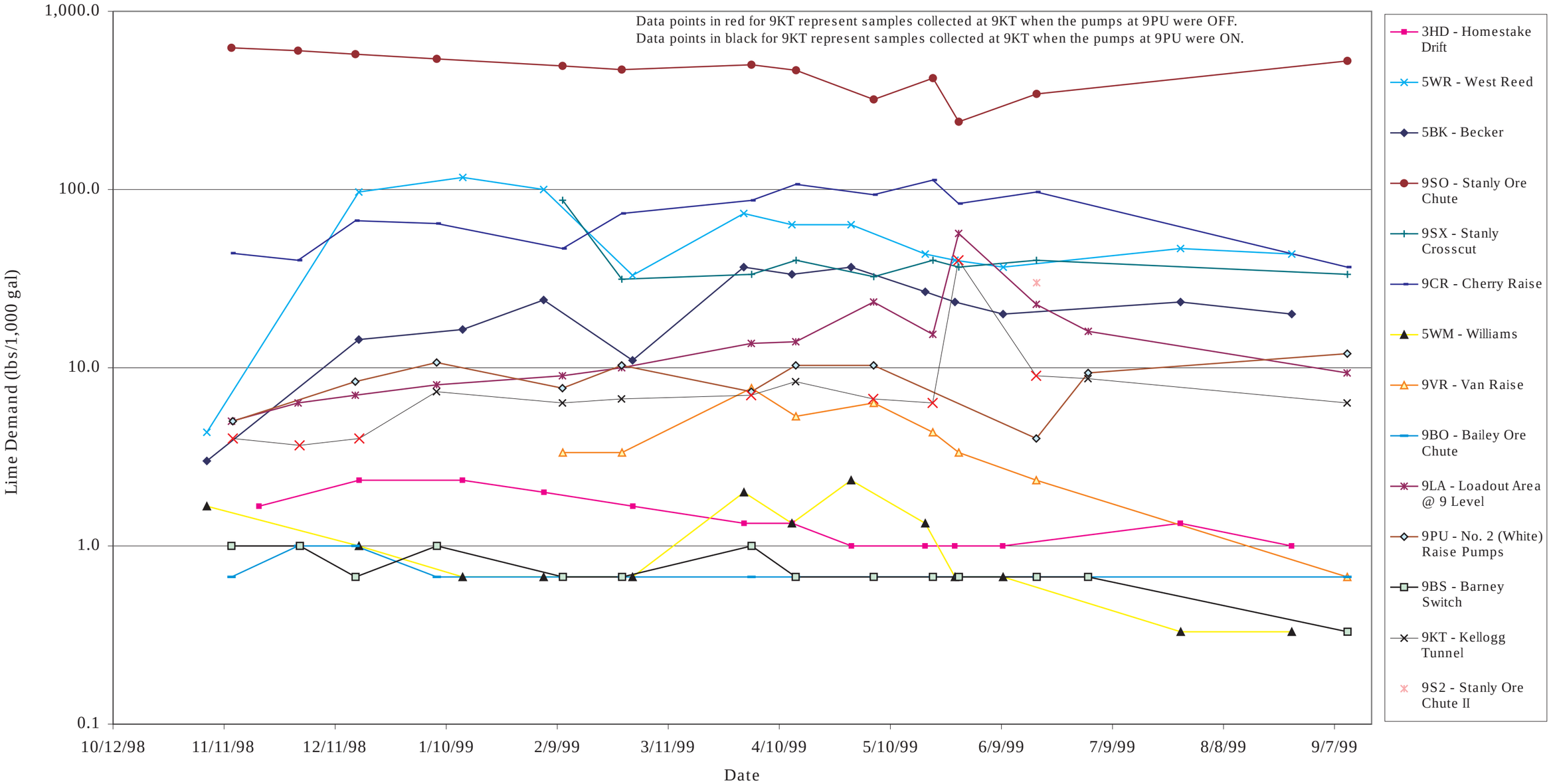

FIGURE 2-17
SUMMARY OF ANALYTICAL DATA FOR LIME DEMAND
BUNKER HILL MINE WATER MANAGEMENT RI/F

CH2MHILL

PHOTO: AUGUST 2000

NORTH
(Approximate)

FIGURE 2-18
MINE WATER - RELATED SURFACE FEATURES
BUNKER HILL MINE WATER MANAGEMENT RI/FS

CH2MHILL

SECTION 3.0

Identification and Screening of Technologies

3.0 Identification and Screening of Technologies

This section identifies and screens technologies that address mine water management at Bunker Hill. Technology screening has been conducted and presented in earlier documents. This section summarizes and references that screening, and identifies technologies used to develop the remedial alternatives discussed in Section 4.

3.1 Description of Remedial Components

Mine water management has been broken into these six general components:

- AMD Mitigations / Source Control
- AMD Collection
- AMD Conveyance
- AMD Storage
- AMD Treatment
- Sludge Management

Figure 3-1 provides a generalized schematic of the six components. The AMD mitigations / source control component pertains to actions that could reduce the volume or improve the quality of the mine water. AMD collection consists of the method used to collect water within the mine and transport it to the mine portal. AMD conveyance consists of transporting the AMD from the portal to a treatment facility. AMD storage addresses the requirement to place AMD in a temporary holding area during those periods when the discharge flow rate from the mine exceeds the capacity of the treatment plant or when the treatment plant is inoperative. AMD treatment consists of changing the chemical characteristics of the mine water such that it is suitable for discharge to Bunker Creek and the SFCdA River. Sludge management consists of dewatering and disposal of sludge generated during the treatment process.

Each component is linked to the other components. For instance, successful mitigation / source control measures will reduce the volume of poor-quality mine water or improve the quality of the water. Lower volumes will reduce the demands on the collection and conveyance system, and reduce the amount of storage needed. Better-quality water will reduce the treatment demands and generate less sludge. The relationships among the components will be evaluated in later sections of this report. The following subsections identify technologies that could be applied to each component, and include a screening to identify the preferred technology options identified for each component.

3.2 Mitigations and Source Control

Several methods to mitigate and / or control the source of the AMD have been discussed, developed, tested and, in some cases, implemented during the past 30 years. This section

provides a brief description of the steps used to identify and screen the mitigations so that the preferred mitigations could be carried forward into the feasibility study. Additional information may be found in the cited references.

3.2.1 Identification and Screening of Mitigations

CH2M HILL first reviewed and summarized potential mitigations during preparation of the presumptive remedy document (CH2M HILL, 1999d). The review included concepts developed during extensive research work done in the 1970s and 1980s by the University of Idaho, and concepts developed by a technical focus group including representatives from EPA, IDEQ, CH2M HILL, Terragraphics, the current mine owner, and other researchers. This included infiltration reduction options, mine flooding, air sealing and capping. All of these options, except infiltration reduction options, were screened from further consideration because of implementability and effectiveness problems. A summary of the mitigations evaluated and the screening rationale is as follows:

- **Surface Water Diversions**. These mitigations consisted of constructing diversions to intercept flow in the West Fork, South Fork, and mainstem of Milo Creek. Flow would be hard-piped around infiltration zones to a point downstream where the flow would discharge into the existing Milo Creek diversion system. These diversion options were considered implementable and effective and were retained for further evaluation. The West Fork and South Fork diversions were thought to have greater AMD mitigation potential compared to additional mainstem diversions.

- **In-Mine Water Diversions**. This technology approach consists of routing relatively clean water within the mine around known acid-producing areas such as the Flood-Stanly Ore Body. The workings are old and consist of numerous unmapped stopes, drill holes, and drifts that would require exploration to determine flow paths. Significant rehabilitation of the workings would be required to gain access to develop specific routing options for further evaluation, to estimate costs, and to determine effectiveness. This option was screened from further consideration because it was considered to have very high cost, difficult implementability, and unknown effectiveness.

- **Flooding the Mine**. This option consists of flooding the mine to reduce oxygen that is required in the chemical reaction for acid generation. This option was screened from further consideration because of high risk of uncontrolled leakage above 9 Level, it would severely limit or eliminate mining activities, and it would create a positive gradient of subsurface flow to the SFCdA River that could eventually contaminate groundwater or the river.

- **Air Seals**. This option consists of sealing adits, raises, and tunnels that are connected to the atmosphere such that oxygen would no longer be able to enter the underlying mine workings, thereby preventing the chemical formation of acid water. This option was screened from further consideration because it is not implementable given the magnitude of the underground workings and their connectivity to the surface.

- **Capping**. This mitigation consists of placing a low-permeability cap over areas of the mine to reduce infiltration. This technology would be very costly to implement over large areas because of the steep and densely forested terrain above the mine. However, it

could be applicable to smaller, selective areas such as over portions of the Flood-Stanly Ore Body. For this reason, capping over selective areas was retained for further evaluation.

Two of the mine water mitigations identified in the presumptive remedy document (South Fork of Milo Creek and West Fork of Milo Creek diversions) were carried forward into a cost/benefit analysis. The analysis estimated the cost of the mitigations and the savings in treatment that would be realized if the mitigations were implemented. The analysis demonstrated that the mitigations had potential to offset treatment costs, particularly if more costly technologies such as evaporation, ion exchange, or microfiltration were needed (CH2M HILL, 1999e). This finding led to the review of over 190 documents, papers, theses, maps, and reports in the project library with emphasis on 25 documents that focus on mine water issues (see Appendix A), and resulted in the identification of several other AMD infiltration reduction mitigation concepts. These were identified by the memorandum titled *Field Reconnaissance of Inflow/Recharge Mechanisms, AMD Generation Mitigations, Bunker Hill Mine Water Management Project* (CH2M HILL, 1999c), which included information obtained from an in-mine reconnaissance of the Flood-Stanly Ore Body (CH2M HILL, 1999b).

The additional mitigations identified during the field reconnaissance and in the presumptive remedy document were ranked during a stakeholder meeting, and summarized in the memorandum, *Ranking Summary of Next Step Mitigations* (CH2M HILL, 1999f). The ranking process considered several criteria, including effectiveness, implementability, and cost. The purpose of the ranking was to identify those mitigations that have a high potential to be successful. However, mitigations that were screened from further evaluation may be beneficial in the future, and should be reviewed after the higher-ranking mitigations are implemented and assessed in terms of actual effectiveness. A summary of the mitigations by basin area and the ranking results is as follows:

West Fork Milo Creek

- **West Fork Diversion**. As described above, a diversion structure or multiple structures would be installed in West Fork Milo Creek to collect flow in the creek. The structure(s) would be keyed into bedrock to intercept alluvial flows. The flows would be transferred into a pipeline that would route water down to the existing Milo Creek channelization system. This option was retained.

- **Surface Diversions above Guy Cave**. A road would be constructed above the caving area to intercept surface flows coming down the hillside to the Guy Cave or into fissures above the Guy Cave. A lined ditch on the inside of the road would be designed to carry flow along the road grade down to the mainstem channelization system, or to tie into the West Fork diversion pipeline or the diversion at the Phil Sheridan raises, if constructed. This option was retained.

- **Capping the Guy Cave.** The capping concept presented above was re-evaluated during the ranking process as two separate mitigations. The first mitigation consists of an engineered cap constructed to cover the flatter, accessible caving area (both upper and lower areas) to minimize the amount of precipitation and run-on entering the cave. Hillsides above the cave could be stabilized and graded to promote run-off. This option was screened from further evaluation due to limited effectiveness, and because the

majority of water entering the Guy Cave Area is believed to be infiltrating through cracks and fissures that are recharged above the caving area.

- **Capping fissure areas**. The second capping option includes capping fractures and fissure areas along West Fork Milo Creek between the potential diversion and the cave area by surface grouting or by extending the Guy Cave cap up to the diversion. This option was screened out because of its very difficult implementability given the steep terrain, and due to limited effectiveness because very little flow was estimated to be removed from the mine.

- **Open Phil Sheridan Raises**. Sediment and other materials that have collected in raises No. 1 and No. 2 would be removed to allow flow down to the Phil Sheridan drift where it would be routed around the Flood-Stanly Ore Body. Collection structures would be built to direct flow to the raises, and a pipeline from the Phil Sheridan portal down to Mainstem Milo Creek would be constructed to convey the collected water. The collection structures would be keyed into bedrock. The Phil Sheridan tunnel floor would be sealed to reduce leakage through fractures in the floor. Two variations of this mitigation were discussed; one constructed in conjunction with the West Fork Milo Creek diversion, and one without. The size of the collection structures and pipelines would be smaller if they were constructed in conjunction with the West Fork Milo Creek diversion. This option was retained for further consideration.

- **New Inclined Drill Holes**. Holes would be drilled from the Phil Sheridan Raise and other suitable locations to dewater subsurface areas that contribute to Guy Cave subsurface inflow. The drill holes would be sloped to drain to a collection point, and piped to Mainstem Milo Creek. Depending on contact with sulfides and the resulting chemistry, it is possible that the collected water may require treatment. This option was screened from further evaluation because of its limited effectiveness in reducing flow to the mine, and because of the possible need for water treatment.

- **Homestake/Utz Near-Surface Diversion**. Roads with lined ditches would be constructed above the near-surface portions of the Homestake and Utz Workings. The ditches would collect surface flows above the workings and route them down and around the near-surface workings to Milo Creek. This option was screened out because of its limited effectiveness for reducing flow into the mine

- **Cemented Backfill**. The Homestake and Utz Workings would be backfilled with sand/cement grout to remove acid-producing voids, reduce heat generation, and reduce flow to lower levels of the mine. This option was screened out because of its limited effectiveness for reducing flow into the mine.

- **Surface Capping**. The hillside above near-surface areas of the Homestake and Utz Workings would be capped to reduce the amount of water available to infiltrate into the workings. This option was screened out because of its limited effectiveness for reducing flow into the mine.

South Fork Milo Creek

- **South Fork Diversions**. A diversion structure or multiple diversion structures would be constructed in South Fork Milo Creek similar to the West Fork Milo Creek diversion

discussed above. The structure(s) would be keyed into bedrock, and water would be piped down to the Mainstem Milo Creek channelization system. This option was retained for further evaluation.

Mainstem Milo Creek

- **Improve Existing Diversion**. The existing upper diversion structure on Mainstem Milo Creek would be improved to reduce creek flow downstream of the structure. Two mitigation options were discussed: sealing and raising the weir, or increasing the capacity of the diversion and pipeline. The first option would include installation of a better seal along the bottom of the diversion structure and raising the weir to direct flow to the pipeline during larger storm events (the current weir is designed to accommodate a 2-year flow event). The second option includes increasing the size of the water intake in the diversion and the associated pipeline down to the second diversion structure to handle much larger flow events. Both these options were retained for further evaluation.

- **Upper Milo Diversion.** An additional diversion would be constructed above the existing upper diversion to divert flows from locations where the Cate Fault and Buckeye Fault are close to the mainstem. The water would be collected in a pipe and conveyed down to the upper diversion collection basin, or further downstream. This option was screened from further consideration because of the low potential for water quality and infiltration reduction improvements, and high cost.

- **Plug Small Hopes Drift.** Portions of the Small Hopes Workings that intercept flow from Mainstem Milo Creek would be plugged with a sand/cement grout or other suitable material. This would be done to eliminate the possibility of high stream flows eroding a direct flow path into the immediately underlying workings, and also to reduce infiltration. This option was retained.

- **Relocate Bunker Hill Dam.** The City of Wardner emergency water supply dam located downstream of the existing upper diversion on Mainstem Milo Creek would be removed or abandoned. Flow that is currently diverted from the upper diversion to the Bunker Hill Dam would be routed directly into the emergency supply pipeline. This option was retained.

Deadwood Creek

- **Plug/Bypass Inez Shaft**. The Inez Shaft would be located and dug out, and a concrete plug constructed to reduce the water infiltrating from Deadwood Creek, and to eliminate the possibility of high stream flows from eroding a direct flow path into the mine. Another option was discussed that would include sealing Deadwood Creek with grout in the vicinity of the Inez Shaft so that water coming down the creek bypasses the shaft. This option was retained.

Other Areas

- **Plug/Pipe Drill Holes**. Drill holes on the 7 Level (DDH #1208) and in the Russell Tunnel, East Reed Drift, Bailey Drift, Van Raise, and Cherry Vent would be sealed by installing packers in the drill holes. This option was retained.

- **Fault/Hillside Dewatering**. Drill holes would be installed to dewater the area within the cone of depression for the mine. The holes would be sloped to allow collection at a central location, and water would be piped to Mainstem Milo Creek. This option was screened from further consideration because of the low potential for water infiltration reduction and water quality improvements.

Additional in-mine mitigations were introduced during a subsequent stakeholder meeting and addressed in the memorandum titled *In-Mine AMD Mitigation Strategies* (CH2M HILL, 2000e). These were as follows:

- **In-Mine Treatment by Liming.** This consisted of transporting lime into the mine and adding it to the AMD, with the sludge piped into a shaft for disposal into the mine pool. This approach was screened out because it would be more costly and less effective than adding the lime at an external treatment plant, plus disposal of sludge in the mine pool could rapidly fill the shaft and prevent it from being used for mining purposes.
- **Diversion of 9BS and 9BO Flows into the Mine Pool.** This consisted of collecting the relatively weaker mine waters within the mine and injecting them into the mine pool, with the goal that the mine pool would gradually become cleaner. This approach was screened out because it would increase the cost to pump and treat the mine pool. The pool would only be diluted, would still require treatment, and the treatment cost would not be reduced.
- **Diversion of Poor-Quality Water That Recharges the Mine Pool.** This consisted of collecting the relatively strong mine waters within the mine and separately piping them out to the surface with the goal that the mine pool would gradually become cleaner. This approach was screened out because it is very unlikely that all the sources could be identified because most the Flood-Stanly Ore Body workings are inaccessible. Even if this were possible, the mine pool would still need to be pumped and treated.
- **Collection of Poor-Quality Water and Discharge Below 14 Level.** This consisted of collecting the relatively strong mine waters within the mine and piping them to below the 14 Level in one of the mine shafts. The goal would be to use the potential anaerobic-reducing conditions to precipitate the metals as sulfides. This approach was screened out because there is potential to fairly rapidly fill the shaft with muck/sludge and prevent it from being used for mining purposes, as described in the technical memorandum titled *Bunker Hill In-Mine AMD Mitigation Strategy—Collection of Poor Quality Water and Discharge Below 14 Level* (CH2M HILL, 2000f).

3.2.2 Descriptions of Remaining Mitigations

Ten mitigations remained after the screening process described above. Conceptual designs and order-of-magnitude cost estimates were prepared for each. These remaining mitigations are described below. More detailed descriptions and a plan view showing the location of the mitigation options in Milo Gulch are included in Appendix C.

- **West Fork Diversion** – The purpose of this diversion is to reduce infiltration into the Guy Cave Area and the underlying Flood-Stanly Ore Body. A diversion structure or multiple structures would be installed in West Fork Milo Creek to collect flow in the creek. The structure(s) would be keyed into bedrock to maximize the interception of

stream flows. The flows would be transferred into a pipeline via a grated inlet structure and perforated pipe drain buried in the upstream channel that would route water down to the Reed Landing area within the existing Milo Creek channelization system. The structure and pipeline would be designed to accommodate the 100-year, 24-hour rainfall with snowmelt event [57 cubic feet per second (cfs)], based on the Milo Gulch Hydrologic Analysis presented as Attachment A to the technical memorandum in Appendix C.

- **Rehabilitate Phil Sheridan Raises** – This proposed action would reduce infiltration through the Guy Cave Area and the underlying Flood-Stanly Ore Body. This action would also provide a backup to the West Fork Diversion, and would collect flows from portions of the west side of the basin, which are outside the capture zone of the West Fork Diversion. Sediment and other materials that have collected in Raises No. 1 and No. 2 would be removed to allow surface water and alluvial groundwater flows that reach the raises to flow down to the Phil Sheridan adit. Surface collection structures would be rehabilitated to help direct flow to raises No. 1 and No. 2. A new portal and drift would be constructed to route the collected water into the pipeline proposed for the West Fork Diversion. The hydraulic design capacity would be the 100-year, 24-hour rainfall with snowmelt event (21 cfs).

- **Upgrade Phil Sheridan Diversion** – In addition to the rehabilitation efforts at the raises and the new portal and drift described above, the ground adjacent to Raise No. 2 would be modified to collect more groundwater. The modification would consist of a grout curtain or similar barrier. No provision for cutoff to bedrock is currently considered for Raise No. 1, unless it is found that there is significant groundwater flow past the raise. The primary purpose of Raise No. 1 is to intercept surface runoff from the area outside the capture zone of the West Fork Diversion during high runoff events.

- **Sidehill Diversion -** A road would be constructed above the Guy Cave Area to intercept surface water flowing down the hillside to the caves or into fissures above the caves. A lined ditch on the inside of the road would be designed to carry flow along the road and discharge to the diversion at Phil Sheridan Raise No. 1. The road adjacent to the ditch would be used for ditch maintenance. A turnaround would be located at the far (northern) end of the road for maintenance vehicles. The Sidehill Diversion would complement the West Fork Diversion and the Phil Sheridan Raise system, and would also be designed for the 100-year, 24-hour rainfall with snowmelt event (19 cfs).

- **South Fork Diversion** – The South Fork Diversion would be similar in design to the proposed West Fork Diversion. A cutoff wall would be constructed to divert South Fork Milo Creek above the Buckeye Fault zone (in the portion of the creek that is perennial). The diverted flow would be piped downstream for discharge to the Reed Landing water collection structure. The diversion structure and pipeline would be designed to handle the 10-year, 24-hour rainfall with snowmelt event (76 cfs).

- **Plug Small Hopes Drift** – Portions of the Small Hopes Workings that lie near the surface below Mainstem Milo Creek would be plugged with a sand/cement grout or other suitable material. A vertical shaft would be installed adjacent to the Mainstem Milo Creek channel, and bulkheads would be placed within the drift below the creek bottom to isolate the backfill zone from other areas of the workings. A sand/cement backfill

would be used to fill the isolated drift area. The primary purpose of this mitigation would be to prevent large creek flows from eroding a direct flow path into the mine.

- **Bypass Bunker Hill Dam** – The Bunker Hill Dam impounds water for diversion into an emergency drinking water supply pipeline for the City of Wardner. Water from the reservoir behind the dam may infiltrate into the underlying mine workings. The outlet gate would be opened and a grizzly screen placed in front of the gate. The dam and screen would help collect stream bedload to reduce the load on the downstream hydraulic structures at the Reed Landing. The City of Wardner emergency water supply would be hard-piped around the dam. This would eliminate the existing pool of water behind the dam.
- **Improve Existing Diversion** – There are two variations for this option. The objective of each would be to reduce the amount of water that overflows or leaks under the upper diversion structure on Milo Creek because the stream reach below may infiltrate water into the underlying mine workings. First, the existing upper diversion structure on Mainstem Milo Creek would be improved to reduce flow observed in the main stem below the structure. Improvements would include installing a better seal along the bottom of the diversion structure, raising the weir to direct more flow to the pipeline (the current weir is designed to handle a 2-year flow event), and improving the screen intake to reduce clogging for the intake pipe. In the second variation of this option, the capacity of the water intake of the diversion structure and the associated pipeline down to the second diversion structure (at the Reed Landing) would be increased to handle the 10-year, 24-hour rainfall with snowmelt event (172 cfs).
- **Plug/Bypass Inez Shaft** – For this option, the Inez Shaft would be located and excavated to bedrock, and a plug would be constructed using concrete to reduce the water infiltrating from Deadwood Creek. The primary purpose of this mitigation is to prevent large creek flows from eroding a direct flow path into the mine.
- **Plug Drillholes** –This option would plug drillholes on the 7 Level (DDH No. 1208) and in the Russell Tunnel, East Reed Drift, Bailey Drift, Van Raise, and Cherry Vent. The drillholes would be sealed by installing packers or other plugs. The purpose of this mitigation would be to reduce groundwater discharge from the underground drillholes into the mine.

Table 3-1 summarizes the mitigation options that were evaluated further by drainage basin.

3.2.3 Mitigation Effectiveness

Several criteria were used to screen the mitigation and source control measures, leaving the mitigations described above. One of those criteria was the effectiveness of the mitigations. Mitigation effectiveness is defined as either reducing the volume of water flowing through the mine, or improving the water quality. Mitigation effectiveness is closely linked with the other remedy components. For instance, if a mitigation can reduce the volume of water coming out of the mine, then the size of the treatment plant can be smaller as well. If a mitigation improves the quality of the mine water, less treatment is required, which reduces treatment costs and sludge management costs.

IDEQ, CH2M HILL, and previous University of Idaho researchers evaluated the water inflow reductions associated with mitigations considered in this study and documented them in the technical memorandum *Field Reconnaissance of Inflow/Recharge Mechanisms, AMD Generation Mitigations, Bunker Hill Mine Water Management Project* (CH2M HILL, 1999c). Table 3-2 summarizes the estimated reductions in flow and improvements to water quality developed by the analyses. These estimates are imprecise and in some cases constitute the best guesses of the expected reduction of inflow to the mine. In general, the analyses indicate that the proposed mitigations will be more effective at reducing peak mine flows than base flows. This is further discussed in Section 4.

It is difficult to estimate the effect of the proposed mitigations on mine water quality because the relationship between reductions in hydraulic load and acid or metal load is not well understood. Because of this uncertainty, a technical focus group, which included AMD experts from CH2M HILL, the U.S. Geological Survey (USGS), and former University of Idaho researchers, evaluated the potential effects of the proposed mitigation components on the discharge of AMD at the site. The focus group concluded that mitigation options that reduce hydraulic load are likely to reduce the lime or treatment demand and associated sludge production at the treatment plant. The reduction of lime demand and sludge production is expected to be greater for mitigations that reduce water inflow to acid-producing areas of the mine, with those reducing flow through the Flood-Stanly Ore Body being the most effective. The technical memorandum prepared by the focus group is included in Appendix B.

3.3 Mine Water Collection

Two options were considered for the collection of AMD within the mine. The first option was to continue with the current method of collection. Mine water flows by gravity from near-surface workings to the 9 Level ditch and out the Kellogg Tunnel portal. A portion of flow from the upper workings may bypass 9 Level and flow to the submerged workings where it is collected along with groundwater inflow. This requires pumping to the 9 Level ditch to maintain a steady water elevation in the mine. A second option was evaluated that included diverting all upper country flows to the submerged workings, and pumping the submerged workings from wells or a shaft installed from the Deadwood side of the mine to a new pipeline that flows to the treatment plant.

Both collection methods require that the mine infrastructure be maintained to allow access to the collection system for maintenance and periodic cleaning. In particular, the Kellogg Tunnel, the 9 Level East Drift , and the 9 Level workings on the west side of the mine must remain open and accessible into the future for mine water collection. Typical maintenance activities required for mine water control are associated with the surface facilities, rail system, hoisting facilities, electrical system, ventilation system, shafts, and drifts, as discussed in Section 2.2.3. If these maintenance activities are neglected, access to the underground workings and control of the mine water will be severely affected or made impossible.

Both options are described in more detail in the presumptive remedy document (CH2M HILL, 1999d). The second option was screened from further consideration in the

presumptive remedy document because of the number of uncertainties associated with the diversion and pumping scheme, and the potential for greater costs and higher risk of failure.

Therefore, the existing collection procedures are carried forward into alternative development. A detailed description of the currently known in-mine water flow paths is presented in the report titled *Acid Mine Drainage – Bunker Hill Mine Water Conceptual Model* (CH2M HILL, 1999a) and summarized in Section 2 of this report.

3.4 Mine Water Conveyance

This component includes the conveyance of mine water from the Kellogg Tunnel portal to the treatment plant. During the spring of 1999, the AMD pipeline experienced a large decrease in capacity, and failed to convey all the mine water. This may have been caused by a buildup of muck inside the pipe that choked the flow. The capacity was reduced to about 1,400 to 1,500 gpm. The pipeline was replaced as part of an emergency action to maintain the flow of mine water to the lined pond. Figure 3-2 presents a plan view of the newly installed pipeline. A new concrete channel and flow measurement flume was installed outside the portal. A new buried 20-inch HDPE pipeline was installed from the concrete channel to the lined pond, which has 7 million gallons of storage capacity. The new concrete channel and pipeline have a capacity of about 7,000 gpm. An overflow manhole in the mine yard allows the mine water to be diverted out of the new pipeline into the old pipeline, as long as the flow is less than the capacity of the old line. This allows the new pipeline to be periodically inspected and cleaned.

From the lined pond, the mine water is pumped to the CTP using an existing pump station. A tee, which is currently closed by a blind flange, was placed in the new pipeline for a future connection directly to the CTP. Having the mine water flow directly to the CTP and bypassing the lined pond will reduce the accumulation of mine muck in the pond and will maintain more of its capacity for mine water. This will also reduce cleaning costs and costs associated with the pump station.

With the installation of the new concrete channel and pipeline, additional mine water conveyance options do not need to be considered. As part of the remedial alternatives developed in Section 4, the new pipeline will be used to convey mine water to the lined pond, and a new pipeline will be installed from the blind-flanged tee section to the CTP.

3.5 Mine Water Storage

AMD storage is required during those infrequent periods when the conveyance or treatment systems are inoperative, or when the Kellogg Tunnel portal discharge flow rate is higher than the treatment plant capacity. Three options for AMD storage were evaluated in the presumptive remedy document (CH2M HILL, 1999d): in-mine storage, storage in surface impoundments 16 million gallons and larger, and use of the existing lined pond. Surface impoundment storage was screened out, based on a cost comparison to in-mine storage and the limited availability of onsite land. The evaluation considered only the storage capacity necessary for CTP shutdown during maintenance and emergency situations.

Since that initial evaluation, an analysis of the effect that TMDL implementation in the SFCdA River will have on the long-term remedy was conducted and is described in Section 4. The analysis indicated that storage is not expected to be needed for achievement of the TMDL, but will be needed to temporarily store mine water flows in excess of the treatment capacity or when the plant is shut down for maintenance or repairs.

The existing lined pond has 7 million gallons of storage capacity if it were cleaned out. The existing capacity is estimated at about 5 million gallons because of accumulation of sediment and muck from the mine water. The current rate of muck accumulation is unknown. The average rate of accumulation since the lined pond was placed into continuous service (about May 1996) is about 450,000 gallons/year. A comparison of Kellogg Tunnel discharge total suspended solids (TSS) to CTP influent TSS data shows that about 100 mg/L of TSS accumulates in the lined pond for every liter of mine water placed in the pond. This is a serious problem that unless corrected will result in the lined pond being full of sediment and muck and unusable for mine water. A routine operating strategy of transporting flow directly to the treatment plant, rather than into the lined pond, would allow the sediment and muck to be continuously removed with the treatment sludge rather than accumulating in the lined pond. This could require the prior removal of material not compatible with CTP operations. The existing lined pond will be used for future storage needs and will be included in each of the alternatives.

The 7-million-gallon lined pond may not have sufficient storage capacity for extended treatment plant shutdowns or if the Kellogg Tunnel flows are significantly higher than treatment capacity. At a typical flow rate of about 1,500 gpm, the lined pond would provide 3.2 days of storage assuming it was cleaned out and empty to begin with.

Additional storage is available in the mine either above the existing mine pool or below, if the pool elevation was lowered by pumping. The elevation of the mine pool is currently kept at about 30 feet below the 11 Level at Raise No. 2, which contains the pumps and pipe column used to maintain the pool elevation. The average pumping rate is about 700 gpm. About 20 million gallons of storage is available from the current water elevation up to the floor of 11 Level. The mine currently uses this storage when Kellogg Tunnel flow reduction is needed by stopping the dewatering pumps and allowing the water level to rise. It takes about 2-½ hours from the time the pumps are shut off for the flow to decrease at the Kellogg Tunnel portal because of the time the approximately 10,000-foot-long Kellogg Tunnel takes to drain.

Additional in-mine storage is available for contingency or emergency use within the 11 Level drift and workings between 11 and 10 Levels. The estimated storage capacity between the floor of the 11 Level drift and the floor of the 10 Level drift is 190 million gallons (CH2M HILL, 1999d). The total storage available from 30 feet below 11 Level to the floor of 10 Level is approximately 210 million gallons. At a typical flow rate of 1,500 gpm, it would take more than three months to fill 210 million gallons of storage. This duration is sufficient to accommodate most foreseeable repair and maintenance activities and high peak flow events.

CH2M HILL reviewed the potential for AMD in the mine water pool to flow to the SFCdA River and reported the findings in the technical memorandum titled *Analysis of Bunker Hill Mine Pool and South Fork Coeur d'Alene River Hydraulic Relationships and Estimation of*

Groundwater Travel Times (CH2M HILL, 1999g). The analysis concluded that mine water elevations could increase up to the 10 Level floor elevation (2,224 feet) with no net flux of mine pool water to the river.

Lowering the mine pool elevation could create additional in-mine storage, although it is very unlikely that more than 210 million gallons of storage would be needed. This additional storage would be more costly than storage above 11 Level because of the increased pumping height. The increased height would require more expensive pumps, more piping, and would consume more power. For these reasons, storage above the existing mine pool elevation of 30 feet below 11 Level is preferred and will be included in alternatives that require additional in-mine storage.

A system is needed to divert the mine water into the pool. Two methods were evaluated to accomplish the diversion. The first method is the pump system currently in place. Pumps are used to pump the water from the 9 Level drainage ditches into a pipeline installed in Raise No. 1. One pump system is installed in the 9 Level ditch downstream of Raise No. 2 (about 800 gpm capacity) and another in the Barney Drift upstream of the Barney Switch (about 250 gpm capacity) (Personal Communication, 2000). By using these pumps to divert flow into the mine pool, and by turning off the extraction pumps, a total of about 1,750 gpm can be held in the mine. The drawback of the existing system is that it would require pumps and electrical power; also, it may not have the capacity to divert high flows. With no backup power source for the mine, a power outage would make the pump diversion system inoperative.

The second diversion method is a gravity diversion system. Gates could be used to divert the ditch flows into the mine pool. One diversion would be needed for the east-side water, and one for the west-side water. East-side water would be diverted down a pipe installed in the No. 2 Raise. West-side water would be diverted down a pipe installed in a newly constructed raise, of through the existing Barney Vent Raise. The gravity system could operate manually if needed, and could be sized for high flows. Such a system could also be configured using overflow weirs to allow passive diversion of flows in excess of the treatment plant's capacity. A conceptual design for a gravity diversion system is described in Appendix D.

Upgrades to the existing mine pool dewatering system are needed to pump diverted water back up from storage in a timely manner. The existing 700-gpm system has insufficient capacity to pump both the steady-state water and the diverted water. The existing system uses a submersible pump hung in the mine pool. The submersible unit pumps water to a centrifugal booster pump mounted in No. 2 Shaft above the 11 Level drift, which then boosts the water into a third pump on the 10 Level, which in turns boosts the water into the 9 Level ditch. Storing water above 11 Level would require the submersible and booster pump with associated electrical gear to be removed prior to flooding; otherwise, they would be damaged. The submersible pump is rated to about 40 feet of submergence. The booster pump is not sealed for submersion.

The technical memorandum included in Appendix D describes an alternate mine pool pumping system that uses two 700-gpm submersible vertical turbine pumps. Two pumps would provide the capacity needed to pump both the steady-state and the diverted water. Two pumps would also provide an installed spare for the steady-state pumping if one

pump required maintenance. These pumps could be installed below 11 Level and could pump the water directly to 9 Level without additional booster pumps. This would allow the water levels to fluctuate higher in the shaft because these pumps are rated for greater submergence pressure. The current electrical system in the mine would be upgraded to support pump operation. In summary, the following three storage options are carried forward into alternative development:

1. Existing 7-million-gallon-capacity lined pond.
2. Existing in-mine storage system that uses pumps to transfer up to 1,050 gpm into the mine pool, and the existing 700 gpm extraction pump system.
3. New gravity diversion system and new extraction system using two 700-gpm submersible pumps.

Implementation of in-mine storage as discussed in this document will require close coordination with the mine owner. The storage system should be developed to meet the needs of both ongoing mine operations and mine water control.

3.6 Mine Water Treatment

All mine water from the Kellogg Tunnel is treated in the CTP, which was initially placed into service in 1974 and has not been changed significantly since that time. The CTP uses lime neutralization to remove the acidity and to precipitate the metals, which are removed by gravity settling, forming a sludge. Significant CTP updates and improvements are needed for the following reasons:

1. **The plant is incapable of achieving the TMDL and all State of Idaho discharge requirements.** Process changes and additional equipment are needed to produce effluent that achieves the load-based discharge limitation established in the TMDL, and State of Idaho water quality standards.
2. **The plant produces a large amount of sludge that is costly to manage**. The treatment process needs to be altered to produce less sludge.
3. **The plant needs reliability improvements.** Much of the equipment and process controls are severely worn or no longer function. Equipment upgrades and replacement are needed to improve treatment flexibility and reliability.
4. **The plant operates inefficiently.** Most of the automated processes no longer function, necessitating manual operation and intervention that increase costs.

The required updates and improvements are fairly extensive and are summarized in the following sections. Appendix E describes the current condition of the CTP and required changes in more detail.

3.6.1 Changes Required to Achieve TMDLs and Water Quality Standards

Several technologies were considered to treat the mine water to levels established in the TMDL and State of Idaho water quality standards. A preliminary technology screening was conducted in the presumptive remedy document (CH2M HILL, 1999d). The screening

process identified 11 options, ranging from upgrading the existing plant to using evaporation and crystallization technology to make deionized water.

Three technologies were selected for treatability testing because of their potential to produce effluent with low metal concentrations at the lowest cost. These three technologies, which would be added to the existing CTP, were iron co-precipitation, sulfide precipitation, and sulfide functional ion exchange.

The treatability testing was conducted in two phases. Phase 1 consisted of a proof-of-principle test conducted at laboratory scale using jar tests, and testing of the existing CTP effluent for dissolved metals. The purpose of Phase 1 was to determine the potential for each of the technologies to meet the TMDL treatment goals using Bunker Hill Mine water. The results showed that all three technologies worked relatively well in decreasing the amount of dissolved metals in the mine water, but sulfide precipitation was preferred over the other two. Sulfide functional ion exchange was eliminated because it would be significantly more costly, and iron co-precipitation was eliminated because it required a higher operational pH (more lime) and produced a less settleable sludge. The testing also indicated that with filtration, lime addition alone (no sulfide addition) at a pH of about 9 to 10 might sufficiently remove dissolved metals. The results of the Phase 1 treatability testing are summarized in the *Phase 1 Testing Results* report (CH2M HILL, 2000g).

Phase 2 testing was conducted at the CTP to assess the addition of sulfide precipitation and filters. Sulfide addition was tested by adding sodium sulfide into the effluent of the neutralization/aeration basin prior to the thickener. Filters were tested by diverting a portion of the thickener overflow through different types of filters. The CTP operational pH was set at 9.5 during the testing. Two types of media filters and two types of micro-filters were tested. The media filters were a mono-media consisting of plastic-coated glass beads, and a tri-media filter consisting of anthracite, garnet, and sand. The micro-filters were a polymeric membrane and a ceramic membrane. The test results are described in detail in the *Phase 2 Testing Results* report (CH2M HILL, 2000h).

The Phase 2 test results showed that all the filters were successful at reducing the suspended solids and total metals concentrations of the effluent below target goals calculated from TMDL loadings, and that sulfide addition was not needed. The tri-media filters were found to be the preferred filter type. The media is widely available from many sources, and this type of filter is commonly used in many water and wastewater applications. Use of the plastic-coated glass bead mono-media would require periodic regeneration to replace the coating, and this type of media is less widely available. The micro-filters were prone to rapid plugging, which would require considerable cleaning and maintenance.

Based on the treatability testing, the anticipated typical CTP effluent concentrations of cadmium, lead, and zinc are shown below. These assume an operational pH of 9.5 and use of tri-media filters.

Anticipated CTP Effluent Concentrations

- Cadmium = <0.7 µg/L
- Lead = <1.0 µg/L
- Zinc = <70 µg/L

The treatability testing also indicated that lower effluent concentrations for cadmium could be achieved by adding sodium sulfide after the neutralization reactor, or by adding a flocculent prior to the filters. However, the test results indicated that these enhanced treatment techniques will not be needed, but they could be considered for future implementation if additional metal removal is desired. Thus, the treatment process carried forward into alternative development is lime neutralization high-density sludge treatment using tri-media filters. The technical memorandum in Appendix E describes proposed changes to the existing CTP.

3.6.2 Changes Required to Make Less Sludge

The CTP is configured as a high-density sludge (HDS) plant. Lime is added to thickened sludge, which is then mixed with the plant influent. Dissolved metals precipitate and settle, forming sludge, and treated water is discharged to Bunker Creek. However, the plant is currently operating in low-density sludge (LDS) mode because the plant does not have filters (required when operating in the HDS mode) to remove suspended solids from the effluent. In the LDS mode, the plant produces a waste sludge of about 1 to 5 percent solids by weight. The HDS mode of operation is preferred because the waste sludge is expected to be about 20 to 25 percent solids by weight, which is expected to dewater to about one-half to one-third the final sludge volume compared to sludge dewatered in the LDS mode. Addition of filter equipment will allow the plant to be operated in the HDS mode.

3.6.3 Changes Required to Increase Reliability

During original CTP process development and design in 1973, the Bunker Hill Company acknowledged the potential for the CTP to experience upsets and breakdown, as summed up in the following statement, “The central impoundment pond will provide surge holding capacity during treatment plant upsets or breakdowns, thereby protecting the quality of the river course at all times” (Baker and Larson, 1973).

With the installation of the cover system, the CIA can no longer be used for mine water storage as was historically done. Thus, to provide protection from CTP upsets or breakdowns, either replacement storage is needed, more backup and redundant treatment capability is needed, or both. Use of both is expected to be more protective and cost-effective.

The CTP master plan in Appendix E describes recommended CTP modifications to cost-effectively reduce upsets or breakdowns. When coupled with emergency in-mine storage and storage provided by the lined pond, the likelihood of discharge of untreated mine water is considerably reduced.

The proposed upgraded treatment plant as described in Appendix E will include the following backup and/or redundant contingency systems. The specific size and capability of each will be determined during design and through completion of a failure modes and effects analysis (FMEA).

Backup Power. The current CTP does not have backup power. A diesel engine-driven generator will supply backup power to all essential treatment systems and work areas. The generator will be switched to start automatically if power supply from the electric utility is lost.

Lime Feed System. Without the ability to make and use lime slurry, the CTP cannot function. The current, inefficient lime makeup and feed system lacks redundancy. Failure of the single lime storage silo, single aspirator system, and single lime slurry tank mixer would shut down the CTP. Also, it is unlikely that the semi-manual lime slurry makeup system could keep up with high lime demands resulting from very high mine water flows. There are also no functioning indicators or alarms to alert the operators of lime makeup or feed problems, other than loss of treatment process pH control (which is too late to prevent process upsets). The current method of pH measurement, coupled with the long retention time in Reactor A and the poor mixing in Reactor B, results in inability to control process pH in Reactor B more accurately than one-half a pH unit. Finer pH control would result in more consistent lime feeding and treatment. To address these shortcomings, the lime feed system will be improved to provide redundancy and sized for large lime demand loads in the event of a mine flood or flushing event that is not stored. This will include two lime silos, two lime slakers, two lime slurry tanks, and two lime slurry recirculation and feed systems.

Large Hydraulic Throughput Capacity. The hydraulic throughput capacity of the CTP will be sized for large flows (approximately 5,000 gpm) to enable flows up to 5,000 gpm to be neutralized and the metals precipitated. This can be done at little incremental cost because the existing CTP piping must be replaced for the new process equipment. This will help ensure that the flows can be managed without overflowing process equipment, and will reduce future costs if later capacity increases are required.

Backup and Redundant Control System. The existing antiquated and mostly inoperable control system will be replaced with a modern computer-based process control and operator interface system. This new system will be installed on redundant computers. The software will be backed up and will be re-installable from a remote computer via modem.

On-Hand Inventory of Critical Spare Parts. Critical spare parts will be stored at the plant and available for rapid installation.

3.6.4 Changes Required to Improve Efficiency

Today, as it was 27 years ago when the CTP was constructed, lime neutralization is still the most cost-effective way to treat the mine water. Use of the HDS process is also the most cost-effective way to reduce sludge volumes. Use of tri-media filters and a pH setpoint of about 9.5 is the most cost-effective way for achieving the TMDL discharge allocations. Maximizing use of existing CTP equipment and infrastructure to the most practical extent possible will minimize the cost to upgrade the CTP to achieve the TMDL, minimize sludge production, and provide more reliable treatment. Cost-effectiveness and reliability would also be improved by adding modern automated systems for process control and monitoring, lime slurry makeup, and polymer makeup.

3.6.4.1 Automated Process Monitoring and Control System

The CTP uses the original panel-mounted process control devices installed in 1974. Most of these antiquated process controls no longer function. Other than pH control and annunciation of certain alarms, there is no automation in the existing control system. Paper for the strip chart recorders is no longer manufactured.

The existing system does not have the flexibility and capability to support new equipment. The system is non-computerized and inefficient. A modern system would be considerably more reliable, efficient, and flexible.

A new automated programmable logic controller (PLC) -based system is needed. This system would automatically monitor system performance, control all pumps and mixers, automatically initiate lime and polymer make-up, record vital record-keeping information (such as flow and effluent metal load), and provide AutoDial alarm functions when needed. The control system would allow the plant to run unassisted overnight or on weekends, depending on the degree of autonomy desired.

A new personal computer will serve as the human-machine interface (HMI). The operator can view each unit process on the computer screen and know the status immediately. Software changes can also be made using the HMI. The HMI can be assessed both at the plant and remotely, and can provide automated reports. This system would track river flow at the Pinehurst gauge, enabling daily automatic calculations required to determine allowable discharge quantity for achieving the TMDL discharge allocations for the CTP.

3.6.4.2 Automated Lime Slurry Makeup and Feed System

The CTP uses lime slurry to neutralize the acidity of the influent and to precipitate the dissolved metals. The CTP uses more costly hydrated lime rather than quicklime because the CTP does not have an operational lime slaker, which is needed to automatically convert the less expensive quicklime to hydrated lime.

The economics of lime usage favors use of pebble quicklime rather than hydrated lime (about a 40 percent savings), slaking at the treatment plant to form hydrated lime, and then automatic slurring and feeding of the hydrated lime into the treatment process. Automatic slaking, slurrying, and feeding are usually performed because the initial capital cost of the equipment is recuperated in labor savings. For these reasons, the CTP initially used quicklime and a slaker for lime slurry preparation. The slaker is currently inoperative and is no longer used. The less-efficient and more costly semi-manual makeup system is used instead. An automatic system would provide more reliable and cost-effective operation.

3.6.4.3 Automated Polymer Makeup and Feed System

Polymer solution used to help settle the suspended solids in the sludge thickener is currently manually made up by adding dry polymer to water in a polymer make-up tank. Polymer dosage is evaluated by observing the settling rate of samples of thickener feed and effluent turbidity, and is adjusted by changing the speed of the feed pump. The current manual make-up system is labor-intensive. There are no alarms to alert the operators of problems, or if the polymer storage tanks are getting low. An automated polymer make-up and feed system would reduce manpower requirements, allow more efficient use of polymer, and increase worker safety.

3.7 Sludge Management

Lime neutralization treatment of AMD results in sludge generation. The sludge consists of entrained and chemically bound water and the precipitated metals removed from the AMD. The major constituents are water, and oxides and hydroxides of iron, zinc, manganese,

magnesium, and aluminum. Gypsum can also be a major constituent depending on the concentration of sulfate in the AMD, which varies seasonally. The sludge also contains oxides and hydroxides of the contaminants of concern, including lead and cadmium. The sludge is brownish in color, resulting from a combination of the yellowish-orange hues from the iron oxy-hydroxides, and the dark brown to black hues from the manganese oxides.

The CTP currently generates sludge consisting of 1 to 5 percent solids. Sludge is pumped daily from the thickener into the unlined sludge disposal bed on the CIA (Figure 3-3), which has about 3 to 5 years remaining capacity. On average, about 140,000 cubic yards (yd^3) of sludge per year are pumped to the CIA. The entrained water slowly drains from the sludge, leaving behind about 15,000 to 20,000 yd^3 of sludge per year. Sludge produced by the HDS plant will average about 20 to 25 percent solids by weight when pumped from the thickener, compared to the existing 1 to 5 percent. On average, this equates to about 20,000 yd^3 of liquid (raw) sludge per year needing to be further dewatered and disposed of, compared to about 140,000 yd^3 in the existing LDS process. The existing sludge passes the toxicity characteristic leaching procedure (TCLP) test, is exempted as a Bevill-excluded waste as described in Section 2.6, and is therefore not classified as hazardous waste. The HDS sludge is also expected to pass the TCLP test and will be Bevill-excluded.

Several HDS sludge dewatering and disposal options were evaluated in the presumptive remedy document. The options were evaluated by general management categories of raw (liquid) sludge disposal, sludge dewatering, dewatered sludge disposal, and metal recovery.

3.7.1 Raw Sludge Disposal

Raw sludge can be disposed of in onsite disposal beds, similar to the current practice, except that the filtrate (water that drains from the sludge) would be collected and treated. Sludge from the CTP thickener would be pumped into the beds every day or every few days. These beds, which would be located on the southeast end of the CIA near the CTP (see Figure 3-3) or above the smelter closure area (Figure 3-4), would both dewater and permanently store the sludge. It is estimated that the HDS sludge would dewater to about 60 percent solids by weight, and would accumulate at about 5,400 yd^3 per year. One disposal bed would be constructed at a time and used for about 10 years. Therefore, three beds would be needed for a 30-year period. Each bed would require about 6 acres of land when in use. If LDS sludge were disposed of, about 20 acres would be needed for each of the three beds--about three times the disposal volume of the HDS sludge. When the first bed approaches capacity, a second bed would be built adjacent to it. Each full bed would be covered with an impermeable cover system and planted with grass. Additional information on how the disposal beds would be constructed and operated can be found in the presumptive remedy document (CH2M HILL, 1999d).

Disposal of raw sludge in the mine was also evaluated in the presumptive remedy document. This option was screened out because no suitable locations could be identified. However, in-mine sludge disposal may be appropriate for use by a future mine operation that uses a sandfill system for in-mine tailings disposal. The sludge could be incorporated into the sandfill.

3.7.2 Sludge Dewatering

Two methods to dewater sludge were evaluated in the presumptive remedy document; these were mechanical dewatering using belt filter presses, and gravity dewatering using sludge drying beds. Plate and frame presses could also be considered if mechanical dewatering is chosen.

The mechanical dewatering equipment would be located at the CTP and would dewater the sludge by mechanically induced draining and compression. The dewatered sludge, known as sludge cake, would be placed into trucks and hauled to a landfill. The drawback of belt filter presses or other mechanical dewatering processes is that they are complex and expensive machines that require close operator attention. However, they require less space than sludge drying beds.

Sludge drying beds would remove water through gravity drainage and evaporation from open-air impoundments similar to the sludge disposal beds described previously. Two drying bed cells would be constructed on the CIA in the area shown on Figure 3-3 for the sludge disposal beds. These two drying beds would be alternated yearly. This would allow time for the sludge to dewater, time for annual sludge removal, and time for reconditioning the sludge bed for the next year's use. The filtrate from the beds would be collected and treated. The drawback of sludge drying beds is that they would require about 3 acres of land. The benefit is that they are very simple and require little operational oversight when compared to the mechanical dewatering equipment.

3.7.3 Dewatered Sludge Disposal

Dewatered sludge disposal options evaluated in the presumptive remedy document included in-mine disposal, or in onsite or offsite landfills. The Hanna Stope, which is a relatively large man-made cavern, was identified as having the highest potential for in-mine disposal. This would involve trucking the dewatered sludge up into Milo Gulch into 5 Level, where the stope is located. This option was screened out because it would be difficult to implement, its effectiveness is questionable, and its cost would be high. To contain the sludge, several plugs would need to be placed in drifts and raises that connect in the stope area. These plugs would be subjected to potentially very high forces from the sludge. This option would be difficult to implement because of the hazardous access to the Hanna Stope and loose rock areas, both conditions making the work dangerous. The effectiveness of this option was questionable because it would be difficult to keep the sludge isolated from mine water and from being displaced or dissolved. The cost was high because of the implementation problems and the costs of monitoring, which would be necessary to ensure the sludge was not being displaced or dissolved by the mine water.

Onsite landfill disposal was evaluated using landfills constructed in gulches or on flat areas within the site. Gulch areas were screened out because they were more costly than flatter areas and more at risk from being damaged by floods. The location considered for an onsite sludge landfill is above the smelter closure area (see Figure 3-4), which is one of the areas considered for raw sludge disposal using disposal beds.

Disposal of sludge in offsite landfills would not require the use of site land. Because the sludge is not a hazardous waste, it could be disposed of in Subtitle D (non-hazardous waste) landfills, such as in Airway Heights, Washington; Roosevelt, Washington; or Arlington,

Oregon. Because sludge drying and hauling is required, offsite landfill disposal is more costly.

3.7.4 Metal Recovery

Recovery of zinc and manganese from the sludge using sludge leaching and electrowinning was evaluated. The process has been demonstrated at bench-scale by research conducted at the University of Idaho. However, considerable work is needed to develop and demonstrate full-scale capability; thus, the implementability, reliability, and long-term cost-effectiveness of the process is unknown. Economic feasibility would also fluctuate with changes in metals prices. Because of these unknowns, the process was screened out but may be considered in the future if the technology effectiveness and cost-effectiveness are demonstrated.

3.7.5 Sludge Management Screening Summary

Four sludge management options remain and are carried into Section 4 for development of alternatives. Two use raw sludge disposal and two use dry sludge disposal, and are summarized below.

Option A: Disposal of raw sludge in onsite sludge disposal beds located on the CIA that both dewater and permanently store the sludge

Option B: Mechanical sludge dewatering and disposal of dry sludge in an offsite landfill.

Option C: Disposal of raw sludge in onsite sludge disposal beds located above the smelter closure area.

Option D: Sludge drying using sludge drying beds and annual excavation and disposal of dry sludge in an onsite landfill located above the smelter closure area.

3.8 Summary of Technology and Option Screening

The technologies remaining for each remedy component are summarized in Table 3-3. These are assembled into alternatives in Section 4.

TABLE 3-1
AMD Mitigation Options
Bunker Hill Mine Water RI/FS Report

Drainage Basin	AMD Mitigation Option
West Milo	West Fork Milo Creek Diversion
	Rehabilitate Phil Sheridan Diversion
	Upgrade Phil Sheridan Diversion
	Sidehill Diversions
South Milo	South Fork Milo Creek Diversion
Mainstem Milo	Plug Small Hopes Drift
	Bypass Bunker Hill Dam
	Improve Existing Diversion
Deadwood	Plug Inez Shaft
Other	Plug Drillholes

TABLE 3-2
Estimated Mitigation Effectiveness in Terms of Reducing Water Inflow to the Mine
Bunker Hill Mine Water RI/FS Report

AMD Mitigation Option	Rough Estimated Average Flow Reduction (gpm)	Rough Estimated Peak Flow Reduction (gpm)
West Fork Diversion	240[a]	2,000[b]
West Fork Diversion w/ Phil Sheridan Raises	300[a]	2,000[b]
West Fork Diversion, Phil Sheridan Raises, & Sidehill Diversion	340[a]	2,240[b]
South Fork Diversion	100 – 120[b]	200[b]
Plug Small Hopes	60 – 90[b,c]	60 – 90[b,c]
Bypass Bunker Hill Dam	30 – 60 [b,c]	30 – 60 [b,c]
Improve Existing Diversion (both improve seal and increase capacity options)	90 – 150 [b,c]	400[b]
Plug/Bypass Inez Shaft	100[b]	800[b]
Plug Drillholes	260[d]	260[d]

Notes:
[a] Based on basin area x average annual precipitation in Kellogg.
[b] Based on best guesses developed during the September 22, 23, and 28, 1999, Field Reconnaissance of Recharge/Inflow Mechanisms, and refined during the September 29 and 30, 1999, Ranking Meeting and the December 16, 1999, Mitigation/Treatment Evaluation interim meeting.
[c] Based on Trexler's research work through the University of Idaho in Mainstem Milo Creek.
[d] Based on 150 gpm from DDH #1208, 45 gpm from Russell drillholes, 25 gpm from East Reed drillholes, 25 gpm from Bailey drillholes, 5 gpm from Van drillholes, 10 gpm from Cherry Vent drillholes.

TABLE 3-3
Remedy Components for Alternative Development
Bunker Hill Mine Water RI/FS Report

AMD Mitigations	AMD Collection	AMD Conveyance	AMD Storage	AMD Treatment	Sludge Management
West Fork Milo Creek diversion Rehabilitate Phil Sheridan raises Plug in-mine drillholes Plug Small Hopes Drift below Mainstem Milo Creek Plug/bypass Inez Shaft below Deadwood Creek Sidehill diversion in West Fork Milo Basin South Fork Milo Creek diversion Bypass Bunker Hill Dam in Mainstem Milo Creek Improve existing diversion in Mainstem Milo Creek Upgrade Phil Sheridan Raise system in West Fork Milo Basin	Continue to use the existing approach, which consists of gravity-draining the combined upper levels water and pumped mine pool water out the Kellogg Tunnel.	Use the existing portal concrete channel and buried pipeline to lined pond. Install tee pipeline for direct flow to CTP	Surface Storage: Use the existing 7-million-gallon lined pond. In-Mine Storage: Use the existing system, or replace it with new gravity diversions and mine pool pumps.	Update and upgrade the existing lime neutralization HDS treatment plant. Add tri-media filters.	Option A: Sludge disposal beds on CIA that dewater and permanently store the sludge. Option B: Mechanical sludge dewatering and disposal of dry sludge in an offsite landfill. Option C: Disposal of raw sludge in onsite sludge disposal beds located above the smelter closure area. Option D: Sludge drying using sludge drying beds and annual excavation and disposal of dry sludge in an on-site landfill located above the smelter closure area.

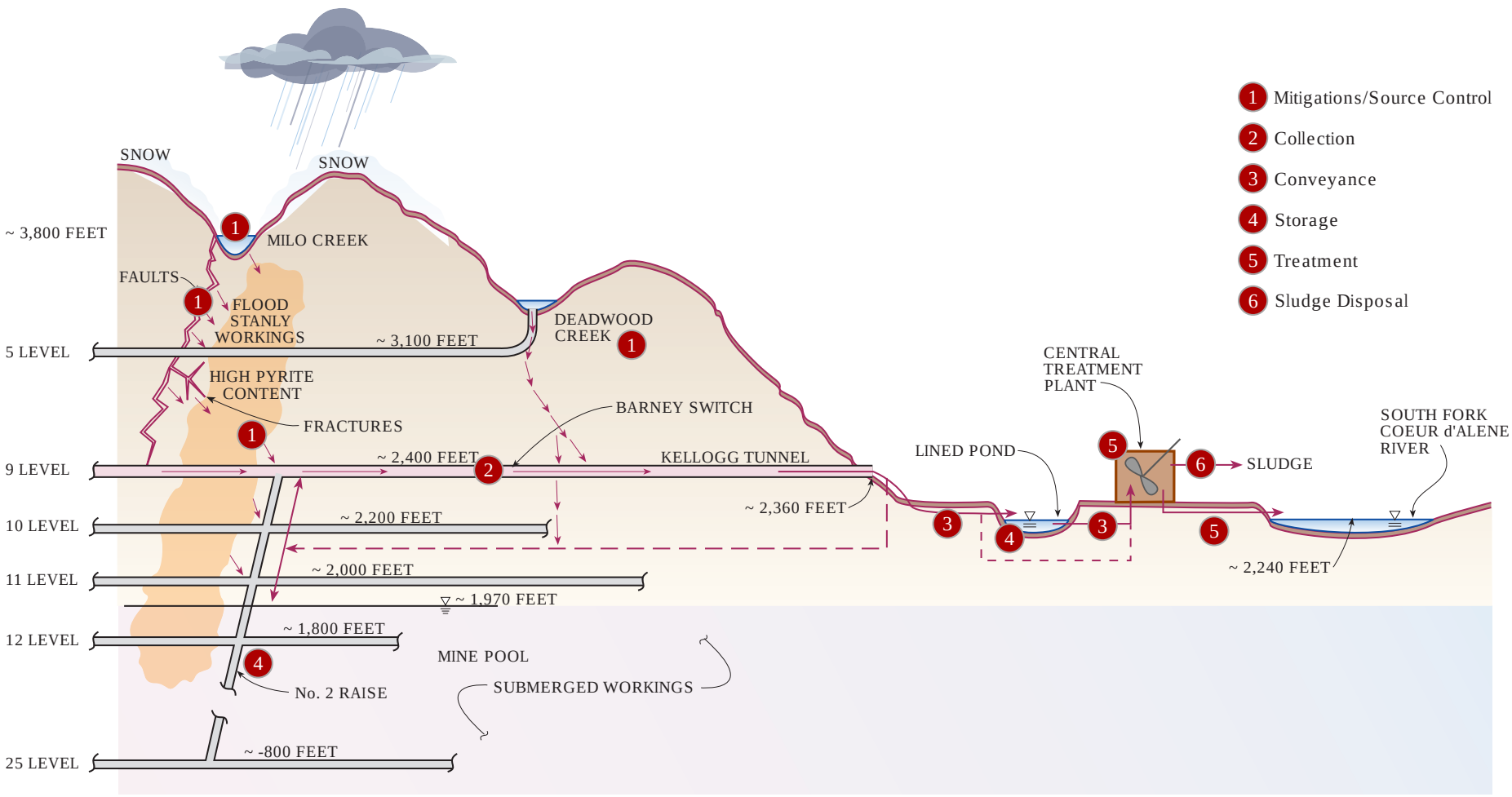

FIGURE 3-1

GENERALIZED CROSS SECTION OF REMEDIAL COMPONENTS

BUNKER HILL MINE WATER MANAGEMENT RI/FS

CH2MHILL

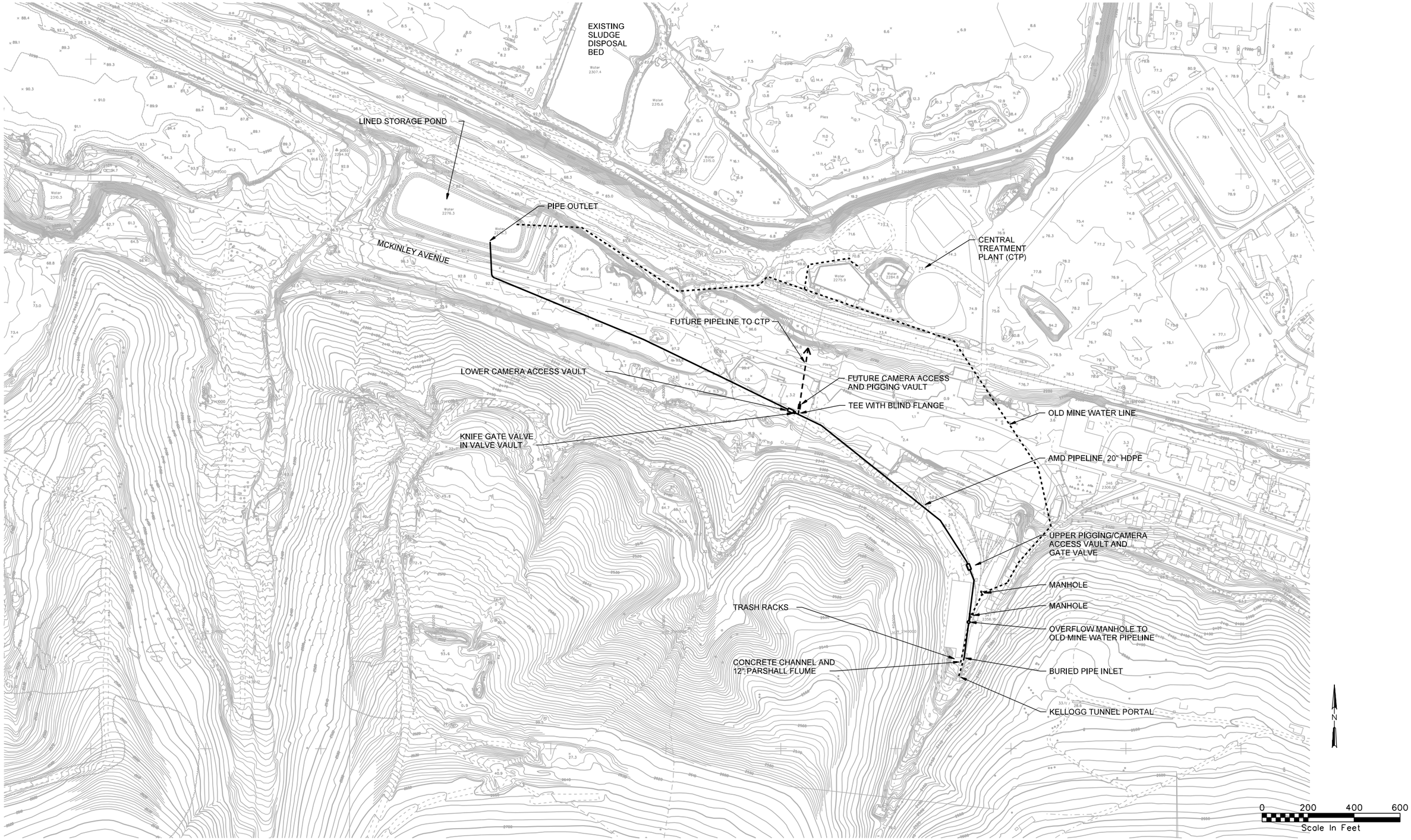

FIGURE 3-2
PLAN VIEW OF THE AMD CONVEYANCE SYSTEM

BUNKER HILL MINE WATER RI/FS REPORT
152215.FS.01

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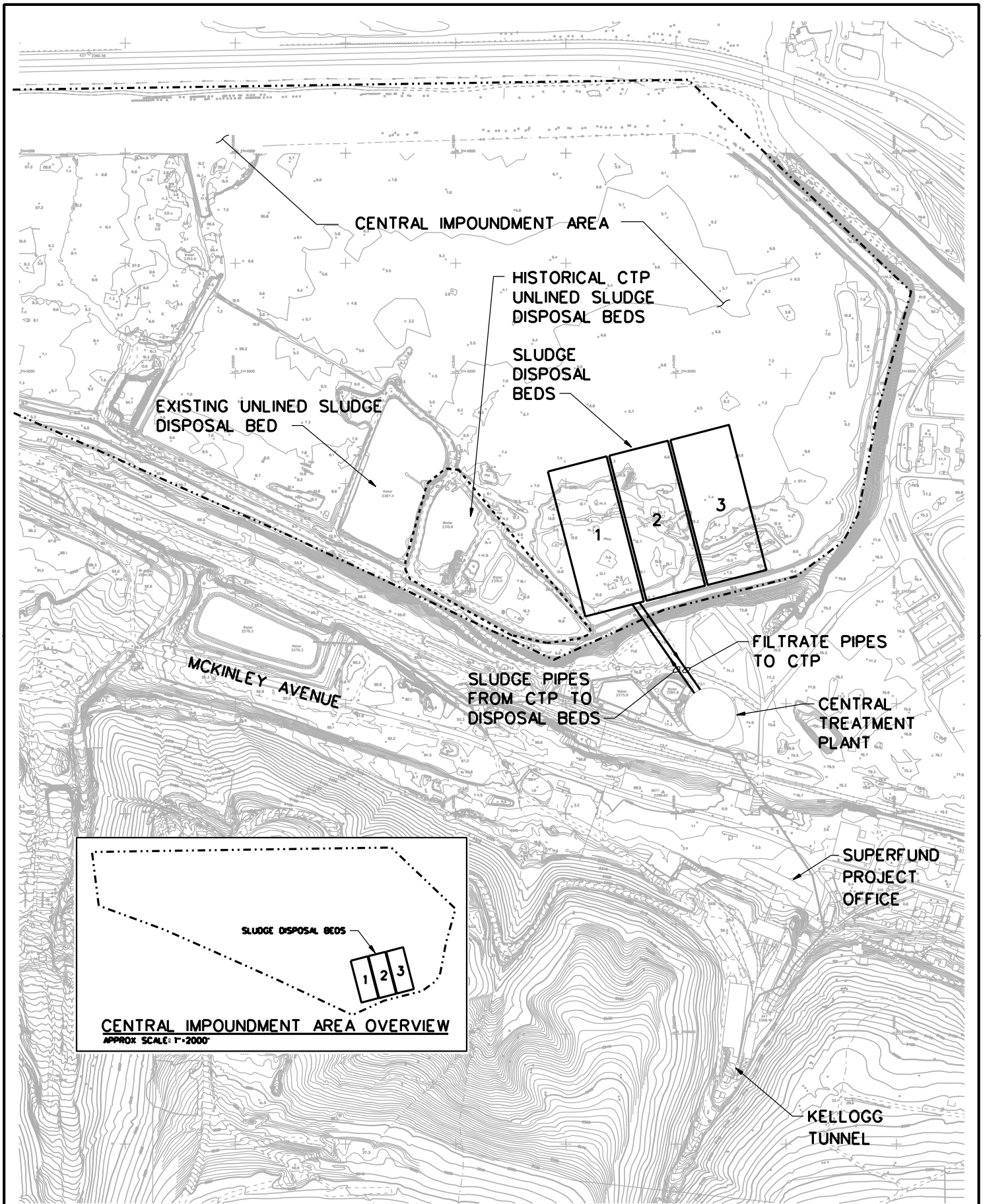

N

0 300 600 900

1"=600'

FIGURE 3-3

GENERAL SITE PLAN
CIA SLUDGE DISPOSAL BEDS

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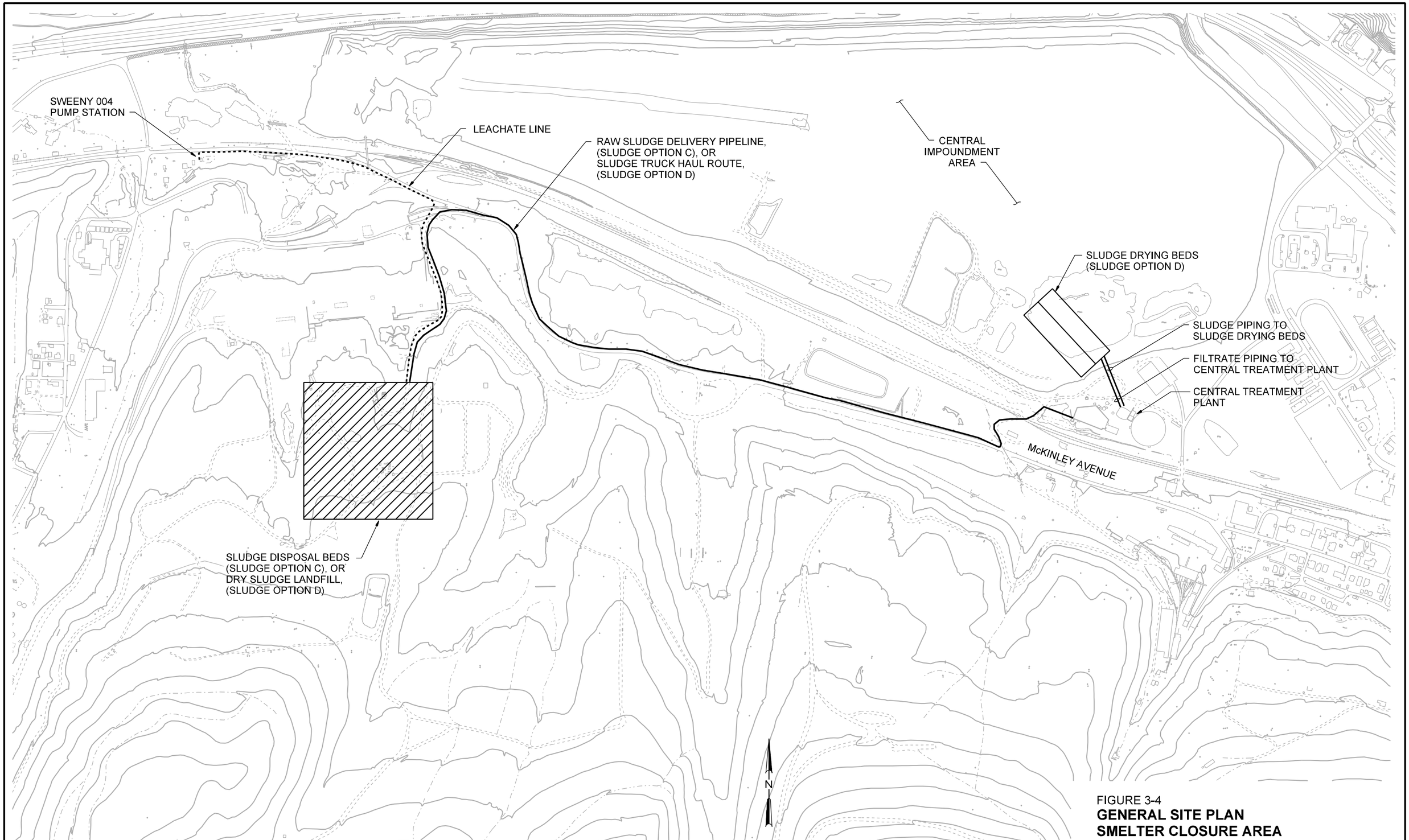

FIGURE 3-4
GENERAL SITE PLAN
SMELTER CLOSURE AREA
SLUDGE DISPOSAL OPTIONS C AND D

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SECTION 4.0

Development of Alternatives

4.0 Development of Alternatives

This section develops five alternatives for mine water management. The alternatives were formulated by combining technologies identified in Section 3. The NCP provides that the primary goal of the FS is to ensure that appropriate remedial alternatives are developed and evaluated such that relevant information concerning the remedial action options can be presented to decision makers and an appropriate remedy selected. The development and evaluation of alternatives reflects the scope and complexity of the remedial actions under consideration and the site problems being addressed. EPA has relied on previous and recently collected information to develop and evaluate a range of alternative approaches consistent with NCP requirements and the RAOs for the Bunker Hill mine water.

4.1 Alternatives Assembly

The alternatives were assembled using the technologies for each of the six remedy components summarized in Table 3-3 for management of the AMD. The six remedy components are:

- AMD Mitigations
- AMD Collection
- AMD Conveyance
- AMD Storage
- AMD Treatment
- Sludge Management

The components are closely related, in that the type, size, or performance of one can influence the type, size, or performance of another. For example, mitigations are intended to reduce the quantity of AMD discharge from the Kellogg Tunnel. Reducing the discharge will reduce the amount of AMD needing to be collected, conveyed, stored, and treated, and likely the amount of sludge produced. A smaller discharge of AMD from the Kellogg Tunnel portal would require a smaller treatment plant. Because of these relationships, it is desirable to assemble alternatives that contain a range of mitigations and treatment plant sizes for comparison.

4.2 Alternatives Development

The relationship between the degree of mitigation implementation and treatment plant size is important for alternative development. Another important consideration is the amount of AMD storage needed for maintenance of the conveyance pipeline and treatment plant, unexpected treatment plant shutdowns, and unusually high Kellogg Tunnel flows. Treatment plant effluent concentrations must be considered because the TMDL discharge limit is metal-load-based, and because load (mass per time) is equal to flow rate (volume per time) times concentration.

4.2.1 TMDL Computer Model

4.2.1.1 TMDL Computer Model Overview

CH2M HILL developed a computer model using Microsoft Excel™ to evaluate the relationship between the TMDL for the CTP, mitigation measures (Kellogg Tunnel flow reductions), treatment (CTP size and effluent concentration), and AMD storage volumes. A detailed explanation of the input parameters, model logic, and assumptions used in the model is presented in Appendix F. Figure 4-1 presents an overview of the logic used in the model. An overview of the TMDL and how it was developed is provided in Section 2.6.2.1.

The model uses flow data for various WYs for which Kellogg Tunnel flow data are available, as described in the hydrologic evaluation document (CH2M HILL, 2000d). The five WYs with the highest Kellogg Tunnel flows (1973, 1974, 1981, 1982, and 1996) were primarily used in the model because these years are the most difficult of the historic data sets for TMDL achievement because of their high Kellogg Tunnel flows. Hydrographs for these years are shown in Figures 4-2 through 4-6.

The model requires the following input data:

- CTP capacity in gpm
- CTP effluent concentrations of total cadmium, lead, and zinc
- Mitigation effectiveness in terms of percent flow reduction for four Kellogg Tunnel flow ranges. Figure 2-15 in Section 2 shows these ranges with respect to historical Kellogg Tunnel flow hydrographs. The flow intervals listed below were used in the analysis:
  - KT <1,500 gpm (low to average flow conditions)
  - 1,500 gpm < KT < 2,500 gpm (medium to medium-high flow conditions)
  - 2,500 gpm < KT < 3,500 gpm (medium-high to high flow conditions)
  - KT > 3,500 gpm (high to very high flow conditions)

The basic model logic is conducted in four general steps (see Figure 4-1), with the rule that the TMDL cannot be exceeded on a daily basis.

Step 1: TMDLs are calculated on a daily basis, based on SFCdA River flow. The TMDL is converted to “allowable discharge” in gpm by dividing the TMDL by the CTP effluent concentrations input to the model. The minimum flow (gpm) is selected based on the minimum computed cadmium, lead, and zinc allowable discharge loads.

Step 2: Kellogg Tunnel discharge is compared to CTP capacity. AMD is either diverted to storage or treated. It is diverted to storage if the Kellogg Tunnel discharge is higher than CTP capacity. This type of storage is called “hydraulic storage” because it is needed as a result of the hydraulic capacity of the CTP. When the volume of AMD in storage is zero, Kellogg Tunnel flow may be less than CTP capacity because there is no stored AMD to augment the difference between CTP capacity and the Kellogg Tunnel flow rate.

Step 3: CTP discharge is compared to the allowable discharge calculated above. AMD is diverted to storage if the calculated CTP discharge load is greater than the

allowable discharge load. This type of storage is called "TMDL storage" because it is needed as a result of CTP discharge limitations imposed by the allowable daily metal discharge load.

Step 4: The net change in storage is calculated and expressed as cumulative storage volume.

The model logic uses assumptions that could potentially be a source of error. First, the model assumes that CTP effluent concentrations are constant and do not fluctuate in response to changes in the flow or metal loads of the CTP influent. However, effluent concentrations are likely to vary to some degree, which can only be determined through operational experience. To account for this uncertainty, a range of CTP effluent concentrations can be evaluated. Second, the effectiveness of the mitigations for reducing flow out the Kellogg Tunnel is uncertain. The actual effectiveness of any mitigation won't be known until it is constructed and monitored. Therefore, a range of potential mitigation effectiveness can be evaluated using the model. For simplicity, the model uses percent Kellogg Tunnel flow reductions to assess mitigation effectiveness over the four Kellogg Tunnel flow ranges. Another assumption is that diversion to storage and pumping from storage can be adjusted to the nearest gpm. The actual diversion and pumping rates will depend on the capabilities of the system constructed. The model also assumes 100 percent efficiency in operating each of the system components.

The model output is displayed graphically in plots of storage required (defined as the total maximum storage required at any time during the WY for both hydraulic storage and TMDL storage) versus treatment plant size. The model output sheets (See Appendix F) list required hydraulic storage separately from required TMDL storage. The output graphs also show the volume of AMD remaining in storage at the end of a WY ("Remaining Storage").

4.2.1.2 Model Runs

Model runs were made to evaluate the effect of the following variables on TMDL achievement and storage requirements:

CTP Effluent Concentration. The model was used to evaluate TMDL achievement using the following anticipated CTP effluent concentrations based on the treatability testing described in Section 3.6.1:

- Cadmium = <0.70 µg/L
- Lead = <1.0 µg/L
- Zinc = <70 µg/L

CTP Capacity. CTP capacities between 1,500 and 7,000 gpm were evaluated using the model. This range covers the anticipated capacities based on the historical Kellogg Tunnel flow record.

Mitigation Effectiveness. The total volume of AMD storage required for either achievement of the TMDL or for hydraulic storage was evaluated using the model for different estimates of mitigation effectiveness. This was done by using estimated flow reduction percentages for the four Kellogg Tunnel flow ranges used in the model. Table 4-1 shows the modeled percent flow reductions.

Greater estimates of mitigation flow reductions were used for higher Kellogg Tunnel flows because in general the mitigations are expected to be more effective diverting the Kellogg Tunnel flow "peaks" than the base flows. This is especially the case for the West Fork Milo Creek stream diversion because all the current flow from the West Fork Milo Basin is believed to enter the mine as described in Section 2. This diversion is expected to capture the flow in the stream and alluvium because it will be keyed into bedrock if possible, but it will not capture flow in the underlying fracture system that recharges the mine year-round.

4.2.1.3 Model Results

CTP Effluent Concentrations. Table 4-2 presents the maximum allowable CTP effluent flow rates at the anticipated CTP effluent concentrations for the four TMDL river flow conditions. The results indicate the discharge rate limiting metals are cadmium and zinc. For both cadmium and zinc the allowable effluent flow rate under 7Q10 discharge conditions is about 2,800 gpm. CTP effluent flow rates below about 2,800 gpm can be discharged without exceeding the allowable daily zinc and cadmium loads. It is apparent from Table 4-2 that the lead TMDL may not limit the CTP effluent flow rate at any river condition, since flows in excess of 11,000 gpm are not expected.

CTP Capacity and Mitigation Effectiveness. The maximum volume of AMD storage required for CTP capacities between 1,500 and 7,000 gpm was evaluated for the flow reduction percentages shown in Table 4-1 using the anticipated effluent concentrations. Higher Kellogg Tunnel flow reductions would allow use of a smaller CTP, less storage volume, and higher effluent concentrations. Figures 4-7 through 4-12 show plots of maximum storage volumes required, remaining AMD storage at the end of the WY, and CTP capacity for the percent mitigation effectiveness ranges shown in Table 4-1. Inspection of the figures shows that decreasing storage is required for smaller CTP capacities as more mitigation effectiveness is achieved. If no mitigations were implemented, as depicted by Figure 4-7, over 400 million gallons of storage would be needed for a 1,500 gpm CTP capacity, and a 7,000 gpm treatment capacity would be needed to eliminate the need for storage (maximum modeled KT flow was 6,700 gpm). The other extreme is depicted in Figure 4-12, which assumes highly effective mitigations. In this instance, about 30 million gallons of storage would be needed for a 1,500 gpm CTP, and a 2,000 gpm CTP would require no storage.

An important finding was that nearly all the storage was needed because the Kellogg Tunnel flow was higher than the CTP capacity (hydraulic storage), and very little storage was needed for TMDL achievement (TMDL storage). The most TMDL-required storage for all conditions modeled was 14.5 million gallons for water year 1973 with a 7,000 gpm capacity CTP and no mitigations. WY 1973 had the highest Kellogg Tunnel flows on record.

Although the specific amount of Kellogg Tunnel flow reduction as a result of the mitigations is unknown, the modeling results provide an estimate of flow reductions depending on assumed effectiveness. Table 4-3 lists the estimated Kellogg Tunnel peak flow, average flow, and average annual volume reductions for water years 1973, 1974, 1981, 1982, and 1996 using the percent flow range reduction approach described in Section 4.2.1.2. Treatment lime consumption and sludge production are expected to be reduced linearly with respect to flow volume reductions, as supported by the findings presented in the technical memorandum in Appendix B.

The application of one set of these flow reductions to WY 1973, The WY with the highest Kellogg Tunnel flow on record, is shown in Figure 4-13. The figure demonstrates the resulting Kellogg Tunnel flow hydrograph if a mitigation were in place during WY 1973 with a flow reduction effectiveness of 15 percent, 30 percent, 50 percent and 80 percent. The peak flows are reduced significantly, while base flows are only slightly reduced.

4.2.2 Considerations for Alternative Development

The most important consideration for alternative development is the quantity and quality of AMD that must be managed. This factor affects every component of an alternative, from mitigations to treatment sludge management. The following sections discuss this and other considerations in more detail.

4.2.2.1 AMD Quantity and Quality

AMD Quantity. The quantity of AMD to be managed in the future is uncertain. Historically, the flow from the Kellogg Tunnel portal has varied significantly, as depicted in Figure 2-15. The highest estimated flow is about 6,700 gpm, which occurred in December 1972 (this flow was recorded as 6,000+ gpm, and the 6,700 gpm is an estimate based on the shape of the hydrograph). In more recent times the highest flow was about 4,000 gpm, which occurred in 1996.

The quantity of Kellogg Tunnel flow depends on how much water is infiltrating into the mine workings. Based on the site conceptual model, high flows are associated with snowmelt and rain-on-snow events that rapidly increase surface flows above the workings, leading to higher infiltration. The historical flow record shows that these events can be sudden, with Kellogg Tunnel flows increasing many thousands of gpm in a few days. The peaks usually involve only a few days but the falling limb of the hydrograph can take a few weeks. The historical peak flows indicate movement of water rapidly from a surface source (probably stream flow) through the upper workings, because the response is too sudden for groundwater flow systems in undisturbed rock.

Reducing the rapid stream flow infiltration, particularly from the West Fork Milo Basin, may significantly reduce peak Kellogg Tunnel flows. Reducing recharge to bedrock fractures and faults that intercept mine workings should reduce base flows. Sealing the Small Hopes Drift below Milo Creek and the Inez Shaft below Deadwood Creek will guard against the streams eroding direct flow paths into the mine.

AMD Quality. The quality of the Kellogg Tunnel discharge has been studied extensively, as summarized in Section 2. Comparison of Kellogg Tunnel discharge chemistry data from the 1970s, 1980s, and 1990s shows variability, with metal concentrations varying sometimes rapidly and also seasonally. Rapid variations can be caused by mining-related water management such as pumping rates, direction of flow paths, ditch cleaning, and drilling operations. Rapid variations can also be caused by spring snowmelt and infiltration from surface streams, which results in more water coming from one area of the mine having different chemistry than other areas.

Seasonal AMD quality variations occur as a result of spring snowmelt. In general, the Kellogg Tunnel discharge quality deteriorates during the higher spring flows because of flushing of accumulated metal salts along mine water flow paths. The result is much higher

metal loads needing treatment in the spring because of these higher flows and higher concentrations.

The majority of the seasonal increase in Kellogg Tunnel metal loads comes from the Flood-Stanly Ore Body. Reducing seasonal recharge through the Flood-Stanly Ore Body will likely decrease the Kellogg Tunnel treatment load by reducing the flushing of accumulated metal salts, as described in the technical memorandum in Appendix B. This memorandum also evaluated the potential for large buildup of metal salts in the absence of periodic flushing, and the possibility that very high metal loads would be released when a flushing event did occur. While this is a possibility, the technical team concluded that this release mechanism is unlikely. Large metal salt accumulations have not been observed in accessible areas of the Flood-Stanly Ore Body; a hysteresis effect has also not been observed in plots of metal concentration versus flow rate in monitoring stations downstream of the Flood-Stanly Ore Body (see Appendix B). If large salt accumulation had occurred, then a hysteresis affect should be present where the rising limb of the monitoring station hydrographs would carry more metal load than the recessional limb. However, this has not been observed.

Although large salt accumulations are not expected if seasonal flushing is reduced by mitigations, accumulation should be monitored as part of implementing mitigations. Contingency measures could be taken to either store or treat very high metal loads in the event of a mine flood, mitigation failure, or high discharge event that would flush accumulated acid and metal salts from the mine.

4.2.2.2 Mitigation Effectiveness

Mitigations constructed to reduce recharge to the mine are expected to reduce average and peak Kellogg Tunnel flows requiring treatment. Mitigations that reduce recharge through the Flood-Stanly Ore Body are expected to reduce the metal load requiring treatment, which will reduce treatment cost and sludge generation. Mitigations in West Fork Milo Basin are expected to be the most effective for reducing peak Kellogg Tunnel flows and metal loads. Because peak Kellogg Tunnel flows are associated with rapid infiltration through streambeds, particularly in the West Fork Milo Basin, it is believed that diversion of West Fork Milo Basin flows away from the Guy Cave Area will significantly reduce peak Kellogg Tunnel flows and associated acid and metal loads. The effectiveness in reducing Kellogg Tunnel flows is expected to be higher for peak flows than base flows.

The goal of reducing infiltration to the mine is to reduce the quantity of AMD and the resulting acid and metal loads needing to be treated. Smaller Kellogg Tunnel flows would allow construction of smaller treatment facilities. Reducing the recharge through the Flood-Stanly Ore Body should reduce the acid and metal load, and hence the amount of lime used and sludge generated. Reduction of peak Kellogg Tunnel AMD flows also reduces the strain placed on AMD collection, conveyance, storage, and treatment facilities, because smaller flows are more readily managed than larger flows. This reduces the risk of failure of any of these components, and also the consequence of untreated AMD discharging to Bunker Creek, because the AMD flow rate is lower.

Because of the complexity of mine recharge, the effectiveness of mitigation measures will not be known until they are constructed and monitored. Even when constructed, their effectiveness may not be known for a number of years because it may take many spring

runoff seasons to accumulate sufficient information to assess long-term trends. Although it is possible to reduce the size of required treatment facilities based on mitigation effectiveness, this approach assumes some risk. A mine flood, mitigation failure, or extreme precipitation event could generate Kellogg Tunnel flows or acid and metal loads that would exceed the constructed treatment capacity. Based on historical flow data, higher than expected flows coming from the mine are possible. Consequently, the risk of such events will remain even after mitigations are constructed. Use of AMD storage would reduce this risk because the excess flows could be stored for subsequent treatment.

In summary, implementation of mitigation measures could be done in conjunction with close effectiveness monitoring to reduce the risk of failure, and with contingency measures to store unexpected and excessive AMD flows. The costs and benefits associated with constructing, operating, and monitoring the mitigations could be tracked to evaluate cost-effectiveness. Phasing the implementation of mitigations and treatment plant capacity could be effective for managing risk and cost. Mitigation effectiveness monitoring and evaluation required to support a phased implementation approach is described in Section 4.3.3.

4.2.2.3 Mine Water Collection

Reducing recharge to the mine, and hence Kellogg Tunnel flow, will reduce the volume of AMD needed to be collected and managed within the mine. AMD is collected within the mine using the ditches along the drifts to collect gravity drainage, and the pump system in No. 2 Shaft to collect mine pool water, as described in Section 2. All flows are conveyed out of the mine via the Kellogg Tunnel.

Successful collection of the gravity flow from the workings above 9 Level and conveyance out the Kellogg Tunnel of the pumped mine pool water relies on the continued operation of the ditch system. This requires considerable maintenance because of ongoing deposition of iron oxy-hydroxides (yellow boy) and other debris. This material must be shoveled out to maintain ditch capacity; otherwise, the water overruns the ditch and flows along the drifts themselves, which damages the railway track, timbers, and other infrastructure.

The in-mine flow paths are fairly well known on 9 and 5 Levels on the east side of the mine, but little is known about flow in other locations that have not been recently mined, many of which are inaccessible. The lack of inspection and maintenance will gradually lead to deterioration of the workings and blockage that impounds AMD, which will lead to less predictable flow on 9 Level. It is possible that floods resulting from the collapse of in-mine AMD impoundments will become more common.

The Kellogg Tunnel ditch inside the portal has limited capacity. The specific capacity is unknown, but likely below the 7,000 gpm capacity of the concrete ditch outside the portal and the AMD conveyance pipeline. This could result in excess AMD not being collected in the concrete ditch. If this occurred and the excess was not diverted back into the concrete channel, it would run through the mine yard and down the hill to Bunker Creek, recontaminating properties that have already been cleaned up. Some AMD may drain into the storm water system that discharges to Bunker Creek. Reduction of mine infiltration is expected to reduce the Kellogg Tunnel flows, which will help ensure that all the AMD will be collected at the portal. Contingency measures or modifications at the portal are needed for collection of Kellogg Tunnel portal discharge in excess of the ditch's carrying capacity.

4.2.2.4 Mine Water Conveyance

The Kellogg Tunnel portal ditch discharges into a concrete channel, which carries the AMD through a Parshall flume for flow measurement and recording, and then into a buried pipeline that conveys it into the lined pond for storage prior to treatment. The concrete ditch and pipeline have a capacity of about 7,000 gpm. The old mine water pipeline, which is connected to the new pipeline downstream of the concrete ditch via an overflow manhole, is limited to an unknown amount of less than about 1,400 gpm based on flow observations during the spring of 1999, when the pipeline failed to convey all the mine water.

Currently, all Kellogg Tunnel flow is conveyed to the lined pond, where a pump station pumps it to the treatment plant. This results in the deposition of considerable sediment and muck in the pond. Direct flow to the treatment plant is needed to prevent continued deposition in the lined pond that is costly to remove and diminishes storage capacity. Trash racks and sediment systems may be needed prior to the CTP to remove material that could plug or harm process equipment. The existing mine water conveyance system with a new tee segment for flow directly to the CTP is included in each of the alternatives evaluated.

4.2.2.5 Mine Water Storage

AMD storage is needed for conveyance system and treatment plant shutdowns, when the Kellogg Tunnel portal discharge rate is higher than the treatment plant capacity, and if the discharge rate became limited by TMDL discharge allocations. Storage options were described in Section 3.5. The amount of storage needed can be reduced by mitigations to reduce recharge to the mine and by constructing more capacity and reliability in the treatment plant. Contingency storage will always be needed when the treatment plant is shut down or inoperative. Providing more backup and redundant treatment systems at the treatment plant can reduce contingency storage.

Each alternative includes the use of the existing lined pond (7 million gallons) and in-mine storage. The lined pond will be used for short durations and scheduled CTP shutdowns. In-mine storage will be used for longer-duration shutdowns and contingency storage for flows or treatment loads in excess of the CTP's capacity, which are expected to be infrequent. In-mine storage is planned for this purpose; that is, the approximately 20 million gallons below 11 Level and the approximately 190 million gallons from the floor of 11 Level up to the floor of 10 Level at the No. 2 Shaft.

Use of in-mine storage above 11 Level will have some impact on mining operations and mine infrastructure. Infrequent level flooding will require extra maintenance for the mineshafts, hoists, and drifts, because of the effects of the rising and falling water elevations.

4.2.2.6 Mine Water Treatment

As described in more detail in Section 3.6 and in Appendix E, the CTP requires significant improvements in order to achieve the TMDL, reduce sludge production, improve reliability, and increase cost efficiency. The CTP Master Plan in Appendix E also describes the existing condition of the CTP and its present shortcomings. It describes upgrades in terms of three phases: Phase 1 are upgrades for a capacity of 2,500 gpm, Phase 2 are additional upgrades needed for a capacity of 5,000 gpm, and Phase 3 are upgrades needed if mechanical sludge

dewatering were implemented. The CTP Master Plan also provides process flow diagrams and describes how the plant can remain in operation as much as possible during upgrades. The most significant change required to achieve the TMDL is the addition of tri-media pressure filters for removal of suspended solids and associated metal from the effluent. These filters will also allow the plant to be operated in the HDS mode, which is expected to reduce the annual sludge volume to about one half to one third of the present volume.

4.2.2.7 Sludge Management

As described in Section 3, four sludge management options will be evaluated for each alternative. The options are:

- Option A: Disposal of raw sludge in onsite sludge disposal beds located on the CIA that both dewater and permanently store the sludge
- Option B: Mechanical sludge dewatering and disposal of dry sludge in an offsite landfill
- Option C: Disposal of raw sludge in onsite sludge disposal beds located above the smelter closure area
- Option D: Sludge drying using sludge drying beds on the CIA and annual excavation and disposal of dry sludge in an onsite landfill located above the smelter closure area.

4.2.2.8 Performance Monitoring

Monitoring the performance of any remedial action is required to determine if it is meeting the remedial action objectives. Performance monitoring is included in each of the alternatives.

4.3 Remedial Alternatives

This section describes the remedial alternatives assembled from the above components and considerations for management of the Bunker Hill mine water. The NCP, in 40 CFR 300.430(e)(7), specifies three criteria that were used to guide the development of remedial alternatives:

- **Effectiveness—**This criterion focuses on the degree to which an alternative reduces contaminant toxicity, mobility, or volume through treatment; minimizes residual risks and affords long-term protection; complies with ARARs; minimizes short-term impacts; and how quickly it achieves protection. Alternatives providing significantly less effectiveness than other more promising alternatives may be eliminated. Alternatives that do not provide adequate protection of human health and the environment shall be eliminated from further consideration.
- **Implementability—**This criterion focuses on the technical feasibility and availability of the technologies that each alternative would employ, and the administrative feasibility of implementing the alternative. Alternatives that are technically or administratively infeasible or that would require equipment, specialists, or facilities not available within a reasonable time may be eliminated from further consideration.

- **Cost**—The cost of construction and any long-term costs to operate and maintain the alternatives were considered. A technically viable alternative with total costs well in excess of other viable alternatives can be screened out based on the cost factor alone. Professional judgment for such a screening is essential because the capital and operating cost estimates are commonly based on limited information.

EPA has developed detailed aspects and key components of the alternatives by an iterative process of data acquisition and evaluation. The development of alternatives based on this effort has led to early elimination of some approaches and more detailed development of others. The remedial alternatives provide a range of approaches for managing the Bunker Hill mine water. The primary difference between the alternatives is the degree to which AMD mitigations and treatment capacity are implemented. They include a No Further Action alternative (Alternative 1), an alternative consisting of a larger treatment plant but no AMD mitigations (Alternative 2), alternatives that use a phased approach for implementing AMD mitigations and treatment capacity (Alternatives 3 and 4), and one using smaller treatment capacity and all the AMD mitigations carried through technology screening (Alternative 5).

All of the following alternatives are carried forward into detailed analysis. All are implementable; all, except for Alternative 1 (No Further Action alternative), are considered effective; and none are considered too cost-excessive compared to the others. In EPA's judgment, the specific detailed alternatives presented below (with the exception of Alternative 1) represent the most appropriate approaches to control, reduce, or eliminate the risks to human health and the environment posed by the Bunker Hill mine water. The following alternatives are described with respect to their major components to facilitate comparison. Table 4-4 provides a comparative summary.

4.3.1 Alternative 1—No Further Action

The No Further Action alternative, Alternative 1, was developed and evaluated as required by the NCP in 40 CFR 300.430(e)(6). With respect to evaluating the alternative's potential for meeting the remedial action objectives for the Bunker Hill mine water, the no action alternative should be considered as "no further action." The no action alternative is commonly used as a baseline alternative against which other alternatives are judged. As the name implies, this alternative does not include any additional remediation activities or improvements. The existing mine water management approaches and systems would continue to be used until the existing sludge disposal area is full, which is estimated to be 3 to 5 years. At that time the CTP will be shut down, because it cannot operate without sludge disposal. This would result in the discharge of untreated AMD into Bunker Creek. All other current mine water management activities would also cease, because there would be no need to operate them. The exception may be AMD collection within the mine, but only if it was done unilaterally by the mine owner for mining operations.

4.3.1.1 AMD Mitigations

No mitigations for reducing water infiltration to the mine would be constructed under this alternative.

4.3.1.2 AMD Collection

There would be no changes to the existing AMD collection system until the CTP is shut down. At that time, AMD collection within the mine would occur only if done unilaterally by the mine owner for mining operations.

4.3.1.3 AMD Conveyance

There would be no changes to the existing AMD conveyance system. It would not be maintained after the CTP is shut down. The mine water would probably continue to flow into the lined pond, and then out the overflow into Bunker Creek.

4.3.1.4 AMD Storage

The existing 7-million-gallon lined pond would continue to be used until the CTP is shut down, at which time it would be abandoned.

4.3.1.5 AMD Treatment

No treatment plant upgrades or repairs would occur for this alternative. Plant failures resulting from aging equipment would be expected to occur more frequently, possibly leading to a CTP failure prior to the CTP being shut down when the sludge disposal capacity is exhausted.

4.3.1.6 Sludge Management

The treatment sludge is currently disposed of on top of the CIA in the unlined sludge impoundment. The estimated sludge accumulation rate is 15,000 to 18,000 cubic yards per year. This would continue until no capacity remained, estimated to be 3 to 5 years from now, depending on mine water flows and sludge generation rates. No additional sludge disposal capacity would be constructed once the existing capacity is consumed. Without additional sludge disposal capacity, the CTP would need to be shut down because it would not be able to operate.

4.3.1.7 Performance Monitoring

The existing monitoring program would continue until the CTP is shut down, at which time all monitoring would cease. The existing monitoring consists of monitoring at the Kellogg Tunnel and CTP. At the Kellogg Tunnel, this consists of continuous flow measurements and periodic (weekly or bi-weekly) samples collected for pH, TSS, and total cadmium, lead, and zinc. The current CTP monitoring consists of flow measurements and daily samples for pH, TSS, and total cadmium, lead, and zinc.

4.3.1.8 Alternative 1 Summary

Table 4-5 summarizes the components of Alternative 1, the No Further Action alternative.

4.3.2 Alternative 2—Treatment Only

Alternative 2 is termed the “Treatment Only” alternative because it would update and improve the treatment plant but would not include any mitigations for reducing infiltration to the mine and the volume of AMD from the Kellogg Tunnel. The treatment plant would be sized at 5,000 gpm, which is considered large enough to treat all Kellogg Tunnel flows

except for the infrequent very high peak flows. These peak flows would be stored either in the lined pond or in the mine for later extraction and treatment.

4.3.2.1 AMD Mitigations

No mitigations for reducing water infiltration to the mine would be constructed under this alternative.

4.3.2.2 AMD Collection

There would be no changes to the existing AMD collection system.

4.3.2.3 AMD Conveyance

The existing conveyance system would be used, and an additional pipeline section (20-inch HDPE) would be added to allow direct flow of AMD to the treatment plant rather than to the lined pond. This would reduce sedimentation and cleaning of the lined pond, and would reduce the costs of operating the lined pond pump station.

4.3.2.4 AMD Storage

The existing 7-million-gallon lined pond would continue to be used for routine storage needs. The existing in-mine storage system would be used for larger storage and contingency needs. The existing diversion system to pump from the gravity ditches into the mine pool (about 1,050 gpm capacity) would be used if the Kellogg Tunnel discharge had to be reduced more than shutting off the mine pool pumping system would achieve (about 700 gpm capacity). The total capacity for in-mine storage is about 1,750 gpm. The largest recorded flow from the mine occurred in December 1972 and was estimated at about 6,700 gpm. This flow could be managed by storing 1,700 gpm and by treating 5,000 gpm. The existing mine pool extraction system would be used to remove stored water for treatment once the flows subsided.

Flows in excess of 5,000 gpm are expected to be very infrequent and have a short duration based on the historical data. Referring to Figure 2-15, which lists Kellogg Tunnel hydrographs for 16 years, it can be seen that 5,000 gpm was exceeded five times. Four of these times were during the 1973 WY, and the fifth was during the 1974 WY. Table 2-1 lists the estimated Kellogg Tunnel flow return intervals. A flow in excess of 5,000 gpm has an estimated return interval of about 13 years, with a probability of occurrence in any year of about 8 percent.

4.3.2.5 AMD Treatment

The CTP would be upgraded to a 5,000-gpm capacity with tri-media filters. For Alternative 2 the plant capacity would be increased to 5,000 gpm in one upgrade. If mechanical sludge dewatering is selected, it would be included with the upgrade.

4.3.2.6 Sludge Management

One of the following four sludge management options would be used:

Option A: Disposal of raw sludge in onsite sludge disposal beds located on the CIA that both dewater and permanently store the sludge

Option B: Mechanical sludge dewatering and disposal of dry sludge in an offsite landfill

Option C: Disposal of raw sludge in onsite sludge disposal beds located above the smelter closure area

Option D: Sludge drying using sludge drying beds on the CIA and annual excavation and disposal of dry sludge in an onsite landfill located above the smelter closure area

4.3.2.7 Performance Monitoring

Monitoring would be conducted at the Kellogg Tunnel portal and at the CTP effluent flow to Bunker Creek. The Kellogg Tunnel portal monitoring is expected to include continuous flow recording and periodic (weekly or bi-weekly) samples for pH, TSS, lime demand/solids formed, and total cadmium, lead, and zinc analysis. The CTP effluent flow would be monitored, which is expected to consist of daily sampling for pH, TSS, and total metals. Additional treatment process control monitoring would be conducted, such as treatment setpoint pH and effluent turbidity.

4.3.2.8 Alternative 2 Summary

Table 4-6 summarizes the components of Alternative 2, the Treatment Only alternative.

4.3.3 Alternative 3—Phased Mitigations/Treatment

Alternative 3 would phase the implementation of mitigations and treatment plant capacity based on monitoring results. An initial set of mitigations would be implemented and an initial CTP capacity would be constructed. Up to 10 years of performance monitoring would be reviewed to determine if the initial mitigations and treatment plant capacity were sufficient, or if more were needed. A decision process consisting of data analysis, conceptual model refinement, assessment of mitigation effectiveness, and cost/benefit analysis would be used to evaluate remedy performance, and to select subsequent actions if warranted.

4.3.3.1 AMD Mitigations

The AMD mitigations that would be implemented initially would be the West Fork Milo Creek Diversion, rehabilitation of the Phil Sheridan diversion system, and plugging of the known in-mine drill holes that are discharging water. These mitigations are believed to have the highest potential for reducing recharge through the Flood-Stanly Ore Body and mine water flow out the Kellogg Tunnel. Additional mitigations that could be constructed later are those listed in Table 3-3 in Section 3 of this report, and possibly other mitigations not identified to date.

4.3.3.2 AMD Collection

The existing gravity drainage system would be used, but the mine pool pumping system in No. 2 Shaft would be replaced with two 700-gpm vertical turbine pumps. These new pumps would increase system reliability and provide quicker extraction of stored mine water.

4.3.3.3 AMD Conveyance

The existing conveyance system would be used, and an additional pipeline section (20-inch HDPE) would be added to allow direct flow of AMD to the treatment plant rather than to the lined pond. This would reduce sedimentation and cleaning of the lined pond.

4.3.3.4 AMD Storage

The existing 7-million-gallon lined pond would continue to be used for routine storage needs. The existing in-mine storage volume from about 30 feet below 11 Level and above would be used for larger storage and contingency needs. The diversion systems into the pool would be upgraded for gravity flow.

4.3.3.5 AMD Treatment

The CTP would initially be upgraded to a 2,500-gpm treatment and filtration capacity, which could be sufficient after the initial mitigations are constructed. This means that the reactor residence times and filter throughput rates would be optimally sized for a 2,500-gpm peak flow. The hydraulic throughput and lime feed capacity would be 5,000 gpm to provide redundancy, and also as a contingency measure for higher-than-expected Kellogg Tunnel flows. If additional CTP capacity is needed later, a second neutralization/oxidation reactor and additional filters could be constructed, as described in Appendix E.

4.3.3.6 Sludge Management

One of the four sludge management options described for Alternative 2 would be used. Alternative 3 is expected to produce about 10 percent less sludge than Alternative 2 as a result of the mine flow reductions caused by the mitigations, as discussed below for performance objectives.

4.3.3.7 Performance Monitoring and Phased Approach

Performance monitoring will be analyzed to assess the remedy performance, and also to determine if additional mitigations and/or treatment capacity are warranted using the phased approach. This would be done using performance objectives, performance monitoring, and performance evaluations.

Performance Objectives

The Alternative 3 mitigations are expected to reduce both peak and base flows, and also to reduce the amounts of treatment lime consumed and sludge generated. For this alternative, the treatment plant is initially sized at 2,500 gpm for optimum treatment and filtration performance as described above. Thus the mitigations, in conjunction with in-mine storage, are expected to reduce the peak flows to less than 2,500 gpm at the Kellogg Tunnel portal. Based on the range of percent flow volume reductions (see Table 4-3) and the given uncertainties associated with these estimates, a 10 percent reduction in annual AMD volume, lime consumption, and sludge production is estimated for Alternative 3.

The following summarizes the Alternative 3 mitigation performance objectives:

- Peak Kellogg Tunnel Flow: 2,500 gpm (after in-mine storage)
- Annual AMD Volume Reduction: 10 percent
- Annual Lime Reduction: 10 percent

- Annual Sludge Reduction: 10 percent

Performance Monitoring

Baseline data collected prior to installation of mitigations will provide the basis for determining if the installed mitigations have performed as expected and met the performance objectives. Subsequent performance monitoring data will be contrasted against the baseline data.

The performance monitoring period is expected to be up to 10 years, depending on the hydrologic conditions that affect the flow in West Fork Milo Creek and mine recharge (such as total rainfall and intensity, snow depth and melt rate, and temperature). For example, a relatively dry year with gradual spring warming may not result in significant flow in the West Fork Milo Creek diversion system. Hence, the ability of the West Fork Milo Creek Diversion to reduce peak Kellogg Tunnel flows to less than 2,500 gpm could not be assessed.

The specific monitoring program would be fully defined during remedial design. The following are the anticipated monitoring requirements, which include both surface and in-mine locations. Data collection is expected to be continuous at all sites except where noted below.

- Flow rate in West Fork Milo Creek at the diversion structure and one or two locations upgradient
- The quantity of water diverted by the West Fork Milo Creek Diversion
- The quantity of water diverted by the Phil Sheridan diversion system
- The quantity of water diverted by the existing Mainstem Milo Creek Diversion
- The water depths in all the Milo Gulch piezometers
- Periodic meteorological data consisting of precipitation, snowpack depth and water content, and temperature
- Mine water monitoring at the Kellogg Tunnel portal and at the locations used in the 1998/1999 program. This would include periodic measurement of flow and AMD chemistry, and could include continuous recording at some sites.
- CTP monitoring as required for demonstration of meeting discharge levels. This is expected to include flow measurements, daily samples for pH, TSS, and total metals, and process control monitoring.

Performance Evaluation and Decision Process

Additional mitigations to be considered for implementation are those described in this RI/FS, and also any additional ones identified during performance monitoring. The decision to add additional mitigations or treatment plant capacity will be based on performance evaluations and cost/benefit analyses as described below:

- Performance Evaluations - Periodic reviews, such as once per year, would be conducted by a technical review group to assess the performance of the mitigations with respect to the performance objectives. This would include refinement of the site conceptual model, reassessment of the estimated effectiveness for the remaining mitigations not yet implemented, and recommendations for changes to the monitoring program.

- Cost/Benefit Analysis – A cost/benefit analysis would be conducted if the performance evaluations suggest additional mitigations should be considered. This would consist of updating the mitigation cost estimates, and also the estimates of mitigation benefits. Cost factors to be considered are capital, annual, and life-cycle costs. Benefits to be considered are capital savings if additional treatment plant expansion can be avoided; cost savings for AMD collection, conveyance, storage, treatment, and sludge reductions; and enhanced remedy protectiveness if the flow rate or strength of the AMD can be reduced, thereby reducing the potential for an uncontrolled release to Bunker Creek.
- Selection – Additional mitigations implemented would be those that have favorable cost/benefit ratios, and/or provide required additional protectiveness.

4.3.3.8 Alternative 3 Summary

Table 4-7 summarizes the components of Alternative 3, the Phased Mitigations/Treatment alternative.

4.3.4 Alternative 4—Phased Mitigations/Treatment with Plugging of Near-Stream Workings

Alternative 4 is similar to Alternative 3 except it would include initially plugging the Small Hopes Drift below Mainstem Milo Creek and the Inez Shaft below Deadwood Creek. This would reduce or eliminate the possibility of high stream flows eroding direct flow paths into the mine through these areas.

Table 4-8 summarizes the components of Alternative 4.

4.3.5 Alternative 5—Treatment with All Mitigations

Alternative 5 does not use a phased approach. It consists of initial implementation of all the mitigations listed in Table 3-3 and construction of 2,500 gpm of upgraded treatment plant capacity. Mitigation performance monitoring is assumed to be conducted for only 5 years, because no future mitigations would be implemented. Table 4-9 summarizes the components of Alternative 5.

TABLE 4-1
Estimated Range of Kellogg Tunnel Flow Reductions Resulting from Mitigations
Bunker Hill Mine Water RI/FS Report

Model KT Flow Range	Estimated KT Flow Reductions[1]
KT < 1,500 gpm (low and base flow conditions)	0 percent to 30 percent
1,500 gpm < KT < 2,500 gpm (medium to medium-high flow conditions)	15 percent to 50 percent
2,500 gpm < KT < 3,500 gpm (medium-high to high flow conditions)	30 percent to 70 percent
KT > 3,500 gpm (high to very high flow conditions)	60 percent to 90 percent

[1]The percent flow reductions are for only the increment of flow in the flow interval. For example, if the KT flow were 5,000 gpm and the percent flow reductions for the ranges were 20 percent, 40 percent, 60 percent, and 90 percent, the corresponding flow reductions would be 300, 400, 600, and 1,350 gpm, and the total KT flow would be reduced by 2,650 gpm.

KT = Kellogg Tunnel

TABLE 4-2
Maximum Allowable CTP Effluent Flow Rates to Meet the TMDL Discharge Conditions
Bunker Hill Mine Water RI/FS Report

	Cadmium	Lead	Zinc
7Q10 River Flow Condition			
TMDL (lb/day)	0.0233	0.135	2.43
Max CTP Flow (gpm)	2,773	11,245	2,892
10 percent River Flow Condition			
TMDL (lb/day)	0.031	0.178	3.22
Max CTP Flow (gpm)	3,689	14,827	3,832
50 percent River Flow Condition			
TMDL (lb/day)	0.0659	0.334	6.60
Max CTP Flow (gpm)	7,842	27,821	7,854
90 percent River Flow Condition			
TMDL (lb/day)	0.103	0.297	8.90
Max CTP Flow (gpm)	12,257	24,739	10,591

Note: Anticipated CTP Effluent Concentrations:
Cadmium = <0.70 µg/L
Lead = <1.0 µg/L
Zinc = <70 µg/L
TMDL = total maximum daily load
CTP = Central Treatment Plant

TABLE 4-3
Estimated KT Peak, Average, and Average Annual Volume Reductions[1]
Bunker Hill Mine Water RI/FS Report

	Modeled Range of Mitigation Effectiveness: KT < 1,500 gpm; 1,500<KT<2,500; 2,500<KT<3,500; 3,500 < KT					
	(0,0,0,0%)	**(5,15,30,60%)**	**(10,25,40,70%)**	**(15,30,50,80%)**	**(20,35,60,90%)**	**(30,50,70,90%)**
Peak KT Flow (gpm)	6,700[2]	4,270[2]	3,660[2]	3,120[2]	2,570[2]	2,170[2]
Avg. Annual KT Flow (gpm)	1,700	1,570	1,470	1,380	1,290	1,110
Percent Estimated Average Annual Flow Volume Reduction	0 percent	7.6 percent	13.5 percent	18.8 percent	24.1 percent	34.7 percent

[1]The values are calculated using the 1973, 1974, 1981, 1982, and 1996 water years.
[2]Assumes no in-mine storage
KT = Kellogg Tunnel

TABLE 4-4
Alternatives Summary
Bunker Hill Mine Water RI/FS Report

AMD Mitigations	AMD Collection	AMD Storage	AMD Conveyance	AMD Treatment	Sludge Management	Performance Monitoring
Alternative 1—No Further Action						
None	Existing System	Lined pond for routine storage. In-mine for contingency storage using the existing diversions, pumping systems, and equipment.	The existing pipeline to the lined pond.	Existing CTP with no upgrades for TMDL achievement or repair of equipment failure. The CTP will be shut down when the existing sludge disposal bed is full.	Existing unlined disposal bed on CIA that has about 3 to 5 years remaining capacity. No additional disposal capacity will be built.	Existing monitoring, KT portal (flow and chemistry) and CTP (flow and chemistry).
Alternative 2—Treatment Only						
None	Same as Alternative 1	Same as Alternative 1	The existing pipeline to the lined pond and new section for direct feed to the CTP.	5,000 gpm—updated and configured for more reliable operation and meeting the new discharge levels.	One of three onsite disposal options or one offsite option.	Same as Alternative 1
Alternative 3—Phased Treatment/Mitigations						
Initially: West Fork Milo Creek Diversion, rehabilitate Phil Sheridan Diversion, plug drill holes. Phased Implementation: Other mitigations as determined by performance monitoring and evaluation.	Same as Alternative 1	Lined pond for routine storage. In-mine for contingency storage. This includes a new gravity diversion system down No. 2 Shaft for east side water and one down a location in the Barney Drift for west side water, and an upgraded pumping system using two vertical turbine pumps.	Same as Alternative 2	Initially: 2,500 gpm— updated and configured for more reliable operation and meeting the new discharge levels. Phased Implementation: Additional capacity as determined by performance monitoring and evaluation.	Same as Alternative 2	Up to 10 Years for Phased Approach: Surface streams (flow), Piezometers (groundwater depth) In-mine (flow and chemistry), Ongoing: KT portal (flow and chemistry), and CTP (flow and chemistry).
Alternative 4—Phased Treatment/Mitigations with Plugging of Near-Stream Workings						
Initially: Same as Alternative 3 plus plug the Inez Shaft, and plug the Small Hopes drift. Phased Implementation: Other mitigations as determined by monitoring and evaluation.	Same as Alternative 1	Same as Alternative 3	Same as Alternative 2	Same as Alternative 3	Same as Alternative 2	Same as Alternative 3
Alternative 5—Treatment with All Mitigations						
Same as Alternative 4 plus upgrade Phil Sheridan diversion system to capture more subsurface flow, South Fork Milo Creek Diversion, improve the existing Milo Creek diversion, sidehill diversions in West Milo Creek basin, bypass Bunker Hill Dam. No phased implementation of subsequent mitigations.	Same as Alternative 1	Same as Alternative 3	Same as Alternative 2	2,500 gpm— updated and configured for more reliable operation and meeting the new discharge levels. No phased implementation of additional capacity.	Same as Alternative 2	Up to 5 Years for Mitigation Assessment: Surface streams (flow), Piezometers (groundwater depth), In-mine (flow and chemistry), Ongoing: KT portal (flow and chemistry), and CTP (flow and chemistry).

KT – Kellogg Tunnel
CTP – Central Treatment Plant

TABLE 4-5
Summary of Alternative 1—No Further Action
Bunker Hill Mine Water RI/FS Report

Remedial Component	Description
AMD Mitigations	None—No mitigations would be implemented to reduce water infiltration to the mine and the volume of mine water requiring management.
AMD Collection	The AMD would be collected as is currently done, using the ditches in the drifts and the existing mine pool pumping system, until the CTP is shut down in 3 to 5 years. At this time, all in-mine AMD collection would cease unless done unilaterally by the mine owner for mining operations.
AMD Conveyance	The existing concrete channel and Parshall flume at the KT portal would continue to collect the flow from the KT ditch, measure the flow, and channel it into the buried pipeline for transport to the lined pond. This would continue until the CTP is shut down, at which time the system would not be maintained. The AMD will flow untreated into Bunker Creek.
AMD Storage	The existing in-mine storage system would continue to be used for 3 to 5 years until the CTP is shut down, at which time there would be no need for AMD storage.
AMD Treatment	The existing lime neutralization treatment plant (CTP) would be used with no upgrades for TMDL achievement. No major repairs or improvements would be made, leading to more frequent and longer-duration shutdowns, possibly causing complete CTP failure prior to the sludge impoundment becoming full. Once the sludge impoundment is full (3 to 5 years), the plant would be shut down permanently. The AMD would flow untreated into Bunker Creek.
Sludge Management	Sludge would continue to be pumped from the sludge thickener into the unlined sludge disposal bed on the CIA until it is full. No replacement storage would be provided. Once the existing storage is full, the CTP would need to be shut down because it cannot operate without sludge disposal.
Performance Monitoring	Existing monitoring would be continued until the CTP is shut down, at which time all monitoring would cease.

AMD = acid mine drainage
CIA = Central Impoundment Area
CTP = Central Treatment Plant
KT = Kellogg Tunnel
TMDL = total maximum daily load

TABLE 4-6
Summary of Alternative 2—Treatment Only
Bunker Hill Mine Water RI/FS Report

Remedial Component	Description
AMD Mitigations	None—No mitigations would be implemented to reduce water infiltration to the mine and the volume of mine water requiring management.
AMD Collection	The gravity drainage AMD would be collected as is currently done using the ditches in the drifts. The mine pool would continue to be pumped.
AMD Conveyance	The existing concrete channel and Parshall flume at the KT portal would continue to collect the flow from the KT ditch, measure the flow, and channel it into the buried pipeline. A new section of pipe would normally convey the AMD directly to the CTP, bypassing the lined pond to reduce sediment accumulation.
AMD Storage	The existing 7-million-gallon lined pond would continue to be used for routine storage. The existing in-mine storage system from about 30 feet below 11 Level and up would be used for contingency storage. The existing diversion system to pump from the gravity ditches into the mine pool would be used, and the existing mine pool extraction system would be used to remove water from storage.
AMD Treatment	The CTP would be upgraded to a 5,000 gpm capacity using the high-density sludge lime neutralization process with tri-media filters for achievement of the new treatment discharge levels.
Sludge Management	One of the four sludge management options would be used: Option A: Disposal of raw sludge in onsite sludge disposal beds located on the CIA that both dewater and permanently store the sludge Option B: Mechanical sludge dewatering and disposal of dry sludge in an offsite landfill Option C: Disposal of raw sludge in onsite sludge disposal beds located above the smelter closure area Option D: Sludge drying using sludge drying beds on the CIA and annual excavation and disposal of dry sludge in an onsite landfill located above the smelter closure area
Performance Monitoring	Monitoring would be conducted at the KT portal and at the CTP effluent flow to Bunker Creek, as is currently done. The KT portal monitoring is expected to include continuous flow recording and periodic (weekly or bi-weekly) samples for pH, TSS, lime demand/solids formed, and total cadmium, lead, and zinc analysis. The CTP effluent flow would be monitored and is expected to consist of daily sampling for pH, TSS, and total metals.

AMD = acid mine drainage
CIA = Central Impoundment Area
CTP = Central Treatment Plant
KT = Kellogg Tunnel
TMDL = total maximum daily load
TSS = total suspended solids

TABLE 4-7
Summary of Alternative 3—Phased Mitigations/Treatment
Bunker Hill Mine Water RI/FS Report

Remedial Component	Description
AMD Mitigations	Initial mitigations would be as follows. Additional mitigations would be phased: • West Fork Milo Creek Diversion • Rehabilitate the Phil Sheridan Diversion • Drill hole plugging
AMD Collection	The gravity drainage AMD would be collected as is currently done using the ditches in the drifts. The mine pool would continue to be pumped.
AMD Conveyance	The existing concrete channel and Parshall flume at the KT portal would continue to collect the flow from the KT ditch, measure the flow, and channel it into the buried pipeline. A new section of pipe would normally convey the AMD directly to the CTP, bypassing the lined pond.
AMD Storage	The existing 7-million-gallon lined pond would continue to be used for routine storage. In-mine storage from about 30 feet below 11 Level and up would be used for contingency storage. Gravity diversions to the mine pool would be constructed, and two 700-gpm pumps installed in No. 2 Shaft to remove stored water and for ongoing mine pool pumping.
AMD Treatment	The initial optimum treatment and filtration capacity would be 2,500 gpm, but the lime feed and hydraulic throughput capacity would be 5,000 gpm as a contingency measure for higher-than-expected KT flows. A second neutralization/oxidation reactor and additional filters would be constructed later if needed. Alternative 3 is expected to use about 10 percent less lime than Alternatives 1 or 2.
Sludge Management	Alternative 3 is expected to produce about 10 percent less sludge than Alternatives 1 or 2. One of the following four sludge management options would be used: Option A: Disposal of raw sludge in onsite sludge disposal beds located on the CIA that both dewater and permanently store the sludge Option B: Mechanical sludge dewatering and disposal of dry sludge in an offsite landfill Option C: Disposal of raw sludge in onsite sludge disposal beds located above the smelter closure area Option D: Sludge drying using sludge drying beds on the CIA and annual excavation and disposal of dry sludge in an onsite landfill located above the smelter closure area
Performance Monitoring	Performance monitoring and evaluation for up to 10 years would be used to support the phased approach, and would consist of: • The quantity of water diverted by the West Fork Milo Creek Diversion, the Phil Sheridan Diversion, and the existing Mainstem Milo Creek Diversion • The water depths in all the Milo Gulch piezometers • Meteorological data consisting of precipitation, snowpack depth and water content, and temperature • KT portal monitoring and in-mine monitoring at the locations used in the 1998/1999 program for flow and chemistry (KT portal monitoring would continue beyond 10 years) • CTP discharge monitoring. This is expected to include flow measurements, daily samples for pH, TSS, and total metals, and process control monitoring (would continue beyond 10 years).

AMD = acid mine drainage
CIA = Central Impoundment Area
CTP = Central Treatment Plant
KT = Kellogg Tunnel
TSS = total suspended solids

TABLE 4-8
Summary of Alternative 4—Phased Mitigations/Treatment with Plugging of Near-Stream Workings
Bunker Hill Mine Water RI/FS Report

Remedial Component	Description
AMD Mitigations	Initial mitigations would be as follows. Additional mitigations would be phased: • West Fork Milo Creek Diversion • Rehabilitate the Phil Sheridan Diversion • Drill hole plugging • Plug the Small Hopes drift below Mainstem Milo Creek • Plug the Inez Shaft below Deadwood Creek
AMD Collection	The gravity drainage AMD would be collected as is currently done using the ditches in the drifts. The mine pool would continue to be pumped.
AMD Conveyance	The existing concrete channel and Parshall flume at the KT portal would continue to collect the flow from the KT ditch, measure the flow, and channel it into the buried pipeline. A new section of pipe would normally convey the AMD directly to the CTP, bypassing the lined pond.
AMD Storage	The existing 7-million-gallon lined pond would continue to be used for routine storage. In-mine storage from about 30 feet below 11 Level and up would be used for contingency storage. Gravity diversions to the mine pool would be constructed, and two 700-gpm pumps installed in No. 2 Shaft to remove stored water and for ongoing mine pool pumping.
AMD Treatment	The initial optimum treatment and filtration capacity would be 2,500 gpm, but the lime feed and hydraulic throughput capacity would be 5,000 gpm as a contingency measure for higher-than-expected KT flows. A second neutralization/oxidation reactor and additional filters would be constructed later if needed. Alternative 4 is expected to use about 10 percent less lime than Alternatives 1 or 2.
Sludge Management	Alternative 4 is expected to produce about 10 percent less sludge than Alternatives 1 or 2. One of the following four sludge management options would be used: Option A: Disposal of raw sludge in onsite sludge disposal beds located on the CIA that both dewater and permanently store the sludge Option B: Mechanical sludge dewatering and disposal of dry sludge in an offsite landfill Option C: Disposal of raw sludge in onsite sludge disposal beds located above the smelter closure area Option D: Sludge drying using sludge drying beds on the CIA and annual excavation and disposal of dry sludge in an onsite landfill located above the smelter closure area
Performance Monitoring	Performance monitoring and evaluation for up to 10 years would be used to support the phased approach, and would consist of: • The quantity of water diverted by the West Fork Milo Creek Diversion, the Phil Sheridan Diversion, and the existing Mainstem Milo Creek Diversion • The water depths in all the Milo Gulch piezometers • Meteorological data consisting of precipitation, snowpack depth and water content, and temperature • KT portal monitoring and in-mine monitoring at the locations used in the 1998/1999 program for flow and chemistry (KT portal monitoring would continue beyond 10 years) • CTP discharge monitoring. This is expected to include flow measurements, daily samples for pH, TSS, and total metals, and process control monitoring (would continue beyond 10 years).

AMD = acid mine drainage
CIA = Central Impoundment Area
CTP = Central Treatment Plant
KT = Kellogg Tunnel
TSS = total suspended solids

TABLE 4-9
Summary of Alternative 5—Treatment with All Mitigations
Bunker Hill Mine Water RI/FS Report

Remedial Component	Description
AMD Mitigations	The following mitigations would be constructed. A phased approach would not be used. • West Fork Milo Creek Diversion • Rehabilitate the Phil Sheridan Diversion • Drill hole plugging • Plug the Small Hopes Drift below Mainstem Milo Creek • Plug the Inez Shaft below Deadwood Creek • Sidehill diversion in West Fork Milo Basin • South Fork Milo Creek Diversion • Bypass Bunker Hill Dam in Mainstem Milo Creek • Improve existing diversion in Mainstem Milo Creek • Upgrade Phil Sheridan raise system in West Fork Milo Basin
AMD Collection	The gravity drainage AMD would be collected as is currently done using the ditches in the drifts. The mine pool would continue to be pumped.
AMD Conveyance	The existing concrete channel and Parshall flume at the KT portal would continue to collect the flow from the KT ditch, measure the flow, and channel it into the buried pipeline. A new section of pipe would normally convey the AMD directly to the CTP, bypassing the lined pond.
AMD Storage	The existing 7-million-gallon lined pond would continue to be used for routine storage. In-mine storage from about 30 feet below 11 Level and up would be used for contingency storage. Gravity diversions to the mine pool would be constructed, and two 700-gpm pumps installed in No. 2 Shaft to remove stored water and for ongoing mine pool pumping.
AMD Treatment	The CTP would be upgraded for optimum treatment and filtration at 2,500 gpm capacity, but the lime feed and hydraulic throughput capacity would be 5,000 gpm as a contingency measure for higher-than-expected KT flows. A phased approach for considering future CTP capacity upgrades would not be used. Alternative 5 is expected to use about 20 percent less lime than Alternatives 1 or 2.
Sludge Management	Alternative 5 is expected to produce about 20 percent less sludge than Alternatives 1 or 2. One of the following four sludge management options would be used: Option A: Disposal of raw sludge in onsite sludge disposal beds located on the CIA that both dewater and permanently store the sludge Option B: Mechanical sludge dewatering and disposal of dry sludge in an offsite landfill Option C: Disposal of raw sludge in onsite sludge disposal beds located above the smelter closure area Option D: Sludge drying using sludge drying beds on the CIA and annual excavation and disposal of dry sludge in an onsite landfill located above the smelter closure area
Performance Monitoring	Mitigation performance monitoring would be conducted for up to 5 years, and would consist of: • The quantity of water diverted by the West Fork Milo Creek Diversion, South Fork Milo Creek Diversion, the Phil Sheridan Diversion, and the existing Mainstem Milo Creek Diversion • The water depths in all the Milo Gulch piezometers • Meteorological data consisting of precipitation, snowpack depth and water content, and temperature • KT portal monitoring and in-mine monitoring at the locations used in the 1998/1999 program for flow and chemistry (KT portal monitoring would continue beyond 10 years) • CTP discharge monitoring would be conducted, and would continue beyond 5 years. This is expected to include flow measurements, daily samples for pH, TSS, and total metals, and process control monitoring.

AMD = acid mine drainage
CIA = Central Impoundment Area
CTP = Central Treatment Plant
KT = Kellogg Tunnel
TSS = total suspended solids

Notes:

→ Mine Water Flow Direction

1. Calculate TMDLs - TMDLs are calculated for cadmium, lead and zinc (lbs/day) according to daily SFCdA River flows. Discharge flows are then calculated by dividing the TMDL by effluent concentrations (ug/L) that were input to the model. The minimum flow is selected from the three metals and termed "allowable discharge flow" (gpm).

2. KT flow is compared to CTP capacity. If mitigations are used, the KT flow is reduced accordingly. AMD is pumped or diverted until KT flow equals CTP capacity. AMD cannot be pumped if storage is empty, so in some cases KT flow is less than CTP capacity.

3. CTP discharge flow (gpm) is compared to the allowable discharge flow (gpm) calculated in Step 1. If CTP discharge flow is greater than allowable discharge flow, AMD is diverted to the Mine Pool until they are equal.

4. Storage is calculated by adding the pump/diversion rates determined in Step 2 to the diversion rates in Step 3.

5. If treated storage is selected in the model input without the alternative water use option, water that is diverted in the third step is first placed in a treated storage pond until it is full. Treated storage is placed in the SFCdA River when flows and therefore allowable discharge is greater than CTP discharge.

6. If alternative water use is selected as an option, alternative water use takes precedence over discharge to the SFCdA River or storage in the treated storage pond. In the event that the alternative water use demand is higher than the amount of water treated at the CTP, any water stored in the treated storage pond (if selected in the model input) will be used to meet the alternative water demand.

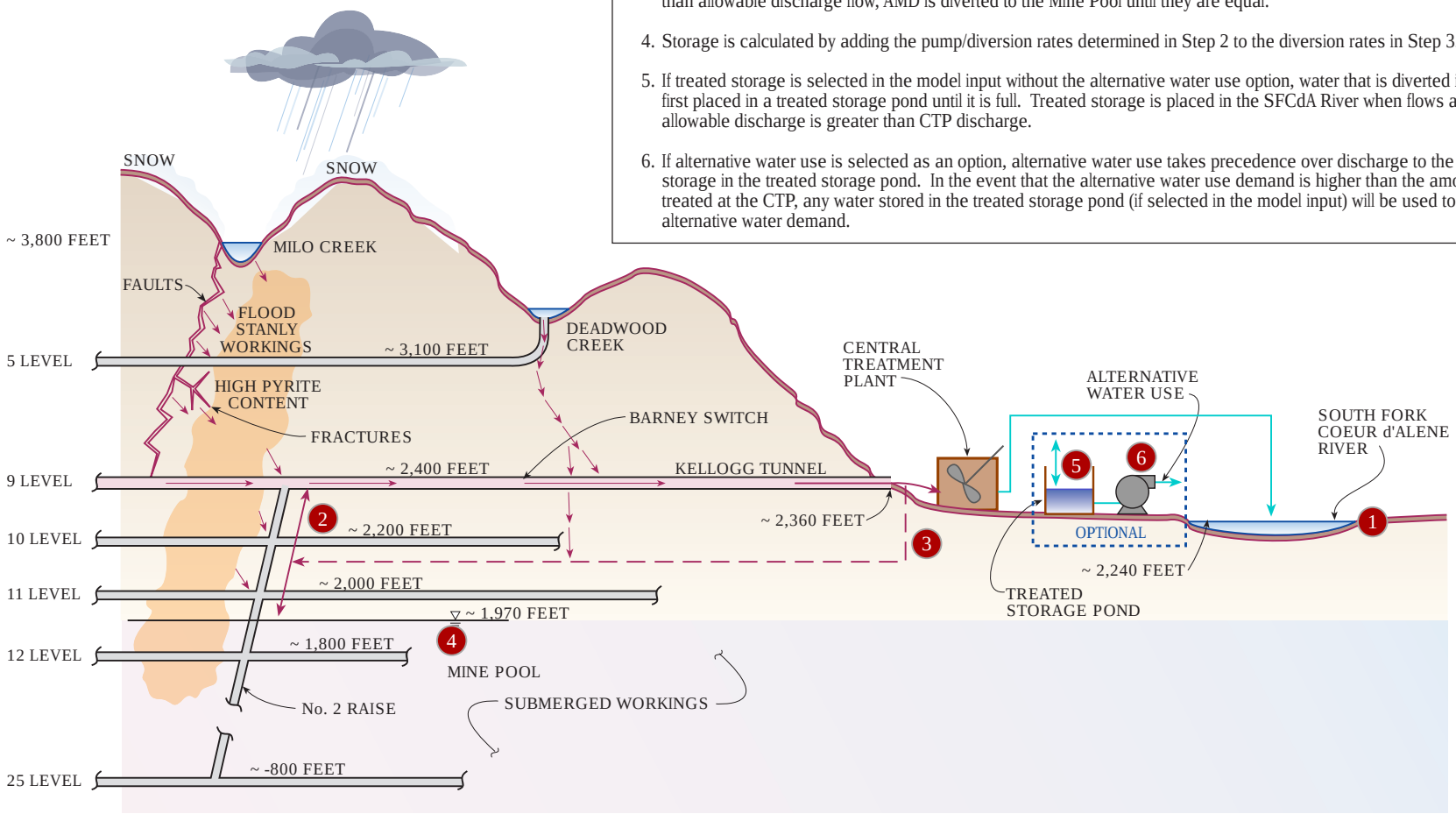

FIGURE 4-1

TMDL COMPUTER MODEL LOGIC

BUNKER HILL MINE WATER MANAGEMENT RI/FS

CH2MHILL

FIGURE 4-2
WATER YEAR 1973
KELLOGG TUNNEL HYDROGRAPH
BUNKER HILL MINE WATER MANAGEMENT RI/FS

CH2MHILL

E122000003CVO 152215.FS.02 Bunker Hill *Fig 4-03.fh8 01/18/01 ams

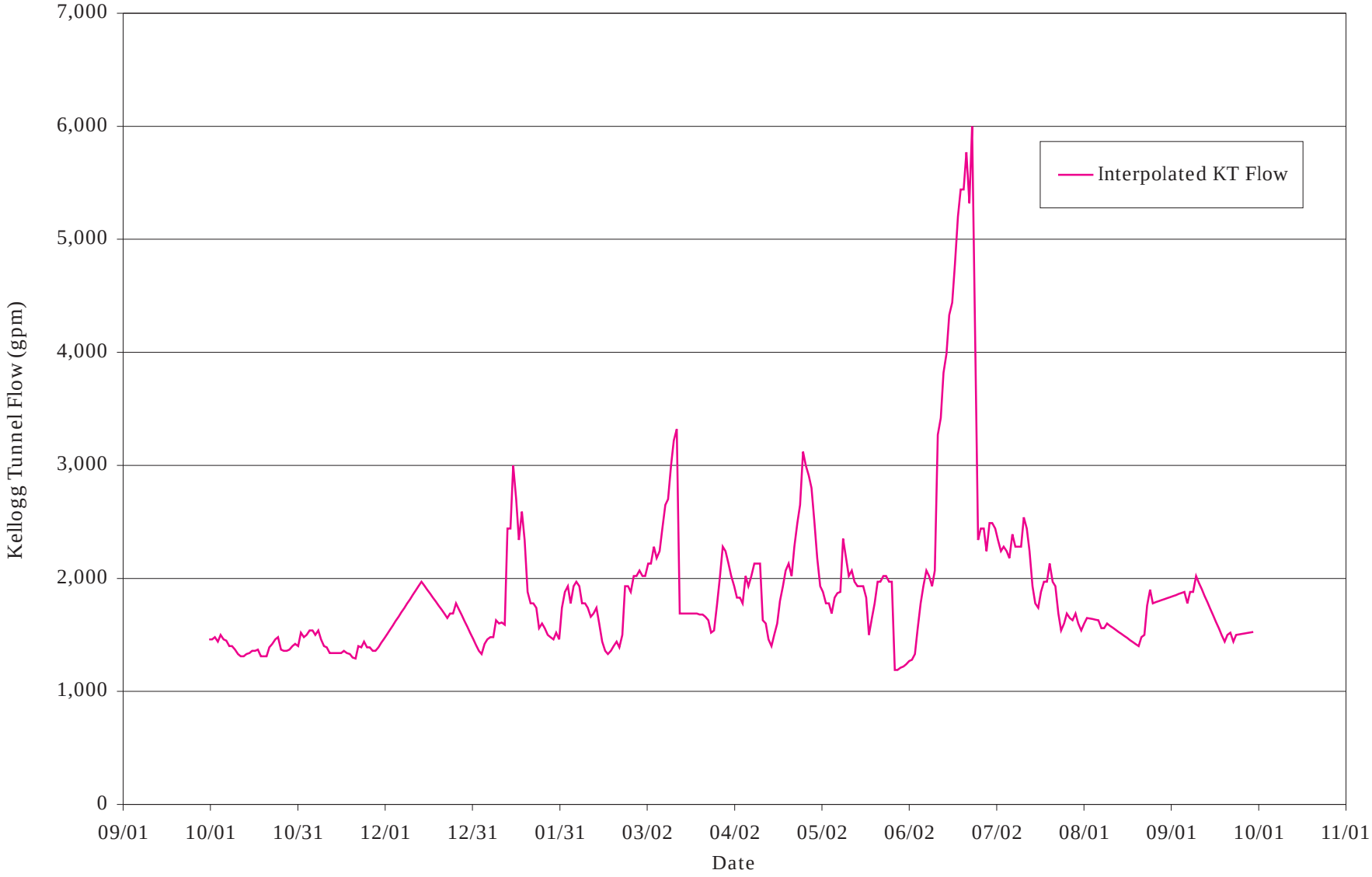

FIGURE 4-3
WATER YEAR 1974
KELLOGG TUNNEL HYDROGRAPH
BUNKER HILL MINE WATER MANAGEMENT RI/FS

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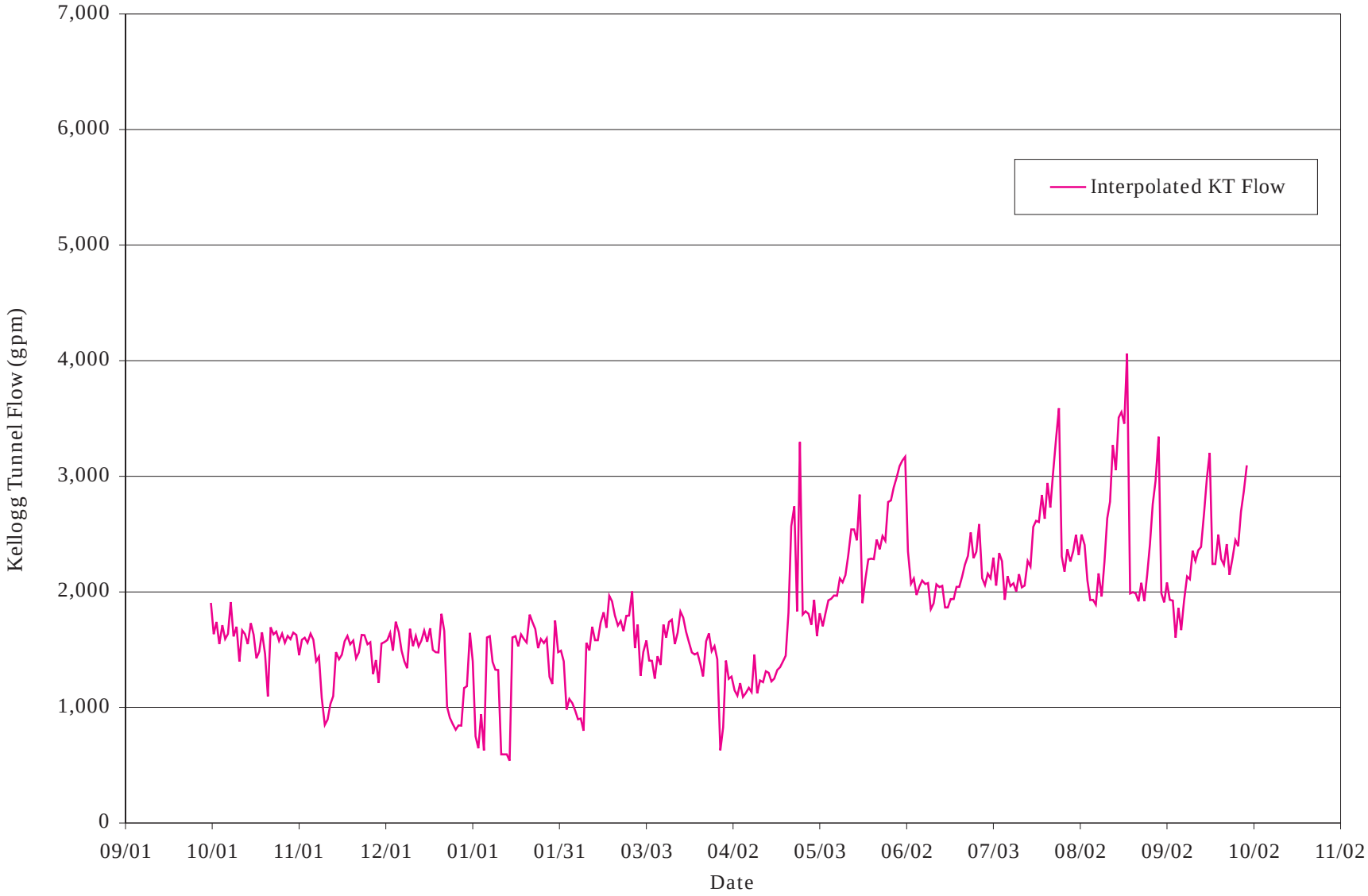

FIGURE 4-4
WATER YEAR 1981
KELLOGG TUNNEL HYDROGRAPH
BUNKER HILL MINE WATER MANAGEMENT RI/FS

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FIGURE 4-5
WATER YEAR 1982
KELLOGG TUNNEL HYDROGRAPH
BUNKER HILL MINE WATER MANAGEMENT RI/FS

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FIGURE 4-6
WATER YEAR 1996
KELLOGG TUNNEL HYDROGRAPH
BUNKER HILL MINE WATER MANAGEMENT RI/FS

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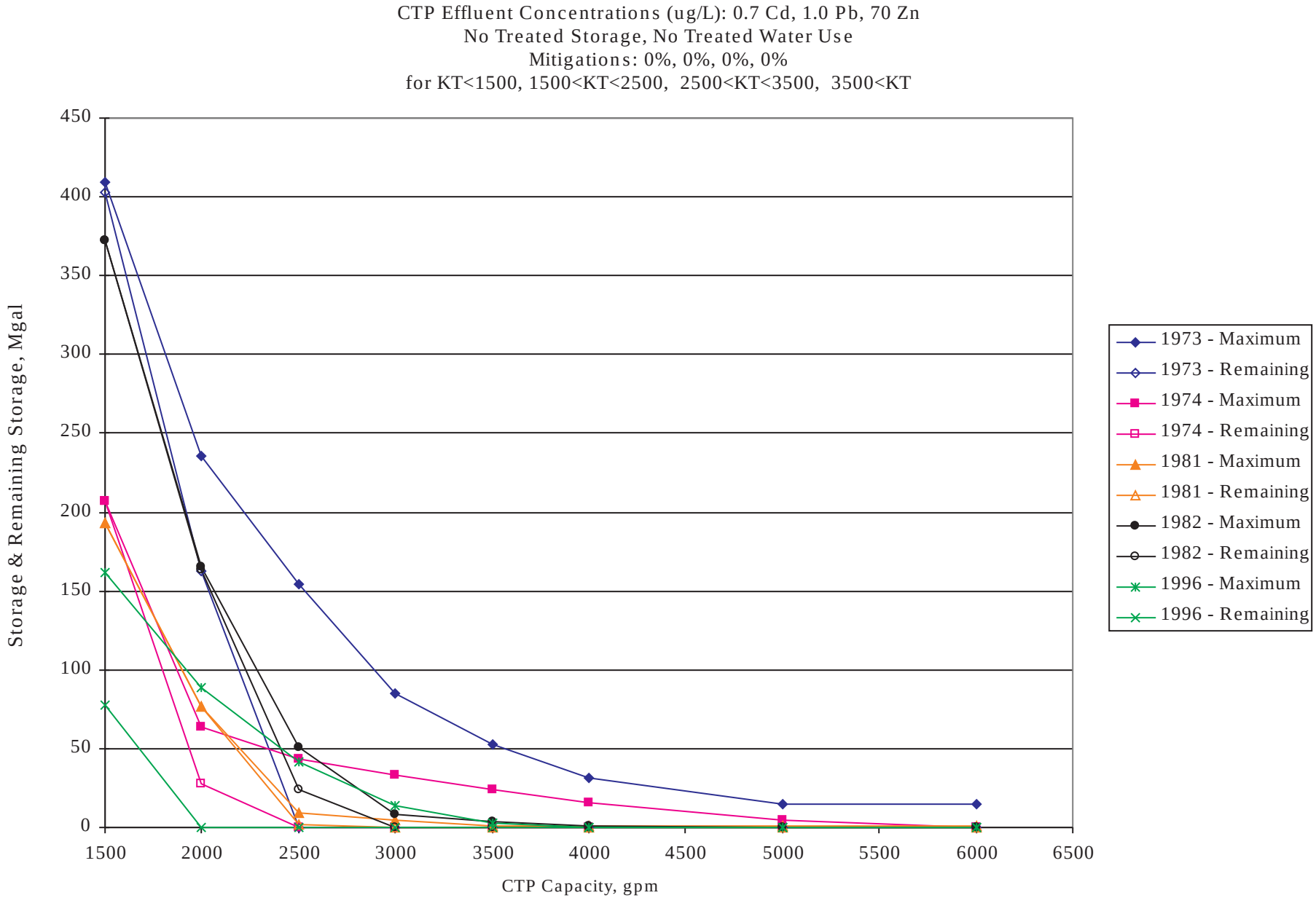

FIGURE 4-7

REQUIRED AND REMAINING STORAGE VS. CTP CAPACITY (0%, 0%, 0%, 0% EFFECTIVE MITIGATIONS)

BUNKER HILL MINE WATER MANAGEMENT RI/FS

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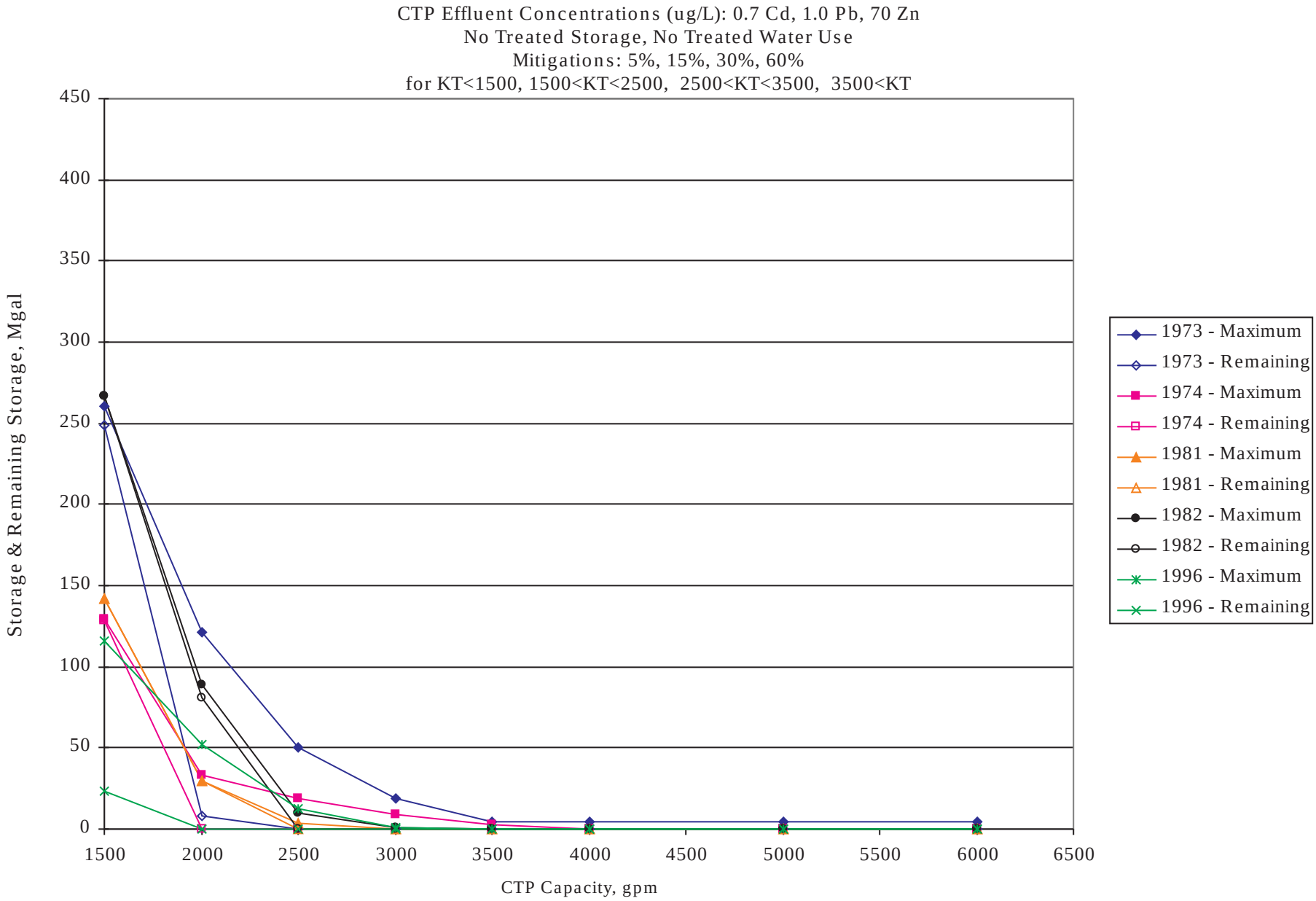

FIGURE 4-8

REQUIRED AND REMAINING STORAGE VS. CTP CAPACITY (5%, 15%, 30%, 60% EFFECTIVE MITIGATIONS)

BUNKER HILL MINE WATER MANAGEMENT RI/FS

CH2MHILL

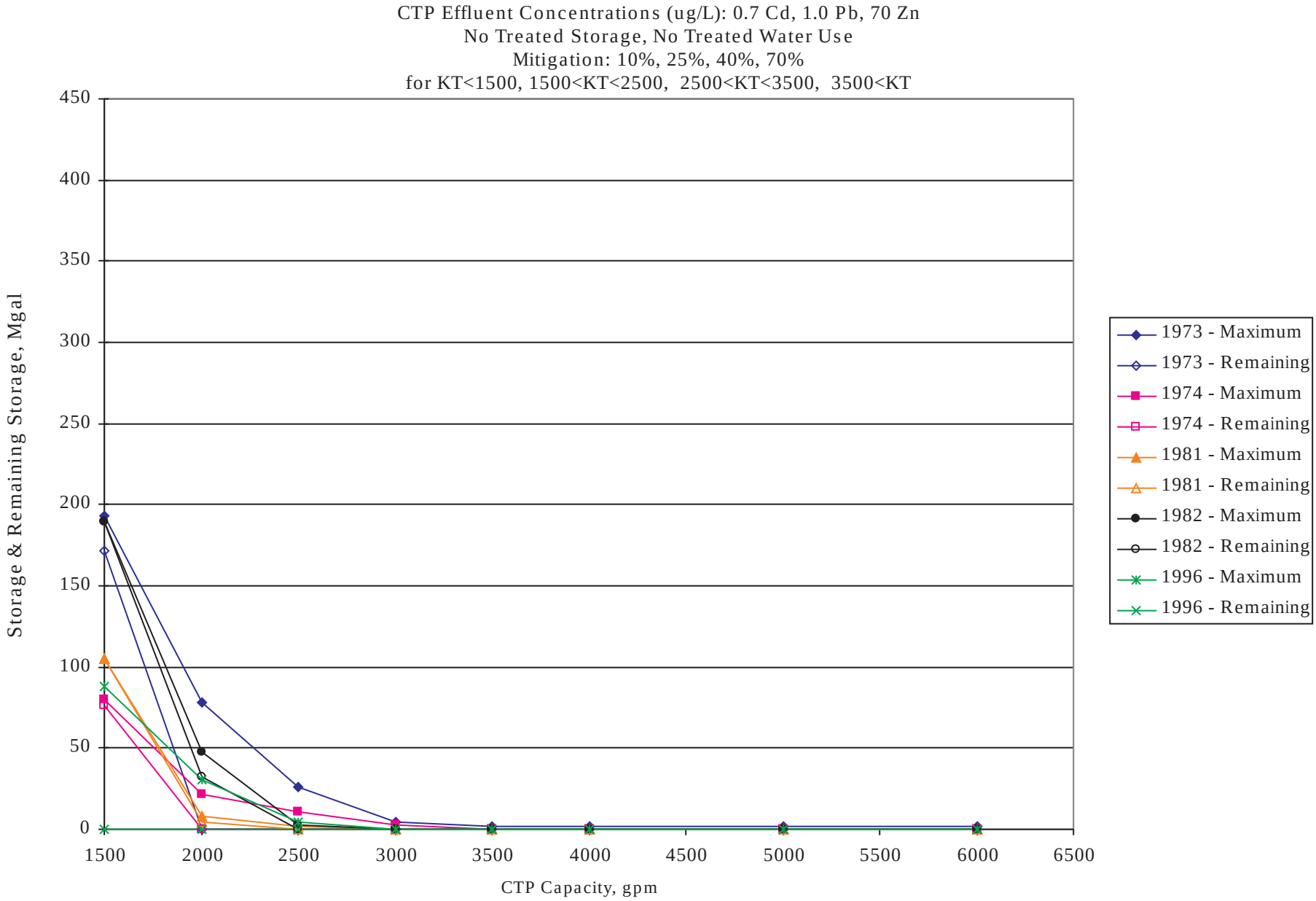

FIGURE 4-9

REQUIRED AND REMAINING STORAGE VS. CTP CAPACITY (10%, 25%, 40%, 70% EFFECTIVE MITIGATIONS)

BUNKER HILL MINE WATER MANAGEMENT RI/FS

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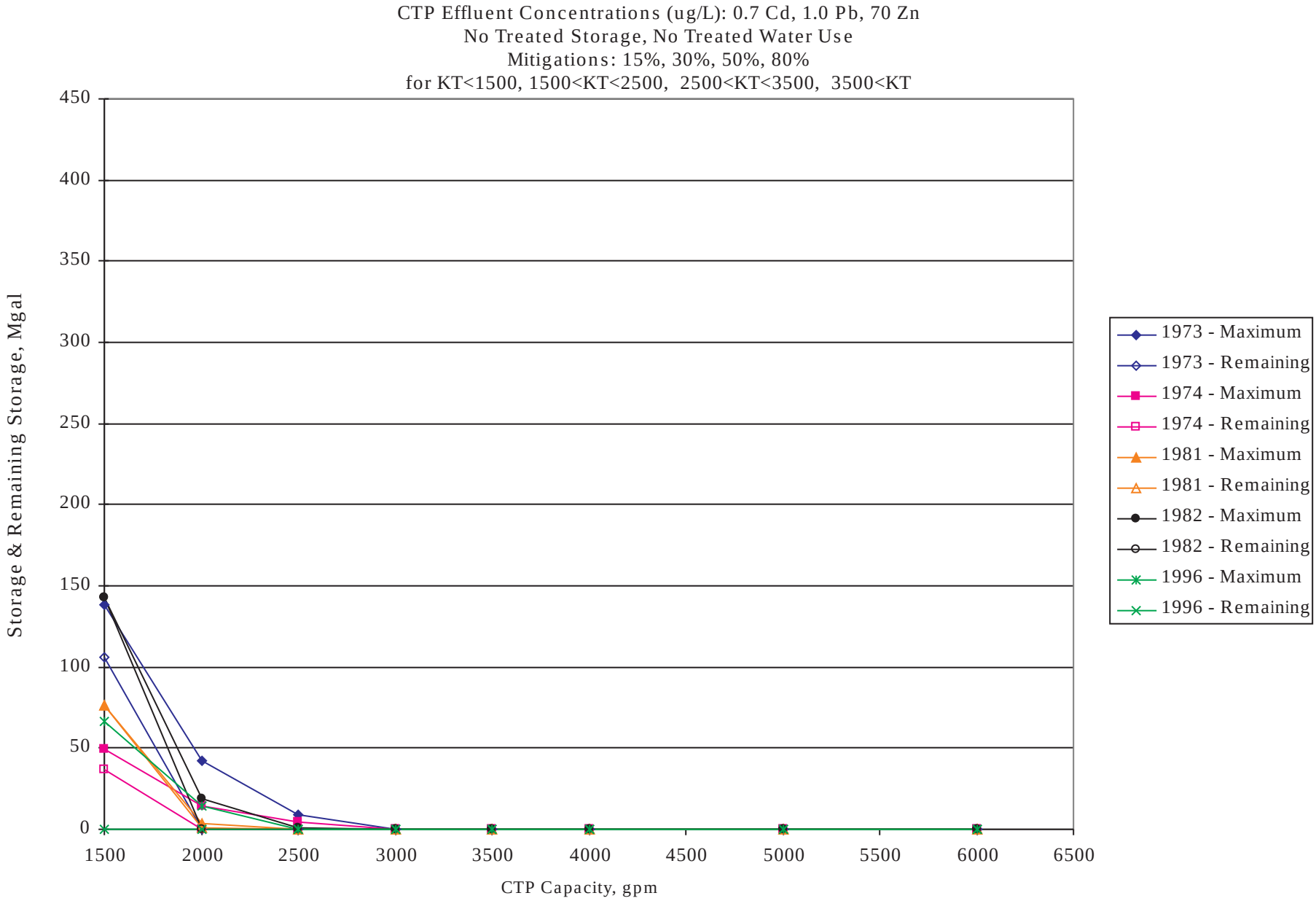

FIGURE 4-10

REQUIRED AND REMAINING STORAGE VS. CTP CAPACITY
(15%, 30%, 50%, 80% EFFECTIVE MITIGATIONS)

BUNKER HILL MINE WATER MANAGEMENT RI/FS

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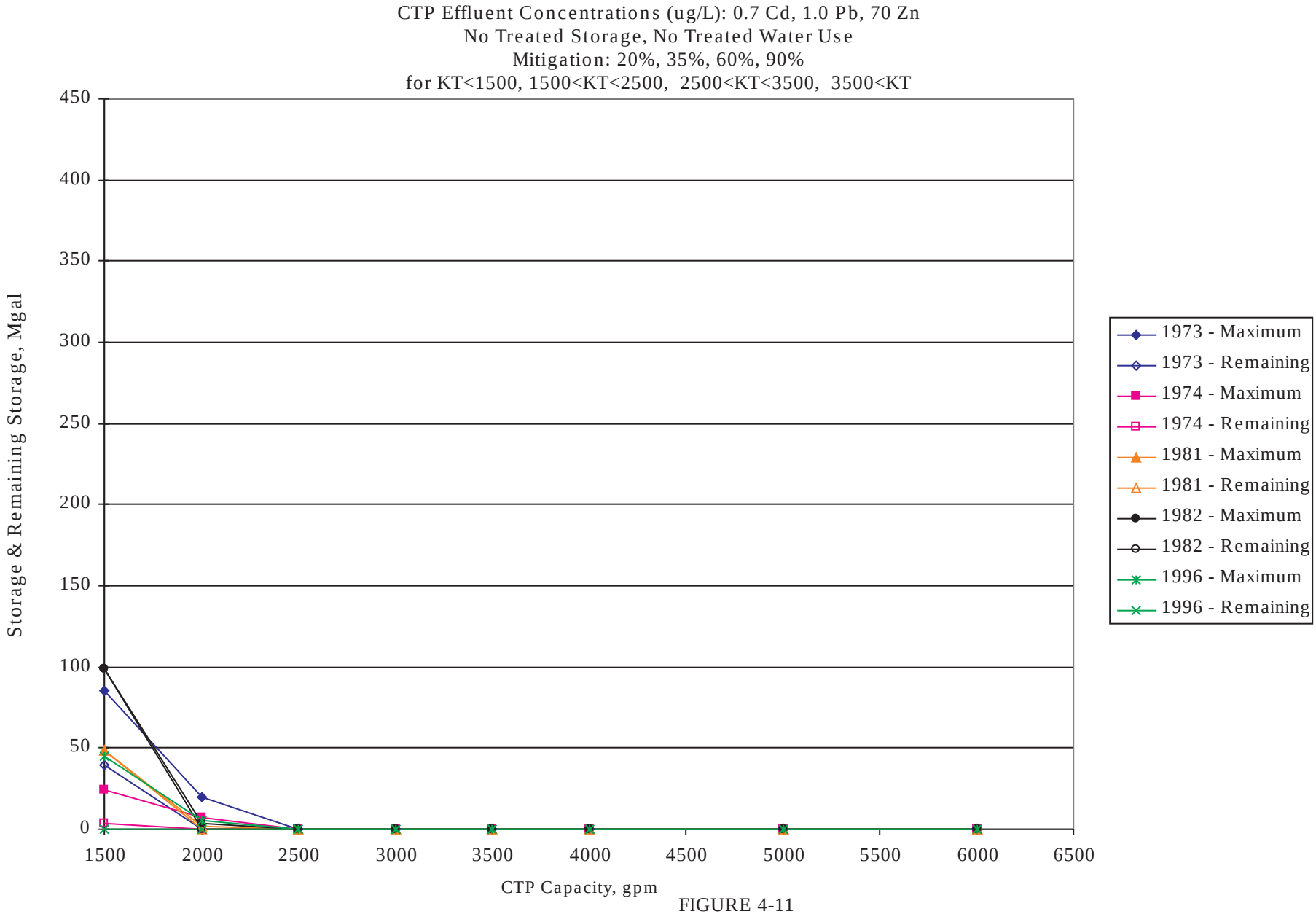

FIGURE 4-11

REQUIRED AND REMAINING STORAGE VS. CTP CAPACITY (20%, 35%, 60%, 90% EFFECTIVE MITIGATIONS)

BUNKER HILL MINE WATER MANAGEMENT RI/FS

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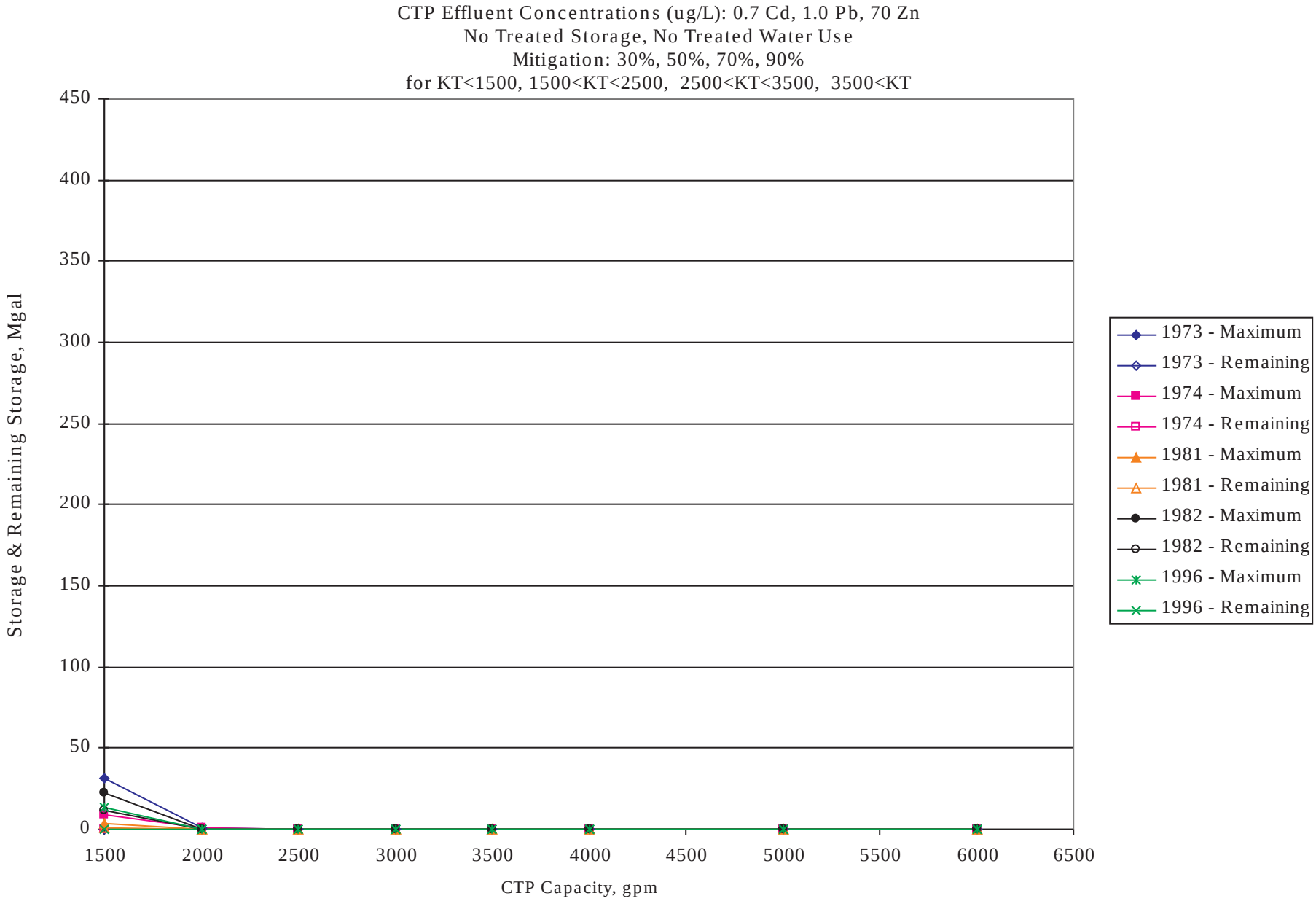

FIGURE 4-12

REQUIRED AND REMAINING STORAGE VS. CTP CAPACITY (30%, 50%, 70%, 90% EFFECTIVE MITIGATIONS)

BUNKER HILL MINE WATER MANAGEMENT RI/FS

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E122000003CVO 152215.FS.02 Bunker Hill *Fig 4-13.fh8 01/18/01 ams

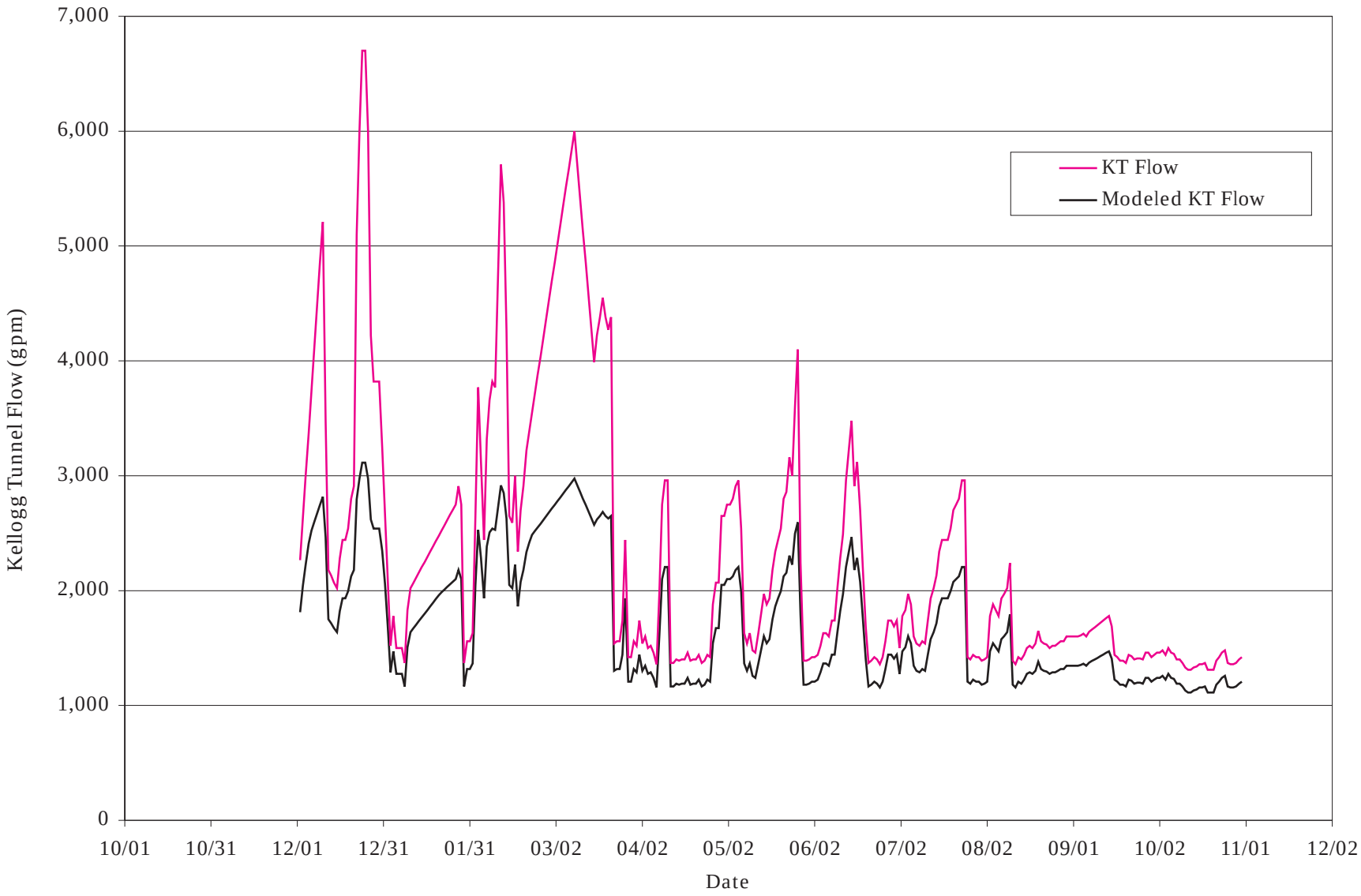

FIGURE 4-13

WATER YEAR 1973 KELLOGG TUNNEL HYDROGRAPH COMPARED TO A MODELED FLOW REDUCTION OF 15, 30, 50, 80%

BUNKER HILL MINE WATER MANAGEMENT RI/FS

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SECTION 5.0

Detailed Evaluation of Alternatives [Draft Final]

5. Detailed Evaluation of Alternatives

Section 5 presents the detailed evaluation of alternatives required by the NCP in 40 CFR 300.430(e)(9). The remedial alternatives were described in detail in Section 4 and are only briefly described in this section. Although the alternatives have been developed to a significant level of detail in this report and in technical memoranda presented in the appendices, it should be noted that the level of detail at this stage is still considered conceptual. Design details and cost estimates will continue to be refined following selection of an alternative and up until final implementation of the remedial action. Section 5.3 provides a comparative analysis that focuses on the relative performance of each alternative against the evaluation criteria.

5.1 Introduction of Evaluation Criteria

The NCP specifies nine criteria for evaluating remedial alternatives [40 CFR 300.430(e)(9)]. The nine criteria fall into three groups: threshold criteria, primary balancing criteria, and modifying criteria. The first two criteria are the threshold criteria, which each alternative must meet to be eligible for selection. The next four criteria are the primary balancing criteria, which are used to weigh major trade-offs among alternatives. The final two criteria are the modifying criteria, which may be considered to the extent that information is available during the FS, but can be fully considered only after receipt of state and public comments in response to the RI/FS. In the final balancing of trade-offs between alternatives upon which the final remedy selection is based, modifying criteria are of equal importance to the balancing criteria.

This section consists of an assessment and comparative analysis of the alternatives with respect to the two threshold criteria and the five balancing criteria. The two modifying criteria, State Acceptance and Community Acceptance, will be evaluated by EPA following receipt of state and public comments at community meetings, agency meetings, and written comments submitted by the state and public in response to the RI/FS. All nine of the criteria are described below:

1. Overall Protection of Human Health and the Environment (Threshold Criterion)

The NCP requires that alternatives "be assessed to determine whether they can adequately protect human health and the environment, in both the short- and long-term, from unacceptable risks posed by hazardous substances, pollutants, or contaminants present at the site by eliminating, reducing or controlling exposure...."

2. Compliance with Applicable or Relevant and Appropriate Requirements (Threshold Criterion)

The NCP [40 CFR 300.430(e)(9)(B)] requires that alternatives "be assessed to determine whether they attain applicable or relevant and appropriate requirements under federal environmental laws and state environmental or facility siting laws or provide grounds for invoking one of the waivers under paragraph (f)(1)(ii)(c) of this section." It is important to

note that the ARARs identified in the discussion below for each alternative are preliminary, and that EPA will make the final determination of applicable ARARs as part of the remedy selection. In addition to ARARs, the TMDL, which was identified as a potential TBC, is also discussed below.

3. Long-Term Effectiveness and Permanence (Balancing Criterion)

The NCP in 40 CFR 300.430(e)(9(C) requires that alternatives be:

"...assessed for the long-term effectiveness and permanence they afford, along with the degree of certainty that the alternative will prove successful. Factors that shall be considered, as appropriate, include the following:

1. Magnitude of residual risk remaining from untreated waste or treatment residuals remaining at the conclusion of the remedial activities. The characteristics of the residuals should be considered to the degree that they remain hazardous, taking into account their volume, toxicity, mobility and propensity to bioaccumulate.

2. Adequacy and reliability of controls such as containment systems and institutional controls that are necessary to manage treatment residuals and untreated waste. This factor addresses in particular the uncertainties associated with land disposal for providing long-term protection from residuals; the assessment of the potential need to replace technical components of the alternative, such as a cap, a slurry wall, or a treatment system; and the potential exposure pathways and risks posed should the remedial action need replacement."

4. Reduction of Toxicity, Mobility, or Volume through Treatment (Balancing Criterion)

The NCP in 40 CFR 300.430(e)(9)(D) requires that:

"The degree to which alternatives employ recycling or treatment that reduces toxicity, mobility, or volume shall be assessed, including how treatment is used to address the principal threats posed by the site. Factors that shall be considered, as appropriate, include the following:

1. The treatment or recycling processes the alternatives employ and materials they will treat;

2. The amount of hazardous substances, pollutants, or contaminants that will be destroyed, treated, or recycled;

3. The degree of expected reduction in toxicity, mobility, or volume of the waste due to treatment or recycling and the specification of which reduction(s) are occurring;

4. The degree to which the treatment is irreversible;

5. The type and quantity of residuals that will remain following treatment, considering the persistence, toxicity, mobility, and propensity to bioaccumulate of such hazardous substances and their constituents; and

6. The degree to which treatment reduces the inherent hazards posed by principal threats at the site."

5. Short-Term Effectiveness (Balancing Criterion)

The NCP in 40 CFR 300.430(e)(9)(E) requires that:

"The short-term impacts of alternatives shall be assessed considering the following:

1. Short-term risks that might be posed to the community during implementation of an alternative;
2. Potential impacts on workers during remedial action and the effectiveness and reliability of protective measures;
3. Potential environmental impacts of the remedial action and the effectiveness and reliability of mitigative measures during implementation; and
4. Time until protection is achieved."

6. Implementability (Balancing Criterion)

The NCP in 40 CFR 300.430(e)(9)(F) requires that:

"The ease or difficulty of implementing the alternatives shall be assessed by considering the following types of factors as appropriate:

1. Technical feasibility, including technical difficulties and unknowns associated with the construction and operation of a technology, the reliability of the technology, ease of undertaking additional remedial actions, and the ability to monitor the effectiveness of the remedy;
2. Administrative feasibility, including activities needed to coordinate with other offices and agencies and the ability and time required to obtain any necessary approvals and permits from other agencies (for off-site actions);
3. Availability of services and materials, including the availability of adequate off-site treatment, storage capacity, and disposal capacity and services; the availability of necessary equipment and specialists, and provisions to ensure any necessary additional resources; the availability of services and materials; and availability of prospective technologies."

7. Cost (Balancing Criterion)

The NCP in 40 CFR 300.430 (e)(9)(G) requires that:

"The types of costs that shall be assessed include the following:

1. Capital costs, including both direct and indirect costs,
2. Annual operation and maintenance costs, and
3. Net present value of capital and operation and maintenance costs."

The detailed evaluation of costs that were developed pursuant to this requirement allows evaluations and comparisons of the costs of the respective alternatives. The detailed analysis presented here draws no conclusion as to the "cost-effectiveness" of the respective

alternatives. The cost-effectiveness finding, which is required by CERCLA, will be determined in the remedy selection phase.

For detailed analysis of alternatives, EPA guidelines recommend that costs be developed with an accuracy of plus 50 percent to minus 30 percent (EPA, 2000f). Cost estimates developed in the analysis of alternatives include capital , and annual O&M costs.

Capital costs are those expenditures that are required to construct a remedial action. Capital costs include all labor, equipment, and material costs, including contractor markups such as overhead and profit, associated with mobilization/demobilization and construction. Capital costs also include expenditures for professional/technical services necessary to support construction of the remedial action.

Annual O&M costs are those costs necessary to ensure the continued effectiveness of the selected remedy following construction. Annual O&M costs include all labor, equipment, and material costs, including contractor markups, associated with activities such as monitoring, operating and maintaining remedial systems, and sludge disposal. Annual O&M costs also include expenditures for professional/technical services necessary to support O&M activities.

All future costs are reduced to net present values to allow equitable comparison of individual remedial alternatives. Net present value costs evaluate expenses over time by discounting future costs to a common base year using a discount rate. The discount rate used is 7 percent, and the present worth analysis period is 30 years for each alternative.

8. State Acceptance (Modifying Criterion)

The NCP in 40 CFR 200.430(e)(9)(H) requires that:

"Assessment of State concerns may not be completed until comments on the RI/FS are received but may be discussed to the extent possible in the proposed plan issued for public comment. The state concerns that shall be assessed include the following:

1. The state's position and key concerns related to the preferred alternative and other alternatives, and
2. State comments on ARARs or the proposed use of waivers."

IDEQ has participated with EPA and other parties over the past few years in the site investigations and analyses associated with this RI/FS, and is in agreement with the alternatives developed in this feasibility study. Issues of concern and goals expressed by the state during the development of this RI/FS include maximizing the extent of developable land within the Bunker Hill Superfund site, maximizing the reduction in the quantity of AMD discharge by source control measures, and minimizing the costs of long-term O&M that may be borne by the state or private parties.

9. Community Acceptance (Modifying Criterion)

The NCP in 40 CFR 300.430(e)(9)(I) requires that an assessment of community acceptance:

"Includes determining which components of the alternatives interested persons in the community support, have reservations about, or oppose. This assessment may not be completed until comments on the proposed plan are received."

As mentioned previously, evaluations of the two final evaluation criteria, State Acceptance and Community Acceptance, are not performed in this document. The NCP provides for opportunities for the public and the state to participate in a review of the alternatives evaluation in a public meeting. The NCP also provides state agencies and the public the opportunity to comment on a proposed plan for remedial action. Final evaluations of the State Acceptance and Community Acceptance criteria will be performed after allowing for state and community input into the remedy selection process. These evaluations are considered during remedy selection.

5.2 Individual Analysis of Each Alternative

This section provides an analysis of each of the alternatives relative to the two threshold criteria and five balancing criteria described above. Each analysis begins with a description of the alternative followed by a criterion-by-criterion evaluation of the alternative.

5.2.1 Alternative 1—No Further Action

5.2.1.1 Description

The NCP in 40 CFR 300.430(e)(6) requires preparation and development of a "No-Action" alternative. With respect to evaluating the alternative's potential for meeting the remedial action objectives for the Bunker Hill mine water, the no-action alternative should be considered as "no further action." The no-action alternative is commonly used as a baseline alternative against which other alternatives are judged. This alternative does not include any additional remediation activities. No CTP repairs would be made, and no sludge replacement facilities would be constructed when the current facility is full, which is expected to be within 3 to 5 years. At this point the CTP would be shut down because it cannot function without sludge disposal. This will result in untreated AMD being discharged into Bunker Creek. At this point all other mine water management components would be shut down, including in-mine AMD collection activities, unless unilaterally continued by the mine owner for mining purposes. Thus, no remedial action funds would be expended for the No Further Action alternative once the sludge impoundment is full.

5.2.1.2 Overall Protection of Human Health and the Environment

Discharge of untreated AMD into Bunker Creek will endanger human health and result in acutely toxic conditions for aquatic life in the creek. Metal concentrations in the SFCdA River downstream of the confluence with Bunker Creek will increase and will result in severe aquatic toxicity (see Table 2-3).

5.2.1.3 Compliance with ARARs

ARAR compliance is addressed by considering chemical-specific, location-specific, and action-specific ARARs separately. Section 2.6 provides a detailed discussion of ARARs that may be applicable.

Chemical-Specific ARARs. The ARARs analysis presented several legal standards that specify water quality goals. The No Further Action alternative will not meet these goals. This alternative will result in toxic water quality in Bunker Creek and in the SFCdA River.

Location-Specific ARARs. Section 2.6 describes possible location-specific ARARs. This alternative will result in degradation of aquatic habitat within Bunker Creek and the SFCdA River. Thus, it will not be in compliance with state and federal fisheries and wildlife protection laws.

Action-Specific ARARs. Section 2.6 describes possible action-specific ARARs. None of these are applicable to this alternative because no actions would be taken.

5.2.1.4 Long-Term Effectiveness and Permanence

Magnitude of Residual Risk. The No Further Action alternative will exacerbate the present risks. Once the CTP quits operating (within 3 to 5 years), the untreated AMD will be discharged to Bunker Creek, resulting in greatly increased pollutant loads into the creek and the SFCdA River. Sludge production and accumulation at the CIA would continue at present rates, estimated at 15,000 to 18,000 cubic yards per year, until the existing sludge impoundment is full (within 3 to 5 years). Once full, it would not be capped under this operable unit, leaving open and exposed sludge and a conduit for continued leaching into the underlying tailings. Capping would need to occur under another site operable unit.

Adequacy of Reliability and Controls. This alternative does not have adequate reliability or controls.

5.2.1.5 Reduction of Toxicity, Mobility, or Volume Through Treatment

Treatment Process and Remedy. The existing CTP lime neutralization treatment process removes heavy metals by precipitation as hydroxides. Acidity is removed by lime addition, which converts the hydrogen ions to water. The pH of the effluent is alkaline and in the 8 to 9 range. The precipitated metals forms a sludge that is pumped from the clarifier/thickener at about 1 to 5 percent solids by weight to the unlined sludge disposal bed on the CIA, where the sludge dries by gravity draining and evaporation to about 30 percent solids. The sludge accumulates at about 15,000 to 18,000 cubic yards per year. Once the sludge impoundment is full (3 to 5 years) the CTP will need to be shut down because it cannot operate without sludge disposal.

Amount of Hazardous Material Destroyed or Treated. The entire mine water flow from the Kellogg Tunnel is collected and treated in the CTP. Using the values listed in Table 1-1, the Kellogg Tunnel portal discharges about 2,500 lbs/year of cadmium, 4900 lbs/year of lead, and 1,130,000 lbs/year of zinc. The treatment process removes all of the acidity, over 99 percent of the cadmium and zinc, and about 85 percent of the lead based on the values listed in Tables 1-1 and 1-2. However, at these removal efficiencies, the CTP will not attain the TMDL or all state water quality criteria in the intervening 3 to 5 years before it is shut down. Once shut down, all of the AMD will enter Bunker Creek untreated.

Reduction of Toxicity, Mobility, or Volume. The current treatment process substantially reduces the toxicity and mobility of the metals, although insufficient to be in compliance with all state and federal water quality criteria or attain the TMDL. The metals are dissolved

in the mine water at low pH conditions. In the dissolved form the metals have the greatest toxicity and mobility. The precipitated metals are immobilized in the sludge under alkaline conditions and removed from contact with water, people, and wildlife, reducing or removing the toxicity. Once the CTP is shut down, the toxicity and mobility of the metals will not be reduced.

Irreversibility of the Treatment. The current treatment process is reversible. Metals in the sludge will have the potential to leach back into solution because a low-permeability cover system will not be placed over the top of the sludge impoundment when it is full. Once the CTP is shut down there will be no treatment, so irreversibility will be moot.

Type and Quantity of Treatment Residual. The treatment residual of concern is the sludge, estimated to accumulate at between 15,000 and 18,000 cubic yards per year for the remaining 3 to 5 years until the CTP is shut down because of the lack of sludge disposal space.

5.2.1.6 Short-Term Effectiveness

Protection of the Community During Remedial Actions. This alternative does not contain any new remedial actions. The community will be at higher risk from uncontrolled discharge of AMD into Bunker Creek during the 3- to 5-year period until the CTP is shut down, and then at much higher risk afterward. There will be no repairs made at the CTP during the 3- to 5-year period; thus, it could break down or fail before the 3- to 5-year period is up.

Protection of Workers During Remedial Actions. This alternative does not include any remedial actions, so this evaluative criterion does not apply.

Environmental Impacts Associated with Construction. This evaluative criterion does not apply.

Time Until Remedial Response Objectives are Achieved. The No Further Action alternative will not achieve any of the remedial response objectives.

5.2.1.7 Implementability

Ability to Construct and Implement Technology. Administrative implementability of the No Further Action alternative will be very difficult given the significant environmental consequences.

Reliability of Technology. This is an unreliable alternative. The CTP will be shut down, resulting in no treatment after 3 to 5 years. It could fail sooner because no repairs will be made.

Ease of Undertaking Additional Remedial Actions, If Necessary. Implementation of the No Further Action alternative should not provide a serious impediment to other remedial actions that may be necessary, although they would be inconsistent with the philosophy of this alternative.

Ability to Monitor Effectiveness of Remedy. Monitoring will be conducted following current practices until the CTP is shut down, at which point all monitoring will cease.

Coordination with Other Agencies. Considerable coordination would be required to implement this alternative, given the environmental consequences.

Availability of Treatment, Storage Capacity, and Disposal Services. The existing sludge disposal capacity will be consumed in 3 to 5 years, at which time the CTP will be shut down because it cannot operate without sludge disposal.

Availability of Necessary Equipment and Specialists. No new materials or workforce are needed to implement the No Further Action alternative.

Availability of Prospective Technologies. No new technologies are required for this alternative.

5.2.1.8 Cost

Table 5-1 summarizes the order-of-magnitude (+50 to –30 percent) cost estimates for this alternative. The costs are summarized by remedy component. A cost period of 4 years is assumed for all components because, for this alternative, no remedial actions will continue once the existing sludge impoundment is full. Additional cost detail is included in Appendix G.

5.2.2 Alternative 2—Treatment Only

5.2.2.1 Description

Alternative 2, Treatment Only, consists of an updated and improved treatment plant, but no mitigations for reducing infiltration to the mine and the volume of AMD from the Kellogg Tunnel. The proposed treatment plant is sized to accommodate a peak inflow of 5,000 gpm, large enough to treat all previously recorded Kellogg Tunnel flows except for infrequent high peak flows (see Figure 2-15). These would be stored either in the lined pond or in the mine for later extraction and treatment. Monitoring will be conducted at the Kellogg Tunnel portal and at the CTP. Sludge would be disposed of using one of the following options:

Option A: Disposal of raw sludge in onsite sludge disposal beds located on the CIA that both dewater and permanently store the sludge

Option B: Mechanical sludge dewatering and disposal of dry sludge in an offsite landfill

Option C: Disposal of raw sludge in onsite sludge disposal beds located above the smelter closure area

Option D: Sludge drying using sludge drying beds on the CIA and annual excavation and disposal of dry sludge in an onsite landfill located above the smelter closure area

5.2.2.2 Overall Protection of Human Health and the Environment

Alternative 2 is expected to be protective of human health and the environment for mine water flows up to 6,750 gpm. The treatment plant will be able to treat 5,000 gpm, and up to 1,750 gpm can be stored in the mine. Flows in excess of 5,000 gpm are expected to be very infrequent and have a short duration based on the historical data. Referring to Figure 2-15, which lists Kellogg Tunnel hydrographs for 16 years, it can be seen that 5,000 gpm was exceeded five times, with no exceedance over 6,700 gpm. Four of these events occurred

during the 1973 WY, and the fifth was during the 1974 WY. Table 2-1 lists the estimated Kellogg Tunnel flow return intervals. A flow in excess of 5,000 gpm has an estimated return interval of about 13 years, with a probability of occurrence in any year of about 8 percent.

All four sludge management options are expected to be protective. There is minor risk that the sludge could leak from the lined disposal units. For options A, C, and D, which use onsite disposal, risks of leakage will be minimized through use of liners and a filtrate collection system. The filtrate will be collected and treated. Land use restrictions would be needed to assure the viability of containing the treatment sludge and preventing dissolution.

For options A and C, one sludge bed will be continuously open to the atmosphere. Fencing and gates will keep out the public. If the surface of the sludge dries out, wind may pick up and transport dust. Based on experience at the existing sludge bed, the potential for wind erosion is low because the surface of the sludge typically remains moist from ongoing sludge placement.

For Option B, the sludge will be mechanically dewatered and hauled to an offsite landfill. The filtrate from mechanical dewatering will be collected and retreated. The sludge will be hauled on public streets and highways. Risk from exposure is considered low because the loads would be covered and transported in accordance with applicable standards.

5.2.2.3 Compliance with ARARs

Chemical-Specific ARARs. Based on the treatability testing results, the anticipated CTP effluent quality should meet most of the potentially applicable surface water requirements, as well as the TMDL discharge levels for the CTP. The TMDL has been identified as a TBC.

The primary goal for water quality is compliance with Idaho water quality standards (WQSs) that apply to Bunker Creek and the SFCdA River. WQS for cadmium, lead, and zinc are achieved through implementation and achievement of the TMDL. By achieving the TMDL, the Bunker Hill mine water remedy achieves requirements of the Idaho WQSs for these three pollutants.

Table 5-2 compares the treatability study results for metals against the potential State of Idaho chemical-specific surface water ARARs for contaminants of concern. The results suggest the CTP effluent will meet requirements for arsenic, cadmium, copper, lead, silver, and zinc (note: for cadmium, lead, and zinc, the TMDL levels differ from the chemical-specific surface water requirements). Based on the available data, it is uncertain whether the requirements for mercury, selenium, and thallium will be consistently met. Results suggest that the mercury limit of 0.012 µg/L may be exceeded slightly. The treatability results for selenium show that it was not detected above 9.6 µg/L. Because the water quality criteria is 5 µg/L, the treatability study results do not have low enough detection limits for direct comparison. Comparison against the thallium criteria is also difficult for the same reason; however, in general, the results suggest that the CTP discharge will either meet, or be very close to meeting, the limits for mercury, selenium, and thallium.

The other potential surface water ARARs that the CTP effluent may not consistently meet based on available information are temperature, dissolved oxygen, and pH. The temperature criterion is 22 degrees Celsius (C) or less, with a maximum daily average of no

greater than 19 degrees C (see Table 2-6). Effluent from the existing CTP often exceeds 19 degrees C during summer months. With the addition of filters, the increase in mechanical energy required to pass water through the filters may increase the temperature in the discharge. For dissolved oxygen, the criterion is >6 mg/L (see Table 2-6). The AMD has chemical oxygen demand because of dissolved ferrous iron and manganese. Although aeration will be conducted within the treatment process, there may be insufficient oxygen transfer to the liquid to increase the dissolved oxygen to greater than 6 mg/L. For pH, the Idaho surface water criterion is between 6.5 and 9.5 pH units (see Table 2-6). The BPT and BAT pH criteria (see Table 2-10) specify a pH range of 6.0 to 9.0. The CTP operational pH setpoint is expected to be in the vicinity of 9.5, which is above the 9.0 criterion. Although it is likely that the pH will be less than 9.0 at the discharge, it is uncertain based on the treatability data.

The foregoing discussion suggests that the effluent from the upgraded CTP will either be in compliance with, or nearly in compliance with, all potentially applicable surface water ARARs. Performance monitoring of the upgraded full-scale CTP is needed to further assess compliance, and to determine if additional process changes or treatment schemes should be considered.

Location-Specific ARARs. Alternative 2 actions are not expected to influence archaeological and/or historic sites of significance, and will not involve construction activities that might degrade Bunker Creek. The possible relocation of the CTP discharge point may be favorable to the creek if it is moved further east, because more habitats would be created during the dry periods when the creek flow consists primarily of CTP effluent. No remedial actions would be implemented that might affect relevant floodplains or wetlands. The residual metal in the CTP discharge is expected to have negligible effect on species considered under the Endangered Species Act (ESA), and is actually expected to dilute concentrations of cadmium, lead, and zinc in the SFCdA River.

EPA is consulting with the United States Fish and Wildlife Service (USFWS) on potential impacts to endangered or threatened species or their habitats resulting from any construction activities associated with this remedy. As a result of this consultation process, measures would be taken to identify and remediate any impacts.

Action-Specific ARARs. The construction work associated with the remedial activities is expected to be in compliance with action-specific ARARs.

5.2.2.4 Long-Term Effectiveness and Permanence

Magnitude of Residual Risk. Alternative 2 employs no actions to reduce the quantity of mine water discharging from the mine. However, the treatment plant is sized at 5,000 gpm, which is expected to be sufficient for all Kellogg Tunnel flows except for the infrequent peak flows.

There is some risk that much higher flows could discharge from the mine as they have in the past, as discussed in Section 5.2.2.2. The peak mine water flow recorded to date is estimated at 6,700 gpm. Table 2-1 shows the estimated Kellogg Tunnel flow return intervals. The estimated 50-year return interval peak flow equals 7,140 gpm, and the estimated 100-year return interval peak flow equals 8,320 gpm. Typically, peak flows are of short duration. Although sufficient capacity exists in the mine to store peak flows of this magnitude, the in-mine system to divert gravity flows into the mine pool has a maximum capacity of

1,050 gpm. Shutting off the mine pool pumps will decrease the Kellogg Tunnel flow by an additional 700 gpm. Thus, the total in-mine capacity to reduce Kellogg Tunnel flows is 1,750 gpm. The combined treatment and in-mine storage capacity is 6,750 gpm.

Flows in excess of 6,750 gpm could be stored in the lined pond, but it may not have sufficient capacity if the flows are of long duration. For example, to manage the 8,320 gpm 100-year return interval flow, 1,570 gpm (8,320 – 6,750 gpm) would need to be stored in the lined pond. The lined pond capacity (assuming it is cleaned out and empty to begin with) is 7 million gallons. This would provide 3 days of storage for the 1,570 gpm, which may be sufficient given the historical pattern of peak flows lasting only a few days or less.

There is a potential for very high flows to be generated during large rain or rain on snow events in the West Fork Milo Creek Drainage Basin (see Table 2-2). The Guy Cave Area lies within this basin. Very high flows could drain over the surface area of the caves, and some portion of this flow will infiltrate to the mine. There is the potential that this could result in much higher flows than anticipated based on the return interval calculations, because they are based on historical flows. There is similar risk from the near-surface workings at the Small Hopes Drift area in Mainstem Milo Creek, and the Inez Shaft area of Deadwood Creek. The existing diversion systems in the mine may have insufficient capacity to divert very high flows into the mine pool. The AMD collection system at the Kellogg Tunnel portal has a capacity of 7,000 gpm, but it is unlikely that this much water would be captured because the Kellogg Tunnel ditch at the portal to which the collection system is tied has far less capacity.

Annual average metal loading to Bunker Creek from the upgraded CTP under Alternative 2 equals approximately <5 lb/yr for cadmium, <7 lb/yr for lead, and <460 lb/yr for zinc, based on an average annual flow of 1,500 gpm and effluent concentrations of <0.7µg/L cadmium, <1.0 µg/L lead, and <70 µg/L zinc. These amounts are significantly lower than current conditions.

Sludge production would be significantly less under Alternative 2 than under present conditions. The estimated current average annual accumulation rate in the CIA sludge disposal pond is 15,000 to 18,000 cubic yards. The average annual sludge accumulation rate for the onsite disposal options (options 2A, 2C, and 2D) is estimated to be 5,400 cubic yards. The average annual production rate for the offsite option (Option 2B) is estimated to be somewhat higher at about 10,300 cubic yards, because the sludge is not expected to dewater to the same extent in the mechanical equipment compared to sludge drying or disposal beds. For all sludge options, any water draining from the sludge as it is dewatered (filtrate) would be collected and re-treated.

Adequacy of Reliability and Controls. The upgraded CTP will include a backup diesel-driven electrical generator, two lime feeding systems, and other upgrades intended to reduce the risk of a failure that would shut down the plant unexpectedly. Land use restrictions would be needed to assure the viability of containing the treatment sludge and preventing dissolution. The existing in-mine diversion system uses pumps to draw mine water out of the ditches and to send it into the mine pool for temporary storage. The mine does not have backup power, so these pumps will not operate in a power outage. It is also possible that their capacity could be exceeded, as discussed earlier.

5.2.2.5 Reduction of Toxicity, Mobility, or Volume Through Treatment

Treatment Process and Remedy. The upgraded CTP lime neutralization treatment process will be operated in the HDS mode. This will provide a discharge having the effluent concentrations described above, but will also produce about one-half to one-third the sludge after dewatering compared to the existing LDS mode of operation.

Amount of Hazardous Material Destroyed or Treated. The upgraded CTP will remove more cadmium, lead, and zinc than the existing facility. The upgraded plant will remove all of the acidity, and over 99.9 percent of the cadmium, lead, and zinc.

Reduction of Toxicity, Mobility, or Volume. Similar to the existing CTP, in the upgraded CTP the mobility of the metals is substantially reduced by the treatment process. The metals are dissolved in the mine water at low pH conditions. In the dissolved form, the metals have the greatest toxicity and mobility. The precipitated metals are immobilized in the sludge under alkaline conditions and removed from contact with water, people, and wildlife, thus reducing or removing the toxicity from the environment.

The mobility of the metals is reduced by the treatment process. The precipitated metals remain immobilized as long as the sludge stays sufficiently alkaline to prevent dissolution and subsequent metal release. This potential will be minimized by either placing the sludge in engineered onsite disposal facilities (Options A, C, and D), or hauled offsite to an appropriate disposal facility (Option B). The filtrate from sludge dewatering would be collected and returned for treatment. The volume of sludge will be reduced to about one-half to one-third of the existing production rate.

Irreversibility of the Treatment. The treatment process is reversible. Metals in the sludge will have the potential to leach back into solution if contacted with sufficient acidity or be recoverable by future resource recovery methods. Thus, the sludge must be disposed in an appropriate facility to reduce the threat to the environment. If properly disposed and managed, the risk of metal release to the environment is expected to be minor. Treatment is considered fully reversible in the sense that other source control, resource recovery, or mining activities could be instituted in the future.

Type and Quantity of Treatment Residual. The treatment residual of concern is the sludge, which is estimated to accumulate at between about 5,400 (options 2A, 2C, and 2D) and 10,300 (Option 2B) cubic yards per year.

5.2.2.6 Short-Term Effectiveness

Protection of the Community During Remedial Actions. The major remedial construction activities for Alternative 2 are as follows:

- Construct the new segment of pipeline to allow direct feed of AMD to the CTP
- Upgrade the CTP to 5,000 gpm capacity for TMDL achievement
- Either construct new onsite sludge disposal beds, or haul dewatered sludge off site.

These activities are typical of industrial construction activities. All work will be done in existing industrial areas and areas already remediated through prior site cleanup actions. All work can be done in a manner protective of the community if appropriate construction practices are followed.

Protection of Workers During Remedial Actions. Workers will be exposed to normal construction-related risks. Following safe construction and best management practices can minimize the risks.

Environmental Impacts Associated with Construction. Environmental impacts associated with construction are expected to be minor. The land has been disturbed by prior development. Stream crossings will be needed for the new pipeline section and potentially for a sludge filtrate pipeline.

Time Until Remedial Response Objectives are Achieved. Alternative 2 is expected to meet the TMDL-based discharge levels and to be in compliance with most Idaho surface water quality criteria as soon as the CTP is upgraded and begins steady-state operation. A monitoring period of a few months may be needed to determine if other changes are needed in order to be in compliance with temperature, pH, dissolved oxygen, mercury, selenium, and thallium criteria. The HDS process will also reduce sludge production as soon as the upgraded plant is started up.

5.2.2.7 Implementability

Ability to Construct and Implement Technology. There are no barriers for construction and implementation of this alternative. All necessary technologies are standard and have been used at other sites. In-mine AMD collection, storage, and monitoring requires the cooperation of the New Bunker Hill Mining Company.

Reliability of Technology. All of the technologies required for this alternative exist and are well-understood and reliable, given proper operation and maintenance. The upgraded CTP will have backup power and redundant capabilities. This will increase reliability compared to the existing plant, and will reduce the risk of future release of partially treated or untreated AMD to the environment.

Ease of Undertaking Additional Remedial Actions, If Necessary. Implementation of Alternative 2 should not provide a serious impediment to other remedial actions, if necessary. Treatment is compatible with other source control and resource recovery options.

Ability to Monitor Effectiveness of Remedy. The monitoring will be the same as that currently done, consisting of continuous flow and periodic sampling at the Kellogg Tunnel portal, and continuous flow and daily sampling at the CTP. These monitoring activities will determine how well the remedy complies with the discharge requirements, and how much and what strength of AMD discharges from the mine. Kellogg Tunnel portal monitoring requires the cooperation of the New Bunker Hill Mining Company.

Coordination with Other Agencies. Administrative implementability for all work associated with this alternative should be straightforward and consistent with past Bunker Hill site agency coordination.

Availability of Treatment, Storage Capacity, and Disposal Services. Space is available at the CTP for the new equipment as described in Appendix E. Sufficient space is available within the mine for contingency AMD storage, although the existing diversion system is limited to about 1,050 gpm. The lined pond has about 7 million gallons of capacity, although currently it holds about 2 million gallons of muck, which is expected to be removed and placed in the

existing sludge disposal bed on the CIA. There is sufficient space on site for 30 years of sludge disposal . There is sufficient regionally available offsite disposal capacity if the dewatered sludge is hauled off site.

Availability of Necessary Equipment and Specialists. The materials and workforce to implement this alternative are readily available. The work force is available locally or regionally.

Availability of Prospective Technologies. All technologies required for this alternative have been used before and are readily available.

5.2.2.8 Cost

Table 5-3 summarizes the order-of-magnitude (+50 to –30 percent) cost estimates for this alternative. The costs are summarized by remedy component. Total 30-year net present value costs at a 7 percent interest rate are shown, including total alternative costs using each sludge option. Additional cost detail is included in Appendix G.

5.2.3 Alternative 3—Phased Mitigations/Treatment

5.2.3.1 Description

Alternative 3 would phase the implementation of mitigations and treatment plant capacity based on monitoring results. An initial set of mitigations would be implemented and an initial CTP capacity (2,500 gpm) would be constructed. Up to 10 years of performance monitoring would be reviewed to determine if the initial mitigations and treatment plant capacity were sufficient, or if more were needed. A decision process consisting of data analysis, conceptual model refinement, assessment of mitigation effectiveness, and a cost/benefit analysis would be used to evaluate remedy performance, and to select subsequent actions if warranted. The cost estimate for Alternative 3 does not include subsequent CTP modifications or mitigations that may be needed after the performance evaluation period.

The following are the initial set of mitigations:

- West Fork Milo Creek Stream Diversion
- Rehabilitation of the Phil Sheridan Diversion System
- Drill Hole Plugging

Mine water flows in excess of 2,500 gpm would be stored in the lined pond or in the mine. A new gravity diversion system and extraction pumps would be installed for in-mine storage. The AMD conveyance pipe would be modified to allow direct flow to the CTP. Sludge would be disposed using one of the four sludge options. The initial remedial construction activities for Alternative 3 are as follows:

- Construct the West Fork Milo Creek Diversion, rehabilitate the Phil Sheridan Diversion, and plug the drill holes.
- Construct the new segment of pipeline to allow direct feed of AMD to the CTP.
- Construct the gravity in-mine diversion systems and the new mine pool extraction system.

- Improve and update the CTP to an initial 2,500 gpm filtration and optimum operation capacity. The hydraulic throughput and neutralization capacity will initially be 5,000 gpm.
- Construct one of the onsite sludge disposal options (options A, C, or D) or the offsite option (Option B).

5.2.3.2 Overall Protection of Human Health and the Environment

Alternative 3 is expected to be protective of human health and the environment. The treatment plant will be configured for compliance with the Idaho water quality standards and achievement of TMDL levels, and will use the same processes, equipment types, and backup systems as the plant described in Alternative 2. The expected typical CTP effluent is the same as for Alternative 2. The mitigations in the West Fork Milo Creek Basin are expected to help protect the area from high infiltration events that lead to very high peak flows from the mine.

The treatment plant capacity of 2,500 gpm is expected to be sufficient for all Kellogg Tunnel flows except for infrequent high flows, particularly with the installation of the West Fork Milo Creek mitigations. These infrequent high flows would be stored in the lined pond or mine for later extraction and treatment. All sludge management options are expected to be protective in the same manner as described for Alternative 2. However, about 10 percent less sludge is expected from Alternative 3 compared to Alternative 2. Disturbance associated with construction of the AMD pipeline, treatment plant, and sludge facilities should be similar to typical construction activities. Construction of the mitigations in the West Fork Milo Creek Basin will have some impact on the creek and drainage basin, but the creek is ephemeral and only flows during spring snowmelt or heavy rains. The stream channel ends at the Guy Cave Area where the water infiltrates to the mine. The diversion will be constructed in the streambed above the Guy Cave Area. The diversion pipe will be laid either beneath the access road approaching from below, or through areas disturbed by previous mining activities. Rehabilitation of the Phil Sheridan Diversion system will have minimal impact because the affected areas have been previously disturbed by past mining activities.

5.2.3.3 Compliance with ARARs

Chemical-Specific ARARs. The Alternative 3 CTP effluent is expected to be similar to that described for Alternative 2. Based on the treatability testing results, the anticipated CTP effluent quality should meet most of the potentially applicable surface water requirements, as well as the TMDL discharge levels for the CTP. The TMDL has been identified as a TBC.

Location-Specific ARARs. Alternative 3 actions are not expected to influence archaeological and/or historic sites of significance, and will not involve construction activities that might degrade Bunker Creek. Some minor amount of ephemeral stream habitat will be disturbed in the West Fork Milo Creek Basin during diversion construction. No remedial actions would be implemented that might affect relevant floodplains or wetlands. The residual metal in the CTP discharge is expected to have negligible impact on species considered under the ESA, and is actually expected to dilute concentrations of cadmium, lead, and zinc in the SFCdA River. EPA is consulting with the USFWS on potential impacts to endangered or threatened species or their habitats.

Action-Specific ARARs. The construction work associated with the remedial activities is expected to be in compliance with action-specific ARARs.

5.2.3.4 Long-Term Effectiveness and Permanence

Magnitude of Residual Risk. Alternative 3 employs actions to reduce the quantity of mine water discharging from the Kellogg Tunnel. The West Fork Milo Creek Diversion is expected to capture and divert stream flow away from the Guy Cave Area, and thereby reduce infiltration through the Flood-Stanly Ore Body. The rehabilitated Phil Sheridan Diversion is expected to reduce peak flows from the west portion of the drainage that is not in the area of influence of the proposed West Fork Milo Creek stream diversion. It will also capture surface flow that exceeds the capacity of the West Fork Milo Creek diversion structure. If Kellogg Tunnel flows in excess of 2,500 gpm were to occur, the excess would be stored in the lined pond or in the mine for later extraction and treatment. The upgraded CTP will also have the capability to hydraulically pass and neutralize up to 5,000 gpm, although filtration capacity is only originally 2,500 gpm.

There is some risk of high mine inflow from stream erosion into near-surface workings at the Small Hopes Drift area in Mainstem Milo Creek, and the Inez Shaft area of Deadwood Creek. These areas will be monitored and addressed by subsequent actions if needed.

The concrete ditch outside the Kellogg Tunnel portal has a capacity of 7,000 gpm, but it is unlikely that this much water would be captured because the ditch in the tunnel has less capacity. Construction of the mitigations is expected to reduce the risk of flows occurring that are higher than the Kellogg Tunnel ditch capacity.

The annual average metal loading to Bunker Creek from the upgraded CTP is expected to be less than for Alternative 2 because of lower mine water flows resulting from the mitigations. The specific reduction is unknown, but is estimated at about 10 percent based on the model results described in Section 4.2.1. Lime consumption and sludge production would be less than for Alternative 2 because of the reduction in AMD discharge collected for treatment. The 10 percent reduction is for implementation of the mitigations built during the initial phase (for Alternatives 3 and 4). Phased implementation of more mitigations may increase this. A maximum of 20 percent is estimated if all mitigations were implemented (for Alternative 5), as described in Section 4.2.1.

Construction of the mitigations, particularly those that reduce peak flows through the Flood-Stanly Ore Body, will reduce the size and frequency of high mine flows that flush accumulated acid salts. There is potential that infrequent flushing could result in accumulation of more salts than observed to date. If this occurred and a flushing event did happen, the resulting mine water could be worse quality than observed to date. However, the likelihood of this occurring is expected to be low (see Appendix B), and the residual risk can be minimized by periodic inspection in accessible areas for salt buildup, and by monitoring of in-mine AMD flows and chemistry. The specific effectiveness of the mitigations will not be known until they are constructed and operated for some time.

Adequacy of Reliability and Controls. The upgraded CTP will have similar backup and redundant systems as described for Alternative 2. The new gravity in-mine diversion system will have more capacity and will not rely on pumps. The mitigations will operate passively and are expected to require no active operation other than periodic inspection and clean-out.

5.2.3.5 Reduction of Toxicity, Mobility, or Volume Through Treatment

Treatment Process and Remedy. The upgraded CTP lime neutralization treatment process will be operated in the HDS mode similar to Alternative 2. This is expected to provide the same effluent concentrations. About 10 percent less sludge is expected because of less mine water needing to be treated because of the inflow reduction resulting from the mitigations.

Amount of Hazardous Material Destroyed or Treated. The mitigations are expected to reduce the total average annual water volume requiring collection and treatment by about 10 percent. The total amount of residual metals being discharged after treatment is expected to decrease by about 10 percent compared to Alternative 2.

Reduction of Toxicity, Mobility, or Volume. Alternative 3 is expected to reduce the volumes of mine water and sludge by about 10 percent compared to Alternative 2. Alternative 3 is expected to reduce the toxicity and mobility of the metals similarly to Alternative 2.

Irreversibility of the Treatment. As in Alternative 2, the treatment process will be reversible and the metals may be recoverable by future resource recovery methods. Metals in the sludge will have the potential to leach back into solution if exposed to acidic conditions; thus, the sludge must be disposed in an appropriate facility to reduce the threat to the environment. If properly disposed and managed, the risk of metal release to the environment is expected to be minor. Treatment is considered fully reversible in the sense that other source control, resource recovery, or mining activities could be instituted in the future.

Type and Quantity of Treatment Residual. The treatment residual of concern is the sludge, which is estimated to be about 10 percent less than Alternative 2.

5.2.3.6 Short-Term Effectiveness

Protection of the Community During Remedial Actions. All the construction activities use standard construction techniques and practices.

Protection of Workers During Remedial Actions. Workers will be exposed to normal construction-related risks. Following safe construction and best management practices can minimize the risks.

Environmental Impacts Associated with Construction. Construction impacts are expected to be minor. A section of the ephemeral West Fork Milo Creek will be affected by the mitigation work. The land in the other areas has been previously disturbed by prior development or mining activities. Stream crossings will be needed for the new pipeline section and possibly for filtrate from onsite sludge disposal facilities. The environmental impacts of these crossings can be reduced by minimizing work within the streambed.

Time Until Remedial Response Objectives are Achieved. Alternative 3 is expected to meet the TMDL-based discharge levels and to be in compliance with most Idaho surface water quality criteria as soon as the CTP is upgraded and begins steady-state operation. A monitoring period of a few months may be needed to determine if other changes are needed, to be in compliance with temperature, pH, dissolved oxygen, mercury, selenium, and thallium. The HDS process will also reduce sludge production as soon as the upgraded plant is started up.

The ultimate effectiveness of the mitigations will not be known until they are constructed, operated, and monitored for some time. A performance-monitoring and evaluation period of up to 10 years will take place following completion of the initial remedial actions. If additional actions are needed, they may consist of more mitigations, more treatment capacity, or both.

5.2.3.7 Implementability

Ability to Construct and Implement Technology. There are no barriers for construction and implementation of this alternative. All necessary technologies are standard and have been used at other sites. Some of the mitigation work will be on private land, such as the West Fork Milo Creek diversion structure and pipeline. Thus, access will need to be obtained. In-mine AMD collection, storage, and monitoring requires access from and coordination with the New Bunker Hill Mining Company.

Reliability of Technology. All required technologies exist, are well understood, and are reliable given proper operation and maintenance. The upgraded CTP will have backup power and redundant capabilities. These will increase the reliability compared to the existing plant, and will reduce the chance for release of partially treated or untreated AMD to Bunker Creek. All technologies required for the mitigations and other remedy components are standard technologies expected to be reliable.

Ease of Undertaking Additional Remedial Actions, If Necessary. Implementation of Alternative 3 should not provide a serious impediment to other remedial actions that may be necessary. Treatment is compatible with other source control and resource recovery options.

Ability to Monitor Effectiveness of Remedy. Monitoring is a key component of this alternative because the decision to implement more actions will be phased based on monitoring and performance evaluation as described in Section 4.3.3.7. This type of monitoring has been performed in the past. In-mine and Kellogg Tunnel portal monitoring requires the cooperation of the New Bunker Hill Mining Company. For the cost estimate it is assumed that surface and in-mine monitoring for performance assessment would be conducted for 10 years, then stopped. This should be sufficiently long enough to assess remedy performance and to implement and monitor any additional remedial measures.

Coordination with Other Agencies. Administrative implementability for all work associated with this alternative should be straightforward and consistent with past Bunker Hill site agency coordination.

Availability of Treatment, Storage Capacity, and Disposal Services. The required treatment, storage capacity, and disposal services are available. Space is available at the CTP for the

required upgrades. Sufficient space is available within the mine for AMD storage. There is sufficient space on- or offsite for 30 years of sludge disposal.

Availability of Necessary Equipment and Specialists. The materials and workforce to implement this alternative are readily available. The work force is available locally or regionally.

Availability of Prospective Technologies. All technologies required for this alternative have been used before and are readily available.

5.2.3.8 Cost

Table 5-4 summarizes the order-of-magnitude (+50 to –30 percent) cost estimate for Alternative 3. The costs are summarized by remedy component. The total alternative net present value using each sludge management option is summarized at the bottom of the table. The cost estimate includes a 10 percent lime and sludge reduction expected from the mitigations. The cost estimate does not include subsequent CTP modifications or mitigations that may be needed after the performance evaluation period. Additional cost detail is included in Appendix G.

5.2.4 Alternative 4—Phased Mitigations/Treatment with Plugging of Near-Stream Workings

5.2.4.1 Description

All components of Alternative 4 are the same as Alternative 3 except it includes two more initial mitigations. These are plugging the Small Hopes drift below Mainstem Milo Creek, and plugging the Inez Shaft below Deadwood Creek. This would reduce or eliminate the possibility of high stream flows eroding direct flow paths into the mine through these areas. Alternative 4 uses the same type of phased approach as Alternative 3 for monitoring performance and determining the need for additional actions.

The initial remedial construction activities for Alternative 4 are as follows:

- Construct the West Fork Milo Creek Diversion, rehabilitate the Phil Sheridan Diversion, plug the drill holes, plug the Small Hopes Drift below Mainstem Milo Creek, and plug the Inez Shaft below Deadwood Creek.
- Construct the new segment of pipeline to allow direct feed of AMD to the CTP.
- Construct the gravity in-mine diversion systems and the new mine pool extraction system.
- Improve and update the CTP to an initial 2,500 gpm optimum operation and filtration capacity. The hydraulic throughput and neutralization capacity will initially be 5,000 gpm.
- Construct one of the four sludge management options.

5.2.4.2 Overall Protection of Human Health and the Environment

Alternative 4 is expected to be protective of human health and the environment. The protection provided is expected to be somewhat greater than for Alternative 3 because of a smaller likelihood of high mine water flows resulting from erosion into workings below Mainstem Milo Creek and Deadwood Creek.

Historically, the Inez Shaft was a location where direct stream inflow could occur. The shaft was constructed in the bottom of Deadwood Creek. Over the years the shaft has become covered by stream-deposited alluvial material. The concern is that this material could be scoured out during high creek flows. A similar situation exists in Milo Creek for the Small Hopes drift. If direct inflow were to occur, the mine water flow may be too high to store or treat, resulting in untreated AMD entering Bunker Creek. Currently there is no indication of appreciable inflow through these areas, based on 1998/1999 in-mine monitoring data. Therefore, the average annual volume of mine water requiring treatment is expected to be similar to Alternative 3.

5.2.4.3 Compliance with ARARs

Chemical-Specific ARARs. Compliance with chemical-specific ARARs is expected to be the same as for Alternative 3. Attainment of the TMDL, a TBC, is also expected to be the same as for Alternative 3.

Location-Specific ARARs. The only difference compared to Alternative 3 will be the construction work associated with the Inez Shaft area in Deadwood Creek and the Small Hopes drift area in Mainstem Milo Creek, where some stream impacts will occur. Both of these areas have been previously disturbed by past mining activities. No remedial actions will be implemented that might affect relevant floodplains or wetlands. The residual metal in the CTP discharge is expected to have negligible impact on species considered under the ESA, and is actually expected to dilute concentrations of cadmium, lead, and zinc in the SFCdA River. EPA is consulting with the USFWS on potential impacts to endangered or threatened species or their habitats.

Action-Specific ARARs. The construction work associated with the remedial activities is expected to be in compliance with action-specific ARARs.

5.2.4.4 Long-Term Effectiveness and Permanence

Magnitude of Residual Risk. Alternative 4 employs actions to reduce the quantity of mine water emanating from the mine, and to protect from erosional flow paths into known near-stream workings. This will initially reduce the residual risk compared to Alternative 3, although, under Alternative 3, the workings could be plugged later if monitoring data suggest it is needed. The specific effectiveness of the mitigations will not be known until they are constructed and operated for some time.

The annual average metal loading to Bunker Creek from the upgraded CTP is expected to be the same as for Alternative 3. The average annual lime consumption and sludge production is also expected to be the same.

Adequacy of Reliability and Controls. The adequacy of reliability and controls is expected to be similar to Alternative 3. The plugs installed in the near-stream workings are expected to require minimal inspection and maintenance.

5.2.4.5 Reduction of Toxicity, Mobility, or Volume Through Treatment

Treatment Process and Remedy. The upgraded CTP lime neutralization treatment process will be operated in the HDS mode similar to Alternatives 2 and 3. This is expected to provide the same effluent concentrations. The average annual lime consumption and sludge production is expected to be the same as for Alternative 3.

Amount of Hazardous Material Destroyed or Treated. The mitigations are expected to reduce the total average annual water volume requiring collection and treatment to about the same extent as Alternative 3. This is a reduction of about 10 percent compared to Alternatives 1 and 2.

Reduction of Toxicity, Mobility, or Volume. Alternative 4 is expected to reduce the volumes of mine water, CTP effluent metals, and sludge to the same amounts as for Alternative 3. Alternative 4 is expected to reduce the toxicity and mobility of the metals similar to Alternatives 2 and 3.

Irreversibility of the Treatment. As in Alternatives 1, 2, and 3, the treatment process will be reversible. Metals in the sludge will have the potential to leach back into solution if exposed to acidic conditions. Thus, the sludge must be disposed in an appropriate facility to reduce the threat to the environment. If the sludge is properly disposed and managed, the risk of metal release to the environment is expected to be minor. Treatment is considered fully reversible in the sense that other source control, resource recovery, or mining activities could be instituted in the future.

Type and Quantity of Treatment Residual. The treatment residual of concern is the sludge, which is estimated to be the same amount as for Alternative 3, and about 10 percent less than Alternative 2.

5.2.4.6 Short-Term Effectiveness

Protection of the Community During Remedial Actions. All the construction activities use standard construction techniques and practices. These activities are expected to be performed in a protective manner.

Protection of Workers During Remedial Actions. Workers will be exposed to normal construction-related risks. Following safe construction and best management practices can minimize the risks.

Environmental Impacts Associated with Construction. Construction impacts are expected to be minor. A section of the ephemeral West Fork Milo Creek will be affected by the diversion. The land in the other areas has been previously disturbed by prior development or mining activities. Stream crossings will be needed for the new pipeline section and possibly for sludge filtrate. The environmental impacts of these crossings are expected to be minor. Construction of the plugs will require temporary diversion of Milo Creek and Deadwood Creek flows around the work areas. The work will be done during the low flow period of the year. Milo Creek is already diverted above the plug location at Small Hopes,

but there may be residual flows or groundwater. Deadwood Creek is already disturbed at the Inez Shaft area from past mining activities, but additional disturbance will be necessary to mobilize equipment and materials in this area.

Time Until Remedial Response Objectives are Achieved. Alternative 4 is expected to meet the TMDL-based discharge levels and to be in compliance with most Idaho surface water quality criteria as soon as the CTP is upgraded and begins steady-state operation. A monitoring period of a few months may be needed to determine if other changes are needed, to be in compliance with temperature, pH, dissolved oxygen, mercury, selenium, and thallium. The HDS process will also reduce sludge production as soon as the upgraded plant is started up. The specific effectiveness of the mitigations will not be known until they are constructed, operated, and monitored for some time. A performance-monitoring and evaluation period of up to 10 years will take place following completion of the initial remedial actions. If additional actions are needed, they may consist of more mitigations, more treatment capacity, or both.

5.2.4.7 Implementability

Ability to Construct and Implement Technology. There are no barriers for construction and implementation of this alternative. All necessary technologies are standard and have been used at other sites. Access will be required for the remedial work on private land. In-mine AMD collection, storage, and monitoring requires access from and coordination with the New Bunker Hill Mining Company.

Reliability of Technology. All technologies required for this alternative are fully developed, are well understood, and are reliable given proper operation and maintenance. The upgraded CTP will have backup power and redundant capabilities. These will increase the reliability compared to the existing plant and will reduce the chance for release of partially treated or untreated AMD to Bunker Creek. All technologies required for the mitigations and other remedy components are standard technologies expected to be reliable.

Ease of Undertaking Additional Remedial Actions, If Necessary. Implementation of Alternative 4 should not provide a serious impediment to other remedial actions that may be necessary. Treatment is compatible with other source control and resource recovery options.

Ability to Monitor Effectiveness of Remedy. Monitoring is a key component of this alternative because the decision to implement more actions will be phased based on monitoring and performance evaluation as described in Section 4.3.3.7. This type of monitoring has been performed in the past. In-mine and Kellogg Tunnel portal monitoring requires the cooperation of the New Bunker Hill Mining Company. For the cost estimate it is assumed that surface and in-mine monitoring for performance assessment would be conducted for 10 years, then stopped. This should be sufficiently long enough to assess remedy performance and to implement and monitor any additional remedial measures.

Coordination with Other Agencies. Administrative implementability for all work associated with this alternative should be straightforward and consistent with past Bunker Hill site agency coordination.

Availability of Treatment, Storage Capacity, and Disposal Services. The required treatment, storage capacity, and disposal services are available. Space is available at the CTP for the

required upgrades. Sufficient space is available within the mine for AMD storage. There is sufficient space on- or offsite for 30 years of sludge disposal.

Availability of Necessary Equipment and Specialists. The materials and workforce to implement this alternative are readily available. The work force is available locally or regionally.

Availability of Prospective Technologies. All technologies required for this alternative have been used before and are readily available.

5.2.4.8 Cost

Table 5-5 summarizes the order-of-magnitude (+50 to –30 percent) cost estimate for Alternative 4. The costs are summarized by remedy component. The total alternative net present value using each sludge management option is summarized at the bottom of the table. The cost estimate includes a 10 percent lime and sludge reduction expected from the mitigations. The cost estimate does not include subsequent CTP modifications or mitigations that may be needed after the performance evaluation period. Additional cost detail is included in Appendix G.

5.2.5 Alternative 5—Treatment with All Mitigations

5.2.5.1 Description

Alternative 5 does not use a phased approach. It consists of initial implementation of all the mitigations and construction of 2,500 gpm of upgraded treatment plant capacity. Mitigation performance monitoring is conducted for the first 5 years, but not after because no subsequent mitigations would be considered for phased implementation.

The remedial construction activities for Alternative 5 are as follows:

- Construct the West Fork Milo Creek Diversion, rehabilitate the Phil Sheridan Diversion, plug the drill holes, plug the Small Hopes Drift below Milo Creek, plug the Inez Shaft below Deadwood Creek, construct the sidehill diversion in West Fork Milo Basin, construct the South Fork Milo Creek Diversion, bypass the Bunker Hill Dam in Mainstem Milo Creek, improve the existing diversion in Mainstem Milo Creek, and upgrade the Phil Sheridan raise system in West Fork Milo Basin.
- Construct the new segment of pipeline to allow direct feed of AMD to the CTP.
- Construct the gravity in-mine diversion systems and the new mine pool extraction system.
- Improve and update the CTP to a 2,500 gpm optimum operation and filtration capacity. The hydraulic throughout and neutralization capacity will be 5,000 gpm.
- Construct one of the four sludge management options.

5.2.5.2 Overall Protection of Human Health and the Environment

Alternative 5 is expected to be protective of human health and the environment. The overall protection provided is expected to be somewhat less than Alternatives 3 and 4 due to the lack of a phased approach. The phased approach provides greater flexibility to use or

benefit from new information gained during the installation and operation of initial mitigations, treatment plant capacity, or both. The average annual volume of mine water requiring treatment is estimated to be about 20 percent less than for Alternatives 1 and 2, and about 10 percent less than for Alternatives 3 and 4 as initially implemented.

5.2.5.3 Compliance with ARARs

Chemical-Specific ARARs. Compliance with chemical-specific ARARs and attainment of TBCs is expected to be the same as for Alternatives 2, 3, and 4. Based on the treatability testing results, the anticipated CTP effluent quality should meet most of the potentially applicable surface water requirements, as well as the TMDL discharge levels for the CTP. The TMDL has been identified as a TBC.

Location-Specific ARARs. Alternative 5 actions are not expected to influence archaeological and/or historic sites of significance, and will not involve construction activities that might degrade Bunker Creek. Some minor amount of ephemeral stream habitat will be disturbed in the West Fork Milo Creek Basin, the South Fork Milo Creek Basin, Mainstem Milo Creek, and in Deadwood Creek Basin as a result of mitigation construction. No remedial actions would be implemented that might affect relevant floodplains or wetlands. The residual metal in the CTP discharge is expected to have negligible impact on species considered under the ESA, and is actually expected to dilute concentrations of cadmium, lead, and zinc in the SFCdA River. EPA is consulting with the USFWS on potential impacts to endangered or threatened species or their habitats.

Action-Specific ARARs. The construction work associated with the remedial activities is expected to be in compliance with action-specific ARARs.

5.2.5.4 Long-Term Effectiveness and Permanence

Magnitude of Residual Risk. Alternative 5 employs actions to reduce the quantity of mine water emanating from the mine, and to protect from erosion of flow paths into known near-stream workings. This will reduce the residual risk. Initial implementation of all mitigations will reduce the risk of mine water flows in excess of treatment plant capacity. The specific effectiveness of the mitigations will not be known until they are constructed and operated for some time. It is possible that the additional mitigations may not substantially increase the overall remedy effectiveness compared to Alternatives 3 and 4. This depends on their effectiveness, which is currently unknown.

The annual average metal loading to Bunker Creek from the upgraded CTP is expected to be about 20 percent less than for Alternative 2, and about 10 percent less than for Alternatives 3 and 4 as initially implemented (additional mitigations implemented for Alternatives 3 and 4 as part of the phased approach may reduce residual metal load to the creek). Sludge production is also expected to be 20 percent less than Alternative 2, and 10 percent less than Alternatives 3 and 4 as initially implemented.

Adequacy of Reliability and Controls. The adequacy of reliability and controls is expected to be similar to Alternatives 3 and 4. The additional mitigations will require inspection and maintenance.

5.2.5.5 Reduction of Toxicity, Mobility, or Volume Through Treatment

Treatment Process and Remedy. The upgraded CTP lime neutralization treatment process will be operated in the high-density sludge mode similar to Alternatives 2, 3, and 4. This is expected to provide the same effluent concentrations.

Amount of Hazardous Material Destroyed or Treated. The mitigations are expected to reduce the total average annual AMD volume requiring collection and treatment by about 20 percent. About the same percentages of metal will be removed as for Alternatives 2, 3, and 4 because the treatment plants are expected to have the same effluent concentrations.

Reduction of Toxicity, Mobility, or Volume. Alternative 5 is expected to initially reduce the volumes of mine water, CTP effluent metals, and sludge more than any of the other alternatives. The reductions are expected to be 20 percent more than for Alternative 2, and 10 percent more than for Alternatives 3 and 4 as initially implemented (additional mitigations could be constructed as part of their phased approach).

Irreversibility of the Treatment. As in all other alternatives, the treatment process will be reversible. Metals in the sludge will have the potential to leach back into solution if exposed to acidic conditions. Thus, the sludge must be disposed in an appropriate facility to reduce the threat to the environment. If the sludge is properly disposed and managed, the risk of metal release to the environment is expected to be minor. Treatment is considered fully reversible in the sense that other source control, resource recovery, or mining activities could be instituted in the future.

Type and Quantity of Treatment Residual. The treatment residual of concern is the sludge, which is estimated to be about 20 percent less than for Alternative 2, and about 10 percent less than for Alternatives 3 and 4 as initially implemented.

5.2.5.6 Short-Term Effectiveness

Protection of the Community During Remedial Actions. All the construction activities use standard construction techniques and practices. These activities are expected to be performed in a protective manner.

Protection of Workers During Remedial Actions. Workers will be exposed to normal construction-related risks. Following safe construction and best management practices can minimize the risks.

Environmental Impacts Associated with Construction. Construction impacts are expected to be minor. A section of the ephemeral West Fork Milo Creek and a section of South Fork Milo Creek will be affected by the diversions. The land in the other areas has been previously disturbed by prior development or mining activities. Stream crossings will be needed for the new pipeline section and possibly for sludge filtrate. The environmental impacts of these crossings are expected to be minor. Construction of the plugs will require temporary diversion of Milo Creek and Deadwood Creek flows around the work areas.

Time Until Remedial Response Objectives Are Achieved. Alternative 5 is expected to meet the TMDL-based discharge levels and to be in compliance with most Idaho surface water quality criteria as soon as the CTP is upgraded and begins steady-state operation. A monitoring period of a few months may be needed to determine if other changes are needed

to be in compliance with temperature, pH, dissolved oxygen, mercury, selenium, and thallium. The HDS process will also reduce sludge production as soon as the upgraded plant is started up.

5.2.5.7 Implementability

Ability to Construct and Implement Technology. There are no barriers for construction and implementation of this alternative. All necessary technologies are standard and have been used at other sites. Some of the mitigation remedial work in Milo Basin will be on private land. In-mine AMD collection, storage and monitoring requires access from and coordination with the New Bunker Hill Mining Company.

Reliability of Technology. All of the technologies required for this alternative are fully developed, are well understood, and are reliable given proper operation and maintenance. The upgraded CTP will have backup power and redundant capabilities as described in Section 3.6. Compared to the existing plant, the improvements will increase plant reliability and will reduce the chance that partially treated or untreated AMD will be released into Bunker Creek.

Ease of Undertaking Additional Remedial Actions, If Necessary. No subsequent mitigation or treatment plant upgrades are considered for Alternative 5. However, implementation of Alternative 5 should not provide a serious impediment to other remedial actions if necessary. Treatment is compatible with other source control and resource recovery options.

Ability to Monitor Effectiveness of Remedy. Monitoring will be conducted to assess mitigation effectiveness and to monitor for buildup of acid salts within the mine. This is assumed to continue for 5 years after construction. Monitoring will be similar to that described for Alternatives 3 and 4. Treatment plant performance will be tracked by continual flow monitoring and daily sampling. All of this monitoring has been performed in the past. In-mine and Kellogg Tunnel portal monitoring requires the cooperation of the New Bunker Hill Mining Company.

Coordination with Other Agencies. Administrative implementability for all work associated with this alternative should be straightforward and consistent with past Bunker Hill site agency coordination.

Availability of Treatment, Storage Capacity, and Disposal Services. The required treatment, storage capacity, and disposal services are available. Space is available at the CTP for the required upgrades. Sufficient space is available within the mine for AMD storage. There is sufficient space on- or off-site for 30 years of sludge disposal.

Availability of Necessary Equipment and Specialists. The materials and workforce to implement this alternative are readily available. The work force is available locally or regionally.

Availability of Prospective Technologies. All technologies required for this alternative have been used before and are readily available.

5.2.5.8 Cost

Table 5-6 summarizes the order-of-magnitude (+50 to –30 percent) cost estimate for Alternative 5. The costs are summarized by remedy component. The total alternative net present value using each sludge management option is summarized at the bottom of the table. The cost estimate includes a 20 percent lime and sludge reduction expected from the mitigations. Additional cost detail is included in Appendix G.

5.3 Comparative Analysis

This concluding section of the Bunker Hill Mine Water Remedial Investigation and Feasibility Study report presents a comparison of the alternatives. The preceding text profiled each alternative against the two threshold criteria and five balancing criteria. This section shifts the focus to the individual criteria and provides a succinct comparison of the advantages and disadvantages for the benefit of stakeholders and decisionmakers. Table 5-7 provides a summary.

5.3.1 Summary Descriptions

The main elements of the alternatives are summarized in Table 4-4. Table 5-8 highlights the major differences.

5.3.2 Overall Protection of Human Health and the Environment

Alternative 1 does not protect human health and the environment. It results in the direct discharge of untreated AMD to Bunker Creek that endangers humans and results in toxic conditions for aquatic life. Alternatives 2 through 5 all use the same treatment technology. They protect human health and the environment by removing the toxicity associated with AMD to levels that achieve the TMDL discharge allocations for the CTP. Alternatives 3, 4, and 5, however, provide some additional protectiveness over Alternative 2. They include mitigations to reduce the overall volume of AMD, and upgraded diversion and pumping systems that permit more significant in-mine water storage. These additional components reduce the chance of high mine water flows exceeding the downstream capacity of the treatment plant and resulting in a release of untreated AMD to Bunker Creek. Alternative 2, which uses a larger-capacity treatment plant, does not have these additional safeguards. Alternatives 3 and 4 are believed to be somewhat more protective than Alternative 5. They employ a phased approach to implementing mitigations and treatment plant sizing. This approach allows careful consideration of the most effective ways to either reduce mine water flow or optimize treatment plant size. Alternative 5 does not use a phased approach; thus, it has no built-in flexibility to use or benefit from new information gained during installation and operation of initial mitigations, treatment capacity, or both. This lack of flexibility reduces its ability to protect as compared to Alternatives 3 and 4.

All four sludge options are expected to be protective of the community and the environment. Options A, C, and D, the onsite sludge disposal options, provide protection by using lined disposal facilities to prevent leakage to the environment. Fencing and gates would also be used to prevent public exposure to sludge. Option A, disposal in sludge beds located on the CIA, may provide somewhat higher worker protection because sludge

handling is minimized. Option B, offsite disposal, provides protection by removing the sludge from the community and transporting it to a secure facility.

5.3.3 Compliance with ARARs

Alternative 1 will not meet chemical-specific ARARs and results in release of untreated AMD to Bunker Creek. All other alternatives are expected to be in compliance with most Idaho surface water discharge criteria, and achieve the TMDL discharge levels for the CTP. Performance monitoring of the upgraded CTP is needed to further assess compliance for Idaho surface water criteria for mercury, selenium, thallium, temperature, dissolved oxygen, and pH. Alternatives 2, 3, 4 and 5 are expected to be in compliance with other chemical-, location-, and action-specific ARARs. All four sludge management options are expected to be in compliance with all ARARs. Therefore, there is no difference between Alternatives 2 through 5 for compliance with ARARs.

5.3.4 Long-Term Effectiveness and Permanence

None of the alternatives will halt the acid-producing reactions occurring within the mine. Acid production and metal release is expected to continue for hundreds or thousands of years unless new technology becomes available and is used to stop the process. The alternatives, however, differ in the degree to which they reduce the quantity of AMD and the magnitude of residual risk remaining from treatment plant sludge.

Alternative 1 takes no measures to reduce the long-term release of AMD from the mine and results in increased long-term human health risk and environmental harm by direct discharge of AMD to Bunker Creek. Alternative 2 also does not reduce the long-term release of AMD from the mine, but uses improved and larger treatment systems to protect human health and the environment. Alternatives 3, 4, and 5 use mitigations to reduce both peak and average AMD flows, which reduces the long-term risk from large flows exceeding treatment capacity compared to Alternative 2. These alternatives, therefore, provide the greatest degree of long-term effectiveness and permanence. The specific effectiveness of the mitigations will not be known until they are constructed and operated for some time; thus, it is possible that the additional mitigations initially implemented in Alternative 5 may not substantially increase overall remedy effectiveness compared to Alternatives 3 and 4.

Alternatives 2 through 5 all require long-term operation, maintenance, and periodic replacement of components. The mitigation facilities of Alternatives 3, 4, and 5 must be inspected and maintained. The mitigation facilities in the West Fork Milo Creek will be difficult to access and clean during winter and spring because of snow accumulation, which increases the probability of clogging by debris and the bypass of water into the mine. However, the potential for this occurring would be minimized during design. AMD collection within the mine is the same for all alternatives. Continual and substantial effort is needed to keep the workings maintained to ensure unimpeded movement of AMD either into storage or out through the Kellogg Tunnel. The in-mine gravity storage system used in Alternatives 3, 4, and 5 will be more reliable than the pumped system of Alternative 2. Alternatives 2 through 5 all use the same treatment processes, which are expected to provide long-term protection by reducing the acid and metals to safe levels. The treatment plants are expected to be reliable and have reasonable backup systems.

Alternatives 2 through 5 all produce the same type of sludge. Compared to Alternative 2, Alternatives 3, 4, and 5 are expected to reduce long-term sludge volumes. These reductions reduce the volume of on- or offsite land required for long-term disposal, and the magnitude of residual risk remaining from the sludge. All four sludge management options are expected to have adequate and reliable controls to prevent migration of contaminants and public exposure, although Option B (offsite disposal) is expected to produce nearly twice the sludge volumes as the other options. Sufficient sludge disposal space is available onsite for Options A, C, and D, or regionally for Option B. Long-term land use restrictions will be needed for the onsite options (A, C, and D) to prevent disturbance of the capped and closed disposal areas. Option D will require about 300 to 600 truckloads of sludge to be hauled each fall along McKinley Avenue from the CIA drying beds to the smelter closure area landfill. Although the trucks would be decontaminated, this volume of truck traffic could be disruptive.

5.3.5 Reduction of Toxicity, Mobility, or Volume Through Treatment

Alternative 1 results in the existing treatment plant shutting down in 3 to 5 years. This causes an increase in the toxicity, mobility, and volume of AMD contaminants compared to current conditions.

Alternatives 2 through 5 all use the same lime HDS treatment process to remove dissolved metals, and the same type of media filters for removal of suspended metals. The same treatment plant effluent quality is expected from each alternative. The treatment process will remove all of the acidity and will reduce cadmium, lead, and zinc to levels that attain the TMDLs. The process is expected to significantly reduce the toxicity, mobility, and volume of AMD contaminants by incorporating them into an alkaline sludge. The sludge is classified as a non-hazardous waste. It is expected to pass the TCLP test, and it is excluded from being characterized as a hazardous waste by the Bevill Amendment to RCRA. Alternative 2 however, does not employ source control measures that are expected to reduce the quantity of AMD generated and volume of sludge produced. Alternatives 3, 4, and 5 all employ such measures and thus provide greater volume reductions than Alternative 2. Alternatives 3 and 4 are expected to produce about 10 percent less AMD and sludge than Alternative 2 as initially implemented (greater reductions may be achieved if additional mitigations are constructed), and Alternative 5 is expected to produce 20 percent less AMD and sludge than Alternative 2.

The treatment process could be reversed if the alkaline sludge is dissolved by contact with sufficient acidity. The onsite options (A, C, and D) use low-permeability liner and cover systems to isolate the sludge from the environment and potential sources of acidity. Long-term land use restrictions are needed to prevent the covered and closed facilities from being disturbed. The offsite option will use appropriate disposal facilities to ensure that the sludge is properly managed.

5.3.6 Short-Term Effectiveness

Alternative 1 increases the risk posed by release of untreated AMD by halting maintenance of existing AMD management systems. Alternatives 2 through 5 are expected to provide about the same short-term protectiveness. The AMD will continue to be collected, stored, and treated using existing systems during construction of new systems. Impacts on the

community during construction of Alternatives 2 through 5 are expected to be similar because they all involve AMD pipeline and CTP upgrades, and possibly sludge disposal onsite. Worker safety is also expected to be about the same because each uses similar construction practices.

Environmental impacts associated with Alternatives 3, 4, and 5 are greater than Alternative 2 because of impacts from mitigation construction. Some of the mitigations require work in stream segments, although some of the segments have been previously disturbed by past mining activities.

Alternatives 2 through 5 will provide protection as soon as they are implemented. The implementation time is similar for each. The phased approach used for Alternatives 3 and 4, may take up to 10 years to complete, but initially implemented remedial actions are expected to provide protection from untreated releases of AMD during the phasing period.

The onsite sludge options (A, C, and D) are expected to have about the same construction impacts on the community because they require similar construction methods and timeframes. Option B, the offsite option, will have minimal community construction impacts because all construction occurs at the CTP.

5.3.7 Implementability

Alternative 1, although technically feasible to implement, may have low administrative feasibility because of the resulting environmental consequences from untreated AMD entering Bunker Creek and the SFCdA River. Alternatives 2 through 5 all have similar implementability. All use standard technologies expected to be reliable given proper operation and maintenance, and all require materials and services available locally or regionally. None of the alternatives prevent the undertaking of additional remedial actions, if necessary. Alternatives 2 through 5 all have the same administrative feasibility, which requires agency coordination similar to that already conducted for other portions of the site. Alternatives 3, 4, and 5 require coordination with landowners to implement mitigations.

Alternatives 2 through 5 require coordination with the New Bunker Hill Mining Company to implement in-mine AMD collection, storage, and monitoring. Alternatives 3, 4, and 5 require in-mine monitoring to assess the effectiveness of the mitigations. In-mine monitoring is technically feasible and requires the cooperation of the New Bunker Hill Mining Company for access to underground monitoring locations. In-mine monitoring is not required for Alternative 2.

Onsite sludge options (A, C, and D) would be constructed on federally owned land and would use standard technologies. Therefore, there are no administrative impediments to locating sludge disposal beds in these areas. These areas are also currently under industrial use (waste containment/disposal) and they are anticipated to remain so in the future. There has been some community interest in reuse of the top of the CIA (such as for a golf course) once it has been capped. However, thus far there are no specific plans or agreements in place regarding what type of reuse may be appropriate. Option A, which would be located on top of the CIA, would not preclude community redevelopment of the CIA in the future because the sludge disposal beds would occupy only a limited portion of the CIA (about 10 percent over 30 years), and would be covered and capped when full. Option C will be more difficult to implement than options A and D because of the required sludge pump

station and pipeline along McKinley Avenue. Reliance on the pump station and pipeline may make Option C less reliable than options A or D. There is sufficient regionally available offsite sludge disposal capacity for Option B.

5.3.8 Cost

5.3.8.1 Cost Comparison

Table 5-9 presents estimates of the 30-year net present value costs for the alternatives. Figure 5-1 provides a cost comparison, with the alternatives arranged from lowest to highest total cost using net present values. The 30-year basis is selected merely to compare the early costs of the alternatives. All of the alternatives, except Alternative 1, are expected to have costs beyond 30 years because present information shows that contaminated mine water flows are expected to continue beyond 30 years. Figure 5-2 shows a graphical comparison of cumulative non-discounted costs to cumulative discounted (net present value) costs for a 100-year period for all alternatives except Alternative 1. The figure illustrates the affects of discounting future costs to net present values using a 7 percent interest rate. The right side of Figure 5-2 lists the alternatives arranged from highest to lowest cost. Alternative 5B is the highest cost alternative, and Alternative 2A is the lowest cost alternative for both non-discounted and discounted scenarios. The 30-year net present value costs range from $6.4 million for Alternative 1 to $66.4 million for Alternative 5B. Alternatives 3 and 4 are in the middle of the cost range. Other than Alternative 1, Alternative 2 is the least costly, and Alternatives 3, 4, and 5, which all use mitigations, are more costly. Total costs generally go up as more mitigations are implemented. Annual O&M costs also go up as more mitigations are implemented.

Of the four sludge options, Option B, which uses mechanical dewatering and offsite disposal, is the most costly. Option A, which uses CIA sludge drying beds, is the least costly. Options C and D have about the same cost.

5.3.8.2 Cost Assumptions and Uncertainties

All the cost estimates are the product of “order-of-magnitude” estimating procedures based on conceptual layouts and preliminary cost information. Estimates of this nature are subject to significant changes as more detailed engineering and cost information becomes available. It is commonly assumed that actual costs may vary from the stated amounts by as much as plus 50 percent and minus 30 percent. The final remedial action costs will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope, final schedule, and other variable factors. As a result, the final remedial action costs will vary from those presented in Table 5-9. Other assumptions and uncertainties that affect the alternative cost estimates are summarized below. Additional cost details and assumptions may be found in Appendix G.

- The discount rate used for net present value is 7 percent, and the analysis period is 30 years for each alternative. Although mine water management is expected to continue beyond 30 years, all alternatives contain remedial components sharing similar life cycles. Thus, a longer net present value period is not expected to accurately change the relative cost rank of the alternatives, nor provide more accurate cost assessments given the inherent uncertainties associated with the order-of-magnitude cost estimates, estimates of mitigation effectiveness, and long-term site, regulatory, social, and technological

conditions. However, it is likely that total costs to manage the mine water forever will be higher than those presented in Table 5-9 (see Figure 5-2). In addition to 7 percent, cost estimates using discount rates of 3, 5, and 10 percent were developed during preparation of the draft RI/FS document. These estimates were not included in the final RI/FS because the different discount rates did not change the relative cost rank of the alternatives.

- Alternative 1 costs (the No Further Action alternative) assume that the CTP and other current mine water management-related control measures are continued for 4 years, then shut down. The 4-year duration is based on 3 to 5 years of remaining volume in the existing sludge disposal area. It is assumed that the CTP would be shut down when the sludge disposal volume is exhausted because the CTP cannot operate without sludge disposal. The actual CTP operational period may vary from the assumed 4-year period.
- The costs consider that the annual mine water volumes and chemistry stay similar to historical values, or are reduced by the mitigations. The actual costs will depend on actual volumes and chemistry.
- Alternatives 3, 4, and 5 include estimated cost savings resulting from mitigation-induced mine water flow reductions. Alternatives 3 and 4 include an assumed 10 percent reduction in lime consumption and sludge production, and Alternative 5 assumes 20 percent reductions. The actual cost savings will depend on the actual mine water flow reductions and the chemistry of the resulting mine water.
- Costs for additional mitigations or treatment plant capacity installed as part of the phased approach for Alternatives 3 and 4 are not included in the cost estimates.
- The 100-year cumulative costs illustrated in Figure 5-2 may not represent long-term future costs because of the assumptions needed to develop the figure. The costs assume replacement of mechanical equipment every 15 years, and no change in remedial technology or approach over the 100-year period.

TABLE 5-1
Cost Summary for Alternative 1—No Further Action
Bunker Hill Mine Water RI/FS Report

Remedy Component	Capital Cost ($)	Annual O&M Cost[1] ($/yr)	4-Year Net Present value[2] ($)
AMD Mitigations	0	0	0
AMD Collection	0	1,071,000	3,627,000
AMD Conveyance	0	93,000	315,000
AMD Storage	0	31,000	105,000
AMD Treatment	0	682,000	2,310,000
Sludge Management[3]	0	0	0
Performance Monitoring[3]	0	0	0
Alternative 1 Totals	0	1,877,000	6,358,000

[1]O&M costs are for only a 4-year period.
[2]Net present value is based on costs to operate the existing components for 4 years, at which point all remedial expenditures will cease. Interest rate for net present value is 7 percent.
[3]Sludge management and performance monitoring costs are included in the treatment costs.

TABLE 5-2
Comparison of Treatability Results to Potential State of Idaho Surface Water ARARs for Chemicals of Concern (µg/L)[1]
Bunker Hill Mine Water RI/FS Report

Chemical	Estimated Effluent Concentration[2]	Freshwater Aquatic Life Protection		Human Health Protection for Consumption of:	
		Acute	Chronic	Water + Organisms	Organisms Only
Arsenic	5.6 U	50	50	50	50
Cadmium[3]	0.22	16.6	2.9	NA	NA
Copper	2.47	62.8	37.1	NA	NA
Lead[3]	0.49 U	281	10.9	NA	NA
Mercury	0.02	2.1	0.012	0.14	0.15
Selenium	9.6 U	20	5	NA	NA
Silver	2.6 U	37.4	NA	NA	NA
Thallium	5.8	NA	NA	1.7	6.3
Zinc[3]	34.6	371	338	NA	NA

[1] Refer to Table 2-7 for the basis of State of Idaho values used in this table.

[2] Average concentrations for dissolved metals collected during the Phase 2 Treatability Study between July 16 and August 15, 2000. One half of the detection limit was used for values that were not detected.

[3] Freshwater and human health concentrations provided in this table are superseded by the source load allocations developed in the TMDL. The values are provided for comparative purposes only.

U = Not detected above the indicated detection limit of the analyses.

NA = Not available.

TABLE 5-3
Cost Summary for Alternative 2—Treatment Only
Bunker Hill Mine Water RI/FS Report

Remedy Component	Capital Cost ($)	Annual O&M Cost ($/yr)	30-Year Net Present Value[1] ($)
AMD Mitigations	0	0	0
AMD Collection	0	1,071,000	13,290,000
AMD Conveyance	340,000	130,000	1,953,000
AMD Storage	0	31,000	385,000
AMD Treatment	9,561,000	849,000	20,096,000
Sludge Management Option A	6,743,000[2]	46,000	7,314,000
Sludge Management Option B	5,590,000[2]	745,000	14,835,000
Sludge Management Option C	11,260,000[2]	72,000	12,153,000
Sludge Management Option D	10,239,000[2]	154,000	12,150,000
Performance Monitoring	0	78,000 (yrs 1-30)	968,000
Alternative 2A Totals	16,644,000	2,205,000	44,006,000
Alternative 2B Totals	15,491,000	2,904,000	51,527,000
Alternative 2C Totals	21,161000	2,231,000	48,846,000
Alternative 2D Totals	20,140,000	2,313,000	48,842,000

[1]The net present value is calculated using a 30-year analysis period and a 7 percent interest rate.
[2]Sludge management capital cost is the net present value of capital expenditures.

TABLE 5-4
Cost Summary for Alternative 3—Phased Mitigations/Treatment
Bunker Hill Mine Water RI/FS Report

Remedy Component	Capital Cost ($)	Annual O&M Cost ($/yr)	30-Year Net Present Value[1] ($)
AMD Mitigations	4,990,000	55,000	5,672,000
AMD Collection	0	1,071,000	13,290,000
AMD Conveyance	340,000	130,000	1,953,000
AMD Storage	1,950,000	157,000	3,898,000
AMD Treatment	8,198,000	797,000	18,088,000
Sludge Management Option A	6,474,000[2]	42,000	6,995,000
Sludge Management Option B	5,350,000[2]	682,000	13,813,000
Sludge Management Option C	10,937,000[2]	67,000	11,768,000
Sludge Management Option D	9,532,000[2]	141,000	11,282,000
Performance Monitoring	0	320,000 yrs 1-10 78,000 yrs 11-30	2,668,000
Alternative 3A Totals	21,952,000	2,572,000 yrs 1-10 2,330,000 yrs 11-30	52,565,000
Alternative 3B Totals	20,828,000	3,212,000 yrs 1-10 2,970,000 yrs 11-30	59,383,000
Alternative 3C Totals	26,415,000	2,597,000 yrs 1-10 2,355,000 yrs 11-30	57,338,000
Alternative 3D Totals	25,010,000	2,671,000 yrs 1-10 2,429,000 yrs 11-30	56,852,000

[1]The net present value is calculated using a 30-year analysis period and a 7 percent interest rate.

[2]Sludge management capital cost is the net present value of capital expenditures.

TABLE 5-5
Cost Summary for Alternative 4—Phased Mitigations/Treatment with Plugging of Near-Stream Workings
Bunker Hill Mine Water RI/FS Report

Remedy Component	Capital Cost ($)	Annual O&M Cost ($/yr)	30-Year Net Present Value[1] ($)
AMD Mitigations	6,000,000	56,000	6,695,000
AMD Collection	0	1,071,000	13,290,000
AMD Conveyance	340,000	130,000	1,953,000
AMD Storage	1,950,000	157,000	3,898,000
AMD Treatment	8,198,000	797,000	18,088,000
Sludge Management Option A	6,474,000[2]	42,000	6,995,000
Sludge Management Option B	5,350,000[2]	682,000	13,813,000
Sludge Management Option C	10,937,000[2]	67,000	11,768,000
Sludge Management Option D	9,532,000[2]	141,000	11,282,000
Performance Monitoring	0	320,000 yrs 1-10 78,000 yrs 11-30	2,668,000
Alternative 4A Totals	22,962,000	2,573,000 yrs 1-10 2,331,000 yrs 11-30	53,588,000
Alternative 4B Totals	21,838,000	3,213,000 yrs 1-10 2,971,000 yrs 11-30	60,405,000
Alternative 4C Totals	27,425,000	2,598,000 yrs 1-10 2,356,000 yrs 11-30	58,361,000
Alternative 4D Totals	26,020,000	2,672,000 yrs 1-10 2,430,000 yrs 11-30	57,874,000

[1]The net present value is calculated using a 30-year analysis period and a 7 percent interest rate.

[2]Sludge management capital cost is the net present value of capital expenditures.

TABLE 5-6
Cost Summary for Alternative 5—Treatment with All Mitigations
Bunker Hill Mine Water RI/FS Report

Remedy Component	Capital Cost ($)	Annual O&M Cost ($/yr)	30-Year Net Present Value[1] ($)
AMD Mitigations	12,060,000	222,000	14,815,000
AMD Collection	0	1,071,000	13,290,000
AMD Conveyance	340,000	130,000	1,953,000
AMD Storage	1,950,000	157,000	3,898,000
AMD Treatment	8,198,000	763,000	17,666,000
Sludge Management Option A	6,205,000	38,000	6,677,000
Sludge Management Option B	5,100,000	618,000	12,769,000
Sludge Management Option C	10,605,000	62,000	11,374,000
Sludge Management Option D	8,821,000	129,000	10,422,000
Performance Monitoring	0	320,000 yrs 1-5 78,000 yrs 6-30	1,960,000
Alternative 5A Totals	28,753,000	2,701,000 yrs 1-5 2,459,000 yrs 6-30	60,260,000
Alternative 5B Totals	27,648,000	3,281,000 yrs 1-5 3,039,000 yrs 6-30	66,352,000
Alternative 5C Totals	33,153,000	2,725,000 yrs 1-5 2,483,000 yrs 6-30	64,957,000
Alternative 5D Totals	31,369,000	2,792,000 yrs 1-5 2,550,000 yrs 6-30	64,005,000

[1]The net present value is calculated using a 30-year analysis period and a 7 percent interest rate.

[2]Sludge management capital cost is the net present value of capital expenditures.

TABLE 5-7
Alternatives Evaluation Summary
Bunker Hill Mine Water RI/FS Report

Overall Protection of Human Health and the Environment	Compliance with ARARs	Long-Term Effectiveness and Permanence	Reduction of Toxicity, Mobility, or Volume through Treatment	Short-Term Effectiveness	Implementability	Cost[1] (million $)
Alternative 1—No Further Action						
Does not protect. Results in discharge of untreated AMD and aquatic toxicity in Bunker Creek and the SFCdA River.	Does not comply with ARARs.	Takes no measures to reduce the long-term release of AMD from the mine and results in increased long-term human health risk and environmental harm by direct discharge of AMD to Bunker Creek.	Results in the existing treatment plant shutting down in 3 to 5 years, increasing the toxicity, mobility, and volume of AMD contaminants compared to current conditions.	Results in increased short-term risks. Never provides protection.	Will likely have low administrative feasibility because of the resulting environmental consequences from untreated AMD entering Bunker Creek and the SFCdA River.	Capital: $0 Annual O&M: $6.36 **Total NPV: $6.4**
Alternative 2—Treatment Only						
Protects by using storage and a large enhanced treatment plant; however, AMD flows are not reduced. Thus, there is potential for peak flows to exceed storage and treatment capacity.	Expected to comply with most Idaho surface water criteria and attain TMDLs.	Does not halt AMD generation or reduce flows. Although treatment is effective, it is needed indefinitely.	Uses treatment to reduce the toxicity, mobility, and volume of contaminants to acceptable levels. Treatment sludge requires long-term management. Treatment process could be reversed if sludge is dissolved.	Alternatives 2 through 5 are expected to provide about the same short-term protectiveness. The AMD will continue to be collected, stored, and treated using existing systems during construction of new systems.	Readily implementable. Uses existing and available technologies. No administrative difficulties. Adequate sludge storage available on or off-site. Require coordination with the mine owner to implement in-mine storage.	Capital: $15.5 – $21.2 Annual O&M: $2.21 – $2.90 **Total NPV: $44.0 – $51.5** **Lowest cost alternative (other than Alternative 1)**
Alternative 3—Phased Treatment/Mitigations						
Protects by use of mitigations to reduce AMD flows, use of an enhanced in-mine storage system, and use of an enhanced treatment plant. Phased implementation of mitigations and treatment capacity provides flexibility to increase protection if needed, and should provide more overall protectiveness than Alternative 2.	Similar to Alternative 2	Reduces long-term risk compared to Alternative 2 by using mitigations to reduce AMD flows, and an enhanced in-mine storage system. Indefinite treatment is still needed. Reduces sludge volume by about 10 percent compared to Alternative 2.	Uses the same treatment and sludge disposal methods as Alternative 2, but mitigations result in about 10 percent less AMD and sludge. Further reductions will occur if more mitigations are built using the phased approach.	Environmental impacts associated with Alternatives 3, 4, and 5 are greater than Alternative 2 because of impacts from mitigation construction.	Similar to Alternative 2, but additional coordination with the mine owner is required to implement in-mine AMD monitoring. Also requires coordination with landowners to implement mitigations.	Capital: $20.8 – $26.4 Annual O&M: $2.47 – $3.11 **Total NPV: $52.6 – $59.4**
Alternative 4—Phased Treatment/Mitigations with Plugging of Near-Stream Workings						
Similar to Alternative 3, but initially more protective since two additional mitigations are constructed.	Similar to Alternative 2	Similar to Alternative 3	Similar to Alternative 3	Similar to Alternative 3	Similar to Alternative 3	Capital: $21.8 – $27.4 Annual O&M: $2.47 – $3.11 **Total NPV: $53.6 – $60.4**
Alternative 5—Treatment with All Mitigations						
Does not use a phased approach and has less flexibility compared to Alternatives 3 and 4. This lack of flexibility reduces its ability to protect as compared to Alternatives 3 and 4.	Similar to Alternative 2	Similar to Alternatives 3 and 4, but since a phased approach is not used, it is possible that the additional mitigations initially implemented may not substantially increase overall remedy effectiveness.	Similar to Alternatives 3 and 4, but mitigations result in about 20 percent less AMD and sludge than Alternative 2.	Similar to Alternative 3	Similar to Alternative 3	Capital: $27.7 – $33.2 Annual O&M: $2.54 – $3.12 **Total NPV: $60.3 – $66.4** **Highest cost alternative**
Sludge Options						
All four sludge options are expected to be protective of the community and the environment.	All four sludge management options are expected to be in compliance with all ARARs.	All four sludge management options are expected to have adequate and reliable controls to prevent migration of contaminants and public exposure. Option D requires about 300 to 600 truckloads of sludge to be hauled each fall along McKinley Avenue from the CIA drying beds to the smelter closure area landfill. Although the trucks would be decontaminated, this volume of truck traffic could be disruptive.	All three onsite options (A, C, and D) use engineering controls or land use restrictions to isolate and protect the sludge from disturbance. The offsite option (B) will use appropriate disposal facilities to ensure that the sludge is properly managed.	The onsite sludge options (A, C, and D) are expected to have about the same construction impacts on the community. Option B, the off-site option, will have minimal community construction impacts because all construction occurs at the CTP.	Onsite sludge options (A, C, and D) would be constructed on federally owned land. Option C more difficult to implement than options A and D because of the sludge pump station and pipeline along McKinley Ave. Sufficient regionally available off-site sludge disposal capacity exists for Option B.	Of the four sludge options, Option B, which uses mechanical dewatering and offsite disposal, is the most costly. Option A, which uses CIA sludge disposal beds, is the least costly. Options C and D have about the same cost.

[1]The cost of each alternative depends on which sludge option is selected. 30-year net present values use a 7 percent interest rate to convert future costs to present cost.

AMD = acid mine drainage

SFCdA = South Fork Coeur d'Alene (River)

ARAR = applicable or relevant and appropriate requirement

TMDL = total maximum daily load

TABLE 5-8
Alternative Summary Descriptions
Bunker Hill Mine Water RI/FS Report

Alternative	Description
1—No Further Action	• No mitigations are constructed • Uses the existing AMD collection, conveyance, storage, treatment, and sludge management systems • CTP is not upgraded or repaired. The CTP is shut down in 3 to 5 years when the existing sludge disposal capacity is exhausted.
2—Treatment Only	• No mitigations are constructed • Uses existing AMD collection, conveyance, and storage systems • Pipeline added for direct flow capability to CTP • CTP upgraded to 5,000 gpm capacity with filters for high-density sludge (HDS) operation, attainment of TMDLs, and compliance with discharge standards. • Alternative 2A uses new CIA sludge disposal beds. Alternative 2B uses mechanical sludge dewatering and offsite disposal. Alternative 2C uses sludge disposal beds located above the smelter closure area. Alternative 2D uses CIA sludge drying beds and annual excavation and disposal in a landfill located above the smelter closure area. Alternatives 2A, 2C, and 2D are estimated to produce about 5,400 y^3/yr of sludge. Alternative 2B is estimated to produce about 10,300 y^3/yr of sludge because the mechanical dewatering is expected to be less efficient than sludge drying beds or sludge disposal beds.
3—Phased Mitigations/Treatment	• Uses a phased implementation and performance evaluation approach for mitigations and CTP sizing. Following initial actions, up to 10 years of monitoring and performance evaluation is used to determine if more mitigations or treatment capacity is needed. • Initially implements the West Fork Milo Creek Diversion, rehabilitates the Phil Sheridan Diversion, and plugs in-mine drill holes, which collectively are expected to significantly reduce peak mine water flows. Total annual volumes are expected to be reduced by about 10 percent by initial mitigations. • Uses existing AMD collection and conveyance with pipeline added for direct flow capability to CTP • Uses existing lined pond and new gravity diversion system into in-mine storage. Also includes new mine pool extraction pumps. • The initial CTP hydraulic and neutralization capacity is 5,000 gpm. The initial filtration capacity is 2,500 gpm. Lime consumption is expected to be reduced by 10 percent by initial mitigations. • Uses one of the four sludge disposal options described for Alternative 2. The sludge volume is expected to be initially 10 percent less than Alternative 2 because of the mitigation-induced AMD volume reduction.
4—Phased Mitigations/Treatment with Plugging of Near-Stream Workings	• Similar to Alternative 3, except plugs are initially placed in the Small Hopes drift below Mainstem Milo Creek, and in the Inez Shaft below Deadwood Creek. These will reduce or eliminate the potential for stream erosion into the underlying mine workings. These two mitigations would be implemented under Alternative 3 if needed, based on the monitoring program and the phased approach.
5—Treatment with All Mitigations	• Similar to Alternatives 3 and 4, except a phased approach is not used. All mitigations (see Table 4-4) are implemented initially, and the CTP is sized at 2,500 gpm with no potential phased expansion. Mitigation performance monitoring is conducted for 5 years, then stopped.

TABLE 5-9
Summary of Costs
Bunker Hill Mine Water RI/FS

Alternative	Capital Costs (million $)	Annual O&M Costs[1] (million $)	30-Yr NPV[2] O&M Costs (million $)	30-Yr NPV[2] Total Costs (million $)
Alternative 1—No Further Action (4-year NPV)				
1—No Further Action	0	1.88 (Yrs 1-4)	6.4	6.4
Alternative 2—Treatment Only				
2A—with CIA Sludge Disposal Beds	16.6	2.21 (Yrs 1-30)	27.4	44.0
2B—with Mechanical Sludge Dewatering and Offsite Disposal	15.5	2.90 (Yrs 1-30)	36.0	51.5
2C—with Smelter Closure Area Sludge Disposal Beds	21.2	2.23 (Yrs 1-30)	27.7	48.8
2D—with CIA Sludge Drying Beds and Smelter Closure Area Sludge Landfill	20.1	2.31 (Yrs 1-30)	28.7	48.8
Alternative 3—Phased Mitigations/Treatment				
3A—with CIA Sludge Disposal Beds	22.0	2.57 (Yrs 1-10) 2.33 (Yrs 11-30)	30.6	52.6
3B—with Mechanical Sludge Dewatering and Offsite Disposal	20.8	3.21 (Yrs 1-10) 2.97 (Yrs 11-30)	38.6	59.4
3C—with Smelter Closure Area Sludge Disposal Beds	26.4	2.60 (Yrs 1-10) 2.36 (Yrs 11-30)	30.9	57.3
3D—with CIA Sludge Drying Beds and Smelter Closure Area Sludge Landfill	25.0	2.67 (Yrs 1-10) 2.43 (Yrs 11-30)	31.8	56.8
Alternative 4—Phased Mitigations/Treatment with Plugging of Near-Stream Workings				
4A—with CIA Sludge Disposal Beds	23.0	2.57 (Yrs 1-10) 2.33 (Yrs 11-30)	30.6	53.6
4B—with Mechanical Sludge Dewatering and Offsite Disposal	21.8	3.21 (Yrs 1-10) 2.97 (Yrs 11-30)	38.6	60.4
4C—with Smelter Closure Area Sludge Disposal Beds	27.4	2.60 (Yrs 1-10) 2.36 (Yrs 11-30)	30.9	58.3
4D—with CIA Sludge Drying Beds and Smelter Closure Area Sludge Landfill	26.0	2.67 (Yrs 1-10) 2.43 (Yrs 11-30)	31.9	57.9
Alternative 5—Treatment with All Mitigations				
5A—with CIA Sludge Disposal Beds	28.8	2.70 (Yrs 1-5) 2.46 (Yrs 6-30)	31.5	60.3
5B—with Mechanical Sludge Dewatering and Offsite Disposal	27.6	3.28 (Yrs 1-5) 3.04 (Yrs 6-30)	38.7	66.4
5C—with Smelter Closure Area Sludge Disposal Beds	33.2	2.73 (Yrs 1-5) 2.48 (Yrs 6-30)	31.8	65.0
5D—with CIA Sludge Drying Beds and Smelter Closure Area Sludge Landfill	31.4	2.79 (Yrs 1-5) 2.55 (Yrs 6-30)	32.6	64.0

[1]The annual O&M costs for Alternatives 3 and 4 is higher the first ten years due to the mitigation performance monitoring assumed to be conducted the first ten years as part of the phased approach. Alternative 5 assumes only 5 years of mitigation performance monitoring.

[2]The 30-yr Net present Value (NPV) costs are calculated using a 7 percent interest rate.

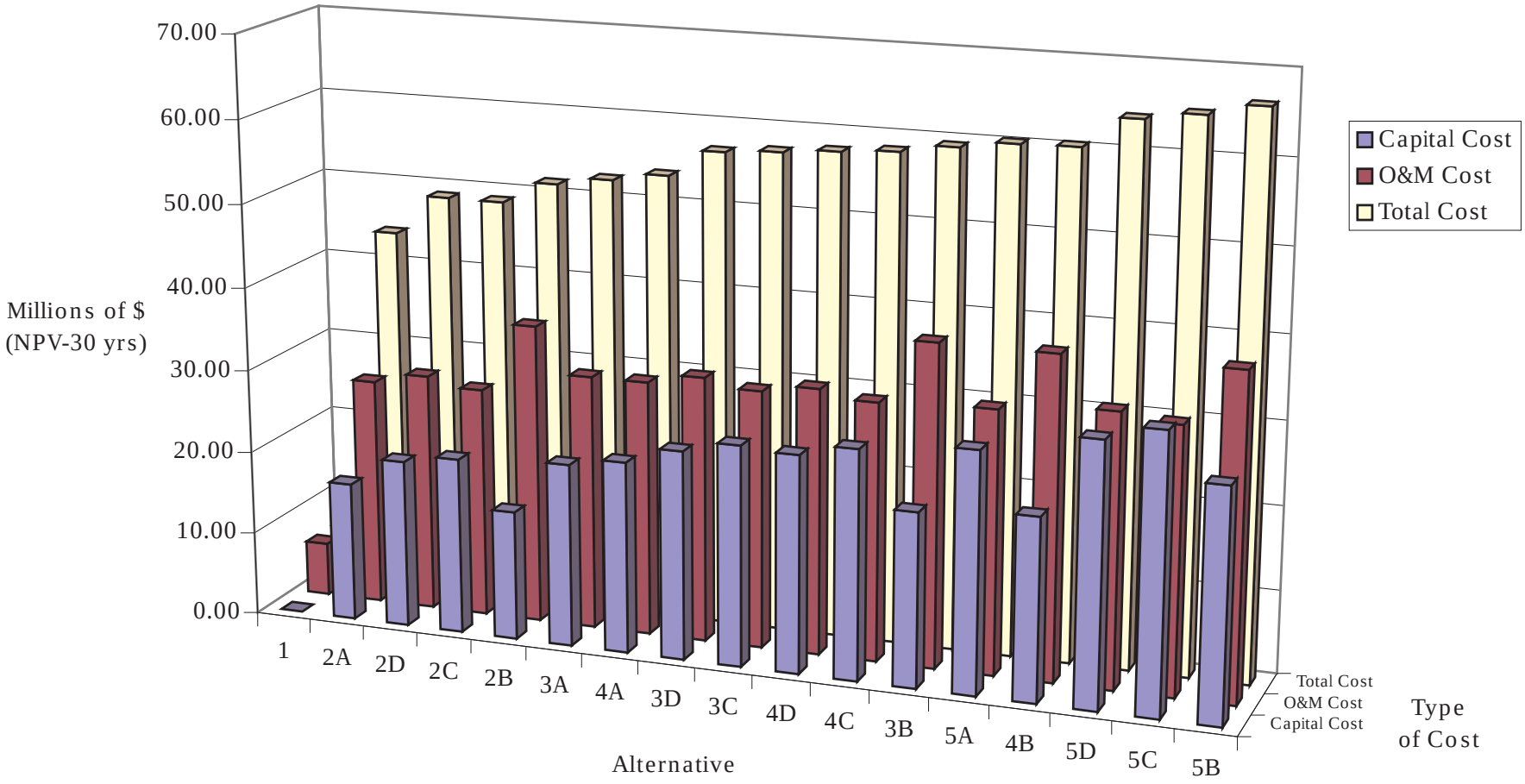

FIGURE 5-1
ALTERNATIVE COST COMPARISON ARRANGED FROM LOWEST TO HIGHEST COST TOTAL
BUNKER HILL MINE WATER MANAGEMENT RI/FS

CH2MHILL

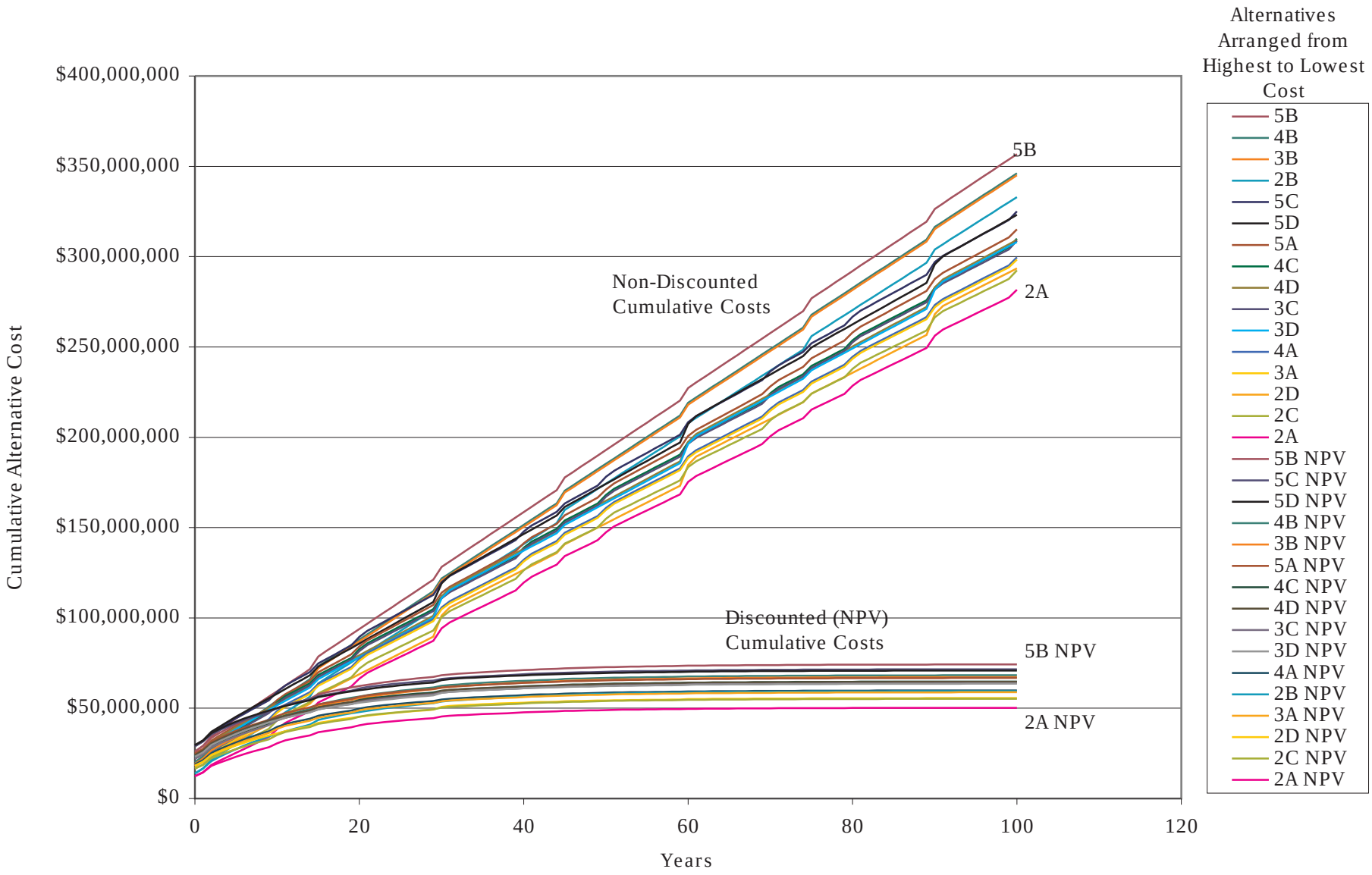

FIGURE 5-2

100-YEAR NON-DISCOUNTED AND DISCOUNTED (NPV) CUMULATIVE COST

BUNKER HILL MINE WATER MANAGEMENT RI/FS

CH2MHILL

SECTION 6.0

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6.0 Works Cited

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APPENDIX A

Summary of Previous Characterization Work from CH2M HILL's Project Library Database

APPENDIX A
Summary of Previous Characterization Work from CH2M HILL's Project Library Database
Bunker Hill Mine Water RI/FS Report

Library #	Date	Document Name	Author	Purpose and Objectives	Study Area	Evaluation Methods	Key Observations with Respect to EPA's Mine Water Management Project	Other Relevant Findings or Suggestions from the Author
809	01-Jan-35	A Mineralogic Study of the Bunker Hill Lode at Kellogg, Idaho	Kroll, Egon H.	To make a detailed mineralogic study of the Bunker Hill lode, Kellogg, Idaho	Bunker Hill, from the outcrop to the lowest workings	Microscopic examination of polished surfaces and thin sections of specimens.	Description of fault locations based on USGS Prof. Paper 732.	
115	01-Dec-73	Solutions to Problems of Pollution Associated with Mining in Northern Idaho	Ralston, Dale; Trexler, Bryson Wai, Chien; Renison, William; Rickman, Francis; University of Idaho and Idaho Bureau of Mines and Geology	To investigate sources and causes of the acid mine drainage in the Bunker Hill Mine in order to provide information for prevention of continued drainage in this and other mines.	Bunker Hill Mine	A network of weirs and flow recorders were installed to investigate water quality and quantity in the upper country and in levels below 9. Recharge potential to the mine was investigated through the use of fluorescent dyes. Laboratory investigation of different ores was conducted to determine the mechanisms of acid production.	Low pH water occurs from 4 Level to 12 Level within the interconnecting stopes of the Flood-Stanly Ore Body (Bluebird Ore). A water loss of 18.6 acre-feet was observed between the West Milo weir and the Phil Sheridan weir (10/1/72 to 5/18/73). Dye tests showed direct connection between mainstem Milo and Small Hopes and Reed Tunnel (less than 1 hour lag time). Three potential recharge areas exist; caving area, old stopped areas near the Bunker Hill dam, and the Cate fault near main stem Milo Creek.	Laboratory leaching test showed that Zn, Pb, and Mn increase in the effluent with a decrease of pH, sulfate ions were found in the effluent of all tests, and that the leaching process slowed down when oxygen levels were reduced. This report is a summary of work performed from May 1972 to May 1973.
106	01-Dec-75	Sources and Causes of Acid Mine Drainage	Trexler, Bryson Ralston, Dale; Reece, Dennis; Williams, Roy	To document the controls, occurrence, movement, and quality of groundwater in and adjacent to a deep, hard rock mine.	Bunker Hill Mine	Same work as done under Ralston above. Data collected through September 1973.	60 gpm loss through the bottom of the Bunker Hill Dam. Interconnection established with dye tracer tests between Deadwood Creek through Inez Shaft and 9 Level. Flushing mechanisms present in Flood-Stanly Ore Body. Drill holes are another source of water inflow to the mine.	Recommendations for reducing recharge include allowing sediment buildup in Bunker Hill Dam, construction of an impermeable cutoff wall at the collector raises to the Phil Sheridan diversion constructed on Deadwood, and cap Diamond Drill Holes (DDHs).
116	01-Jun-75	The Hydrogeology of Acid Production in a Lead-Zinc Mine	Trexler, Bryson	Same as above.	Bunker Hill Mine	Same work as above.	Surface water recharge may account for 70 percent of the mine discharge. 20 percent is attributed to groundwater entering through fractures.	Same as above.
114	1980	Production of Acid Water in a Lead-Zinc Mine, Coeur D'Alene, Idaho	Wai, Chien; Reece, Dennis; Trexler, Bryson; Ralston, Dale; Williams, Roy	To investigate sources of acid mine drainage and methods for preventing pollution.	Bunker Hill Mine	Leaching tests (summary of tests done in #115), review of previous work.	Ore types can be classified into four groups: Group I (Newgard 5 Level, J Ore Body 17 Level, Francis Ore Body Level 22) produces a basic solution when exposed to water. Group II (March Ore Body, J Ore Body 20 – 22 Level) produces little effect when exposed to water. Group III (Flood-Stanly beneath caving area, 4 Level) produces a strongly acidic solution. Group IV (Small Hopes upper & lower ore bodies, Bluebird Ore similar to Flood-Stanly, Francis Ore Body Level 17 and 22) produce acid initially but then consumes it to give a solution that is neutral or basic. Acid water production is related to oxidation of pyrite and pyrite to calcite ratio in the rock. Rock with a ratio in excess of 0.6 should eventually produce acid.	Authors suggest that introducing lime or limestone into lower drainage ways of an acid-producing area is a possible way of minimizing the acid water problem.

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523	01-Apr-82	Water Flow Patterns Within the Bunker Hill Mine, Idaho	Eckwright, Terry Alan	To describe the patterns of water movement and fracture with depth in a fractured metamorphic environment.	Bunker Hill Mine	Literature review, recharge investigation, water measurement on fourteen levels (9 Level to 27 Level) between July and August 1977.	Groundwater enters the mine through DDHs or mine workings that intersect water-bearing fracture systems. Ratio of discharge to drift length averages 0.009 gpm/foot.	More than 100 DDHs were observed flowing > 1 gpm. Some water from the direction of the Crescent mine is drained to Bunker Hill on 23 Level.
503	11-Sep-84	Analysis of Recharge to an Underground Lead-Zinc Mine, Coeur D'Alene Mining District, Idaho.	Hunt, Joel	To identify locations and mechanisms that control recharge to the Bunker Hill Mine in order to delineate reclamation procedures to reduce acid mine drainage	Milo Basin	A variety of field techniques were used including; a spring survey installation of piezometer nests dye tracing surface resistivity dye dilution on Milo Creek and South Fork Milo Creek hydrochemical analyses	Smaller springs are seasonal, suggesting that fracture flow systems generally do not carry large flows in the study area. Dye-dilution gain-loss studies do not support Trexler's findings of <u>significant</u> loss above Bunker Dam and South Fork confluence. Surface resistivity profiling showed that high resistivity on the West Fork in the vicinity of the Katherine fault may indicate that the fault is unsaturated in the area of the survey. Dye tracing did not verify the existence of short flow paths connecting mainstem Milo Creek to the Bailey Ore Chute or 5 Level drain, and failed to locate pathways of direct infiltration from West Milo Creek to "sites of known flow on the 5 and 9 Levels," but did establish a connection between West Milo Creek and Phil Sheridan (Raise No. 2, No. 3, and the drill hole). Nested piezometers indicate significant downward gradients (up to 1.75 ft/ft) in the vicinity of South Milo Creek and the main stem of Milo Creek.	Fault locations based on Bunker Hill Soils Anomaly Map, Bunker Hill Company, 1967. West Fork of Milo Creek is spring-fed ~2,300 feet upstream of Guy Cave Area. Detection of dye in the Phil Sheridan drill hole suggests that water underlying West Fork of Milo Creek moves through an intricate, diffuse fracture system, vertical groundwater velocities are estimated at 10 feet per hour. Approximately 1% of the total volume of injected dye was accounted for in the Phil Sheridan drill hole. Stream sections flowing northward or northeastward are more likely to intersect major fracture zones than stream sections with other orientations due to the general north-northwestern trend and southerly dip of most major faults. Katherine fault is located approx. 650' upstream from Phil Sheridan Raise No. 2. West Fork of Milo Creek diversion recommended. Fault dewatering with drill holes from Phil Sheridan also recommended.

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101	01-May-85	Delineation of Abandonment Procedures for the Bunker Hill and Crescent mines, Shoshone County, Idaho	Hampton, Kathleen	To investigate the application of alternative abandonment procedures to the Bunker Hill and Crescent mines. Specific objectives include: • Summarize classic abandonment procedures. • Describe physical and geohydrologic characteristics. • Describe recharge mechanisms. • Discuss potential effects of abandonment procedures.	Bunker Hill and Crescent mines	• Computer search of abandonment procedures. • Water sample collection.	• Infiltration control (surface sealing of fractures, streambeds, water diversions) mine sealing (dry, air, hydraulic), and in-mine diversions are typical abandonment procedures.	• Author suggests that if infiltration control is used solely to decrease the quantity of discharge at the Bunker Hill Mine, studies should be conducted on the economics of treating a lesser quantity of water that has a higher concentration of pollutants, as compared to treating a greater quantity of effluent that is more dilute.
108	01-Jul-85	Acid Water Implications for Mine Abandonment, Coeur d'Alene Mining District, Idaho	Riley, John	To identify and evaluate alternative reclamation procedures for controlling acid water discharge after the abandonment of the Bunker Hill Mine.	Bunker Hill upper country	• Literature review • Design and operate an underground monitoring network	• Bailey Ore Chute may receive recharge from the Katherine fault (near the junction with Marblehead fault) via DDH #1208 on 7 Level (and 7 Level Dam). • Dilution vs. flushing mechanisms are described. • Four sites (Stanly Ore Chute, Stanly X-cut, Cherry Raise, and 7 Level Drain) contribute more than 75% of the zinc load but only 3% of the flow.	• Author suggests a detailed understanding of the mechanisms controlling recharge to and flow within the Flood-Stanly Ore Body, which should be a high priority for research in order to successfully improve the quality of the water discharging from the mine.
107	01-Jul-85	Analysis of Water Movement in an Underground Lead-Zinc Mine CDA Mining District, Idaho	Erickson, Daniel	To identify and evaluate reclamation alternatives to reduce long term acid discharge from the Bunker Hill Mine. Specific objectives include: • Review the geologic and hydrologic information to develop a conceptual model of mine inflow. • Design and implement a mine water monitoring network. • Analyze discharge hydrographs to test the conceptual model and to identify sources and mechanisms of recharge.	Bunker Hill upper country	• Design and operate an underground monitoring network. • Hydrograph analysis.	• A hierarchical distribution of hydraulic conductivity is suggested (fractures in Cate Fault > fractures in other northwest-southwest faults (Katherine Fault believed to be largest contributor of these, pg. 77) > northeast-southeast faults > relict bedding planes). • Primary source of recharge intercepted by the Bunker Hill Mine is spring snow melt. • West Fork of Milo Creek is most probable source of water to the Stanly Crosscut and Stanly Ore Chute. • West Fork of Milo Creek to Katherine fault may be reduced by cutoff wall /diversion above the fault, and or dewatering the fault through drill holes or drifts from the Phil Sheridan. • Bedding planes and joints provide no significant inflow to the mine (pg 83 – contrary to Lachmar No. 506) • Surface contouring and sealing may be effective in reducing precipitation recharge to the near surface workings in the Flood-Stanly Ore Body between the top of the Cherry Raise and the Guy Cave Area.	• Workings on the 4 Level over the Becker Weir penetrate the alluvium of Milo Creek approximately 270 feet downstream from the Milo Creek Dam (aka Bunker Hill Dam). • Reclamation procedures will primarily result in the diversion of good quality water away from the mine. The remaining mine discharge will be of worse quality because there will be less water to dilute (pg 81). • Similar studies should be conducted for the Barney side.

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509	Jan-86	Application of Mathematical Modeling to the Analysis of Ground Water Flow Patterns Near a Deep Underground Mine	Frankel, Paul	• To gain a better understanding of the groundwater fluid potential distribution of the mine. • To utilize a numerical groundwater flow model to evaluate the relative importance of several major structural features on the fluid potential distribution near the mine.		• Literature review of previous work and available mathematical models. • Conduct modeling.	• A model could not be constructed to represent the details of the groundwater flow system because the present level of knowledge of the flow system is too limited. • Best fit values of hydraulic conductivity are 1.5 x 10^{-5} cm/sec for blocks and 1.5 x 10^{-3} for faults.	Suggested techniques to reduce inflow to the mine through fault zones: • Lining stream channels where faults zones occur, • Diversion away from faults, • Underground drainage of faults, • Grouting tunnel intersections with faults.
513	01-Jul-86	A Study of Groundwater Age in the Bunker Hill Mine, Idaho	Hartman, Mary J	To develop a better understanding of how groundwater age relates to depth and faulting in the Bunker Hill Mine, so that abandonment procedures can be tailored to the flow paths intercepted by the mine.	Surface water, 5 Level to 27 Level	• Literature review. • Mine recon to assess accessibility. • Groundwater sampling and analysis of isotopes (tritium, half life = 12.43 years) on surface and 5 Level to 27 Level.	• Relative contribution of pre-bomb (1953) water to the total flow of groundwater into the mine increases with depth. • No clear relationship between groundwater age and proximity of major faults is evident in the mine • Drill holes with low discharge rates tend to discharge post-bomb water (water that was present in the atmosphere after 1953) and holes with high discharge rates tend to discharge pre-bomb water (water that was surface water or infiltrated into the ground before 1953). Therefore, longer flow paths tend to be characterized by higher rates of flow (page 43, 45). • Both long, tortuous flow paths and short, direct flow paths exist in the vicinity of the mine.	• Author suggests that surface water diversions probably would have only limited effects on water quality because surface water recharge is probably not direct (note - based on sampling rock bolt water and drill hole water). • Author suggests that most promising abandonment plans appear to be a combination of grouting and underground diversions.
501	01-May-87	Rock Discontinuity Properties and Ground Water Flow in an Underground Lead-Zinc Mine, Coeur d'Alene Mining District, Idaho	Haskell, Kenneth	To study the influence of rock mass discontinuities on ground water flow to the Bunker Hill Mine as an aid to the development and evaluation of solutions to the acid mine drainage problem.	5 Level – New East Reed Drift, Mainstem Milo	Discontinuity mapping (scanline and cell surveys), characterization, and flow measurements, and statistical analysis.	• Relict bedding planes appear to be the primary flow paths through the rock mass. • Trace lengths display a significant positive linear correlation with the proportion of discontinuities that were observed to conduct water.	• Study may be biased because New E. Reed Drift does not cross any major faults.
512	30-Sep-87	Evaluation of Waste and Water Contamination for Closure of a Hard Rock Mine Complex (Quarterly Report – not a thesis)	Williams, Roy	Project C – To determine the relationship between poor water quality and bacterial activity	3 and 5 Levels	Bacterial culturing of samples collected from the underground locations on the 3 and 5 Levels	• Highly contaminated flow locations (West Reed Flume, Green House, Homestake Ore Chute, and Homestake 2R) gave high bacterial counts. Locations with low metals contamination (Reed Tunnel Flume, Becker Weir, Homestake Blue) gave low to very low bacterial counts.	• Project C – Underground Work by Jim Osiensky includes hydrogeologic evaluation of boreholes on New East Reed that may be of value.

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506	01-Feb-89	Analysis of Fracture-Flow Hydrogeology in an underground Lean-Zinc Mine, CDA Mining District	Lachmar, Thomas	To determine which man-made and natural features control groundwater flow through the mine, evaluate the applicability of several types of fracture-flow models, and gain understanding of fracture-flow hydrogeology to identify mitigative measures.	5 Level – New East Reed Drift.	• Scanline surveys, cell surveys, coring logs from drillholes. • Flow measurements from rock bolt, drill holes, and structural features. • Pressure measurements and flow testing at drill holes. • Nested piezometer measurements. • Modeling.	• Flow rates in eight tarps installed in the New East Reed Drift under rock bolts, drill holes, and structural features exhibit seasonal fluctuations. • Bedding planes appear to be the primary conduits for groundwater flow in the fractured quartzites of the Bunker Hill Mine. Bedding planes occur at or near the surface over virtually the entire Milo watershed, therefore recharge may occur over a much wider area than previously thought, and the contribution of individual sites identified by Trexler and Hunt may be relatively small (pg 158). • Water levels in piezometers probably reflect a shallow perched aquifer system, whereas pressure fluctuations in drill holes reflect the true potentiometric surface. (pg 103) • Agrees with Hunt - Surface water recharge from mainstem and South Milo is not as rapid as Trexler suggests (pg 157) [note: does not consider alluvial flow in South Milo.] • Surface water recharge directly to the mine is a major factor in the production of poor quality water. • Agrees with Hunt – inflow to the underground workings from the groundwater flow system (most of which would occur below 9 Level) may account for more mine water than sites of direct infiltration (pg 159). • Dewatering the major fault zones probably would not cause a significant reduction in the amount of poor quality water produced. Grouting faults and bedding planes, and diversion of West Milo may offer best hope for minimizing water inflow or recharge. • Fault infilling material (gouge vs. breccia) probably control the hydrogeologic character of the faults. Faults filled with gouge (33 or 36 in NERD) should act as barriers to flow.	• Good summary of previous hydrology work (pg 22 – 26). • No major faults intersect the New East Reed Drift, therefore the conclusions regarding contribution from bedding planes is biased. • Author suggests that it seems unlikely that the production of poor quality water could ever be halted completely. • Average hydraulic conductivity of fractured rock generally lies within 10^{-6} to 10^{-5} cm/sec.
118	01-Apr-89	Ground-Surface Delineation of Fractures that Appear to be Connected to Underlying Mined-Out Openings Using A Naturally Occurring Gaseous Tracer	Kirschner, Frederick	To study the occurrence of minor subsurface structural features that may constitute recharge pathways from unsaturated mountain slopes to underlying acid producing rocks.	West Milo drainage around Guy Cave.	Soil gas survey using CO2 as a tracer gas.	• Subsurface conduits that connect mined-out areas in the subsurface to the ground surface within the study area can be detected through soil gas surveys.	• Interesting cross section of Flood Stanly Ore Body (pg 16). • References Schwab (1952) who looked at the 3-dimensional boundary of the ore body. • The position of the Buckeye fault is observable on the eastern wall of the Guy Cave.

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524	01-Dec-89	Spatial Characterization of Geologic Structures and Ground Water Discharge in an Underground Lead-Zinc Mine, Coeur d'Alene Mining District	Whitbread, James	To map and describe pertinent characteristics of geologic discontinuities, leading to a better understanding of groundwater flow in discontinuous rock mass.	5 Level – New East Reed, Asher Drift, Russel Tunel.	Scanline mapping and cell mapping	• There appears to be a pattern of fracture wetness associated with the Dull and Sullivan faults. Areas of low fracture wetness are located in hanging or southwest walls of the Dull and Sullivan faults. As the distance in a southwest direction from the faults increases, the proportion of wet fractures increases until the next successive fault is encountered (pg 89). • Fault structures contain gouge filling, most likely allowing groundwater flow primarily in directions parallel to faults.	• Larger scale investigation than that conducted by Lachmar and Haskell.
121	01-Dec-89	Near-Surface Acid Mine Water Pools and their Implications for Mine Abandonment, Coeur D'Alene Mining District.	Bretherton, Bart	To describe the temporal, physical, and chemical characteristics of pooled water in the Homestake workings	3 Level Homestake Workings	• 24 Monitoring sites (15 in Homestake, 4 on Cherry 4, 5 on 5 Level Reed) consisting of flumes and tarps. • Condensate samples from evaporation pan. • Bacterial sampling.	• Significant production of acid water occurs in the very near surface workings (Homestake) over the Flood-Stanly Ore Body. • Metals are transported by the vapor in the water saturated mine exhaust air • Fractures in the Homestake first flowed towards the end of the workings, then progressively appeared towards the center of the workings. The arrival of peak fracture flow at sites 500 and 700 feet from the end of the workings was separated by two to three weeks. • The intersection of the Cate fault with South Milo and the intersection of the Buckeye fault, Guy Cave, and Utz workings are two important sources of recharge to the Homestake.	• Provides a cross section of the 1000 NW that shows interpretation of the surface expression of the Flood Stanly Ore Body extending from the Buckeye fault to a location between the Cherry Raise and the Sullivan fault (pg 101).
505	01-May-90	Analysis of the Hydrogeologic Role of Geologic Structures with Application to Acid Mine Drainage Abatement	Levins, Russell	To investigate the role of geologic structures and fractures in controlling ground water flow into the mine. Specific objectives include: • Develop a hydrogeologic conceptual model, • Implement a hydraulic testing program, • Interpret results relative to conceptual model.	5 Level – New East Reed Drift (continuation of Lachmar's work)	Packer tests (single and double packers) in drill holes in the New East Reed Drift.	• The results of reconnaissance level hydraulic tests show that the majority of water that discharges from the five underground drillholes is derived from two or three short intervals in each drillhole separated by large intervals of rock that produce little water. • Clayey gouge associated with McGatlin Fault probably constitutes a relatively continuous hydraulic barrier in the groundwater flow system. Where gouge is absent, northwest trending faults may comprise positive recharge boundaries.	• Author suggests that on the largest scale the major northwest trending faults probably control the overall pattern of mine water inflow within the mine. Fold related structures like those observed in the New East Reed Drift probably control water inflow patterns on a more local scale. • Author suggests that a detailed evaluation of geologic structures found in the vicinity of acid producing areas will be necessary prior to the adoption of final acid mine drainage mitigation procedures such as grouting.

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516	01-Jun-90	A Comparison of Multivariate Statistical Analysis and the Use of an Indicator Ion for the Interpretation of Water Quality Data	Riley, John	To compare and evaluate the relative advantages of the use of selected multivariate statistical techniques and the use of single indicator ion in the interpretation of groundwater data from the Bunker Hill Mine.	Upper country – 9 Level and above.	Field monitoring, sample collection and analysis (January 1983 to December 1985), and interpretation of water quality characteristics.	• Five sites (West Reed Flume, Cherry Raise, 7 Level Drain, Stanly Ore Chute, Stanly Crosscut) constitute 3 percent of mine discharge and 76 percent of zinc load coming from the mine. The source of water for all of these locations is the Flood Stanly Ore Body. • Flood Stanly Ore Body extends from land surface near the collar of the Cherry Raise downward to between 11 and 12 Level. Stopes on 12 Level connect to the March Ore Body. • Flushing of acid reaction products from drifts, stopes, and pools is the primary mechanism for the introduction of dissolved metal into the mine water flow system. Dilution of poor quality water by good quality water is much less prevalent. • Reduction of mine water inflow that reaches specific acid producing areas would significantly improve mine water quality. Reduction of inflow would have little effect on the zinc load discharging from the mine unless the reduction of inflow decreases the flushing mechanism. • The use of carefully selected multivariate statistical techniques constitutes a significant improvement over the use of an indicator ion in the identification of complex chemical interactions in a contaminated groundwater flow system.	• These five sites are included in the current monitoring network as 5WR, 9CR, 9SO, 9SX, and 9SX2. • Author suggests DDH #1208 on 7 Level is major source of water to the Bailey Ore Chute. Remaining water at Bailey Flume is from exploration drill holes at the end of the drift. • Author suggests underground maintenance (eliminating muck piles, drift undulations, and other sources of pooled water) would decrease residence time and improve water quality by an unknown amount.

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510	01-May-91	Analysis of the Sub-Regional Influence of Geologic Structures on Ground Water Flow in Acid Producing Metamorphic Rocks	Demuth, Hal	To evaluate the influence of geologic structures on ground water flow on sub-regional and local scales, and to apply the results to an analysis on a regional scale. This work is an extension of Leven's work to evaluate a larger area which includes the Cate Fault, and to analyze the spatial influence of major geologic structures between 5 level and land surface.	5 Level and surface	Hydraulic testing of DDH on 5 Level – New East Reed Drift, and of a surface drill hole.	• Zone of disturbance associated with Cate Fault is 30 to 90 feet wide, McGatlin Fault is 40 feet wide. • Amount of gouge material in a fault depends on the magnitude of displacement along the fault and type of rock. Gouge distribution is more commonly higher in the footwall side of a fault. Gouge development is limited in small structures with little displacement. • Hydraulic conductivity of fractures in the hanging wall is commonly orders of magnitude higher than in the footwall. Hydraulic conductivity of small faults with limited displacements exceeds that of larger structures on a local scale. Gouge associated with larger faults may reduce horizontal hydraulic conductivity; therefore, adjacent northwest trending fault blocks may have different hydraulic head values. • Groundwater flow occurs downward through the fractured fault zones toward the mine workings (in a NW direction). • Smaller east-west trending structures may represent significant hydrogeologic features, but only on a local scale. The major faults, which extend spatially throughout the study area, probably provide a significant portion of the groundwater inflow to the mine on a regional scale. • Long term data shows similar pressure response along the length of drill holes. This suggest that surface streams, such as Milo Creek, are not the predominant recharge source for the ground water system in the vicinity of the mine. If this were the case, the temporal pressure response would vary along the drill holes between fault blocks.	• Author references Hobbs (1965, pg. 64) – deformation preceded sculpting of the present landscape sufficiently long ago that none of the original irregularities are reflected in the topography today; no fault scarp or fold can be traced by its surface expression. • Author suggests that runoff from short, intense events such as summer thunderstorms do not infiltrate the fractured bedrock system to the same degree as recharge events of longer duration (spring snowmelt). It appears that most of the water provided to the fault-controlled fracture system derives from groundwater infiltration, rather than from direct fracture connection to the surface streams. • Hydraulic conductivity across (through) the faults zones appears to be low. Research of Morrow and other (1984) shows that hydraulic conductivity of the gouge in fault zones is on the order of 10^{-10} ft/day (3.5×10^{-14} cm/sec). • Author suggests that diversion of groundwater from acid producing areas is the best method to reduce acid drainage. Suggests fracture grouting through drillholes.

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517	12-Oct-97	Ideas on Milo Creek Remediation Alternatives	Ralston, Dale; U of I	To provide ideas on the remediation work within Milo Creek drainage.	Bunker Hill — Upper Country	Analysis of existing information	• Increased mine discharge reported by Mr. Hopper is likely due to 1) greater than average precipitation after an extended period of lower than average precipitation, 2) changes in the Milo Creek channel in the reach from the water supply dam to the Reed adit, and/or 3) changes in underground workings including collapse or alteration of near-surface workings. • Most viable remediation projects are 1) Milo Creek diversion on mainstem groundwater in the alluvium as well as surface water must be diverted to be effective, and 2) improve Phil Sheridan diversion system by cleaning raises, assessing and repairing leaks in the drift, installing grout cutoff walls at the diversions, and piping or ditch diversion flow from the adit to the mainstem.	• Author suggests hydrologic evaluation of KT with respect to surface water flows to document changes in the mine discharge reported by Mr. Hopper. Also suggests water quality comparison of recent KT vs. past KT including metal concentration and loading. • Author suggests an underground recon of workings below the creek (Small Hopes, Reed and Russell areas) to assess potential increase in flow.
606	26-Aug-98	References for Bunker Hill Mine Project	Ralston, Dale; Riley, John	Provides a reference list for the Bunker Hill Mine Project.	Bunker Hill Mine	References by category (Hydrologic studies, Geologic, Treatment process studies, General,	• Presents list of references for the following areas concerning Bunker Hill Mine: Hydrogeologic Studies, Geologic Studies, Treatment Process Studies, General References on Abatement of AMD Problems.	
2011	Sep-99	Bunker Hill Mine Flood-Stanly In-Mine Reconnaissance Report	CH2M HILL	Identify surface water and groundwater recharge mechanisms and acid producing areas, understand mine water flow paths, identify missing hydraulic and metal loads identified during CH2M HILL mine water monitoring program.	Bunker Hill Mine Water – Flood-Stanly Ore Body	Underground field reconnaissance, field measurements of specific electrical conductivity	• Flow within the Flood-Stanly Ore Body consists of complex combination of low gradient ditch flow, steeply dipping manmade structures, and/or collapsed ground. Ponding occurs in undulations in drifts. Pyrite is ubiquitous in and around the ore body. Recharge controlled by localized heating in near surface workings and low and high elevation snowmelt.	• Substantial portion of the workings are inaccessible; direct modifications of accessible workings may have only a limited benefit of acid production and metal transport on the whole.
2013	15-Nov-99	Field Reconnaissance of Inflow/Recharge Mechanisms	CH2M HILL	Investigate recharge and surface water inflow features that provide a mechanism for water to flow into the mine and contribute to the generation of AMD.	Milo and Deadwood Basin overlying the Bunker Hill Mine.	Visual inspection	• Several recharge/inflow mechanisms were identified and very rough estimates of flow contribution to the mine were made. These mechanisms could be mitigated through a variety of methods.	
2006	Jul-99	Bunker Hill Mine Water Presumptive Remedy	CH2M HILL	Summarizes the initial presumptive remedy for long-term management of the Bunker Hill AMD. This document was used as part of the RI/FS for the mine water. It provides technology screening and development of the major components of a remedy, including AMD mitigations, AMD collection, AMD conveyance, AMD storage, AMD treatment, and sludge management. Some of the document findings were updated and/or modified through the subsequent RI/FS document.	Bunker Hill Mine Water	Engineering Analysis	• The document approach was to initially brainstorm a "presumptive remedy", then collect information needed to confirm, modify, or fill-in data gaps. The presumptive remedy was then refined. This document summarizes that process. • The document findings were used as part of the RI/FS for the mine water. Some were modified/updated during preparation of the RI/FS	

Library #	Date	Document Name	Author	Purpose and Objectives	Study Area	Evaluation Methods	Key Observations with Respect to EPA's Mine Water Management Project	Other Relevant Findings or Suggestions from the Author
2005	Jul-99	Acid Mine Drainage – Bunker Hill Mine Water Conceptual Model	CH2M HILL	Provides a review of existing information on flow and quality of water within the mine, summarizes the1998/1999 mine water sampling program that was implemented to document changes over approximately the past 15 years, summarizes known flow paths within the mine, and identifies current sources of poor quality water.	Bunker Hill Mine Water	Review of current and previous data collected on mine water flow rates and quality.	• Water inflow to the mine occurs from direct interception of surface water to the workings, recharge to the local groundwater system, and submerged workings. Intra mine flow is complex and not fully understood. The historical database indicates that the three biggest contributors of zinc load are 9SO, 9CR, and 9SX, which monitor discharge from the Flood-Stanly workings.	• Continuation of the 1998/1999 sampling program will provide valuable information on the current mine water characteristics relative to previous studies.
2020	22-Jul-99	Field Reconnaissance of Hanna Stope	CH2M HILL	Gain a better understanding of the underground conditions, configuration, and characteristics of the Hanna Stope to evaluate its potential for use as an underground depository for waste sludge	Hanna Stope	Underground reconnaissance, Sample collection and analysis.	• Access from the older workings to the west side of the stope is not available, little is known about the interconnections between the stope and the Hall and Williams Raise. Additional investigation would be necessary to identify and systematically plug all access to the stope for use as a depository.	
2017	1-Feb-00	Supplement No. 1B—Bunker Hill Mine Conceptual Model—Final Data Summary for 1998/1999 Monitoring Program	CH2M HILL	Presents, summarizes, and interprets the data from the in-mine monitoring program conducted in 1998/1999. Presents mass balances for flow, zinc, and lime demand for flow areas within the mine.	AMD within the Bunker HILL Mine	Underground flow monitoring and sample collection for many different locations. Development of mass balances.	• The in-mine flows and chemistry was similar in 1998/1999 as compared to 1983/1984/1985. • Located monitoring locations that can be used to evaluate the performance of mitigations.	
2018	7-Feb-00	Hydrologic Evaluation for Bunker Hill Mine TMDL Compliance	CH2M HILL	Evaluate the relationship between Kellogg Tunnel and SFCdA River flows to help develop selection and design criteria for mine water management systems that comply with upcoming TMDL requirements.	Kellogg Tunnel and SFCdA River	Historic hydrograph assembly and evaluation.	• There is not a good correlation between KT and SFCdA flow at the Pinehurst gauge.	• Additional modeling is necessary to evaluate the interrelationship between the mine water management components and the TMDL requirements.

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APPENDIX B

Potential for Lime and Sludge Reduction by Bunker Hill Mine Water Mitigation Measures

Potential for Lime and Sludge Reduction by Bunker Hill Mine Water Mitigation Measures

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DATE: July 26, 2000

Summary

Bunker Hill mine water acid production occurs primarily in the pyrite-rich Flood-Stanly Ore Body. Discharge from the Flood-Stanly Ore Body represents only about 9 percent of the flow but carries more than 90 percent of the metal load from the mine. Application of mitigation options to reduce the amount of surface water infiltration into the Flood-Stanly Ore Body should reduce lime consumption and sludge production at the mine's Central Treatment Plant (CTP). The amount of reduction cannot be accurately estimated because of the complexity of both the surface water infiltration and mine water flow paths. Implementation of Flood-Stanly Ore Body inflow mitigation measures is expected to reduce seasonal peak lime consumption and sludge production more than seasonal base flow conditions. This is because lime consumption is controlled more by flow than by metals concentrations, using historical (1983 to 1988) and recent data (1998 and 1999) as a basis of judgement. Furthermore, documented historical large flow events typically have a sharp rise to a peak and relatively rapid fall with a short overall duration from a few days to perhaps a few weeks.

Available data strongly suggest that accumulation of metal-bearing salts has not occurred in the mine to date. Field observation underground and the lack of dissolution-related hysteresis at monitoring station 9LA demonstrate this. However, if mitigations are constructed there may be a possibility of accumulation of soluble metal-bearing sulfate salts as a result of decreased periodic flushing. If this occurs, it may take several years to accumulate a significant amount of salts. The potential for accumulation should be monitored, although significant portions of the ore body are currently inaccessible. Assuming significant accumulation did happen and a large in-mine flow event occurred that dissolved the salts, there would be high acid and metal loads that could stress or overwhelm treatment capacity. The extreme events could be handled either by diversion into the mine pool for later treatment, or treated in a CTP that has sufficient capacity.

Mitigation effectiveness must be monitored, particularly in the West Fork Milo Creek (West Fork Milo Creek), which overlays the Flood-Stanly Ore Body. This should include surface

water, piezometer water levels, and in-mine water monitoring. At a minimum, in-mine monitoring should include stations 9LA, 9PU, and 9KT, although other more mitigation-specific locations are desirable.

1.0 Introduction

The purpose of this memorandum is to evaluate whether significant reductions in lime consumption and sludge generation will result from the construction of mitigation measures to reduce recharge to the Bunker Hill Mine. As described in more detail in the following sections, reducing the surface water recharge in the West Fork Milo Creek could serve two purposes: a) keeping surface water from contacting metal-bearing minerals and subsequent metal leaching (keeping clean water clean), and b) reducing the water volume infiltrating into the mine. The basic tenet is that by reducing the amount of water infiltrating into the mine, particularly the Flood-Stanly Ore Body, not only is the amount of water needing treatment reduced, but this reduction should also reduce metals concentrations and sludge production.

2.0 Conceptual Model

The conceptual model of acid water production and drainage from the underground workings of the Bunker Hill Mine has been described in a number of documents (see Section 7.0, Cited References). This section of the report is a brief summary of this published information.

The production of acid drainage from an underground mine requires the presence of three contributing components: oxygen, sulfide minerals, and water (CH2M HILL, 1999a and 1999b). Oxygen is present in non-flooded portions of a mine because of the naturally circulating mine atmosphere through the mine workings down to the mine pool water elevation (between the 11 and 12 levels). Water is present because of recharge at land surface from snowmelt runoff and rainfall within the area of influence of the mine and the extensive mine workings that create a large drawdown of the water table (particularly in the West Fork Milo Creek drainage at Bunker Hill). Water is also available as water vapor in the mine atmosphere, which is saturated or near saturation in most areas. Sulfide minerals are present in varying abundance in most metal mines but occur in higher concentrations within and adjacent to specific ore bodies.

The Bunker Hill Mine hydrology is complicated by the evolution of the mining history and the complex nature of the underground workings (Trexler, 1975; Eckwright, 1982; Riley, 1990). The mine was initially developed at higher elevations within the Milo Creek drainage with shallow workings along near-surface ore bodies. The individual workings were combined into a single mine with numerous working levels (on approximately 200-foot vertical spacing) to considerable depths. Shortly after 1900, the Kellogg Tunnel was constructed from a much lower elevation (9 Level) to allow more efficient transport of men and materials. All mine water discharges from the Kellogg Tunnel. The mine was then developed down from 9 Level (Kellogg Tunnel level) to 30 Level. A tunnel was constructed on 23 Level to connect the Bunker Hill Mine with the nearby Crescent Mine. The configuration of adits, tunnels, and other mine workings make it essentially impossible to

flood the mine workings above 9 Level because there are so many adits and near-surface stopes above 9 Level. These workings would discharge acidic water if the Kellogg Tunnel were flooded.

The 9 and higher levels, called the upper country of the mine, have additional surface openings that would make mine sealing very difficult. The mine workings, from about 30 feet below 11 Level, are currently flooded, causing the formation of a mine pool. The water level is currently maintained by pumping water from the pool that is measured at the 9PU monitoring station.

Studies conducted at the University of Idaho in the 1970s and 1980s show that most of the acidic water containing elevated concentrations of metals originates in the Flood-Stanly Ore Body in the upper country of the mine (Trexler, 1975; Riley, 1990). This conclusion has been confirmed by data collected in the 1998-1999 period in which the pH ranged between 0.59 and 3.9 at monitoring stations that measure drainage from the Flood-Stanly Ore body. The mineralized zone extends from near land surface downward to and beyond 9 Level. Most of the ore body has been mined but has been backfilled with sulfide-rich gob. Gob is material containing zinc, lead, and iron sulfides that was non-economic to recover during the early years of mining. Mining within the Flood-Stanly Ore Body facilitated acid water production by exposing acid-producing minerals to oxygen and water. In addition, the mining created zones of very high vertical hydraulic conductivity, which allows flushing of the acid reaction products to lower portions of the mine. Oxygen has been, and will continue to be, available within most of the Flood-Stanly Ore Body because of the numerous open stopes, transfer chutes, and other workings that intersect the ore body.

The block caving mining method used within the Flood-Stanly Ore Body during the 1940s and 1960s further complicates the acid water drainage problem. Caved mineralized zones and fracturing associated with this mining technique extend to land surface. The major surface depression caused by the block cave mining is called the Guy Cave Area, and occurs near the bottom of the West Fork Milo Creek drainage. Cracking caused by the caving extends to the surface and provides a major conduit for surface water infiltration into the Flood-Stanly Ore Body. In addition, surface water infiltrates into the mine workings in much of the Milo Creek area through other mining-related conduits and the subregional groundwater system, thus forming the third component required for acid water production.

In summary, acid water containing elevated concentrations of metals drains from the Bunker Hill Mine because the underground workings provide the required components for the production of acid water and both the dissolution and transport of elevated metals concentrations. The subregional groundwater system provides recharge of carbonate-buffered water to the mine through natural fractures in the unmined metamorphic rocks surrounding mineralization. Most of the recharge to the mine and the acid-producing ore body in particular is via man-made openings. The recharge to the mine from undisturbed rock is very small.

Water from the annual surface water runoff/infiltration event associated with spring snowmelt and streamflow moves through the upper country mine workings, dissolving acid salts from oxidizing sulfide sites and moving ponded acid water from within the mine drifts. Most of the drainage from the upper country workings discharges on 9 Level and drains out the Kellogg Tunnel. The quantity that drains from the Kellogg Tunnel is

relatively well-documented, but an unquanitified portion of the water from the upper workings bypasses 9 Level to discharge on levels 10 and 11 and ultimately into the mine pool. Comparison of mine pool temperature measurements with the believed geothermal gradient suggests that this upper country recharge impacts the 12 Level mine pool water but probably has little impact on the mine pool water below 13 Level. This implies little mixing of the upper country water into the deeper pool. Rather, the upper country recharge is thought to flow across the upper pool toward the extraction pumps, which maintain the pool level at about 30 feet below 11 Level at Raise No. 2.

Water chemistry varies greatly from site to site within the Bunker Hill Mine. The drainage from the Kellogg Tunnel represents the collection of water of varying quantity and chemistry from throughout the mine. Several generalizations can be made. First, most of the poor quality water originates within the upper country portion of the Flood-Stanly Ore Body. Second, flushing of the upper workings during spring recharge events causes higher metal concentrations with higher flows at the CTP. Thus, the highest metal loading from the mine occurs in the spring and early summer and is related to infiltration of snowmelt runoff and flushing of the mine workings. Water movement through the Flood-Stanly Ore Body causes the greatest increase in metals concentrations.

3.0 Hydrogeologic Setting

The following text provides detailed information on the mine geology and hydrology.

3.1 Geology and Mine Development

The Bunker Hill Mine is located in the Kellogg-Wardner area within the South Fork Coeur d'Alene (SFCdA) River drainage basin of northern Idaho. The Bunker Hill Mine is one of many located within the Coeur d'Alene mining district.

The principal rock types found in the Coeur d'Alene mining district belong to the Belt Supergroup of Precambrian metamorphic rocks (Hobbs et al., 1965; Riley, 1990). They are composed of fine-grained argillites and quartzites associated with smaller amounts of carbonate-bearing dolomitic rocks. The formations of the Belt Series from oldest to youngest are Prichard, Burke, Revette, St. Regis, Wallace, and Striped Peak.

The Coeur d'Alene mining district lies at the intersection of a broad arch that extends from Kimberly, British Columbia, to the St. Joe River in Idaho and the Lewis and Clark Lineament (Trexler, 1975). The Lewis and Clark Lineament is represented in the district by the Osburn and related faults. The patterns of the folds and faults in the district are governed by the Osburn Fault, an extensive fault with a west-northwest strike and a large strike-slip displacement. Movement along the Osburn Fault is right lateral with a maximum displacement of 16 miles.

The faulted block of Belt Series sediments that includes the Bunker Hill Mine lies south of the Osburn Fault and contains several additional major faults. Major faults intercepted in the Bunker Hill Mine include the Cate, Sullivan, Dull, Katherine, Buckeye, and Kruger. These major faults make up the skeleton along which the ore bodies are associated. The Cate Fault is the major structure in the mine, striking northwesterly and dipping 40 to 60 degrees to the southwest. The Sullivan, Dull, and Kruger faults lie in the foot wall (northeast) of the

Cate Fault. The Katherine and Buckeye faults lie in the hanging wall (southwest) of the Cate Fault. All these faults strike more westerly than the Cate, with a dip of 50 to 30 degrees to the southwest.

The Bunker Hill Mine itself is located within a highly faulted block of transition rock between the Revette and St. Regis formations. The Revette formation is composed primarily of massive quartzites interlaminated and interbedded with argillites. The St. Regis formation includes argillites and argillaceous quartzite, which grade downward to the base into nearly pure quartzite.

The Bunker Hill Mine includes three general ore types based on mineralogy. Trexler (1975, p. 23-24) describes them as follows.

> "The Bluebird ore contains considerable pyrite and galena, which usually exceeds or equals sphalerite in a siderite-quartz gangue. The Bunker Hill ore consists mainly of galena in a siderite-quartz gangue. The Jersey ore consists of galena with considerable sphalerite in a quartz-siderite gangue. The major mineralogical difference between the three ore types is the presence of large quantities of pyrite in the Bluebird ore and the high degree of oxidation found in the Bluebird ore areas (upper levels of the mine)."

Carbonate gangue minerals can provide significant neutralization capacity. Siderite, a ferrous carbonate gangue [$FeCO_3$ when pure], is a common accessory to the ore minerals (Kroll, 1935, Hobbs et al., 1965). Unfortunately, the ferrous iron in siderite will oxidize and hydrolyze, overcoming the neutralization of the carbonate:

$$FeCO_3 + {}^{1}/_{4}\,O_2 + {}^{5}/_{2}\,H_2O \Rightarrow Fe(OH)_3 + HCO_3 + H^+$$

The amount of helpful carbonate buffering will depend on the amount of ankerite, calcite, and dolomite in the gangue minerals. These quantities are not known.

The ores occur along major faults with little dispersion out into the country rocks. The mine was developed with levels on about 200-foot-elevation intervals generally following the structural features associated with the Cate Fault. Thus, the shafts are inclined, with workings generally following a strike to the northwest and a dip of about 60 degrees to the southwest. The main entrance to the mine, the Kellogg Tunnel, was constructed from the valley of the SFCdA River to the underground workings on 9 Level. Historically, mining has occurred from near land surface on the 3 and 4 levels to below 30 Level.

3.2 Mine Hydrology

Water flow in and near the Bunker Hill Mine reflects the intentional and unintentional impact of mining activities on the regional bedrock groundwater flow system. Trexler (1975), Eckwright (1982), Hunt (1984), Erikson (1985) and Riley (1990) provide detailed information on water flow in and near the mine from a series of studies conducted by the University of Idaho. Eckwright (1982, p. 24) divides the occurrence and movement of water within the mine into two groups.

> "1) water movement that occurs through man-made openings from the surface to the underground mine levels and from level to level down through the mine, and

> 2) water discharged into the mine from natural fracture systems in the rock either through drill holes or directly into drifts and stopes."

Trexler (1975, p. 54) describes the development of the mine and the impacts on water flow patterns as follows:

> "After the mining began in 1885, the equilibrium of the ground-water system in the mine area was disturbed. Often the stopes were worked to the surface, some even into the creek bed. This caused increased recharge through stopes and increased discharge from the portals. The Milo Creek area (Small Hope and East Reed workings) and the Deadwood Creek area (Inez, Arizona and Oakland workings) are excellent examples of such a disturbance.
>
> As the mining activity extended downward from the upper levels, a vertical zone of high permeability was developed. The porosity is secondary, formed from multilevel stopes and other interconnections, man-raises and ore passes.
>
> Block caving, used in the upper levels (4, 5 and 6) of the Bunker Hill Mine, forms another vertical zone of high permeability. The surface depression caused by the subsidence brought about by the caving creates a major surface recharge site. This surface feature channels three small intermittent tributary valleys of Milo Creek directly into the caved area where the water freely moves on down through the old workings."

The mine workings interconnect the pre-mining subregional groundwater system almost exclusively through fractures within the block caving imposed by the mining methods. These subregional groundwater system fractures are hydraulically connected to the Milo Creek drainage.

Much of the water draining by gravity through the mine workings is captured on 9 Level and drains out the Kellogg Tunnel. Water currently not captured from the upper workings and water from the lower workings is pumped up to 9 Level to join the upper country drainage. The pumping maintains the mine pool water level between the 11 and 12 levels. Riley (1990) indicated in the 1980s that about 44 percent of the Kellogg Tunnel discharge was gravity drainage, with the remaining 56 percent pumped from the lower workings.

Both Trexler (1975) and Riley (1990) document flow changes in the mine related to annual recharge events. The flow is most sensitive to snowmelt runoff, and higher discharges are most dominant at sites in the upper country portion of the mine.

Hunt (1984) studied recharge within portions of the Milo Creek watershed. He concluded the following (page 65):

> "All of the flow from West Milo Creek drainage enters fracture flow systems which ultimately discharge into the mine.
>
> Other probable areas of recharge to flow systems feeding the mine are: near the South Milo-Cate Fault intersection, the area of cottonwoods in Milo Creek below Milo Creek Dam, along the south bank of Milo Creek near its Cate Fault intersection, and along other stream-fault intersections."

The authors cited above state that reduction of recharge to the Bunker Hill Mine is a viable remedial option for reducing the acid mine drainage (AMD). The specific areas where mitigation activities were recommended are those outlined above by Hunt.

In summary, the Bunker Hill Mine workings have created a large zone of drawdown in which the subregional groundwater system is dominated by unsaturated flow conditions but with numerous small perched and saturated zones. Recharge occurs as a result of sub-regional groundwater flow systems and seasonal snowmelt/rainfall/recharge. The sub-regional system is generally expressed by long-term, fairly steady flow within the mine. Seasonal phenomena are expressed by short-term peaks (a few days to a few weeks) in the hydrologic record. The peaks usually involve only a few days but the falling limb of the hydrograph can take a few weeks. The peak flows indicate movement of water rapidly from a surface source (probably streamflow) through the upper workings. The peak flows cannot originate from groundwater flow systems in undisturbed rock. Groundwater collected by the upcountry mine workings predominantly moves through the workings in a series of cascading ditch flow systems. These flows converge and currently discharge from the Kellogg Tunnel and are treated.

3.3 Water Flow in the Mine

Flow measurements taken at several points in the mine (Level 3HD, 5BK, 5WM and 5WR, 9VR, 9SX, 9SO, 9CR, 9LA, 9BS, and 9BO) during the snowmelt runoff in 1999 indicate that peak flows occur first on 5 Level (March 11 to 17 for 5BK and 5WR, March 31 for 5WM), followed by April 2 for 9BS; April 29 for 3HD; May 28 for both 9SO and 9CR; and June 4 for 9SX, 9LA, and 9BO. These time differences suggest that different parts of the mine receive recharge from snowmelt runoff at different times, which underscores the complex hydraulic connections within the mine. Also, 9 Level receives flow from the upper levels. Some of the lag times result from delays caused by water movement within the mine.

A comparison between historical (1983 through 1988) and more recent and current data (1998 and 1999) indicates that the timing of peak flows for most stations has not changed appreciably (CH2M HILL, 2000). The timing of flow peaks is essentially the same for 3HD and 5WR. Flow peaks and base flow at 5BK and 5WM are very similar. These results suggest that recharge quantities along the main stem of Milo Creek have not changed substantially in recent years. Similarly, the conditions at 9BO are similar and indicate that discharge from the drill hole on 7 Level has not changed. Flow at 9BS is also very similar between the historical and current data, indicating that recharge from Deadwood has not changed substantially. However, stations downgradient of and receiving flow from the Flood-Stanly Ore Body (9CR, 9SO, 9SX and 9LA) have shown that even though base flow conditions have essentially not changed, there has been an increase in peak flows by a factor ranging between 2 and 12. The timing of the 1999 peak flows through the Flood-Stanly Ore Body coincides with the onset of high elevation snowmelt and observed infiltration near the hanging wall of the Guy Cave Area near the bottom of the West Fork Milo Creek. The rising and falling limbs of the hydrographs are steep and the duration of peak flow short (a few days). These relationships suggest a direct flow path for infiltrating West Fork surface water through the Flood-Stanly Ore Body into the mine workings.

These measured differences in peak flows at 9CR, 9SO, 9SX, and 9LA may be a result of a higher runoff and higher flows in the West Fork Milo Creek, which resulted in water

reaching further down the basin than that measured in the 1980s data. Joel Hunt (1984) reported that during field measurements in 1984 the lowest the West Fork flows were observed before they disappeared into the ground was 220 feet upstream from Phil Sheridan Raise No. 2. During the spring of 1999 the West Fork Milo Creek flows were observed to reach the Phil Sheridan Raise No. 2, overflow the raise because it was plugged with debris, and then flow into the ground a few hundred feet below the raise but still above the Guy Cave Area. It was during this time that the very high flows at 9CR, 9SO, 9SX, and 9LA were observed. Therefore, there may not be fundamental changes in the flow paths, only differences in observed and measured flows resulting from the size of the West Fork Milo Creek runoff and its infiltration location.

Water temperature data underground can be used to understand water movement patterns and to help locate acid-producing areas. In an undisturbed groundwater system, the water temperature generally increases with depth because of the natural geothermal gradient of the earth. The increase is about 1 degree C per 100 feet. Figure 1 (all figures are found at the end of the text) shows a plot of sample site water temperatures with depth within the mine. Data points falling on or near the geothermal gradient line reflect the expected normal groundwater temperatures. Points falling below the line (such as 9VR) probably represent conditions where water has moved rapidly down from higher mine levels. Points falling above the line probably represent heating of the water because of exothermic chemical reactions (acid water formation). Note that the 9PU site has been placed at the elevation equivalent to about 13 Level even though the pump intake is about 30 feet below 11 Level. The 13 Level is much more extensive than the 12 Level and probably is the dominant source of the 9PU discharge.

Water temperatures underground depend on several factors, principally the length of equilibration with the natural thermal gradient (increasing temperature with depth) as discussed above. A complication, however, is the heat released by the exothermic chemical reaction between water and oxidizing sulfides. Again using the 1999 water data, only the temperature of water flowing through stations 3HD and 5BK shows a slight decrease in temperature with increasing flow from snowmelt runoff. Water at all other stations increases in temperature with increasing flow. This suggests that direct hydraulic connection between the surface snowmelt runoff and the workings is probably upgradient of stations 3HD and 5BK. The hydraulic connection is either increasingly distant from the surface snowmelt runoff and / or is in direct hydraulic connection with very actively oxidizing sulfides at the other stations. A comparison of the lowest temperature for each station (base temperature) is another measure that can be used to separate hydraulic connection from oxidizing sulfide. A linear least square fit equation for the data indicates that the lowest beginning temperature of 6.2 degrees C occurs at station 5WM, followed by 9BO, 5WR, and 5BK with base temperatures of 7.3, 8.1, and 8.3 C, respectively. The next higher are 3HD and 9SX at 14.1 and 14.6, respectively. The highest is 9PU with a temperature of 16.6 C. Obviously, the combination of 3 Level and 9 Level waters having the same base temperature indicates that at least water upgradient of 3HD and 9SX involves actively oxidizing sulfides. Another indication of the effect of oxidizing sulfides on water temperatures can be seen when comparing the range of temperatures for the Stanly Ore Chute and the Stanly Crosscut. Water temperatures there range from 15-20ºC, higher than temperatures almost anywhere else in the mine (typically 5-12ºC). These temperatures reflect the greater intensity of oxidation in the Flood-Stanly Ore Body. Nevertheless, these

temperatures are not in the range of 20-70ºC. Such temperatures typically promote the formation of efflorescent salts through evaporation. Furthermore, there are no dramatic excursions in temperature with snowmelt or periods of high runoff that would reflect an effect from dissolution of large quantities of salts. Hence, the temperature data support the opinion that efflorescent salts have not played a noticeable role in the mobility of metals from the Bunker Hill Mine.

4.0 Geochemistry

4.1 Controls on Acid Production

Interrelated primary factors that influence the production and distribution of AMD include both chemical characteristics:

Availability of pyrite
Sulfide oxidation - by oxygen and iron (III)
Oxidation of iron (II) to iron (III), catalyzed by bacteria
Temperature
Gangue dissolution
Lithology and mineralogy of country rock (presence of carbonate minerals)
Buffering capacity of non-mineralized groundwater
Formation and dissolution of efflorescent salts

And physical characteristics:

Recharge locations, controls, and temporal patterns
Whether groundwater flow is under saturated or unsaturated conditions
Hydraulic conductivity of the undisturbed rock
Hydraulic conductivity caused by mining activities (mine openings and mine-induced fractures)
Storage of acid water, particularly pooling in drifts
Evaporation and vapor transport for formation of efflorescent salts

Sulfides will continue to react and produce acidic products until:

Sulfides are exhausted
Oxygen is eliminated (sulfides are submerged under static water)
Water is eliminated
Reaction products are neutralized

Sulfate is the major anion in the water chemistry of the mine water. Sulfate is generated by the oxidation of iron sulfide (dominantly pyrite), which produces sulfuric acid and is described by the following chemical reaction:

$$FeS_2 + {}^{7}/_{2}\, O_2 + H_2O = Fe^{2+} + 2\, H^{+} + 2SO_4^{2-}$$

The acid generated by the oxidation of pyrite attacks the associated sulfides sphalerite (zinc sulfide) and galena (lead sulfide), plus the associated carbonate gangue minerals siderite and ferroan dolomite (ankerite). Each of these minerals has impurities of other elements, occasionally at significant concentrations that are released with the major ions.

Oxidation of pyrite, sphalerite, and other sulfide minerals releases iron, lead, zinc, cadmium, and other associated metals to become part of the acid mine water. Pyrite and other iron sulfide minerals are ubiquitous major gangue (valueless) minerals associated with the ore deposit and, along with sphalerite, were typically not extracted as part of early mining operations. Based on the mine water chemistry, pyrite and sphalerite are the major sulfides in the Flood-Stanly Ore Body. Sphalerite [ideally zinc sulfide (ZnS)] likely contains most of the cadmium released to the mine water. Similar to pyrite, sphalerite oxidizes and releases zinc and sulfate and other ions to the acid mine water. Argentiferous galena was the major ore mineral recovered in the mining district and essentially the only ore mineral recovered prior to flotation. However, there is probably a remnant amount of galena still being oxidized, releasing lead, sulfate, and associated ions to the acid mine water.

Siderite, a major gangue mineral associated with ore minerals, also contains an average 0.023 percent calcium, 0.06 percent magnesium, and 0.082 percent manganese in the Coeur d'Alene mining district (Balistrieri et al., 1999). Unfortunately, there is still so much iron present that, as mentioned previously, siderite cannot offer much buffering capacity.

4.2 Relationships to Mine Workings and Water Flow Patterns

The degree to which sulfides and acidic reaction products from sulfide oxidation are available for solubilization and mobilization is directly related to the amount of air and water mixture that can contact them. Air circulation underground carries oxygen that is required for the direct oxidation of pyrite, and the support of *Thiobacillus* sp. in the catalysis of the oxidation of ferrous to ferric iron. In addition, air circulation is responsible for moving substantial quantities of water in the vapor phase. The vast majority of water flowing within the mine is relatively good quality water. Only water that contacts the pyrite/sphalerite-rich Flood-Stanly Ore Body becomes highly acidic. Approximately 100 gallons per minute (gpm) (on average) of highly acidic mine water discharges from the Flood-Stanly Ore Body; however, this small discharge mobilizes and transports essentially all of the metal load from the upper workings. **Discharge from the Flood-Stanly Ore Body represents only about 9 percent of the flow but carries more than 90 percent of the metal load from the mine.**

Some flow within the Flood-Stanly Ore Body drains past 9 Level into the mine pool, and is pumped up for discharge and treatment via the Kellogg Tunnel. Therefore, reduction in recharge to and around the Flood-Stanly Ore Body should reduce the quantity of metal that is mobilized, because a smaller quantity of water would be confined to a smaller area within the flow path.

Evaporation and circulation of water vapor can lead to buildup of efflorescent salts along the borders of ditches carrying elevated metals concentrations from AMD. This process creates metal salts that are easily dissolved when infiltration increases the water flow through the mine.

Flushing of metals generated by sulfide oxidation occurs during snowmelt recharge to the mine. This includes washing of acid salts from reaction sites, flushing of acid water pools on drift floors, and breaking of yellow boy dams within the drifts. At most in-mine monitoring locations that receive drainage from the Flood-Stanly Ore Body, an increase in flow is accompanied by an increase in metal concentration. The metal concentrations on the falling limb of the hydrograph are similar to or slightly lower than the concentrations on the rising

limb. This relation between metal concentration and water discharge of the two limbs of the hydrograph is referred to as a hysteresis effect. A high level of hysteresis indicates an elevated but finite storage of soluble metals generated by oxidizing sulfides and/or ponded mine water accumulated along the mine water flowpath by a significant seasonal increase in flow.

Understanding the contribution from the hysteresis effect is important to be able to understand the storage of metalliferous reaction products and their subsequent mobilization. This understanding, in turn, is important to be able to extrapolate observed metal flux and predict plausible future flux characteristics. Interpretation of these and other relations could help in understanding current and historical data and what may occur as a result of a major infiltration event.

4.3 Analysis of Mine Data

Historical chemical and flow data collected from 1983 through 1985 (Riley, 1990) are generally similar to data gathered during the current investigation, in 1998 and 1999 (CH2M HILL, 2000a). The timing, duration, and magnitude of discharge and loading peak events have remained very similar, except at certain locations in the Flood-Stanly Ore Body. The most dramatic observed difference was an increase in peak discharge in the Stanly crosscut (9SX), where maximum discharge increased from 30 to almost 400 gpm. However, as discussed in Section 3.3, this may be a result of the magnitude of runoff and the infiltration location in the West Fork Milo Creek, rather than in-mine flow path changes. A more thorough comparison of the historical to current data is presented in CH2M HILL, 2000a.

Lime demand in units of pounds per 1,000 gallons of water is the amount of lime needed at the treatment plant to neutralize the acidity and thereby significantly decrease the dissolved metals. Although lime demand was not analyzed in the historical work (1983–1985), lime demand was part of the analysis for the 1998-1999 data. Because the lime demand is highly correlated with zinc concentration in recent data, the lime demand of the historical data can be estimated. Zinc, in turn, is highly correlated with other major metals and sulfate, the major anion in the mine drainage. Table 1 illustrates the correlation among lime demand, zinc, iron and sulfate at 9LA during 1998-1999. The values represent pairwise Pearson linear correlation coefficients based on data collected during monitoring. There are 14 analyses in the data set. Similar significant correlations exist between these and other metals.

Table 2 lists the analogous correlations using the 48 pairs of analyses in the historical data collected during 1983 through 1985.

The correlations in parentheses for the historical data (1983 – 1985) in Table 2 are those calculated with only one outlier removed from the historical data. The correlations among metals in the historical data are excellent. However, the correlations between flow and metals are noticeably lower in the historical data than in the current data. The historical correlations are lower because when flows were changing, concentrations were not. The change in concentration lagged behind the change in flow, and was accompanied by no measurable change in flow. This is illustrated and presented more fully in the discussion of hysteresis that follows.

Figures 2 and 3 illustrate graphically the strong correlations between flow (Q), zinc, iron, sulfate and lime demand (LIMED in the current and historical data sets, respectively). The bar graphs are frequency histograms that illustrate the distribution of data for a given variable. The significant linear correlations indicate that essentially any of these parameters can be used as an indicator of overall metal content. However, zinc, with its elevated concentration, conservative nature in the acid mine water, and strong geochemical association with the other parameters (particularly cadmium), is selected to describe the overall chemical and flux characteristics in the mine water. Zinc also allows the combined use of the historical as well as the recent data.

The relation between discharge and zinc concentration at 9LA suggests that little or no acidic salts accumulate in the tributary flow paths from year to year. The hysteresis concept is discussed in Section 4.2. If substantial quantities of salts had built up and were in storage along the flow path, then the zinc concentration on the rising limb of the hydrograph would be higher at a given flow than on the falling limb. Figure 4 illustrates that little or no hysteresis effect is evident at 9LA. This indicates that only minimal quantities of salts accumulate underground during the drier seasons. An increase in concentration always occurs with an increase in discharge. Likewise, a decrease in concentration is associated with a decrease in discharge. Some of the zinc concentrations on both the rising and falling limbs are different for a given discharge rate. However, for others the concentrations on the two limbs are similar and this suggests that there is not time between significant flow events for a sufficient accumulation of soluble metal from either oxidation or ponded water. Alternately, one or more of the upgradient-contributing source areas of the mine do not participate in the significant increase in flow.

An examination of the zinc concentration and discharge at 9LA for separate years reveals more clearly the lack of a strong hysteresis effect. Figures 5 and 6 present zinc concentration and discharge data for calendar years 1984 and 1985, respectively. Insufficient zinc concentration data on the rising limb exist for 1983 to present, for all limbs for that year.

The results from 1984 exhibit limited separation between the limbs of the hydrograph. Rather than a hysteresis effect, results suggest a simple linear relation between discharge and zinc concentration. The rising and falling limbs cross, suggesting that a substantial amount of acidic salts were not available for mobilization during spring runoff. The first data point on the rising limb of the hydrograph is associated with no increase in zinc concentration. The increase in discharge comes from tributary sources that have relatively good water quality, with zinc concentrations generally from 10 to 100 ppm. Subsequent data points on the rising limb show an increase in zinc concentration in response to contributions from sources that discharge very poor-quality water, with zinc concentrations up to 17,000 ppm, and have low discharges, while the earlier clean discharges have tapered off.

The results from 1985 (Figure 6) exhibit greater separation between the limbs than did those from 1984. The maximum zinc concentration occurred on the rising limb. However, the rising limb generally has lower zinc concentrations than the falling limb at a given discharge rate. This suggests little or no accumulation of acidic salts underground during the annual drier season. The contributions of tributary sources to 9LA with markedly different water quality are illustrated strongly in Figure 6. An increase in discharge of approximately 160 gpm is accompanied by a decrease in zinc concentration at the beginning of the rising limb of the hydrograph. Subsequent data points on the rising limb show a very modest increase

in discharge that is associated with a dramatic increase in zinc concentration. This pattern is very similar to that in 1984 and suggests the hydraulics for clean water flow versus poor-quality water flow behaves in a consistent manner.

The early increase in discharge comes largely from 5BK, 5WM, and the old Reed Pump Back system. Together, they account for 80 percent of the observed increase in discharge. They all produce fairly good-quality water.

The sharp increase in zinc concentration is associated with no measurable change in discharge. The tributary sources that are responsible for the increase in zinc concentration all drain the Flood-Stanly Ore Body, and contribute only a small amount of discharge. The locations that contribute to the increase in concentration are 9SO, 9SX, and the old 7 Level drain system. The aggregate change in discharge from these locations between the sampling events was 24 gpm, well within the measurement error at 9LA. Zinc concentrations from these locations reached up to 14,000 ppm.

The responses at 9LA suggest the following:

- A strong hysteresis effect from the dissolution of acidic salts is not evident, although the sampling frequency of two to three times per month was too infrequent to demonstrate or to definitively refute a hysteresis effect
- The contribution of tributary sources with markedly different water quality occurs with an observable time lag
- A very substantial change in water quality can be associated with very little change in discharge

Examination of tributary monitoring stations to 9LA station demonstrate very different relations between zinc concentrations and discharge rates at various sites that drain the Flood-Stanly Ore Body. For example, Figures 7 and 8 clearly show that zinc concentrations do not change much with discharge ranging from 50 to 500 gpm at the 9SX station in either the historical or current data sets. The data all fall within a typical analytical error band of plus or minus 10 percent.

In strong contrast to 9SX, zinc concentration decreases as discharge increases at 9SO as shown on Figure 9. These relationships also show little hysteresis between rising and falling limbs of the hydrograph. The linear least square fit equations for the historical and current zinc concentrations in milligrams per liter (mg/L) based on natural logarithm of flow are essentially the same:

Historical: Zinc (mg/L) = 18,200 – 3,720 * Ln Flow (r=0.88)

Current: Zinc (mg/L) = 18,500 – 4,000 * Ln Flow (r=0.95)

The lack of hysteresis and close similarity between the historical and current data strongly suggest that there is little to no storage of oxidation products or mine pools in the flow path of this part of the Flood-Stanly Ore Body. Furthermore, even though the flow at 9SO is significantly lower than the flow at other stations, the pH is significantly lower and metals concentrations significantly higher at this location than at any other measuring station. This location would have been the location expected to show a major hysteresis effect because of

its low base flow and apparently relatively long flow path. The zinc-flow relationship indicates that this water is being diluted (decreasing metals concentration) with increasing flow (increasing infiltration). Nevertheless, zinc loading and therefore lime demand increases with increasing flow because the discharge rate increases more than the concentration decreases.

Zinc loading at 9LA integrates the majority of flows and metal contributions from the gravity drainage on the Milo Creek side of the mine. The characteristics represent a very diverse mixture comprised of relatively excellent quality water from drill holes and fracture drainage from the subregional groundwater system, which combines with highly acidic drainage from the Flood-Stanly Ore Body (9SO, 9SX etc.).

Figure 10 shows that a strong linear relation exists between zinc load and collective discharge at 9LA. The data presented are those collected from 1983 through 1985 because there are so many more observations on which to establish a relation. As discussed previously, the 1983 through 1985 and the 1998 and 1999 data at this location are similar. The zinc load increase is tightly correlated with the increase in discharge rate. In addition, the rate of increase in zinc load is approximately 10 times the rate of increase in discharge. For example, as discharge increases from 400 to 600 gpm, the zinc load increases from 1,600 to 3,600 pounds per day.

Extrapolation of the data to the X intercept suggests that approximately 250 gpm of the discharge carries no metal load at all. This is confirmed by measuring drill hole discharge and other regional groundwater sources that consistently have relatively good to excellent quality water (pH near and above neutral and very low metals concentrations). For example, the drill hole on 7 Level discharges between 150 and 170 gpm, and drill holes on 5 Level discharge 60 to 90 gpm. The drill hole on 7 Level discharges water that has a pH between 3 and 5, and zinc concentration between 0.1 and 1 ppm. The 5 Level drill holes discharge water that has a pH between 3 and 7, and zinc concentration between 0.02 and 0.2 ppm.

The relation between zinc loading and discharge strongly suggest two concepts. First, a decrease in recharge on the West Fork Milo Creek side of the mine will likely result in a decrease in zinc loading at 9LA. This is largely because recharge to the Flood-Stanly Ore Body comes mostly from the West Fork Milo Creek basin. Second, the zinc loading at 9LA is clearly a result of mixing of originally very good-quality water with highly acidic metal-bearing water. Remediation that restricts excellent-quality surface water from infiltrating into the Flood-Stanly Ore Body should significantly reduce the amount of elevated metal concentrations and acidic water created by this infiltration. Additionally, both reduction and segregation of the water that flows from the Flood-Stanly Ore Body, and that from the subregional groundwater system, would result in reduced precipitation and accumulation of metal hydroxides created by their mixing within the mine, and would thereby decrease mine maintenance (mucking out of accumulated metal hydroxides). Because the two water sources are spatially separated, perhaps the in-mine separation of these two may be feasible and cost-effective.

4.4 Buildup of Efflorescent Salts as a Reservoir of Metals

The buildup of efflorescent salts within the mine is a potentially negative result of recharge reduction efforts. Such a buildup could provide the basis for a large metal load in the future during a period of high precipitation. However, buildup of sufficient quantities of salts at the Bunker Hill Mine to create a significant reservoir of soluble metals seems fairly unlikely. Salt accumulation in any of the accessible portions of the Flood-Stanly Ore Body or surrounding workings has not been observed. What is much more common at the Bunker Hill Mine is the development of numerous pools of poor-quality water in undulations in the drifts, behind yellow boy (predominantly iron oxyhydroxide precipitate) and constructed dams, and in plugged transfer raises. The ponds constitute a reservoir of poor-quality water but less of a reservoir than metals-bearing salt deposits. Furthermore, the water chemistry at 9SX, 9SO, 9VR and 9CR do not indicate that reservoirs of soluble salts are building up along their respective flow paths into the mine under historical and current conditions. There is a relatively high correlation between historical and current metal concentrations and, therefore, lime demand. Salt buildup, if it were occurring, should have become evident in these relationships. Inspection for salt buildup (where accessible) and monitoring of water flow and quality underground are critical components of recharge reduction measures. Data generated as a result of monitoring will allow assessment of potential buildup of salts within the mine.

5.0 Risks/Uncertainties

As with any work involving relatively complex inter-related natural and anthropogenic surface water/groundwater conditions, there are always uncertainties and associated risks. However, given what is described in the preceding text, reduction of recharge to the Bunker Hill Mine should result in a decrease in lime demand and associated sludge generation. There is uncertainty in the amount of decrease that will likely occur and, therefore, the effectiveness of the mitigation efforts. Furthermore, there is uncertainty whether or not recharge reduction efforts will result in sufficiently large soluble metal precipitate accumulation and subsequent release at a future high flow event. However, even if salts do accumulate and are released by a large flow event, there is a sufficiently large storage volume in the mine for retention of essentially any foreseeable future high flow event (under current mine management conditions), although the capability of capturing and storing these high flows must be constructed, demonstrated, and maintained. Also, a treatment plant could be designed to handle flows and concentrations of concern. The following text provides a more thorough discussion of risk and uncertainty questions.

5.1 Recharge Reduction Mechanisms and Effectiveness

Water flow within the mine occurs primarily through man-made openings under partially saturated conditions. Flow is along the bottom of drifts and inclined shafts. Only a very small percentage of the upper country workings are flooded and these are behind local dams. Water movement through open and backfilled stopes is under unsaturated to partially saturated conditions. Historical and current data show that the dominant infiltration events to the mine coincide with the spring snowmelt period. Water flow is much higher during this period than during the remainder of the year. In fact, the flow in

the mine decreases throughout the remainder of the year, much like a recession pattern in a groundwater-fed stream.

Acid salts are formed at reaction sites where they remain until washed into the water flow system within the mine by infiltrating surface water. Pools of acidic water form in drifts, particularly where yellow boy deposition is common. In many cases the reaction salts and pools of acid water remain in place until there is a flushing effect from recharge, generally related to snowmelt infiltration. The data of flow versus lime demand at the 9LA site show an approximately linear relationship between these factors. The higher metal concentrations at higher flow result from the flushing of soluble metal salts and acid water from the mine workings.

A reduction in recharge to the underground workings would act to reduce both the high flow surge of water in the mine and the low flow component. Research results from sites at the end of the New East Reed drift on 5 Level show that near-surface fracture systems effectively "fill up" during the spring recharge event and drain to the mine throughout the rest of the year.

A recharge reduction program that is targeted at the West Fork Milo Creek drainage has a high potential to decrease the surface water infiltration responsible for the flushing/washing effect within the Flood-Stanly Ore Body. Obviously, complete elimination of surface water infiltration and flushing/washing within this portion of the upper country would go a long way toward elimination of the Bunker Hill AMD problem, but it is unrealistic to expect complete elimination. The reduction in recharge to this portion of the mine through various recharge reduction measures is unknown. However, the effectiveness of recharge reduction efforts in this area should be high rather than low simply because the configuration of the drainage relative to the ore body leads to this conclusion. All aspects of the geology and hydrology that have been investigated support the likelihood of success using this approach.

5.2 Potential for a Significant Acid Water Release at a Future High Flow Event

The question has been raised whether installation of recharge reduction facilities, particularly in the West Fork Milo Creek drainage, would lead to a significant storage and release of metals at a future high flow event. Such an event might be triggered by the following conditions. First, the recharge reduction facilities might greatly reduce the annual surface water recharge events. Second, without the annual flushing/washing events, acid salts might continue to build up and store soluble metals available for mobilization in acid water at a later high-flow event. Third, a run-off event might occur that greatly exceeded the capacity of the recharge mitigation options, or the mitigation could fail. Fourth, this flood event in the underground would flush the accumulated acid salts in an extreme event that could exceed either storage or treatment capacity.

This scenario is dependent on several conditions that would require a considerable number of inter-related conditions to be present and events to occur. The first question is whether, in the absence of frequent flushing/washing events, acid salts would continue to build up. There have been considerable changes in the mining activities and seasonal flow conditions incorporated in the historical and current flow and chemistry data. These data do not indicate a recognizable salt buildup. Furthermore, the high flow event would have to have

both significantly higher flow and, more importantly, duration to exceed the storage or treatment capacity. A sufficiently large metal-bearing salt buildup would probably take several years to accumulate, during which time monitoring at historical sites should measure and provide both considerable warning of the buildup rate and allow response prior to a release. Also, the extreme flood event scenario might also be eliminated by redundant recharge mitigation options.

Another question deals with how water might move through the underground workings during an extreme high recharge event under both present conditions and under future conditions where flow underground is modified. Prediction of future flow through the mine involves more open-ended questions and necessary assumptions than just the question of reduced lime demand and sludge production by reducing the surface water infiltration into the mine workings. There are far too many unknowns to allow speculation before an estimate is attempted through further investigation. Future mine management must be the first defined condition for such an estimate.

6.0 Recommendations to Fill Data Gaps and Minimize Uncertainty

The present understanding of water flow and acid production from the Bunker Hill Mine has resulted from surface and subsurface research efforts both in the 1970s and 1980s by the University of Idaho, and in the recent efforts. The classic approach to hydrogeologic investigation is to physically change the hydraulic characteristics of the system and observe the response patterns. This approach is the optimum way to gain additional understanding in order to respond to the questions raised in the previous section.

Construction of a first stage or several related stages of mitigation options in the West Fork Milo Creek drainage is needed to collect data on the effect of reducing infiltration through the Flood-Stanly Ore Body. This should include monitoring of both surface water and mine water / metals concentrations / lime demand response.

Flow and quality monitoring in the underground workings is essential for assessing mitigation performance and to further the understanding of the mine water. Cooperation with the mine owner / operator is essential.

Measurement of stream flow within the potential recharge areas is necessary to assess the effectiveness of recharge reduction mitigation options. At present, the potential for recharge-related savings from the mitigations is based on runoff estimates but not field data, because stream flow measurement sites do not exist.

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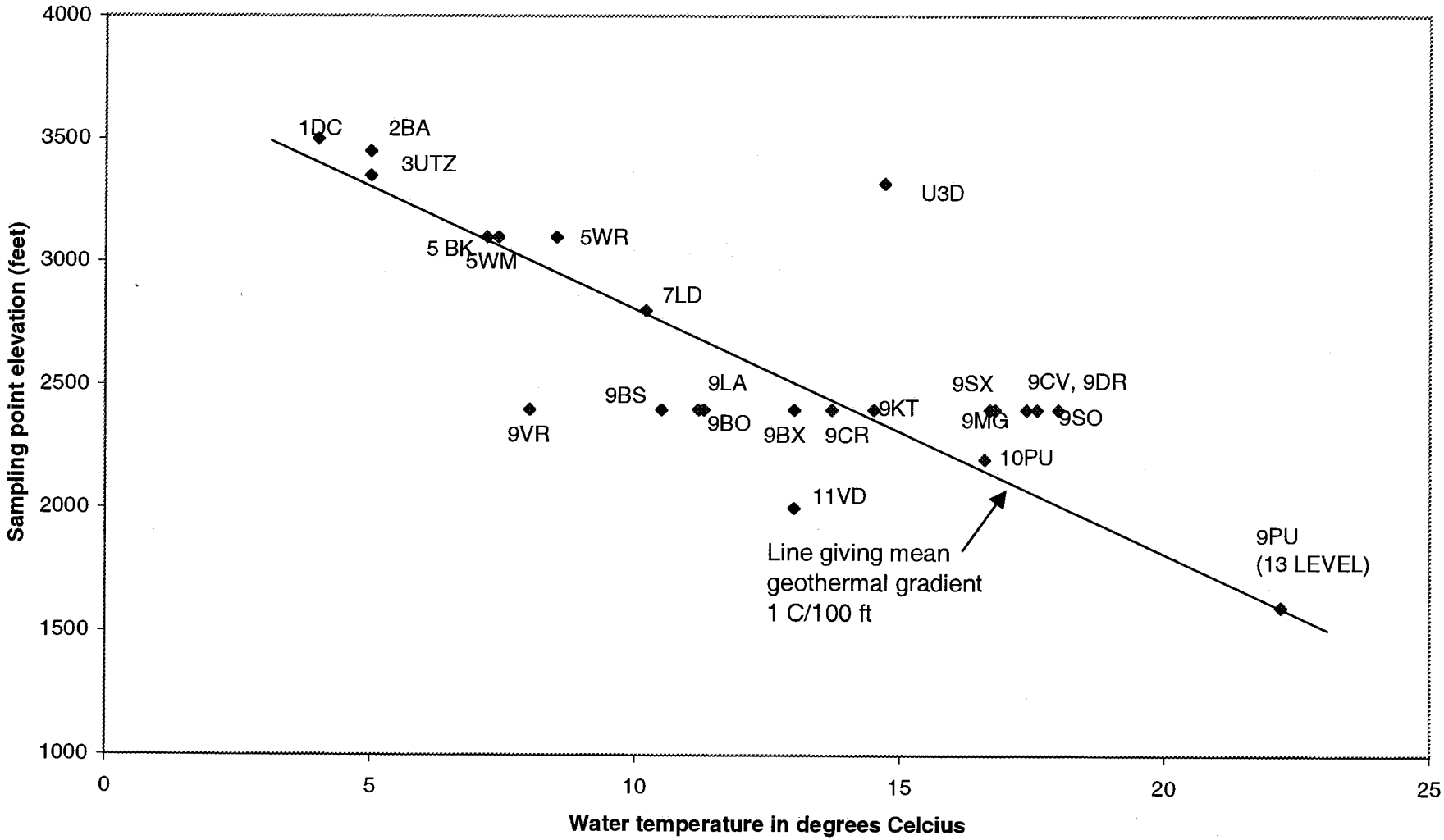
TABLE 1
Correlation Among Iron, Zinc, Sulfate and Lime Demand
9LA Water Samples (1998 and 1999 Data)

	Discharge	Iron	Zinc	Sulfate	Lime Demand
Discharge	1.000				
Iron	0.992	1.000			
Zinc	0.946	0.936	1.000		
Sulfate	0.994	0.995	0.967	1.000	
Lime Demand	0.994	0.989	0.948	0.995	1.000

TABLE 2
Correlation Among Iron, Zinc, Sulfate and Lime Demand
9LA Water Samples (1983 through 1985 Data)

	Discharge	Iron	Zinc	Sulfate
Discharge	1.000			
Iron	0.661 (0.725)	1.000		
Zinc	0.662 (0.743)	0.973	1.000	
Sulfate	0.652 (0.721)	0.919	0.928	1.000

Figure 1
Average Water Temperature at Underground Sampling Sites, 1998-99 Data



9LA Current Correlations

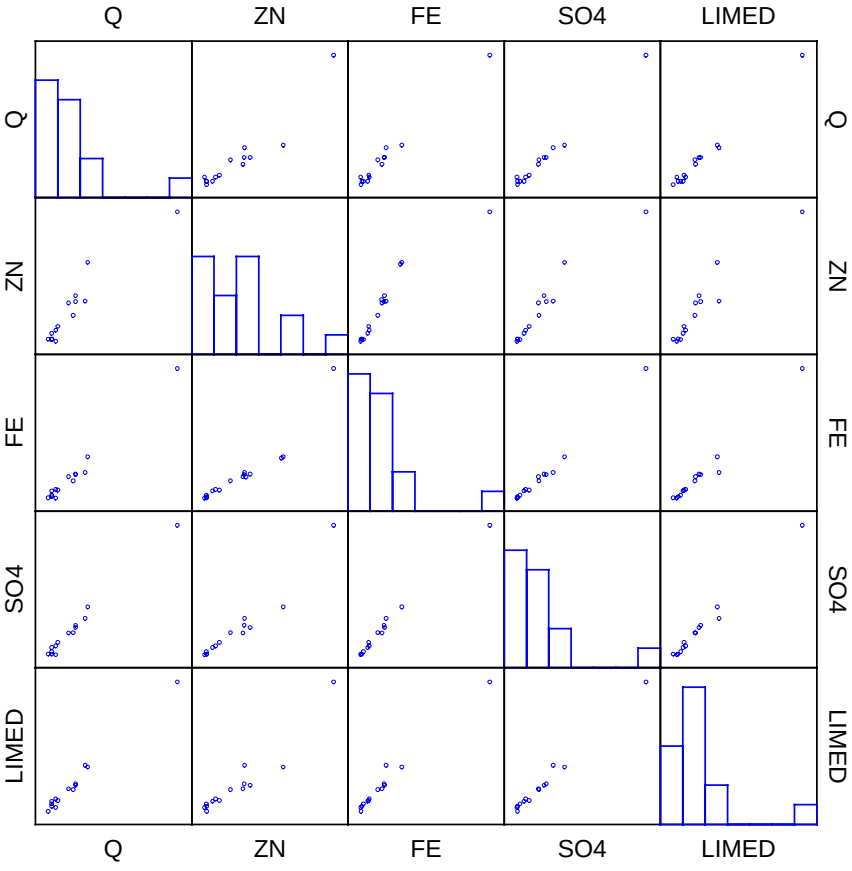


FIGURE 2
Correlations Among Selected Variables at 9LA (1998-1999 Data)

9LA Historical Correlations

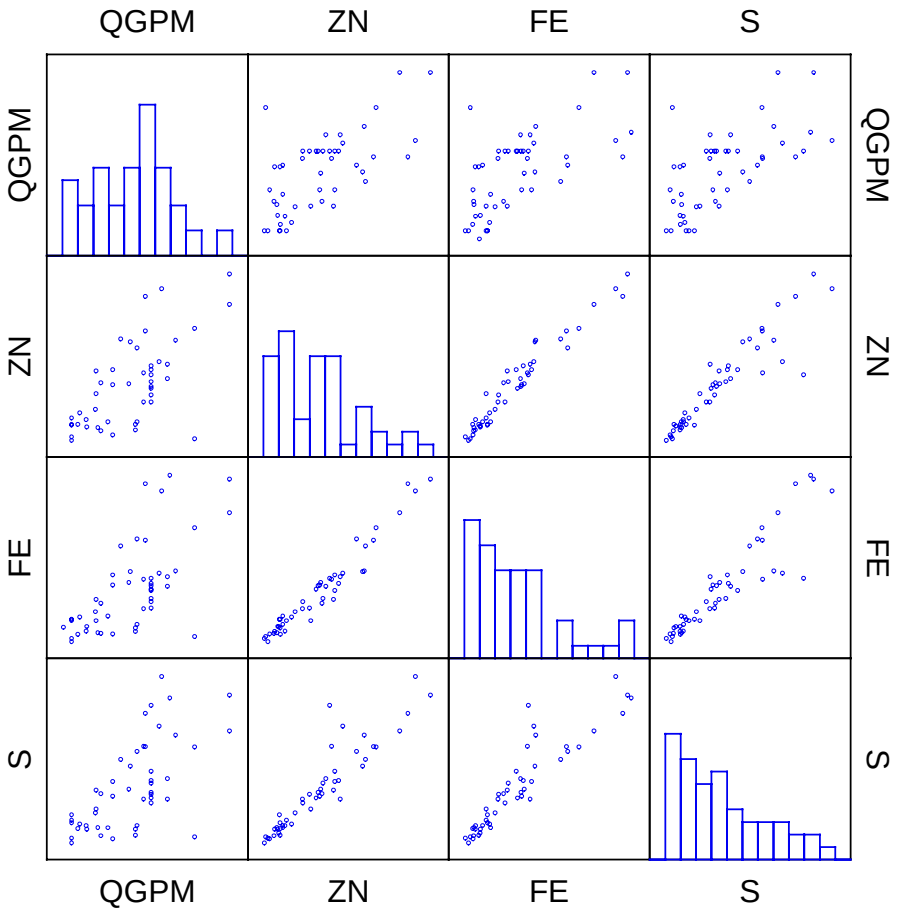


FIGURE 3
Correlations Among Selected Variables at 9LA (1983-1985 Data)

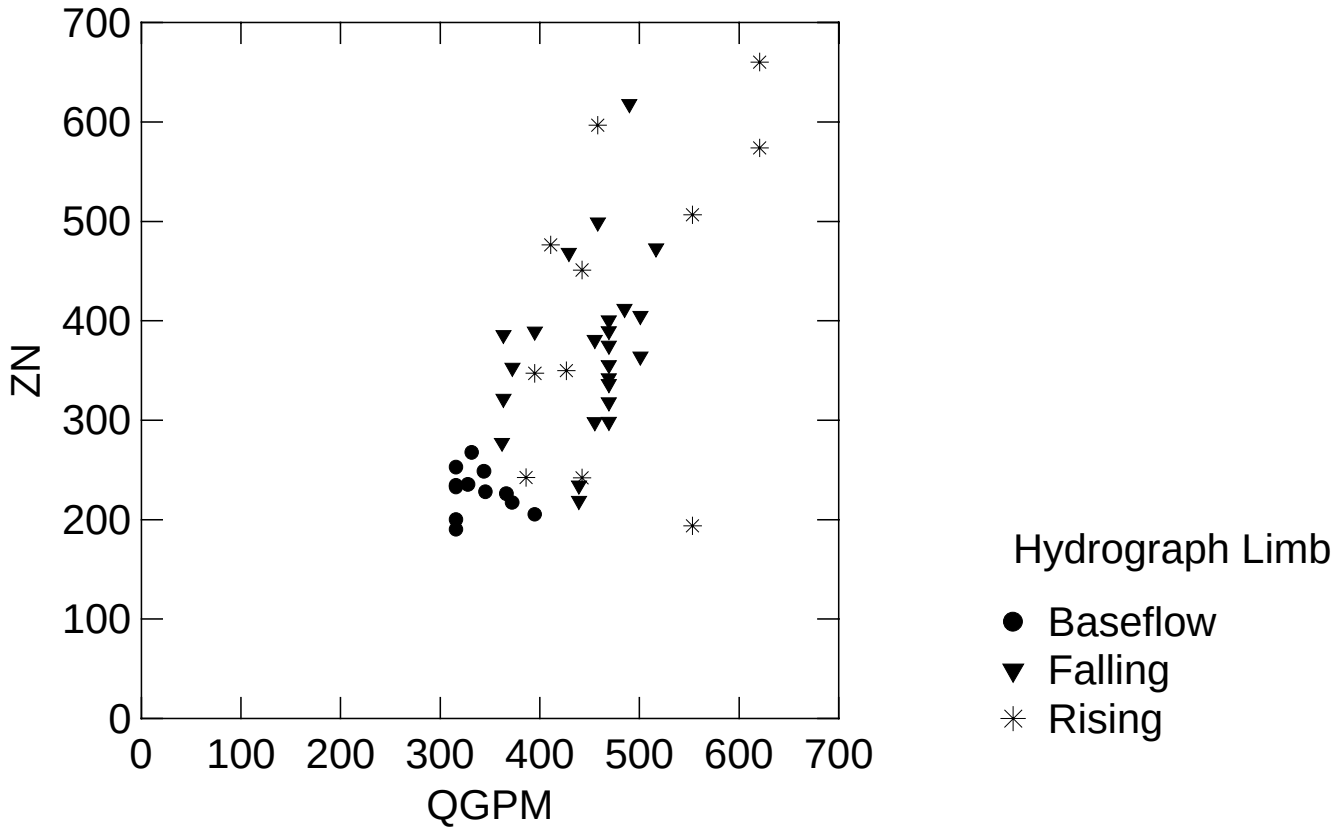


FIGURE 4
Relation Between Zinc Concentration (mg/L) and Discharge at 9LA.

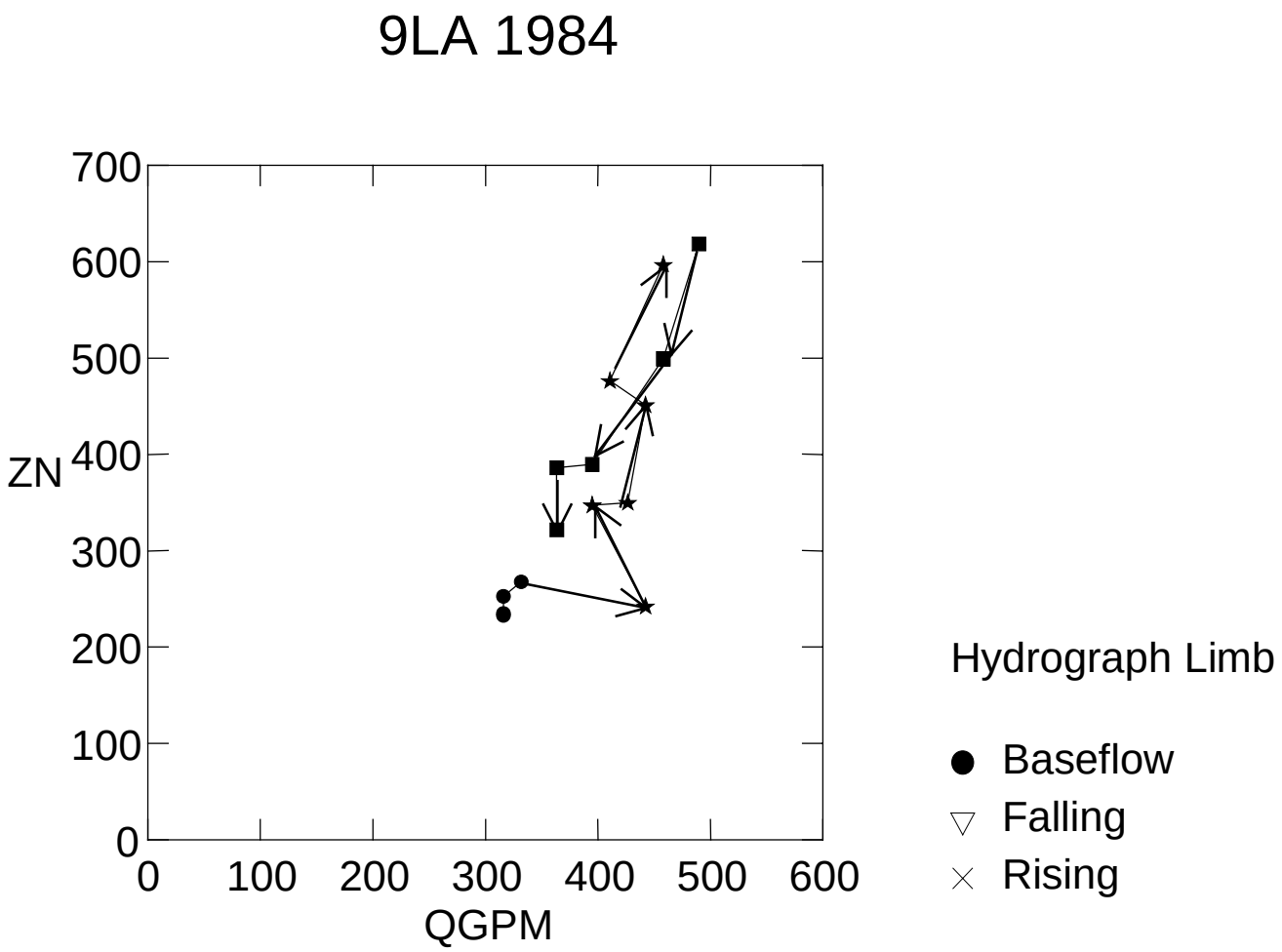


FIGURE 5
Relation Between Zinc Concentration (mg/L) and Discharge at 9LA (1984 Data)

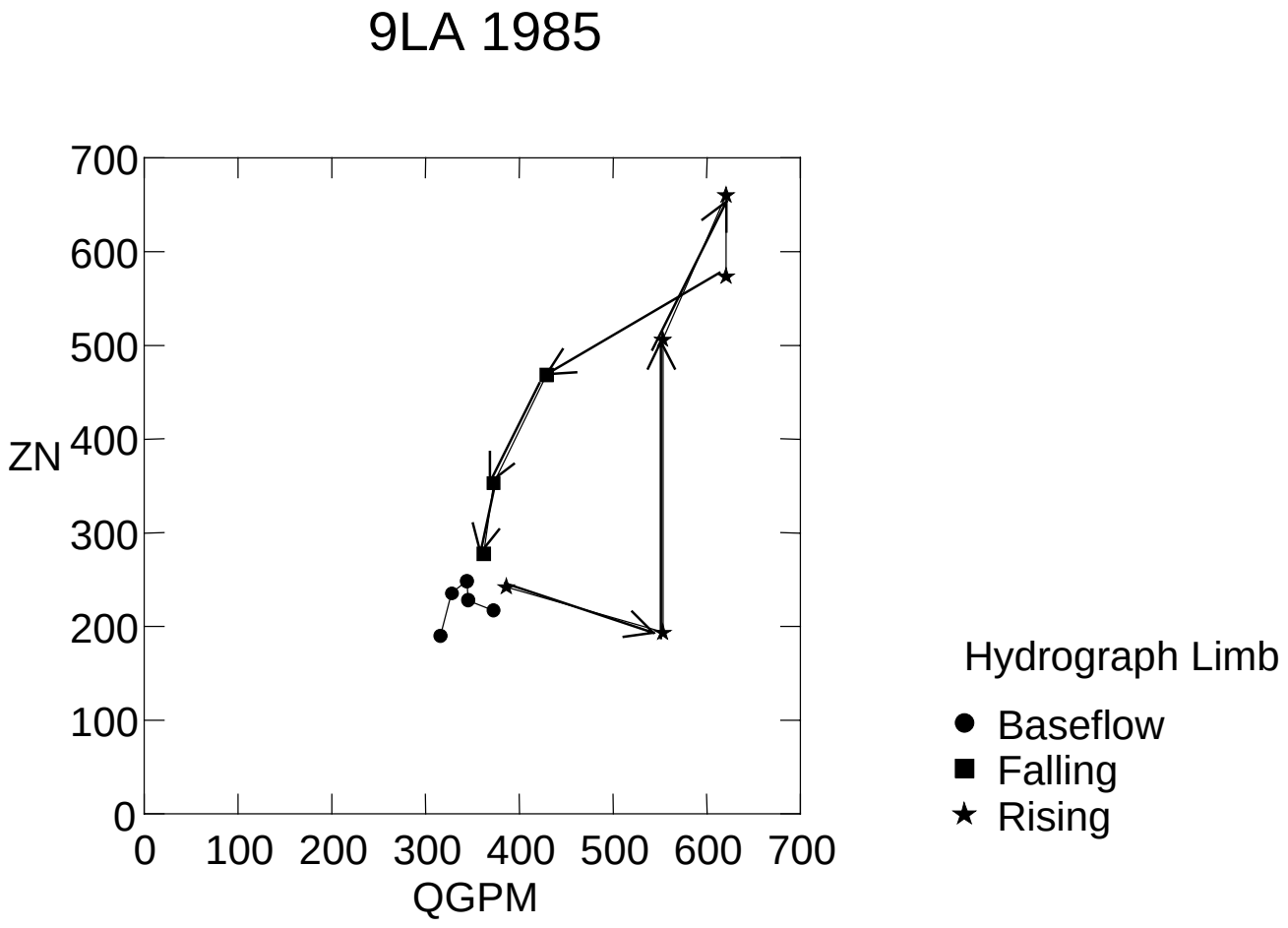


FIGURE 6
Relation Between Zinc Concentration (mg/L) and Discharge at 9LA (1985 Data)

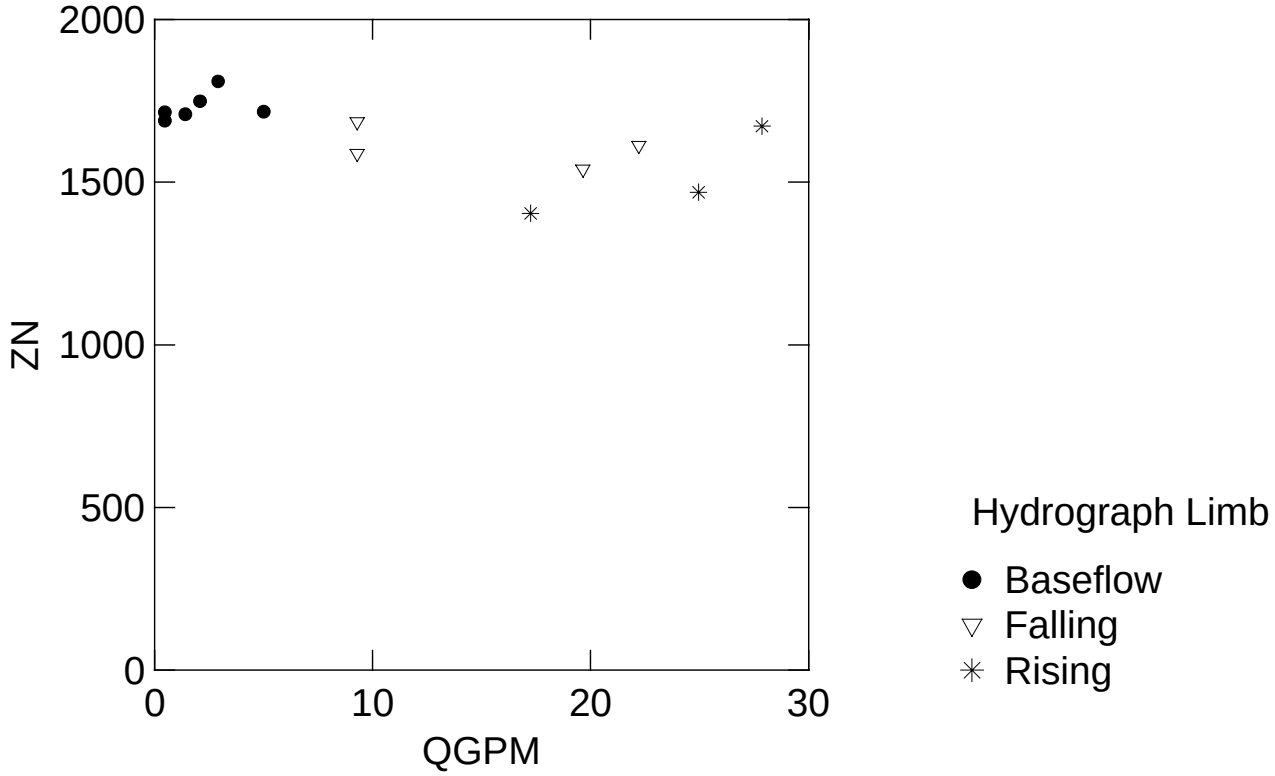


FIGURE 7
Relation Between Zinc Concentration (mg/L) and Discharge at 9SX (1983-1985 Data)

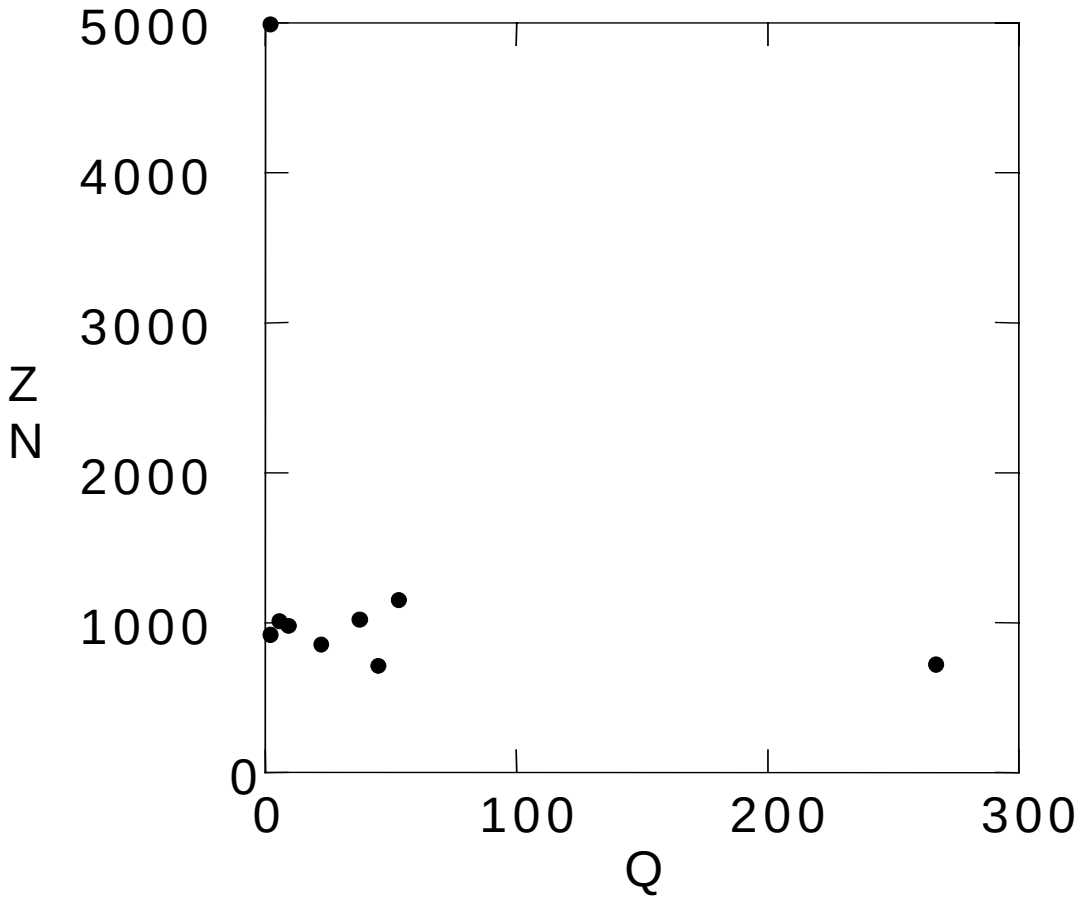


FIGURE 8
Relation Between Zinc Concentration (mg/L) and Discharge at 9SX (1998-1999 Data)

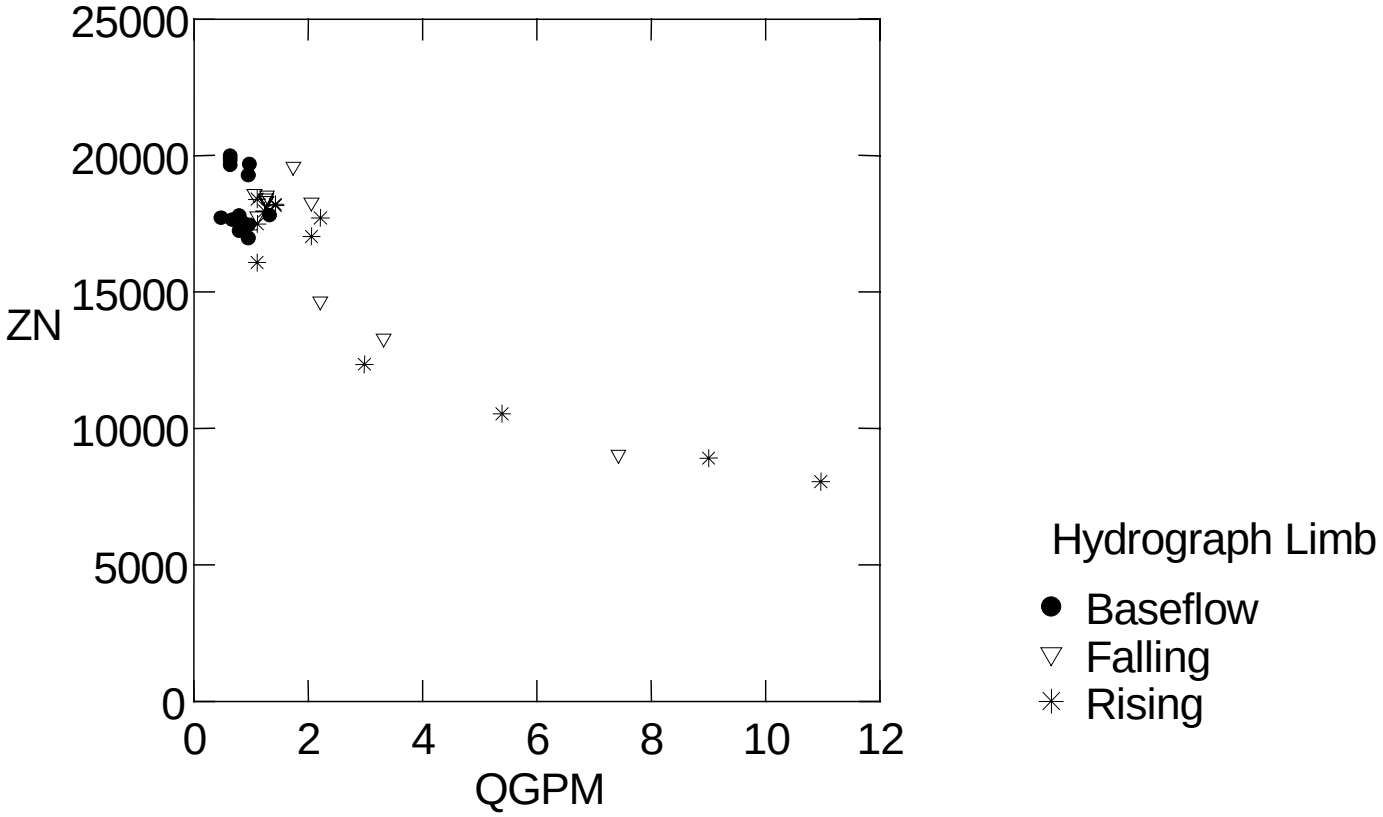


FIGURE 9
Relation Between Zinc Concentration (mg/L) and Discharge at 9SO.

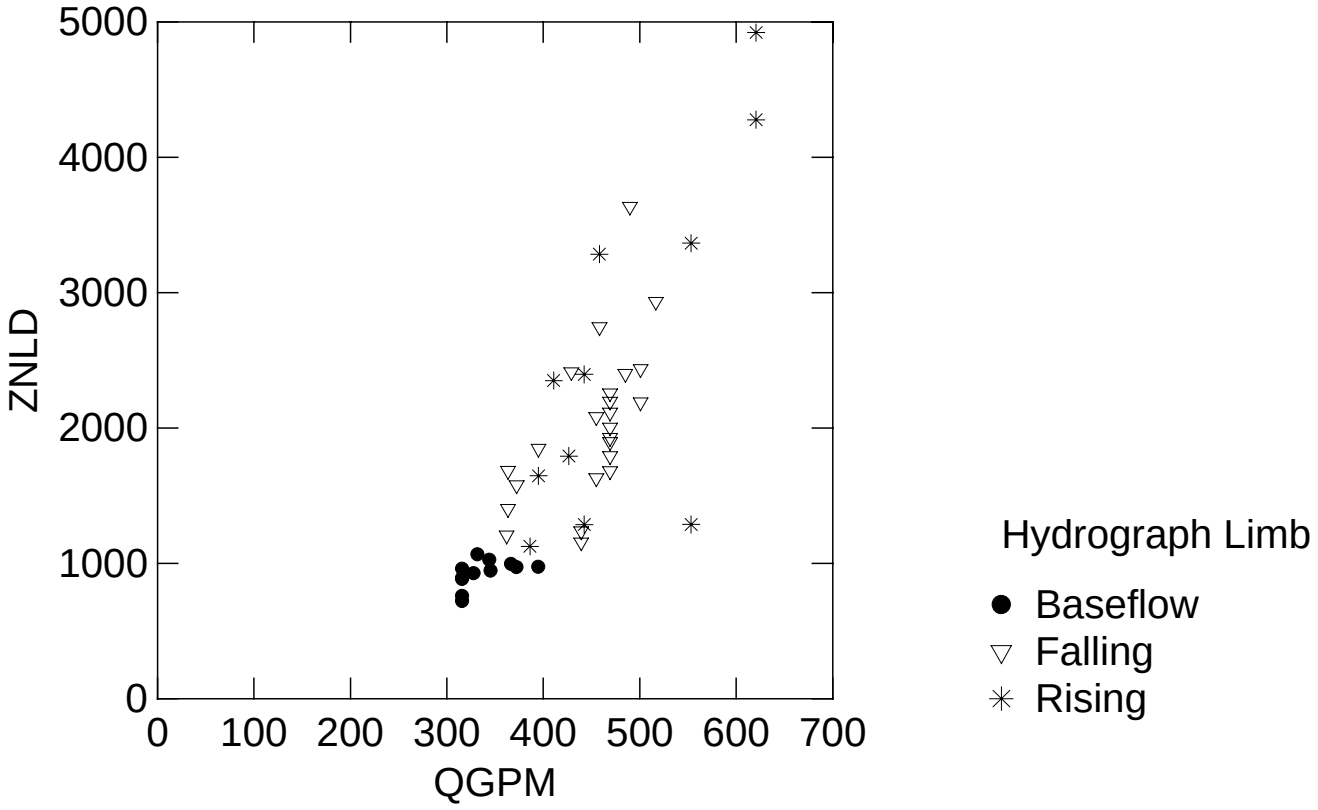


FIGURE 10
Relation Between Zinc Load (pounds/day) and Discharge at 9LA (1983-1985 Data)

APPENDIX C

AMD Mitigations Conceptual Designs and Cost Evaluation—Update

AMD Mitigations Conceptual Designs and Cost Evaluation—Update

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DATE: July 2000

1.0 Introduction

1.1 Purpose and Objectives

This technical memorandum presents updated conceptual design development and cost evaluations for acid mine drainage (AMD) mitigation alternatives for the Bunker Hill mine, which were originally presented in Appendix A of the *Draft Preliminary Screening for TMDL Compliance* report (CH2M HILL, February 2000a). The original costs were modified in Appendix A of the *Supplement to the Draft Preliminary Screening for TMDL Compliance* report (CH2M HILL, 2000b). Mitigation options in this memorandum have been revised based on the May 18, 2000, Bunker Hill meeting that is documented in the *Bunker Hill Mine Water FS Alternatives* memorandum (CH2M HILL, 2000c). The revisions are summarized in Table 1 and are described in detail in their respective sections of this technical memorandum. Those that are listed in Table 1 as having no modifications have been included for completeness of all currently considered AMD mitigation alternatives.

1.2 Document Organization

This document is organized into seven main sections:

Section 1. Introduction—This section includes the purpose, objectives, document organization, and limitations of this technical memorandum.

Section 2. West Fork Milo Creek—This section describes AMD mitigation measures that apply to the West Fork Milo Creek drainage basin area. A description is provided for each mitigation measure, along with the design criteria, conceptual design, and costs [both capital and long-term operations and maintenance (O&M)].

Section 3. South Fork Milo Creek—This section describes AMD mitigation measures that apply to the South Fork Milo Creek drainage basin area. Diversion is the only mitigation carried forward for the South Fork. For this mitigation, a description is provided, along with the design criteria, conceptual design, and costs (both capital and long-term O&M).

Section 4. Mainstem Milo Creek—This section presents the conceptual design and costs for the AMD mitigation measures that apply to the Mainstem Milo Creek drainage basin area. A description is provided for each mitigation, along with the design criteria and costs (both capital and long-term O&M).

Section 5. Deadwood Creek—This section presents the conceptual design and costs for the AMD mitigation measure that applies to the Deadwood Creek drainage basin area. Plugging the Inez Shaft is the only mitigation carried forward for Deadwood Creek. A description is provided for this alternative, along with the design criteria and costs (both capital and long-term O&M).

Section 6. Other Areas—This section presents the conceptual design and costs for the AMD mitigation measures that apply to other areas of the Milo Creek drainage basin area. Plugging drill holes is the only mitigation carried forward for other areas of the mine. For this mitigation, a description is provided, along with the design criteria and costs (both capital and long-term O&M).

Section 7. AMD Mitigations Cost Summary—This section presents a summary of the capital and O&M costs developed for each mitigation alternative.

1.3 Limitations

Detailed design has not been conducted on any of the AMD mitigation approaches summarized in this technical memorandum. The mitigation concepts and resulting implementation costs have been developed for comparison with the costs and benefits of other components of what is believed to be a logical presumptive remedy for long-term water management at the Bunker Hill Mine. The conceptual designs are based on existing data only. Limited additional field investigations (installation of eight piezometers at four locations) have been conducted to augment the existing information. These limited investigations and existing data will have to be supplemented for subsequent design development stages of mitigation implementation and cost refinement. Costs have not been included for in-mine performance monitoring associated with any of the mitigation measures.

Order-of-magnitude cost estimates have been prepared based on conceptual designs of AMD mitigation measures. The cost estimates are in January 2000 dollars and do not include escalation. They were prepared using information available at that time and are subject to adjustments in the scope and details of each design. The cost estimates have been prepared for guidance in project evaluation and should be carefully reviewed prior to making specific financial decisions or establishing final project budgets. The actual costs to implement any of the mitigation approaches are expected to vary from the costs shown herein, based on actual labor and material costs, competitive market conditions, final project scope and other variable factors.

2.0 West Fork Milo Creek

This section describes the AMD mitigation measures that apply to the West Fork Milo Creek drainage basin area: West Fork Diversion, Phil Sheridan (Opening Phil Sheridan Raises, Enhanced Phil Sheridan Raise Rehabilitation, and Proposed Drift Construction), and Surface

Diversions Above Guy Cave. Locations of these mitigation efforts within the West Fork are shown in Figure 1. For each mitigation, a description is provided, along with the design criteria, the conceptual design, and the costs (both capital and long-term O&M costs).

One mitigation measure for the West Fork, which appears in Table 1, Cemented Backfill into Homestake/Utz Workings, was screened out due to high costs and expected low effectiveness during the May 18, 2000, Bunker Hill Mine Water Feasibility Study Alternatives Meeting that is documented by the *Bunker Hill Mine Water FS Alternatives* memorandum (CH2M HILL, 2000c).

2.1 West Fork Diversion

2.1.1 Description

The West Fork Milo Creek (West Milo) is a small ephemeral creek located in the upper watershed of the Milo Creek Basin. West Milo flows are primarily the result of spring snowmelt and storm events. As a result of the depression created by the Guy Cave, West Milo Creek flows directly into the underground workings and does not connect with the flows of the Mainstem of Milo Creek. In addition, Hunt (Hunt, 1984) conducted tracer tests within the West Milo drainage that indicated a direct interconnection of the surface flow with the mine workings. The Katherine Fault intercepts West Milo at approximately elevation 3,900 feet (Figure 1). Hunt was unable to discern the amount of infiltration of water into the mine from the Katherine Fault.

To mitigate this drainage into the mine, a diversion structure or multiple structures would be installed in the West Fork Milo Creek to collect flow. The structure would be keyed into bedrock to cut off and intercept alluvial flows. The flows would be transferred into a pipeline via a grated inlet structure and perforated pipe drain buried in the upstream channel that would route water down to the Reed Landing area within the existing Milo Creek channel system. Figures 2, 3, and 4 show the general configuration of the system.

For costing purposes, it is assumed that a single West Fork diversion structure would initially be developed at a location above the Katherine Fault, near the anticipated upstream edge of the influence zone for downward vertical groundwater gradients to the mine workings. This diversion would be used in conjunction with diversion at Phil Sheridan Raise No. 2 to intercept remaining flows from the West Fork. Because the primary purpose of the diversion is to intercept surface runoff from snowmelt conditions, it is considered important to be able to intercept surface water as well as flow in the alluvial zone above bedrock. Thus, a primary focus for determining the exact siting of the diversion structure will be to locate a point along the stream where bedrock is closest to the ground surface, and where an alluvial cutoff could most easily and effectively be accomplished. In the future, additional foundation grouting of the underlying bedrock beneath the diversion structure could be undertaken if it is determined that fracture grouting would be cost-effective.

Additional diversions could also be considered in the future if necessary, to be located between the initial diversion structure and Raise No. 2, depending on how successful the diversions prove to be. Figure 2 depicts the location of the proposed diversion and the relative position of the Phil Sheridan Adit, Katherine Fault, recent monitoring well borings, and the Guy Cave Area. The secondary diversion at Raise No. 2 is discussed in Section 2.2.

An access road would be required to the dam site for construction and maintenance. It is assumed that the road would be constructed at a grade of about 10 percent. It also is assumed that the access road would tie into the Kellogg Ski Area road that presently crosses that drainage basin above the dam site. This installation would require the construction of about 3,500 feet of new access road (Access Road B). Other Access Road B alignments are possible and could combine sidehill diversions with a road-side ditch. Water collected in the road-side ditch would be diverted directly into the West Fork Diversion screen structure and pipeline diversion system. Other road alignments will be considered during remedial design efforts.

2.1.2 Design Criteria

General design criteria for the West Fork diversion system are as follows:

- Capture alluvial flow and surface flow that comes from drainage basin areas above the diversion location
- Provide capacity to handle the 100-year rainfall event with snowmelt
- Locate the diversion close to the upgradient edge of the mine workings influence zone on groundwater, and locate the structure at a point along the stream where bedrock is closest to the ground surface.
- Minimize potential for plugging of the inlet structure by providing a perforated collector pipe and substantial reserve for the cross-sectional screen area.
- Provide system inflow redundancy
- Convey diversion water from West Milo down to the Reed Landing diversion structure on Mainstem Milo Creek
- Maintain hillside stability and minimize hillside erosion from pipeline construction
- Establish access to diversion dam / intake for maintenance
- Minimize inspection and sediment removal from intake area
- Minimize disturbance in the watershed (roads and logging) above the diversion structure in order to minimize runoff and sediment transport
- Minimize other system maintenance
- Maintain hydraulic profile for proper flow conveyance
- Maintain pipeline stability and structural integrity

Surface Water Flow Estimates

A conceptual design for the West Milo diversion system was presented in a memorandum, *AMD Mitigations Evaluation*, dated July 28, 1999 (part of the presumptive remedy document, CH2M HILL, 1999). Design flows were developed for West Milo in the *Milo Gulch Flood Hydrology and Water Quality Improvement Plan* (Spectrum Engineering, 1996). The design flows include both rainfall events and rainfall events with snow melt. These are summarized in Table 2.

These flow rates are estimated for the entire West Milo basin that drains into the Guy Cave Area. The specific location of the West Fork Diversion structure will be determined during remedial design. The areas currently considered are elevations between 3,900 and 4,100 feet above mean sea level (famsl). The assumed location of the diversion for this analysis is at an elevation of 4,035 famsl, and would capture about two-thirds of the total drainage basin area.

CH2M HILL performed additional hydrologic modeling, based on the proposed position of the West Fork diversion shown in Figure 1, in order to refine anticipated sub-basin flows to the diversion structure. Hydrologic modeling was conducted using HEC1 developed by the U.S. Army Corps of Engineers. A detailed description of the model and the assumptions used in developing the model are presented in Attachment A to this technical memorandum. Results of the modeling are shown in Table 3.

In the July 1999 mitigation evaluation memorandum, the design criterion for the diversion was proposed to be the 5-year rainfall event with snowmelt or the 25-year rainfall-only event, whichever was greater. CH2M HILL recommends upgrading the design to accommodate the 100-year rainfall event with snowmelt. Reasons for the upgrade include:

- Nearly 100 percent of the water from West Milo infiltrates the acid-producing areas of the mine, based on recent reconnaissance efforts.
- Mine flushing events could occur if the diversion capacity was exceeded. Such events could significantly reduce the effectiveness of the mitigation for reducing metal load to the Central Treatment plant (CTP).

Diversion Pipeline Design Criteria

Preliminary sizing of the West Milo diversion pipeline was based on the 100-year, 24-hour rain event with snowmelt flow of 57 cubic feet per second (cfs). Specific pipeline design criteria are as follows:

- Pipe material—welded high-density polyethylene (HDPE), dimension ratio (DR) of 17.
- Pipe diameter—Manning's open channel flow model was used to calculate minimum pipe diameters (*n* value of 0.011 for HDPE pipe) to carry the anticipated flows.
- As a conservative measure for this conceptual design, the design diameters were increased one to two standard pipe sizes above the minimum size, which were calculated using Manning's model.

2.1.3 Conceptual Design

West Fork Diversion Structure

The West Fork Diversion consists of the construction of a small dam to impound water from the stream and an inlet/screen structure to collect and screen water before it enters the pipeline, as shown in Figures 3 and 4. The diversion dam should extend to bedrock, as required to cut off groundwater flow in the alluvium. Based on borings from piezometers recently installed near the proposed diversion location, the depth to bedrock is estimated to range from about 20 to 40 feet below the ground surface. It is assumed that a backhoe would be used to trench to bedrock or close to bedrock to remove large rock. The trench would be backfilled with a material suitable for driving sheet piling through. The sheet piling would

be driven to refusal at the rock surface. Seepage could be further controlled by trenching a foot or more into rock and concrete encasing the base of the sheets in the rock surface, if the depth to rock is about 20 feet or less. If the depth to rock is more than 20 feet, grouting from the ground surface could later be performed to further control seepage past the dam, if warranted. If the depth to rock is greater than 20 feet, then use of a grout curtain may be more cost-effective. A grout curtain would most likely consist of three rows of staged grout holes, with the spacing split down until the grout take is minimal (estimated at 5- to 10-foot spacing). Some grouting of the upper bedrock also may be warranted if it is found to be fractured and pervious.

The dam would be designed for emergency overtopping if the flow should exceed the design hydraulic capacity of the pipeline or the inlet structure becomes clogged. The central portion of the dam would be constructed as a weir, with a slightly lower elevation than the abutments on either side. The downstream side of the dam would be constructed with riprap or grouted riprap for erosion protection.

A screen diversion structure would be located immediately upstream of the dam. The diversion pipeline would connect into a rectangular to round hydraulic transition at the downstream end of the screen diversion structure. The screen diversion structure would be sized for reserve screen area to account for conservative assumptions for clogging. Experience has shown that the most significant maintenance issue would probably be associated with natural accumulation of sediment bed load in the vicinity of the intake. The accumulation of sediment would in time block and/or partially clog the screened opening to the collection chamber. This condition is often appreciably affected by grading, road building, logging and other similar activities in the drainage area above the screen intake area. Grading and construction activities in the drainage basin are beyond the control of this project, but it is assumed that these concerns will be conveyed to the owner of the property and access roads and other construction will be carried out in a manner that minimizes this concern.

A slotted collection pipeline should be installed upstream of the screen intake structure. The purpose of the collection pipeline is to collect most of the surface water in the stream at points upstream of the screen structure. The sediment bed load in the stream can be expected to drop out as the flow in the stream diminishes through infiltration into the slotted pipe, thereby allowing most of the sediment to collect along the stream bed upstream of the screen structure. The slotted pipe would be installed in a shallow trench (2 to 3 feet of cover) and backfilled with clean, gap-graded pea gravel. A series of gabion sediment traps would also be installed along the streambed upstream of the screen structure to further encourage infiltration and collection of sediment at points upstream of the screen structure. Refer to Figures 3 and 4 for typical sections of the dam and screen intake structures.

An access road to the dam site would be required for construction and maintenance. The permanent road should be a minimum of about 12 feet wide and ditched as required to control surface runoff. It is assumed that the road would be constructed at a grade of about 10 percent. It also is assumed that the access road would tie into the spur road off the Kellogg Ski Area road that presently crosses the drainage basin above the dam site. This installation would require the construction of about 3,500 feet of new access road.

A steep access road also would be available along the pipeline route during construction. The slope of this road is estimated to be as steep as about 22 percent and the road would tie into the Guy Cave access road in the West Fork Milo Creek basin.

Diversion Pipeline

A 30-inch-diameter HDPE pipe carrying an anticipated maximum flow rate of 57 cfs would begin at the diversion structure (4,035 famsl), as shown in Figure 1, and would be routed down a newly constructed road to an area adjacent to Raise No. 2. In this area, the pipeline would be routed down Access Road A (see Figure 1) to approximately 3,650 famsl where it would drop into a standard U.S. Bureau of Reclamation stilling basin at the confluence with the Phil Sheridan pipeline, as discussed in Section 2.2.1. The combined, energy dissipated flows (maximum flow rate of 97 cfs) would enter a 36-inch-diameter HDPE pipe at the discharge point of the stilling basin and would generally align northeast, dropping approximately 180 feet into the second stilling basin in the area of the Lower Guy Cave (3,470 famsl). The 36-inch-diameter pipeline alignment would continue northeast down Access Road A where it would drop into a third stilling basin at approximate elevation 3,360 famsl before surfacing at 3,170 famsl and discharging into an HDPE overland pipe 150 feet long and 36 inches in diameter.

The overland pipe would be laid directly on the ground surface and would be anchored at the top (3,170 famsl) by a concrete block. At the bottom of the overland pipe Section (3,125 famsl), an HDPE slip pipe 42 inches in diameter would be anchored at the bottom and laid uphill, overlapping the overland pipe by approximately 15 feet. This slip pipe would provide coverage of the overland pipe during thermal movements of expansion and contraction and would provide enough length to catch back-splashing. A slip gasket would be installed at the upstream end of the slip pipe to prevent soil and debris from entering along the annulus between the two pipes. The overland pipe would then discharge into a fourth stilling basin. The overflow from the stilling basin would discharge into the Reed Landing Dam on Mainstem Milo Creek.

2.1.4 Costs

The cost analysis for the West Fork Diversion was performed on the basis of information contained in U.S. Environmental Protection Agency (EPA) guidance documents, experience in estimating similar projects, independent estimates, and engineering judgment. Order of magnitude estimates (plus 50 percent, minus 30 percent) have been prepared for capital implementation costs and for annual O&M costs. Capital implementation costs include engineering and construction management allowances. Net present value (NPV) for annual O&M costs are also included for a 30-year period at 7 percent interest.

Assumptions used in development of the cost estimate for the West Fork Diversion include:

- Design and construction of a 3,500-foot access road routed from the spur road off the Kellogg Ski Hill Area road
- Design and construction of a West Milo Diversion structure, including the dam, foundation cutoff provisions (both a sheetpile and a grout curtain), intake screen, and transition structure
- Design and construction of the upstream collector pipe and gabions

- Design and construction of a 3,350-foot pipeline routed from the diversion structure down to the Reed Landing Dam
- Installation of four standard U.S. Bureau of Reclamation stilling basins to dissipate water energy along the entire length of the pipeline from the diversion structure down to the Reed Landing Dam
- Costs for the West Milo Diversion to the confluence with the Phil Sheridan Diversion pipeline and from the confluence to the Reed Landing Dam are included
- O&M costs include annual inspection, road maintenance, and pipeline and structure maintenance and repairs

Order of magnitude costs for the West Milo Diversion are shown in Table 8 in Section 7 of this memorandum. The cost estimate data sheets for West Milo Diversion are provided in Attachment B of this memorandum.

2.2 Phil Sheridan

This section describes the AMD mitigation alternatives that apply to the Phil Sheridan and ultimately to the West Fork Milo Creek drainage basin area. Two alternatives are considered in This section. The first is rehabilitation of the Phil Sheridan Diversion, which includes opening the raises, and installation of a new drift and diversion pipeline. The second alternative is an additional improvement to Phil Sheridan Raise No. 2 that includes provisions for an alluvial flow cutoff wall.

2.2.1 Rehabilitate Phil Sheridan Diversion

This section describes the AMD mitigation measures for rehabilitating the Phil Sheridan Diversion, including opening Phil Sheridan Raises No. 1 and No. 2, and constructing a new drift and diversion pipeline.

2.2.1.1 Description

Open Phil Sheridan Raises

There are three Phil Sheridan raises. Raises No. 1 and No. 2 are completed to the surface, but the surface expression of Raise No. 3 has not been confirmed. As shown in Figure 1, Raise No. 2 is located about 650 feet downstream along West Fork Milo Creek from the proposed diversion structure. Raise No. 1 is located about 200 feet north of Raise No. 2 and captures flow from areas that are outside of the drainage basin captured by the West Fork Diversion.

Sediment and other materials that have collected in Raises No. 1 and No. 2 would be removed to allow surface water flows that reach the raises to flow down to the Phil Sheridan Adit. Surface collection structures would be built to direct flow to Raises No. 1 and No. 2.

As discussed in Section 2.1, Raise No. 2 lies downstream of the West Fork Diversion; thus, flows to this raise would be significantly reduced by the diversion. In conjunction with the upper diversion dam, Raise No. 2 would serve to catch runoff from portions of the watershed outside of the boundaries of the upper diversion. At Raise No. 1, it is anticipated that this raise could be built to also collect flows from the new Sidehill Diversion constructed above the Guy Cave Area, as discussed in Section 2.3. As a result of these

diversions, flows to Raise No. 1 could be significantly increased as compared to existing flows currently collected by the structure.

Drift Construction

As previously mentioned (CH2M HILL, 2000a), several cracks in the floor and sides of the Phil Sheridan Adit were observed. In addition, there is considerable uncertainty about the stoping below the Phil Sheridan, and its related safety. These issues have instigated several safety concerns for accessing and constructing a pipeline diversion system in the area of the Phil Sheridan portal as previously proposed (CH2M HILL, 2000a), and has prompted the alternative of advancing a new adit to intersect with the Phil Sheridan Adit. The intersection of the new adit with the Phil Sheridan Adit is approximately 250 feet north of Raise No. 1. The location of the proposed adit portal and its alignment is shown in Figure 1.

During remedial design of the new drift, locations for new raises to capture additional surface water flow should be considered.

2.2.1.2 Design Criteria

General design criteria for rehabilitating the Phil Sheridan Diversion are as follows:

- Minimize hillside erosion in areas of new construction
- Minimize underground and raise maintenance
- Capture surface flow from drainage basin areas within the West Fork drainage basin that will not be captured at the diversion location
- Provide capacity to handle the 100-year rainfall event with snowmelt
- Minimize potential for plugging of inlet structure by providing substantial reserve for the cross-sectional screen area.
- Minimize disturbance in the watershed (roads and logging) above the diversion structure in order to minimize runoff and sediment transport
- Establish access to diversion dam for maintenance
- Convey diversion water from the Phil Sheridan raises down the newly constructed drift and into a U.S. Bureau of Reclamation stilling basin at the confluence with the West Fork Diversion pipeline
- Maintain a hydraulic profile for proper flow conveyance
- Maintain pipeline stability and structural integrity
- Conceptually design the diversion pipeline to accommodate 100-year rainfall event with snowmelt for Raise No. 2 and Raise No. 1 with Sidehill Diversion, which is the largest combined flow that would be anticipated from the Phil Sheridan diversion system

Surface Water Flow Estimates

Hydrologic modeling performed as part of the West Fork Diversion evaluation also modeled stormwater flows that would access Raise No. 2, assuming that the West Fork Diversion was in place, and Raise No. 1, both with and without Sidehill Diversion (discussed in Section 2.3). Modeling was conducted using HEC1 developed by the U.S.

Army Corps of Engineers. A detailed description of the model and the assumptions used in developing the model are presented in Attachment A of this technical memorandum. Results of the modeling are shown in Tables 4 and 5.

As with the West Fork Diversion, CH2M HILL recommends using the 100-year rainfall event with snowmelt design flows for sizing the diversion structures and conveyance pipelines for the Phil Sheridan Raises.

Diversion Pipeline

Preliminary sizing of the Phil Sheridan diversion pipeline was based on the combined 100-year rainfall event with snowmelt for Raise No. 1 with Sidehill Diversion (Table 5) and Raise No. 2 (see Table 4), yielding a combined flow of 40 cfs. Specific pipeline design criteria are as follows:

- Pipe material—welded HDPE, DR of 17.
- Pipe diameter—Manning's open channel flow model was used to calculate minimum pipe diameters (*n* value of 0.011 for HDPE pipe) to carry the anticipated flows.
- As a conservative measure for this conceptual design, the design diameters were increased one to two standard pipe sizes above the minimum size, which were calculated using Manning's model.

2.2.1.3 Conceptual Design

Open Phil Sheridan Raises

Figure 1 provides the overall locations of the Phil Sheridan Adit and Raises No. 1 and No. 2. The concept requires opening up both raises down to the Phil Sheridan Adit. The raises have filled in over time with rock, sand, and debris from the Phil Sheridan Adit to the ground surface. It is assumed that the raises would be opened by rehabilitating the inlet and by mining from below. These raises were partially cleaned out from the surface in 1999.

For Raise No. 2, a steel casing pipe would be installed from the ground surface through the overburden zone to control future cave-ins. A screen structure would be constructed on the top and sized conservatively to allow for the possibility of some clogging. Some re-grading would be required to enlarge the existing openings, grade to the proper elevations, and provide erosion protection around the intake structure. Figure 5 shows a schematic view of the raise and its components as described.

Rehabilitation of Raise No. 1 is similar to Raise No. 2. A steel casing would be installed from the top of bedrock to the ground surface, and a screen structure would be provided at the top of the casing pipe.

Drift Construction

The construction of the proposed drift would start at an elevation of approximately 3,670 famsl and would be advanced using typical underground drilling techniques for approximately 300 feet at a slope of 1 percent to intersect with the Phil Sheridan Adit as shown in Figure 1. A new access road (approximately 150 feet in length) from Access Road A to the area of the proposed drift portal would need to be constructed and maintained. It is assumed that the new drift would be constructed with the same dimensions as the Phil Sheridan Adit (approximately 8 feet wide by 10 feet tall).

The pipeline would require a partial bulkhead located just upstream of the confluence of the Phil Sheridan Adit to force the water into the pipeline for diversion. The bulkhead would consist of a rectangular concrete collar around the perimeter of the adit with a steel plate and gasket bolted to the concrete collar. The steel plate would in turn attach to a collar on the pipeline to form a watertight connection. A bolted bulkhead door could be provided for entry past the bulkhead for periodic inspection during periods when flow was not occurring. Provisions for air exchange to the back of the drift will be needed.

It is expected that a build-up of sand and other granular debris could occur over a period of time upstream of the bulkhead. This build-up is not expected to cause a serious maintenance problem, but it could result in the accumulation of several feet of sedimentation in the bottom of the 8-foot-wide adit. Although not included in this estimate, alternate provisions to reduce this maintenance could include the construction of a shotcrete or concrete lined, sloping, low-flow channel in the center of the base of the adit. The goal of this concept would be to keep the velocity of the water higher to allow transport of the sediment into the pipe and through the diversion system.

Diversion Pipeline

Collected stormwater would be diverted into a HDPE pipeline 42 inches in diameter by a steel bulkhead located just upstream of the confluence with the proposed drift. The pipeline would rest on the floor of the adit from the bulkhead to the portal (3,670 famsl). At the portal, the pipeline would transition into a HDPE pipe 36 inches in diameter and would be buried in the newly constructed staging area roadway to Access Road A (approximately 150 feet) where it would drop into a U.S. Bureau of Reclamation stilling basin at the confluence with the West Fork Diversion pipeline (3,650 famsl).

2.2.1.4 Costs

The cost analysis for rehabilitating Phil Sheridan Diversion was performed on the basis of information contained in EPA guidance documents, experience in estimating similar projects, independent estimates, and engineering judgment. Order of magnitude estimates (plus 50 percent, minus 30 percent) have been prepared for capital implementation costs and for annual O&M costs. Capital implementation costs include engineering and construction management allowances. NPV for annual O&M costs are also included for a 30-year period at 7 percent interest.

Assumptions used in developing the cost estimate to rehabilitate Phil Sheridan Diversion:

- Opening of Phil Sheridan Raise No. 1 and Raise No. 2 and site grading
- Construction of casing and screened intake structure
- O&M costs include annual inspection and road maintenance and repairs
- Construction of a 300-foot drift starting at 3,670 famsl and intersecting the Phil Sheridan Adit with a bulkhead dam to divert water into the Phil Sheridan Diversion pipeline
- Design and construction of the Phil Sheridan Diversion pipeline beginning inside the drift at the bulkhead dam and routed toward the U.S. Bureau of Reclamation stilling basin at the confluence with the West Fork Milo Creek diversion pipeline

- O&M costs include annual inspection, road maintenance, and pipeline and structure maintenance and repairs

Order of magnitude costs for opening Phil Sheridan Raises No. 1 and No. 2 are summarized in Table 8 in Section 7. Costs for opening Phil Sheridan Raises No. 1 and No. 2 are provided in more detail in Attachment B of this technical memorandum.

2.2.2 Improve Phil Sheridan Raise Rehabilitation

This section describes the improved Phil Sheridan Raise No. 2 rehabilitation effort through installing a grout curtain cutoff wall.

2.2.2.1 Description

As an addition to rehabilitating the Phil Sheridan Diversion, as described in Section 2.2.1, and to enhance water collection by Phil Sheridan Raise No. 2, a grout curtain or similar cutoff mechanism is needed. It is suspected that groundwater currently travels around the raise and eventually infiltrates into the lower mine workings. This barrier would catch a significant portion of the alluvial water from the natural drainage and divert it into Raise No. 2 to eventually be routed along the existing Phil Sheridan Adit, through the new drift, and into a pipeline leading to the West Fork Milo Creek diversion pipeline.

2.2.2.2 Design Criteria

General design criteria for groundwater collection enhancement of the Phil Sheridan Raise diversion system are as follows:

- Capture alluvial flow that enters into Phil Sheridan Raise No. 2
- Divert alluvial flow in the vicinity of Raise No. 2 down to the West Fork Milo Creek diversion pipeline and eventually to the Reed Landing Dam on Mainstem Milo.

2.2.2.3 Conceptual Design

In order to collect groundwater flow near the bedrock surface, a cutoff is needed below Raise No. 2. It is assumed that the cutoff will consist of 90 feet of sheetpile extending from ground surface to top of bedrock (assumed 20 feet) and a grout curtain immediately downstream of Raise No. 2. The grout curtain is assumed to be about 90 feet long, transverse to the stream, and would require three parallel rows of grout holes drilled on about 10-foot staggered centers to a depth of about 50 feet. Perforated collection pipe would be installed in deep trenches upstream of the cutoff to provide drainage back to Raise No. 2.

No provision for cutoff to bedrock was assumed for Raise No. 1. It is assumed that the surface ditch along a new diversion road, as mentioned in Section 2.1, would be used primarily to intercept surface runoff during high runoff events, and would collect water that in turn would be diverted directly into Raise No. 1. In the future, a cutoff could be added if it was determined that a groundwater cutoff provision was needed.

2.2.2.4 Costs

The cost analysis for improved Phil Sheridan Diversion Rehabilitation was performed on the basis of information contained in EPA guidance documents, experience in estimating similar projects, independent estimates, and engineering judgment. Order of magnitude estimates (plus 50 percent, minus 30 percent) have been prepared for capital implementation costs and for annual O&M costs. Capital implementation costs include

engineering and construction management allowances. NPV for annual O&M costs are also included for a 30-year period at 7 percent interest.

Assumptions used in developing the cost estimate for the improved Phil Sheridan Raise Rehabilitation effort include:

- Placement of a 90-foot-long sheetpile wall transverse to the stream bed
- Placement of three parellel 90-foot-long grout curtains (grout holes 10 feet on center)
- Installation of a perforated collector pipe laid in trenches on top of bedrock for Raise No. 2 (assuming bedrock 20 feet or less below ground surface)
- O&M costs include annual inspection

Order of magnitude costs for enhanced Phil Sheridan Raise Rehabilitation are summarized in Table 8 in Section 7. Costs for enhanced Phil Sheridan Raise Rehabilitation are provided in more detail in Attachment B of this technical memorandum.

2.3 Sidehill Diversions Above Guy Cave

2.3.1 Description

A road would be constructed above the caving area to intercept surface flows coming down the hillside to the Guy Cave or into fissures above the Guy Cave. A lined ditch on the inside of the road would be designed to carry flow along the road grade and discharge to the diversion at the Phil Sheridan Raise No. 1 or to tie into the West Fork Milo Creek diversion pipeline, if constructed. For the purposes of this conceptual design, it is assumed that the ditch flows will be diverted into Raise No. 1. Conceptual location of the hillside diversion is shown in Figure 1. The road adjacent to the ditch would be used for ditch maintenance; a turnaround would be located at the north end of the road for maintenance vehicles.

If additional surface water flow needed to be captured, Sidehill Diversions Above Guy Cave would be constructed in conjunction with the Raise No. 1 improvements. A screened intake structure would be provided along the nearby diversion road, and a short pipe would connect from the ditch intake structure directly to Raise No. 1.

2.3.2 Design Criteria

General criteria for this mitigation are as follows:

- Provide capacity to handle the 100-year rainfall event with snowmelt
- Reduce inflow to Guy Cave Area from overland flow sources by collecting water with a screened intake structure along the ditch and conveying it to the Phil Sheridan Raise No. 1
- Minimize channel velocity along the ditch
- Provide a ditch lining to enhance collection and retention of water in the ditch
- Minimize hillside erosion
- Provide access for maintenance/clean-out along the ditch

Surface Water Flow Estimates

Hydrologic modeling was performed for this option to determine the capacity necessary for surface ditches to capture overland flow that would otherwise flow into the Guy Cave. Modeling included stormwater flows captured by the sidehill ditch alone, as well as combined flows with Raise No. 1. Modeling was conducted using HEC1 developed by the U.S. Army Corps of Engineers. A detailed description of the model and the assumptions used in developing the model are presented in Attachment A to this technical memorandum. Results of the modeling are shown in Table 5.

As with the previous West Fork mitigations, CH2M HILL recommends using the 100-year rainfall event with snowmelt design flows for the sizing the Sidehill Diversion Ditch and conveyance pipelines.

2.3.3 Conceptual Design

This alternative requires the construction of about 940 feet of hillside road above the Guy Cave Area. The road would be laid out at about a 10 percent grade and is located as shown in Figure 1. Figure 6 provides a typical cross section of the road showing the ditch liner, cut slope, cross slope for the road, and liner and road surfacing materials.

The screen diversion structure would be constructed in the ditch at a point near Raise No. 1. The screen diversion would convey the water collected in the ditch into a pipe and into the vertical raise. If the screens become clogged, the water would flow over the road and down the slope to the nearby raise location where it would pass through a cone screen at the top of the steel casing installed in the raise.

The construction of a cutoff or grout curtain has not been assumed to be required at the Raise No. 1 location, because it is not located in a drainage swale where appreciable subsurface alluvial flows are known to exist. The remaining elements of this diversion (Phil Sheridan Raise No. 1 improvements) are described in Section 2.2.

2.3.4 Costs

The cost analysis for the Sidehill Diversions Above Guy Cave mitigation was performed on the basis of information contained in EPA guidance documents, experience in estimating similar projects, independent estimates, and engineering judgment. Order of magnitude estimates (plus 50 percent, minus 30 percent) have been prepared for capital implementation costs and for annual O&M costs. Capital implementation costs include engineering and construction management allowances. NPV for annual O&M costs are also included for a 30-year period at 7 percent interest.

Assumptions used in developing the cost estimate for Sidehill Diversions Above Guy Cave include:

- Installation of a ditch lining system
- Need for control of erosion and sedimentation
- Design and construction of a screen intake structure
- O&M costs include annual inspection, road maintenance, and pipeline and structure maintenance and repairs

Order of magnitude costs for hillside diversions are summarized in Table 8 in Section 7. Costs for the Sidehill Diversions Above Guy Cave are provided in more detail in Attachment B of this technical memorandum.

3.0 South Fork Milo Creek

This section presents the conceptual design and costs for the AMD mitigations that apply to the South Fork Milo Creek drainage basin area. A single mitigation is identified in Table 1 for the South Fork—the South Fork Diversion. Figure 1 shows the location of this mitigation within the South Fork Milo Creek drainage basin. For this mitigation, a description is provided, along with design criteria, the conceptual design, and costs (both capital and long-term O&M).

3.1 South Fork Diversion

3.1.1 Description

The South Fork Milo Creek is a steep mountain stream that is ephemeral in its upper reaches and perennial for approximately 700 feet above its confluence with the Mainstem of Milo Creek. South Fork Milo Creek is spring-fed from a talus slope that extends up Kellogg and Wardner peaks. As shown in Figure 1, the Cate and Buckeye faults cross South Fork Milo Creek in the portion of the creek that is perennial, with the Katherine Fault crossing the creek further upstream in its ephemeral stretch.

The concept that was evaluated requires the diversion of South Fork Milo Creek from above the Buckeye fault zone (in the portion of the creek's length that is perennial). From there it would be hard-piped to the Reed Landing Dam. Another option, not evaluated, would be to pipe the flow only to the existing upper diversion that was constructed in Mainstem Milo Creek in 1998. At this point, the water would be piped into the existing pipeline or a new line extending downgradient from that point. This option was not evaluated; using a 10-year rainfall event with snowmelt for design of the South Fork diversion, the existing pipeline is undersized for this capacity.

3.1.2 Design Criteria

General design criteria for the South Fork diversion system are similar to those for the West Fork diversion and include:

- Capture alluvial flow and surface flow that comes from drainage basin areas above the diversion location
- Provide capacity to handle the 10-year rainfall event with snowmelt
- Locate the diversion at or above the influence zone for groundwater entering the underground mine workings
- Minimize potential for plugging of the inlet structure by providing a perforated collector pipe and substantial reserve for the cross-sectional screen area.
- Provide system inflow redundancy

- Convey diversion water from South Fork Milo Creek down to the Reed Landing diversion structure on Mainstem Milo Creek
- Provide energy dissipation at pipeline discharge
- Maintain hillside stability and minimize hillside erosion from pipeline construction
- Establish access to diversion dam/intake for maintenance
- Minimize inspection and sediment removal from intake area
- Minimize disturbance in the watershed (from road construction and logging) above the diversion structure in order to minimize runoff and sediment transport
- Minimize other system maintenance
- Maintain hydraulic profile for proper flow conveyance
- Maintain pipeline stability and structural integrity

South Fork Milo Creek Design Flow Rates and Pipe Sizing

Initial pipeline sizing was completed based on available hydrology information developed by others. The intent is to size the pipeline for a storm with a reasonable return period that will allow most of the annual flow in the South Milo Creek watershed to be collected and conveyed to bypass the mine workings.

A conceptual design for the South Fork Milo Creek diversion system was presented in the memorandum *AMD Mitigations Evaluation*, dated July 28, 1999 (part of the presumptive remedy document, CH2M HILL 1999a). Design flows were developed for South Fork Milo Creek in the *Milo Gulch Flood Hydrology and Water Quality Improvement Plan* (Spectrum Engineering, 1996). The design flows included both rainfall events and rainfall events with snowmelt. These events are summarized in Table 6.

These flow rates are estimated for the entire drainage basin of South Fork Milo Creek. The proposed diversion would be located upstream in the South Fork Milo Creek basin and would thereby reduce the contributing area of the basin slightly from these numbers. In the case of the South Fork Milo Creek drainage area, with the diversion located approximately at elevation 3,510, about 75 percent of the drainage basin is above this diversion location. Because the higher elevations in the basin represent the source of snowmelt, using the estimated flows from the Spectrum report (Spectrum Engineering, 1996) to initially size the diversion pipelines seems reasonable without being overly conservative.

CH2M HILL proposes sizing the pipelines from the diversions to convey the 10-year rainfall with snowmelt storm event. These flows are larger than the previous recommendation of the 5-year event with snowmelt event as presented in the memorandum *AMD Mitigations Evaluation* (part of the presumptive remedy document, CH2M HILL, 1999). The recommendation to increase design flows to the 10-year event is based on the desire to reduce the frequency of bypass flows in the South Fork Milo Creek that could access mine workings, in conjunction with looking at the cost increase of the diversion structure and conveyance pipeline for the higher flows. The 100-year design flow used for the West Fork Diversion was considered to be too extreme, and therefore too costly, for the larger South Fork Milo Creek drainage system, particularly considering that a smaller percentage of the South Fork flows reach lower mine workings via the localized fault system (in comparison

to the West Fork Diversion). The creek diversion structure would be designed so flows associated with larger storm events would be bypassed without damage to the diversion structure.

The discharge pipeline design criteria identified for the South Fork Milo Creek Diversion are as follows:

- Pipe material—welded HDPE, DR of 17
- Pipe diameter —Manning's open channel flow model was used to calculate minimum pipe diameters (*n* values of 0.011 for HDPE pipe) to carry the anticipated flow
- As a conservative measure for this conceptual design, the design diameters were increased one to two standard pipe sizes above the minimum size, which were calculated using Manning's model.

3.1.3 Conceptual Design

South Fork Diversion Structure

The South Fork Diversion consists of construction of a small dam to impound water from the stream and an inlet/screen structure to collect and screen water before it enters the pipeline. The diversion dam/cutoff system should extend to bedrock as required to cut off groundwater flow in the alluvium. Based on observations in the area, it is likely that the depth to the rock surface in this area is less than 20 feet. Therefore, it is assumed that a backhoe would be used to trench to bedrock for forming a seepage cutoff. The trench would be backfilled with a material suitable for installing or driving sheet piling in. The sheet piling would be driven to refusal at the rock surface. Seepage could be further controlled by trenching a foot or more into rock, encasing the base of the sheets in concrete at the rock surface (if necessary), and performing foundation curtain grouting of the bedrock

The dam would be designed for emergency overtopping if the flow exceeds the design hydraulic capacity of the pipeline or the inlet structure becomes clogged. The central portion of the dam would be constructed as a weir having a slightly lower elevation than the abutments on either side. The downstream side of the dam would be constructed with riprap or grouted riprap for erosion protection.

A screen diversion structure would be located immediately upstream of the dam. The diversion pipeline would connect into a rectangular to round hydraulic transition at the downstream end of the screen diversion structure. The screen diversion structure would be sized for reserve screen area to account for some clogging. Experience has shown that the most significant maintenance issue would probably be associated with natural accumulation of sediment bed load in the vicinity of the intake. The accumulation of sediment would in time block and/or partially clog the screened opening to the collection chamber. This condition is often appreciably affected by grading, road building, logging, and other similar activities in the drainage area above the screen intake area. Grading and construction activities in the drainage basin are beyond the control of this project, but it is assumed that these concerns would be conveyed to the owner of the property and access roads and other construction would be constructed in a manner that minimizes this concern.

A slotted collection pipeline would be installed upstream of the screen intake structure. The collection pipeline would collect most of the surface water in the stream at points upstream

of the screen structure. The sediment bedload in the stream can be expected to drop out as the flow in the stream diminishes through infiltration into the slotted pipe, thereby allowing most of the sediment to collect along the streambed upstream of the screen structure. The slotted pipe would be installed in a shallow trench (2 to 3 feet of cover), and backfilled with clean, gap-graded pea gravel. A series of gabion sediment traps would also be installed along the streambed upstream of the screen structure to further encourage infiltration and collection of sediment at points upstream of the screen structure. The diversion structure, including dam and screen intake, for South Fork Milo Creek will be similar to the diversion structure for West Fork Milo Creek, as shown in Figures 3 and 4.

An access road to the dam site would be required for construction and maintenance. The permanent road should be a minimum of about 12 feet wide and ditched as required to control surface runoff.

Diversion Pipeline

The diversion pipeline (36-inch-diameter HDPE) would start at the South Fork Diversion Structure (3,530 famsl) and align north-northeast for approximately 550 feet, where it would drop into a U.S. Bureau of Reclamation stilling basin at 3,390 famsl. The discharge of the stilling basin would enter another 36-inch-diameter HDPE pipeline, cross Mainstem Milo Creek, and would then turn north-northwest, crossing the existing 36-inch-diameter corrugated metal discharge pipeline for the Upper Milo Diversion Dam. In this area, the pipeline would be constructed in a new grade to be established by benching into the hillside on one side of the stream between the Upper Milo Diversion Dam and the existing Bunker Hill Reservoir. The grade would be slightly above the hydraulic grade of the stream, and the base of the slope would be reinforced with large riprap to protect the pipeline installation against erosion from the stream, if water were to bypass the Upper Milo Diversion dam. The pipeline would then discharge into a standard U.S. Bureau of Reclamation stilling basin. The overflow from the stilling basin would discharge into the existing Reed Landing Dam on Mainstem Milo Creek. The alignment for the South Fork Diversion pipeline is shown in Figure 1.

3.1.4 Costs

The cost analysis for the South Fork Diversion was performed on the basis of information contained in EPA guidance documents, experience in estimating similar projects, independent estimates, and engineering judgment. Order of magnitude estimates (plus 50 percent, minus 30 percent) have been prepared for capital implementation costs and for annual O&M costs. Capital implementation costs include engineering and construction management allowances. NPV for annual O&M costs are also included for a 30-year period at 7 percent interest.

Assumptions used in developing the cost estimate for the South Fork Diversion include:

- Design and construction of a South Fork Diversion structure, including the dam, foundation cutoff provisions (both a sheetpile wall and a grout curtain), intake screen, and transition structure.
- Design and construction of an upstream collector pipe and gabions
- Design and construction of a 2,200-foot pipeline

- Installation of a standard U.S. Bureau of Reclamation stilling basin at Reed Landing and near the crossing of Mainstem Milo Creek
- O&M costs include annual inspection, road maintenance, and pipeline and structure maintenance and repairs

Order of magnitude costs for the South Fork Diversion are summarized in Table 8 in Section 7. The costs for the South Fork Diversion are detailed in Attachment B of this technical memorandum.

4.0 Mainstem Milo Creek

This section presents the conceptual design and costs for the AMD mitigation measures that apply to the Mainstem Milo Creek drainage basin area. These measures include: Plug Small Hopes Drift, Remove Bunker Hill Dam, and Improve the Existing Upper Diversion Structure. Figure 1 shows the locations of these mitigation measures within the Mainstem. A description is provided for each mitigation measure, along with the design criteria, the conceptual design, and the costs (both capital and long-term O&M).

As discussed in the March 14 and 15, 2000, meeting with EPA and the State of Idaho, concrete lining/grouting of Mainstem Milo Creek from the upper diversion structure to the Reed Landing was identified as a potential option, but it was determined the technical feasibility is difficult and questionable because of the following:

- Steep hydraulic profile of the creek
- Uncertainties with underground mine workings and influence on lining construction and long-term O&M
- Ability to convey sidehill drainage into channel
- Influence and effects on existing improvements within the creek
- Impact of carrying bedload down to Reed Landing

It was, therefore, decided to not pursue this option at this time, but to possibly reconsider it in the future if further inflow reduction is needed.

4.1 Plug Small Hopes Drift

4.1.1 Description

Portions of the shallow Small Hopes workings that intercept flow from Mainstem Milo Creek would be located and plugged with a sand/cement grout or another suiTable material. In addition, vertical raises that connect the Small Hopes Drift with lower areas of the mine would be sealed with concrete to further control seepage into the mine.

4.1.2 Design Criteria

General design criteria for the cemented backfill option is as follows:

- Seal the old Small Hopes workings in a 75-foot section where it passes under the Mainstem of Milo Creek in order to reduce water infiltration into the lower areas of the mine
- Stabilize the workings from future collapse
- Minimize potential for water build-up, release, and flooding of lower-level workings

4.1.3 Conceptual Design

To construct this alternative, the old Small Hopes Drift would be relocated by survey methods in the field. The approximate location is shown in Figure 1. Access to the Small Hopes Drift would be re-established by constructing a vertical shaft adjacent to the Mainstem Milo Creek channel, or the shallow cave-ins and workings would be open-excavated as required to expose the remnants of the Small Hopes Drift. This work would be accomplished during a period when no water was flowing in the stream.

Once the drift had been opened, two raises that drop to lower levels of the mine would need to be located. These raises would then be cleaned out as required and plugged with concrete to prevent further infiltration of surface water into the lower workings of the mine. It is assumed that plugging the raises would require construction of a bulkhead in the raises; a concrete plug would be formed in rock above the bulkhead (assume 8 feet in diameter and 16 feet long). After the raises had been sealed, both ends of the old Small Hopes Drift would be bulkheaded off and a 75-foot section of drift under the creek would be backfilled with sand/cement backfill to seal the workings under the stream. The stream bed would then be restored over the top of the construction area. Figure 7 shows the anticipated cross section of the Small Hopes Drift and possible location of raises that extend to lower levels of the mine.

4.1.4 Costs

The cost analysis for Plugging the Small Hopes Drift mitigation was performed on the basis of information contained in EPA guidance documents, experience in estimating similar projects, independent estimates, and engineering judgment. Order of magnitude estimates (plus 50 percent, minus 30 percent) have been prepared for capital implementation costs and for annual O&M costs. Capital implementation costs include engineering and construction management allowances. NPV for annual O&M costs are also included for a 30-year period at 7 percent interest. Assumptions used in developing the cost estimate for this mitigation include:

- Performing a survey to determine the location of Small Hopes Drift
- Installing a new access drift to Small Hopes Drift
- Cleaning out Small Hopes Drift , locating two raises to 5 Level, and cleaning out and plugging shafts to 5 Level
- Transporting mix to pump site (including 3 to 4 percent cement)
- O&M costs include annual inspection and structure maintenance and repairs

Order of magnitude costs for Plugging the Small Hopes Drift mitigation are summarized in Table 8 in Section 7.

4.2 Bypass Bunker Hill Dam

4.2.1 Description

The Bunker Hill Dam is located downstream of the existing Upper Milo Diversion structure on Mainstem Milo Creek. The dam impounds water for diversion into an emergency drinking water supply pipeline for the town of Wardner. Figure 1 shows the location of the dam, which is in the vicinity of underground mine workings where impounded water is suspected to access these workings. Under this mitigation, the dam would be bypassed and the headworks of the dam modified.

4.2.2 Design Criteria

The following design criteria pertain to bypassing the Bunker Hill Dam structure:

- Remove water from the dam to minimize future infiltration of water into the underground workings through this area
- Maintain an area upstream of the existing dam to capture bedload
- Maintain an emergency water source for the town of Wardner

4.2.3 Conceptual Design

The location of the existing Bunker Hill Dam and existing pipeline are shown in Figure 1. Water is supplied to the dam at the present time by tee connection and valve on the stream diversion pipeline that feeds a small polyvinyl chloride (PVC) pipeline. Water is dumped into the small impoundment, and from there it is conveyed to the town via an existing pipeline down the hill beside the stream.

In this mitigation measure, the pipeline that currently diverts flow from the upper diversion to the Bunker Hill Dam would be extended and connected to the existing pipeline that conveys emergency water to the town of Wardner. The dam would be modified to maintain its capture of stream bedload during high flows in the spring. The outlet works of the dam would require the removal of the slide filter units and a section of the headwall to extend the upper diversion pipeline and connect with the existing water supply pipe. In addition, the hand-wheel-operated gate would need to be removed and an angled bar rack (grizzly) installed in its place. A concrete approach/anchor pad and a new concrete headwall extending over into the damaged section, where the filters would be removed, would also need to be constructed.

4.2.4 Costs

The cost analysis for bypassing the Bunker Hill dam was performed on the basis of information contained in EPA guidance documents, experience in estimating similar projects, independent estimates, and engineering judgment. Order of magnitude estimates (plus 50 percent, minus 30 percent) have been prepared for capital implementation costs and for annual O&M costs. Capital implementation costs include engineering and construction management allowances. NPV for annual O&M costs are also included for a 30-year period at 7 percent interest.

Assumptions used in developing the cost estimate for this mitigation include:

- Extending the existing upper diversion pipeline and connection to the water line to maintain an emergency water supply for the town of Wardner
- Modify the outlet works of the dam for collection of debris and stream bedload

Order of magnitude costs for bypassing the Bunker Hill dam are summarized in Table 8 in Section 7. Costs for this mitigation measure are provided in more detail in Attachment B of this technical memorandum.

4.3 Improve Existing Diversion (Improve Seal/Decrease Overflow)

4.3.1 Description

The existing upper diversion structure on Mainstem Milo Creek would be improved to reduce the occurrence of overflow observed in the Mainstem below the structure. The location of this diversion structure is shown in Figure 1. This mitigation option would include (1) enlarging the screen diversion structure to increase the screen intake area and reduce clogging of the screen, (2) raising the weir to direct more flow into the pipeline (the current weir is designed to accommodate a 2-year flow event), and (3) installing an alluvial flow cut-off wall immediately downstream of the existing diversion. The alluvial flow cut-off wall will be constructed similar to the proposed West Fork Diversion structure alluvial cut-off as stated in Section 2.1A second option involving this structure includes significantly increasing the size of the water intake in the diversion, and increasing the sizing of the associated pipeline down to the second diversion structure to accommodate much larger flow events. This second option is discussed in Section 4.4.

4.3.2 Design Criteria

The following design criteria pertain to improving the existing diversion:

- Enhance the efficiency of the existing dam by minimizing overtopping of the weir during flows that are less than the design event, and capture alluvial flow that comes from drainage basin areas above the diversion location
- Establish a much larger intake capable of controlling the incidence of clogging at the intake screens
- Use the existing corrugated metal diversion pipeline
- Enhance the ability to clean the reservoir for periodic removal of sediment

4.3.3 Conceptual Design

For this alternative, it is assumed that the efficiency of diversion to the pipeline would be improved by establishing a larger, sloped screen intake structure and raising the weir on the dam to allow greater impoundment of water for diversion into the pipeline. This would be accomplished by constructing a new concrete diversion structure, screened grating, and associated improvements to the dam. Figures 8 through 11 show a concept for these improvements.

The existing corrugated metal pipeline would be reconnected to the new intake structure. A short hydraulic transition structure would be constructed to transition from the diversion structure to the corrugated metal pipeline.

The reservoir would be enlarged as a result of raising the dam. Currently the reservoir is sealed by use of a geosynthetic clay liner (GCL) under the area of the existing reservoir. It is assumed that the existing lining would be damaged by the new construction. The new, larger reservoir area would require enlargement of the lining system. Therefore, it is assumed that the base of the reservoir would be re-graded and that a new GCL would be provided under the impoundment area to help seal the bottom from leakage.

Good access to the reservoir would be provided so that the small reservoir area could be cleaned out on a regular basis. History has shown that Mainstem Milo Creek carries a significant bedload of sand, gravel, and rocks that must be cleaned out at regular intervals to assure that the diversion continues to function properly.

No other improvement would be considered with this alternative. More extensive diversion capacity and sediment control alternatives for this structure are discussed in Section 4.4 of this technical memorandum.

4.3.4 Costs

The cost analysis for improving the seal and decreasing the overflow of the existing diversion structure on the Mainstem of Milo Creek was performed on the basis of information contained in EPA guidance documents, experience in estimating similar projects, independent estimates, and engineering judgment. Order of magnitude estimates (plus 50 percent, minus 30 percent) have been prepared for capital implementation costs and for annual O&M costs. Capital implementation costs include engineering and construction management allowances. NPV for annual O&M costs are also included for a 30-year period at 7 percent interest.

Assumptions used in development of the cost estimate for this mitigation include:

- Construction of approximately 600 square feet of steel screened inlet
- Raising the weir elevation of the existing dam up to 5 feet
- Construction for the improved diversion structure would require excavation, re-grading, and installation of a new concrete basin

O&M costs include annual inspection and structure maintenance and repairs, and screen/reservoir cleanout. Order of magnitude costs for seal improvement/overflow reduction at the existing Mainstem Milo Creek diversion structure are summarized in Table 8 in Section 7. Costs for decreasing the overflow of the existing Mainstem Milo Creek diversion structure are provided in Attachment B of this technical memorandum.

4.4 Improve Existing Diversion (Increase Pipeline Capacity)

4.4.1 Description

In this option, the size of the water intake in the diversion structure and the associated pipeline down to the second diversion structure (at the Reed Landing) would be increased

to handle much larger flow events. The general location of the proposed pipeline routing is shown on Figure 1. In this alternative, the diversion structure and pipeline would be redesigned to accommodate the larger 10-year rainfall event with snowmelt flow as a design requirement.

4.4.2 Design Criteria

The following design criteria pertain to improving the existing Mainstem Milo Creek Diversion structure and increasing the discharge pipe sizing:

- Minimize overtopping of the weir during flows that are less than the design event
- Establish an intake capable of reducing the incidence of clogging at the intake screens
- Improve the blanket/cutoff under the dam and reservoir to minimize leakage under existing diversion to Mainstem Milo Creek
- Enhance the ability for cleaning the reservoir for removal of sediment
- Provide a new discharge pipeline to accommodate the 10-year rainfall event with snowmelt flow of 172 cfs as shown in Table 7

Surface Water Flow Estimates

Design flows were developed for Mainstem Milo Creek (Upper Milo Gulch) in the *Milo Gulch Flood Hydrology and Water Quality Improvement Plan* (Spectrum Engineering, 1996). The design flows include both rainfall events and rainfall events with snowmelt. These are summarized in Table 7.

4.4.3 Conceptual Design

For this alternative, more extensive modifications would be made to the existing upper diversion structure and diversion pipeline. The screen structure would be made much larger than the existing facility and the dam would be raised similar to the concept described in Section 4.3 (see Figures 8 through 11). A transition structure would be constructed to divert flow into a new HDPE pipeline 54 inches in diameter. The existing corrugated metal pipeline would be removed and the new pipe would be constructed along the same alignment.

In addition to all of the modifications described in Section 4.3, a perforated collector pipeline would be constructed in the Mainstem Milo Creek streambed upstream of the diversion structure. It is assumed that the perforated collector pipeline would be 36 inches in diameter and would be installed in a trench and backfilled with clean, poorly graded pea gravel to the streambed. It also is assumed that the collector pipe would be 450 feet long. The collector pipe would allow infiltration of most of the water in the streambed before it reached the diversion structure, thereby causing much of the sediment load in the streambed to drop out upstream with decreasing flow in the stream. Gabions would be constructed at regular intervals to help trap sediment and enhance infiltration to the collector pipe. The collector pipe would tap directly into the screen/diversion structure for conveyance to the new diversion pipeline.

4.4.4 Costs

The cost analysis for increasing the pipeline capacity of the existing diversion structure on Mainstem Milo Creek was performed on the basis of information contained in EPA guidance documents, experience in estimating similar projects, independent estimates, and engineering judgment. Order of magnitude estimates (plus 50 percent, minus 30 percent) have been prepared for capital implementation costs and for annual O&M costs. Capital implementation costs include engineering and construction management allowances. NPV for annual O&M costs are also included for a 30-year period at 7 percent interest.

Assumptions used in developing the cost estimate for this mitigation include:

- Increase capacity of the existing Mainstem Milo Creek diversion structure
- Construct grated concrete inlet structure
- Raise the weir of the existing dam
- Construct the upstream perforated collector pipe and gabions
- Remove the existing corrugated metal discharge pipeline
- Construct approximately 1,400 feet of HDPE discharge pipeline (52 inches in diameter) routed from the diversion structure down to the Reed Landing Dam
- Install standard U.S. Bureau of Reclamation stilling basins to dissipate water energy before water enters the Reed Landing Dam
- O&M costs include annual inspection, structure maintenance and repairs, and reservoir cleanout

Order of magnitude costs for increasing the pipeline capacity at the existing Mainstem Milo Creek diversion structure are summarized in Table 8 in Section 7. Costs for increasing the capacity of the existing Mainstem Milo Creek diversion structure are provided in more detail in Attachment B of this technical memorandum.

5.0 Deadwood Creek

This section presents the conceptual design and costs for the AMD mitigations that apply to the Deadwood Creek drainage basin area. A single mitigation is identified in Table 1 for Deadwood Creek, which is Plugging Inez Shaft. For this mitigation a description is provided, along with the design criteria, a conceptual design, and the costs (both capital and long-term O&M).

5.1 Plug Inez Shaft

5.1.1 Description

The Inez Shaft would be located and dug out down to competent bedrock and a plug would be constructed using concrete to reduce the water infiltrating into the mine workings from Deadwood Creek.

5.1.2 Design Criteria

Design criteria for plugging Inez Shaft include:

- Minimize leakage of water from both stream flow and alluvial groundwater flows in Deadwood Creek down the Inez Shaft
- Provide structural support for potential future loads to the shaft

5.1.3 Conceptual Design

Overburden soils have caved in around the entrance to the Inez Shaft. The shaft is located in Deadwood Creek along the east side of the stream. It is CH2M HILL's understanding that the old workings are located very close to the streambed and a direct correlation of inflow to the mine has been witnessed by miners as the flow in the stream increases.

This concept requires that the old shaft location first be determined by field survey methods. After the approximate location has been determined, a backhoe would be used to excavate into the overburden to confirm its location. Once the location can be determined, a braced sheet pile excavation would be constructed. The sheetpile would be dug and/or driven to bedrock and braced internally, as required. The sheet excavation would be centered on the shaft location. It also is CH2M HILL's understanding that the shaft extends down at about 30 to 45 degrees from vertical, sloping to the east. It is assumed that the shaft is about 6 to 8 feet in diameter.

Once the opening into the bedrock has been located, it would be cleaned out to expose a minimum length of competent rock in the walls of the shaft equal to about twice the diameter of the shaft. Bolting and shoring might be required for safety and support during the work. Next, a bulkhead would be constructed at the bottom and a Section of the shaft equal to twice the diameter of the shaft would be sealed with concrete to achieve a near water tight condition. After this was completed, the shoring would be removed and the area would be regraded. This alternative is shown in concept in Figure 12.

5.1.4 Costs

The cost analysis for plugging the Inez Shaft in Deadwood Creek was performed on the basis of information contained in EPA guidance documents, experience in estimating similar projects, independent estimates, and engineering judgment. Order of magnitude estimates (plus 50 percent, minus 30 percent) have been prepared for capital implementation costs and for annual O&M costs. Capital implementation costs include engineering and construction management allowances. NPV for annual O&M costs are also included for a 30-year period at 7 percent interest.

Assumptions used in developing the cost estimate for this mitigation include:

- Location of the Inez Shaft would require a field survey, then an excavation to verify the location
- A braced sheet pile excavation would be required
- The shaft is approximately 8 feet in diameter
- 16 feet of shaft would be excavated and cleaned out for plug preparation

- Once the concrete plug has been inserted, the stream bed would be regraded
- O&M costs include annual inspection of the area for caving

Order of magnitude costs for plugging the Inez Shaft in Deadwood Creek are summarized in Table 8 in Section 7. Costs for plugging the Inez Shaft are provided in more detail in Attachment B of this technical memorandum.

6.0 Other Areas

This section presents the conceptual design and costs for AMD mitigations that apply to other areas of the Milo Creek drainage basin area. Plugging drill holes is the only mitigation carried forward for other areas of the mine. For this mitigation, a description is provided, along with design criteria, the conceptual design, and the costs (both capital and long-term O&M).

6.1 Plug Drill Holes

6.1.1 Description

Drill holes on the 7 Level [Diamond Drill Hole (DDH) #1208] and in the Russell Tunnel, East Reed Drift, Bailey Drift, Van Raise, and Cherry Vent would be sealed by installing packers in the drill holes.

Another option includes collecting the clean water and piping it to a surface water drainage or to the treatment plant, depending on water quality. This second option might be necessary if attempts to plug drill holes resulted in increased infiltration in other areas of the mine.

6.1.2 Design Criteria

Design criteria for this mitigation option include:

- Pack drill holes to withstand 300 psi water pressure (200 psi maximum measured times safety factor of 1.5)
- Provide valving to vary flow from existing drill hole flow down to zero flow

6.1.3 Conceptual Design

This concept would be fairly easy to implement. It would require selected drill holes to be sealed to prevent water from directly contributing to drainage into the mine. The effectiveness of this alternative is unknown; plugging the drill holes might simply result in the water establishing other, less obvious flow paths into the mine through cracks and fissures, along fracture zones, or through other drill holes. However, if the rock formation is relatively tight, the plugging could significantly reduce the total flow from these sources.

The plugging would be achieved with mechanical packers, which would be inserted into the drill holes to an appropriate location. The packer would be seated by tightening it against the rock wall of the borehole. Use of a borehole camera would help establish suitable locations for each packer. Each installation would be provided with a central drain pipe and valve to allow flow past the packer until the packer could be seated against the rock.

One or more of the drill holes are known to be operating under a considerable amount of pressure. In these areas, an anchor plate would be installed at the discharge point to assist in anchoring the packer assembly into the hole.

Careful monitoring would be required to assess whether the packers reduced the flow from various areas of the mine. Weirs and frequent monitoring for a period following the installation of the packers might be required to determine if the flows were increasing in other areas as a result of the plugging of drill holes. Monitoring is not included in the costs of this or any mitigation measures.

6.1.4 Costs

The cost analysis for plugging drill holes was performed on the basis of information contained in EPA guidance documents, experience in estimating similar projects, independent estimates, and engineering judgment. Order of magnitude estimates (plus 50 percent, minus 30 percent) have been prepared for capital implementation costs and for annual O&M costs. Capital implementation costs include engineering and construction management allowances. NPV for annual O&M costs are also included for a 30-year period at 7 percent interest.

Assumptions used in developing the cost estimate for this mitigation include:

- Adits would require clearing for access to the drill holes
- Twenty low-pressure drill holes and one high-pressure drill hole would require plugging
- O&M costs include annual inspection, maintenance, and repairs

Order of magnitude costs for plugging drill holes are summarized in Table 8 in Section 7. Costs for plugging drill holes are provided in more detail in Attachment B of this technical memorandum.

7.0 AMD Mitigations Cost Summary

Table 8 provides a summary of the proposed AMD mitigation options with their respective estimated costs. These costs are subject to the limitations described in Section 1.3 of this technical memorandum.

8.0 References

CH2M HILL, 2000a. *Draft Preliminary Screening for TMDL Compliance.* February. CH2M HILL, Spokane, Washington.

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CH2M HILL, 2000c. *Bunker Hill Mine Water FS Alternatives.* June. CH2M HILL, Spokane, Washington.

CH2M HILL, 1999. *Bunker Hill Mine Water Presumptive Remedy*. July. CH2M HILL, Spokane, Washington.

Hunt, Joel. 1984. *Analysis of Recharge to an Underground Lead-Zinc Mine, Coeur D' Alene Mining District, Idaho*. September.

Spectrum Engineering, 1996. *Milo Gulch Flood Hydrology and Water Quality Improvement Plan*. March.

TABLE 1
Summary of Modifications to Original AMD Mitigations
Mitigation/Treatment Evaluation – Bunker Hill Mine Water Management

AMD Mitigation Option	Modification
West Fork Milo Creek	
West Fork Diversion	• Increase the number of stilling basins along the pipeline's descent to Reed Landing • Changed position of confluence with Phil Sheridan pipeline
Phil Sheridan	• Separate the Phil Sheridan Diversion system mitigation options into Rehabilitating the Phil Sheridan Diversion and Improved Phil Sheridan Diversion Rehabilitation • Discontinue the option of conveying the collected water through the Phil Sheridan Adit • Construct a new drift that connects with the Phil Sheridan Adit for access to the Phil Sheridan Raises #1 and #2 and for pipeline installation for the Phil Sheridan diversion pipeline • Add the installation of a grout curtain for Raise #2 as an Improved Phil Sheridan Diversion Rehabilitation
Sidehill Diversions Above Guy Cave	None
Cemented Backfill into Homestake/Utz Workings	• Screened out as an ineffective alternative
South Fork Milo Creek	
South Fork Diversion	• A second U.S. Bureau of Reclamation stilling basin was added
Mainstem Milo Creek	
Remove Bunker Hill Dam	• Modified as bypassing the dam rather than removing the dam
Plug Small Hopes Drift	None
Improve Existing Diversion (improve seal, decrease weir overflow)	None
Improve Existing Diversion (increase pipeline capacity)	None
Deadwood Creek	
Plug Inez Shaft	None
Other Areas	
Plug Drill Holes	None

TABLE 2
Design Flows for West Milo Drainage Basin (From Spectrum, 1996)
Mitigation/Treatment Evaluation – Bunker Hill Mine Water Management

Return Period (years)	Rainfall w/ Snowmelt	Rainfall Only
2	6 cfs	0 cfs
5	17 cfs	2 cfs
10	34 cfs	4 cfs
25	53 cfs	8 cfs
100	86 cfs	28 cfs

TABLE 3
Design Flows for West Milo Diversion Structure (141 acres)
Mitigation/Treatment Evaluation – Bunker Hill Mine Water Management

Return Period (years)	Rainfall w/ Snowmelt	Rainfall Only
2	7 cfs	0 cfs
5	14 cfs	1 cfs
10	23 cfs	3 cfs
25	36 cfs	5 cfs
100	57 cfs	19 cfs

TABLE 4
Design Flows for Phil Sheridan Raises No. 1 and No. 2
Mitigation/Treatment Evaluation – Bunker Hill Mine Water Management

Raise No. 2 With West Fork Diversion In-Place (10.6 acres)		
Return Period (years)	**Rainfall w/ Snowmelt**	**Rainfall Only**
2	1 cfs	0 cfs
5	1 cfs	0 cfs
10	2 cfs	0 cfs
25	4 cfs	1 cfs
100	6 cfs	2 cfs
Raise No. 1 Without Sidehill Drainage Diversion (30.1 acres)		
Return Period (years)	**Rainfall w/ Snowmelt**	**Rainfall Only**
2	2 cfs	0 cfs
5	4 cfs	0 cfs
10	6 cfs	1 cfs
25	9 cfs	2 cfs
100	15 cfs	6 cfs

TABLE 5
Design Flows for Sidehill Diversion Ditches Alone and In Conjunction with Phil Sheridan Raise No. 1
Mitigation/Treatment Evaluation – Bunker Hill Mine Water Management

Sidehill Diversion Ditch Alone (22.2 acres)		
Return Period (years)	**Rainfall w/ Snowmelt**	**Rainfall Only**
2	5 cfs	0 cfs
5	7 cfs	1 cfs
10	10 cfs	3 cfs
25	13 cfs	6 cfs
100	19 cfs	11 cfs
Sidehill Diversion Ditch with Raise No. 1 (52.3 acres)		
Return Period (years)	**Rainfall w/ Snowmelt**	**Rainfall Only**
2	7 cfs	0 cfs
5	11 cfs	1 cfs
10	16 cfs	4 cfs
25	22 cfs	8 cfs
100	34 cfs	17 cfs

TABLE 6
Predicted Flows for the South Milo Creek Basin
Mitigation/Treatment Evaluation – Bunker Hill Mine Water Management

Return Period (years)	Rainfall with Snowmelt	Rainfall Only
2	11 cfs	1 cfs
5	40 cfs	4 cfs
10	76 cfs	8 cfs
25	118 cfs	22 cfs
100	186 cfs	70 cfs

(From Spectrum Engineering, 1996)

TABLE 7
Design Flows for Upper Milo Gulch Drainage Basin
Mitigation/Treatment Evaluation – Bunker Hill Mine Water Management

Return Period (years)	Rainfall w/ Snowmelt	Rainfall Only
2	37 cfs	3 cfs
5	105 cfs	12 cfs
10	172 cfs	33 cfs
25	251 cfs	83 cfs
100	376 cfs	184 cfs

(From Spectrum Engineering, 1996)

TABLE 8
AMD Mitigations Cost Summary
Mitigation/Treatment Evaluation – Bunker Hill Mine Water Management

AMD Mitigation Option ($)	Capital Cost ($)	Annual O&M Cost ($)	Total 30-year Present Worth Cost[1] ($)
West Fork Milo Creek			
West Fork Diversion	3,590,000	27,700	3,934,000
Rehabilitate Phil Sheridan Diversion	1,250,000	18,200	1,476,000,
Improve Phil Sheridan Diversion Rehabilitation	380,000	500	386,000
Sidehill Diversions above Guy Cave	490,000	11,700	635,000
South Fork Milo Creek			
South Fork Diversion	1,870,000	29,900	2,241,000
Mainstem Milo Creek			
Plug Small Hopes Drift	360,000	500	366,000
Bypass Bunker Hill Dam	60,000	24,300	362,000
Improve Existing Diversion—Improve Seal/Decrease Flow	590,000	99,300	1,822,000
Improve Existing Diversion—Increase Pipeline Capacity	2,670,000	99,300	3,902,000
Deadwood Creek			
Plug Inez Shaft	650,000	500	656,000
Other Areas			
Plug Drill Holes	150,000	9,200	264,000

[1]Total 30-year present worth of capital cost and net present worth at 7 percent interest.

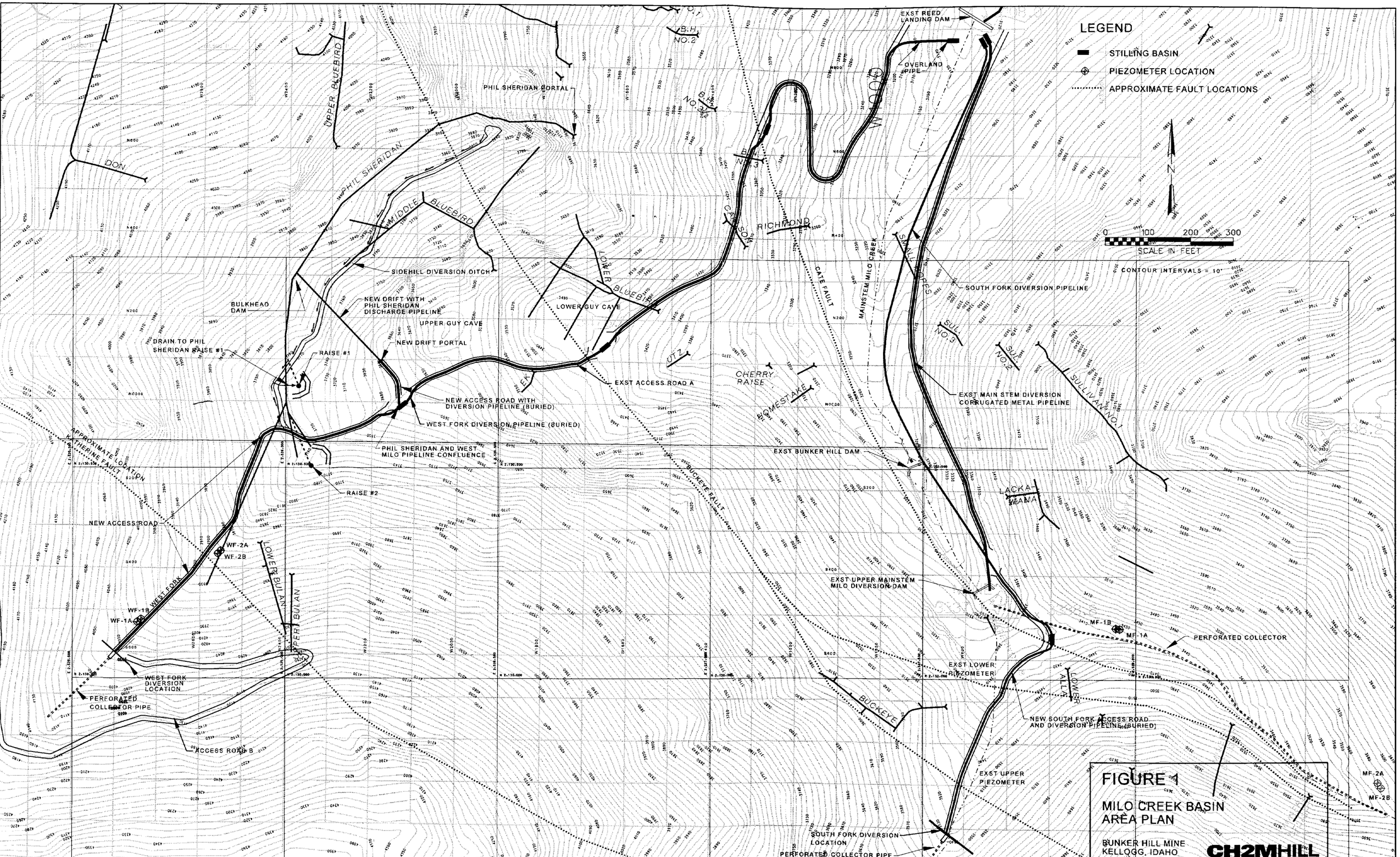


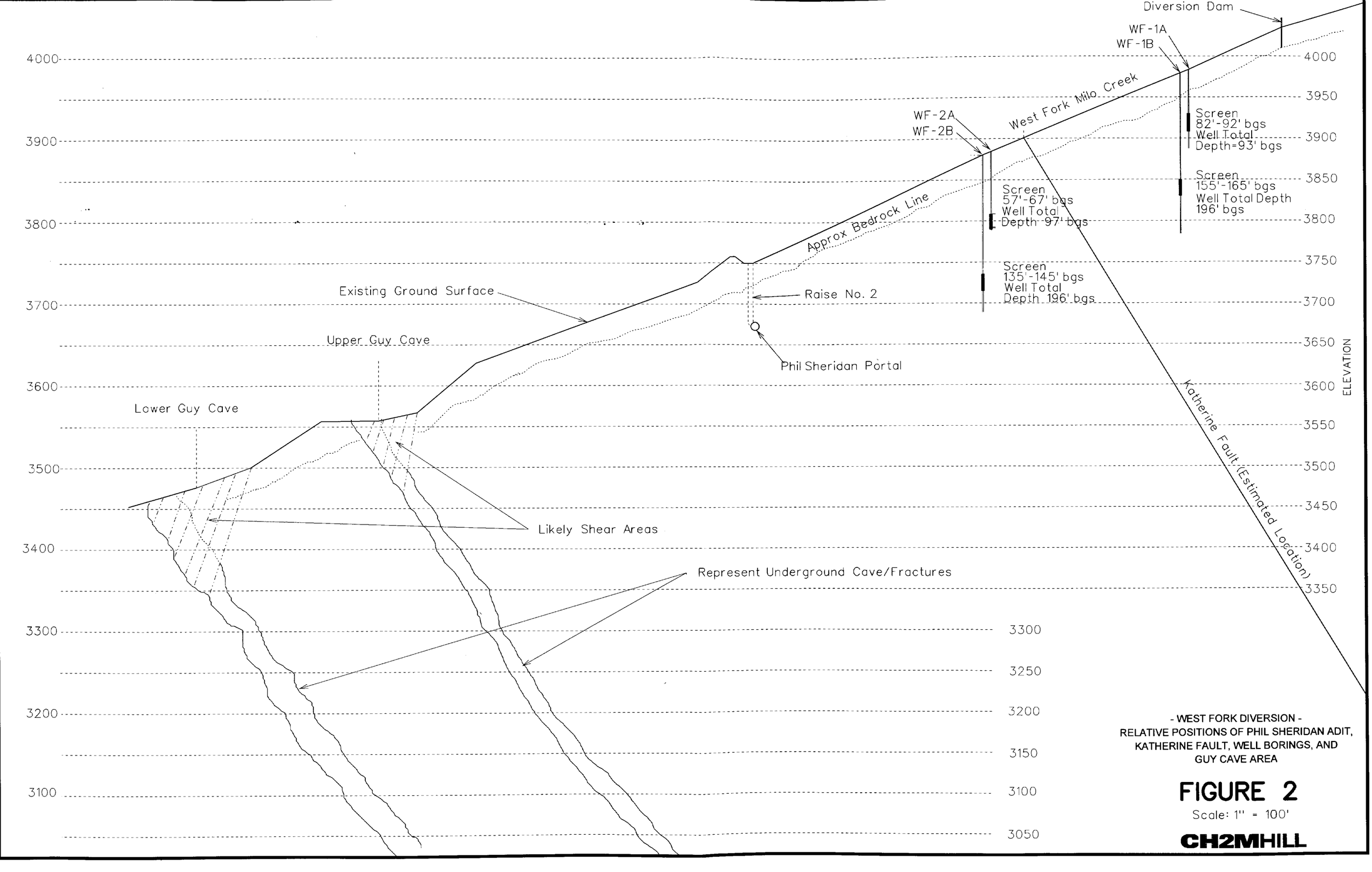
FIGURE 1

MILO CREEK BASIN AREA PLAN

BUNKER HILL MINE
KELLOGG, IDAHO

CH2MHILL

NDM 148562 152215.RS.06 90DXX015.DLV 18-JUL-2000 15:15:19

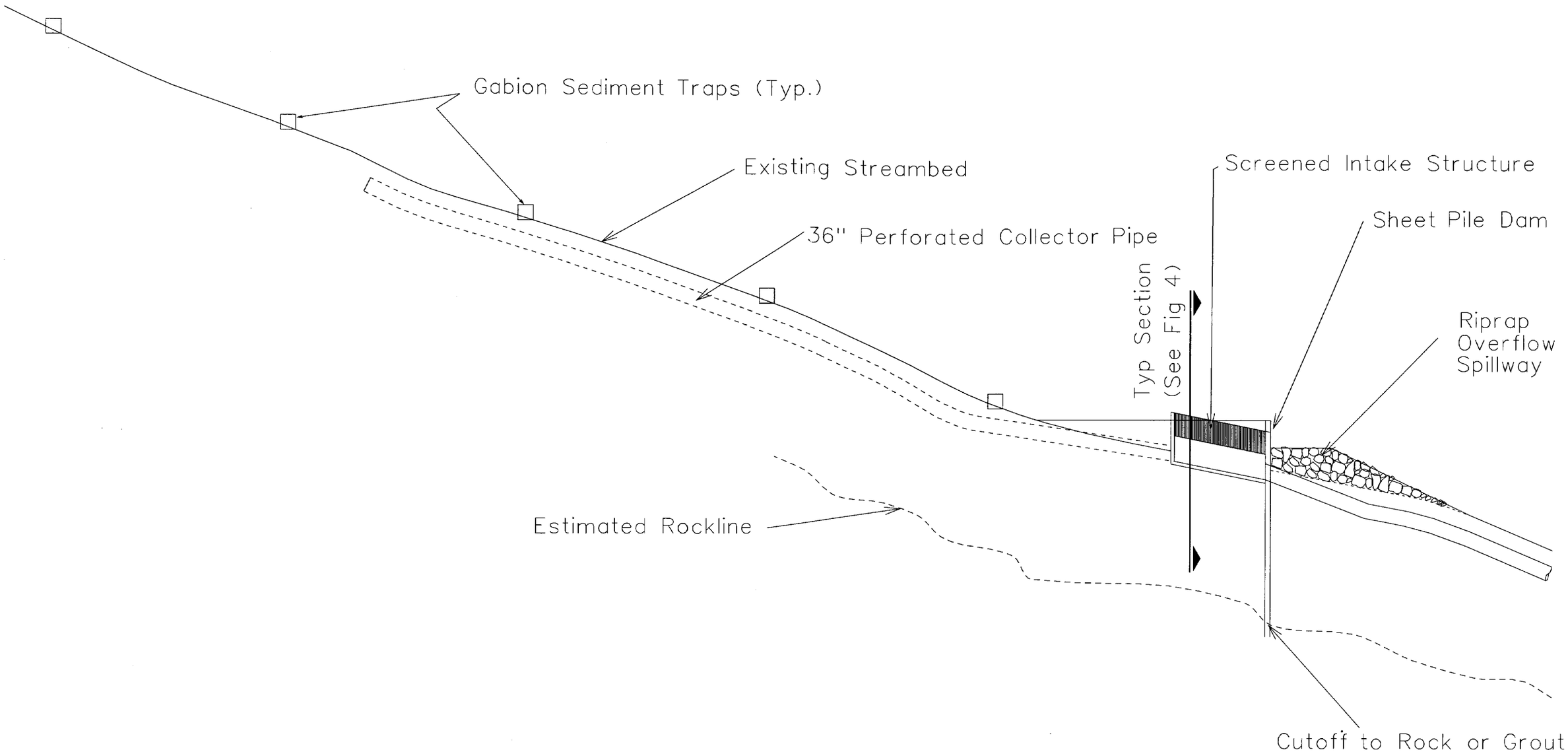


- WEST FORK DIVERSION -
RELATIVE POSITIONS OF PHIL SHERIDAN ADIT, KATHERINE FAULT, WELL BORINGS, AND GUY CAVE AREA

FIGURE 2

Scale: 1" = 100'

CH2MHILL



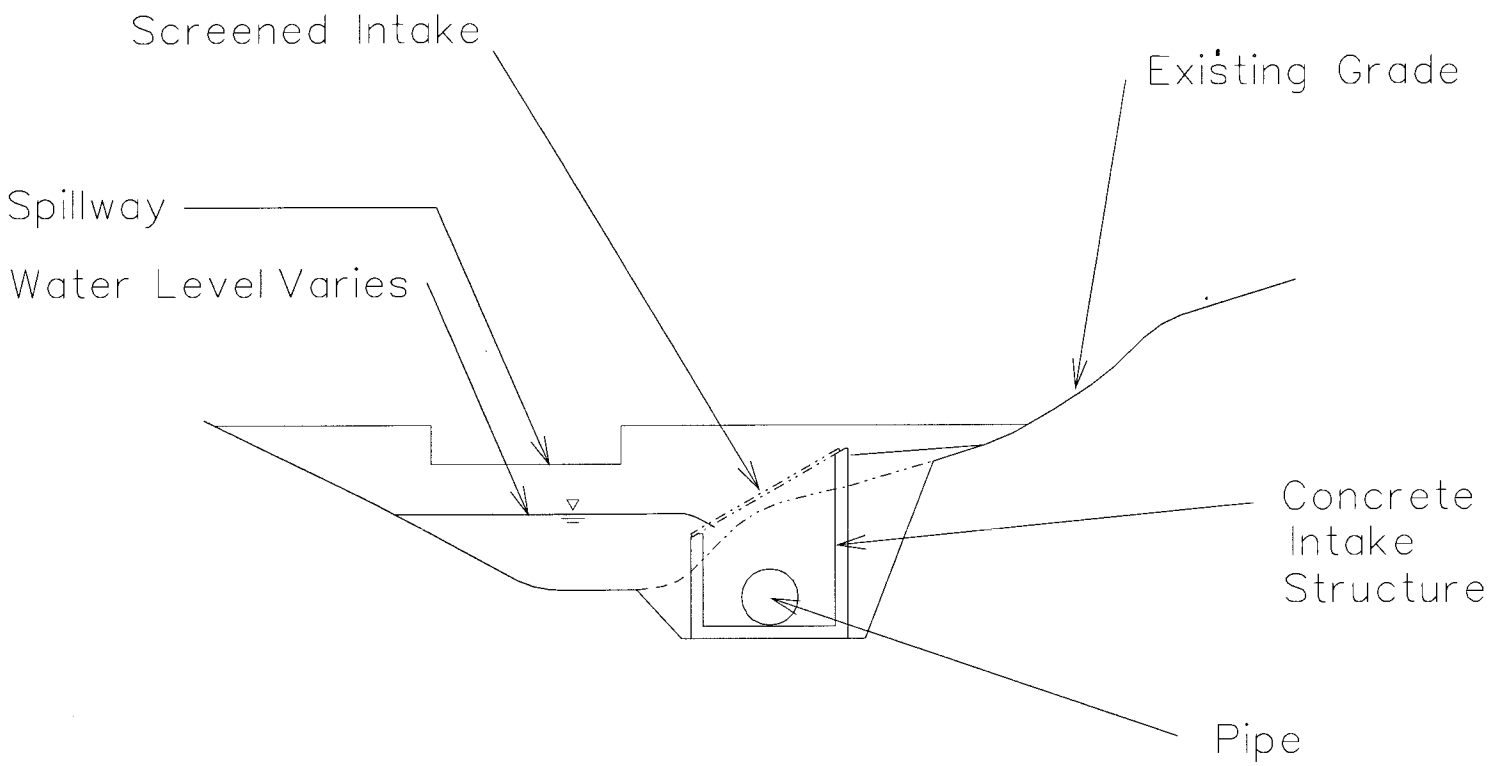
Longitudinal Section @ Intake Screen Structure

1" = 20'

- WEST FORK -
DIVERSION STRUCTURE PROFILE

FIGURE 3

CH2MHILL



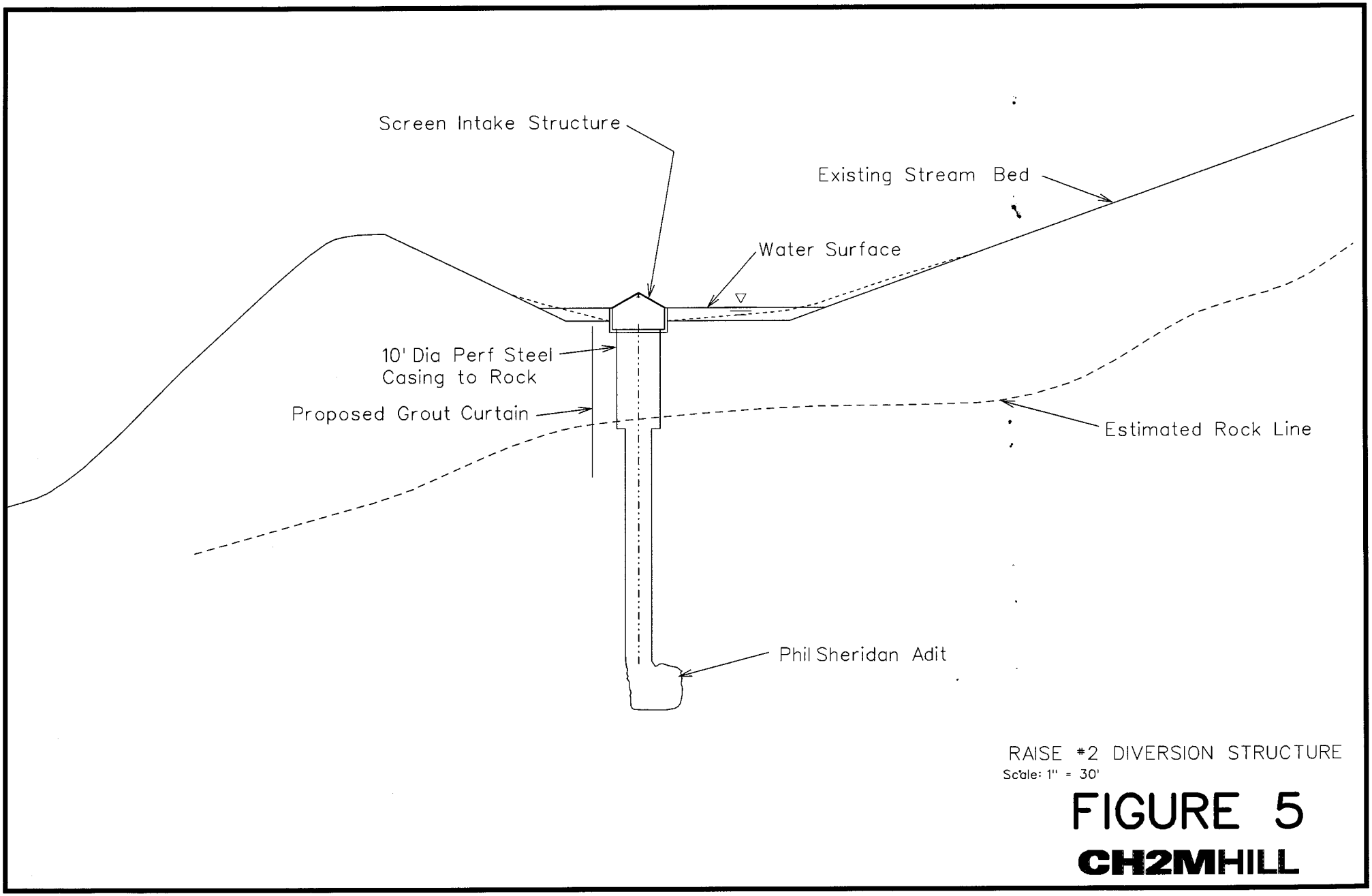
TYPICAL SECTION
1" = 10'

- WEST FORK -
DIVERSION STRUCTURE SECTION

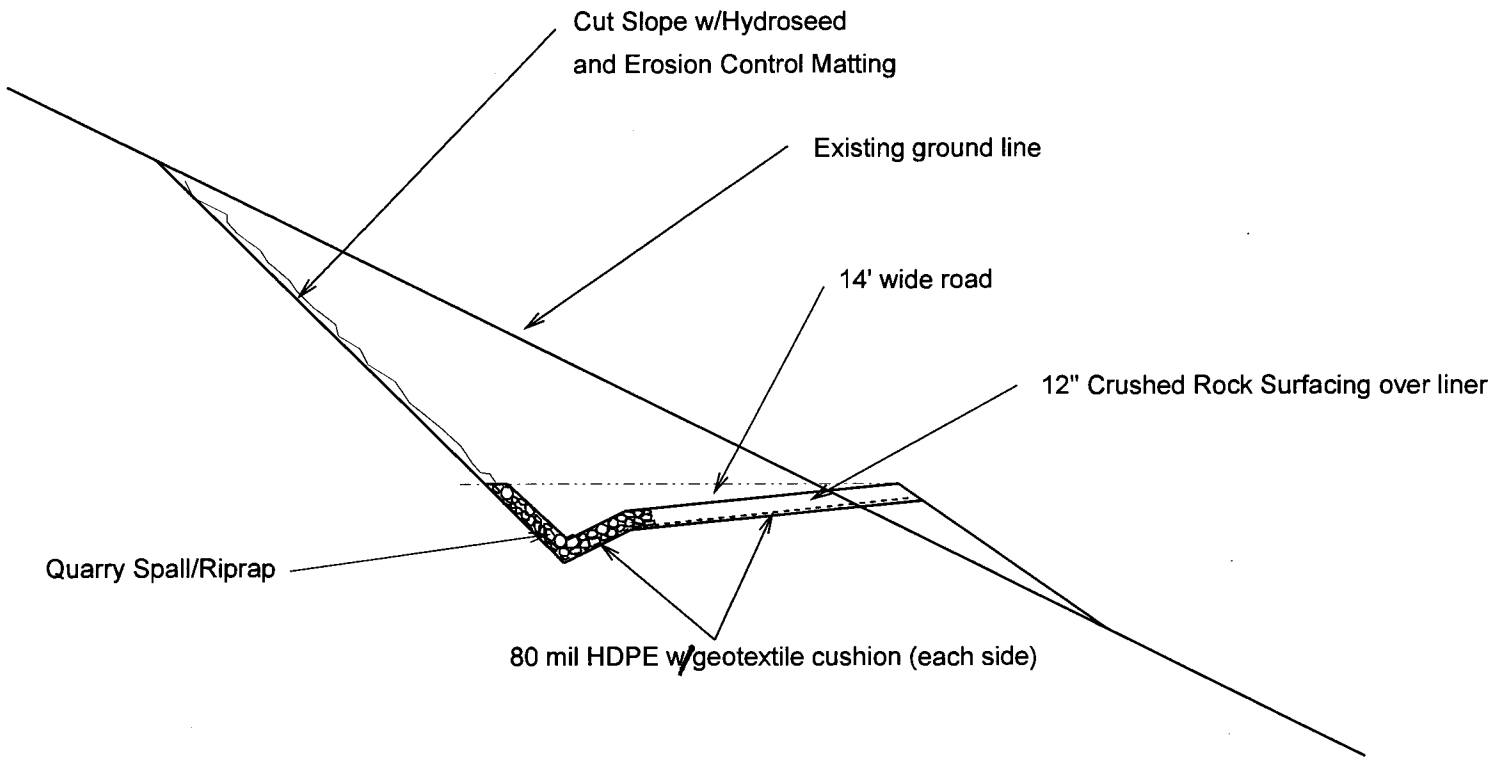
FIGURE 4

CH2MHILL

NEXT


Screen Intake Structure
Existing Stream Bed
Water Surface
10' Dia Perf Steel
Casing to Rock
Proposed Grout Curtain
Estimated Rock Line
Phil Sheridan Adit
RAISE #2 DIVERSION STRUCTURE
Scale: 1" = 30'
FIGURE 5
CH2MHILL

NEXT



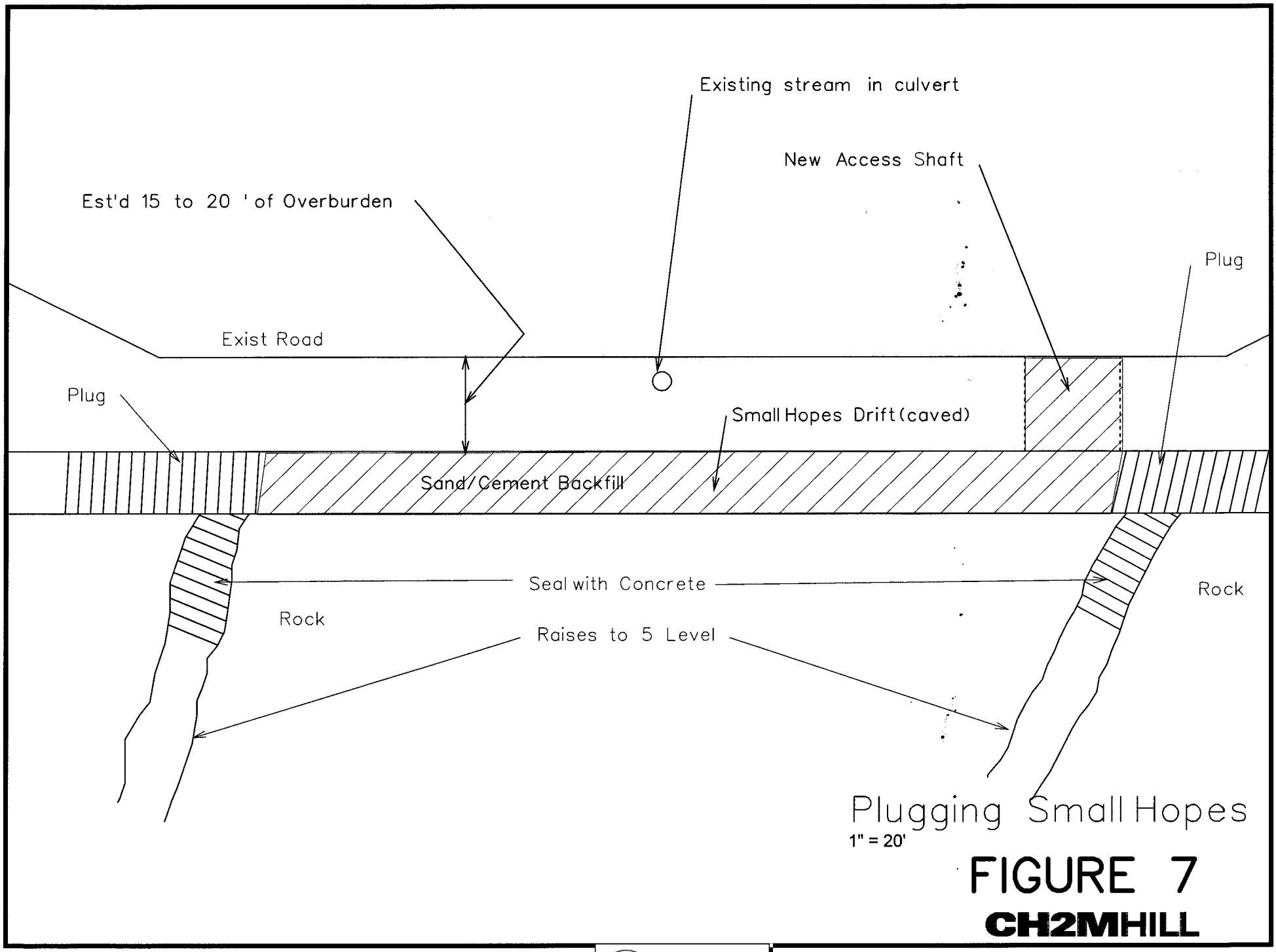
SIDEHILL DIVERSIONS ABOVE
GUY CAVE INTERCEPTOR
DITCH SECTION

1" = 10'

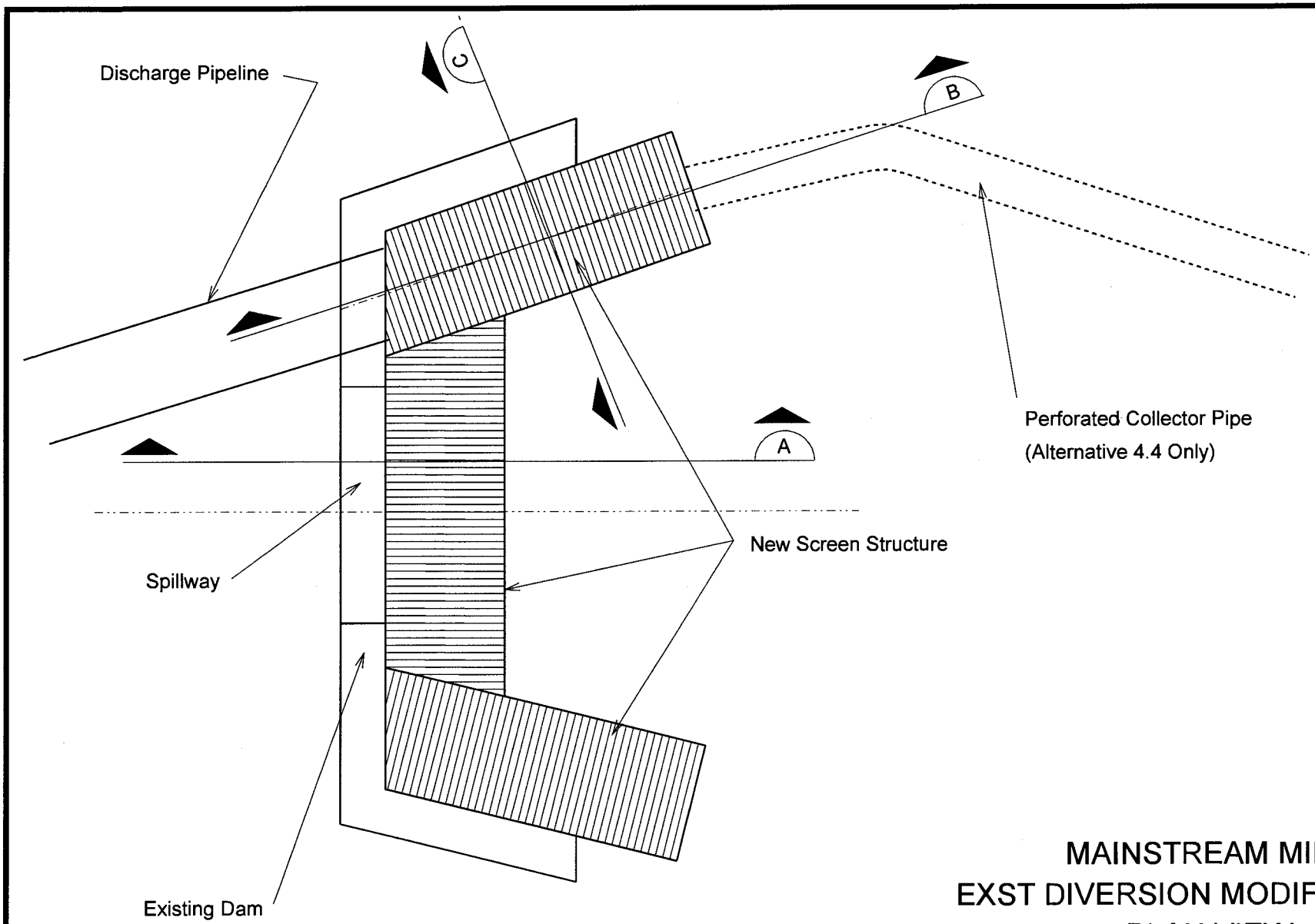
FIGURE 6

CH2MHILL

NEXT


Existing stream in culvert
New Access Shaft
Est'd 15 to 20 ' of Overburden
Plug
Exist Road
Plug
Small Hopes Drift (caved)
Sand/Cement Backfill
Seal with Concrete
Rock
Rock
Raises to 5 Level
Plugging Small Hopes
1" = 20'
FIGURE 7
CH2MHILL

NEXT



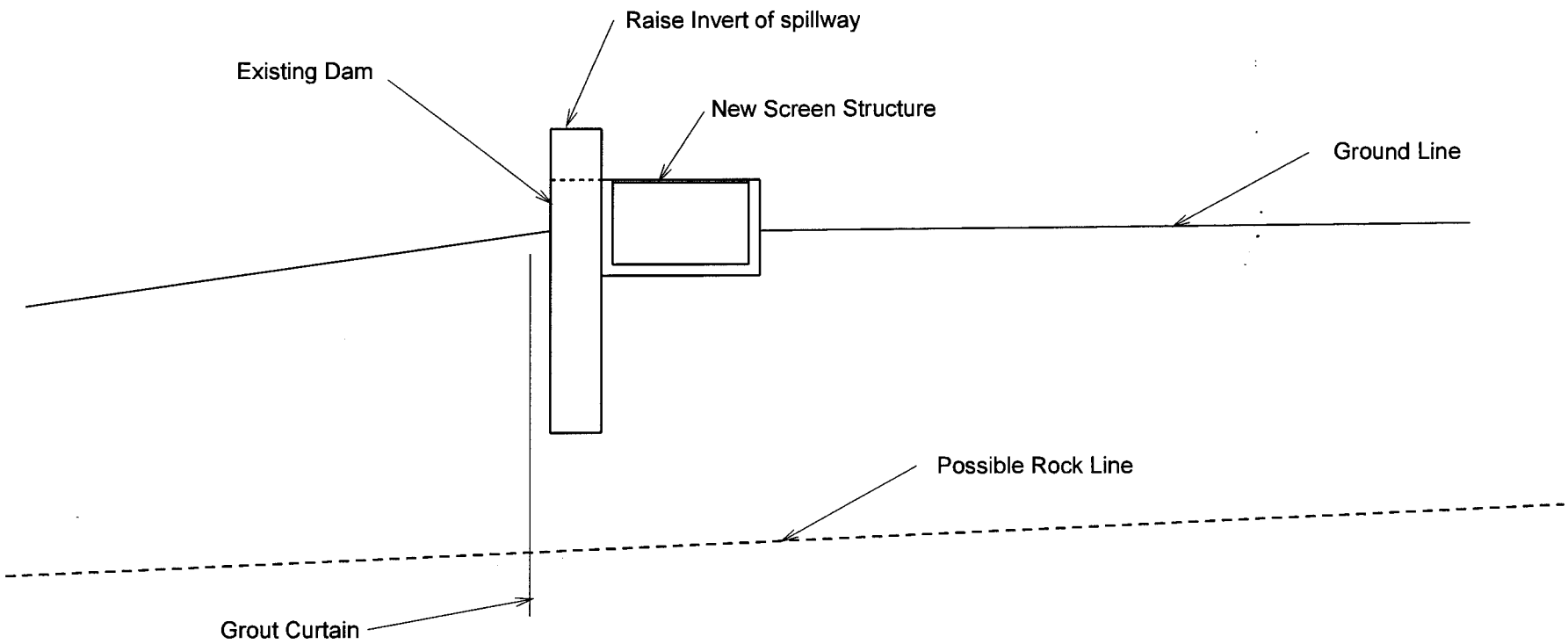
SCREEN STRUCTURE
UPPER DIVERSION
1" = 10'

MAINSTREAM MILO
EXST DIVERSION MODIFICATIONS
- PLAN VIEW -

FIGURE 8

CH2MHILL

NEXT



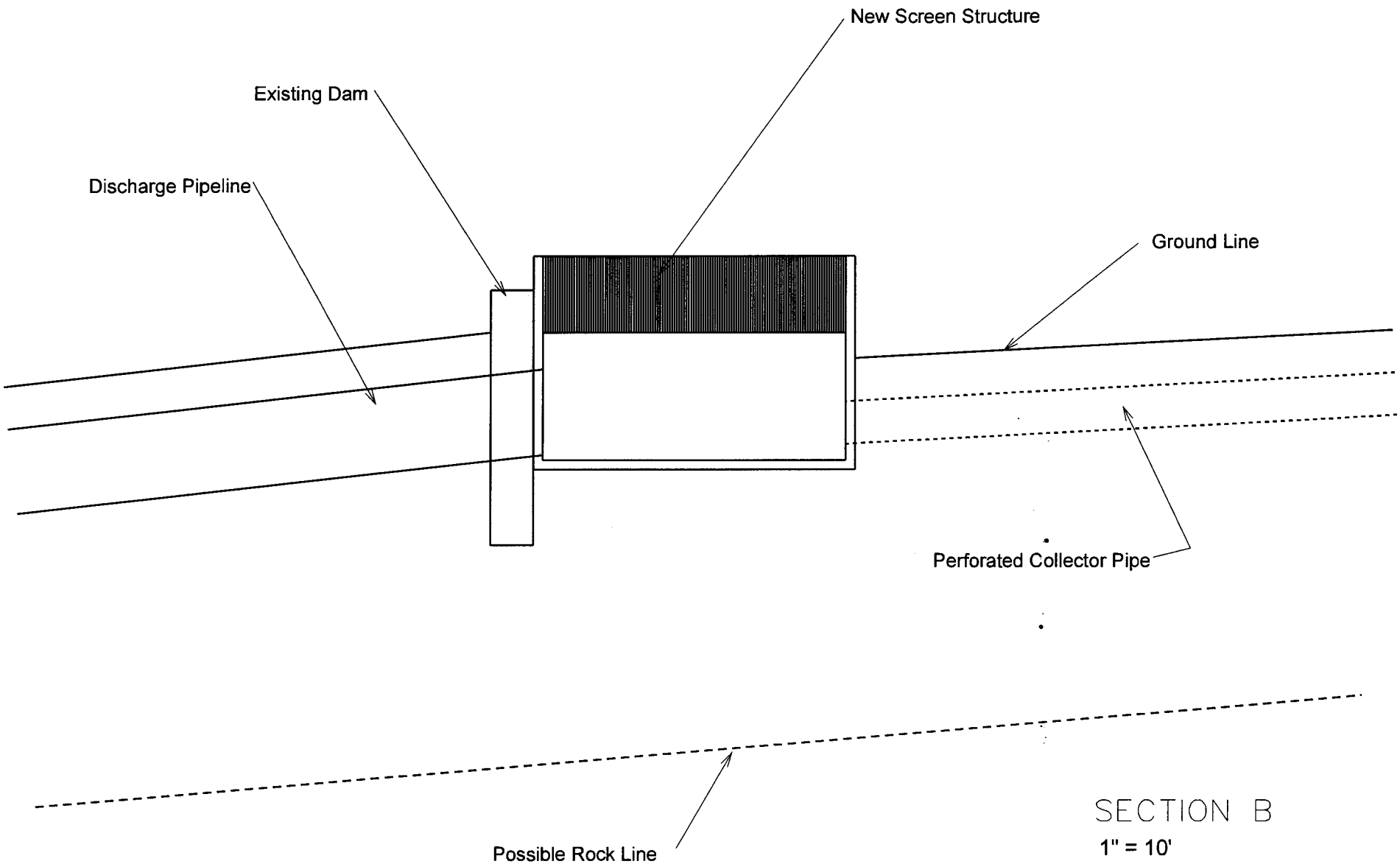
SECTION A

1" = 10'

FIGURE 9

CH2MHILL

NEXT



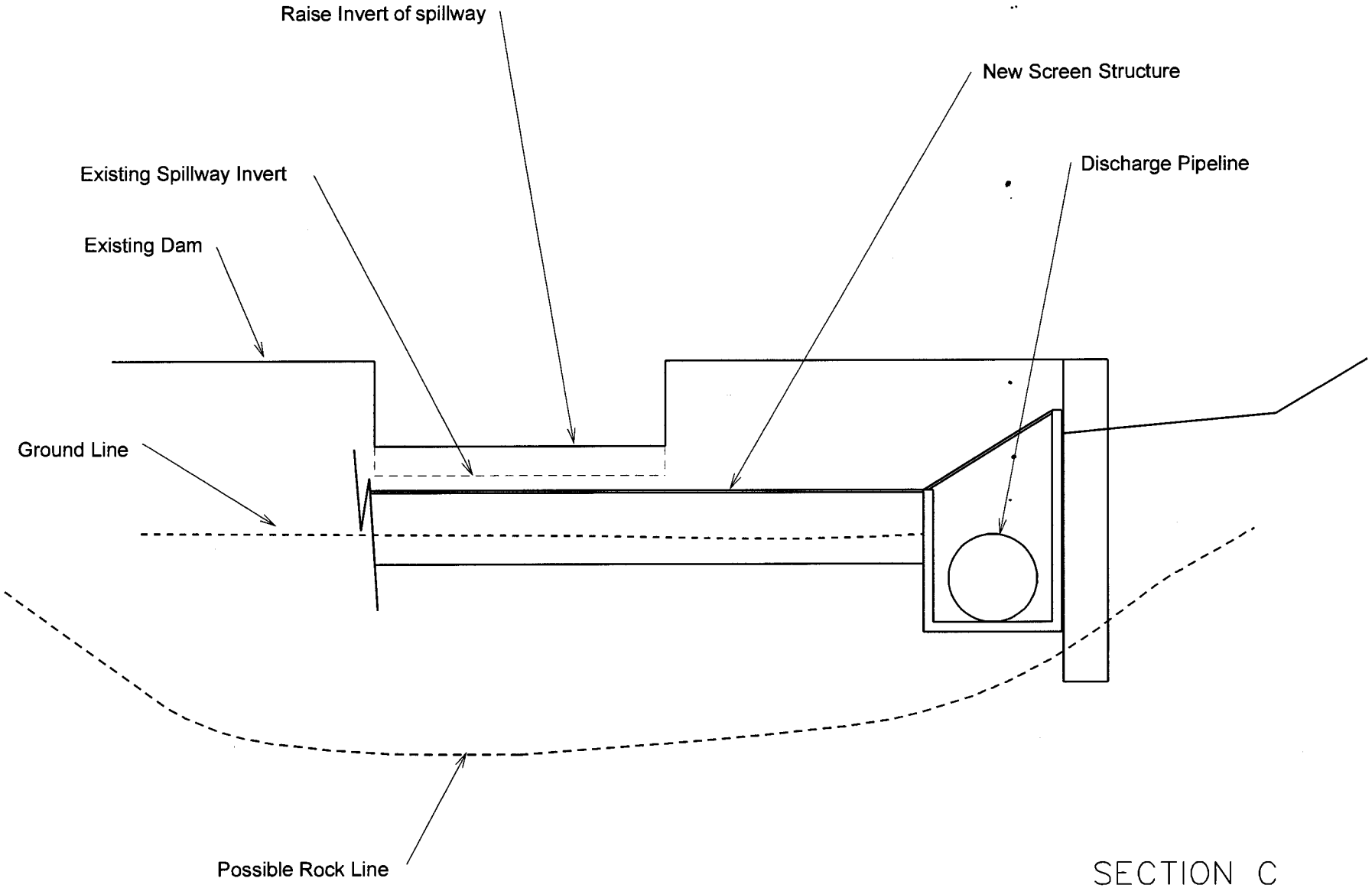
SECTION B

1" = 10'

FIGURE 10

CH2MHILL

NEXT



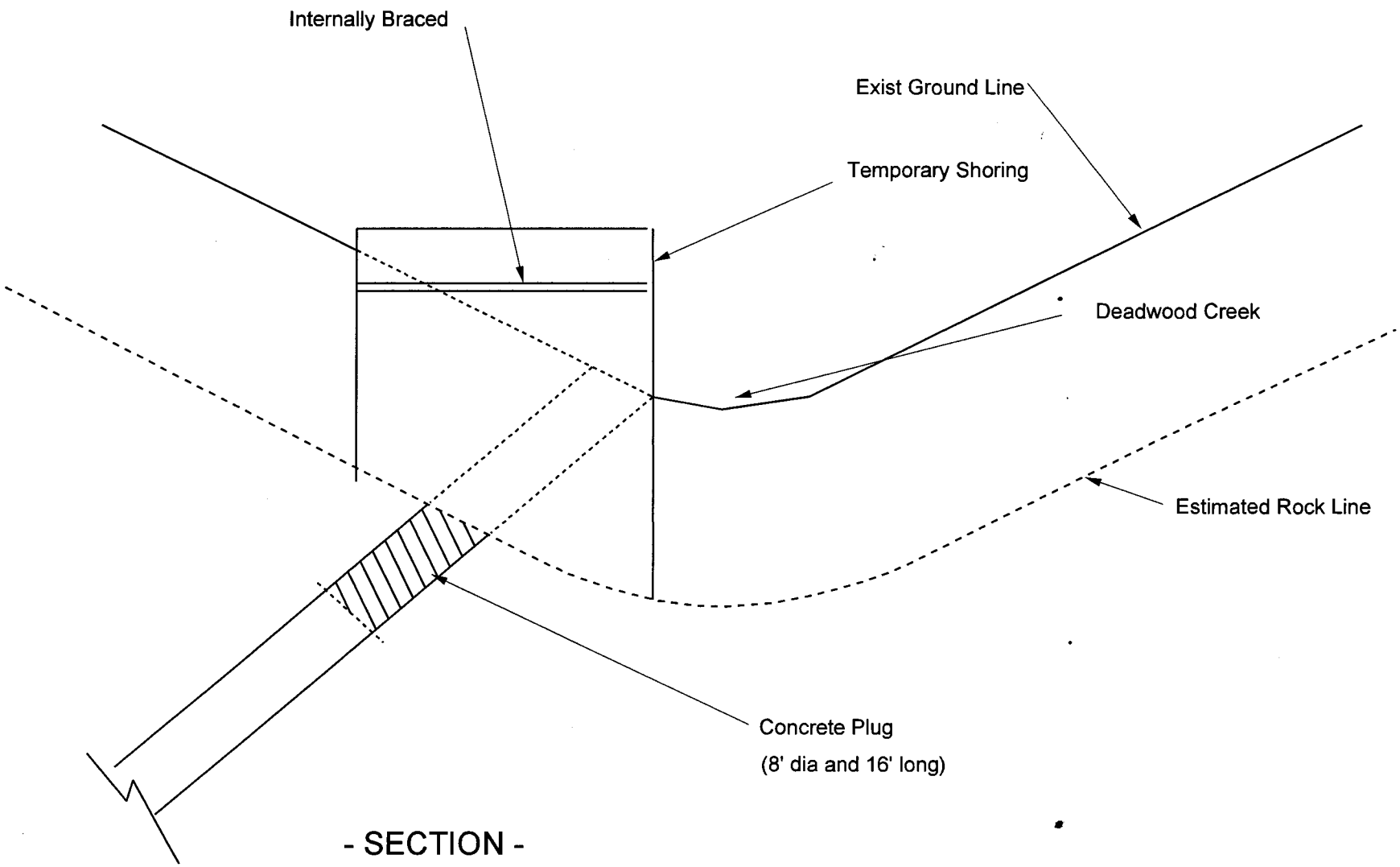
SECTION C

1" = 10'

FIGURE 11

CH2MHILL

NEXT



- SECTION -

1" = 20'

PLUGGING OF INEZ SHAFT

FIGURE 12

CH2MHILL

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NEXT

APPENDIX C - ATTACHMENT A

Milo Gulch Hydrologic Analysis

Milo Gulch Hydrologic Analysis

TO: Matt Germon/SPK
Jim Stefanoff/SPK

COPIES: Jerry Scheller/SEA

FROM: Andrea Escame-Hedger

DATE: January 12, 2000

This memorandum describes the hydrologic analysis performed on the Milo Gulch area. The Guy Cave basin was subdivided into the following sub-basins: Raise 1 (A), Raise 2 (B), West Milo Diversion (C), and Surface Diversion (D). The Inez Shaft basin (E) was also modeled. Figure 1 shows the subbasin delineations.

Summary of Hydrologic Analysis

Existing land use peak stormwater runoff rates were computed for the 2-, 10-, 25-, and 100 year, 24-hour design storms. Hydrologic analysis was performed using SCS methodology. Stormwater rates were calculated according to guidance found in the *Basis for Hydrologic Calculations for Gulches, Bunker Hill* (CH2M HILL, 1995). The hydrologic model HEC1 was used to compute flow rates.

The hydrologic model HEC1 simulates the rainfall-runoff process in a sub-basin. The model uses input data to calculate peak flow rates for different storm events. The input data in the HEC 1 model are sub-basin area, curve number (CN), a synthetic precipitation hytegraph, and time of concentration. The CN accounts for varying runoff characteristics due to various land types and is based on soil type and land use within the sub-basin. CN indirectly represents the amount of infiltration. A low CN represents low runoff and a high CN represents high runoff. A synthetic precipitation hytegraph is a plot of rainfall depth versus time for a given design storm event. Time of concentration is the time it takes for water to travel from the most remote location to the point of interest in the sub-basin. Time of concentration influences the shape and peak of the runoff hydrograph, for example, a low time of concentration represents low peak flow rates and a high time of concentration represents high peak flow rates.

Tables 1 through 4 show the precipitation input for events with and without snowmelt. The CN values represent existing land use conditions, and no attempt was made to predict future land use conditions. Table 5 shows the input and output of the hydrologic analysis. Appendix A shows supporting data. Sample input and output data for the 100 yr-24 hr storm event with and without snowmelt is provided in Appendix B.

Additional Sources

The following sources were used to obtain input data:

Milo Gulch Flood Hydrology and Water Quality Improvement Plan (Spectrum Engineering, March 1996)

- CN for sub-basins B and C (labeled Guy Caves)
- Precipitation values for sub-basins A, B, C, and D (labeled Guy Caves)

Bunker Creek and Government Gulch Flood Hydrology (Bunker Creek Plan) (Spectrum Engineering, March 1996)

- CN for sub-basin E (labeled Upper Deadwood Gulch)
- Precipitation values for sub-basin E (labeled Upper Deadwood Gulch)

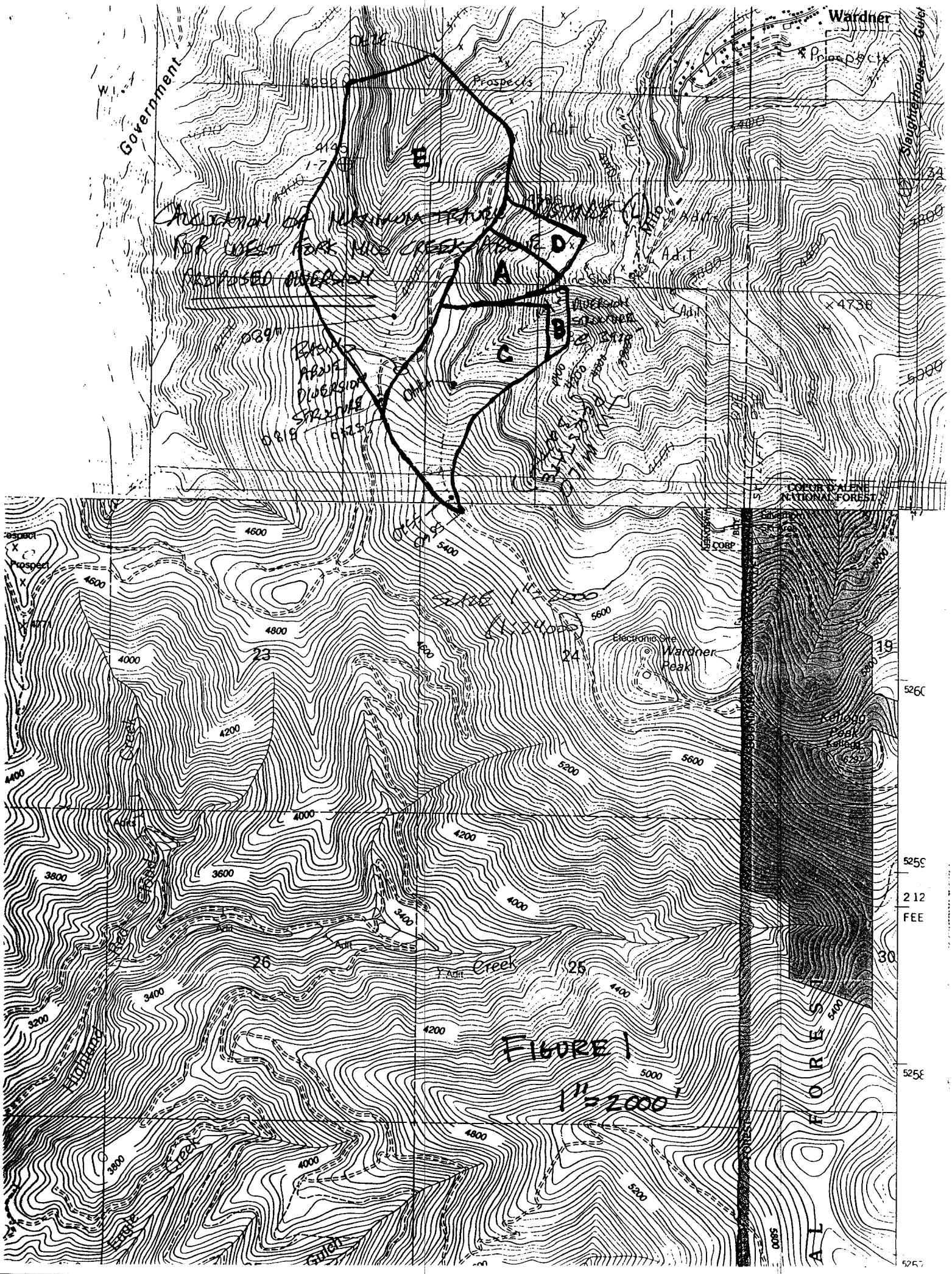

Wardner
Government
Prospects
Slaughterhouse Gulch
Adit
Diversion Structure
Wardner Peak
Kellogg Peak
Electronic Site
COEUR D'ALENE NATIONAL FOREST
Highland Creek
Eagle Creek
Gulch
Y Adit
Creek
23
24
25
26
19
30
34
FEE
FOREST
A
B
C
D
E
1" = 2000'

FIGURE 1

Table 1. No Snow Precipitation-Frequency Relationship for sub-basins A-D at elevation 4200-ft

Return Period	Duration							
YR	5-min	15-min	1-hr	2-hr	3-hr	6-hr	12-hr	24-hr
2	0.12	0.24	0.42	0.56	0.69	1.00	1.50	2.00
5	0.17	0.33	0.57	0.73	0.87	1.20	1.80	2.40
10	0.20	0.39	0.69	0.87	1.02	1.40	2.10	2.80
25	0.25	0.48	0.85	1.04	1.20	1.60	2.40	3.20
100	0.31	0.62	1.09	1.31	1.51	2.00	2.90	3.80

source: Milo Gulch Flood Hydrology and Water Quality Improvement Plan, Spectrum Engineering, March 1996

Table 2. Snowmelt Precipitation-Frequency Relationship for sub-basins A-D at elevation 4200-ft

Return Period	Duration							
YR	5-min	15-min	1-hr	2-hr	3-hr	6-hr	12-hr	24-hr
2	0.13	0.26	0.50	0.74	0.95	1.52	2.44	3.69
5	0.17	0.35	0.66	0.90	1.13	1.72	2.74	4.09
10	0.21	0.42	0.78	1.04	1.28	1.92	3.04	4.49
25	0.25	0.51	0.93	1.21	1.46	2.12	3.34	4.89
100	0.32	0.64	1.17	1.49	1.77	2.52	3.84	5.49

source: Milo Gulch Flood Hydrology and Water Quality Improvement Plan, Spectrum Engineering, March 1996

Table 3. No Snow Precipitation-Frequency Relationship for sub-basin E at elevation 4200-ft

Return Period	Duration							
YR	5-min	15-min	1-hr	2-hr	3-hr	6-hr	12-hr	24-hr
2	0.12	0.24	0.42	0.56	0.69	1.00	1.50	2.00
5	0.17	0.33	0.57	0.73	0.87	1.20	1.80	2.40
10	0.20	0.39	0.69	0.87	1.02	1.40	2.10	2.80
25	0.25	0.48	0.85	1.04	1.20	1.60	2.40	3.20
100	0.31	0.62	1.09	1.31	1.51	2.00	2.90	3.80

source: Milo Gulch Flood Hydrology and Water Quality Improvement Plan, Spectrum Engineering, March 1996

Table 4. Snowmelt Precipitation-Frequency Relationship for sub-basins E at elevation 4200-ft

Return Period	Duration							
YR	5-min	15-min	1-hr	2-hr	3-hr	6-hr	12-hr	24-hr
2	0.13	0.26	0.50	0.74	0.95	1.52	2.44	3.70
5	0.17	0.35	0.66	0.90	1.13	1.72	2.74	4.10
10	0.21	0.42	0.78	1.04	1.28	1.92	3.04	4.50
25	0.25	0.51	0.93	1.21	1.46	2.12	3.34	4.90
100	0.32	0.64	1.17	1.49	1.77	2.52	3.84	5.50

source: Milo Gulch Flood Hydrology and Water Quality Improvement Plan, Spectrum Engineering, March 1996

Table 5. Hydrologic Input and Output Data

NO SNOW MELT

BASIN	NAME	AREA	CN	Tc	PEAK DISCHARGE RATE, 24 HR STORM EVENT (cfs)				
		(mi2)		(hr)	2 YR	5 YR	10 YR	25 YR	100 YR
A	Raise #1	0.047	58	0.307	0	0	1	2	6
B	Raise #2	0.0166	55.9	0.175	0	0	0	1	2
C	West Milo Diversion	0.22	55.9	0.324	0	1	3	5	19
D	Surface Diversion	0.0347	66	0.245	0	1	3	6	11
A-D	BASINS A-D	0.3183			0	2	7	14	38
E	Inez Shaft	0.484	55.3	0.359	1	3	5	9	35
A+D	Raise #1+ Surface Diversion	0.0817			0	1	4	8	17

WITH SNOW MELT

BASIN	NAME	AREA	CN	Tc	PEAK DISCHARGE RATE, 24 HR STORM EVENT (cfs)				
		(mi2)		(hr)	2 YR	5 YR	10 YR	25 YR	100 YR
A	Raise #1	0.047	58	0.307	2	4	6	9	15
B	Raise #2	0.0166	55.9	0.175	1	1	2	4	6
C	West Milo Diversion	0.22	55.9	0.324	7	14	23	36	57
D	Surface Diversion	0.0347	66	0.245	5	7	10	13	19
A-D	BASINS A-D	0.3183			15	26	41	62	97
E	Inez Shaft	0.483	55.3	0.359	12	27	44	70	114
A+D	Raise #1+ Surface Diversion	0.0817			7	11	16	22	34

APPENDIX A

SOURCE: MILO GULCH FLOOD HYDROLOGY + WATERQUALITY IMPROVEMENT PLAN (SPECTRUM ENGR., MAR 96)

Precipitation-Frequency Relationships
Point Precipitation Values

Guy Caves near Kellogg, Idaho

Elev. = 4200 Feet

Return Period (Yr)	Duration 5-min	15-min	30-min	1-hr	2-hr	3-hr	6-hr	12-hr	24-hr
2	0.12	0.24	0.33	0.42	0.56	0.69	1.00	1.50	2.00
5	0.17	0.33	0.45	0.57	0.73	0.87	1.20	1.80	2.40
10	0.20	0.39	0.55	0.69	0.87	1.02	1.40	2.10	2.80
25	0.25	0.48	0.67	0.85	1.04	1.20	1.60	2.40	3.20
50	0.28	0.55	0.76	0.97	1.18	1.36	1.80	2.65	3.50
100	0.31	0.62	0.86	1.09	1.31	1.51	2.00	2.90	3.80

Guy Caves near Kellogg, Idaho
Rainfall plus Snowmelt

Elev. = 4200 Feet

Snow Melt Add-on	0.01	0.02	0.04	0.09	0.17	0.26	0.52	0.94	1.69

Return Period (Yr)	Duration 5-min	15-min	30-min	1-hr	2-hr	3-hr	6-hr	12-hr	24-hr
2	0.13	0.26	0.37	0.50	0.74	0.95	1.52	2.44	3.69
5	0.17	0.35	0.50	0.66	0.90	1.13	1.72	2.74	4.09
10	0.21	0.42	0.59	0.78	1.04	1.28	1.92	3.04	4.49
25	0.25	0.51	0.71	0.93	1.21	1.46	2.12	3.34	4.89
50	0.29	0.57	0.81	1.05	1.35	1.62	2.32	3.59	5.19
100	0.32	0.64	0.90	1.17	1.49	1.77	2.52	3.84	5.49

Guy Cave South
Rainfall plus Snowmelt

Elev. = 4200 Feet

Snow Melt Add-on	0.01	0.02	0.05	0.09	0.19	0.28	0.56	1.02	1.84

Return Period (Yr)	Duration 5-min	15-min	30-min	1-hr	2-hr	3-hr	6-hr	12-hr	24-hr
2	0.13	0.26	0.38	0.51	0.75	0.97	1.56	2.52	3.84
5	0.17	0.35	0.50	0.67	0.92	1.15	1.76	2.82	4.24
10	0.21	0.42	0.59	0.78	1.06	1.30	1.96	3.12	4.64
25	0.25	0.51	0.72	0.94	1.22	1.48	2.16	3.42	5.04
50	0.29	0.57	0.81	1.06	1.36	1.64	2.36	3.67	5.34
100	0.32	0.64	0.90	1.18	1.50	1.79	2.56	3.92	5.64

SOURCE: BUNKER CREEK AND GOVERNMENT GULCH FLOOD HYDROLOGY (SPECTRUM ENGR., MAR 1996)

Bunker Creek
Precipitation-Frequency Relationships
Point Precipitation Values

Upper Deadwood Gulch near Kellogg, Idaho

Elev. = 4200 Feet

Return Period (Yr)	Duration 5-min	15-min	30-min	1-hr	2-hr	3-hr	6-hr	12-hr	24-hr
2	0.12	0.24	0.33	0.42	0.56	0.69	1.00	1.50	2.00
5	0.17	0.33	0.45	0.57	0.73	0.87	1.20	1.80	2.40
10	0.20	0.39	0.55	0.69	0.87	1.02	1.40	2.10	2.80
25	0.25	0.48	0.67	0.85	1.04	1.20	1.60	2.40	3.20
50	0.28	0.55	0.76	0.97	1.18	1.36	1.80	2.65	3.50
100	0.31	0.62	0.86	1.09	1.31	1.51	2.00	2.90	3.80
Snow Melt Add-on	0.01	0.02	0.04	0.09	0.17	0.26	0.52	0.94	1.70

Upper Deadwood Gulch near Kellogg, Idaho
Rainfall plus Snowmelt

Elev. = 4200 Feet

Return Period (Yr)	Duration 5-min	15-min	30-min	1-hr	2-hr	3-hr	6-hr	12-hr	24-hr
50% 2	0.13	0.26	0.37	0.50	0.74	0.95	1.52	2.44	3.70
20% 5	0.17	0.35	0.50	0.66	0.90	1.13	1.72	2.74	4.10
10% 10	0.21	0.42	0.59	0.78	1.04	1.28	1.92	3.04	4.50
4% 25	0.25	0.51	0.71	0.93	1.21	1.46	2.12	3.34	4.90
2% 50	0.29	0.57	0.81	1.05	1.35	1.62	2.32	3.59	5.20
1% 100	0.32	0.64	0.90	1.17	1.49	1.77	2.52	3.84	5.50

Precipitation-Frequency Relationships
Point Precipitation Values

Kellogg, Idaho

Elev. = 3200 Feet

Return Period (Yr)	Duration 5-min	15-min	30-min	1-hr	2-hr	3-hr	6-hr	12-hr	24-hr
2	0.12	0.23	0.32	0.41	0.54	0.66	0.95	1.38	1.80
5	0.16	0.32	0.44	0.56	0.70	0.83	1.15	1.68	2.20
10	0.19	0.38	0.53	0.67	0.84	0.99	1.35	1.98	2.60
25	0.24	0.47	0.64	0.82	1.00	1.16	1.55	2.28	3.00
50	0.27	0.53	0.73	0.93	1.13	1.31	1.75	2.58	3.40
100	0.30	0.59	0.82	1.04	1.27	1.47	1.95	2.88	3.80

SOURCE: MILO GULCH FLOOD HYDROLOGY + WATER QUALITY IMPROVEMENT PLAN [SPECTRUM ENGR., MAR 96]

Milo Gulch

CN Computatuon Tables

Area: Milo Upper

Soil Type Name	Slopes,%	Map Unit Number	Hydro Soil Type	Cover	CN	Area	CN X Area
Ahrs-Pine Creek	35-75	107	B	Woods-Poor	74	36.73	2718.02
Latour	35-75	116	B	Woods-Good	55	245.05	13477.75
Latour	15-35	117	B	Woods-Good	55	22.82	1255.10
Latour -Rubble Land	35-75	118	B	Woods Poor: Ski Runs	74	196.63	14550.62
Honey Jones-Ahrs	35-75	127	B	Woods-Good	55	221.48	12181.40
Total/Average					61.1	722.71	44,182.89

Area: Milo Upper Trib

Soil Type Name	Slopes,%	Map Unit Number	Hydro Soil Type	Cover	CN	Area	CN X Area
Ahrs-Pine Creek	35-75	107	B	Woods-Poor	74	8.26	611.24
Ahrs-Pine Creek	35-75	107	B	Woods-Good	55	33.80	1,859.00
Latour	35-75	116	B	Woods Poor: Ski Runs	74	31.04	2,296.96
Latour	35-75	116	B	Woods-Good	55	138.84	7,636.20
Honey Jones-Ahrs	35-75	127	B	Woods-Good	55	128.19	7,050.45
Pinecreek	35-65	171	B	Woods-Good	55	26.63	1,464.65
Total/Average					57.0	366.76	20,918.50

Area: Guy Cave South Drainage

Soil Type Name	Slopes,%	Map Unit Number	Hydro Soil Type	Cover	CN	Area	CN X Area
Ahrs-Pine Creek	35-75	107	B	Woods-Poor	74	8.08	597.92
Ahrs-Pine Creek	35-75	107	B	Woods-Good	55	4.03	221.65
Honey Jones-Ahrs	35-75	127	B	Woods-Good	55	4.20	231.00
Honey Jones-Ahrs	35-75	178	B	Woods-Good	55	13.26	729.30
Total/Average					60.2	29.57	1,779.87

→ **Area: Guy Caves**

Soil Type Name	Slopes,%	Map Unit Number	Hydro Soil Type	Cover	CN	Area	CN X Area
Latour	35-75	116	B	Woods-Good	55	37.10	2,040.50
Honey Jones-Ahrs	15-35	126	B	Woods-Good	55	13.59	747.45
Honey Jones-Ahrs	35-75	127	B	Woods-Good	55	70.71	3,889.05
Pinecreek	35-65	171	B	Woods-Good	55	20.02	1,101.10
Honey Jones-Ahrs	35-75	178	B	Woods-Impacted	60	37.28	2,236.80
Honey Jones-Ahrs	35-75	178	B	Woods-Good	55	31.41	1,727.55
Total/Average					55.9	210.11	11,742.45

Area: Upper Grizzly

Soil Type Name	Slopes,%	Map Unit Number	Hydro Soil Type	Cover	CN	Area	CN X Area
Honey Jones-Ahrs	35-75	127	B	Woods-impacted	60	29.94	1,796.40
Honey Jones-Ahrs	35-75	127	B	Woods-Good	55	60.42	3,323.10
Total/Average					56.7	90.36	5,119.50

Area: Lower Grizzly

Soil Type Name	Slopes,%	Map Unit Number	Hydro Soil Type	Cover	CN	Area	CN X Area
Honey Jones-Ahrs	35-75	127	B	Woods-Good	55	51.24	2,818.20
Honey Jones-Ahrs	35-75	178	B	Woods-impacted	60	75.11	4,506.60
Honey Jones-Ahrs	35-75	178	B	Woods-Good	55	76.22	4,192.10
Total/Average					56.9	202.57	11,516.90

SOURCE : BUNKER CREEK AND GOVERNMENT GULCH FLOOD HYDROLOGY [SPECTRUM ENGR, MAR. 96]

Bunker Creek

Preliminary CN Computation Tables
(7½-minute Quads Used)

Area: Portal Gulch

Soil Type Name	Slopes %	Map Unit Number	Hydro Soil Type	Cover	CN	Area	CN X Area
Fluv Arents	0-4	173	C	Range, Poor	86	11.75	1010.50
Hobo Silt Loam, Acidic	15-35	176	D	Range, Fr-Pr	86.5	40.21	3478.17
Hobo-Helmer Silt Loam	5-15	177	D	Range, Fr-Pr	86.5	5.88	508.62
Hugus gravelly Loam	30-65	180	B	Woods, Impacted	60	159.96	9597.60
Tigley ext. grav. Loam	60-80	185	B	Woods, Impacted	60	7.53	451.80
Total/Average					66.8	225.33	15,046.69

[redacted]

Area: Railroad Gulch

Soil Type Name	Slopes %	Map Unit Number	Hydro Soil Type	Cover	CN	Area	CN X Area
Slickens		162	C	Range-Poor	86	1.47	126.42
Fluv Arents	0-4	173	C	Range-Poor	86	12.67	1,089.62
Hobo Silt Loam, Acidic	15-35	176	D	Range, Fr-Pr	86.5	30.30	2,620.95
Hobo-Helmer Silt Loam	5-15	177	D	Range, Fr-Pr	86.5	37.65	3,258.73
Hugus gravelly Loam	30-65	180	B	Woods, Impacted	60	26.81	1,608.60
Total/Average					79.9	108.90	8,702.32

INEZ SHAPT
BSN. E →

Area: Upper Deadwood Gulch

Soil Type Name	Slopes %	Map Unit Number	Hydro Soil Type	Cover	CN	Area	CN X Area
Tigley ext. grav. Loam	60-80	185	B	Woods-Good	55	0.74	40.70
Tigley ext. grav. Loam	60-80	185	B	Woods, Impacted	60	5.59	335.40
Honey Jones-Ahrs	35-75	178	B	Woods-Good	55	79.87	4,392.85
Honey Jones-Ahrs	35-75	178	B	Woods, Impacted	60	10.05	603.00
Honey Jones-Ahrs	35-75	127	B	Woods-Good	55	181.15	9,963.25
Honey Jones-Ahrs	35-75	127	B	Woods, Impacted	60	1.87	112.20
Honey Jones-Ahrs	15-35	126	B	Woods-Good	55	22.53	1,239.15
Pinecreek	35-65	171	B	Woods-Good	55	10.42	573.10
Total/Average					55.3	312.22	17,259.65

CLOSE TO OUR BASIN AREA

Area: Lower Deadwood Gulch

Soil Type Name	Slopes %	Map Unit Number	Hydro Soil Type	Cover	CN	Area	CN X Area
Slickens		162	C	Range-Poor	86	14.14	1,216.04
Fluv Arents	0-4	173	C	Range-Poor	86	37.47	3,222.42
Hobo Silt Loam, Acidic	15-35	176	D	Range, Fr-Pr	86.5	24.97	2,159.91
Hobo-Helmer Silt Loam	5-15	177	D	Range, Fr-Pr	86.5	14.33	1,239.55
Hugus gravelly Loam	30-65	180	B	Woods, Impacted	60	216.35	12,981.00
Hugus gravelly Loam	30-65	180	B	Range, Fr-Pr	74	31.77	2,350.98
Honey Jones-Ahrs	35-75	178	B	Woods, Impacted	60	100.90	6,054.00
Tigley ext. grav. Loam	60-80	185	B	Range, Fr-Pr	74	43.62	3,227.88
Tigley ext. grav. Loam	60-80	185	B	Woods, Impacted	60	4.41	264.60
Total/Average					67.0	487.96	32,716.37

Area: Magnet Gulch

Soil Type Name	Slopes %	Map Unit Number	Hydro Soil Type	Cover	CN	Area	CN X Area
Slickens		162	C	Range-Poor	86	3.49	300.14
Fluv Arents	0-4	173	C	Range-Poor	86	2.94	252.84
Hobo Silt Loam, Acidic	15-35	176	D	Wds-Fair	79	57.60	4,566.20
Hobo Silt Loam, Acidic	15-36	176	D	Range-Fr-Pr	86.5	57.72	4,992.78
Hobo-Helmer Silt Loam	5-15	177	D	Range-Fr-Pr	86.5	47.75	4,130.38
Hugus gravelly Loam	30-65	180	B	Range-Fr-Pr	74	117.35	8,683.90
Honey Jones-Ahrs	35-75	178	B	Woods-Fair	60	2.02	121.20
Total/Average					79.7	289.07	23,047.44

Milo Creek

EXISTING CONDITIONS LAND USE INPUT DATA

Basin Name	Total Area (ac)	Land Use/ Hydrologic Soil Group	Area (ac)	CN*	Composite CN	Flow Type	Land Cover	Travel Length (ft)	Slope (ft/ft)	n or K	Velocity (fps)	Travel Time (min)	Time of Concentration (min)
A		Pervious:				Pervious							
	30.10	Soil Type B	30.10	58.0		Sheet	forested	300	0.1600	0.40		28.47	
						Shallow	forested	630	0.6200		12.70	0.83	
						Channel	meand. stream	1220	0.5500	20	14.83	1.37	30.7
												LAG	18.4
B		Pervious:				Pervious							
	10.60	Soil Type B	10.60	55.9		Sheet	forested	300	0.6600	0.40		16.15	
						Shallow	forested	720	0.6600		13.11	0.92	
						Channel	meand. stream	360.00	0.460	20	13.56	0.44	17.51
												LAG	10.5
C		Pervious:				Pervious							
	140.80	Soil Type B	140.80	55.9		Sheet	forested	300	0.2000	0.40		26.04	
						Shallow	forested	1950	0.4000		10.20	3.18	
						Channel	meand. stream	2280	0.3600	20	12.00	3.17	32.4
												LAG	19.4
D		Pervious:				Pervious							
	22.20	Soil Type B	22.20	66.0		Sheet	forested	[illegible]	0.1200	0.40		[illegible]	
						Shallow	forested	1250	0.5500		7.97	[illegible]	
						Channel	meand. stream	260	0.460	20	7.39	[illegible]	24.5
												LAG	14.7
E		Pervious:				Pervious							
	300.50	Soil Type B	300.50	55.1		Sheet	forested	[illegible]	0.2000	0.40		26.14	
						Shallow	forested	[illegible]	0.5200		9.27	2.70	
						Channel	meand. stream	970	0.5000	20	11.95	7.15	35.9
												LAG	21.5

NOTES

2-year, 24-hour rainfall = 2.00 inches

Sheet Flow Tt = (0.42*(K##*I##)^0.8)/((D29^0.5)*(J##^0.4))

	BASIN NAME
A	Raise #1
B	Raise #2
C	West Milo Diversion
D	Surface Diversion
E	Inez Shaft

*CN: Curve number for basins A-D were taken from the Milo Gulch Flood Hydrology and Water Quality Improvement Plan (1996), Guy Caves CN computation table.
Curve number for basin E was taken from the Milo Gulch Flood Hydrology and Water Quality Improvement Plan (1996), Upper Deadwood Gulch CN computation table.

APPENDIX B

GUY CAVES (BASINS A-D) + INEZ SHAFT (BASIN E)
100 YR/24 HR STORM EVENT
NO SNOW

```
1*************************************
*                                   *
*   FLOOD HYDROGRAPH PACKAGE  (HEC-1)*
*              JUN   1998           *
*           VERSION 4.1             *
*                                   *
*  RUN DATE   04JAN00  TIME  14:46:13*
*                                   *
*************************************
```

```
*************************************
*                                   *
*    U.S. ARMY CORPS OF ENGINEERS   *
*    HYDROLOGIC ENGINEERING CENTER  *
*          609 SECOND STREET        *
*       DAVIS, CALIFORNIA 95616     *
*           (916) 756-1104          *
*                                   *
*************************************
```

```
X     X  XXXXXXX   XXXXX           X
X     X  X        X     X         XX
X     X  X        X                X
XXXXXXX  XXXX     X        XXXXX   X
X     X  X        X                X
X     X  X        X     X          X
X     X  XXXXXXX   XXXXX          XXX
```

THIS PROGRAM REPLACES ALL PREVIOUS VERSIONS OF HEC-1 KNOWN AS HEC1 (JAN 73), HEC1GS, HEC1DB, AND HEC1KW.

THE DEFINITIONS OF VARIABLES -RTIMP- AND -RTIOR- HAVE CHANGED FROM THOSE USED WITH THE 1973-STYLE INPUT STRUCTURE.
THE DEFINITION OF -AMSKK- ON RM-CARD WAS CHANGED WITH REVISIONS DATED 28 SEP 81. THIS IS THE FORTRAN77 VERSION
NEW OPTIONS: DAMBREAK OUTFLOW SUBMERGENCE , SINGLE EVENT DAMAGE CALCULATION, DSS:WRITE STAGE FREQUENCY,
DSS:READ TIME SERIES AT DESIRED CALCULATION INTERVAL LOSS RATE:GREEN AND AMPT INFILTRATION
KINEMATIC WAVE: NEW FINITE DIFFERENCE ALGORITHM

```
1                                          HEC-1 INPUT                                          PAGE  1

          LINE          ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10

             1          ID      LO GULCH
             2          ID   MILO GULCH
             3          ID   MILO GULCH
             4          IT      03 21DEC99    2400     601
             5          IO       3       0

             6          KK  BASINA
             7          KM   BASIN RUNOFF FOR BASIN A, RAISE #1
             8          BA   0.047
             9          PH     100            0.31    0.62    1.09    1.31    1.51    2.00    2.90    3.80
            10          LS       0      58
            11          UD    0.31

            12          KK  BASINB
            13          KM   BASIN RUNOFF FOR BASIN B, RAISE #2
            14          BA  0.0166
            15          LS       0    55.9
            16          UD    0.18

            17          KK  BASINC
            18          KM   BASIN RUNOFF FOR BASIN C, WEST MILO DIVERSION
            19          BA    0.22
            20          LS       0    55.9
            21          UD    0.33

            22          KK  BASIND
            23          KM   BASIN RUNOFF FOR BASIN D, SURFACE DIVERSION
            24          BA  0.0347
            25          LS       0      66
            26          UD    0.25

            27          KK  BASIN3
            28          KM   BASIN RUNOFF FOR BASIN E, INEZ SHAFT
            29          BA   0.484
            30          LS       0    55.3
            31          UD    0.36
            32          ZZ
```


```
1*************************************
*                                   *
*   FLOOD HYDROGRAPH PACKAGE  (HEC-1)*
*              JUN   1998           *
*           VERSION 4.1             *
*                                   *
*  RUN DATE   04JAN00  TIME  14:46:13*
*                                   *
*************************************
```

```
*************************************
*                                   *
*    U.S. ARMY CORPS OF ENGINEERS   *
*    HYDROLOGIC ENGINEERING CENTER  *
*          609 SECOND STREET        *
*       DAVIS, CALIFORNIA 95616     *
*           (916) 756-1104          *
*                                   *
*************************************
```


```
                          LO GULCH
                        MILO GULCH
                        MILO GULCH

  5 IO          OUTPUT CONTROL VARIABLES
                     IPRNT          3  PRINT CONTROL
```

```
                IPLOT          0  PLOT CONTROL
                QSCAL         0.  HYDROGRAPH PLOT SCALE

  IT        HYDROGRAPH TIME DATA
                 NMIN          3  MINUTES IN COMPUTATION INTERVAL
                IDATE     21DEC99  STARTING DATE
                ITIME        0000  STARTING TIME
                   NQ         601  NUMBER OF HYDROGRAPH ORDINATES
               NDDATE     23DEC99  ENDING DATE
               NDTIME        0600  ENDING TIME
               ICENT           19  CENTURY MARK

            COMPUTATION INTERVAL     .05 HOURS
                 TOTAL TIME BASE   30.00 HOURS

      ENGLISH UNITS
           DRAINAGE AREA          SQUARE MILES
           PRECIPITATION DEPTH    INCHES
           LENGTH, ELEVATION      FEET
           FLOW                   CUBIC FEET PER SECOND
           STORAGE VOLUME         ACRE-FEET
           SURFACE AREA           ACRES
           TEMPERATURE            DEGREES FAHRENHEIT


*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***


          **************
          *            *
  6 KK    *   BASINA   *
          *            *
          **************
                    BASIN RUNOFF FOR BASIN A, RAISE #1

        SUBBASIN RUNOFF DATA

  8 BA    SUBBASIN CHARACTERISTICS
               TAREA         .05  SUBBASIN AREA

          PRECIPITATION DATA

  9 PH                          DEPTHS FOR 100-PERCENT HYPOTHETICAL STORM
          ..... HYDRO-35 .....  ............... TP-40 ...............  ........... TP-49 ...........
          5-MIN  15-MIN  60-MIN   2-HR    3-HR    6-HR   12-HR   24-HR   2-DAY   4-DAY   7-DAY  10-DAY
            .31     .62    1.09   1.31    1.51    2.00    2.90    3.80     .00     .00     .00     .00

                                                STORM AREA =     .05

 10 LS    SCS LOSS RATE
               STRTL        1.45  INITIAL ABSTRACTION
              CRVNBR       58.00  CURVE NUMBER
               RTIMP         .00  PERCENT IMPERVIOUS AREA

 11 UD    SCS DIMENSIONLESS UNITGRAPH
                TLAG         .31  LAG

                                                  ***

                                              UNIT HYDROGRAPH
                                          33 END-OF-PERIOD ORDINATES
          4.      13.      26.      44.      59.      67.      67.      63.      56.      47.
         35.      27.      21.      17.      13.      10.       8.       6.       5.       4.
          3.       2.       2.       1.       1.       1.       1.       1.       0.       0.
          0.       0.       0.

    ***          ***          ***          ***          ***

                 HYDROGRAPH AT STATION   BASINA

   TOTAL RAINFALL =    3.80, TOTAL LOSS =    3.22, TOTAL EXCESS =     .58

 PEAK FLOW     TIME                        MAXIMUM AVERAGE FLOW
                                   6-HR       24-HR       72-HR     30.00-HR
+  (CFS)       (HR)
                          (CFS)
+      6.     12.45                2.          1.          1.          1.
                        (INCHES)  .378        .576        .576        .576
                         (AC-FT)    1.          1.          1.          1.

                        CUMULATIVE AREA =     .05 SQ MI


*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***


          **************
          *            *
 12 KK    *   BASINB   *
          *            *
          **************
                    BASIN RUNOFF FOR BASIN B, RAISE #2
```

```
                SUBBASIN RUNOFF DATA

 14 BA            SUBBASIN CHARACTERISTICS
                        TAREA          .02  SUBBASIN AREA

                  PRECIPITATION DATA

  9 PH                                 DEPTHS FOR 100-PERCENT HYPOTHETICAL STORM
                  ..... HYDRO-35 .....   ............... TP-40 ...............   ........... TP-49 ...........
                  5-MIN  15-MIN  60-MIN    2-HR    3-HR    6-HR   12-HR   24-HR   2-DAY   4-DAY   7-DAY  10-DAY
                    .31     .62    1.09    1.31    1.51    2.00    2.90    3.80     .00     .00     .00     .00

                                                   STORM AREA =      .02

 15 LS            SCS LOSS RATE
                        STRTL         1.58  INITIAL ABSTRACTION
                       CRVNBR        55.90  CURVE NUMBER
                        RTIMP          .00  PERCENT IMPERVIOUS AREA

 16 UD            SCS DIMENSIONLESS UNITGRAPH
                         TLAG          .18  LAG

                                                        ***

                                                   UNIT HYDROGRAPH
                                              20 END-OF-PERIOD ORDINATES
                  5.      18.      34.      39.      36.      28.      18.      12.       8.       5.
                  4.       2.       2.       1.       1.       1.       0.       0.       0.       0.

     ***            ***            ***            ***            ***

                         HYDROGRAPH AT STATION   BASINB

    TOTAL RAINFALL =    3.80, TOTAL LOSS =    3.31, TOTAL EXCESS =     .49

  PEAK FLOW     TIME                          MAXIMUM AVERAGE FLOW
                                        6-HR       24-HR       72-HR     30.00-HR
+   (CFS)       (HR)
                                     (CFS)
+      2.      12.30                     1.          0.          0.          0.
                                   (INCHES)       .316        .488        .488        .488
                                    (AC-FT)         0.          0.          0.          0.

                         CUMULATIVE AREA =     .02 SQ MI


*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***


                *************
                *           *
 17 KK          *   BASINC  *
                *           *
                *************
                         BASIN RUNOFF FOR BASIN C, WEST MILO DIVERSION

                SUBBASIN RUNOFF DATA

 19 BA            SUBBASIN CHARACTERISTICS
                        TAREA          .22  SUBBASIN AREA

                  PRECIPITATION DATA

  9 PH                                 DEPTHS FOR 100-PERCENT HYPOTHETICAL STORM
                  ..... HYDRO-35 .....   ............... TP-40 ...............   ........... TP-49 ...........
                  5-MIN  15-MIN  60-MIN    2-HR    3-HR    6-HR   12-HR   24-HR   2-DAY   4-DAY   7-DAY  10-DAY
                    .31     .62    1.09    1.31    1.51    2.00    2.90    3.80     .00     .00     .00     .00

                                                   STORM AREA =      .22

 20 LS            SCS LOSS RATE
                        STRTL         1.58  INITIAL ABSTRACTION
                       CRVNBR        55.90  CURVE NUMBER
                        RTIMP          .00  PERCENT IMPERVIOUS AREA

 21 UD            SCS DIMENSIONLESS UNITGRAPH
                         TLAG          .33  LAG

                                                        ***

                                                   UNIT HYDROGRAPH
                                              35 END-OF-PERIOD ORDINATES
                 18.      52.     104.     177.     247.     287.     299.     292.     264.     231.
                186.     141.     111.      88.      72.      57.      45.      36.      29.      22.
                 18.      14.      11.       9.       7.       6.       4.       4.       3.       2.
                  2.       1.       1.       1.       0.

     ***            ***            ***            ***            ***

                         HYDROGRAPH AT STATION   BASINC

    TOTAL RAINFALL =    3.80, TOTAL LOSS =    3.31, TOTAL EXCESS =     .49
```

```
  PEAK FLOW     TIME                          MAXIMUM AVERAGE FLOW
                                     6-HR       24-HR       72-HR     30.00-HR
+   (CFS)       (HR)
                          (CFS)
+      19.     12.50                 7.          3.          2.          2.
                        (INCHES)   .310        .488        .488        .488
                         (AC-FT)     4.          6.          6.          6.

                        CUMULATIVE AREA =     .22 SQ MI


*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***


            **************
            *            *
  22 KK     *    BASIND  *
            *            *
            **************
                        BASIN RUNOFF FOR BASIN D, SURFACE DIVERSION

               SUBBASIN RUNOFF DATA

  24 BA          SUBBASIN CHARACTERISTICS
                      TAREA          .03  SUBBASIN AREA

                 PRECIPITATION DATA

   9 PH                              DEPTHS FOR 100-PERCENT HYPOTHETICAL STORM
                 ..... HYDRO-35 .....   ............... TP-40 ...............   ........... TP-49 ...........
                 5-MIN  15-MIN  60-MIN    2-HR    3-HR    6-HR   12-HR   24-HR   2-DAY   4-DAY   7-DAY  10-DAY
                   .31     .62    1.09    1.31    1.51    2.00    2.90    3.80     .00     .00     .00     .00

                                                   STORM AREA =     .03

  25 LS          SCS LOSS RATE
                      STRTL        1.03  INITIAL ABSTRACTION
                     CRVNBR       66.00  CURVE NUMBER
                      RTIMP         .00  PERCENT IMPERVIOUS AREA

  26 UD          SCS DIMENSIONLESS UNITGRAPH
                       TLAG         .25  LAG

                                                        ***

                                                   UNIT HYDROGRAPH
                                              27 END-OF-PERIOD ORDINATES
                 5.      16.      34.      52.      60.      60.      54.      44.      32.      23.
                17.      13.      10.       7.       5.       4.       3.       2.       2.       1.
                 1.       1.       1.       0.       0.       0.       0.

     ***            ***            ***            ***            ***

                       HYDROGRAPH AT STATION   BASIND

    TOTAL RAINFALL =    3.80, TOTAL LOSS =    2.83, TOTAL EXCESS =     .97

  PEAK FLOW     TIME                          MAXIMUM AVERAGE FLOW
                                     6-HR       24-HR       72-HR     30.00-HR
+   (CFS)       (HR)
                          (CFS)
+      11.     12.30                 2.          1.          1.          1.
                        (INCHES)   .666        .968        .968        .968
                         (AC-FT)     1.          2.          2.          2.

                        CUMULATIVE AREA =     .03 SQ MI


*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***


            **************
            *            *
  27 KK     *    BASIN3  *
            *            *
            **************
                        BASIN RUNOFF FOR BASIN E, INEZ SHAFT

               SUBBASIN RUNOFF DATA

  29 BA          SUBBASIN CHARACTERISTICS
                      TAREA          .48  SUBBASIN AREA

                 PRECIPITATION DATA

   9 PH                              DEPTHS FOR 100-PERCENT HYPOTHETICAL STORM
                 ..... HYDRO-35 .....   ............... TP-40 ...............   ........... TP-49 ...........
                 5-MIN  15-MIN  60-MIN    2-HR    3-HR    6-HR   12-HR   24-HR   2-DAY   4-DAY   7-DAY  10-DAY
                   .31     .62    1.09    1.31    1.51    2.00    2.90    3.80     .00     .00     .00     .00
```

STORM AREA = .48

30 LS SCS LOSS RATE

STRTL	1.62	INITIAL ABSTRACTION
CRVNBR	55.30	CURVE NUMBER
RTIMP	.00	PERCENT IMPERVIOUS AREA

31 UD SCS DIMENSIONLESS UNITGRAPH

TLAG	.36	LAG

***

UNIT HYDROGRAPH
38 END-OF-PERIOD ORDINATES

31.	93.	181.	308.	449.	551.	602.	605.	577.	523.
457.	371.	287.	230.	186.	153.	124.	101.	81.	65.
53.	43.	34.	28.	23.	18.	15.	12.	10.	8.
6.	6.	5.	4.	3.	2.	1.	0.		

*** *** *** *** ***

HYDROGRAPH AT STATION BASIN3

TOTAL RAINFALL = 3.80, TOTAL LOSS = 3.33, TOTAL EXCESS = .46

PEAK FLOW (CFS)	TIME (HR)		MAXIMUM AVERAGE FLOW 6-HR	24-HR	72-HR	30.00-HR
		(CFS)				
35.	12.55		15.	6.	5.	5.
		(INCHES)	.291	.463	.463	.463
		(AC-FT)	8.	12.	12.	12.

CUMULATIVE AREA = .48 SQ MI

1

RUNOFF SUMMARY
FLOW IN CUBIC FEET PER SECOND
TIME IN HOURS, AREA IN SQUARE MILES

OPERATION	STATION	PEAK FLOW	TIME OF PEAK	AVERAGE FLOW FOR MAXIMUM PERIOD 6-HOUR	24-HOUR	72-HOUR	BASIN AREA	MAXIMUM STAGE	TIME OF MAX STAGE
HYDROGRAPH AT	BASINA	6.	12.45	2.	1.	1.	.05		
HYDROGRAPH AT	BASINB	2.	12.30	1.	0.	0.	.02		
HYDROGRAPH AT	BASINC	19.	12.50	7.	3.	2.	.22		
HYDROGRAPH AT	BASIND	11.	12.30	2.	1.	1.	.03		
HYDROGRAPH AT	BASIN3	35.	12.55	15.	6.	5.	.48		

*** NORMAL END OF HEC-1 ***

GUY CAVES (BASINS A-D) + INEZ SHAFT (BASIN E)
100 YR / 24 HR STORM EVENT
SNOW MELT

```
1*************************************
*                                   *
*   FLOOD HYDROGRAPH PACKAGE  (HEC-1)*
*              JUN   1998           *
*            VERSION 4.1            *
*                                   *
*  RUN DATE   04JAN00  TIME  14:53:15*
*                                   *
*************************************
```

```
*************************************
*                                   *
*    U.S. ARMY CORPS OF ENGINEERS   *
*    HYDROLOGIC ENGINEERING CENTER  *
*          609 SECOND STREET        *
*       DAVIS, CALIFORNIA 95616     *
*           (916) 756-1104          *
*                                   *
*************************************
```

```
X     X  XXXXXXX   XXXXX          X
X     X  X        X     X        XX
X     X  X        X               X
XXXXXXX  XXXX     X        XXXXX  X
X     X  X        X               X
X     X  X        X     X         X
X     X  XXXXXXX   XXXXX         XXX
```

THIS PROGRAM REPLACES ALL PREVIOUS VERSIONS OF HEC-1 KNOWN AS HEC1 (JAN 73), HEC1GS, HEC1DB, AND HEC1KW.

THE DEFINITIONS OF VARIABLES -RTIMP- AND -RTIOR- HAVE CHANGED FROM THOSE USED WITH THE 1973-STYLE INPUT STRUCTURE.
THE DEFINITION OF -AMSKK- ON RM-CARD WAS CHANGED WITH REVISIONS DATED 28 SEP 81. THIS IS THE FORTRAN77 VERSION
NEW OPTIONS: DAMBREAK OUTFLOW SUBMERGENCE , SINGLE EVENT DAMAGE CALCULATION, DSS:WRITE STAGE FREQUENCY,
DSS:READ TIME SERIES AT DESIRED CALCULATION INTERVAL LOSS RATE:GREEN AND AMPT INFILTRATION
KINEMATIC WAVE: NEW FINITE DIFFERENCE ALGORITHM

1 HEC-1 INPUT PAGE 1

```
LINE          ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10

  1           ID      LO GULCH
  2           ID   MILO GULCH
  3           ID   MILO GULCH
  4           IT      03 21DEC99    2400     601
  5           IO       3       0

  6           KK  BASINA
  7           KM   BASIN RUNOFF FOR BASIN A, RAISE #1
  8           BA   0.047
  9           PH     100            0.32    0.64    1.17    1.49    1.77    2.52    3.84    5.49
 10           LS       0      58
 11           UD    0.31

 12           KK  BASINB
 13           KM   BASIN RUNOFF FOR BASIN B, RAISE #2
 14           BA  0.0166
 15           LS       0    55.9
 16           UD    0.18

 17           KK  BASINC
 18           KM   BASIN RUNOFF FOR BASIN C, WEST MILO DIVERSION
 19           BA    0.22
 20           LS       0    55.9
 21           UD    0.33

 22           KK  BASIND
 23           KM   BASIN RUNOFF FOR BASIN D, SURFACE DIVERSION
 24           BA  0.0347
 25           LS       0      66
 26           UD    0.25

 27           KK  BASIN3
 28           KM   BASIN RUNOFF FOR BASIN E, INEZ SHAFT
 29           BA   0.484
 30           LS       0    55.3
 31           UD    0.36
 32           ZZ
```


```
1*************************************
*                                   *
*   FLOOD HYDROGRAPH PACKAGE  (HEC-1)*
*              JUN   1998           *
*            VERSION 4.1            *
*                                   *
*  RUN DATE   04JAN00  TIME  14:53:15*
*                                   *
*************************************
```

```
*************************************
*                                   *
*    U.S. ARMY CORPS OF ENGINEERS   *
*    HYDROLOGIC ENGINEERING CENTER  *
*          609 SECOND STREET        *
*       DAVIS, CALIFORNIA 95616     *
*           (916) 756-1104          *
*                                   *
*************************************
```


```
                    LO GULCH
                 MILO GULCH
                 MILO GULCH

  5 IO        OUTPUT CONTROL VARIABLES
                IPRNT          3  PRINT CONTROL
```

```
                IPLOT          0  PLOT CONTROL
                QSCAL         0.  HYDROGRAPH PLOT SCALE

  IT        HYDROGRAPH TIME DATA
                 NMIN          3  MINUTES IN COMPUTATION INTERVAL
                IDATE     21DEC99  STARTING DATE
                ITIME        0000  STARTING TIME
                   NQ         601  NUMBER OF HYDROGRAPH ORDINATES
               NDDATE     23DEC99  ENDING DATE
               NDTIME        0600  ENDING TIME
                ICENT          19  CENTURY MARK

          COMPUTATION INTERVAL     .05 HOURS
               TOTAL TIME BASE   30.00 HOURS

     ENGLISH UNITS
          DRAINAGE AREA          SQUARE MILES
          PRECIPITATION DEPTH    INCHES
          LENGTH, ELEVATION      FEET
          FLOW                   CUBIC FEET PER SECOND
          STORAGE VOLUME         ACRE-FEET
          SURFACE AREA           ACRES
          TEMPERATURE            DEGREES FAHRENHEIT


*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***


          **************
          *            *
  6 KK    *    BASINA  *
          *            *
          **************
                    BASIN RUNOFF FOR BASIN A, RAISE #1

             SUBBASIN RUNOFF DATA

  8 BA         SUBBASIN CHARACTERISTICS
                  TAREA          .05  SUBBASIN AREA

               PRECIPITATION DATA

  9 PH                                DEPTHS FOR 100-PERCENT HYPOTHETICAL STORM
               ..... HYDRO-35 ......   ............... TP-40 ...............   ........... TP-49 ...........
               5-MIN  15-MIN  60-MIN    2-HR    3-HR    6-HR   12-HR   24-HR   2-DAY   4-DAY   7-DAY  10-DAY
                 .32     .64    1.17    1.49    1.77    2.52    3.84    5.49     .00     .00     .00     .00

                                                STORM AREA =     .05

 10 LS         SCS LOSS RATE
                  STRTL        1.45  INITIAL ABSTRACTION
                 CRVNBR       58.00  CURVE NUMBER
                  RTIMP         .00  PERCENT IMPERVIOUS AREA

 11 UD         SCS DIMENSIONLESS UNITGRAPH
                   TLAG         .31  LAG

                                                    ***

                                                UNIT HYDROGRAPH
                                            33 END-OF-PERIOD ORDINATES
               4.      13.      26.      44.      59.      67.      67.      63.      56.      47.
              35.      27.      21.      17.      13.      10.       8.       6.       5.       4.
               3.       2.       2.       1.       1.       1.       1.       1.       0.       0.
               0.       0.       0.

    ***          ***          ***          ***          ***

                  HYDROGRAPH AT STATION   BASINA

   TOTAL RAINFALL =    5.49, TOTAL LOSS =    4.04, TOTAL EXCESS =    1.45

 PEAK FLOW     TIME                        MAXIMUM AVERAGE FLOW
                                     6-HR       24-HR       72-HR     30.00-HR
+   (CFS)       (HR)
                         (CFS)
+     15.     12.35                   4.          2.          1.          1.
                       (INCHES)     .872       1.448       1.448       1.448
                        (AC-FT)       2.          4.          4.          4.

                       CUMULATIVE AREA =     .05 SQ MI


*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***


          **************
          *            *
 12 KK    *    BASINB  *
          *            *
          **************
                    BASIN RUNOFF FOR BASIN B, RAISE #2
```

```
            SUBBASIN RUNOFF DATA

 14 BA        SUBBASIN CHARACTERISTICS
                   TAREA          .02  SUBBASIN AREA

              PRECIPITATION DATA

  9 PH                              DEPTHS FOR 100-PERCENT HYPOTHETICAL STORM
              ..... HYDRO-35 ......   ............... TP-40 ...............   ........... TP-49 ...........
              5-MIN  15-MIN  60-MIN    2-HR    3-HR    6-HR   12-HR   24-HR   2-DAY   4-DAY   7-DAY  10-DAY
                .32     .64    1.17    1.49    1.77    2.52    3.84    5.49     .00     .00     .00     .00

                                                STORM AREA =     .02

 15 LS        SCS LOSS RATE
                   STRTL         1.58  INITIAL ABSTRACTION
                  CRVNBR        55.90  CURVE NUMBER
                   RTIMP          .00  PERCENT IMPERVIOUS AREA

 16 UD        SCS DIMENSIONLESS UNITGRAPH
                    TLAG          .18  LAG

                                                  ***

                                                UNIT HYDROGRAPH
                                            20 END-OF-PERIOD ORDINATES
              5.       18.       34.       39.       36.       28.       18.       12.        8.        5.
              4.        2.        2.        1.        1.        1.        0.        0.        0.        0.

    ***            ***            ***            ***            ***

                      HYDROGRAPH AT STATION   BASINB

   TOTAL RAINFALL =    5.49, TOTAL LOSS =    4.19, TOTAL EXCESS =    1.30

  PEAK FLOW     TIME                          MAXIMUM AVERAGE FLOW
                                    6-HR       24-HR       72-HR     30.00-HR
+   (CFS)       (HR)
                          (CFS)
+       6.     12.25                 1.          1.          0.          0.
                        (INCHES)    .783       1.297       1.297       1.297
                         (AC-FT)     1.          1.          1.          1.

                      CUMULATIVE AREA =     .02 SQ MI


*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***


            **************
            *            *
 17 KK      *    BASINC  *
            *            *
            **************
                      BASIN RUNOFF FOR BASIN C, WEST MILO DIVERSION

            SUBBASIN RUNOFF DATA

 19 BA        SUBBASIN CHARACTERISTICS
                   TAREA          .22  SUBBASIN AREA

              PRECIPITATION DATA

  9 PH                              DEPTHS FOR 100-PERCENT HYPOTHETICAL STORM
              ..... HYDRO-35 ......   ............... TP-40 ...............   ........... TP-49 ...........
              5-MIN  15-MIN  60-MIN    2-HR    3-HR    6-HR   12-HR   24-HR   2-DAY   4-DAY   7-DAY  10-DAY
                .32     .64    1.17    1.49    1.77    2.52    3.84    5.49     .00     .00     .00     .00

                                                STORM AREA =     .22

 20 LS        SCS LOSS RATE
                   STRTL         1.58  INITIAL ABSTRACTION
                  CRVNBR        55.90  CURVE NUMBER
                   RTIMP          .00  PERCENT IMPERVIOUS AREA

 21 UD        SCS DIMENSIONLESS UNITGRAPH
                    TLAG          .33  LAG

                                                  ***

                                                UNIT HYDROGRAPH
                                            35 END-OF-PERIOD ORDINATES
             18.       52.      104.      177.      247.      287.      299.      292.      264.      231.
            186.      141.      111.       88.       72.       57.       45.       36.       29.       22.
             18.       14.       11.        9.        7.        6.        4.        4.        3.        2.
              2.        1.        1.        1.        0.

    ***            ***            ***            ***            ***

                      HYDROGRAPH AT STATION   BASINC

   TOTAL RAINFALL =    5.49, TOTAL LOSS =    4.19, TOTAL EXCESS =    1.30
```

```
 PEAK FLOW     TIME                          MAXIMUM AVERAGE FLOW
                                   6-HR       24-HR       72-HR     30.00-HR
+   (CFS)       (HR)
                          (CFS)
+      57.     12.40                18.          8.          6.           6.
                        (INCHES)   .778       1.296       1.296        1.296
                         (AC-FT)     9.         15.         15.          15.

                        CUMULATIVE AREA =     .22 SQ MI


*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***


            **************
            *            *
  22 KK     *   BASIND   *
            *            *
            **************
                        BASIN RUNOFF FOR BASIN D, SURFACE DIVERSION

              SUBBASIN RUNOFF DATA

  24 BA         SUBBASIN CHARACTERISTICS
                      TAREA          .03  SUBBASIN AREA

                PRECIPITATION DATA

   9 PH                              DEPTHS FOR 100-PERCENT HYPOTHETICAL STORM
                ..... HYDRO-35 .....   ............... TP-40 ...............   ........... TP-49 ...........
                5-MIN  15-MIN  60-MIN    2-HR    3-HR    6-HR   12-HR   24-HR   2-DAY   4-DAY   7-DAY  10-DAY
                  .32     .64    1.17    1.49    1.77    2.52    3.84    5.49     .00     .00     .00     .00

                                                   STORM AREA =     .03

  25 LS         SCS LOSS RATE
                      STRTL         1.03  INITIAL ABSTRACTION
                     CRVNBR        66.00  CURVE NUMBER
                      RTIMP          .00  PERCENT IMPERVIOUS AREA

  26 UD         SCS DIMENSIONLESS UNITGRAPH
                       TLAG          .25  LAG

                                                        ***

                                                   UNIT HYDROGRAPH
                                             27 END-OF-PERIOD ORDINATES
                5.      16.      34.      52.      60.      60.      54.      44.      32.      23.
               17.      13.      10.       7.       5.       4.       3.       2.       2.       1.
                1.       1.       1.       0.       0.       0.       0.

     ***          ***          ***          ***          ***

                        HYDROGRAPH AT STATION   BASIND

    TOTAL RAINFALL =    5.49, TOTAL LOSS =    3.42, TOTAL EXCESS =    2.07

 PEAK FLOW     TIME                          MAXIMUM AVERAGE FLOW
                                   6-HR       24-HR       72-HR     30.00-HR
+   (CFS)       (HR)
                          (CFS)
+      19.     12.30                 5.          2.          2.           2.
                        (INCHES)  1.234       2.069       2.069        2.069
                         (AC-FT)     2.          4.          4.           4.

                        CUMULATIVE AREA =     .03 SQ MI


*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***


            **************
            *            *
  27 KK     *   BASIN3   *
            *            *
            **************
                        BASIN RUNOFF FOR BASIN E, INEZ SHAFT

              SUBBASIN RUNOFF DATA

  29 BA         SUBBASIN CHARACTERISTICS
                      TAREA          .48  SUBBASIN AREA

                PRECIPITATION DATA

   9 PH                              DEPTHS FOR 100-PERCENT HYPOTHETICAL STORM
                ..... HYDRO-35 .....   ............... TP-40 ...............   ........... TP-49 ...........
                5-MIN  15-MIN  60-MIN    2-HR    3-HR    6-HR   12-HR   24-HR   2-DAY   4-DAY   7-DAY  10-DAY
                  .32     .64    1.17    1.49    1.77    2.52    3.84    5.49     .00     .00     .00     .00
```

```
                                                STORM AREA =      .48

 30 LS          SCS LOSS RATE
                      STRTL        1.62  INITIAL ABSTRACTION
                     CRVNBR       55.30  CURVE NUMBER
                      RTIMP         .00  PERCENT IMPERVIOUS AREA

 31 UD          SCS DIMENSIONLESS UNITGRAPH
                       TLAG         .36  LAG

                                                  ***

                                                UNIT HYDROGRAPH
                                           38 END-OF-PERIOD ORDINATES
              31.       93.      181.      308.      449.      551.      602.      605.      577.      523.
             457.      371.      287.      230.      186.      153.      124.      101.       81.       65.
              53.       43.       34.       28.       23.       18.       15.       12.       10.        8.
               6.        6.        5.        4.        3.        2.        1.        0.

     ***            ***            ***            ***            ***

                        HYDROGRAPH AT STATION   BASIN3

    TOTAL RAINFALL =    5.49, TOTAL LOSS =    4.23, TOTAL EXCESS =    1.25

  PEAK FLOW     TIME                          MAXIMUM AVERAGE FLOW
                                     6-HR       24-HR       72-HR     30.00-HR
+   (CFS)       (HR)
                                   (CFS)
+     114.     12.45                 39.         16.         13.         13.
                                (INCHES)       .750       1.253       1.253       1.253
                                 (AC-FT)        19.         32.         32.         32.

                        CUMULATIVE AREA =     .48 SQ MI

1
                                                RUNOFF SUMMARY
                                          FLOW IN CUBIC FEET PER SECOND
                                       TIME IN HOURS,  AREA IN SQUARE MILES

                                     PEAK   TIME OF     AVERAGE FLOW FOR MAXIMUM PERIOD      BASIN     MAXIMUM    TIME OF
          OPERATION       STATION    FLOW    PEAK                                          AREA      STAGE     MAX STAGE
+                                                        6-HOUR     24-HOUR     72-HOUR
          HYDROGRAPH AT
+                         BASINA      15.   12.35          4.          2.          1.       .05
          HYDROGRAPH AT
+                         BASINB       6.   12.25          1.          1.          0.       .02
          HYDROGRAPH AT
+                         BASINC      57.   12.40         18.          8.          6.       .22
          HYDROGRAPH AT
+                         BASIND      19.   12.30          5.          2.          2.       .03
          HYDROGRAPH AT
+                         BASIN3     114.   12.45         39.         16.         13.       .48

 *** NORMAL END OF HEC-1 ***
```

APPENDIX C - ATTACHMENT B

Mitigation Cost Estimates

O & M COST ESTIMATE DETAILS

Tasks	Qty	Unit	Material Unit Cost	Labor Unit Cost	Equip Unit Cost	Total Cost	Comments
Annual Costs							
Inspection	1	YR	0	400	80	$480	asm 1 times/year & 8hrs/time @ $50/hr labor & $10 for pickup
Road Maintenance & Repairs	1	YR	0	0	0	$0	
Pipeline & Structure Maint. & Repairs	1	YR	0	11,700	9,900	$21,600	asm 3 times/year & 8hrs/time + material allowance
						$22,080	
Contingency	10%					$2,208	
Total Annual Cost						**$24,288**	

Bunker Hill — **DATE: 06/13/2000**
AMD Mitigation Concepts — **PROJECT NO.: 152215.FS.02**
4.2: Bypass Bunker Hill Reservoir — **ESTIMATE BY: D. Hedglin**
Order of Magnitude Cost Opinion — **T.Pyle**

DESCRIPTION	QTY	UNIT	TOTAL UNIT COST	TOTAL COST	COMMENTS
Modify Outlet Works	1	LS	15,000.00	$15,000	
New Pipeline and Connection	1	LS	15,000.00	$15,000	
SUBTOTAL				**$30,000**	
MISC ALLOWANCE	**10%**			**$3,000**	
SUBTOTAL				**$33,000**	
CONTINGENCY	**30%**			**$9,900**	
SUBTOTAL				**$42,900**	
MOBILIZATION	**15%**			**$6,435**	
CONSTRUCTION TOTAL				**$49,335**	
SALES TAX ON MATERIALS	**5.0%**			**$0**	
ENGINEERING AND SUPPORT	**20%**			**$9,867**	
CONST MANAGEMENT	**8%**			**$3,947**	
CAPITAL TOTAL (ROUNDED)				**$60,000**	
ANNUAL O&M COST			**$24,300**		
NPV OF ANNUAL O&M COSTS (30 YEARS @ 7% INTEREST)				**$302,000**	
TOTAL 30-YEAR PRESENT WORTH COST @ 7% INTEREST				**$362,000**	

NOTES:

Misc Allowance markup is to include items known to exist but cannot be quantified at this time.
Contingency is for scope changes that are presently unforeseen.
Mobilization includes bonds, insurance, temporary facilities, health & safety, demobilization, etc.

Bunker Hill **DATE: 06/13/2000**
AMD Mitigation Concepts **PROJECT NO.: 152215.FS.02**
4.3: Improve Existing Diversions (Improve Seal, Decrease Weir Overflow)
Order of Magnitude Cost Opinion **ESTIMATE BY: D. Hedglin**

DESCRIPTION	QTY	UNIT	TOTAL UNIT COST	TOTAL COST	COMMENTS
Modifications to Existing Diversion Structure					
Diversion/Care of Water	1	LS	20,000.00	$20,000	
Excavate for New Structure	150	CY	17.23	$2,585	
Native Backfill Around Structure	60	CY	13.30	$798	
Raise Existing Spillway on Dam	1	LS	23,299.89	$23,300	allowance
Excavate for Screen Structure	70	CY	17.23	$1,206	
Native Backfill Around Screen Structure	20	CY	13.30	$266	
Backfill Riprap Overflow Spillway	325	CY	39.95	$12,984	
Construct Screen Intake Structure	45	CY	552.24	$24,851	
Construct Transition Structure	30	CY	552.24	$16,567	
Bar Screen	1	LS	22,659.98	$22,660	
Foundation Grout Curtain	1,500	LF	40.00	$60,000	
Excavation	833	CY	17.23	$14,358	
Gravel pad for concrete pad	50	CY	20.00	$1,000	
Concrete base pad, 8+ thick	70	CY	300.00	$21,000	
Riprap Cover	625	CY	28.62	$17,884	
SUBTOTAL				**$239,459**	
MISC ALLOWANCE	**10%**			**$23,946**	
SUBTOTAL				**$263,405**	
CONTINGENCY	**50%**			**$131,703**	
SUBTOTAL				**$395,108**	
MOBILIZATION	**15%**			**$59,266**	
CONSTRUCTION TOTAL				**$454,374**	
SALES TAX ON MATERIALS	**5.0%**			**$5,113**	
ENGINEERING AND SUPPORT	**20%**			**$90,875**	
CONST MANAGEMENT	**8%**			**$36,350**	
CAPITAL TOTAL (ROUNDED)				**$590,000**	
ANNUAL O&M COST			**$99,300**		
NPV OF ANNUAL O&M COSTS (30 YEARS @ 7% INTEREST)				**$1,232,000**	
TOTAL 30-YEAR PRESENT WORTH COST @ 7% INTEREST				**$1,822,000**	

NOTES:
Misc Allowance markup is to include items known to exist but cannot be quantified at this time.
Contingency is for scope changes that are presently unforeseen.
Mobilization includes bonds, insurance, temporary facilities, health & safety, demobilization, etc.

O & M COST ESTIMATE DETAILS

Tasks	Qty	Unit	Material Unit Cost	Labor Unit Cost	Equip Unit Cost	Total Cost	Comments
Annual Costs							
Inspection	1	YR	0	400	80	$480	asm 1 times/year & 8hrs/time @ $50/hr labor & $10 for pickup
Road Maintenance & Repairs	1	YR	0	0	0	$0	
Pipeline & Structure Maint. & Repairs	1	YR	0	0	0	$0	
						$480	
Contingency	10%					$48	
Total Annual Cost						**$528**	

Bunker Hill **DATE: 06/13/2000**
AMD Mitigation Concepts **PROJECT NO.: 152215.FS.02**
4.1: Plug Small Hopes (SH) Drift **ESTIMATE BY: D. Hedglin**
Order of Magnitude Cost Opinion

DESCRIPTION	QTY	UNIT	TOTAL UNIT COST	TOTAL COST	COMMENTS
Plug Shaft					
Survey to Determine Location of SH Drift	1	LS	1,600.00	$1,600	
Install New Access Shaft to SH Drift	1	LS	10,000.00	$10,000	
Clean Out SH Drift & Find 2-Raises to Level 5	1	LS	51,690.24	$51,690	
Clean Out Min. of 16 Feet of Shafts to 5 Level	1	LS	10,338.05	$10,338	
Prepare for Plug	2	EA	5,319.96	$10,640	
Concrete Plug	60	CY	272.30	$16,338	
Construct Bulkhead Each End of SH Drift	2	EA	3,398.96	$6,798	400bf each @ 1.50/bf * 8hrs to install
Transport Mix to Pump Site	400	CY	3.29	$1,315	
Fill all Bulkheaded Areas w/Sand/Cement	400	CY	83.05	$33,222	add for mixing as in Cherry, etc
Remove/Backfill Access Shaft	1	LS	2,659.98	$2,660	
Replace Culvert Under Road	1	LS	3,546.02	$3,546	
SUBTOTAL				**$148,147**	
MISC ALLOWANCE	**10%**			**$14,815**	
SUBTOTAL				**$162,962**	
CONTINGENCY	**50%**			**$81,481**	
SUBTOTAL				**$244,443**	
MOBILIZATION	**15%**			**$36,666**	
CONSTRUCTION TOTAL				**$281,109**	
SALES TAX ON MATERIALS	**5.0%**			**$1,365**	
ENGINEERING AND SUPPORT	**20%**			**$56,222**	
CONST MANAGEMENT	**8%**			**$22,489**	
CAPITAL TOTAL (ROUNDED)				**$360,000**	
ANNUAL O&M COST			**$500**		
NPV OF ANNUAL O&M COSTS (30 YEARS @ 7% INTEREST)				**$6,000**	
TOTAL 30-YEAR PRESENT WORTH COST @ 7% INTEREST				**$366,000**	

NOTES:
Misc Allowance markup is to include items known to exist but cannot be quantified at this time.
Contingency is for scope changes that are presently unforeseen.
Mobilization includes bonds, insurance, temporary facilities, health & safety, demobilization, etc.

Bunker Hill **DATE: 06/13/2000**
AMD Mitigation Concepts **PROJECT NO.: 152215.FS.02**
5.1: Plug/Bypass Inez Shaft **ESTIMATE BY: D. Hedglin**
Order of Magnitude Cost Opinion

DESCRIPTION	QTY	UNIT	TOTAL UNIT COST	TOTAL COST	COMMENTS
Plug Shaft					
Survey to Determine Location of Shaft	1	LS	3,200.00	$3,200	
Provide 2000' of 15' wide access road	2,000	LF	25.00	$50,000	
Excavate to Find Location	1	LS	51,690.24	$51,690	15 days
Sheetpiles	2,700	SF	21.65	$58,455	
Excavate to Top of Rock	555	CY	34.46	$19,125	
Backfill Excavation	555	CY	13.30	$7,381	
Prepare for Plug	1	LS	5,319.96	$5,320	
Excavate & Waste 16' of Shaft	30	CY	258.45	$7,754	largely handwork
Concrete Plug	30	CY	143.08	$4,292	
Hydroseed all disturbed areas	60,000	SF	0.10	$6,000	
Regrade Stream	1	LS	51,690.24	$51,690	
SUBTOTAL				**$264,908**	
MISC ALLOWANCE	**10%**			**$26,491**	
SUBTOTAL				**$291,399**	
CONTINGENCY	**50%**			**$145,699**	
SUBTOTAL				**$437,098**	
MOBILIZATION	**15%**			**$65,565**	
CONSTRUCTION TOTAL				**$502,663**	
SALES TAX ON MATERIALS	**5.0%**			**$2,175**	
ENGINEERING AND SUPPORT	**20%**			**$100,533**	
CONST MANAGEMENT	**8%**			**$40,213**	
CAPITAL TOTAL (ROUNDED)				**$650,000**	
ANNUAL O&M COST			**$500**		
NPV OF ANNUAL O&M COSTS (30 YEARS @ 7% INTEREST)				**$6,000**	
TOTAL 30-YEAR PRESENT WORTH COST @ 7% INTEREST				**$656,000**	

NOTES:
Misc Allowance markup is to include items known to exist but cannot be quantified at this time.
Contingency is for scope changes that are presently unforeseen.
Mobilization includes bonds, insurance, temporary facilities, health & safety, demobilization, etc.

O & M COST ESTIMATE DETAILS

Tasks	Qty	Unit	Material Unit Cost	Labor Unit Cost	Equip Unit Cost	Total Cost	Comments
Annual Costs							
Inspection	1	YR	0	400	80	$480	asm 1 times/year & 8hrs/time @ $50/hr labor & $10 for pickup
Road Maintenance & Repairs	1	YR	0	0	0	$0	
Pipeline & Structure Maint. & Repairs	1	YR	0	0	0	$0	asm 2 times/year & 8hrs/time + material allowance
						$480	
Contingency	10%					$48	
Total Annual Cost						**$528**	

O & M COST ESTIMATE DETAILS

Tasks	Qty		Unit Cost	Total Cost	Comments
Annual Costs					
Packer Inspection and Maintenance	21	Each	400	$8,400	$400/hole @ 21 holes
				$8,400	
Contingency	10%			$840	
Total Annual Cost				**$9,240**	

Bunker Hill **DATE: 06/13/2000**
AMD Mitigation Concepts **PROJECT NO.: 152215.FS.02**
6.1: Plug Drill Holes **ESTIMATE BY: D. Hedglin**
Order of Magnitude Cost Opinion

DESCRIPTION	QTY	UNIT	TOTAL UNIT COST	TOTAL COST	COMMENTS
Plug Holes					
Tunnel Clearing	1	LS	10,822.00	$10,822	2 week w/4 man crew & equipment
Add anchor flange for high pressure hole	1	LS	10,000.00	$10,000	
Plug Low Pressure Hole	20	EA	1,392.64	$27,853	1 day w/ 3 man crew
Plug High Pressure Hole	1	EA	22,926.40	$22,926	
SUBTOTAL				**$71,601**	
MISC ALLOWANCE	**10%**			**$7,160**	
SUBTOTAL				**$78,761**	
CONTINGENCY	**30%**			**$23,628**	
SUBTOTAL				**$102,390**	
MOBILIZATION	**15%**			**$15,358**	
CONSTRUCTION TOTAL				**$117,748**	
SALES TAX ON MATERIALS	**5.0%**			**$600**	
ENGINEERING AND SUPPORT	**20%**			**$23,550**	
CONST MANAGEMENT	**8%**			**$9,420**	
CAPITAL TOTAL (ROUNDED)				**$150,000**	
ANNUAL O&M COST			**$9,200**		
NPV OF ANNUAL O&M COSTS (30 YEARS @ 7% INTEREST)				**$114,000**	
TOTAL 30-YEAR PRESENT WORTH COST @ 7% INTEREST				**$264,000**	

NOTES:

Misc Allowance markup is to include items known to exist but cannot be quantified at this time.
Contingency is for scope changes that are presently unforeseen.
Mobilization includes bonds, insurance, temporary facilities, health & safety, demobilization, etc.

Bunker Hill **DATE: 06/13/2000**
AMD Mitigation Concepts **PROJECT NO.: 152215.FS.02**
3.1: South Fork Diversion **ESTIMATE BY: D. Hedglin**
Order of Magnitude Cost Opinion

DESCRIPTION	QTY	UNIT	TOTAL UNIT COST	TOTAL COST	COMMENTS	
Site Access Road						
Clear & Grub New Road	1,330	LF	8.62	$11,458	asm 30'w & 50'/hour	
Grade, Fill & Compact New Road	1,330	LF	38.16	$50,756		
Base Course on New Road	493	CY	24.92	$12,277		
Grade & Improve Existing Road	800	LF	28.90	$23,118		
Erosion & Sedimentation Control	1	LS	41,643.58	$41,644	$/LF allowance for ditches, culverts, silt fences, sed ponds, etc	
Diversion Structure						**$65.38**
Diversion/Care of Water	1	LS	10,000.00	$10,000		
Excavate for Sheetpile Dam	900	CY	17.23	$15,507		
Native Backfill Around Sheetpiles	900	CY	13.30	$11,970		
Sheetpile Wall for Cutoff	1,100	SF	30.00	$33,000		
Excavate for Screen Structure	70	CY	17.23	$1,206		
Native Backfill Around Screen Structure	20	CY	13.30	$266		
Backfill Riprap Overflow Spillway	325	CY	39.95	$12,984		
Construct Screen Intake Structure	15	CY	552.24	$8,284		
Construct Transition Structure	15	CY	552.24	$8,284		
Foundation Grout Curtain	750	LF	40.00	$30,000		
Bar Screen	1	LS	10,329.99	$10,330		
Collector Pipe & Gabions						
Excavation	300	CY	17.23	$5,169		
Imported Bed, Zone & Backfill	250	CY	31.62	$7,906		
Waste	300	CY	3.29	$986		
36" Perf. Collector Pipe	200	LF	68.62	$13,724		
Regrade Stream	1	LS	20,676.10	$20,676		
Gabion Sediment Traps	50	CY	183.25	$9,162		
Pipeline & Access Road						
36" Pipeline in Imp Road	850	LF	127.24	$108,152	including earthwork & fittings	
36" Pipeline in New Road	1,350	LF	127.24	$171,771	including earthwork & fittings	
Stream Crossing	1	EA	4,579.02	$4,579		
Thrust Block	1	EA	822.38	$822		
Air Vent	3	EA	586.19	$1,759		
Cut-Off Trench Seepage Walls	22	EA	2,100.00	$46,200	asm 7cy @ $300/cy	
Thrust Block	2	EA	3,789.51	$7,579		
Bureau of Reclamation Stilling Basin						
Structure Complete	2	LS	67,230.08	$134,460	based on Lake Tapps design & estimate	
SUBTOTAL				**$814,028**		
MISC ALLOWANCE	**10%**			**$81,403**		
SUBTOTAL				**$895,431**		
CONTINGENCY	**40%**			**$358,173**		
SUBTOTAL				**$1,253,604**		
MOBILIZATION	**15%**			**$188,041**		
CONSTRUCTION TOTAL				**$1,441,644**		
SALES TAX ON MATERIALS	**5.0%**			**$20,664**		
ENGINEERING AND SUPPORT	**20%**			**$288,329**		
CONST MANAGEMENT	**8%**			**$115,332**		
CAPITAL TOTAL (ROUNDED)				**$1,870,000**		
ANNUAL O&M COST			**$29,900**			
NPV OF ANNUAL O&M COSTS (30 YEARS @ 7% INTEREST)				**$371,000**		
TOTAL 30-YEAR PRESENT WORTH COST @ 7% INTEREST				**$2,241,000**		

NOTES:
Misc Allowance markup is to include items known to exist but cannot be quantified at this time.
Contingency is for scope changes that are presently unforeseen.
Mobilization includes bonds, insurance, temporary facilities, health & safety, demobilization, etc.

O & M COST ESTIMATE DETAILS

Tasks	Qty	Unit	Material Unit Cost	Labor Unit Cost	Equip Unit Cost	Total Cost	Comments
Annual Costs							
Inspection	1	YR	0	3,200	320	$3,520	asm 8 times/year & 8hrs/time @ $50/hr labor & $10 for pickup
Road Maintenance & Repairs	1	YR	1,000	3,724	3,168	$7,892	asm 1 time/year & 8hrs/time + material allowance
Pipeline & Structure Maint. & Repairs	1	YR	2,000	7,448	6,336	$15,784	asm 4 times/year & 8hrs/time + material allowance
						$27,196	
Contingency	10%					$2,720	
Total Annual Cost						**$29,916**	

O & M COST ESTIMATE DETAILS

Tasks	Qty	Unit	Material Unit Cost	Labor Unit Cost	Equip Unit Cost	Total Cost	Comments
Annual Costs							
Inspection	1	YR	0	400	80	$480	asm 1 time/year & 8hrs/time @ $50/hr labor & $10 for pickup
Road Maintenance & Repairs	1	YR	500	4,477	2,016	$6,993	asm 13time/year & 8hrs/time + material allowance
Pipeline & Structure Maint. & Repairs	1	YR	0	0	3,168	$3,168	asm 1 times/year & 8hrs/time + material allowance
						$10,641	
Contingency	10%					$1,064	
Total Annual Cost						**$11,705**	

Bunker Hill **DATE: 06/13/2000**
AMD Mitigation Concepts **PROJECT NO.: 152215.FS.02**
2.3: Sidehill Diversion above Guy Cave **ESTIMATE BY: D. Hedglin**
Order of Magnitude Cost Opinion

DESCRIPTION	QTY	UNIT	TOTAL UNIT COST	TOTAL COST	COMMENTS
Access Roads					
Clear & Grub	940	LF	8.62	$8,098	asm 30'w & 50'/hour
Grade, Fill & Compact	940	LF	76.32	$71,745	60% rock
Crushed Surfacing Base Course	348	CY	21.65	$7,537	
Erosion matting & mulch on all disturbed cut slopes	47,000	SF	1.00	$47,000	jute mat & hydroseed-allow
Ditch Lining System	940	LF	47.90	$45,024	
Construct Screen Intake Structure	20	CY	500.90	$10,018	
Erosion & Sedimentation Control	1	LS	9,400.00	$9,400	$/LF allowance for ditches, culverts, silt fences, sed ponds, etc
SUBTOTAL				**$198,823**	
MISC ALLOWANCE	**10%**			**$19,882**	
SUBTOTAL				**$218,705**	
CONTINGENCY	**50%**			**$109,352**	
SUBTOTAL				**$328,057**	
MOBILIZATION	**15%**			**$49,209**	
CONSTRUCTION TOTAL				**$377,266**	
SALES TAX ON MATERIALS	**5.0%**			**$2,306**	
ENGINEERING AND SUPPORT	**20%**			**$75,453**	
CONST MANAGEMENT	**8%**			**$30,181**	
CAPITAL TOTAL (ROUNDED)				**$490,000**	
ANNUAL O&M COST			**$11,700**		
NPV OF ANNUAL O&M COSTS (30 YEARS @ 7% INTEREST)				**$145,000**	
TOTAL 30-YEAR PRESENT WORTH COST @ 7% INTEREST				**$635,000**	

NOTES:
Misc Allowance markup is to include items known to exist but cannot be quantified at this time.
Contingency is for scope changes that are presently unforeseen.
Mobilization includes bonds, insurance, temporary facilities, health & safety, demobilization, etc.

Bunker Hill — **DATE: 06/13/2000**
AMD Mitigation Concepts — **PROJECT NO.: 152215.FS.02**
2.1: West Fork Diversion — **ESTIMATE BY: D. Hedglin**
Order of Magnitude Cost Opinion — **T. Pyle**

DESCRIPTION	QTY	UNIT	TOTAL UNIT COST	TOTAL COST	COMMENTS
Site Access Road					
Clear & Grub New Road	3,500	LF	8.62	$30,153	asm 30'w & 50'/hour
Grade, Fill & Compact New Road	3,500	LF	76.32	$267,137	encounter rock
Base Course on New Road	1,296	CY	24.92	$32,307	
Grade & Improve Existing Road	400	LF	28.90	$11,559	
Erosion & Sedimentation Control	1	LS	47,054.48	$47,054	$/LF allowance for ditches, culverts, silt fences, sed ponds, etc
Diversion Structure					
Diversion/Care of Water	1	LS	10,000.00	$10,000	
Excavate for Sheetpile Dam	1,800	CY	17.23	$31,014	
Native Backfill Around Sheetpiles	1,800	CY	13.30	$23,940	
Sheetpile Wall for Cutoff	2,250	SF	30.00	$67,500	
Excavate for Screen Structure	70	CY	17.23	$1,206	
Native Backfill Around Screen Structure	20	CY	13.30	$266	
Backfill Riprap Overflow Spillway	325	CY	39.95	$12,984	
Construct Screen Intake Structure	15	CY	552.24	$8,284	
Construct Transition Structure	15	CY	552.24	$8,284	
Foundation Grout Curtain	1,500	LF	40.00	$60,000	Includes diamond drilling, grout pipe, pressure testing, etc.
Bar Screen	1	LS	10,329.99	$10,330	
Collector Pipe & Gabions					
Excavation	300	CY	17.23	$5,169	
Imported Bed, Zone & Backfill	250	CY	31.62	$7,906	
Waste	300	CY	3.29	$986	
36" Perf. Collector Pipe	200	LF	68.62	$13,724	
Regrade Stream	1	LS	20,676.10	$20,676	
Gabion Sediment Traps	50	CY	183.25	$9,162	
Pipeline & Access Road					
36" Pipeline in Imp Road	750	LF	127.24	$95,430	including earthwork & fittings
30" Pipeline in New Road	750	LF	117.24	$87,928	including earthwork & fittings
36" Pipeline in Unimp Road	1,700	LF	241.71	$410,912	including earthwork & fittings
36" Overland Pipe	150	LF	214.48	$32,171	including earthwork, supports & fittings
42" Slip Pipe for Overland Pipe	40	LF	127.24	$5,090	including earthwork, supports & fittings
Anchor Block	2	EA	4,061.89	$8,124	asm 6cy & 5hrs to form, rebar, place
Anchor Fitting	2	EA	1,172.38	$2,345	allowance
Slip Joint Gasket	1	EA	1,186.19	$1,186	based on quote for Lake Tapps outfall
Thrust Block	7	EA	822.38	$5,757	
Air Vent	2	EA	586.19	$1,172	
Cut-Off Trench Seepage Walls	30	EA	2,100.00	$63,000	asm 7cy @ $300/cy
22 1/2 Degree Elbow	10	EA	2,572.38	$25,724	
Bureau of Reclamation Stilling Basin					
Structure Complete	4	LS	67,230.08	$268,920	based on Lake Tapps design & estimate
SUBTOTAL				**$1,687,400**	
MISC ALLOWANCE	**10%**			**$168,740**	
SUBTOTAL				**$1,856,140**	
CONTINGENCY	**30%**			**$556,842**	
SUBTOTAL				**$2,412,983**	
MOBILIZATION	**15%**			**$361,947**	
CONSTRUCTION TOTAL				**$2,774,930**	
SALES TAX ON MATERIALS	**5.0%**			**$33,487**	
ENGINEERING AND SUPPORT	**20%**			**$554,986**	
CONST MANAGEMENT	**8%**			**$221,994**	
CAPITAL TOTAL (ROUNDED)				**$3,590,000**	
ANNUAL O&M COST			**$27,700**		
NPV OF ANNUAL O&M COSTS (30 YEARS @ 7% INTEREST)				**$344,000**	
TOTAL 30-YEAR PRESENT WORTH COST @ 7% INTEREST				**$3,934,000**	

NOTES:
Misc Allowance markup is to include items known to exist but cannot be quantified at this time.
Contingency is for scope changes that are presently unforeseen.
Mobilization includes bonds, insurance, temporary facilities, health & safety, demobilization, etc.

O & M COST ESTIMATE DETAILS

Tasks	Qty	Unit	Material Unit Cost	Labor Unit Cost	Equip Unit Cost	Total Cost	Comments
Annual Costs							
Inspection	1	YR	0	400	80	$480	asm 1 times/year & 8hrs/time @ $50/hr labor & $10 for pickup
Road Maintenance & Repairs	1	YR	0	0	0	$0	
Pipeline & Structure Maint. & Repairs	1	YR	0	0	0	$0	
						$480	
Contingency	10%					$48	
Total Annual Cost						**$528**	

Bunker Hill | **DATE: 06/13/2000**
AMD Mitigation Concepts | **PROJECT NO.: 152215.FS.02**
2.2.2: Improve Phil Sheridan Diversion Rehabilitation | **ESTIMATE BY: D. Hedglin**
Order of Magnitude Cost Opinion | **T. Pyle**

DESCRIPTION	QTY	TOTAL UNIT COST	TOTAL COST	COMMENTS
Foundation Grout Curtain	1,500	40.00	$60,000	
Sheetpile Wall for Cutoff	3,000	30.00	$90,000	
Dig/Drill/Install Collection Drains for Groundwater	50	120.00	$6,000	
SUBTOTAL			**$156,000**	
MISC ALLOWANCE	**10%**		**$15,600**	
SUBTOTAL			**$171,600**	
CONTINGENCY	**50%**		**$85,800**	
SUBTOTAL			**$257,400**	
MOBILIZATION	**15%**		**$38,610**	
CONSTRUCTION TOTAL			**$296,010**	
SALES TAX ON MATERIALS	**5.0%**		**$1,925**	
ENGINEERING AND SUPPORT	**20%**		**$59,202**	
CONST MANAGEMENT	**8%**		**$23,681**	
CAPITAL TOTAL (ROUNDED)			**$380,000**	
ANNUAL O&M COST		**$500**		
NPV OF ANNUAL O&M COSTS (30 YEARS @ 7% INTEREST)			**$6,000**	
TOTAL 30-YEAR PRESENT WORTH COST @ 7% INTEREST			**$386,000**	

NOTES:

Misc Allowance markup is to include items known to exist but cannot be quantified at this time.
Contingency is for scope changes that are presently unforeseen.
Mobilization includes bonds, insurance, temporary facilities, health & safety, demobilization, etc.

O & M COST ESTIMATE DETAILS

Tasks	Qty	Unit	Material Unit Cost	Labor Unit Cost	Equip Unit Cost	Total Cost	Comments
Annual Costs							
Inspection	1	YR	0	1,800	240	$2,040	asm 3 times/year & 8hrs/time @ $50/hr labor & $10 for pickup
Road Maintenance & Repairs	1	YR	1,000	1,492	672	$3,164	asm 1 time/year & 8hrs/time + material allowance
Pipeline & Structure Maint. & Repairs	1	YR	1,000	5,586	4,752	$11,338	asm 3 times/year & 8hrs/time + material allowance
						$16,542	
Contingency	10%					$1,654	
Total Annual Cost						**$18,197**	

Bunker Hill — **DATE: 06/13/2000**
AMD Mitigation Concepts — **PROJECT NO.: 152215.FS.02**
2.2.1: Rehabilitate Phil Sheridan Diversion — **ESTIMATE BY: D. Hedglin**
Order of Magnitude Cost Opinion — **T. Pyle**

DESCRIPTION	QTY	UNIT	TOTAL UNIT COST	TOTAL COST	COMMENTS
Open Phil Sheridan Raises					
Site Access Road					
Grade & Improve Existing Road	200	LF	28.90	$5,779	
Erosion & Sedimentation Control	1	LS	5,328.72	$5,329	$/LF allowance for ditches, culverts, silt fences, sed ponds, etc
Raise #1					
Open Up Raise #1	100	CY	107.69	$10,769	
Sink 6' Casing from Surface to Rock Line	25	LF	228.92	$5,723	
Prefabricated Steel Inlet Structure	1	LS	10,000.00	$10,000	
Native Backfill Around Screen Structure	100	CY	17.23	$1,723	
Place Riprap	100	CY	26.65	$2,665	
Raise #2					
Open Up Raise #2	100	CY	107.69	$10,769	
Sink 10' Casing from Surface to Rock Line	25	CY	2,500.00	$62,500	
Native Backfill Around Screen Structure	100	CY	17.23	$1,723	
Construct Screen Intake Structure	20	CY	500.90	$10,018	
Screens for Inlet Structure	2	LS	10,659.98	$21,320	
Regrade Stream	1	LS	10,338.05	$10,338	
Place Riprap	100	CY	26.65	$2,665	
Drift Construction					
Site Access Road					
Clear & Grub New Road for Access	150	LF	8.62	$1,292	
Grade, Fill & Compact New Road	150	LF	76.32	$11,449	$/LF allowance for ditches, culverts, silt fences, sed ponds, etc
Base Course on New Road	56	CY	24.92	$1,385	
Erosion & Sedimentation Control	1	LS	7,410.90	$7,411	
Proposed Drift Construction					
Drift Advancement	300	LF	500.00	$150,000	Based on costs provided by Bill Hudson
Access Road and Staging Area	1	LS	15,000.00	$15,000	Based on costs provided by Bill Hudson
Diversion/Care of Water	1	LS	20,000.00	$20,000	
Bulkhead/Bracing for new portal area	1	LS	25,000.00	$25,000	
Concrete Collar with Steel Bulkhead Dam	8	CY	566.25	$4,530	
HDPE Diversion Pipeline					
42" HDPE Pipeline in adit	300	LF	264.48	$79,343	including supports & fittings
36" HDPE buried in Unimp Road	100	LF	241.71	$24,171	including earthwork & fittings
Anchor Block	2	EA	4,061.89	$8,124	asm 6cy & 5hrs to form, rebar, place
Cut-Off Trench Seepage Walls	1	EA	2,100.00	$2,100	asm 7cy @ $500/cy
Concentric Reducer 42" by 36"	1	EA	2,572.38	$2,572	

SUBTOTAL			**$513,697**
MISC ALLOWANCE	**10%**		**$51,370**
SUBTOTAL			**$565,067**
CONTINGENCY	**50%**		**$282,534**
SUBTOTAL			**$847,601**
MOBILIZATION	**15%**		**$127,140**
CONSTRUCTION TOTAL			**$974,741**
SALES TAX ON MATERIALS	**5.0%**		**$1,710**
ENGINEERING AND SUPPORT	**20%**		**$194,948**
CONST MANAGEMENT	**8%**		**$77,979**
CAPITAL TOTAL (ROUNDED)			**$1,250,000**
ANNUAL O&M COST		**$18,200**	
NPV OF ANNUAL O&M COSTS (30 YEARS @ 7% INTEREST)			**$226,000**
TOTAL 30-YEAR PRESENT WORTH COST @ 7% INTEREST			**$1,476,000**

NOTES:
Misc Allowance markup is to include items known to exist but cannot be quantified at this time.
Contingency is for scope changes that are presently unforeseen.
Mobilization includes bonds, insurance, temporary facilities, health & safety, demobilization, etc.

APPENDIX D

AMD Storage Conceptual Designs

AMD Storage Conceptual Designs

PREPARED FOR: Mary Kay Voytilla / USEPA

PREPARED BY: John Winters / CH2M HILL
Matt Germon / CH2M HILL
Jim Stefanoff / CH2M HILL

DATE: February 18, 2000

This memorandum presents conceptual designs for acid mine drainage (AMD) storage options within the Bunker Hill Mine.

1.0 Background

AMD storage options were previously reviewed in the report, *Bunker Hill Mine Water Presumptive Remedy* (CH2M HILL, 1999). The review and subsequent recommendations were based on the assumption that all AMD flow throughout the year would be delivered to the Central Treatment Plant (CTP). Further, only during infrequent plant shutdowns would in-mine storage be used. The report recommended keeping the mine pool pumped down to below 12 Level and then temporarily flooding 12 Level if in-mine storage was required for a CTP shutdown.

Since that report was issued, total maximum daily loads (TMDLs) have been developed by the U.S. Environmental Protection Agency (EPA) for the South Fork Coeur d'Alene (SFCdA) River. The TMDLs specify loads for cadmium, lead, and zinc that can be placed in the river, depending on SFCdA River flows. One method of meeting the TMDL discharge requirements is to store AMD in the mine for treatment later when river flows are higher and allow a higher discharge rate. This could be useful during periods of high AMD flow and low SFCdA River flow. Also, since that report was issued, use of the existing volume above the current mine pool has been evaluated. This volume is currently used by the mine for working or contingency storage. The benefit of this option is that the mine water does not need to be lowered, and hence the piping and pumping distances are less, which will reduce the long-term power consumption and maintenance requirements.

1.1 Purpose and Objectives

This technical memorandum presents conceptual layout and cost information for installing diversion and pumping facilities at the Bunker Hill Mine. Options for using the storage above the existing mine pool (11 Level) and new storage created by lowering the water level to below 12 Level are evaluated.

This document uses the term "storage" to indicate raw AMD stored in the Bunker Hill Mine. A number of other storage options exist, including treated water storage ponds and alternative water uses that could reduce or eliminate the need for storage. However, these options are beyond the scope of this memorandum.

1.2 Limitations

Detailed design has not been conducted on any of the approaches summarized in this technical memorandum. The concepts and resulting implementation costs have been developed for comparison with the costs and benefits of other components for long-term water management at the Bunker Hill Mine. The conceptual designs are based on existing data only.

Order of magnitude cost estimates have been prepared based on conceptual designs. The cost estimates are in January 2000 dollars and do not include escalation. They were prepared using information available at that time, and therefore may be subject to adjustments in the scope and details of each design. The cost estimates have been prepared for guidance in project evaluation and should be carefully reviewed prior to making specific financial decisions or establishing final project budgets. The actual costs to implement any of the mitigation approaches are expected to vary from the costs shown herein based on actual labor and material costs, competitive market conditions, final project scope, and other variable factors.

2.0 Diversion to Storage Using Gravity Flow

2.1 Location

Two diversions are necessary to allow flexibility in the rate of AMD diverted to storage. One diversion point would be located near No. 2 Shaft, and a second diversion would be located on the Barney Drift. Each diversion would consist of two fabricated slide gates and a new diversion channel. The diversion channel would lead from the AMD channel to a new inlet funnel and diversion pipe mounted in No. 2 Shaft at the 9 Level and at a suitable location in the Barney Drift. The slide gate on the main channel would be partially lowered (closed) and the slide gate on the diversion channel raised (opened) to divert the AMD to storage. See Figure 1 for a diversion layout sketch.

2.2 Gate Type and Material Selection

The gate frame bottom would be mounted flush with the channel floor. Gates would have a self-contained frame and motorized operator. The gate frame would be 316 stainless steel (SST) and the gate disk would be fiberglass. The gate disk would have a bottom rubber seal and polyethylene guides in the frame. The gate seal would not be drop-tight but would close off most of the AMD to the diversion when diversion is not required. Materials would be selected for corrosion resistance. Ongoing maintenance will be needed to prevent the gate seals from fouling by mine muck and yellow boy. For this reason, other diversion configurations may be considered during design.

2.3 Diversion Pipe

The diversion pipe would be high-density polyethylene (HDPE), 12 inches in diameter. Because the pipe would flow by gravity, a standard dimension ratio of 17 is assumed. The pipe is large to address the uncertainty in peak diversion flow requirements. A riser-type clamp system would be required to hold the diversion pipe in place. Spacing for the clamps would need to be sized during final design. For the conceptual design, 10-foot on-center is

assumed. The top section (approximately 10 feet long) of the diversion pipe might have to be 14 inches in diameter to minimize entrance headloss and assure smooth entry of the diverted flow. A fabricated metal (SST) box with funnel bottom would be included to lead the diverted flow from the channel to the diversion pipe.

2.4 Flow Measurement with Cutthroat Flumes

Cutthroat flumes would be used to measure the diverted flow and the AMD flow that continues toward the Kellogg Tunnel portal. The flumes would be constructed of fiberglass for corrosion resistance. An ultrasonic level element would be installed above each of the two flumes. These elements, with associated hardware and software, would be used to measure the water level reading for each flume. Isolation (and throttling) slide gates would be located upstream of the flumes so as not to submerge the flume throat and destroy flow measurement accuracy. During final design, the size and type of flume and flow measurement equipment should be revisited to assure that the best combination of flow accuracy and maintainability is provided.

2.5 Conduits and Conductors

To control the slide gates and transmit channel level measurements to the CTP, conductors would be extended in conduits along the 9 Level tunnel to the Kellogg Tunnel portal. From the portal, the conduits could be buried and extended to the CTP. The estimated distance for these conductors is 10,000 feet.

Power for the slide gate operators (480 volts) is assumed to be available near the No. 2 Shaft for extension to the diversion gates.

3.0 Storage Levels

3.1 12 Level Storage

12 Level has approximately 80 million gallons (MG) of storage (12 Level track to 11 Level track). The typical water level would be at 20 to 30 feet below 12 Level. The mine water would need to be lowered about 200 feet for this option.

3.2 11 Level Storage

This option would use the existing storage used by the mine, which consists of about 20 MG from 30 feet below 11 Level up to the 10 Level, and an additional estimated 190 MG from the 11 Level track to the 10 Level track.

4.0 Pump Layout Options

Conceptual pump layouts are described below for both 11 Level and 12 Level options.

4.1 Conceptual Layouts

A variety of pumping options could be used to satisfy the AMD storage pumping needs. Figure 2 shows the conceptual pump layout for the 12 Level option, which uses a vertical turbine pump for the first pump and either a horizontal centrifugal or possibly a vertical can

pump as the booster pump. Figure 3 shows the option for 11 Level storage. In this case, only the vertical turbine pumps are needed because they could pump directly to 9 Level without booster pumps. Both options could allow the water level to fluctuate an entire level, but typical water levels in the absence of diversion would fluctuate about 10 to 30 feet. The submersible vertical turbine pump could operate at this depth of submergence (about 200 feet) without damage.

Many flow rate options exist that could be met using multiple single or variable speed pumps. Use of variable speed pumps is discussed in Section 5 of this technical memorandum. The least cost option would be constant speed pumps. Constant speed pumps are used in the existing AMD pumping system. The following conceptual layouts use two 700 gallons per minute (gpm) constant speed pumps, which could provide nearly twice the capacity of the existing system, which is about 700 gpm.

4.2 12 Level Option

This option uses two 700 gpm constant speed vertical turbine pumps (Pump A) mounted approximately 20 feet below the bottom of 12 Level as shown in Figure 2. These would discharge flow through a 12-inch SST pipe to the suction of two centrifugal pumps (Pump B) located in the shaft near 11 Level, or on the 11 Level. Each Pump B would have an air release valve on its suction side, and check and isolation valves on its discharge. The discharge from Pump B would be carried up No. 2 Shaft in a SST pipe to the discharge on 9 Level. Isolation and check valves would be provided on the discharge sides of Pumps A and B.

SST pipe is recommended for corrosion resistance and the higher pressure rating needs of this installation. Costs would be comparable to costs for HDPE pipe with the same pressure rating.

4.3 11 Level Option

The 11 Level option uses two pumps to provide about 700 gpm each, which could pump directly to 9 Level without booster pumps, as shown in Figure 3. These would be constant speed vertical turbine pumps located about 30 feet below 11 Level. More in-shaft storage volume could be obtained by placing them lower in the shaft and drawing down the water.

4.4 Water Depth Monitoring

The water level (top of the mine pool) could be monitored using a bubbler tube or other system. The bubbler tube discharge point would be mounted at a known elevation in the No. 2 Shaft. The bubbler system might need two pressure transducers: one to accurately read pressure when the water level fluctuates slightly, and the other for greater fluctuations. Submersible pressure transducers could also be used for level measurement, but the bubbler system may be better-suited for the mine water.

5.0 Flow Control

5.1 Throttling

Constant speed pump output could be reduced with a throttling valve on the pump discharge side. The throttling obviously would expend additional energy for the volume pumped, as well as creating additional costs associated with the throttling valve installation, repair and, ultimately, replacement. The throttling valve could be positioned by an electric operator. A flow meter upstream of the valve would monitor flow rate.

5.2 Variable Speed Drive

For the AMD pumping options, some reduction in flow could be achieved with a variable frequency drive (VFD). It is estimated that the flow rate could be reduced about 30 percent with a VFD. If a VFD were used, it would most likely be located at the 9 Level. Care would be needed to ensure the VFD was installed in an environment that could provide long service life. The inside of a mine is not an ideal location for installation of a VFD, because of moisture and corrosion concerns. With either a VFD or a throttling valve, the pump output could be controlled by an operator at the CTP.

5.3 Multiple Pumps

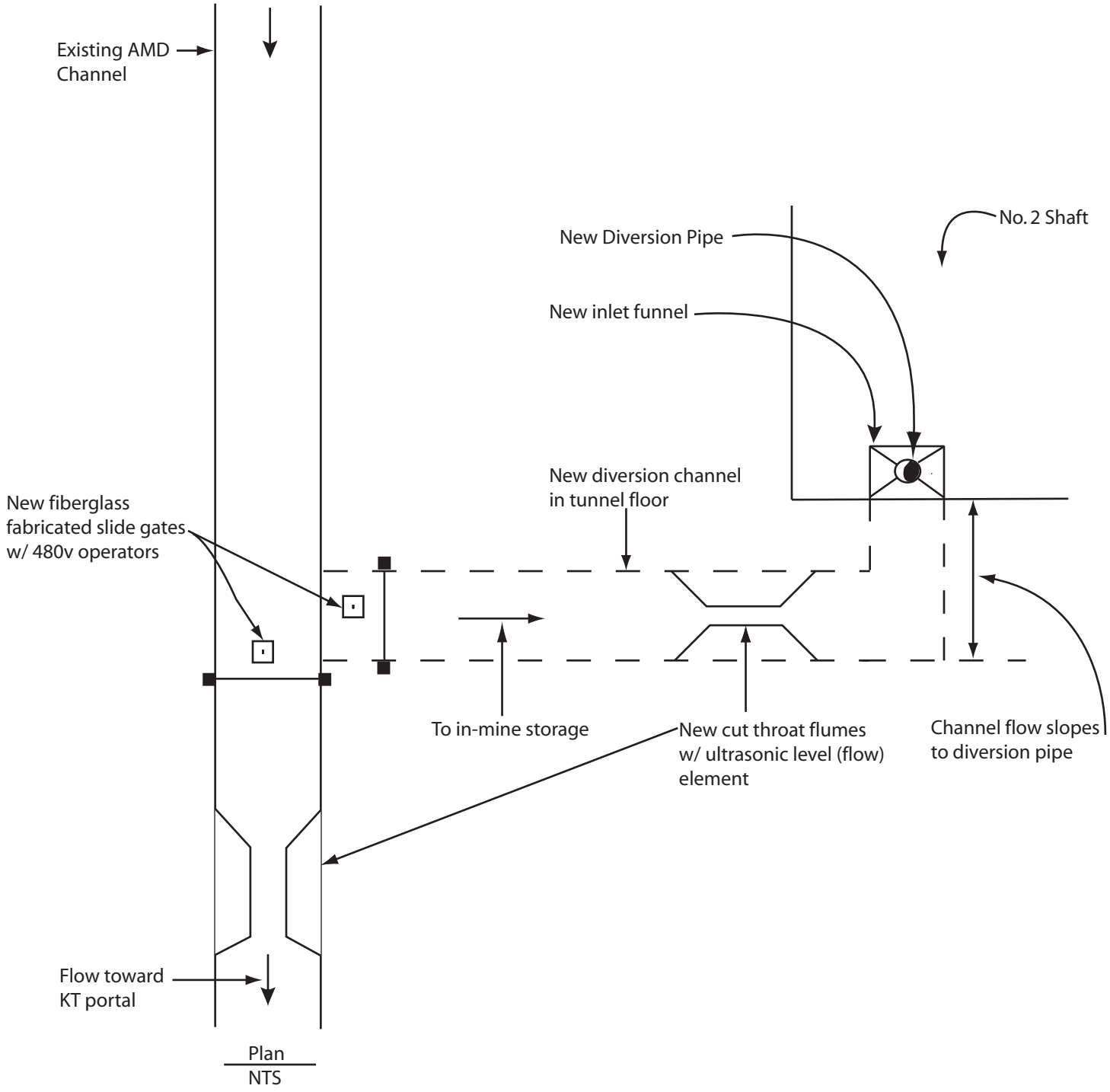
One method of providing pumping rate flexibility would be to use multiple constant speed pumps of different sizes. For example, a 700 gpm pump and a 1,200 gpm pump could provide three levels of pumping (700, 1,200, and 1,900 gpm).

Judging by the size of the No. 2 Shaft, it might not be practical to install multiple pumps. This option should be revisited during final design.

References

CH2M HILL, 1999. *Bunker Hill Mine Water Presumptive Remedy*. Bunker Hill Mine Water Management, July. CH2M HILL, Spokane, Washington.

Storage Diversion Layout



CH2MHILL

SPK/152215.FS.02/Figure 1 - Storage Diversion Layout.ai

Figure 1
Storage Diversion Layout

12 Level Pumping Layout

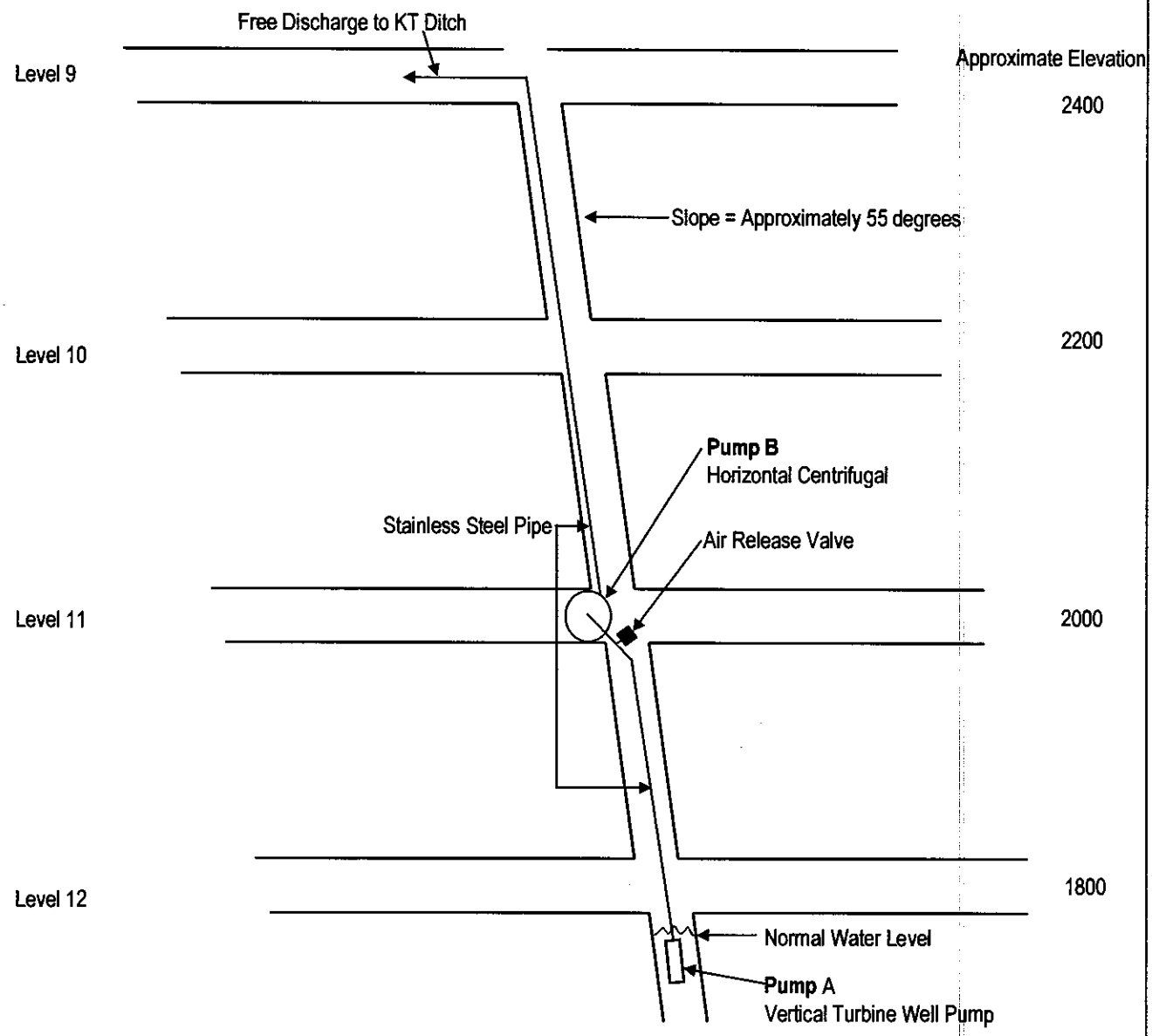


Figure 2
Conceptual Pumping Layout for 12 Level Option

11 Level Pumping Layout

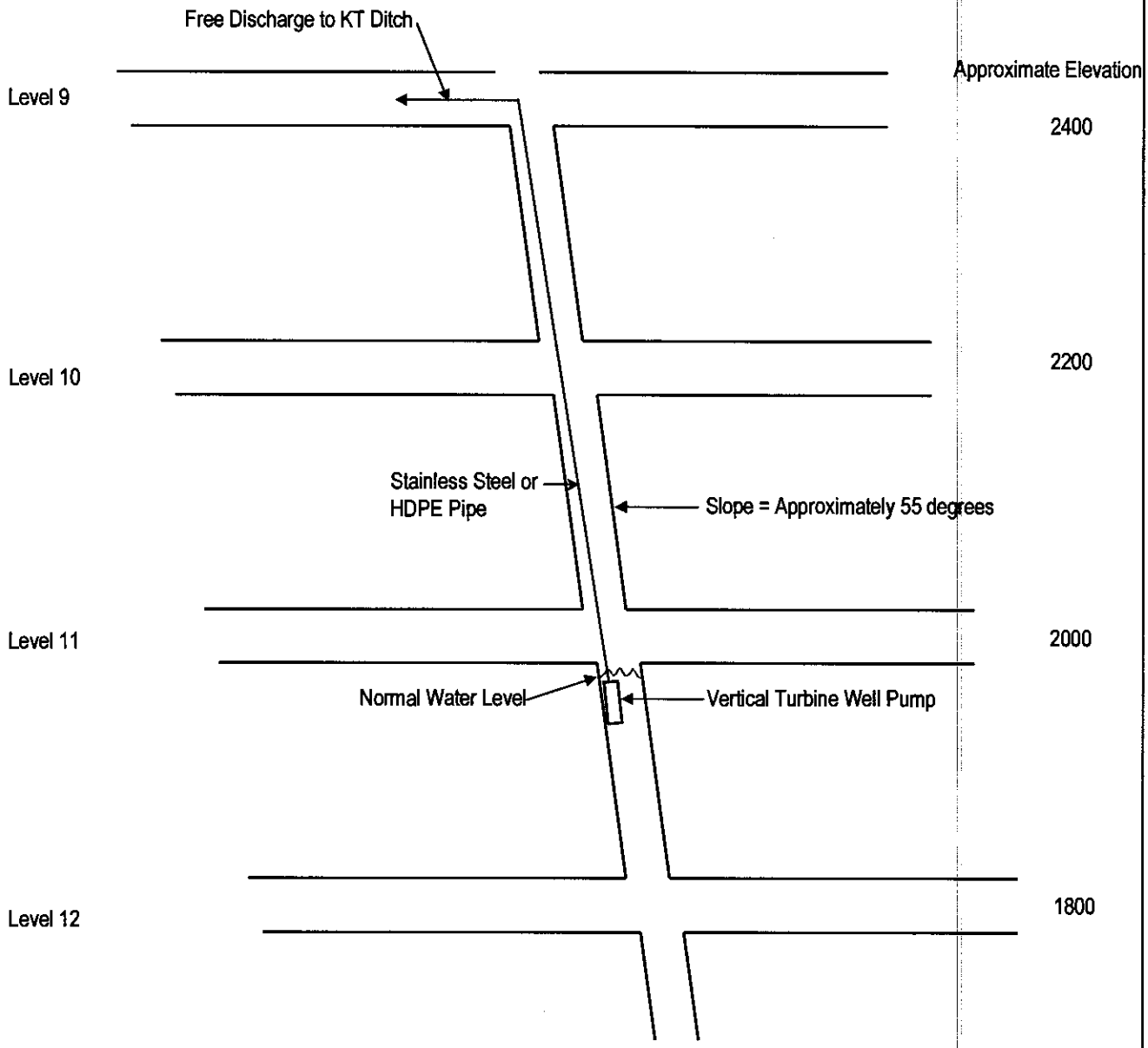


Figure 3
Conceptual Pumping Layout for 11 Level Option

APPENDIX E

CTP Master Plan for Improvement

CTP Master Plan for Improvements

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DATE: December 26, 2000

1.0 Introduction

1.1 Background

The Central Treatment Plant (CTP) was installed in 1973 by the Bunker Hill Company to treat the combined effluents from the Bunker Hill mine, mill, lead plant, and zinc plant. The four main processing objectives for the CTP were: 1) acceptable effluent quality, 2) minimum sludge production, 3) maximum system reliability, and 4) acceptable capital and operating costs (Baker and Larson, 1973). Twenty-seven years later, the CTP is still treating mine water, and the same four processing objectives still exist.

Acceptable Effluent Quality

In August 2000, EPA and the State of Idaho finalized total maximum daily loads (TMDLs) for the Coeur d'Alene Basin. The TMDLs result in a reduction in the allowable amounts of cadmium, lead, and zinc that may be discharged from the CTP. The current effluent quality will not meet the more stringent TMDL requirements.

EPA and CH2M HILL conducted a treatability program in 1999 and 2000 to determine what process changes were required to meet the TMDL requirements. The program identified two changes: 1) increase the operational pH setpoint to about 9.5 to reduce dissolved metals concentrations, and 2) add tri-media filtration to remove suspended metals.

It is interesting to note that the CTP operated for a period with media filters. These were single media filters installed in 1979 in response to new treatment requirements based on discharge of total metal, rather than only dissolved metal. These new requirements were established in December 1977 and stipulated that compliance be achieved by January 1, 1980. The sand filter system was supplied by G. T. Woods Company and consisted of two rows of 20 filters, for a total of 40 filters. Each filter consisted of a 36-inch-diameter by 8-foot-long steel tank mounted horizontally (laying on its side). These filters were removed from service because of poor performance and high operating costs.

Removal of the filters did not remove the treatment requirements. Rather than using the filters, the operators developed alternative procedures that enabled the plant to meet the discharge limits most of the time by reducing sludge recycle and optimizing clarification.

However, these procedures reduced the ability of the plant to minimize sludge production because a high-density sludge could no longer be produced.

Minimum Sludge Production

When the media filters were removed, the only way the CTP could meet the discharge requirements was by reducing sludge recycle. This reduced suspended metal in the effluent, but had the detrimental effect of producing more sludge. However, at that time the sludge was being pumped to the top of the Central Impoundment Area (CIA), which had considerable storage capacity; thus, there was no motivation to reduce sludge volumes. Although the CTP is still being operated this way, the remaining sludge disposal capacity of the CIA is nearly exhausted.

The CTP treats the mine water using a lime precipitation process. Lime is contacted with the incoming mine water, resulting in precipitation of dissolved metals as sludge. During process evaluation, the Bunker Hill Company realized that disposal of large volumes of low-density sludge would be difficult given the confines of the mountainous terrain of the Kellogg Area (Baker and Larson, 1973). For this reason, a high-density sludge (HDS) process was incorporated into the design of the CTP.

The benefit of the HDS process is that considerably less sludge is produced. Recirculating large quantities of sludge within the treatment process progressively builds sludge particle size. The large size retains less water, enabling the sludge to drain and consolidate much more effectively. The drawback of the HDS process is the requirement to cycle large sludge volumes. This consumes electrical pumping power, requires a larger solids/liquid separation clarifier, and can increase the amount of suspended solids in the plant effluent. It was this last detriment that initiated the requirement to install the media filters. Without filters, too much suspended solids and associated metals were carried into the plant effluent.

Currently, the EPA is in the process of placing a cover system over the CIA to minimize infiltration and metal leaching. The remaining sludge disposal area is expected to be full in 3 to 5 years. Thus, sludge disposal volume is again a significant issue, which is best addressed by minimizing the volume of sludge that must be managed. To achieve this, the CTP must be operated in the HDS mode, which once again requires use of media filters for removal of the suspended metal from the plant effluent. Thus, installation of tri-media filters will allow both attainment of the TMDL, and operation of the CTP in HDS mode.

Maximum System Reliability

During CTP process development and design, the Bunker Hill Company acknowledged the potential for the CTP to experience upsets and breakdown, as summarized in the following statement: “The central impoundment pond will provide surge holding capacity during treatment plant upsets or breakdowns, thereby protecting the quality of the river course at all times” (Baker and Larson, 1973).

With the installation of the cover system, the CIA can no longer be used for mine water storage as done by the Bunker Hill Company. Thus, to provide protection from CTP upsets or breakdowns, either replacement storage is needed, more backup and redundant

treatment capability is needed, or both. Use of both is expected to be more protective and cost-effective.

This CTP master plan describes recommended CTP modifications to cost-effectively reduce upsets or breakdowns. When coupled with emergency in-mine storage and storage provided by the lined pond, the likelihood of discharge of untreated mine water is considerably reduced.

Acceptable Capital and Operating Costs

Today, as was the case 27 years ago, lime neutralization is still the most cost-effective way to treat the mine water. Use of the HDS process is also the most cost-effective way to reduce sludge volumes. Use of tri-media filters and a pH setpoint of about 9.5 is the most cost-effective way to meet the TMDL treatment requirements. Maximizing use of existing CTP equipment and infrastructure to the most practical extent possible will minimize the cost to upgrade the CTP for compliance with the TMDL, minimize sludge production, and provide reliable treatment.

1.2 Objectives of the CTP Master Plan

The objectives of this CTP master plan are to describe changes needed to do the following:

1) Provide acceptable effluent quality that is compliant with the TMDL
2) Minimize sludge production
3) Maximize system reliability
4) Provide acceptable capital and operating costs

This plan does not provide detailed engineering design, but instead focuses on the types of changes needed and where the new equipment and facilities should be located. Section 2 describes a phased approach for these changes.

2.0 Phased Approach

Three phases have been developed for upgrading the CTP. These phases allow the improvements to be done around the existing equipment and operations, both to minimize plant down time and to use existing equipment to the maximum extent practicable. The changes described in Phase 1 are necessary to most cost-effectively meet the requirements of the TMDL, minimize sludge volume, and maximize system reliability. The changes described in Phase 2 are only needed if the CTP capacity must be greater than 2,500 gpm. The changes described in Phase 3 are only needed if mechanical sludge dewatering is needed for offsite sludge disposal.

Phase 1 consists of modernizing the CTP to reliably meet the TMDL requirements and produce HDS at a capacity of 2,500 gpm. It will be constructed while the existing unit processes are still operating to the maximum extent reasonable. A total shutdown of about 4 to 5 weeks is anticipated so the sludge thickener can be taken out of service for overhaul. Some of the current CTP components will remain in place after Phase 1 construction is

complete; however, they will be placed in standby mode to provide backup and redundant service.

Completion of Phase 1 improvements under the master plan eliminates the need for active operation of the existing aeration basin (Reactor B), Reactor A, and floc tank. The Phase 1 upgrades would allow the existing finished water reservoir (polishing pond) to be permanently removed from service. The area made available can be used for other purposes and for Phase 2 improvements.

Phase 2 would be done if additional treatment capacity were needed, and in this master plan consists of adding additional equipment to treat up to 5,000 gpm of AMD. This would involve removal of the existing aeration basin, adding a second neutralization/oxidation treatment reactor, and adding additional filters.

Phase 3 would be initiated if mechanical sludge dewatering and offsite disposal were implemented. This would involve adding a sludge dewatering system and building.

3.0 Influent Design Conditions for Upgraded CTP

The influent design conditions for the upgraded treatment plant are shown in Table 1. During Phase 1 the CTP will be sized to hydraulically pass and neutralize 5,000 gpm, but HDS production and filtration capacity will be sized at only 2,500 gpm. Initially constructing a 5,000 gpm hydraulic throughput capacity will add little cost, but will provide considerable savings if Phase 2 is implemented because a retrofit would be avoided. Providing for sufficient lime feed capacity for 5,000 gpm for both phases provides lime feed redundancy at all but the peak flows, and assures that large flows and/or lime demands can be neutralized, thus preventing the release of high metal concentration acid water. As can be seen in Table 1, there is a large peaking factor that must be handled in the design of the upgraded CTP, even in Phase 1.

4.0 Description of Existing Facility and Recommended Phase 1 Improvements

The CTP was originally designed and operated as a HDS plant as described earlier. In the HDS mode, lime slurry is added to recirculated thickened sludge in the sludge conditioning reactor (Reactor A), which is then contacted with the plant influent in the neutralization/oxidation reactor (Reactor B). This reactor overflows to a polymer addition/flocculation chamber, which overflows to the thickener. However, the plant is currently operated in a mode of inadequate sludge recycle and inventory in the thickener to achieve thickened sludge concentrations necessary to produce HDS. Over the years the operators have found that, given the lack of effluent filters and the available infrastructure, operation in this low-density sludge (LDS) mode produces better effluent quality than operation in the HDS mode. However, the LDS mode produces about three times the volume of sludge as the HDS mode. Figure 1 shows the present facility layout (all tables and figures follow the text).

The following sections provide descriptions of the major components of the existing CTP, their current shortcomings, and recommended Phase 1improvements. Figure 2 shows the

Phase 1 CTP additions and modifications, and Figure 3 is a process flow diagram of the CTP after Phase 1 improvements. Table 2 summarizes preliminary equipment sizes.

4.1 Lined Pond and Pump Station

Description

All influent to the CTP (including the mine water) currently comes from the lined pond, which has 7 million gallons of storage capacity. A pump station pumps the pond contents to the CTP. The quiescent water conditions in the pond promote deposition of muck that settles from the mine water. This is a serious problem that must be remedied or the pond will become unusable. About 2 million gallons of muck has accumulated since the pond became fully operational in May 1996. The lined pond pump station is equipped with three identical pumps that are used to deliver flows from the lined pond to the CTP. Either one or two of the pumps are constantly used to pump from the lined pond to the CTP. In general, the pump station components are relatively new and work well.

Shortcomings

It is estimated that about 450,000 gallons per year of muck is accumulating in the lined pond. This reduces its capacity for holding mine water, and will eventually require costly removal. This accumulation will continue as long as the mine water is deposited into the pond.

The pump station pumps can now be controlled remotely from the CTP control room; however, there is currently no provision for monitoring the water level in the lined pond. There also are no alarms at the CTP to alert the operators of a pump station problem.

Recommended Phase 1 Improvements

Bypass piping around the lined pond is needed if the pump station is inoperative. This bypass piping would also allow mine water to be routinely piped directly to the CTP by gravity, which reduces maintenance and wear of the pump station, reduces electrical power used for pumping, and reduces the deposition of mine muck in the lined pond that is costly to remove.

The water level in the lined pond should be displayed at the CTP so the operators can track and better manage its volume. The run status of each of the pump station pumps should also be displayed at the CTP, in addition to automatic alarms to alert the operators if the pumps become inoperative or if the pond is becoming full.

4.2 Lime Feed System

Description

The CTP uses lime slurry to neutralize the acidity of the influent and to precipitate the dissolved metals. The CTP uses hydrated lime rather than quicklime because the CTP does not have an operational lime slaker. The following describes how lime slurry is currently semi-manually produced and fed into the treatment process at the CTP.

1. Lime (hydrated lime) is pneumatically transferred from the delivery trucks into the single 200-ton storage silo.

2. An operator turns on a water aspirator system (eductor) that induces a vacuum below the cone of the silo, which in turn pulls lime out of the silo and into the water stream. The water source is plant effluent pumped from the polishing basin.
3. The aspirated lime/water mixture discharges into a sump cut in the floor at the base of the dysfunctional lime slaker.
4. An operator sits next to the sump and manually varies the amount of dilution water added to the sump, using a water wand to prevent the sump from becoming clogged.
5. A sump pump pumps the slurry out of the sump into an adjacent lime slurry storage tank.
6. One of two slurry pumps continually pumps lime slurry out of the bottom of the tank, through a lime slurry loop, and then back into the top of the tank.
7. An automatic valve on the lime slurry loop opens in response to a signal sent from a pH probe in the aeration basin effluent to divert lime slurry from the loop into the treatment process at the sludge conditioning reactor (Reactor A).
8. An operator makes a new batch of lime once the level of the lime slurry in the storage tank drops below a predetermined level.

Shortcomings

The economics of lime usage favor the use of pebble quicklime rather than hydrated lime (about a 40 percent savings), slaking at the treatment plant to form hydrated lime, and then automatic slurring and feeding of the hydrated lime into the treatment process. Automatic slaking, slurrying, and feeding are usually performed because the initial capital cost of the equipment is recuperated in labor savings. For these reasons, the CTP initially used quicklime and a slaker for lime slurry preparation. The slaker is currently inoperative and is no longer used. The less-efficient and more costly semi-manual makeup system is used instead.

Without the ability to make and use lime slurry, the CTP cannot function. The current lime makeup and feed system lacks redundancy. Failure of the single lime storage silo, single aspirator system, and single lime slurry tank mixer would shut down the CTP. Also, it is unlikely that the semi-manual lime slurry makeup system could keep up with high lime demands resulting from very high mine water flows.

There are no functioning indicators or alarms to alert the operators of lime makeup or feed problems, other than loss of treatment process pH control, which is too late to prevent process upsets. The current method of pH measurement, coupled with the too large retention time in Reactor A and the poor mixing in Reactor B, results in the inability to control process pH in Reactor B more accurately than one-half a pH unit. Finer pH control would result in more consistent lime feeding and treatment.

Recommended Phase 1 Improvements

The CTP will continue to use lime slurry to neutralize the AMD acidity and to precipitate the dissolved metals. Hydrated lime, which is more expensive than quicklime, is currently used because there is no operational lime slaking system. The present method of lime

preparation is also labor-intensive and presents a potential safety hazard, requiring the use of respirators. It also produces lime slurry with potentially high variability in concentration.

Previous analysis has shown that, at the average usage rates for the CTP, (unhydrated) pebble quicklime is more cost-effective than hydrated lime. The payback period accounting for both labor and lime cost reduction is estimated at 1.5 years. This assumes that four hours of labor per day is saved or devoted to some other activity that is currently consuming labor hours, such as plant maintenance.

The entire CTP would need to be shut down if the existing lime make-up system were to malfunction for more than a day, because there are no redundancies. In addition, it is unlikely that the existing lime system can deliver the peak lime demand. For these reasons, during Phase 1 a new lime silo, slaking, slurry transfer and storage, and feed system will be installed. This will allow the existing lime system to be taken off-line and upgraded by adding a new slaker system, which will result in redundant lime preparation and feed systems. The new silo and slaker will be located along the access road east of the existing silo (see Figure 2). The new lime slurry tank will be located further east than the silo.

The existing silo appears to be in good condition and will be cleaned out and retained. The new slaker will allow the existing system to use quicklime as well. New slurry transfer pumps and piping will be installed. The lime slurry tank and mixer also appear to be in sound condition and of adequate size for future use. They will also be cleaned, reconditioned, and reused.

New lime slurry recirculation pumps will be installed to transfer the lime through a redundant set of looped piping to Reactor A. High velocities will be maintained in the lime system to minimize scaling of the pipe walls.

The two independent lime slurry delivery systems will be different sizes to accommodate a wide range of influent lime demands. A smaller system will be used during average flow, with the large system available as standby and for peak demand periods.

4.3 Sludge Conditioning Reactor (Reactor A)

Description

The sludge conditioning reactor (Reactor A) is used to contact the recycled sludge with lime slurry to produce lime-coated sludge particles, which are in turn added into the feed launder of the aeration basin. Reactor A is made of steel and is listed as having a volume of 15,000 gallons. The reactor has four baffles. A mixer provides agitation. Visual inspection indicated good mixing. The discharge consists of an overflow box, which is about four feet from where the recycle sludge pipeline introduces sludge. The recycle sludge is discharged vertically into the top of the tank.

Shortcomings

The tank is too large to serve as an efficient sludge conditioning reactor. The long detention time causes too much lime to be added before the pH in Reactor B responds, contributing to pH swings. When the pH in Reactor B reaches a high set point, the lime-treated solids inventory in Reactor A continues to enter Reactor B, even though no more lime is added. This causes about a 0.5 pH unit swing in Reactor B.

Recommended Phase 1 Improvements

The existing Reactor A will be replaced by a new Reactor A, with a capacity of about 2,500 gallons. A smaller reactor will allow better response time for pH control, avoiding the pH swings inherent in the existing system. It will also be easier to clean out. Lime and recycled sludge will be mixed in this tank using a small mixer. The tank will be located such that the lime-coated sludge will flow by gravity either to the old aeration basin (old Reactor B) or to the new aeration tank (new Reactor B). Experience has proven that there is no need for a redundant Reactor A, because even if the mixer breaks, there is enough turbulence induced by flow into the small tank for mixing to be adequate until repairs can be made.

4.4 Aeration Basin (Reactor B)

Description

The pumped influent from the lined pond enters the CTP on the west end of the aeration basin (Reactor B). The aeration basin has a platform-mounted 50-hp slow-speed surface aerator/mixer. The aeration basin is lined with a 60-mil high-density polyethylene (HDPE) liner, which was installed in 1994. The basin is designed to be 10 feet deep, with a floor measuring 50 feet by 60 feet with 1-1/2:1 side slopes. The design volume is approximately 370,000 gallons. The CTP operator reported that, in the past, the basin would be periodically cleaned of accumulated sludge using a backhoe, but now that it has been lined this is not feasible. A 4-inch-diameter pipe was installed to remove solids from the basin using Sludge Pump No. 1, but this is not effective.

Shortcomings

The existing aerating basin and platform-mounted splashing aerator are inefficient, prone to short-circuiting, and are incapable of maintaining solids in suspension. The mixer provides good agitation at the center of the basin, but poor mixing in the rest of the basin. The central location and radial flow creates short-circuiting around the basin sides. The basin is nearly full of sludge, except within about a 10- to 20-foot radius of the mixer. If higher-density solids were fed to Reactor B, even more deposition would occur. The current sludge build-up problem will be compounded when the plant is run in HDS mode. Also, there is currently no redundancy; if this reactor were to shut down, or if the mixer were to fail, the CTP would have to be shut down.

Recommended Phase 1 Improvements

These shortcomings will be corrected by adding a new, 75,000-gallon mixed and aerated steel reactor between the existing filter building and the existing aeration basin. A retaining wall will be built to allow adequate room for the new tank. The new Reactor B will be configured to operate in parallel with the aeration basin, which would serve as a backup. The new reactor will be baffled and equipped with a submerged turbine aerator/mixer to keep the contents completely mixed and to supply aeration for the oxidation of reduced iron and manganese. This is the configuration installed at the Iron Mountain Mine Superfund site in California, and it is producing excellent results. The existing aeration basin will be cleaned out and decommissioned, but left in place as a backup to the new reactor.

4.5 Flocculation Basin

Description

The aeration basin discharges into a flocculation chamber through a discharge launder. The flocculation chamber is located between the aeration basin and the thickener. The flocculation basin was originally intended to flocculate the feed to the thickener using a flocculent aid (polymer). The flocculation chamber measures 32 feet wide, 32 feet long, and 12 feet deep, and is completely full of sludge. This equates to a liquid volume of 88,000 gallons. A 1.5-hp motor had been used to rotate a flocculation paddle, which has been shut off.

Shortcomings

The flocculation basin is no longer used. The mixer has been shut off because mixing was insufficient to prevent solids deposition. Polymer is being added into the discharge launder from the flocculation basin just prior to the pipe leading to the thickener center well. This point of polymer addition has been empirically found to provide better results than addition before the flocculation basin.

Recommended Phase 1 Improvements

The flocculation chamber no longer serves any useful purpose and will be cleaned out and decommissioned, but left in place in case the aeration basin is operated. The discharge from the new Reactor B will flow through a new pipeline into the center well of the thickener. A new polymer feed system will be configured so flocculent can be added either into the pipeline, at the center well, or both.

4.6 Polymer Make-up and Feed System

Description

Polymer solution is currently manually made up by adding dry polymer to water in a polymer make-up tank. Two side-mounted mixers are used for mixing. A transfer pump, operated on a level switch, is used to transfer polymer solution from the make-up tank to a polymer feed tank. A small variable speed pump is used to pump polymer from the feed tank to the discharge launder of the flocculation chamber, where the polymer mixes with the thickener feed. Polymer dosage is evaluated by observing the settling rate of samples of thickener feed and effluent turbidity, and is adjusted by changing the speed of the feed pump.

Shortcomings

The current manual make-up system is labor-intensive. There are no alarms to alert the operators of problems, or if the polymer storage tanks are getting low.

Recommended Phase 1 Improvements

A new polymer make-up and feed system will be installed. An automated polymer make-up and feed system would reduce manpower requirements, allow more efficient use of polymer (fewer fisheyes), and increase worker safety. This system will be located inside the existing building.

4.7 Thickener

Description

The discharge from the flocculation chamber enters a 24-inch-diameter pipe and is carried to the center of the thickener, where it discharges into a 20-foot-diameter center well that rotates with the rake. Discharge from the center well into the thickener is through six rectangular ports that are approximately 6 feet below the surface. The thickener is 236 feet in diameter and was supplied by Eimco Process Equipment Company, now Baker Process. The thickener has a concrete bottom and a steel side wall. The water depth is 10 feet on the side. The bottom slopes at a 1 in 12 slope from the side wall to within 50 feet of the center, where the slope steepens to 2 in 12. The center well depth is 27.67 feet. The thickener volume is 4.4 million gallons.

The purpose of the thickener is to separate the sludge from the treated water by gravity settling, and also to thicken the settled sludge to remove water to create less sludge volume. Settled sludge is scraped into the center by the thickener rake mechanism and pumped via sludge recycle pumps to the sludge conditioning reactor (Reactor A). Periodically, usually daily when the plant is operating, sludge is wasted to the sludge basin (formally referred to as the decant pond) located on top of the CIA.

It appears that very little solids actually settle near the perimeter of the thickener, because the bottom of the thickener is clearly visible near the wall. Most solids deposition occurs near the center well. Typically, clear effluent with low suspended solids (between 1 and 6 mg/L) leaves the thickener. Some pin floc has been observed near the wall, indicating that almost the entire area of the thickener is used to clarify the treated water.

It has been empirically found over years of operation that the LDS mode of operation produces the best effluent quality in the absence of effluent filtration. Given the large disposal area previously provided by the CIA, there has historically been no impetus to concentrate wasted sludge solids, so the thickener is currently being operated primarily as a clarifier and not up to its full potential as a thickener. The CTP was operated in the HDS mode for a portion of 1997. During that time, the effluent total suspended solids (TSS) was observed to increase. This increase was correlated with higher feed solid loadings. Higher feed mass loading results from increases in recycle ratio and/or increases in underflow solids concentration. The optimal TSS removal was found to occur when the thickener feed solids concentration (including recycle) was less than 1 percent (wt %). Higher feed solids load also affects the polymer dosage, as measured by mg/lb dry solids in feed. It appears the higher TSS is a result of decreased effectiveness of the polymer because of either reduced dosage when operating in the HDS mode, or reduced mixing effectiveness of polymer and solids.

In the LDS mode, an amount of sludge sufficient to permit a high degree of thickening as a result of sludge compression is not allowed to build up. This is evidenced by the fact that the solids of samples from thickener underflow left standing for several days will settle to roughly 30 percent of their original volume (CH2M HILL, 1997). However, the LDS mode of operation is required to meet the current discharge limitations because no filters are available to filter out the higher levels of suspended solids that overflow the thickener weir during operation in the HDS mode.

Clarified effluent is discharged radially from the top of the thickener into the perimeter effluent launder, where it flows to a discharge pipe located at the end of the bridge walkway. This pipe conveys the effluent into the polishing basin.

Shortcomings

Although the thickener is nearly 30 years old, it appears to be in relatively good structural condition. The thickener drive head (model number C84B2P) was replaced in June 1994. Eimco (now Baker Process) in Salt Lake City was contacted about the capability of the mechanism to handle a denser sludge. They said that because the mechanism does not have a rake lift, it should have sufficient torque to operate on sludge of between 20 and 30 wt %. They recommended that a rake-lifting device be installed for use on sludge of greater than 30 wt %. A rake lift will not be needed because the underflow sludge will be kept between 20 and 30 wt % during HDS operation.

Recommended Phase 1 Improvements

The thickener will need to be taken out of service and rehabilitated. This would include emptying, sandblast and repair, repaint inside and out, cure, repair and replace thickener rakes, make center well modifications, and test and make adjustments, followed by startup. A shallow groundwater investigation will be needed prior to emptying to determine if groundwater drawdown is needed to prevent buckling of the thickener floor. The weir plates should be replaced with new plates of a V-notch design that would provide a more uniform overflow around the circumference of the thickener.

The estimated duration of the overhaul is 4 to 5 weeks, during which the CTP will be shut down. This down time could be reduced by fast-track construction, working around the clock. During the shutdown, the AMD will need to be stored in the mine and lined pond, necessitating close coordination with the mine owner. During this same shutdown period, other Phase 1 tie-ins to the existing treatment system will be made.

4.8 Polishing Pond

Description

The polishing pond is a concrete trapezoidal basin located between the thickener and Bunker Creek. There are several feet of sludge solids in the basin, which reportedly has never been cleaned. The basin was originally intended to be a reservoir for recycling water back to the ore concentrator, which no longer exists. Water is still pumped from the polishing basin for use as lime slurry make-up water. Treated water from the thickener enters the basin on the northeast corner. Water flows across the basin to the southwest corner, where it is discharged through a 12-inch Parshall flume into Bunker Creek at Outfall 006.

Shortcomings

An unknown amount of water is leaking through the construction joints of the walls as evidenced by drips and the presence of green plants at the joints. The basin is larger than needed to supply lime slurry make-up water, and takes up space needed for the new filter system. The sludge within the basin is prone to disturbance and subsequent carryover into Bunker Creek.

Recommended Phase 1 Improvements

A treated water supply tank will replace the polishing basin. The tank will be considerably smaller and take up much less space. This tank will receive filtered effluent from the filter system, which will be used for filter backwash, lime slurrying, wash water, and pump cooling. City water will be used for lime slaking, drinking, and other needs that require a low total dissolved solids (TDS) water. Recycled effluent could also be used for lime slaking in the event of a City supply failure. Excess water, which overflows the top of the tank, would discharge through a flow-measuring device to Bunker Creek.

4.9 Sludge Recycle and Wasting Pumps

Description

Three sludge recycle and wasting pumps are located in the control room, which is adjacent to the thickener. Two pumps (Pumps 1 and 2) are currently used for sludge recirculation, and two pumps (Pumps 1 and 3) are used for wasting. Two steel sludge recirculation lines are available. One is an 8-inch outside diameter (O.D.) and the other is a 10-inch O.D.

Sludge is generally pumped (wasted) into the CIA sludge disposal area for one to two hours per day, until the underflow slurry reaches a targeted specific gravity of typically 1.03 to 1.06. The target specific gravity is temperature-dependent and has been determined by empirical observation by the operators to achieve good treatment performance, indicated primarily by low suspended solids in the effluent.

Shortcomings The existing sludge recycle and waste pumps are original equipment. Although they are still functional, they are worn and need overhaul or replacement.

Recommended Phase 1 Improvements

The existing sludge recycle and wasting pumps will be overhauled or replaced. Additional pumps will be used to provide flow rate flexibility and redundancy. Up to four recycle and up to two waste pumps may be used.

4.10 Control System

Description

The CTP uses the original panel-mounted process control devices installed in 1974. Most of the antiquated process controls no longer function. Other than pH control and annunciation of certain alarms, there is no automation in the existing control system. Paper for the strip chart recorders is no longer manufactured.

Shortcomings

The existing system does not have the flexibility and capability to support new equipment. The system is non-computerized and inefficient. A modern system would be considerably more reliable, efficient, and flexible.

Recommended Phase 1 Improvements

A new automated programmable logic controller- (PLC) based system is recommended. This system would automatically monitor system performance, control all pumps and

mixers, automatically initiate lime and polymer make-up, record vital record-keeping information (such as flow and effluent metal load), and provide AutoDial alarm functions when needed. The control system will allow the plant to run unassisted overnight or on weekends, depending on the degree of autonomy desired.

A new personal computer will serve as the human-machine interface (HMI). The operator can view each unit process on the computer screen and know the status immediately. Software changes can also be made using the HMI. The HMI can be assessed both at the plant and remotely, and can provide automated reports. This system would also track river flow at the Pinehurst gauge, enabling daily automatic calculations required to determine discharge quantity for complying with TMDL requirements.

4.11 Control Building

Description

The control building houses the existing polymer make-up system, sludge recycle and control pumps, electrical gear, and control system. It also contains a small bathroom with toilet and sink, a small desk, and storage cabinets.

Shortcomings

The control building is too small to accommodate additional pumps, the polymer system, and the new control room.

Recommended Phase 1 Improvements

The control building should be enlarged. It was assumed that the new building addition would be approximately 600 square feet, approximately double the size of the existing building. The new pumps will be located in the existing control room. The area occupied by the current polymer system will be used for spare parts storage and will perhaps continue to be used to house the finished polymer solution tank. If desired, additional space could be added for an operator break room, small laboratory, and office.

4.12 Add Tri-Media Filtration of CTP Effluent

As discussed earlier, tri-media filters are required for compliance with the TMDL discharge requirements, and for operating in the HDS mode. The headroom of the present building is inadequate for the new filters. Vertical pressure filtration vessels will be installed inside a new building located at the current site of the old filter building, which will be removed and possibly reused elsewhere onsite for spare parts storage. These types of filters are expected to work much more efficiently than the old horizontally configured filters previously discarded.

A new wet well and pump station will intercept flow from the thickener launder heading to the finished water reservoir. The pump station will pressurize up to 2,500 gpm through piping into the filter building. Flows greater than 2,500 gpm will overflow through a pipe from the wet well into Bunker Creek. The pressurized influent to the filters passes through a gallery to filters located on both sides of the building. Individual pipes will carry a portion of the flow into individual pressure vessels. The flow is distributed uniformly and passes into the media. Filtered wastewater passes out of the media bed and into an under-drain,

where it is collected and routed out of the pressure vessel. The accumulated filtered water passes out of the building and into a backwash supply tank. Excess water overflows the outlet on top of the tank through a flow-measuring device to Bunker Creek. This tank will also supply lime slurry make-up water. Following completion of Phase 1, the polishing pond will no longer receive flow and can be removed from service.

As solids are captured in the media bed, pressure loss increases at a given flow rate. The bed is regenerated by backwashing, when a high flow rate of water is applied to the bed in a turbulent, upflow fashion to remove the solids. An air scour system may also be installed to assist with backwashing. Backwash water will be supplied from the backwash supply tank. Dirty backwash water will be collected in a mixed tank and bled at a slow uniform rate back to the treatment plant inlet.

4.13 Other Recommended Phase 1 Improvements

Other recommended Phase 1 improvements are listed below.

Backup Power System. The current CTP has no backup power system. Loss of power supply results in plant shutdown. A diesel generator and fuel storage tank will be added to provide backup power to critical plant components. This system will start automatically if the main power system shuts down.

Influent Flow Meter. There is currently not an adequate way to measure the influent flow to the CTP. An old venturi type meter operating on a differential pressure concept was originally installed but is no longer operational. Currently, the CTP inflow rate is estimated empirically based on valve settings, or by using the Outfall 006 flume. Accurate inflow rate information is needed to determine plant operating conditions, track chemical consumption, and evaluate plant performance for daily compliance with TMDL requirements. A new magnetic flow meter will be added to accurately measure the incoming flow.

Sulfide Feed System or Filter Feed Flocculent System. The treatability testing program showed that additional metal could be removed from the effluent by either adding sulfide into the effluent of Reactor B, or by adding flocculent prior to the filters. Although these systems are not expected to be needed for compliance with the TMDL, consideration will be given for future addition if they become desirable.

5.0 Phase 2 Improvements

Phase 2 improvements are needed only if more than 2,500 gpm must be treated. Figure 4 shows the CTP configured for Phase 2, and Figure 5 shows a process flow diagram. Phase 2 improvements would include the following:

- Removal of the existing Reactor A, aeration basin, flocculation basin and associated equipment and piping
- Re-grading the area previously occupied by these facilities
- Installing a second Reactor B in the area previously occupied by these facilities
- Modifying Reactor A to provide capability to feed both B reactors

- Piping work to allow the B reactors to operate in series or parallel, and for flow to the thickener center well
- Add or modify the sludge recycle pumps to increase the solids recirculation ratio
- Add additional filtration capability and expand the filtration building.

The addition of the above equipment will allow the system to process 5,000 gpm at the influent conditions shown in Table 1.

6.0 Phase 3 Improvements

Phase 3 improvements are needed only if it is decided to mechanically dewater the sludge for offsite disposal. This would consist of the following:

- Demolition and regrading of the polishing pond if not already done
- Installation of sludge dewatering facilities inside a new building on the site previously occupied by the polishing pond

TABLE 1
Bunker Hill CTP Influent Design Conditions
Bunker Hill CTP Master Plan

Parameter	(Units)	Maximum Design	Typical Design[1]
AMD Hydraulic Throughput and Neutralization Capacity	gpm	5,000 (both phases)	1,500 (both phases)
Filtration Capacity	gpm	2,500 (Phase 1) 5,000 (Phase 2)	1,500 (both phases)
pH	Units	2.0	3.1
Lime Demand (Calcium Hydroxide)	lb/1,000 gal	80.0	10
Solids Formed	lb/1,000 gal	130	12.5
Dissolved Ferrous Iron	mg/L	200	41
Manganese	mg/L	400	130
Sulfate	mg/L	7,000	1,900
TSS	mg/L	600	170
TDS	mg/L	11,000	3,000

[1]Average chemistry is based on Kellogg Tunnel discharge data from 1998/1999 monitoring program. Average flow is based on historical data between 1972 and 1999.

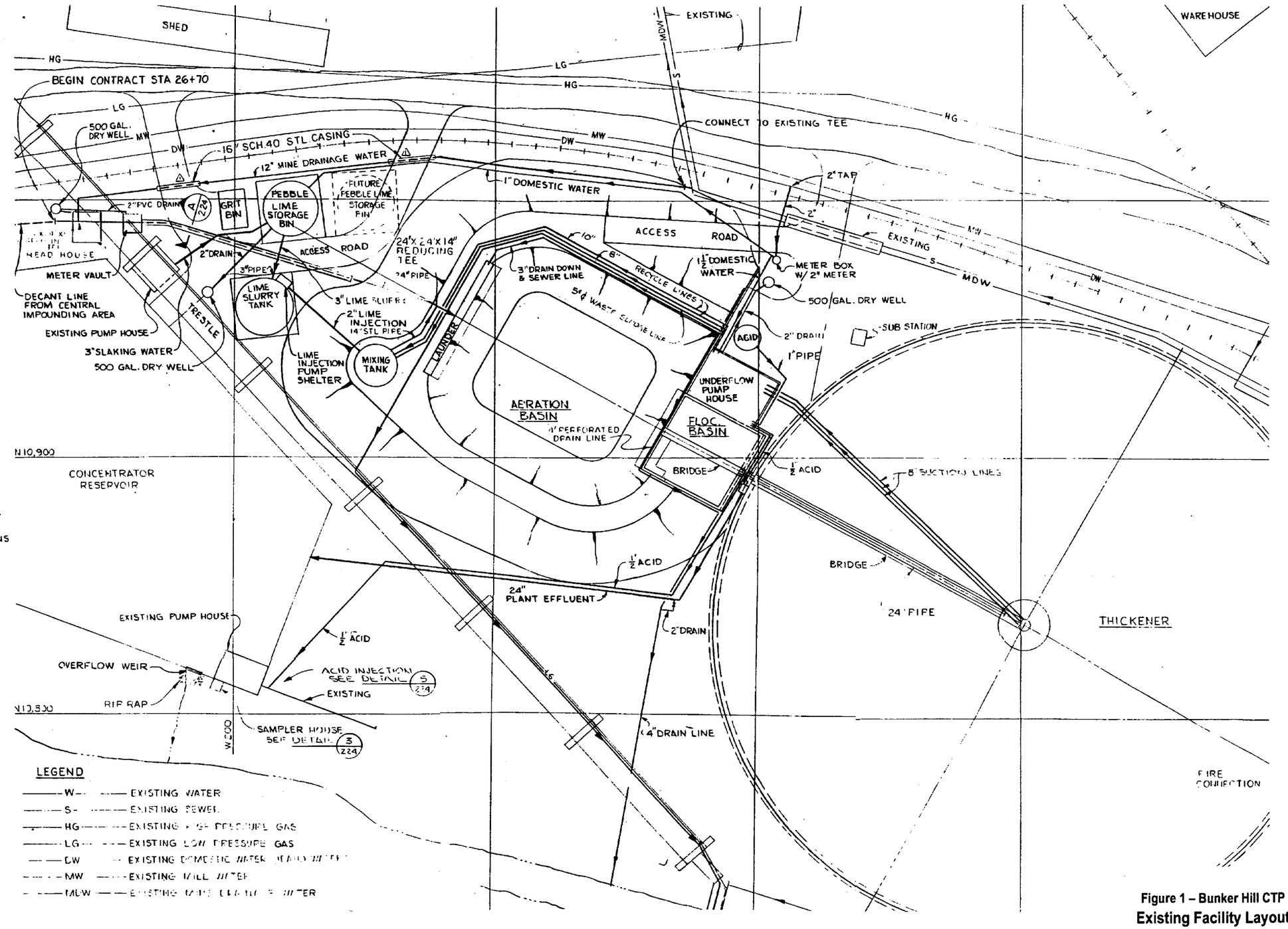
NOTE: lb/1,000 gal = pounds per 1,000 gallons
mg/L = milligrams per liter

TABLE 2
Preliminary Equipment Sizing
Bunker Hill CTP Master Plan

		Average Flow		Peak Flow	
	Units	**Normal Concentration**	**Peak Concentration**	**Normal Concentration**	**Peak Concentration**
Preliminary Design HDS Solids Recycle Ratio					
Phase 1	solids recycled/ solids formed	50	20	50	12
Phase 2	solids recycled/ solids formed	50	20	50	9.5
Reactor A (Sludge Conditioning)					
Number		1	1	1	1
Size (each)	gallons	2,500	2,500	2,500	2,500
Reactor B (Neutralization and Oxidation)					
Phase 1 Number		1	1	1	1
Phase 1 Size (each)	gallons	75,000	75,000	75,000	75,000
Phase 2 Number		1	2	1	2
Phase 2 Size	gallons	75,000	75,000	75,000	75,000
Estimated Solids Recycle Flows and Pump Sizes					
Phase 1 Flows	gpm	400	1,500	600	1,500
Phase 1 Pump Sizes		(2) 400 gpm and (2) 800 gpm			
Phase 2 Flows	gpm	400	1,500	1,200	2,400
Estimated Sludge Wasting Flows and Pump Sizes					
Phase 1 Volume Wasted	gal/day	10,500	110,000	18,000	183,000
Phase 2 Volume Wasted	gal/day	10,500	110,000	35,000	370,000
Preliminary Lime Systems					
Phase 1 Estimated Lime Use	Tons (as CAO)/day	8.6	69	14	115
Phase 2 Estimated Lime Use	Tons (as CAO)/day	8.6	69	29	230
Phase 1 Lime Slurry Feed Rate	gpm	17	140	30	230
Phase 2 Lime Slurry Feed Rate	gpm	17	140	60	450
Number of Slakers (Same for both Phase 1 and 2)		2	2	2	2

TABLE 2
Preliminary Equipment Sizing
Bunker Hill CTP Master Plan

		Average Flow		Peak Flow	
	Units	**Normal Concentration**	**Peak Concentration**	**Normal Concentration**	**Peak Concentration**
Granular Media Effluent Filtration System					
Phase 1 and 2 Filter Sizing	gpm/sf	4	4	4	4
Phase 1 Number of 12-ft-Diameter Filters Operational		4	4	6	6
Phase 2 Number of 12-ft-Diameter Filters Operational		4	4	12	12



NOTES:

1. ALL PIPES UNDER ROADWAYS AND OR TRAFFIC AREAS WILL BE ENCASED IN STEEL OR CONCRETE, UNLESS OTHERWISE DIRECTED
2. PIPE LOCATIONS, ROUTING AND CONNECTIONS ARE APPROXIMATE AS SHOWN; ACTUAL LOCATIONS TO BE FIELD DETERMINED.

Figure 1 – Bunker Hill CTP
Existing Facility Layout

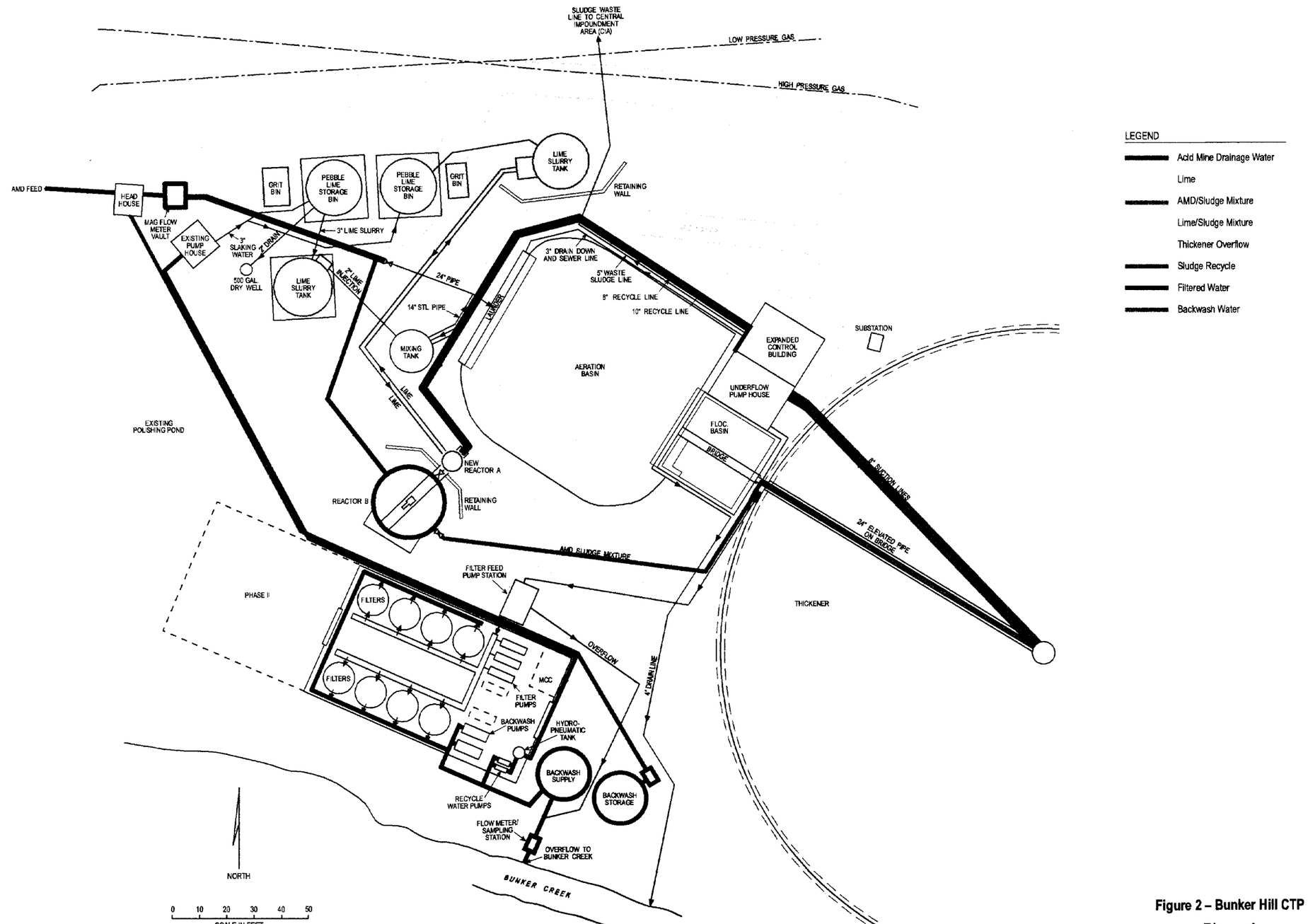
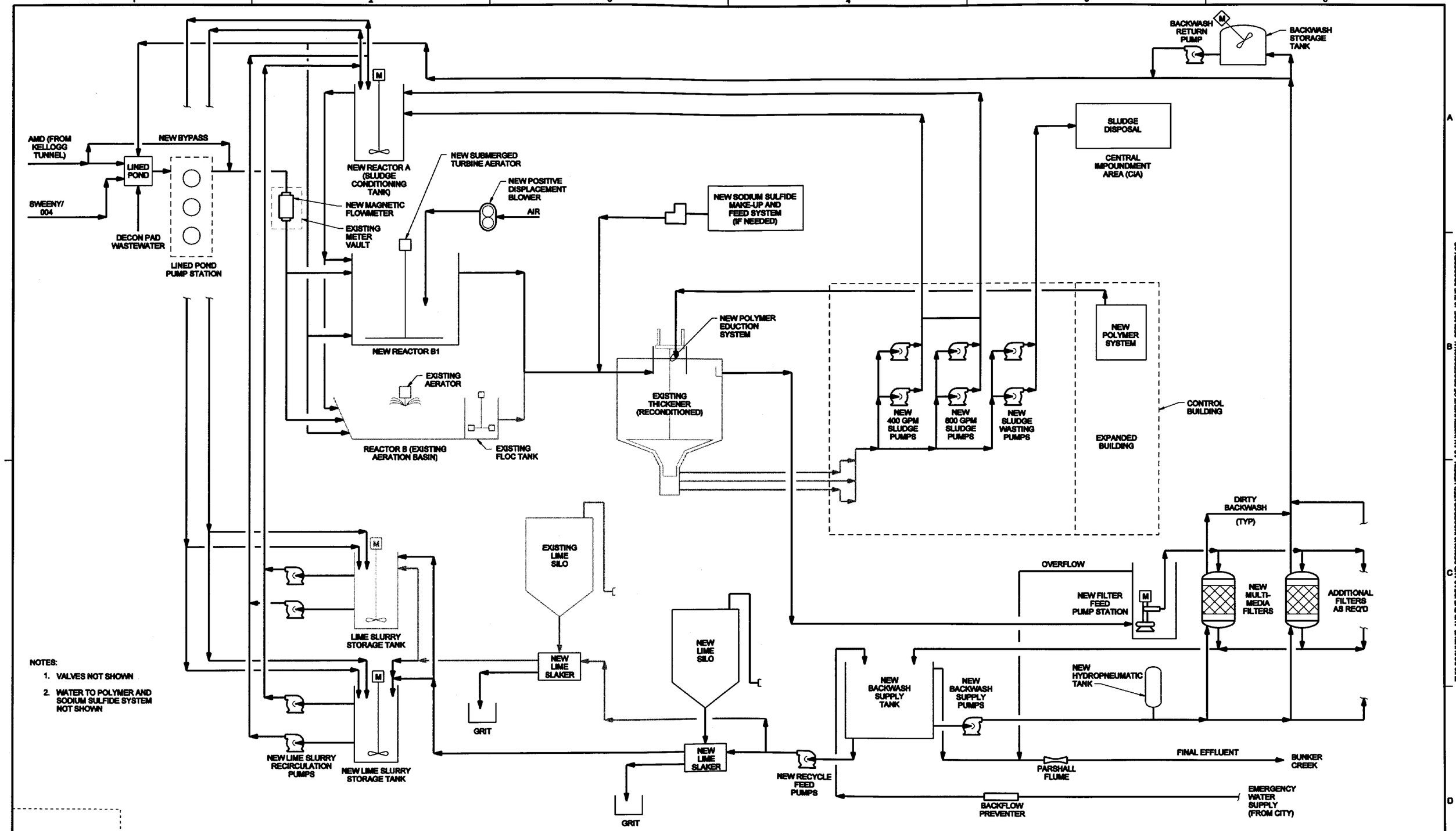


Figure 2 – Bunker Hill CTP

Phase 1

Additions and Modifications



NOTES:

1. VALVES NOT SHOWN
2. WATER TO POLYMER AND SODIUM SULFIDE SYSTEM NOT SHOWN

PRELIMINARY

NOT FOR CONSTRUCTION

DSGN	J MACK
DR	D SUNSERI
CHK	B YORK
APVD	J STEFANOFF

NO.	DATE	REVISION	BY	APVD

VERIFY SCALE
BAR IS ONE INCH ON ORIGINAL DRAWING.
0 1"
IF NOT ONE INCH ON THIS SHEET, ADJUST SCALES ACCORDINGLY.

CH2MHILL

BUNKER HILL
CENTRAL WATER TREATMENT PLANT

FIGURE 3 - PHASE 1
PROCESS FLOW DIAGRAM

SHEET	
DWG	
DATE	AUG 2000
PROJ	182220

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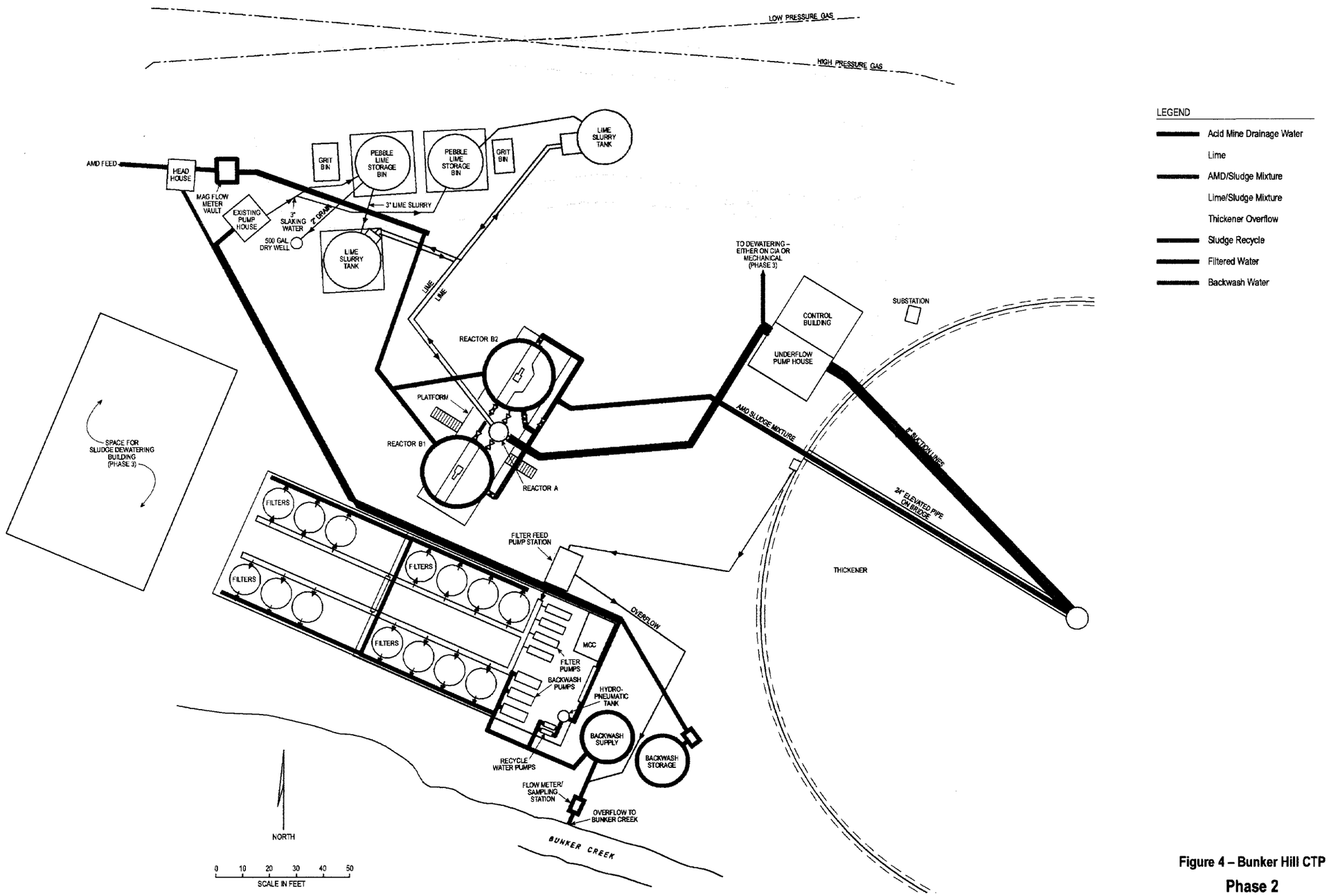
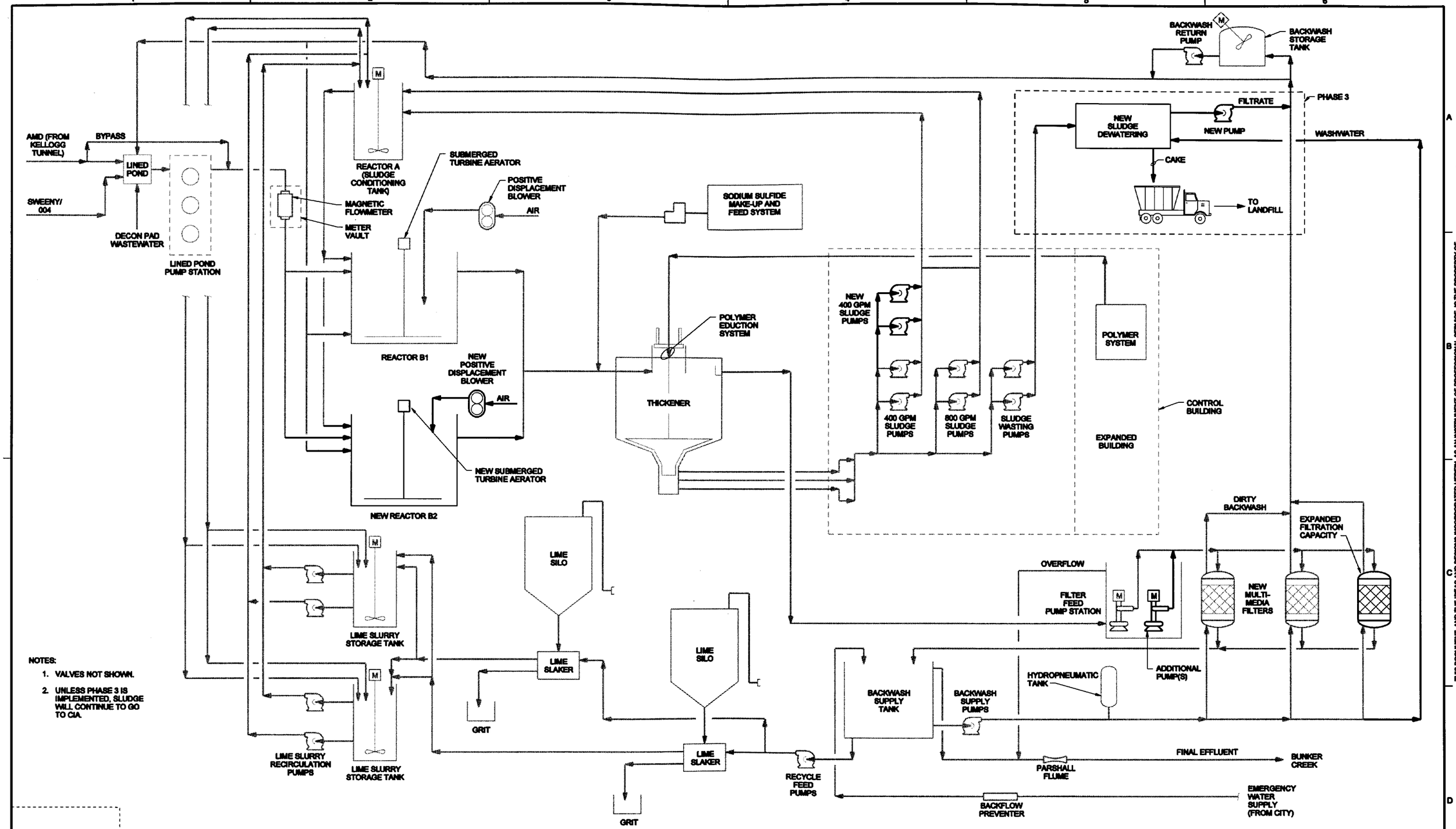


Figure 4 – Bunker Hill CTP

Phase 2

Additions and Modifications



NOTES:

1. VALVES NOT SHOWN.
2. UNLESS PHASE 3 IS IMPLEMENTED, SLUDGE WILL CONTINUE TO GO TO CIA.

PRELIMINARY

NOT FOR CONSTRUCTION

DSGN	J MACK
DR	D SUNSERI
CHK	B YORK
APVD	J STEFANOFF

NO.	DATE	REVISION	BY	APVD

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CENTRAL WATER TREATMENT PLANT

FIGURE 5 - PHASE 2 (AND 3) PROCESS FLOW DIAGRAM

SHEET	
DWG	
DATE	AUG 2000
PROJ	182220

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APPENDIX F

Updated TMDL Compliance Model Description

Updated TMDL Compliance Model Description

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PREPARED BY: Nahide Gulensoy / CH2M HILL
Matt Germon / CH2M HILL
Jim Stefanoff / CH2M HILL

DATE: June 22, 2000

1.0 Introduction

1.1 Purpose and Objectives

This technical memorandum presents a detailed description of the Total Maximum Daily Load (TMDL) Compliance Model Version 6 developed by CH2M HILL. *TMDL Compliance Model Description* (CH2M HILL, 2000a) was prepared for Version 1 of the model. This memorandum encompasses all changes made to the model since Version 1. The purpose of this model is to assist U.S. Environmental Protection Agency (EPA) Region 10 in evaluating the treatment, storage, and mitigation measures for acid mine drainage (AMD) coming from the Kellogg Tunnel at the Bunker Hill Mine in Idaho.

The model allows input of Central Treatment Plant (CTP) size and CTP effluent concentrations, and calculates the volume of AMD storage, and in some cases the volume of treated water storage, required to meet EPA Water Group's draft TMDLs for the Coeur d'Alene Basin for five water years (1973, 1982, 1981, 1987, and 1996). These five water years were selected to represent a range of Kellogg Tunnel flow conditions based on available Kellogg Tunnel data. More information on the relationship between Kellogg Tunnel and the South Fork Coeur d'Alene (SFCdA) River is presented in the *Hydrologic Evaluation for Bunker Hill Mine TMDL Compliance* (CH2M HILL, 2000b).

There are three separate copies of the TMDL Compliance Model Version 6, which include Version 6_max, Version 6_med, and Version 6_min. These versions of the model evaluate different water years than the five discussed above for Version 6. Version 6_max includes the five water years with the highest Kellogg Tunnel peaks (1973, 1974, 1981, 1982, and 1996). Version 6_med includes the five water years with the medium Kellogg Tunnel peaks (1978, 1979, 1980, 1983, and 1989). Version 6_min includes the four water years with the minimum Kellogg Tunnel peaks (1984, 1986, 1987, and 1988), and a high peak water year for comparison (1973).

1.2 Document Organization

This document is organized into five main sections, a reference section, and an attachment:

Section 1. Introduction—This section includes the purpose, objectives, and document organization of this technical memorandum.

Section 2. Model Instructions and Organization—This section presents model instructions, established links to other worksheets, embedded circular references, and descriptions of all worksheets.

Section 3. Model Input—This section presents definitions of each input parameter selected to run the model.

Section 4. Model Logic and Assumptions—This section presents the required input parameters and explains how they are used to run the model and produce output data and plots. It also describes the logic and assumptions involved in determining the TMDLs, identifying allowable discharge and storage requirements, conducting hydraulic routing and loading analysis, evaluating alternative water use, and establishing mitigation effectiveness.

Section 5. Model Output Parameters and Chart Output—This section contains output information for five water years based on the input parameters that were specified in the input section. The list of output parameters and a short description for each is presented in this section for two cases (with and without mitigation). This section also includes the output figures that present storage-related output for different CTP sizes in a graphic format for five water years.

Section 6. References—This section lists the references cited in this technical memorandum.

Attachment—The attachment contains instructions and assumptions for the TMDL compliance model, and worksheets for a sample scenario including input parameters, output parameters and charts, and alternative water use hydrograph.

2.0 Model Instructions and Organization

2.1 Starting the Model

The TMDL compliance model is contained in an Excel file. When the spreadsheet first appears on the screen, Excel asks if links to other worksheets should be updated. Updating the links for the model will update the Kellogg Tunnel and Pinehurst flow data if the user has access to the CH2M HILL server. However, the historic Kellogg Tunnel and Pinehurst flow data are not expected to change; thus, updating most likely will not be necessary.

Excel will then identify the presence of circular references. The “Cancel” option should be selected for this prompt. Circular references are necessary to build the output summary charts, also included in this Excel file. For practical purposes, the number of maximum iterations under Tools/Options/Calculation should be set to five or less.

2.2 Model Organization

The model is a spreadsheet that contains 10 worksheets. The “Instructions & Assumptions” worksheet presents an introduction and a brief background to the model.

The “Input” worksheet includes the input parameters required to run the model, as well as selected output parameters calculated for different input scenarios.

The “1973” worksheet contains the data and formulae that calculate the output parameters for water year 1973. The worksheets “1982,” “1981,” “1987,” and “1996” are similar to “1973” for the corresponding water years.

The “Alt. Water Use” worksheet includes the alternative water use (e.g., irrigation) hydrograph and calculates the output parameters accordingly, if the alternative water use option is selected.

The “Storage” worksheet presents storage-related output in million gallons (Mgal) for different CTP sizes [in gallons per minute (gpm)] in a graphic format when no AMD mitigation measures are taken. The storage-related output includes untreated storage required and untreated storage remaining at the end of a water year without mitigation.

In a similar manner, the “Storage + Mitigations” worksheet presents storage-related output in Mgal for different CTP sizes (in gpm) in a graphic format when one or more AMD mitigation measures are taken. The storage-related output includes untreated storage required and untreated storage remaining at the end of a water year when mitigation measures are taken to reduce Kellogg Tunnel flow.

3.0 Model Input

The selected input parameters that should be entered into the *Input* section of the “Input” worksheet are defined below.

Input for the **CTP size (gpm)** is required as a first step.

Treated Storage Size (Mgal) is another input parameter, which may be zero for design options that do not require a treated storage pond. Otherwise, 16 Mgal can be used as the treated storage size for a pond that had already been designed for the Bunker Hill Mine project.

Effluent Concentrations (µg/L) for total cadmium, total lead, and total zinc are the next input parameters required to run the model.

If **Mitigation Effectiveness** is being evaluated, the percent Kellogg Tunnel flow reduction associated with a proposed mitigation measure or combination of measures should be entered into this *Input* section. The model allows input of variable percent Kellogg Tunnel flow reductions for different ranges of Kellogg Tunnel flow. For example, input of 60 percent, 50 percent, 40 percent, and 30 percent would mean 60 percent reduction of flow for Kellogg Tunnel flows that are greater than 3,500 gpm; 50 percent reduction of flow for Kellogg Tunnel flows between 2,500 and 3,500 gpm; 40 percent reduction of flow for Kellogg Tunnel flows between 1,500 and 2,500 gpm; and 30 percent reduction of flow for Kellogg Tunnel flows less than 1,500 gpm.

TMDL Selection must be made for the TMDL calculation method (interpolated or step), and the percent allowable discharge load (100 percent in most cases) should also be specified in the *Input* section. Interpolated versus step TMDL calculation methods are described in Section 4.2. The input TMDLs used in this model are based on EPA’s draft TMDLs for the Coeur d'Alene Basin. Modifications may be necessary when the final TMDLs are available.

An **Alternative Use for Treated Water** is provided as an option, which would apply the water use hydrograph from the "Alt. Water Use" worksheet if this option were selected.

Acreage Irrigated must be selected if alternative water use is chosen as an option for irrigation. The water use hydrograph from the "Alt. Water Use" worksheet would provide alternative water use demand to irrigate 100 acres of land if "1" is selected for Acreage Irrigated. Similarly, "2" would provide irrigation of 200 acres, "3" would provide irrigation of 300 acres, and so on.

4.0 Model Logic and Assumptions

This section describes the logic and assumptions involved in running the TMDL compliance model. Figure F-1 demonstrates the TMDL compliance model logic and the different steps involved in calculating the output parameters. These steps are discussed in more detail below. The output parameters summarized in the *Output* section of the "Input" worksheet are printed in bold letters in the following discussion.

4.1 Hydraulic Routing Analysis

Maximum and Average KT Flow (gpm) present the maximum and average Kellogg Tunnel (KT) flow observed during a given water year. The available Kellogg Tunnel flow data for 1973 are for the timeframe between December 1, 1972, and October 31, 1973 (October data are included to make a more complete data set). For all other water years, Kellogg Tunnel flow data for October 1 to September 30 are used. The flow data are interpolated for those days when data are missing. Therefore, the average Kellogg Tunnel flow computed in this model is slightly different than the average flow reported for the same water years in the hydrologic evaluation (CH2M HILL, 2000a).

The model attempts to match Kellogg Tunnel flow with CTP size on a daily basis. If flow exceeds CTP size, the excess mine water is diverted to Storage (termed "hydraulic storage"). If Kellogg Tunnel flow is less than CTP size, Storage is pumped to match CTP size (as long as Storage is not empty). Storage starts at zero and cannot be less than zero during a water year. Effective CTP discharge (gpm) is Kellogg Tunnel flow adjusted on a daily basis by subtracting Storage diverted into hydraulic storage and adding Storage diverted to CTP. This number cannot be higher than the CTP size. The model assumes that exact pump rates can be achieved when pumping from or diverting to Storage. For instance, if Kellogg Tunnel flow is 3,510 gpm and CTP capacity is 3,500 gpm, exactly 10 gpm can be diverted to Storage.

The model was built to provide insight into the effectiveness of various AMD mitigation approaches, if this option is selected as an input for a given scenario. This is conducted by calculating an **Adjusted KT Flow (Maximum and Average)** that represents a reduction resulting from mitigation measures. The calculation is based on a range of percent reduction for varying Kellogg Tunnel flows. For instance, input of 60 percent, 50 percent, 40 percent, and 30 percent would mean 60 percent reduction of Kellogg Tunnel flow for Kellogg Tunnel flows that are greater than 3,500 gpm; 50 percent reduction of flow for Kellogg Tunnel flows between 2,500 and 3,500 gpm; 40 percent reduction of flow for Kellogg Tunnel flows between 1,500 and 2,500 gpm; and 30 percent reduction of flow for Kellogg Tunnel flows less than 1,500 gpm. The hydraulic results of the **KT Flow Reduction (Maximum and Average)** can be viewed in the difference between maximum and average Kellogg Tunnel

flows with and without the mitigations (as shown in the sample scenario worksheets included in the Attachment).

If **Treated Storage** is selected in the model input without the alternative water use option, water that is diverted into the Mine Pool as a result of exceedances of allowable discharge is first treated and placed in a treated storage pond until it is full. Treated storage is placed in the SFCdA River when flows and therefore allowable discharge is greater than CTP discharge.

If **Alternative Water Use** is selected as an option, then the **Alternative Water Use** hydrograph from "Alt. Water Use" is used to calculate the output parameters accordingly. **Acreage Irrigated** must be selected if alternative water use is chosen as an option for irrigation. The treated storage pond is used as a reservoir for the alternative use water. In this case, alternative water use takes precedence over discharge to the SFCdA River or storage in the treated storage pond. If alternative water use demand is higher than the amount of water treated at the CTP, any water stored in the treated storage pond (if selected in the model input) will be used to meet the alternative water demand.

Storage Required and **Annual TMDL Compliance** output parameters are computed based on the hydraulic routing and loading analyses, alternative water use option, and mitigation effectiveness. The loading analysis is mostly dependent on the interpolated or step TMDLs.

The logic and assumptions adapted in determining these output parameters are discussed in the following sections.

4.2 Loading Analysis

Interpolated TMDLs are calculated for a given SFCdA River flow condition from the nearest corresponding flow conditions. For example, the cadmium waste load allocation for a SFCdA River flow of 150 cubic feet per second (cfs) would be calculated by interpolating between the load allocation for the 10 percent flow condition (97 cfs, 0.00506 lb / day) and the 50 percent flow condition (268 cfs, 0.01920 lb / day). The result would be 0.00944 lb / day. Waste load allocations are not interpolated beyond the 90 percent flow condition. The EPA Region 10 Water Group is currently considering this interpolation method for SFCdA River.

Step TMDLs are determined as follows. For SFCdA River flows between zero and 10 percent, the 7Q10 flow condition applies. For SFCdA River flows between 10 percent and 50 percent, the 10 percent flow condition applies. For SFCdA River flows between 50 percent and 90 percent, the 50 percent flow condition applies. Finally, for SFCdA River flows greater than 90 percent, the 90 percent flow condition applies. For example, the cadmium waste load allocation for SFCdA River flow of 150 cfs would be 0.00506 lb / day.

The *percent allowable discharge metal load* (100 percent in most cases) is specified as an input parameter to evaluate the effect of slight increases in the allowable metal load to SFCdA River. This percentage is multiplied by the interpolated or step TMDL to calculate the *allowable metal discharge load* (pounds per day) to the SFCdA River on a daily basis.

The model forces CTP discharge to meet allowable loads by calculating an *allowable discharge* (in gpm) (termed "TMDL or metal-based load") on a daily basis. The *allowable discharge* is calculated by dividing the TMDL by the CTP effluent concentration and selecting the lowest

value for the three metals. For a 100 percent allowable load, the annual TMDL compliance will always be less than 100 percent (i.e., discharge load will be less than 100 percent of what is allowable), because some days the CTP discharge will not be able to match the allowable load of SFCdA River.

If the hydraulic load from the *effective CTP discharge* is greater than the *allowable discharge* (a flow rate based on loading for the limiting metal), then the excess flow is diverted. The model will first divert treated water for alternative water use. If diverted water is more than alternative water use demand, the model will then divert treated water to *Treated Storage* until it is full, unless it is zero. The model will then divert untreated water to *Storage* (termed "TMDL storage"). **Percent TMDL Storage** is the percentage of water diverted to Storage because of excess metal loading, while **Percent Hydraulic Storage** is the percentage of water diverted to Storage because of excess hydraulic loading.

If *the effective CTP discharge* is less than the *allowable discharge* (metal load-based), the model will pump from *Treated Storage* until it is empty. The pump rate from *Treated Storage* to the SFCdA River is not limited. For some days, the *effective CTP discharge* cannot be increased to match *allowable discharge* because it is either at CTP capacity or it is less and *Storage* is empty.

4.3 Storage Requirement

Cumulative Storage is the combined hydraulic and TMDL (metal load-based) storage diverted into *Storage* after subtracting volumes pumped out of *Storage*, calculated on a daily basis. **Maximum Storage Required (Mgal)** is the maximum storage requirement observed for *Cumulative Storage* in a given year, while **Remaining Storage at End of Water Year (Mgal)** is the remaining storage for *Cumulative Storage* at the end of a given water year.

4.4 Treated Storage Requirement

Cumulative Treated Storage is the combined hydraulic and TMDL (metal load-based) treated water storage diverted into *Treated Storage* after subtracting volumes pumped out of *Treated Storage* for discharge and for alternative water use, calculated on a daily basis. **Remaining Treated Storage at End of Water Year (Mgal)** is the remaining treated storage for *Cumulative Treated Storage* at the end of a given water year.

4.5 Allowable Discharge

Total CTP Discharge is the actual rate of discharge from the CTP, considering all diversion to and from *Storage*, *Treated Storage,* and *Alternative Water Use* for a given day. Actual mass loading is calculated for each metal by using the corresponding CTP effluent concentrations and *Total CTP Discharge*. The results are expressed as percent of allowable discharge for each metal over the entire water year (**Percent Allowable Cadmium, Lead, and Zinc Load**).

5.0 Model Output Parameters and Chart Output

5.1 Model Output Parameters

The *Output* section contains output information for five water years based on the input parameters that were specified earlier. The following is a list and short description of output parameters for two cases (with and without mitigation measures). The output parameters

summarized in the *Output* section of the "Input" worksheet are printed in bold letters in the following list.

- **Maximum KT Flow (gpm)** presents the maximum Kellogg Tunnel flow observed during a given water year.
- **Average KT Flow (gpm)** presents the average Kellogg Tunnel flow observed during a given water year.
- **Maximum Storage Required (Mgal)** is the maximum storage requirement observed for *Cumulative Storage* in a given year.
- **Remaining at End of Water Year (Mgal)** is the remaining storage in *Cumulative Storage* at the end of a given water year.
- **Treated Storage Remaining at End of Water Year (Mgal)** is the remaining treated storage in *Cumulative Treated Storage* at the end of a given water year.
- **Percent Hydraulic Storage** is the percentage of water diverted to Storage due to excess hydraulic loading.
- **Percent TMDL Storage** is the percentage of water diverted to Storage due to excess metal loading.
- **Alternative Water Demand (Mgal)** is calculated based on the alternative water use selection and number of acreage selected for irrigation for a given water year.
- **Actual Alternative Water Use (Mgal)** is the amount of treated water applied for alternative uses (such as irrigation) in a given water year.
- **Volume of Water Pumped from Storage (Mgal)** is the amount of AMD pumped from in-mine storage to CTP for treatment in a given water year.
- **Volume of Water Diverted to Storage (Mgal)** is the amount of AMD diverted to in-mine storage as a result of TMDL-based or hydraulic loading above the CTP capacity in a given water year.
- **Volume of CTP Discharge (Mgal)** is the amount of discharge from the CTP considering all diversion to and from storage, treated storage, and alternative water use for a given water year.
- **Percent Allowable Cadmium Load** is the percent of allowable cadmium discharge over the entire water year.
- **Percent Allowable Lead Load** is the percent of allowable lead discharge over the entire water year.
- **Percent Allowable Zinc Load** is the percent of allowable zinc discharge over the entire water year.
- **Adjusted KT flow (Maximum and Average) (gpm)** presents the maximum and average Kellogg Tunnel flow that represents a reduction resulting from mitigation measures.

The rest of the analysis and output parameters are similar to the analysis without mitigation measures as described in the earlier sections.

5.2 Model Chart Output

The *Chart Output* section contains storage-related output data used to plot figures in worksheets "Storage" and "Storage + Mitigations." The *Chart Output* section requires updating after modification of any input parameter (except CTP size), because of the presence of circular references. Each CTP size included in *Chart Output* section should be entered in the *Input* section CTP size cell for update. This will also update all storage-related output presented in the output figures.

The output figures present storage-related output in Mgal for different CTP sizes (in gpm) in a graphic format for five water years. The storage-related output includes untreated storage required and untreated storage remaining at the end of a water year. These figures provide a useful comparison of storage requirements at Bunker Hill Mine for a range of CTP sizes for selected five water years with and without AMD mitigation measures.

The *Chart Output* section also contains data for treated storage remaining (Mgal) at the end of a water year for different CTP sizes (gpm) when no mitigation measures are taken.

6.0 References

CH2M HILL, 2000a. *TMDL Compliance Model Description*. June 2000. CH2M HILL, Spokane, Washington.

CH2M HILL, 2000b. *Hydrologic Evaluation for Bunker Hill Mine TMDL Compliance*. February 2000. CH2M HILL, Spokane, Washington.

Notes:

→ Mine Water Flow Direction

1. Calculate TMDLs - TMDLs are calculated for cadmium, lead and zinc (lbs/day) according to daily SFCdA River flows. Discharge flows are then calculated by dividing the TMDL by effluent concentrations (ug/L) that were input to the model. The minimum flow is selected from the three metals and termed "allowable discharge flow" (gpm).
2. KT flow is compared to CTP capacity. If mitigations are used, the KT flow is reduced accordingly. AMD is pumped or diverted until KT flow equals CTP capacity. AMD cannot be pumped if storage is empty, so in some cases KT flow is less than CTP capacity.
3. CTP discharge (gpm) is compared to the allowable discharge (gpm) calculated in Step 1. If CTP discharge is greater than allowable discharge, AMD is diverted to the Mine Pool until they are equal.
4. Storage is calculated by adding the pump/diversion rates determined in Step 2 to the diversion rates in Step 3.
5. If treated storage is selected in the model input without the alternative water use option, water that is diverted in the third step is first placed in a treated storage pond until it is full. Treated storage is placed in the SFCdA River when flows and therefore allowable discharge is greater than CTP discharge.
6. If alternative water use is selected as an option, alternative water use takes precedence over discharge to the SFCdA River or storage in the treated storage pond. In the event that the alternative water use demand is higher than the amount of water treated at the CTP, any water stored in the treated storage pond (if selected in the model input) will be used to meet the alternative water demand.

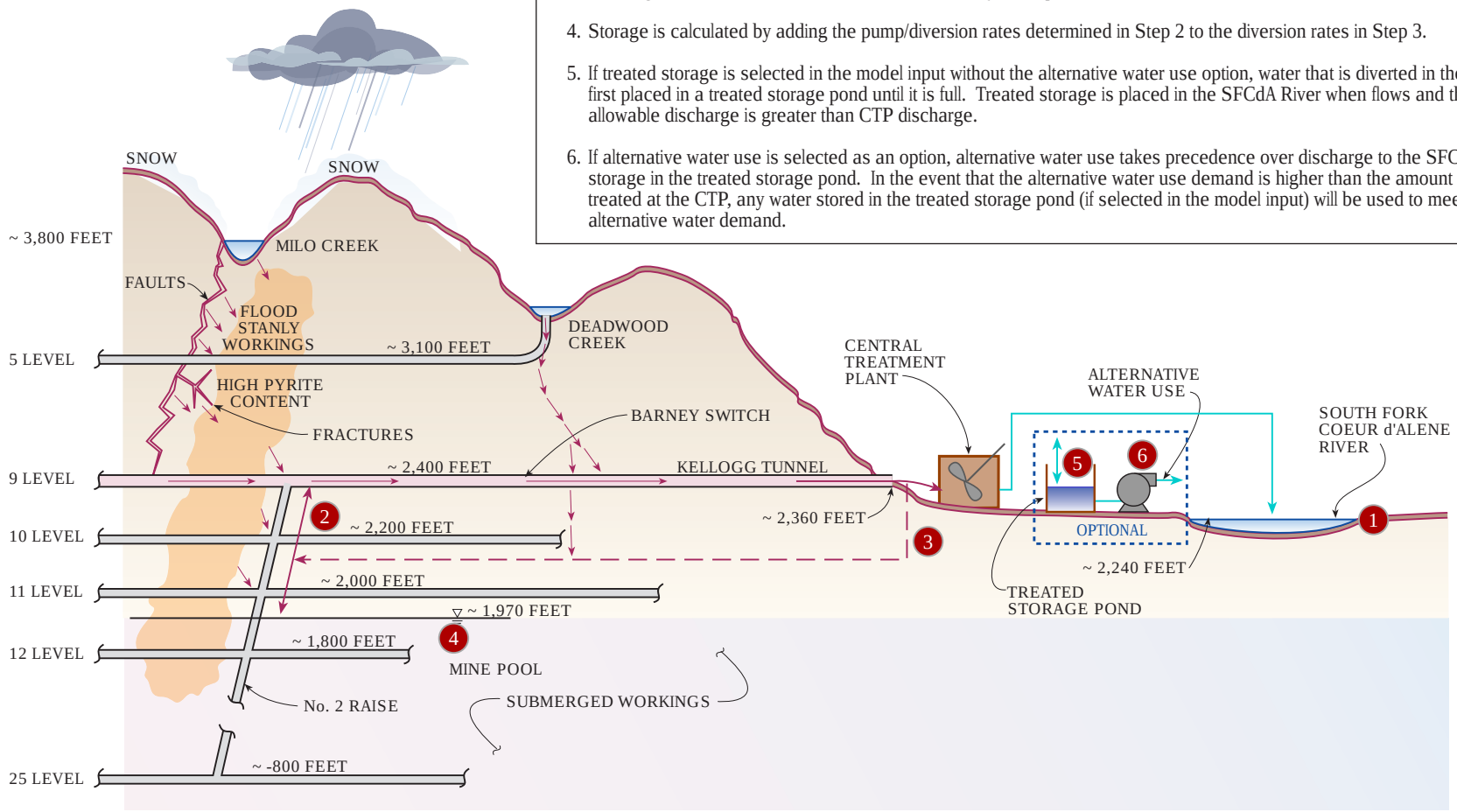


FIGURE F-1

TMDL COMPLIANCE MODEL LOGIC

BUNKER HILL MINE WATER MANAGEMENT RI/FS

CH2MHILL

Appendix F - Attachment 1

TMDL Compliance Model Instructions & Assumptions, Version 6
Bunker Hill Mine Water Management
Developed by Matt Germon/CH2M HILL for EPA Region 10

Introduction

This model was developed to assist EPA Region 10 in evaluating the treatment and storage of acid mine drainage coming from the Kellogg Tunnel (KT) at the Bunker Hill Mine in Idaho. The model allows input of Central Treatment Plant (CTP) size and CTP effluent concentrations and calculates the volume of AMD storage, and in some cases the volume of treated water storage, required to meet EPA Water Group's Draft Total Maximum Daily Loads (TMDLs) for the Coeur d'Alene Basin for five water years (1973, 1982, 1981, 1987, and 1996). These five water years were selected to represent a range of KT flow conditions based on available KT data. More information on the relationship between KT and SFCdA, and the development of synthetic SFCdA flows at Pinehurst, is presented in the draft *Hydrologic Evaluation of the Kellogg Tunnel and South Fork Coeur d'Alene River*, CH2M HILL, July 1999.

Instructions

When first opening the spreadsheet, Excel will ask if **links to other worksheets** should be updated. Click no. A **circular reference** will then be identified. Click cancel. Circular references are necessary to build the charts. They can be used in Excel, but the number of iterations under Tools/Options/Calculations should be set to 5 or less.

Input parameters required to operate the model are summarized in the "Input" worksheet. They include CTP size, treated storage size, and CTP effluent concentrations for cadmium, lead, and zinc. If a mitigation is being evaluated, the percent reduction in KT flow needs to be entered. Also, the TMDL calculation method (interpolated or step) needs to be specified, and the percent allowable load should be entered (in most cases this is 100 percent). An alternative use of treated water (e.g., irrigation) is provided as an option. If selected, the actual water use hydrograph needs to be input into the 'Alt. Water Use' worksheet. The existing hydrograph assumes irrigation of 100 acres of hillsides; the acreage may be increased in the input as well. The TMDLs are based on EPA's draft TMDLs for the Coeur d'Alene Basin, changes may be necessary when the final TMDLs are available.

After all input parameters are entered into the model, the model output is presented in the 'output' section of the "Input" worksheet. The output is also placed into data tables and can be viewed graphically in the graph worksheets. The data tables require updating (due to presence of circular references) after any input parameters is changed (except CTP size). To update, enter in each CTP size included in the data tables. This will update all storage-related output used to plot the summary graphs "Storage" and "Storage + Mitigations".

Model Logic and Assumptions

Model logic and assumptions are presented by category below.

TMDL Calculation -

Interpolated TMDLs are calculated for a given SFCdA flow condition from the nearest corresponding flow conditions. For example, the cadmium waste load allocation for SFCdA flow of 150 cfs would be calculated by interpolating between the load allocation for the 10% flow condition (97 cfs, 0.00506 lb/day) and the 50% flow condition (268 cfs, 0.01920 lb/day). The result would be 0.00944 lb/day. Waste load allocations are not interpolated beyond the 90% flow condition. This interpolation method is currently being considered by the EPA Region 10 Water Group.

Step TMDLs are determined as follows: for SFCdA flows between zero and 10%, the 7Q10 flow condition applies. For SFCdA flows between 10% and 50%, the 10% flow condition applies. For SFCdA flows between 50% and 90%, the 50% flow condition applies. Finally, for SFCdA flows greater than 90%, the 90% flow condition applies. For example, the cadmium waste load allocation for SFCdA flow of 150 cfs would be 0.00506 lb/day.

The percent allowable load feature was built into the model to evaluate the effect of slight increases in the allowable load to the SFCdA. The percent allowable load is multiplied by the interpolated or step TMDL to calculate the allowable load to the SFCdA on a daily basis. This feature can be effectively turned off by setting the percent allowable load to 100.

The model forces CTP discharge to meet allowable loads by calculating an allowable discharge (in gpm) on a daily basis. The allowable discharge is calculated by dividing the TMDL by the CTP effluent concentration, and selecting the lowest value for the three metals. For a 100 percent allowable load, the annual TMDL compliance will always be less than 100 percent because some days the capacity of the CTP will not be able to match the allowable load of SFCdA.

Hydraulic Routing -

The model attempts to match KT flow with CTP size on a daily basis. If KT flow exceeds CTP size, the excess is diverted to Storage (termed 'hydraulic storage'). If KT flow is less than CTP size, Storage is pumped to match CTP size (as long as storage is not 'empty').

Daily KT flow measurements were interpolated for those days when data were missing. Average KT flow for each year was calculated using actual and interpolated KT flow data.

Storage starts at zero and cannot be less than zero during a water year.

Actual alternative water use (gpm) is determined by the alternative water use demand (e.g., amount of water required to irrigate 100 acres or more for different months). This number cannot be higher than the CTP capacity or the KT flow, unless treated water in storage is used as alternative water in addition to the treated water from the CTP.

Effective CTP discharge (gpm) is calculated on a daily basis by subtracting INTO Storage and subtracting Alternative Water Use and adding OUT OF Storage to KT flow. This number cannot be higher than the CTP size.

The model assumes that exact pump rates can be achieved when pumping from or diverting to Storage or Treated Storage. For instance, if KT flow is 3510 gpm and CTP capacity is 3500 gpm, exactly 10 gpm can be diverted to Storage.

Loading Analysis -

If the hydraulic load from the effective CTP discharge is greater than the allowable discharge (a flow rate based on loading for the limiting metal), then the excess flow is diverted. The model will first divert treated water to Treated Storage until it is full, unless it is zero. The model will then divert untreated water to Storage (termed 'TMDL storage').

If the effective CTP discharge is less than the allowable discharge (metal load-based), the model will pump from Treated Storage until it is empty. The pump rate from Treated Storage to the SFCdA is not limited.

Note that for some days the effective CTP discharge cannot be increased to match allowable discharge because it is either at CTP capacity, or it is less and Storage is empty.

Cumulative Storage is the combined hydraulic and TMDL (metal load-based) storage diverted into Storage after subtracting volumes pumped out of Storage, calculated on a daily basis.

Total CTP Discharge is the actual rate of discharge from the CTP considering all diversion to and from Storage, Treated Storage, and Alternative Water Use for a given day.

Actual mass loading is calculated for each metal by using the corresponding CTP effluent concentrations and Total CTP Discharge. The results are expressed as percent of allowable discharge for each metal over the entire water year.

Alternative Water Use -

The Treated Storage pond is used as a reservoir for the alternative use of water. Even if treated storage is set to zero, if alternative water use option is selected in the input sheet, alternative water use will be incorporated in the results of the model. In the event that treated water can be pumped for discharge to SFCdA and treated water can also be used for alternative use, alternative water use takes precedence over discharge to SFCdA. In the event that alternative water use demand is higher than the amount of water treated at the CTP, any treated water stored in the treated storage pond will be used to meet the alternative water demand.

Mitigation Effectiveness -

The model was built to provide insight into the effectiveness of various AMD mitigations. This is conducted by calculating an adjusted KT flow that represents a reduction due to mitigation measures. The calculation is based on a percent reduction. For instance, a 10% KT flow reduction would result in a daily KT hydrograph with values that are 90% of the actual values for a given water year. Version 4_Dale of the Model allows input of variable % KT flow reductions for different ranges of KT flow (e.g., 60% reduction for KT>3500 gpm, 50% reduction for 3500>KT>2500, 40% reduction for 2500>KT>1500, 30% reduction for 1500>KT). The hydraulic results of the reduction can be viewed in the difference between maximum and average KT flows with and without the reduction. The rest of the analysis is similar to the analysis without mitigations as described above.

Example Input

TMDL Compliance Model Input/Output, Version 6_max
Bunker Hill Mine Water Management
Developed by Matt Germon/CH2M HILL for EPA Region 10

Input:

CTP/Treated Storage Size:		**Mitigation Effectiveness:**	% KT Flow Reduction
CTP size (gpm)	6,000	KT>3500 gpm:	60
Treated Storage size (Mgal)	0.0	3500 gpm>KT>2500 gpm:	50
Effluent Concentrations:		2500 gpm>KT>1500 gpm:	40
Cadmium (ug/L)	0.50	1500 gpm>KT:	30
Lead (ug/L)	3.0	**TMDL Selection:**	
Zinc (ug/L)	50.0	Interpolated or Step ("I" or "S")	S
Alternative Water Use:		Percent Allowable Discharge	100
Include Alt. Use? ("Y" or "N")	N	**Acreage Irrigated:** (1=100, 2=200, 3=300)	1

Draft TMDLs:

Flow Condition	Flow (cfs)	Cd (lb/day)	Pb (lb/day)	Zn (lb/day)
7Q10	68	0.02340	0.13400	2.42000
10%	97	0.03100	0.17600	3.20000
50%	268	0.06620	0.33300	6.56000
90%	1290	0.10500	0.29500	8.84000

Output:

Water Year	1973	1974	1981	1982	1996
Maximum KT Flow (gpm)	6,700	6,000	4,062	4,114	4,025
Average KT Flow (gpm)	2,338	1,877	1,831	2,209	1,421
Storage Required					
Maximum (Mgal)	5.4	0.0	0.0	0.0	0.0
Remaining at End of Water Year (Mgal)	0.0	0.0	0.0	0.0	0.0
reated Storage Remaining at End of Water Year (Mgal)	0.0	0.0	0.0	0.0	0.0
% Hydraulic Storage	25%	0%	0%	0%	0%
% TMDL Storage	75%	0%	0%	0%	0%
Alternative Water Demand (Mgal)	68.2	68.2	68.2	68.2	68.2
Actual Alternative Water Used (Mgal)	0.0	0.0	0.0	0.0	0.0
Volume of Water Pumped from Storage (Mgal)	8.2	0.0	0.0	0.0	0.0
Volume of Water Diverted to Storage (Mgal)	8.2	0.0	0.0	0.0	0.0
Volume of CTP Discharge (Mgal)	113.1	87.8	86.4	104.2	67.0
Annual TMDL Compliance					
% Allowable Cadmium Load	24%	15%	16%	20%	11%
% Allowable Lead Load	31%	23%	23%	29%	18%
% Allowable Zinc Load	24%	16%	17%	22%	13%
Storage Required w/ Mitigation					
Maximum KT Flow (gpm)	3,430	3,150	2,375	2,396	2,360
Average KT Flow (gpm)	1,491	1,259	1,235	1,462	949
Maximum KT Flow Reduction (gpm)	3,270	2,850	1,687	1,718	1,665
Average KT Flow Reduction (gpm)	847	618	596	747	472
Maximum (Mgal)	0.0	0.0	0.0	0.0	0.0
Remaining at end of water year (Mgal)	0.0	0.0	0.0	0.0	0.0
reated Storage Remaining at End of Water Year (Mgal)	0.0	0.0	0.0	0.0	0.0
% Hydraulic Storage	0%	0%	0%	0%	0%
% TMDL Storage	0.0%	0%	0%	0%	0%
Actual Alternative Water Used (Mgal)	0.0	0.0	0.0	0.0	0.0
Volume of Water Pumped from Storage (Mgal)	0.0	0.0	0.0	0.0	0.0
Volume of Water Diverted to Storage (Mgal)	0.0	0.0	0.0	0.0	0.0
Volume of CTP Discharge (Mgal)	210.4	81.5	58.2	90.4	47.5

Chart Output:

Storage (Mgal) vs. CTP Size (gpm)

	1973 - Ma>	1974 - Ma>	1981 - Ma>	1982 - Ma>	1996 - Maximum
1500	409.6	207.2	193.0	372.4	161.4
2000	235.5	63.5	76.6	165.6	88.9
2500	154.3	43.8	9.1	50.9	41.9
3000	85.5	33.7	4.2	8.4	13.8
3500	52.9	24.0	0.8	3.5	2.5
4000	30.8	15.7	0.1	0.5	0.0
5000	7.9	4.6	0.0	0.0	0.0
6000	5.4	0.0	0.0	0.0	0.0

Storage Remaining (Mgal) vs. CTP Size (gpm)

	1973 - Ren	1974 - Ren	1981 - Ren	1982 - Ren	1996 - Remaining
1500	402.9	207.2	193.0	372.4	77.7
2000	162.5	27.6	76.6	163.5	0.0
2500	0.0	0.0	1.7	23.7	0.0
3000	0.0	0.0	0.1	0.0	0.0
3500	0.0	0.0	0.0	0.0	0.0
4000	0.0	0.0	0.0	0.0	0.0
5000	0.0	0.0	0.0	0.0	0.0
6000	0.0	0.0	0.0	0.0	0.0

Treated Storage Remaining (Mgal) vs. CTP Size (gpm)

	1973	1974	1981	1982	1996
1500	0.0	0.0	0.0	0.0	0.0
2000	0.0	0.0	0.0	0.0	0.0
2500	0.0	0.0	0.0	0.0	0.0
3000	0.0	0.0	0.0	0.0	0.0
3500	0.0	0.0	0.0	0.0	0.0
4000	0.0	0.0	0.0	0.0	0.0
5000	0.0	0.0	0.0	0.0	0.0
6000	0.0	0.0	0.0	0.0	0.0

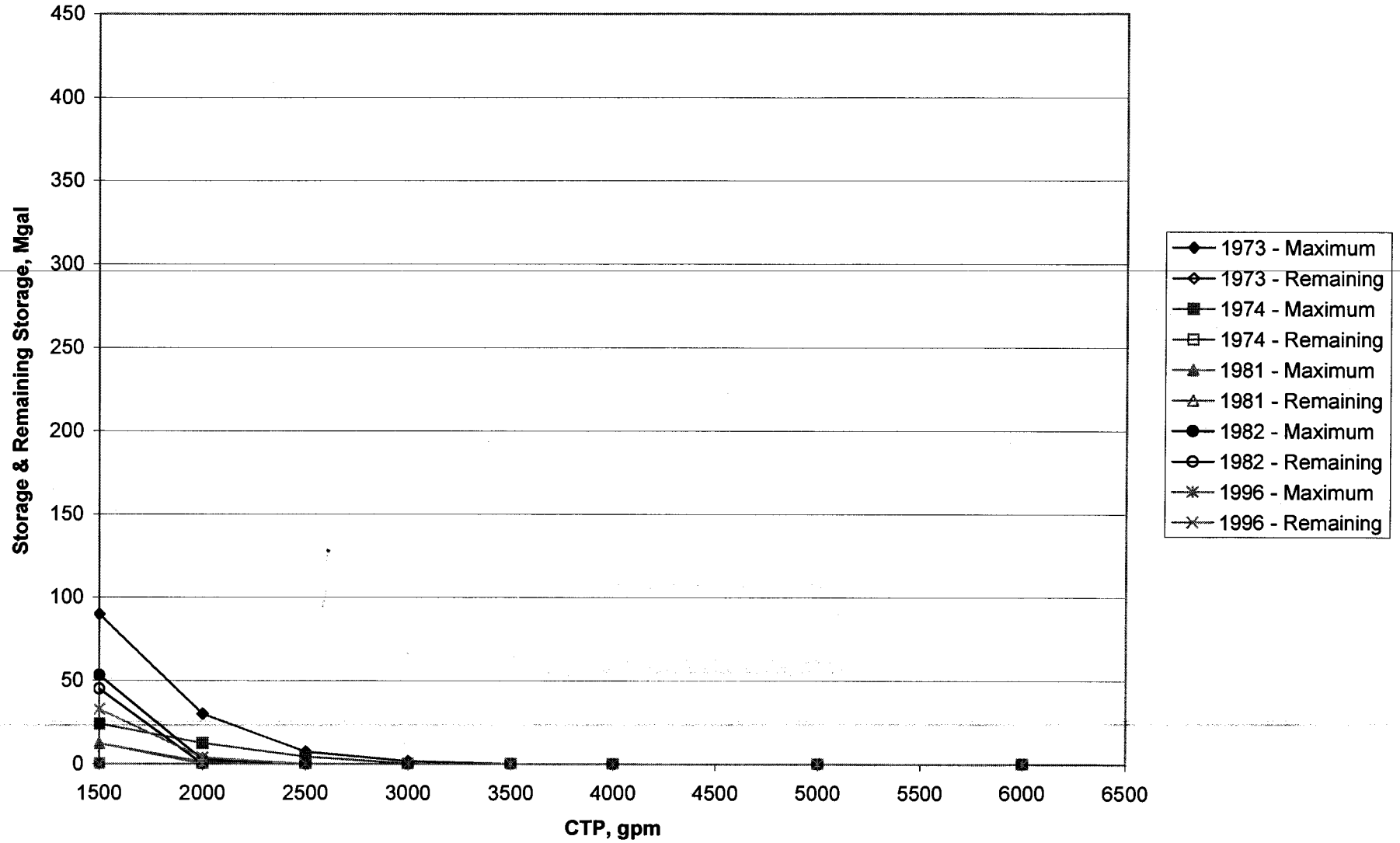
Storage (Mgal) w/Mitigation vs. CTP Size (gpm)

	1973	1974	1981	1982	1996
1500	89.8	24.1	12.3	53.2	32.8
2000	30.0	12.4	1.2	2.6	3.8
2500	7.3	4.3	0.0	0.0	0.0
3000	1.7	0.2	0.0	0.0	0.0
3500	0.0	0.0	0.0	0.0	0.0
4000	0.0	0.0	0.0	0.0	0.0
5000	0.0	0.0	0.0	0.0	0.0
6000	0.0	0.0	0.0	0.0	0.0

Storage Remaining (Mgal) w/ Mitigation vs. CTP Size (gpm)

	1973	1974	1981	1982	1996
1500	0.0	0.0	12.3	45.0	0.0
2000	0.0	0.0	0.0	0.0	0.0
2500	0.0	0.0	0.0	0.0	0.0
3000	0.0	0.0	0.0	0.0	0.0
3500	0.0	0.0	0.0	0.0	0.0
4000	0.0	0.0	0.0	0.0	0.0
5000	0.0	0.0	0.0	0.0	0.0
6000	0.0	0.0	0.0	0.0	0.0

Example Chart
Required and Remaining Storage vs. CTP Capacity
CTP Effluent Concentrations: 0.50 Cd, 3.0 Pb, 50 Zn
No Treated Storage, No Treated Water Use
Mitigations: 60%, 50%, 40%, 30%
for KT>3500, 3500>KT>2500, 2500>KT>1500, 1500>KT



Appendix F - Attachment 2

TMDL Compliance Model Instructions & Assumptions, Version 6
Bunker Hill Mine Water Management
Developed by Matt Germon/CH2M HILL for EPA Region 10

Introduction

This model was developed to assist EPA Region 10 in evaluating the treatment and storage of acid mine drainage coming from the Kellogg Tunnel (KT) at the Bunker Hill Mine in Idaho. The model allows input of Central Treatment Plant (CTP) size and CTP effluent concentrations and calculates the volume of AMD storage, and in some cases the volume of treated water storage, required to meet EPA Water Group's Draft Total Maximum Daily Loads (TMDLs) for the Coeur d'Alene Basin for five water years (1973, 1982, 1981, 1987, and 1996). These five water years were selected to represent a range of KT flow conditions based on available KT data. More information on the relationship between KT and SFCdA, and the development of synthetic SFCdA flows at Pinehurst, is presented in the draft *Hydrologic Evaluation of the Kellogg Tunnel and South Fork Coeur d'Alene River*, CH2M HILL, July 1999.

Instructions

When first opening the spreadsheet, Excel will ask if **links to other worksheets** should be updated. Click no. A **circular reference** will then be identified. Click cancel. Circular references are necessary to build the charts. They can be used in Excel, but the number of iterations under Tools/Options/Calculations should be set to 5 or less.

Input parameters required to operate the model are summarized in the "Input" worksheet. They include CTP size, treated storage size, and CTP effluent concentrations for cadmium, lead, and zinc. If a mitigation is being evaluated, the percent reduction in KT flow needs to be entered. Also, the TMDL calculation method (interpolated or step) needs to be specified, and the percent allowable load should be entered (in most cases this is 100 percent). An alternative use of treated water (e.g., irrigation) is provided as an option. If selected, the actual water use hydrograph needs to be input into the 'Alt. Water Use' worksheet. The existing hydrograph assumes irrigation of 100 acres of hillsides; the acreage may be increased in the input as well. The TMDLs are based on EPA's draft TMDLs for the Coeur d'Alene Basin, changes may be necessary when the final TMDLs are available.

After all input parameters are entered into the model, the model output is presented in the 'output' section of the "Input" worksheet. The output is also placed into data tables and can be viewed graphically in the graph worksheets. The data tables require updating (due to presence of circular references) after any input parameters is changed (except CTP size). To update, enter in each CTP size included in the data tables. This will update all storage-related output used to plot the summary graphs "Storage" and "Storage + Mitigations".

Model Logic and Assumptions

Model logic and assumptions are presented by category below.

TMDL Calculation -

Interpolated TMDLs are calculated for a given SFCdA flow condition from the nearest corresponding flow conditions. For example, the cadmium waste load allocation for SFCdA flow of 150 cfs would be calculated by interpolating between the load allocation for the 10% flow condition (97 cfs, 0.00506 lb/day) and the 50% flow condition (268 cfs, 0.01920 lb/day). The result would be 0.00944 lb/day. Waste load allocations are not interpolated beyond the 90% flow condition. This interpolation method is currently being considered by the EPA Region 10 Water Group.

Step TMDLs are determined as follows: for SFCdA flows between zero and 10%, the 7Q10 flow condition applies. For SFCdA flows between 10% and 50%, the 10% flow condition applies. For SFCdA flows between 50% and 90%, the 50% flow condition applies. Finally, for SFCdA flows greater than 90%, the 90% flow condition applies. For example, the cadmium waste load allocation for SFCdA flow of 150 cfs would be 0.00506 lb/day.

The percent allowable load feature was built into the model to evaluate the effect of slight increases in the allowable load to the SFCdA. The percent allowable load is multiplied by the interpolated or step TMDL to calculate the allowable load to the SFCdA on a daily basis. This feature can be effectively turned off by setting the percent allowable load to 100.

The model forces CTP discharge to meet allowable loads by calculating an allowable discharge (in gpm) on a daily basis. The allowable discharge is calculated by dividing the TMDL by the CTP effluent concentration, and selecting the lowest value for the three metals. For a 100 percent allowable load, the annual TMDL compliance will always be less than 100 percent because some days the capacity of the CTP will not be able to match the allowable load of SFCdA.

Hydraulic Routing -

The model attempts to match KT flow with CTP size on a daily basis. If KT flow exceeds CTP size, the excess is diverted to Storage (termed 'hydraulic storage'). If KT flow is less than CTP size, Storage is pumped to match CTP size (as long as storage is not 'empty').

Daily KT flow measurements were interpolated for those days when data were missing. Average KT flow for each year was calculated using actual and interpolated KT flow data.

Storage starts at zero and cannot be less than zero during a water year.

Actual alternative water use (gpm) is determined by the alternative water use demand (e.g., amount of water required to irrigate 100 acres or more for different months). This number cannot be higher than the CTP capacity or the KT flow, unless treated water in storage is used as alternative water in addition to the treated water from the CTP.

Effective CTP discharge (gpm) is calculated on a daily basis by subtracting INTO Storage and subtracting Alternative Water Use and adding OUT OF Storage to KT flow. This number cannot be higher than the CTP size.

The model assumes that exact pump rates can be achieved when pumping from or diverting to Storage or Treated Storage. For instance, if KT flow is 3510 gpm and CTP capacity is 3500 gpm, exactly 10 gpm can be diverted to Storage.

Loading Analysis -

If the hydraulic load from the effective CTP discharge is greater than the allowable discharge (a flow rate based on loading for the limiting metal), then the excess flow is diverted. The model will first divert treated water to Treated Storage until it is full, unless it is zero. The model will then divert untreated water to Storage (termed 'TMDL storage').

If the effective CTP discharge is less than the allowable discharge (metal load-based), the model will pump from Treated Storage until it is empty. The pump rate from Treated Storage to the SFCdA is not limited.

Note that for some days the effective CTP discharge cannot be increased to match allowable discharge because it is either at CTP capacity, or it is less and Storage is empty.

Cumulative Storage is the combined hydraulic and TMDL (metal load-based) storage diverted into Storage after subtracting volumes pumped out of Storage, calculated on a daily basis.

Total CTP Discharge is the actual rate of discharge from the CTP considering all diversion to and from Storage, Treated Storage, and Alternative Water Use for a given day.

Actual mass loading is calculated for each metal by using the corresponding CTP effluent concentrations and Total CTP Discharge. The results are expressed as percent of allowable discharge for each metal over the entire water year.

Alternative Water Use -

The Treated Storage pond is used as a reservoir for the alternative use of water. Even if treated storage is set to zero, if alternative water use option is selected in the input sheet, alternative water use will be incorporated in the results of the model. In the event that treated water can be pumped for discharge to SFCdA and treated water can also be used for alternative use, alternative water use takes precedence over discharge to SFCdA. In the event that alternative water use demand is higher than the amount of water treated at the CTP, any treated water stored in the treated storage pond will be used to meet the alternative water demand.

Mitigation Effectiveness -

The model was built to provide insight into the effectiveness of various AMD mitigations. This is conducted by calculating an adjusted KT flow that represents a reduction due to mitigation measures. The calculation is based on a percent reduction. For instance, a 10% KT flow reduction would result in a daily KT hydrograph with values that are 90% of the actual values for a given water year. Version 4_Dale of the Model allows input of variable % KT flow reductions for different ranges of KT flow (e.g., 60% reduction for KT>3500 gpm, 50% reduction for 3500>KT>2500, 40% reduction for 2500>KT>1500, 30% reduction for 1500>KT). The hydraulic results of the reduction can be viewed in the difference between maximum and average KT flows with and without the reduction. The rest of the analysis is similar to the analysis without mitigations as described above.

Example Input

TMDL Compliance Model Input/Output, Version 6_max
Bunker Hill Mine Water Management
Developed by Matt Germon/CH2M HILL for EPA Region 10

Input:

CTP/Treated Storage Size:		**Mitigation Effectiveness:**	% KT Flow Reduction
CTP size (gpm)	6,000	KT>3500 gpm:	60
Treated Storage size (Mgal)	0.0	3500 gpm>KT>2500 gpm:	50
Effluent Concentrations:		2500 gpm>KT>1500 gpm:	40
Cadmium (ug/L)	0.50	1500 gpm>KT:	30
Lead (ug/L)	3.0	**TMDL Selection:**	
Zinc (ug/L)	50.0	Interpolated or Step ("I" or "S")	S
Alternative Water Use:		Percent Allowable Discharge	100
Include Alt. Use? ("Y" or "N")	N	**Acreage Irrigated:** (1=100, 2=200, 3=300)	1

Draft TMDLs:

Flow Condition	Flow (cfs)	Cd (lb/day)	Pb (lb/day)	Zn (lb/day)
7Q10	68	0.02340	0.13400	2.42000
10%	97	0.03100	0.17600	3.20000
50%	268	0.06620	0.33300	6.56000
90%	1290	0.10500	0.29500	8.84000

Output:

Water Year	1973	1974	1981	1982	1996
Maximum KT Flow (gpm)	6,700	6,000	4,062	4,114	4,025
Average KT Flow (gpm)	2,338	1,877	1,831	2,209	1,421
Storage Required					
Maximum (Mgal)	5.4	0.0	0.0	0.0	0.0
Remaining at End of Water Year (Mgal)	0.0	0.0	0.0	0.0	0.0
reated Storage Remaining at End of Water Year (Mgal)	0.0	0.0	0.0	0.0	0.0
% Hydraulic Storage	25%	0%	0%	0%	0%
% TMDL Storage	75%	0%	0%	0%	0%
Alternative Water Demand (Mgal)	68.2	68.2	68.2	68.2	68.2
Actual Alternative Water Used (Mgal)	0.0	0.0	0.0	0.0	0.0
Volume of Water Pumped from Storage (Mgal)	8.2	0.0	0.0	0.0	0.0
Volume of Water Diverted to Storage (Mgal)	8.2	0.0	0.0	0.0	0.0
Volume of CTP Discharge (Mgal)	113.1	87.8	86.4	104.2	67.0
Annual TMDL Compliance					
% Allowable Cadmium Load	24%	15%	16%	20%	11%
% Allowable Lead Load	31%	23%	23%	29%	18%
% Allowable Zinc Load	24%	16%	17%	22%	13%
Storage Required w/ Mitigation					
Maximum KT Flow (gpm)	3,430	3,150	2,375	2,396	2,360
Average KT Flow (gpm)	1,491	1,259	1,235	1,462	949
Maximum KT Flow Reduction (gpm)	3,270	2,850	1,687	1,718	1,665
Average KT Flow Reduction (gpm)	847	618	596	747	472
Maximum (Mgal)	0.0	0.0	0.0	0.0	0.0
Remaining at end of water year (Mgal)	0.0	0.0	0.0	0.0	0.0
reated Storage Remaining at End of Water Year (Mgal)	0.0	0.0	0.0	0.0	0.0
% Hydraulic Storage	0%	0%	0%	0%	0%
% TMDL Storage	0.0%	0%	0%	0%	0%
Actual Alternative Water Used (Mgal)	0.0	0.0	0.0	0.0	0.0
Volume of Water Pumped from Storage (Mgal)	0.0	0.0	0.0	0.0	0.0
Volume of Water Diverted to Storage (Mgal)	0.0	0.0	0.0	0.0	0.0
Volume of CTP Discharge (Mgal)	210.4	81.5	58.2	90.4	47.5

Chart Output:

Storage (Mgal) vs. CTP Size (gpm)

	1973 - Ma>	1974 - Ma>	1981 - Ma>	1982 - Ma>	1996 - Maximum
1500	409.6	207.2	193.0	372.4	161.4
2000	235.5	63.5	76.6	165.6	88.9
2500	154.3	43.8	9.1	50.9	41.9
3000	85.5	33.7	4.2	8.4	13.8
3500	52.9	24.0	0.8	3.5	2.5
4000	30.8	15.7	0.1	0.5	0.0
5000	7.9	4.6	0.0	0.0	0.0
6000	5.4	0.0	0.0	0.0	0.0

Storage Remaining (Mgal) vs. CTP Size (gpm)

	1973 - Ren	1974 - Ren	1981 - Ren	1982 - Ren	1996 - Remaining
1500	402.9	207.2	193.0	372.4	77.7
2000	162.5	27.6	76.6	163.5	0.0
2500	0.0	0.0	1.7	23.7	0.0
3000	0.0	0.0	0.1	0.0	0.0
3500	0.0	0.0	0.0	0.0	0.0
4000	0.0	0.0	0.0	0.0	0.0
5000	0.0	0.0	0.0	0.0	0.0
6000	0.0	0.0	0.0	0.0	0.0

Treated Storage Remaining (Mgal) vs. CTP Size (gpm)

	1973	1974	1981	1982	1996
1500	0.0	0.0	0.0	0.0	0.0
2000	0.0	0.0	0.0	0.0	0.0
2500	0.0	0.0	0.0	0.0	0.0
3000	0.0	0.0	0.0	0.0	0.0
3500	0.0	0.0	0.0	0.0	0.0
4000	0.0	0.0	0.0	0.0	0.0
5000	0.0	0.0	0.0	0.0	0.0
6000	0.0	0.0	0.0	0.0	0.0

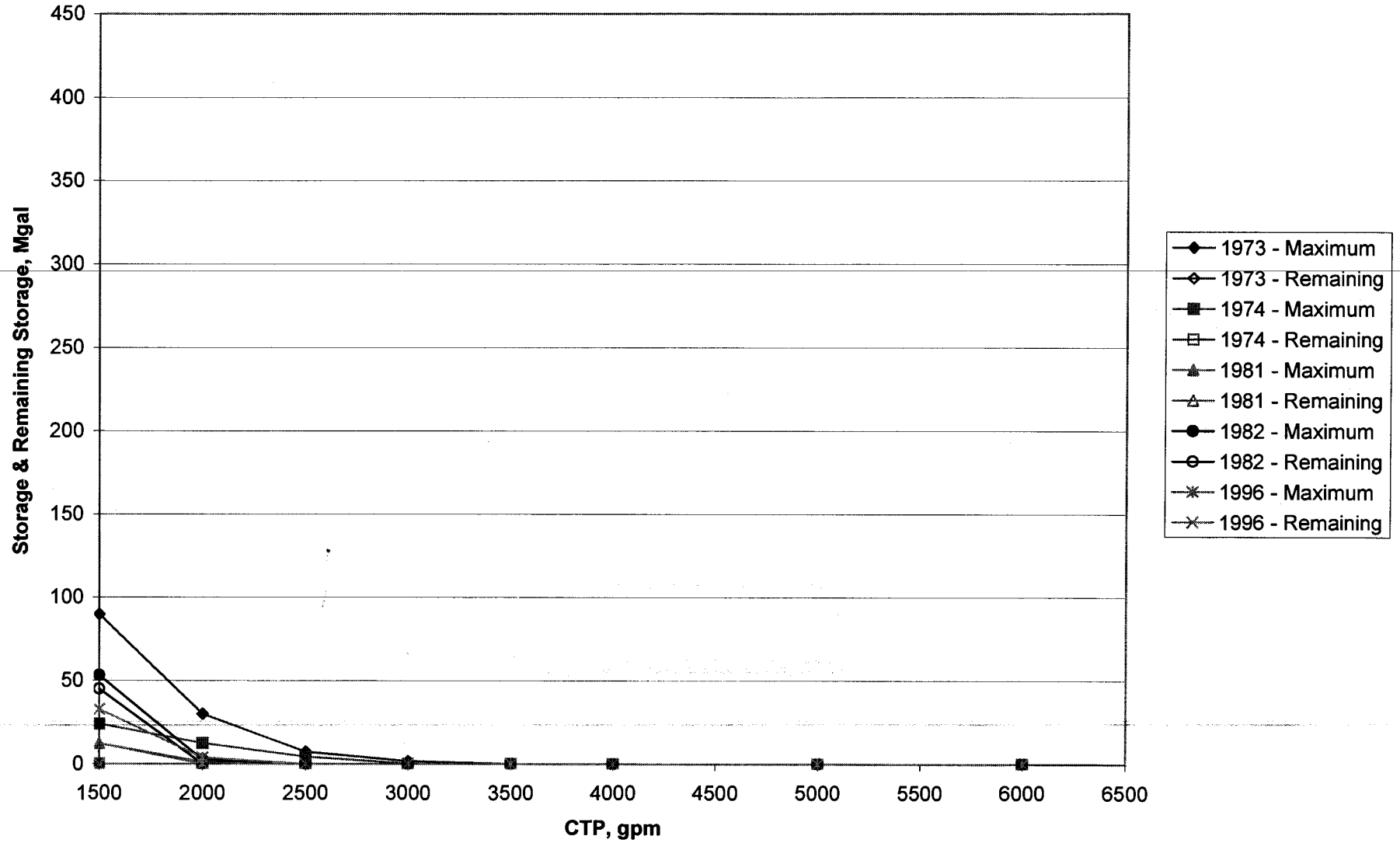
Storage (Mgal) w/Mitigation vs. CTP Size (gpm)

	1973	1974	1981	1982	1996
1500	89.8	24.1	12.3	53.2	32.8
2000	30.0	12.4	1.2	2.6	3.8
2500	7.3	4.3	0.0	0.0	0.0
3000	1.7	0.2	0.0	0.0	0.0
3500	0.0	0.0	0.0	0.0	0.0
4000	0.0	0.0	0.0	0.0	0.0
5000	0.0	0.0	0.0	0.0	0.0
6000	0.0	0.0	0.0	0.0	0.0

Storage Remaining (Mgal) w/ Mitigation vs. CTP Size (gpm)

	1973	1974	1981	1982	1996
1500	0.0	0.0	12.3	45.0	0.0
2000	0.0	0.0	0.0	0.0	0.0
2500	0.0	0.0	0.0	0.0	0.0
3000	0.0	0.0	0.0	0.0	0.0
3500	0.0	0.0	0.0	0.0	0.0
4000	0.0	0.0	0.0	0.0	0.0
5000	0.0	0.0	0.0	0.0	0.0
6000	0.0	0.0	0.0	0.0	0.0

Example Chart
Required and Remaining Storage vs. CTP Capacity
CTP Effluent Concentrations: 0.50 Cd, 3.0 Pb, 50 Zn
No Treated Storage, No Treated Water Use
Mitigations: 60%, 50%, 40%, 30%
for KT>3500, 3500>KT>2500, 2500>KT>1500, 1500>KT



Example Alternative Water Use Selection

Enter flow rates that can be directed to an alternative water use if this option is selected on the 'Input" worksheet.

Month	Alt. Water Use gpm
Oct	0.0
Nov	0.0
Dec	0.0
Jan	0.0
Feb	0.0
Mar	0.0
Apr	0.0
May	27.0
Jun	287.0
Jul	499.0
Aug	499.0
Sep	232.0

APPENDIX G

Cost Estimates

Alternative 1

Existing Mine Water Collection System O&M Costs

	Qty	Unit	Total Unit Cost	Total Cost	Comments
Annual Costs					
Mine Operation Labor	52	Week		$320,840	Weekly cost based on estimate of existing mine owner incurred cost. Includes a crew of a foreman, hoistman, backup hoistman, and 3-man repair crew. Total labor at $4,410/week and a benefits package at $1,760/week = $6,170/week total
Power	12	Month		$102,000	Power cost estimated for existing mine operations
Level Repair and Maintenance	1	Year	81,000	$81,000	9, 10, and 11 level areas necessary for mine water control
Compressor Maintenance	1	Year	20,000	$20,000	Compressor maintenance costs
Hoist Maintenance	1	Year	160,000	$160,000	Cherry Hoist, #2 Hoist, and #1 Temporary Hoist
Pumps and Pipe Columns	1	Year	100,000	$100,000	Maintenance of mine dewatering pumps in #2 Shaft, #1 Shaft, 9 Level Pumps, and piping
Electrical System Maintenance	1 Year		40,000	$40,000	
Subtotal				**$823,840**	
Contingency	15%			**$123,576**	15% contingency for repairs and maintenance
Allowance	15%			**$123,576**	15% allowance for unaccounted for costs
Total Annual Cost				**$1,070,992**	

KT Portal Channel and Flume Cleaning Costs

	Qty	Unit	Total Unit Cost	Total Cost	Comments
Annual Costs					
Inspection and Cleanout	12	Month	1,875	$22,500	Based on USACE cost of $1,875/month for existing cleanout work
Contingency	10%			$2,250	
Total Annual Cost				**$24,750**	

Cost Summary

Alternative 1
Cost Summary

Alternative 1
No Further Action
Interest = 7%

Remedy Component	Capital Cost ($)	Annual O&M Cost ($/yr)
AMD Mitigations	0	0
AMD Collection (Assumes 4 years)	0	1,071,000
AMD Conveyance (Assumes 4 years)	0	93,000
AMD Storage (Assumes 4 years)	0	31,000
AMD Treatment (Assumes 4 years)	0	682,000
Sludge Management (Assumes 4 years)[2]	0	0
Performance Monitoring (Assumes 4 years)[2]	0	0
Totals	**0**	**1,877,000**
4-Year NPV of O&M[1]		**6,358,000**
Total 4-Year Net Present Value	**6,358,000**	

[1]A four-year net present value period is assumed because the CTP will be shut down in 3 to 5 years depending on remaining sludge disposal capacity.

[2] O&M costs included in treatment costs.

AMD Mitigations	Capital	O&M
None	0	0
	0	0
Subtotal	0	0

AMD Collection	Capital	O&M
Existing In Mine System	0	1,071,000
Subtotal	0	1,071,000

AMD Conveyance	Capital	O&M
Existing Concrete Channel	0	25,000
Existing HDPE Pipeline	0	68,000
Subtotal	0	93,000

AMD Storage	Capital	O&M
Existing Lined Pond	0	31,000
Subtotal	0	31,000

AMD Treatment	Capital	O&M
Existing CTP	0	682,000
Subtotal	0	682,000

Sludge Management	NPV of Capital	Annualized O&M
CIA Sludge Beds	0	0
Subtotal	0	0

Performance Monitoring	Capital	O&M
KT Portal	0	0
CTP	0	0
Subtotal	0	0

Alternative 2

ALTERNATIVE 2
Bunker Hill Mine Water RI/FS
Performance Monitoring Costs

Tasks	Qty	Unit	Material Unit Cost	Labor Unit Cost	Equip Unit Cost	Annual Cost	Comments
Annual Costs							
KT Portal (flow and chemistry)							
KT Flow Data Management & Reporting	1	MO	0	800	0	$9,600	Monthly data management; asm 10 hrs/month (1 person) @ $80/hr labor
KT Sampling and Analysis	1	WK	300	0	0	$15,600	Weekly sample collection; asm analysis cost of $300/sample for Cd, Pb, Zn, SO4, LD/SF
Sample Collection Supplies	1	YR	500	0	0	$500	Allowance
Sample Shipment	1	YR	500	0	0	$500	Allowance
Subtotal						**$16,600**	
Allowance	10%					**$1,660**	
Total Annual Cost						**$18,260**	
CTP (flow and chemistry)							
	1	Day	150	0	0	$54,750	Total, Cd, Pb, and Zn low level analysis
Subtotal						**$54,750**	
Allowance	10%					**$5,475**	
Total Annual Cost						**$60,225**	
TOTAL ANNUAL COST (YEARS 1 THROUGH 30)						**$78,485**	

Cost Summary

Alternative 2A
Cost Summary

Alternative 2A
Treatment Only (with CIA Sludge Disposal Beds)
Interest = 7%

Remedy Component	Capital Cost ($)	Annual O&M Cost ($/yr)
AMD Mitigations	0	0
AMD Collection	0	1,071,000
AMD Conveyance	340,000	130,000
AMD Storage	0	31,000
AMD Treatment	9,561,000	849,000
Sludge Management[1]	6,743,000	46,000
Performance Monitoring	0	78,000
Totals	**16,644,000**	**2,205,000**
30-Year NPV of O&M		**27,362,000**
Total 30-Year Net Present Value	**44,006,000**	

[1]The capital cost is the present worth of capital expenditures which occur during the 30-year time period. See the sludge option NPV calculation summary sheet for details.

AMD Mitigations	Capital	O&M
None	0	0
	0	0
Subtotal	0	0

AMD Collection	Capital	O&M
Existing In Mine System	0	1,071,000
Subtotal	0	1,071,000

AMD Conveyance	Capital	O&M
Existing Concrete Channel	0	25,000
Existing HDPE Pipeline	0	68,000
New HDPE Pipline to CTP	340,000	37,000
Subtotal	340,000	130,000

AMD Storage	Capital	O&M
Existing Lined Pond	0	31,000
Subtotal	0	31,000

AMD Treatment	Capital	O&M
Upgraded 5000 gpm CTP with Media Filters	9,561,000	849,000
Subtotal	9,561,000	849,000

Sludge Management	NPV of Capital	O&M
CIA Sludge Disposal Beds	5,083,000	46,000
Close Existing CIA Disposal Bed (Yr 2)	1,660,000	0
Subtotal	6,743,000	46,000

Performance Monitoring	Capital	O&M
KT Portal	0	18,000
CTP	0	60,000
Subtotal	0	78,000

Alternative 2B
Cost Summary

Alternative 2B		
Treatment Only (with Mechanical Dewatering and Offsite Sludge Disposal)		
Interest =	**7%**	
Remedy Component	**Capital Cost ($)**	**Annual O&M Cost ($/yr)**
AMD Mitigations	0	0
AMD Collection	0	1,071,000
AMD Conveyance	340,000	130,000
AMD Storage	0	31,000
AMD Treatment	9,561,000	849,000
Sludge Management[1]	5,590,000	745,000
Performance Monitoring	0	78,000
Totals	**15,491,000**	**2,904,000**
30-Year NPV of O&M		**36,036,000**
Total 30-Year Net Present Value	**51,527,000**	

[1]The capital cost is the present worth of capital expenditures which occur during the 30-year time period.

AMD Mitigations	Capital	O&M
None	0	0
	0	0
Subtotal	0	0

AMD Collection	Capital	O&M
Existing In Mine System	0	1,071,000
Subtotal	0	1,071,000

AMD Conveyance	Capital	O&M
Existing Concrete Channel	0	25,000
Existing HDPE Pipeline	0	68,000
New HDPE Pipline to CTP	340,000	37,000
Subtotal	340,000	130,000

AMD Storage	Capital	O&M
Existing Lined Pond	0	31,000
Subtotal	0	31,000

AMD Treatment	Capital	O&M
Upgraded 5000 gpm CTP with Media Filters	9,561,000	849,000
Subtotal	9,561,000	849,000

Sludge Management	NPV of Capital	O&M
Mechanical Dewatering System	3,930,000	152,000
Offsite Haulage and Disposal		593,000
Close Existing CIA Disposal Bed (Yr 2)	1,660,000	0
Subtotal	5,590,000	745,000

Performance Monitoring	Capital	O&M
KT Portal	0	18,000
CTP	0	60,000
Subtotal	0	78,000

Alternative 2C
Cost Summary

Alternative 2C
Treatment Only (with Smelter Closure Area Sludge Disposal Beds)
Interest = 7%

Remedy Component	Capital Cost ($)	Annual O&M Cost ($/yr)
AMD Mitigations	0	0
AMD Collection	0	1,071,000
AMD Conveyance	340,000	130,000
AMD Storage	0	31,000
AMD Treatment	9,561,000	849,000
Sludge Management[1]	11,260,000	72,000
Performance Monitoring	0	78,000
Totals	**21,161,000**	**2,231,000**
30-Year NPV of O&M		**27,685,000**
Total 30-Year Net Present Value	**48,846,000**	

[1]The capital cost is the present worth of capital expenditures which occur during the 30-year time period. See the sludge option NPV calculation summary sheet for details.

AMD Mitigations	Capital	O&M
None	0	0
	0	0
Subtotal	0	0

AMD Collection	Capital	O&M
Existing In Mine System	0	1,071,000
Subtotal	0	1,071,000

AMD Conveyance	Capital	O&M
Existing Concrete Channel	0	25,000
Existing HDPE Pipeline	0	68,000
New HDPE Pipline to CTP	340,000	37,000
Subtotal	340,000	130,000

AMD Storage	Capital	O&M
Existing Lined Pond	0	31,000
Subtotal	0	31,000

AMD Treatment	Capital	O&M
Upgraded 5000 gpm CTP with Media Filters	9,561,000	849,000
Subtotal	9,561,000	849,000

Sludge Management	NPV of Capital	O&M
Smelter Closure Area Sludge Disposal Beds	9,600,000	72,000
Close Existing CIA Disposal Bed (Yr 2)	1,660,000	0
Subtotal	11,260,000	72,000

Performance Monitoring	Capital	O&M
KT Portal	0	18,000
CTP	0	60,000
Subtotal	0	78,000

Alternative 2D
Cost Summary

Alternative 2D
Treatment Only (with CIA Sludge Drying Beds and Smelter Closure Area Landfill)
Interest = 7%

Remedy Component	Capital Cost ($)	Annual O&M Cost ($/yr)
AMD Mitigations	0	0
AMD Collection	0	1,071,000
AMD Conveyance	340,000	130,000
AMD Storage	0	31,000
AMD Treatment	9,561,000	849,000
Sludge Management[1]	10,239,000	154,000
Performance Monitoring	0	78,000
Totals	**20,140,000**	**2,313,000**
30-Year NPV of O&M		**28,702,000**
Total 30-Year Net Present Value	**48,842,000**	

[1]The capital cost is the present worth of capital expenditures which occur during the 30-year time period.

AMD Mitigations	Capital	O&M
None	0	0
	0	0
Subtotal	0	0

AMD Collection	Capital	O&M
Existing In Mine System	0	1,071,000
Subtotal	0	1,071,000

AMD Conveyance	Capital	O&M
Existing Concrete Channel	0	25,000
Existing HDPE Pipeline	0	68,000
New HDPE Pipline to CTP	340,000	37,000
Subtotal	340,000	130,000

AMD Storage	Capital	O&M
Existing Lined Pond	0	31,000
Subtotal	0	31,000

AMD Treatment	Capital	O&M
Upgraded 5000 gpm CTP with Media Filters	9,561,000	849,000
Subtotal	9,561,000	849,000

Sludge Management	NPV of Capital	O&M
Smelter Closure Area Landfill	6,770,000	103,000
Landfill Closure (Yr 31)	278,000	0
CIA Sludge Drying Beds	1,531,000	51,000
Close Existing CIA Disposal Bed (Yr 2)	1,660,000	0
Subtotal	10,239,000	154,000

Performance Monitoring	Capital	O&M
KT Portal	0	18,000
CTP	0	60,000
Subtotal	0	78,000

Alternative 2
Option A

Bunker Hill
Acid Mine Drainage
Disposal of Raw Sludge in CIA Disposal Beds
Order of Magnitude Cost Opinion

DATE: 11/22/2000
PROJECT NO.: 152215.FS.02
ESTIMATE BY: D. Bunte
N. Gulensoy

DESCRIPTION	QTY	UNIT	TOTAL UNIT COST	TOTAL COST
Subgrade Stabilization	10,500	C. Y.	4.00	$42,000
Liner Protection Sand	8250	C. Y.	10.00	$82,500
Drain Rock	1,950	C. Y.	18.00	$35,100
Ditch Lining Geotextile	21,200	S. Y.	1.65	$34,980
G C L	18,100	S. Y.	4.05	$73,305
H D P E Geomembrane	18,100	S. Y.	5.40	$97,740
H D P E Pipe, 10"	550	L. F.	23.00	$12,650
Erosion Control Matting	11800	S.Y.	1.50	$17,700
Perf Pipe, 4"	2000	L. F.	2.00	$4,000
Perf Pipe, 6"	580	L. F.	3.00	$1,740
HDPE Pipe, 6"	130	L. F.	2.50	$325
Strip Drains	700	L. F.	1.75	$1,225
Valves, 6" Knife Gate	2	Each	700.00	$1,400
Valves, 10" Knife Gate	6	Each	1,000.00	$6,000
Air/Vacuum Release Valve	1	Each	2,000.00	$2,000
Valve Vault	6	Each	1,950.00	$11,700
Water Tight Manhole	1	Each	3,500.00	$3,500
Vertical Filtrate Drains	6	Each	4,000.00	$24,000
Cleanouts	2	Each	750.00	$1,500
Perimeter Road Embankment (not reduced)	28275	C. Y.	10	$282,750
Chain Link Fence and Gates (not reduced)	1000	L.F.	12	$12,000
Crushed Rock Surfacing (not reduced)	1500	C. Y.	15	$22,500
SUBTOTAL				**$1,024,865**
MISC ALLOWANCE	**10%**			**$102,487**
SUBTOTAL				**$1,127,352**
CONTINGENCY	**30%**			**$338,205**
SUBTOTAL				**$1,465,557**
MOBILIZATION	**15%**			**$219,834**
CONSTRUCTION TOTAL				**$1,685,390**
SALES TAX ON MATERIALS	**5.0%**			**$25,622**
ENGINEERING AND SUPPORT	**20%**			**$337,078**
CONSTRUCTION MANAGEMENT	**8%**			**$134,831**
CAPITAL COST SUBSEQUENT BEDS TOTAL (ROUNDED)				**$2,180,000**
ANNUAL O&M COST FOR OPERATING BED			**$46,000**	
NPV OF ANNUAL O&M COSTS (30 YEARS @ 7% INTEREST)				**$566,000**
NPV OF INITIAL AND SUBSEQUENT BEDS & CLOSURES CAPITAL COSTS @ 7% INTERES1				**$6,859,000**
TOTAL 30-YEAR PRESENT WORTH COST @ 7% INTEREST				**$7,425,000**

NOTES:
Misc Allowance markup is to include items known to exist but cannot be quantified at this time.
Contingency is for scope changes that are presently unforeseen.
Mobilization includes bonds, insurance, temporary facilities, health & safety, demobilization, etc.

NOTE: The above cost opinion is in November 2000 dollars and does not include escalation. The order of magnitude cost opinion shown has been prepared for guidance in project evaluation at the time of preparation. The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope, final schedule and other variable factors. As a result, the final project costs will vary from those presented above. Because of these factors, funding needs must be carefully reviewed prior to making specific financial decisions or establishing final budgets.

Alternative 2A
Cost Summary

Alternative 2A
Treatment Only (with CIA Sludge Disposal Beds)
Interest = 7%

Remedy Component	Capital Cost ($)	Annual O&M Cost ($/yr)
AMD Mitigations	0	0
AMD Collection	0	1,071,000
AMD Conveyance	340,000	130,000
AMD Storage	0	31,000
AMD Treatment	9,561,000	849,000
Sludge Management[1]	6,743,000	46,000
Performance Monitoring	0	78,000
Totals	**16,644,000**	**2,205,000**
30-Year NPV of O&M		**27,362,000**
Total 30-Year Net Present Value	**44,006,000**	

[1]The capital cost is the present worth of capital expenditures which occur during the 30-year time period. See the sludge option NPV calculation summary sheet for details.

AMD Mitigations	Capital	O&M
None	0	0
	0	0
Subtotal	0	0

AMD Collection	Capital	O&M
Existing In Mine System	0	1,071,000
Subtotal	0	1,071,000

AMD Conveyance	Capital	O&M
Existing Concrete Channel	0	25,000
Existing HDPE Pipeline	0	68,000
New HDPE Pipline to CTP	340,000	37,000
Subtotal	340,000	130,000

AMD Storage	Capital	O&M
Existing Lined Pond	0	31,000
Subtotal	0	31,000

AMD Treatment	Capital	O&M
Upgraded 5000 gpm CTP with Media Filters	9,561,000	849,000
Subtotal	9,561,000	849,000

Sludge Management	NPV of Capital	O&M
CIA Sludge Disposal Beds	5,083,000	46,000
Close Existing CIA Disposal Bed (Yr 2)	1,660,000	0
Subtotal	6,743,000	46,000

Performance Monitoring	Capital	O&M
KT Portal	0	18,000
CTP	0	60,000
Subtotal	0	78,000

Alternative 3

ALTERNATIVES 3 AND 4
Bunker Hill Mine Water RI/FS
Performance Monitoring Costs

Tasks	Qty	Unit	Material Unit Cost	Labor Unit Cost	Equip Unit Cost	Annual Cost	Comments
Annual Costs							
KT Portal (flow and chemistry) (Years 1 through 30)							
KT Flow Data Management & Reporting	1	MO	0	800	0	$9,600	Monthly data management; asm 10 hrs/month (1 person) @ $80/hr labor
KT Sampling and Analysis	1	WK	300	0	0	$15,600	Weekly sample collection; asm analysis cost of $300/sample for Cd, Pb, Zn, SO4, LD/SF
Sample Collection Supplies	1	YR	500	0	0	$500	Allowance
Sample Shipment	1	YR	500	0	0	$500	Allowance
Subtotal						**$16,600**	
Allowance	10%					**$1,660**	
Total Annual Cost						**$18,260**	
CTP (flow and chemistry) (Years 1 through 30)							
	1	Day	150	0	0	$54,750	Total, Cd, Pb, and Zn low level analysis
Subtotal						**$54,750**	
Allowance	10%					**$5,475**	
Total Annual Cost						**$60,225**	
Surface Streams (flow only) (Years 1 through 10)							
Automatic Flow Recorder Data Download	1	MO	0	1,280	0	$15,360	Monthly data download from 3 flow recorders and 8 piezometers; asm 16 hrs/month (2 persons, 1 field day) @ $80/hr labor
Flow Data Recording & Management for surface water diversions	1	MO	0	320	0	$3,840	Monthly data management; asm 4 hrs/month (1 person) @ $80/hr labor
Data management & reporting for existing piezometers	1	MO	0	640	0	$7,680	Monthly data management and reporting; asm 8 hrs/month (1 person) @ $80/hr labor
Subtotal						**$26,880**	
Allowance	10%					**$2,688**	
Total Annual Cost						**$29,568**	
In-Mine (flow and chemistry) (Years 1 through 10)							
Sample Collection	15	Event	0	3,840	0	$57,600	15 events, 48 hrs/event (3 persons, 2 field days) @ $80/hr labor
Sample Collection Materials	15	Event	0	0	0	$2,000	Allowance
Sample Preparation and Packaging	15	Event	0	2,560	0	$38,400	15 events, 32 hrs/event (2 persons, 2 days) @ $80/hr labor
Sample Shipment	15	Event	100	0		$1,500	
Sample Analysis	15	Event	5,600	0	0	$84,000	15 events, 14 samples/event, $400/sample for analytical (total and dissolved metals, sulfate, lime demand, solids formed, TSS)
Data management, interpretation, QA/QC and reporting	15	Event	0	640	0	$9,600	15 events, 8 hrs/event, @ $80/hr labor
Subtotal						**$193,100**	
Allowance	10%					**$19,310**	
Total Annual Cost						**$212,410**	

Cost Summary

Alternative 3A
Cost Summary

Alternative 3A
Phased Mitigations/Treatment (with CIA Sludge Disposal Beds)
Interest = 7%

Remedy Component	Capital Cost ($)	Annual O&M Cost ($/yr)
AMD Mitigations	4,990,000	55,000
AMD Collection	0	1,071,000
AMD Conveyance	340,000	130,000
AMD Storage	1,950,000	157,000
AMD Treatment	8,198,000	797,000
Sludge Management[1]	6,474,000	42,000
Performance Monitoring[2]	0	215,000
Totals	**21,952,000**	**2,467,000**
30-Year NPV of O&M		**30,613,000**
Total 30-Year Present Worth	**52,565,000**	

[1]The capital cost is the present worth of capital expenditures which occur during the 30-year time period. See the sludge option NPV calculation summary sheet for details.

[2]The monitoring annual O&M cost is the annualized amount of the 30-year net present value , since annual costs vary over the 30-year period. See the monitoring summary sheet for details.

AMD Mitigations	Capital	O&M
West Fork Milo Creek Diversion	3,590,000	28,000
Rehabilitate Phil Sheridan Diversion	1,250,000	18,000
Plug Drill Holes	150,000	9,000
Subtotal	4,990,000	55,000

AMD Collection	Capital	O&M
Existing In Mine System	0	1,071,000
Subtotal	0	1,071,000

AMD Conveyance	Capital	O&M
Existing Concrete Channel	0	25,000
Existing HDPE Pipeline	0	68,000
New HDPE Pipeline to CTP	340,000	37,000
Subtotal	340,000	130,000

AMD Storage	Capital	O&M
In-Mine Gravity Diversion System	710,000	Included in Extraction System
New Mine Pool Extraction System	1,240,000	126,000
Existing Lined Pond	0	31,000
Subtotal	1,950,000	157,000

AMD Treatment	Capital	O&M
Upgraded 2,500 gpm CTP with Media Filters	8,198,000	797,000
Subtotal	8,198,000	797,000

Sludge Management	NPV of Capital	O&M
CIA Sludge Disposal Beds	4,814,000	42,000
Close Existing CIA Disposal Bed (Yr 2)	1,660,000	0
Subtotal	6,474,000	42,000

Performance Monitoring	Capital	O&M
KT Portal (Years 1 -30)	0	18,000
CTP (Years 1-30)	0	60,000
Surface (Years 1 - 10)	0	30,000
In-Mine (Years 1-10)	0	212,000
Subtotal	0	320,000
	Annualized O&M (Yrs 1-30)	214,983

Alternative 3B
Cost Summary

Alternative 3B
Phased Mitigations/Treatment (with Mechanical Sludge Dewatering and Offsite Disposal)
Interest = 7%

Remedy Component	Capital Cost ($)	Annual O&M Cost ($/yr)
AMD Mitigations	4,990,000	55,000
AMD Collection	0	1,071,000
AMD Conveyance	340,000	130,000
AMD Storage	1,950,000	157,000
AMD Treatment	8,198,000	797,000
Sludge Management[1]	5,350,000	682,000
Performance Monitoring[2]	0	215,000
Totals	**20,828,000**	**3,107,000**
30-Year NPV of O&M		**38,555,000**
Total 30-Year Present Worth	**59,383,000**	

[1]The capital cost is the present worth of capital expenditures which occur during the 30-year time period. See the sludge option NPV calculation summary sheet for details.

[2]The monitoring annual O&M cost is the annualized amount of the 30-year net present value , since annual costs vary over the 30-year period. See the monitoring summary sheet for details.

AMD Mitigations	Capital	O&M
West Fork Milo Creek Diversion	3,590,000	28,000
Rehabilitate Phil Sheridan Diversion	1,250,000	18,000
Plug Drill Holes	150,000	9,000
Subtotal	4,990,000	55,000

AMD Collection	Capital	O&M
Existing In Mine System	0	1,071,000
Subtotal	0	1,071,000

AMD Conveyance	Capital	O&M
Existing Concrete Channel	0	25,000
Existing HDPE Pipeline	0	68,000
New HDPE Pipeline to CTP	340,000	37,000
Subtotal	340,000	130,000

AMD Storage	Capital	O&M
In-Mine Gravity Diversion System	710,000	Included in Extraction System
New Mine Pool Extraction System	1,240,000	126,000
Existing Lined Pond	0	31,000
Subtotal	1,950,000	157,000

AMD Treatment	Capital	O&M
Upgraded 2,500 gpm CTP with Media Filters	8,198,000	797,000
Subtotal	8,198,000	797,000

Sludge Management	NPV of Capital	O&M
Mechanical Dewatering System	3,690,000	148,000
Offsite Haulage and Disposal		534,000
Close Existing CIA Disposal Bed (Yr 2)	1,660,000	0
Subtotal	5,350,000	682,000

Performance Monitoring	Capital	O&M
KT Portal (Years 1 -30)	0	18,000
CTP (Years 1-30)	0	60,000
Surface (Years 1 - 10)	0	30,000
In-Mine (Years 1-10)	0	212,000
Subtotal	0	320,000
	Annualized O&M (Yrs 1-30)	214,983

Alternative 3C
Cost Summary

Alternative 3C
Phased Mitigations/Treatment (with smelter closure area sludge disposal beds)
Interest = 7%

Remedy Component	Capital Cost ($)	Annual O&M Cost ($/yr)
AMD Mitigations	4,990,000	55,000
AMD Collection	0	1,071,000
AMD Conveyance	340,000	130,000
AMD Storage	1,950,000	157,000
AMD Treatment	8,198,000	797,000
Sludge Management[1]	10,937,000	67,000
Performance Monitoring[2]	0	215,000
Totals	**26,415,000**	**2,492,000**
30-Year NPV of O&M		**30,923,000**
Total 30-Year Present Worth	**57,338,000**	

[1]The capital cost is the present worth of capital expenditures which occur during the 30-year time period. See the sludge option NPV calculation summary sheet for details.

[2]The monitoring annual O&M cost is the annualized amount of the 30-year net present value , since annual costs vary over the 30-year period. See the monitoring summary sheet for details.

AMD Mitigations	Capital	O&M
West Fork Milo Creek Diversion	3,590,000	28,000
Rehabilitate Phil Sheridan Diversion	1,250,000	18,000
Plug Drill Holes	150,000	9,000
Subtotal	4,990,000	55,000

AMD Collection	Capital	O&M
Existing In Mine System	0	1,071,000
Subtotal	0	1,071,000

AMD Conveyance	Capital	O&M
Existing Concrete Channel	0	25,000
Existing HDPE Pipeline	0	68,000
New HDPE Pipeline to CTP	340,000	37,000
Subtotal	340,000	130,000

AMD Storage	Capital	O&M
In-Mine Gravity Diversion System	710,000	Included in Extraction System
New Mine Pool Extraction System	1,240,000	126,000
Existing Lined Pond	0	31,000
Subtotal	1,950,000	157,000

AMD Treatment	Capital	O&M
Upgraded 2,500 gpm CTP with Media Filters	8,198,000	797,000
Subtotal	8,198,000	797,000

Sludge Management	NPV of Capital	O&M
Smelter Closure Area Sludge Disposal Beds	9,277,000	67,000
Close Existing CIA Disposal Bed (Yr 2)	1,660,000	0
Subtotal	10,937,000	67,000

Performance Monitoring	Capital	O&M
KT Portal (Years 1 -30)	0	18,000
CTP (Years 1-30)	0	60,000
Surface (Years 1 - 10)	0	30,000
In-Mine (Years 1-10)	0	212,000
Subtotal	0	320,000
	Annualized O&M (Yrs 1-30)	214,983

Alternative 3D
Cost Summary

Alternative 3D
Phased Mitigations/Treatment (with sludge drying beds and smelter closure area landfill)
Interest = 7%

Remedy Component	Capital Cost ($)	Annual O&M Cost ($/yr)
AMD Mitigations	4,990,000	55,000
AMD Collection	0	1,071,000
AMD Conveyance	340,000	130,000
AMD Storage	1,950,000	157,000
AMD Treatment	8,198,000	797,000
Sludge Management[1]	9,532,000	141,000
Performance Monitoring[2]	0	215,000
Totals	**25,010,000**	**2,566,000**
30-Year NPV of O&M		**31,842,000**
Total 30-Year Present Worth	**56,852,000**	

[1]The capital cost is the present worth of capital expenditures which occur during the 30-year time period. See the sludge option NPV calculation summary sheet for details.

[2]The monitoring annual O&M cost is the annualized amount of the 30-year net present value , since annual costs vary over the 30-year period. See the monitoring summary sheet for details.

AMD Mitigations	Capital	O&M
West Fork Milo Creek Diversion	3,590,000	28,000
Rehabilitate Phil Sheridan Diversion	1,250,000	18,000
Plug Drill Holes	150,000	9,000
Subtotal	4,990,000	55,000

AMD Collection	Capital	O&M
Existing In Mine System	0	1,071,000
Subtotal	0	1,071,000

AMD Conveyance	Capital	O&M
Existing Concrete Channel	0	25,000
Existing HDPE Pipeline	0	68,000
New HDPE Pipeline to CTP	340,000	37,000
Subtotal	340,000	130,000

AMD Storage	Capital	O&M
In-Mine Gravity Diversion System	710,000	Included in Extraction System
New Mine Pool Extraction System	1,240,000	126,000
Existing Lined Pond	0	31,000
Subtotal	1,950,000	157,000

AMD Treatment	Capital	O&M
Upgraded 2,500 gpm CTP with Media Filters	8,198,000	797,000
Subtotal	8,198,000	797,000

Sludge Management	NPV of Capital	O&M
Smelter Closure Area Landfill	6,147,000	94,000
Landfill Closure (Yr 31)	241,000	0
CIA Sludge Drying Beds	1,484,000	47,000
Close Existing CIA Disposal Bed (Yr 2)	1,660,000	0
Subtotal	9,532,000	141,000

Performance Monitoring	Capital	O&M
KT Portal (Years 1 -30)	0	18,000
CTP (Years 1-30)	0	60,000
Surface (Years 1 - 10)	0	30,000
In-Mine (Years 1-10)	0	212,000
Subtotal	0	320,000
	Annualized O&M (Yrs 1-30)	214,983

Alternative 4

Cost Summary

Alternative 4A
Cost Summary

Alternative 4A
Phased Mitigations/Treatment with Plugging of Near-Stream Workings (with CIA Sludge Disposal Beds)
Interest = 7%

Remedy Component	Capital Cost ($)	Annual O&M Cost ($/yr)
AMD Mitigations	6,000,000	56,000
AMD Collection	0	1,071,000
AMD Conveyance	340,000	130,000
AMD Storage	1,950,000	157,000
AMD Treatment	8,198,000	797,000
Sludge Management[1]	6,474,000	42,000
Performance Monitoring[2]	0	215,000
Totals	**22,962,000**	**2,468,000**
30-Year NPV of O&M		**30,626,000**
Total 30-Year Present Worth	**53,588,000**	

[1]The capital cost is the present worth of capital expenditures which occur during the 30-year time period. See the sludge option NPV calculation summary sheet for details.

[2]The monitoring annual O&M cost is the annualized amount of the 30-year net present value , since annual costs vary over the 30-year period. See the monitoring summary sheet for details.

AMD Mitigations	Capital	O&M
West Fork Milo Creek Diversion	3,590,000	28,000
Rehabilitate Phil Sheridan Diversion	1,250,000	18,000
Plug Drill Holes	150,000	9,000
Plug Small Hopes	360,000	500
Plug/Bypass Inez Shaft	650,000	500
Subtotal	6,000,000	56,000

AMD Collection	Capital	O&M
Existing In Mine System	0	1,071,000
Subtotal	0	1,071,000

AMD Conveyance	Capital	O&M
Existing Concrete Channel	0	25,000
Existing HDPE Pipeline	0	68,000
New HDPE Pipeline to CTP	340,000	37,000
Subtotal	340,000	130,000

AMD Storage	Capital	O&M
In-Mine Gravity Diversion System	710,000	Included in Extraction System
New Mine Pool Extraction System	1,240,000	126,000
Existing Lined Pond	0	31,000
Subtotal	1,950,000	157,000

AMD Treatment	Capital	O&M
Upgraded 2,500 gpm CTP with Media Filters	8,198,000	797,000
Subtotal	8,198,000	797,000

Sludge Management	NPV of Capital	O&M
CIA Sludge Disposal Beds	4,814,000	42,000
Close Existing CIA Disposal Bed (Yr 2)	1,660,000	0
Subtotal	6,474,000	42,000

Performance Monitoring	Capital	O&M
KT Portal (Years 1 -30)	0	18,000
CTP (Years 1-30)	0	60,000
Surface (Years 1 - 10)	0	30,000
In-Mine (Years 1-10)	0	212,000
Subtotal	0	320,000
	Annualized O&M (Yrs 1-30)	214,983

Alternative 4B
Cost Summary

Alternative 4B
Phased Mitigations/Treatment with Plugging of Near-Stream Workings (with Mechanical Dewatering and Offsite Sludge Disposal)
Interest = 7%

Remedy Component	Capital Cost ($)	Annual O&M Cost ($/yr)
AMD Mitigations	6,000,000	56,000
AMD Collection	0	1,071,000
AMD Conveyance	340,000	130,000
AMD Storage	1,950,000	157,000
AMD Treatment	8,198,000	797,000
Sludge Management[1]	5,350,000	682,000
Performance Monitoring[2]	0	215,000
Totals	**21,838,000**	**3,108,000**
30-Year NPV of O&M		**38,567,000**
Total 30-Year Present Worth	**60,405,000**	

[1]The capital cost is the present worth of capital expenditures which occur during the 30-year time period. See the sludge option NPV calculation summary sheet for details.

[2]The monitoring annual O&M cost is the annualized amount of the 30-year net present value , since annual costs vary over the 30-year period. See the monitoring summary sheet for details.

AMD Mitigations	Capital	O&M
West Fork Milo Creek Diversion	3,590,000	28,000
Rehabilitate Phil Sheridan Diversion	1,250,000	18,000
Plug Drill Holes	150,000	9,000
Plug Small Hopes	360,000	500
Plug/Bypass Inez Shaft	650,000	500
Subtotal	6,000,000	56,000

AMD Collection	Capital	O&M
Existing In Mine System	0	1,071,000
Subtotal	0	1,071,000

AMD Conveyance	Capital	O&M
Existing Concrete Channel	0	25,000
Existing HDPE Pipeline	0	68,000
New HDPE Pipeline to CTP	340,000	37,000
Subtotal	340,000	130,000

AMD Storage	Capital	O&M
In-Mine Gravity Diversion System	710,000	Included in Extraction System
New Mine Pool Extraction System	1,240,000	126,000
Existing Lined Pond	0	31,000
Subtotal	1,950,000	157,000

AMD Treatment	Capital	O&M
Upgraded 2,500 gpm CTP with Media Filters	8,198,000	797,000
Subtotal	8,198,000	797,000

Sludge Management	NPV of Capital	O&M
Mechanical Dewatering System	3,690,000	148,000
Offsite Haulage and Disposal		534,000
Close Existing CIA Disposal Bed (Yr 2)	1,660,000	0
Subtotal	5,350,000	682,000

Performance Monitoring	Capital	O&M
KT Portal (Years 1 -30)	0	18,000
CTP (Years 1-30)	0	60,000
Surface (Years 1 - 10)	0	30,000
In-Mine (Years 1-10)	0	212,000
Subtotal	0	320,000
	Annualized O&M (Yrs 1-30)	214,983

Alternative 4C
Cost Summary

Alternative 4C

Phased Mitigations/Treatment with Plugging of Near-Stream Workings (with Smelter Closure Area Sludge Disposal Beds)

Interest = 7%

Remedy Component	Capital Cost ($)	Annual O&M Cost ($/yr)
AMD Mitigations	6,000,000	56,000
AMD Collection	0	1,071,000
AMD Conveyance	340,000	130,000
AMD Storage	1,950,000	157,000
AMD Treatment	8,198,000	797,000
Sludge Management[1]	10,937,000	67,000
Performance Monitoring[2]	0	215,000
Totals	**27,425,000**	**2,493,000**
30-Year NPV of O&M		**30,936,000**
Total 30-Year Present Worth	**58,361,000**	

[1]The capital cost is the present worth of capital expenditures which occur during the 30-year time period. See the sludge option NPV calculation summary sheet for details.

[2]The monitoring annual O&M cost is the annualized amount of the 30-year net present value , since annual costs vary over the 30-year period. See the monitoring summary sheet for details.

AMD Mitigations	Capital	O&M
West Fork Milo Creek Diversion	3,590,000	28,000
Rehabilitate Phil Sheridan Diversion	1,250,000	18,000
Plug Drill Holes	150,000	9,000
Plug Small Hopes	360,000	500
Plug/Bypass Inez Shaft	650,000	500
Subtotal	6,000,000	56,000

AMD Collection	Capital	O&M
Existing In Mine System	0	1,071,000
Subtotal	0	1,071,000

AMD Conveyance	Capital	O&M
Existing Concrete Channel	0	25,000
Existing HDPE Pipeline	0	68,000
New HDPE Pipeline to CTP	340,000	37,000
Subtotal	340,000	130,000

AMD Storage	Capital	O&M
In-Mine Gravity Diversion System	710,000	Included in Extraction System
New Mine Pool Extraction System	1,240,000	126,000
Existing Lined Pond	0	31,000
Subtotal	1,950,000	157,000

AMD Treatment	Capital	O&M
Upgraded 2,500 gpm CTP with Media Filters	8,198,000	797,000
Subtotal	8,198,000	797,000

Sludge Management	NPV of Capital	O&M
Smelter Closure Area Sludge Disposal Beds	9,277,000	67,000
Close Existing CIA Disposal Bed (Yr 2)	1,660,000	0
Subtotal	10,937,000	67,000

Performance Monitoring	Capital	O&M
KT Portal (Years 1 -30)	0	18,000
CTP (Years 1-30)	0	60,000
Surface (Years 1 - 10)	0	30,000
In-Mine (Years 1-10)	0	212,000
Subtotal	0	320,000
	Annualized O&M (Yrs 1-30)	214,983

Alternative 4D
Cost Summary

Alternative 4D
Phased Mitigations/Treatment with Plugging of Near-Stream Workings (with CIA Sludge Drying Beds and Smelter Closure Area Landfill)
Interest = 7%

Remedy Component	Capital Cost ($)	Annual O&M Cost ($/yr)
AMD Mitigations	6,000,000	56,000
AMD Collection	0	1,071,000
AMD Conveyance	340,000	130,000
AMD Storage	1,950,000	157,000
AMD Treatment	8,198,000	797,000
Sludge Management[1]	9,532,000	141,000
Performance Monitoring[2]	0	215,000
Totals	**26,020,000**	**2,567,000**
30-Year NPV of O&M		**31,854,000**
Total 30-Year Present Worth	**57,874,000**	

[1]The capital cost is the present worth of capital expenditures which occur during the 30-year time period. See the sludge option NPV calculation summary sheet for details.

[2]The monitoring annual O&M cost is the annualized amount of the 30-year net present value , since annual costs vary over the 30-year period. See the monitoring summary sheet for details.

AMD Mitigations	Capital	O&M
West Fork Milo Creek Diversion	3,590,000	28,000
Rehabilitate Phil Sheridan Diversion	1,250,000	18,000
Plug Drill Holes	150,000	9,000
Plug Small Hopes	360,000	500
Plug/Bypass Inez Shaft	650,000	500
Subtotal	6,000,000	56,000

AMD Collection	Capital	O&M
Existing In Mine System	0	1,071,000
Subtotal	0	1,071,000

AMD Conveyance	Capital	O&M
Existing Concrete Channel	0	25,000
Existing HDPE Pipeline	0	68,000
New HDPE Pipeline to CTP	340,000	37,000
Subtotal	340,000	130,000

AMD Storage	Capital	O&M
In-Mine Gravity Diversion System	710,000	Included in Extraction System
New Mine Pool Extraction System	1,240,000	126,000
Existing Lined Pond	0	31,000
Subtotal	1,950,000	157,000

AMD Treatment	Capital	O&M
Upgraded 2,500 gpm CTP with Media Filters	8,198,000	797,000
Subtotal	8,198,000	797,000

Sludge Management	NPV of Capital	O&M
Smelter Closure Area Landfill	6,147,000	94,000
Landfill Closure (Yr 31)	241,000	0
CIA Sludge Drying Beds	1,484,000	47,000
Close Existing CIA Disposal Bed (Yr 2)	1,660,000	0
Subtotal	9,532,000	141,000

Performance Monitoring	Capital	O&M
KT Portal (Years 1 -30)	0	18,000
CTP (Years 1-30)	0	60,000
Surface (Years 1 - 10)	0	30,000
In-Mine (Years 1-10)	0	212,000
Subtotal	0	320,000
	Annualized O&M (Yrs 1-30)	214,983

Alternative 5

ALTERNATIVE 5
Bunker Hill Mine Water RI/FS
Performance Monitoring Costs

Tasks	Qty	Unit	Material Unit Cost	Labor Unit Cost	Equip Unit Cost	Annual Cost	Comments
Annual Costs							
KT Portal (flow and chemistry) (Years 1 through 30)							
KT Flow Data Management & Reporting	1	MO	0	800	0	$9,600	Monthly data management; asm 10 hrs/month (1 person) @ $80/hr labor
KT Sampling and Analysis	1	WK	300	0	0	$15,600	Weekly sample collection; asm analysis cost of $300/sample for Cd, Pb, Zn, SO4, LD/SF
Sample Collection Supplies	1	YR	500	0	0	$500	Allowance
Sample Shipment	1	YR	500	0	0	$500	Allowance
Subtotal						**$16,600**	
Allowance	10%					**$1,660**	
Total Annual Cost						**$18,260**	
CTP (flow and chemistry) (Years 1 through 30)							
	1	Day	150	0	0	$54,750	Total, Cd, Pb, and Zn low level analysis
Subtotal						**$54,750**	
Allowance	10%					**$5,475**	
Total Annual Cost						**$60,225**	
Surface Streams (flow only) (Years 1 through 5)							
Automatic Flow Recorder Data Download	1	MO	0	1,280	0	$15,360	Monthly data download from 3 flow recorders and 8 piezometers; asm 16 hrs/month (2 persons, 1 field day) @ $80/hr labor
Flow Data Recording & Management for surface water diversions	1	MO	0	320	0	$3,840	Monthly data management; asm 4 hrs/month (1 person) @ $80/hr labor
Data management & reporting for existing piezometers	1	MO	0	640	0	$7,680	Monthly data management and reporting; asm 8 hrs/month (1 person) @ $80/hr labor
Subtotal						**$26,880**	
Allowance	10%					**$2,688**	
Total Annual Cost						**$29,568**	
In-Mine (flow and chemistry) (Years 1 through 5)							
Sample Collection	15	Event	0	3,840	0	$57,600	15 events, 48 hrs/event (3 persons, 2 field days) @ $80/hr labor
Sample Collection Materials	15	Event	0	0	0	$2,000	Allowance
Sample Preparation and Packaging	15	Event	0	2,560	0	$38,400	15 events, 32 hrs/event (2 persons, 2 days) @ $80/hr labor
Sample Shipment	15	Event	100	0		$1,500	
Sample Analysis	15	Event	5,600	0	0	$84,000	15 events, 14 samples/event, $400/sample for analytical (total and dissolved metals, sulfate, lime demand, solids formed, TSS)
Data management, interpretation, QA/QC and reporting	15	Event	0	640	0	$9,600	15 events, 8 hrs/event, @ $80/hr labor
Subtotal						**$193,100**	
Allowance	10%					**$19,310**	
Total Annual Cost						**$212,410**	

Alternative 5
Option A

Bunker Hill
Acid Mine Drainage
Disposal of Raw Sludge in CIA Disposal Beds
Order of Magnitude Cost Opinion (Quantity reduced by 20%)

DATE: 11/22/2000
PROJECT NO.: 152215.FS.02
ESTIMATE BY: D. Bunte
N. Gulensoy

DESCRIPTION	QTY	QTY Reduced by 20%	UNIT	TOTAL UNIT COST	TOTAL COST
Subgrade Stabilization	10,500	8,400	C. Y.	4.00	$33,600
Liner Protection Sand	8250	6,600	C. Y.	10.00	$66,000
Drain Rock	1,950	1,560	C. Y.	18.00	$28,080
Ditch Lining Geotextile	21,200	16,960	S. Y.	1.65	$27,984
G C L	18,100	14,480	S. Y.	4.05	$58,644
H D P E Geomembrane	18,100	14,480	S. Y.	5.40	$78,192
H D P E Pipe, 10"	550	440	L. F.	23.00	$10,120
Erosion Control Matting	11800	9,440	S.Y.	1.50	$14,160
Perf Pipe, 4"	2000	1,600	L. F.	2.00	$3,200
Perf Pipe, 6"	580	464	L. F.	3.00	$1,392
HDPE Pipe, 6"	130	104	L. F.	2.50	$260
Strip Drains	700	560	L. F.	1.75	$980
Valves, 6" Knife Gate	2		Each	700.00	$1,400
Valves, 10" Knife Gate	6		Each	1,000.00	$6,000
Air/Vacuum Release Valve	1		Each	2,000.00	$2,000
Valve Vault	6		Each	1,950.00	$11,700
Water Tight Manhole	1		Each	3,500.00	$3,500
Vertical Filtrate Drains	6		Each	4,000.00	$24,000
Cleanouts	2		Each	750.00	$1,500
Perimeter Road Embankment (not reduced)	28275	28,275	C. Y.	10	$282,750
Chain Link Fence and Gates (not reduced)	1000	1,000	L.F.	12	$12,000
Crushed Rock Surfacing (not reduced)	1500	1,500	C. Y.	15	$22,500
SUBTOTAL					**$926,212**
MISC ALLOWANCE	**10%**				**$92,621**
SUBTOTAL					**$1,018,833**
CONTINGENCY	**30%**				**$305,650**
SUBTOTAL					**$1,324,483**
MOBILIZATION	**15%**				**$198,672**
CONSTRUCTION TOTAL					**$1,523,156**
SALES TAX ON MATERIALS	**5.0%**				**$25,622**
ENGINEERING AND SUPPORT	**20%**				**$304,631**
CONSTRUCTION MANAGEMENT	**8%**				**$121,852**
CAPITAL COST SUBSEQUENT BEDS TOTAL (ROUNDED)					**$1,980,000**
ANNUAL O&M COST FOR OPERATING BED				**$38,000**	
NPV OF ANNUAL O&M COSTS (30 YEARS @ 7% INTEREST)					**$471,000**
NPV OF INITIAL AND SUBSEQUENT BEDS & CLOSURES CAPITAL COSTS @ 7% INTEREST					**$6,321,000**
TOTAL 30-YEAR PRESENT WORTH COST @ 7% INTEREST					**$6,792,000**

NOTES:
Misc Allowance markup is to include items known to exist but cannot be quantified at this time.
Contingency is for scope changes that are presently unforeseen.
Mobilization includes bonds, insurance, temporary facilities, health & safety, demobilization, etc.

NOTE: The above cost opinion is in November 2000 dollars and does not include escalation. The order of magnitude cost opinion shown has been prepared for guidance in project evaluation at the time of preparation. The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope, final schedule and other variable factors. As a result, the final project costs will vary from those presented above. Because of these factors, funding needs must be carefully reviewed prior to making specific financial decisions or establishing final budgets.

Alternative 5
Option C

Bunker Hill
Acid Mine Drainage
Disposal of Raw Sludge in Smelter Closure Area Disposal Beds
Order of Magnitude Cost Opinion (Quantity reduced by 20%)

DATE: 11/29/2000
PROJECT NO.: 152215.FS.02
ESTIMATE BY: D. Bunte
N. Gulensoy

DESCRIPTION	QTY	QTY Reduced by 20%	UNIT	TOTAL UNIT COST	TOTAL COST
CAPITAL COST FOR NEW CELLS IN FUTURE YEARS (DOES NOT INCLUDE PUMPING AND PIPING COST)					
Sludge Disposal Bed (per each)					
Excavation	25,000	20,000	C. Y.	3.30	$66,000
Subgrade Preparation	5	4	Acres	3,300.00	$13,200
Subgrade Stabilization	10,500	8,400	C. Y.	4.40	$36,960
Liner Protection Sand	8250	6,600	C. Y.	19.80	$130,680
Drain Rock	1,950	1,560	C. Y.	19.80	$30,888
Ditch Lining Geotextile	21,200	16,960	S. Y.	1.82	$30,782
G C L	18,100	14,480	S. Y.	4.46	$64,508
H D P E Geomembrane	18,100	14,480	S. Y.	5.94	$86,011
H D P E Pipe, 10"	550	440	L. F.	25.30	$11,132
Erosion Control Matting	11800	9,440	S.Y.	1.65	$15,576
Perf Pipe, 4"	2000	1,600	L. F.	2.20	$3,520
Perf Pipe, 6"	580	464	L. F.	3.30	$1,531
HDPE Pipe, 6"	130	104	L. F.	2.75	$286
Strip Drains	700	560	L. F.	1.93	$1,078
Valves, 6" Knife Gate	2		Each	770.00	$0
Valves, 10" Knife Gate	6		Each	1,100.00	$0
Air/Vacuum Release Valve	1		Each	2,200.00	$0
Valve Vault	6		Each	2,145.00	$0
Water Tight Manhole	1		Each	3,850.00	$0
Vertical Filtrate Drains	6		Each	4,400.00	$0
Cleanouts	2		Each	825.00	$0
Perimeter Road Embankment (not reducec	28275	28,275	C. Y.	11.00	$311,025
Chain Link Fence and Gates (not reduced)	1000	1,000	L.F.	13.20	$13,200
Groundwater Monitoring Wells	2		Each	6,600.00	$13,200
Crushed Rock Surfacing (not reduced)	1500	1,500	C. Y.	16.50	$24,750

SUBTOTAL			**$1,090,113**
MISC ALLOWANCE	**10%**		**$109,011**
SUBTOTAL			**$1,199,125**
CONTINGENCY	**30%**		**$359,737**
SUBTOTAL			**$1,558,862**
MOBILIZATION	**15%**		**$233,829**
CONSTRUCTION TOTAL			**$1,792,691**
SALES TAX ON MATERIALS	**5.0%**		**$27,572**
ENGINEERING AND SUPPORT	**20%**		**$358,538**
CONSTRUCTION MANAGEMENT	**8%**		**$143,415**
CAPITAL COST SUBSEQUENT BEDS TOTAL (ROUNDED)			**$2,320,000**
ANNUAL O&M COST FOR OPERATING BED		**$62,000**	
NPV OF ANNUAL O&M COSTS (30 YEARS @ 7% INTEREST)			**$765,000**
NPV OF INITIAL AND SUBSEQUENT BEDS & CLOSURES CAPITAL COSTS @ 7% INTEREST			**$10,722,000**
TOTAL 30-YEAR PRESENT WORTH COST @ 7% INTEREST			**$11,487,000**

NOTES:
Misc Allowance markup is to include items known to exist but cannot be quantified at this time.
Contingency is for scope changes that are presently unforeseen.
Mobilization includes bonds, insurance, temporary facilities, health & safety, demobilization, etc.

NOTE: The above cost opinion is in November 2000 dollars and does not include escalation. The order of magnitude cost opinion shown has been prepared for guidance in project evaluation at the time of preparation. The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope, final schedule and other variable factors. As a result, the final project costs will vary from those presented above. Because of these factors, funding needs must be carefully reviewed prior to making specific financial decisions or establishing final budgets.

Cost Summary

Alternative 5A
Cost Summary

Alternative 5A
Phased Mitigations/Treatment with Plugging of Near-Stream Workings (with CIA Sludge Disposal Beds)
Interest = 7%

Remedy Component	Capital Cost ($)	Annual O&M Cost ($/yr)
AMD Mitigations	12,060,000	222,000
AMD Collection	0	1,071,000
AMD Conveyance	340,000	130,000
AMD Storage	1,950,000	157,000
AMD Treatment	8,198,000	763,000
Sludge Management[1]	6,205,000	38,000
Performance Monitoring[2]	0	158,000
Totals	**28,753,000**	**2,539,000**
30-Year NPV of O&M		**31,507,000**
Total 30-Year Present Worth	**60,260,000**	

[1]The capital cost is the present worth of capital expenditures which occur during the 30-year time period. See the sludge option NPV calculation summary sheet for details.

[2]The monitoring annual O&M cost is the annualized amount of the 30-year net present value , since annual costs vary over the 30-year period. See the monitoring summary sheet for details.

AMD Mitigations	Capital	O&M
West Fork Milo Creek Diversion	3,590,000	28,000
Rehabilitate Phil Sheridan Diversion	1,250,000	18,000
Plug Drill Holes	150,000	9,000
Plug Small Hopes	360,000	500
Plug/Bypass Inez Shaft	650,000	500
Improve Phil Sheridan Diversion	380,000	500
Sidehill Diversions above Guy Cave	490,000	12,000
South Fork Diversion	1,870,000	30,000
Bypass Bunker Hill Dam	60,000	24,000
Improve Existing Mainstem Milo Diversion, Seal/Decrease Subflow	590,000	99,000
Improve Existing Mainstem Milo Diversion, Increase Capacity	2,670,000	Accounted For Above
Subtotal	12,060,000	222,000

AMD Collection	Capital	O&M
Existing In Mine System	0	1,071,000
Subtotal	0	1,071,000

AMD Conveyance	Capital	O&M
Existing Concrete Channel	0	25,000
Existing HDPE Pipeline	0	68,000
New HDPE Pipeline to CTP	340,000	37,000
Subtotal	340,000	130,000

AMD Storage	Capital	O&M
In-Mine Gravity Diversion System	710,000	Included in Extraction System
New Mine Pool Extraction System	1,240,000	126,000
Existing Lined Pond	0	31,000
Subtotal	1,950,000	157,000

AMD Treatment	Capital	O&M
Upgraded 2,500 gpm CTP with Media Filters	8,198,000	763,000
Subtotal	8,198,000	763,000

Sludge Management	NPV of Capital	O&M
CIA Sludge Disposal Beds	4,545,000	38,000
Close Existing CIA Disposal Bed (Yr 2)	1,660,000	0
Subtotal	6,205,000	38,000

Performance Monitoring	Capital	O&M
KT Portal (Years 1 -30)	0	18,000
CTP (Years 1-30)	0	60,000
Surface (Years 1 - 5)	0	30,000
In-Mine (Years 1-5)	0	212,000
Subtotal	0	320,000
	Annualized O&M (Yrs 1-30)	157,969

Alternative 5B
Cost Summary

Alternative 5B
Phased Mitigations/Treatment with Plugging of Near-Stream Workings (with Mechanical Dewatering and Offsite Sludge Disposal)
Interest = 7%

Remedy Component	Capital Cost ($)	Annual O&M Cost ($/yr)
AMD Mitigations	12,060,000	222,000
AMD Collection	0	1,071,000
AMD Conveyance	340,000	130,000
AMD Storage	1,950,000	157,000
AMD Treatment	8,198,000	763,000
Sludge Management[1]	5,100,000	618,000
Performance Monitoring[2]	0	158,000
Totals	**27,648,000**	**3,119,000**
30-Year NPV of O&M		**38,704,000**
Total 30-Year Present Worth	**66,352,000**	

[1]The capital cost is the present worth of capital expenditures which occur during the 30-year time period. See the sludge option NPV calculation summary sheet for details.

[2]The monitoring annual O&M cost is the annualized amount of the 30-year net present value , since annual costs vary over the 30-year period. See the monitoring summary sheet for details.

AMD Mitigations	Capital	O&M
West Fork Milo Creek Diversion	3,590,000	28,000
Rehabilitate Phil Sheridan Diversion	1,250,000	18,000
Plug Drill Holes	150,000	9,000
Plug Small Hopes	360,000	500
Plug/Bypass Inez Shaft	650,000	500
Improve Phil Sheridan Diversion	380,000	500
Sidehill Diversions above Guy Cave	490,000	12,000
South Fork Diversion	1,870,000	30,000
Bypass Bunker Hill Dam	60,000	24,000
Improve Existing Mainstem Milo Diversion, Seal/Decrease Subflow	590,000	99,000
Improve Existing Mainstem Milo Diversion, Increase Capacity	2,670,000	Accounted For Above
Subtotal	12,060,000	222,000

AMD Collection	Capital	O&M
Existing In Mine System	0	1,071,000
Subtotal	0	1,071,000

AMD Conveyance	Capital	O&M
Existing Concrete Channel	0	25,000
Existing HDPE Pipeline	0	68,000
New HDPE Pipeline to CTP	340,000	37,000
Subtotal	340,000	130,000

AMD Storage	Capital	O&M
In-Mine Gravity Diversion System	710,000	Included in Extraction System
New Mine Pool Extraction System	1,240,000	126,000
Existing Lined Pond	0	31,000
Subtotal	1,950,000	157,000

AMD Treatment	Capital	O&M
Upgraded 2,500 gpm CTP with Media Filters	8,198,000	763,000
Subtotal	8,198,000	763,000

Sludge Management	NPV of Capital	O&M
Mechanical Dewatering System	3,440,000	143,000
Offsite Haulage and Disposal		475,000
Close Existing CIA Disposal Bed (Yr 2)	1,660,000	0
Subtotal	5,100,000	618,000

Performance Monitoring	Capital	O&M
KT Portal (Years 1 -30)	0	18,000
CTP (Years 1-30)	0	60,000
Surface (Years 1 - 5)	0	30,000
In-Mine (Years 1-5)	0	212,000
Subtotal	0	320,000
	Annualized O&M (Yrs 1-30)	157,969

NEXT

Alternative 5C
Cost Summary

Alternative 5C
Phased Mitigations/Treatment with Plugging of Near-Stream Workings (with Smelter Closure Area Sludge Disposal Beds)
Interest = 7%

Remedy Component	Capital Cost ($)	Annual O&M Cost ($/yr)
AMD Mitigations	12,060,000	222,000
AMD Collection	0	1,071,000
AMD Conveyance	340,000	130,000
AMD Storage	1,950,000	157,000
AMD Treatment	8,198,000	763,000
Sludge Management[1]	10,605,000	62,000
Performance Monitoring[2]	0	158,000
Totals	**33,153,000**	**2,563,000**
30-Year NPV of O&M		**31,804,000**
Total 30-Year Present Worth	**64,957,000**	

[1]The capital cost is the present worth of capital expenditures which occur during the 30-year time period. See the sludge option NPV calculation summary sheet for details.

[2]The monitoring annual O&M cost is the annualized amount of the 30-year net present value , since annual costs vary over the 30-year period. See the monitoring summary sheet for details.

AMD Mitigations	Capital	O&M
West Fork Milo Creek Diversion	3,590,000	28,000
Rehabilitate Phil Sheridan Diversion	1,250,000	18,000
Plug Drill Holes	150,000	9,000
Plug Small Hopes	360,000	500
Plug/Bypass Inez Shaft	650,000	500
Improve Phil Sheridan Diversion	380,000	500
Sidehill Diversions above Guy Cave	490,000	12,000
South Fork Diversion	1,870,000	30,000
Bypass Bunker Hill Dam	60,000	24,000
Improve Existing Mainstem Milo Diversion, Seal/Decrease Subflow	590,000	99,000
Improve Existing Mainstem Milo Diversion, Increase Capacity	2,670,000	Accounted For Above
Subtotal	12,060,000	222,000

AMD Collection	Capital	O&M
Existing In Mine System	0	1,071,000
Subtotal	0	1,071,000

AMD Conveyance	Capital	O&M
Existing Concrete Channel	0	25,000
Existing HDPE Pipeline	0	68,000
New HDPE Pipeline to CTP	340,000	37,000
Subtotal	340,000	130,000

AMD Storage	Capital	O&M
In-Mine Gravity Diversion System	710,000	Included in Extraction System
New Mine Pool Extraction System	1,240,000	126,000
Existing Lined Pond	0	31,000
Subtotal	1,950,000	157,000

AMD Treatment	Capital	O&M
Upgraded 2,500 gpm CTP with Media Filters	8,198,000	763,000
Subtotal	8,198,000	763,000

Sludge Management	NPV of Capital	O&M
Smelter Closure Area Sludge Disposal Beds	8,945,000	62,000
Close Existing CIA Disposal Bed (Yr 2)	1,660,000	0
Subtotal	10,605,000	62,000

Performance Monitoring	Capital	O&M
KT Portal (Years 1 -30)	0	18,000
CTP (Years 1-30)	0	60,000
Surface (Years 1 - 5)	0	30,000
In-Mine (Years 1-5)	0	212,000
Subtotal	0	320,000
	Annualized O&M (Yrs 1-30)	157,969

NEXT

Alternative 5D
Cost Summary

Alternative 5D
Phased Mitigations/Treatment with Plugging of Near-Stream Workings (with CIA Sludge Drying Beds and Smelter Closure Area Landfill)
Interest = 7%

Remedy Component	Capital Cost ($)	Annual O&M Cost ($/yr)
AMD Mitigations	12,060,000	222,000
AMD Collection	0	1,071,000
AMD Conveyance	340,000	130,000
AMD Storage	1,950,000	157,000
AMD Treatment	8,198,000	763,000
Sludge Management[1]	8,821,000	129,000
Performance Monitoring[2]	0	158,000
Totals	**31,369,000**	**2,630,000**
30-Year NPV of O&M		**32,636,000**
Total 30-Year Present Worth	**64,005,000**	

[1]The capital cost is the present worth of capital expenditures which occur during the 30-year time period. See the sludge option NPV calculation summary sheet for details.

[2]The monitoring annual O&M cost is the annualized amount of the 30-year net present value , since annual costs vary over the 30-year period. See the monitoring summary sheet for details.

AMD Mitigations	Capital	O&M
West Fork Milo Creek Diversion	3,590,000	28,000
Rehabilitate Phil Sheridan Diversion	1,250,000	18,000
Plug Drill Holes	150,000	9,000
Plug Small Hopes	360,000	500
Plug/Bypass Inez Shaft	650,000	500
Improve Phil Sheridan Diversion	380,000	500
Sidehill Diversions above Guy Cave	490,000	12,000
South Fork Diversion	1,870,000	30,000
Bypass Bunker Hill Dam	60,000	24,000
Improve Existing Mainstem Milo Diversion, Seal/Decrease Subflow	590,000	99,000
Improve Existing Mainstem Milo Diversion, Increase Capacity	2,670,000	Accounted For Above
Subtotal	12,060,000	222,000

AMD Collection	Capital	O&M
Existing In Mine System	0	1,071,000
Subtotal	0	1,071,000

AMD Conveyance	Capital	O&M
Existing Concrete Channel	0	25,000
Existing HDPE Pipeline	0	68,000
New HDPE Pipeline to CTP	340,000	37,000
Subtotal	340,000	130,000

AMD Storage	Capital	O&M
In-Mine Gravity Diversion System	710,000	Included in Extraction System
New Mine Pool Extraction System	1,240,000	126,000
Existing Lined Pond	0	31,000
Subtotal	1,950,000	157,000

AMD Treatment	Capital	O&M
Upgraded 2,500 gpm CTP with Media Filters	8,198,000	763,000
Subtotal	8,198,000	763,000

Sludge Management	NPV of Capital	O&M
Smelter Closure Area Landfill	5,523,000	86,000
Landfill Closure (Yr 31)	223,000	0
CIA Sludge Drying Beds	1,415,000	43,000
Close Existing CIA Disposal Bed (Yr 2)	1,660,000	0
Subtotal	8,821,000	129,000

Performance Monitoring	Capital	O&M
KT Portal (Years 1 -30)	0	18,000
CTP (Years 1-30)	0	60,000
Surface (Years 1 - 5)	0	30,000
In-Mine (Years 1-5)	0	212,000
Subtotal	0	320,000
	Annualized O&M (Yrs 1-30)	157,969

NEXT

Alternative 5A
Cost Summary

Alternative 5A
Phased Mitigations/Treatment with Plugging of Near-Stream Workings (with CIA Sludge Disposal Beds)
Interest = 7%

Remedy Component	Capital Cost ($)	Annual O&M Cost ($/yr)
AMD Mitigations	12,060,000	222,000
AMD Collection	0	1,071,000
AMD Conveyance	340,000	130,000
AMD Storage	1,950,000	157,000
AMD Treatment	8,198,000	763,000
Sludge Management[1]	6,205,000	38,000
Performance Monitoring[2]	0	158,000
Totals	**28,753,000**	**2,539,000**
30-Year NPV of O&M		**31,507,000**
Total 30-Year Present Worth	**60,260,000**	

[1]The capital cost is the present worth of capital expenditures which occur during the 30-year time period. See the sludge option NPV calculation summary sheet for details.

[2]The monitoring annual O&M cost is the annualized amount of the 30-year net present value , since annual costs vary over the 30-year period. See the monitoring summary sheet for details.

AMD Mitigations	Capital	O&M
West Fork Milo Creek Diversion	3,590,000	28,000
Rehabilitate Phil Sheridan Diversion	1,250,000	18,000
Plug Drill Holes	150,000	9,000
Plug Small Hopes	360,000	500
Plug/Bypass Inez Shaft	650,000	500
Improve Phil Sheridan Diversion	380,000	500
Sidehill Diversions above Guy Cave	490,000	12,000
South Fork Diversion	1,870,000	30,000
Bypass Bunker Hill Dam	60,000	24,000
Improve Existing Mainstem Milo Diversion, Seal/Decrease Subflow	590,000	99,000
Improve Existing Mainstem Milo Diversion, Increase Capacity	2,670,000	Accounted For Above
Subtotal	12,060,000	222,000

AMD Collection	Capital	O&M
Existing In Mine System	0	1,071,000
Subtotal	0	1,071,000

AMD Conveyance	Capital	O&M
Existing Concrete Channel	0	25,000
Existing HDPE Pipeline	0	68,000
New HDPE Pipeline to CTP	340,000	37,000
Subtotal	340,000	130,000

AMD Storage	Capital	O&M
In-Mine Gravity Diversion System	710,000	Included in Extraction System
New Mine Pool Extraction System	1,240,000	126,000
Existing Lined Pond	0	31,000
Subtotal	1,950,000	157,000

AMD Treatment	Capital	O&M
Upgraded 2,500 gpm CTP with Media Filters	8,198,000	763,000
Subtotal	8,198,000	763,000

Sludge Management	NPV of Capital	O&M
CIA Sludge Disposal Beds	4,545,000	38,000
Close Existing CIA Disposal Bed (Yr 2)	1,660,000	0
Subtotal	6,205,000	38,000

Performance Monitoring	Capital	O&M
KT Portal (Years 1 -30)	0	18,000
CTP (Years 1-30)	0	60,000
Surface (Years 1 - 5)	0	30,000
In-Mine (Years 1-5)	0	212,000
Subtotal	0	320,000
	Annualized O&M (Yrs 1-30)	157,969

NEXT

Alternative 5B
Cost Summary

Alternative 5B
Phased Mitigations/Treatment with Plugging of Near-Stream Workings (with Mechanical Dewatering and Offsite Sludge Disposal)
Interest = 7%

Remedy Component	Capital Cost ($)	Annual O&M Cost ($/yr)
AMD Mitigations	12,060,000	222,000
AMD Collection	0	1,071,000
AMD Conveyance	340,000	130,000
AMD Storage	1,950,000	157,000
AMD Treatment	8,198,000	763,000
Sludge Management[1]	5,100,000	618,000
Performance Monitoring[2]	0	158,000
Totals	**27,648,000**	**3,119,000**
30-Year NPV of O&M		**38,704,000**
Total 30-Year Present Worth	**66,352,000**	

[1]The capital cost is the present worth of capital expenditures which occur during the 30-year time period. See the sludge option NPV calculation summary sheet for details.

[2]The monitoring annual O&M cost is the annualized amount of the 30-year net present value , since annual costs vary over the 30-year period. See the monitoring summary sheet for details.

AMD Mitigations	Capital	O&M
West Fork Milo Creek Diversion	3,590,000	28,000
Rehabilitate Phil Sheridan Diversion	1,250,000	18,000
Plug Drill Holes	150,000	9,000
Plug Small Hopes	360,000	500
Plug/Bypass Inez Shaft	650,000	500
Improve Phil Sheridan Diversion	380,000	500
Sidehill Diversions above Guy Cave	490,000	12,000
South Fork Diversion	1,870,000	30,000
Bypass Bunker Hill Dam	60,000	24,000
Improve Existing Mainstem Milo Diversion, Seal/Decrease Subflow	590,000	99,000
Improve Existing Mainstem Milo Diversion, Increase Capacity	2,670,000	Accounted For Above
Subtotal	12,060,000	222,000

AMD Collection	Capital	O&M
Existing In Mine System	0	1,071,000
Subtotal	0	1,071,000

AMD Conveyance	Capital	O&M
Existing Concrete Channel	0	25,000
Existing HDPE Pipeline	0	68,000
New HDPE Pipeline to CTP	340,000	37,000
Subtotal	340,000	130,000

AMD Storage	Capital	O&M
In-Mine Gravity Diversion System	710,000	Included in Extraction System
New Mine Pool Extraction System	1,240,000	126,000
Existing Lined Pond	0	31,000
Subtotal	1,950,000	157,000

AMD Treatment	Capital	O&M
Upgraded 2,500 gpm CTP with Media Filters	8,198,000	763,000
Subtotal	8,198,000	763,000

Sludge Management	NPV of Capital	O&M
Mechanical Dewatering System	3,440,000	143,000
Offsite Haulage and Disposal		475,000
Close Existing CIA Disposal Bed (Yr 2)	1,660,000	0
Subtotal	5,100,000	618,000

Performance Monitoring	Capital	O&M
KT Portal (Years 1 -30)	0	18,000
CTP (Years 1-30)	0	60,000
Surface (Years 1 - 5)	0	30,000
In-Mine (Years 1-5)	0	212,000
Subtotal	0	320,000
	Annualized O&M (Yrs 1-30)	157,969

NEXT

Alternative 5C
Cost Summary

Alternative 5C
Phased Mitigations/Treatment with Plugging of Near-Stream Workings (with Smelter Closure Area Sludge Disposal Beds)
Interest = 7%

Remedy Component	Capital Cost ($)	Annual O&M Cost ($/yr)
AMD Mitigations	12,060,000	222,000
AMD Collection	0	1,071,000
AMD Conveyance	340,000	130,000
AMD Storage	1,950,000	157,000
AMD Treatment	8,198,000	763,000
Sludge Management[1]	10,605,000	62,000
Performance Monitoring[2]	0	158,000
Totals	**33,153,000**	**2,563,000**
30-Year NPV of O&M		**31,804,000**
Total 30-Year Present Worth	**64,957,000**	

[1]The capital cost is the present worth of capital expenditures which occur during the 30-year time period. See the sludge option NPV calculation summary sheet for details.

[2]The monitoring annual O&M cost is the annualized amount of the 30-year net present value , since annual costs vary over the 30-year period. See the monitoring summary sheet for details.

AMD Mitigations	Capital	O&M
West Fork Milo Creek Diversion	3,590,000	28,000
Rehabilitate Phil Sheridan Diversion	1,250,000	18,000
Plug Drill Holes	150,000	9,000
Plug Small Hopes	360,000	500
Plug/Bypass Inez Shaft	650,000	500
Improve Phil Sheridan Diversion	380,000	500
Sidehill Diversions above Guy Cave	490,000	12,000
South Fork Diversion	1,870,000	30,000
Bypass Bunker Hill Dam	60,000	24,000
Improve Existing Mainstem Milo Diversion, Seal/Decrease Subflow	590,000	99,000
Improve Existing Mainstem Milo Diversion, Increase Capacity	2,670,000	Accounted For Above
Subtotal	12,060,000	222,000

AMD Collection	Capital	O&M
Existing In Mine System	0	1,071,000
Subtotal	0	1,071,000

AMD Conveyance	Capital	O&M
Existing Concrete Channel	0	25,000
Existing HDPE Pipeline	0	68,000
New HDPE Pipeline to CTP	340,000	37,000
Subtotal	340,000	130,000

AMD Storage	Capital	O&M
In-Mine Gravity Diversion System	710,000	Included in Extraction System
New Mine Pool Extraction System	1,240,000	126,000
Existing Lined Pond	0	31,000
Subtotal	1,950,000	157,000

AMD Treatment	Capital	O&M
Upgraded 2,500 gpm CTP with Media Filters	8,198,000	763,000
Subtotal	8,198,000	763,000

Sludge Management	NPV of Capital	O&M
Smelter Closure Area Sludge Disposal Beds	8,945,000	62,000
Close Existing CIA Disposal Bed (Yr 2)	1,660,000	0
Subtotal	10,605,000	62,000

Performance Monitoring	Capital	O&M
KT Portal (Years 1 -30)	0	18,000
CTP (Years 1-30)	0	60,000
Surface (Years 1 - 5)	0	30,000
In-Mine (Years 1-5)	0	212,000
Subtotal	0	320,000
	Annualized O&M (Yrs 1-30)	157,969

NEXT

Alternative 5D
Cost Summary

Alternative 5D
Phased Mitigations/Treatment with Plugging of Near-Stream Workings (with CIA Sludge Drying Beds and Smelter Closure Area Landfill)
Interest = 7%

Remedy Component	Capital Cost ($)	Annual O&M Cost ($/yr)
AMD Mitigations	12,060,000	222,000
AMD Collection	0	1,071,000
AMD Conveyance	340,000	130,000
AMD Storage	1,950,000	157,000
AMD Treatment	8,198,000	763,000
Sludge Management[1]	8,821,000	129,000
Performance Monitoring[2]	0	158,000
Totals	**31,369,000**	**2,630,000**
30-Year NPV of O&M		**32,636,000**
Total 30-Year Present Worth	**64,005,000**	

[1]The capital cost is the present worth of capital expenditures which occur during the 30-year time period. See the sludge option NPV calculation summary sheet for details.

[2]The monitoring annual O&M cost is the annualized amount of the 30-year net present value , since annual costs vary over the 30-year period. See the monitoring summary sheet for details.

AMD Mitigations	Capital	O&M
West Fork Milo Creek Diversion	3,590,000	28,000
Rehabilitate Phil Sheridan Diversion	1,250,000	18,000
Plug Drill Holes	150,000	9,000
Plug Small Hopes	360,000	500
Plug/Bypass Inez Shaft	650,000	500
Improve Phil Sheridan Diversion	380,000	500
Sidehill Diversions above Guy Cave	490,000	12,000
South Fork Diversion	1,870,000	30,000
Bypass Bunker Hill Dam	60,000	24,000
Improve Existing Mainstem Milo Diversion, Seal/Decrease Subflow	590,000	99,000
Improve Existing Mainstem Milo Diversion, Increase Capacity	2,670,000	Accounted For Above
Subtotal	12,060,000	222,000

AMD Collection	Capital	O&M
Existing In Mine System	0	1,071,000
Subtotal	0	1,071,000

AMD Conveyance	Capital	O&M
Existing Concrete Channel	0	25,000
Existing HDPE Pipeline	0	68,000
New HDPE Pipeline to CTP	340,000	37,000
Subtotal	340,000	130,000

AMD Storage	Capital	O&M
In-Mine Gravity Diversion System	710,000	Included in Extraction System
New Mine Pool Extraction System	1,240,000	126,000
Existing Lined Pond	0	31,000
Subtotal	1,950,000	157,000

AMD Treatment	Capital	O&M
Upgraded 2,500 gpm CTP with Media Filters	8,198,000	763,000
Subtotal	8,198,000	763,000

Sludge Management	NPV of Capital	O&M
Smelter Closure Area Landfill	5,523,000	86,000
Landfill Closure (Yr 31)	223,000	0
CIA Sludge Drying Beds	1,415,000	43,000
Close Existing CIA Disposal Bed (Yr 2)	1,660,000	0
Subtotal	8,821,000	129,000

Performance Monitoring	Capital	O&M
KT Portal (Years 1 -30)	0	18,000
CTP (Years 1-30)	0	60,000
Surface (Years 1 - 5)	0	30,000
In-Mine (Years 1-5)	0	212,000
Subtotal	0	320,000
	Annualized O&M (Yrs 1-30)	157,969

NEXT

O & M COST ESTIMATE DETAILS

Tasks	Qty	Unit	Material Unit Cost	Labor Unit Cost	Equip Unit Cost	Total Cost	Comments
Annual Costs							
Inspection	1	YR	0	400	80	$480	asm 1 times/year & 8hrs/time @ $50/hr labor & $10 for pickup
Road Maintenance & Repairs	1	YR	0	0	0	$0	
Pipeline & Structure Maint. & Repairs	1	YR	0	0	0	$0	
						$480	
Contingency	10%					$48	
Total Annual Cost						**$528**	

Bunker Hill **DATE: 08/24/2000**
AMD Mitigation Concepts **PROJECT NO.: 152215.FS.02**
4.1: Plug Small Hopes (SH) Drift **ESTIMATE BY: D. Hedglin**
Order of Magnitude Cost Opinion

DESCRIPTION	QTY	UNIT	TOTAL UNIT COST	TOTAL COST	COMMENTS
Plug Shaft					
Survey to Determine Location of SH Drift	1	LS	1,600.00	$1,600	
Install New Access Shaft to SH Drift	1	LS	10,000.00	$10,000	
Clean Out SH Drift & Find 2-Raises to Level 5	1	LS	51,690.24	$51,690	
Clean Out Min. of 16 Feet of Shafts to 5 Level	1	LS	10,338.05	$10,338	
Prepare for Plug	2	EA	5,319.96	$10,640	
Concrete Plug	60	CY	272.30	$16,338	
Construct Bulkhead Each End of SH Drift	2	EA	3,398.96	$6,798	400bf each @ 1.50/bf * 8hrs to install
Transport Mix to Pump Site	400	CY	3.29	$1,315	
Fill all Bulkheaded Areas w/Sand/Cement	400	CY	83.05	$33,222	add for mixing as in Cherry, etc
Remove/Backfill Access Shaft	1	LS	2,659.98	$2,660	
Replace Culvert Under Road	1	LS	3,546.02	$3,546	
SUBTOTAL				**$148,147**	
MISC ALLOWANCE	**10%**			**$14,815**	
SUBTOTAL				**$162,962**	
CONTINGENCY	**50%**			**$81,481**	
SUBTOTAL				**$244,443**	
MOBILIZATION	**15%**			**$36,666**	
CONSTRUCTION TOTAL				**$281,109**	
SALES TAX ON MATERIALS	**5.0%**			**$1,365**	
ENGINEERING AND SUPPORT	**20%**			**$56,222**	
CONST MANAGEMENT	**8%**			**$22,489**	
CAPITAL TOTAL (ROUNDED)				**$360,000**	
ANNUAL O&M COST			**$500**		
NPV OF ANNUAL O&M COSTS (30 YEARS @ 7% INTEREST)				**$6,000**	
TOTAL 30-YEAR PRESENT WORTH COST @ 7% INTEREST				**$366,000**	

NOTES:
Misc Allowance markup is to include items known to exist but cannot be quantified at this time.
Contingency is for scope changes that are presently unforeseen.
Mobilization includes bonds, insurance, temporary facilities, health & safety, demobilization, etc.

O & M COST ESTIMATE DETAILS

Tasks	Qty	Unit	Material Unit Cost	Labor Unit Cost	Equip Unit Cost	Total Cost	Comments
Annual Costs							
Inspection	1	YR	0	400	80	$480	asm 1 times/year & 8hrs/time @ $50/hr labor & $10 for pickup
Road Maintenance & Repairs	1	YR	0	0	0	$0	
Pipeline & Structure Maint. & Repairs	1	YR	0	0	0	$0	asm 2 times/year & 8hrs/time + material allowance
						$480	
Contingency	10%					$48	
Total Annual Cost						**$528**	

Bunker Hill **DATE: 08/24/2000**
AMD Mitigation Concepts **PROJECT NO.: 152215.FS.02**
5.1: Plug/Bypass Inez Shaft **ESTIMATE BY: D. Hedglin**
Order of Magnitude Cost Opinion

DESCRIPTION	QTY	UNIT	TOTAL UNIT COST	TOTAL COST	COMMENTS
Plug Shaft					
Survey to Determine Location of Shaft	1	LS	3,200.00	$3,200	
Provide 2000' of 15' wide access road	2,000	LF	25.00	$50,000	
Excavate to Find Location	1	LS	51,690.24	$51,690	15 days
Sheetpiles	2,700	SF	21.65	$58,455	
Excavate to Top of Rock	555	CY	34.46	$19,125	
Backfill Excavation	555	CY	13.30	$7,381	
Prepare for Plug	1	LS	5,319.96	$5,320	
Excavate & Waste 16' of Shaft	30	CY	258.45	$7,754	largely handwork
Concrete Plug	30	CY	143.08	$4,292	
Hydroseed all disturbed areas	60,000	SF	0.10	$6,000	
Regrade Stream	1	LS	51,690.24	$51,690	
SUBTOTAL				**$264,908**	
MISC ALLOWANCE	**10%**			**$26,491**	
SUBTOTAL				**$291,399**	
CONTINGENCY	**50%**			**$145,699**	
SUBTOTAL				**$437,098**	
MOBILIZATION	**15%**			**$65,565**	
CONSTRUCTION TOTAL				**$502,663**	
SALES TAX ON MATERIALS	**5.0%**			**$2,175**	
ENGINEERING AND SUPPORT	**20%**			**$100,533**	
CONST MANAGEMENT	**8%**			**$40,213**	
CAPITAL TOTAL (ROUNDED)				**$650,000**	
ANNUAL O&M COST			**$500**		
NPV OF ANNUAL O&M COSTS (30 YEARS @ 7% INTEREST)				**$6,000**	
TOTAL 30-YEAR PRESENT WORTH COST @ 7% INTEREST				**$656,000**	

NOTES:
Misc Allowance markup is to include items known to exist but cannot be quantified at this time.
Contingency is for scope changes that are presently unforeseen.
Mobilization includes bonds, insurance, temporary facilities, health & safety, demobilization, etc.

O & M COST ESTIMATE DETAILS

Tasks	Qty	Unit	Material Unit Cost	Labor Unit Cost	Equip Unit Cost	Total Cost	Comments
Annual Costs							
Inspection	1	YR	0	400	80	$480	asm 1 times/year & 8hrs/time @ $50/hr labor & $10 for pickup
Road Maintenance & Repairs	1	YR	0	0	0	$0	
Pipeline & Structure Maint. & Repairs	1	YR	0	11,700	9,900	$21,600	asm 3 times/year & 8hrs/time + material allowance
						$22,080	
Contingency	10%					$2,208	
Total Annual Cost						**$24,288**	

Bunker Hill **DATE: 08/24/2000**
AMD Mitigation Concepts **PROJECT NO.: 152215.FS.02**
4.2: Bypass Bunker Hill Reservoir **ESTIMATE BY: D. Hedglin**
Order of Magnitude Cost Opinion **T.Pyle**

DESCRIPTION	QTY	UNIT	TOTAL UNIT COST	TOTAL COST	COMMENTS
Modify Outlet Works	1	LS	15,000.00	$15,000	
New Pipeline and Connection	1	LS	15,000.00	$15,000	
SUBTOTAL				**$30,000**	
MISC ALLOWANCE	**10%**			**$3,000**	
SUBTOTAL				**$33,000**	
CONTINGENCY	**30%**			**$9,900**	
SUBTOTAL				**$42,900**	
MOBILIZATION	**15%**			**$6,435**	
CONSTRUCTION TOTAL				**$49,335**	
SALES TAX ON MATERIALS	**5.0%**			**$0**	
ENGINEERING AND SUPPORT	**20%**			**$9,867**	
CONST MANAGEMENT	**8%**			**$3,947**	
CAPITAL TOTAL (ROUNDED)				**$60,000**	
ANNUAL O&M COST			**$24,300**		
NPV OF ANNUAL O&M COSTS (30 YEARS @ 7% INTEREST)				**$302,000**	
TOTAL 30-YEAR PRESENT WORTH COST @ 7% INTEREST				**$362,000**	

NOTES:

Misc Allowance markup is to include items known to exist but cannot be quantified at this time.
Contingency is for scope changes that are presently unforeseen.
Mobilization includes bonds, insurance, temporary facilities, health & safety, demobilization, etc.

O & M COST ESTIMATE DETAILS

Tasks	Qty	Unit	Material Unit Cost	Labor Unit Cost	Equip Unit Cost	Total Cost	Comments
Annual Costs							
Inspection	1	YR	0	1,600	320	$1,920	asm 4 times/year & 8hrs/time @ $50/hr labor & $10 for pickup
Road Maintenance & Repairs	1	YR	0	1,492	672	$2,164	asm 1 time/year & 8hrs/time + material allowance
Pipeline & Structure Maint. & Repairs	1	YR	0	46,550	39,600	$86,150	asm 12 times/year & 8hrs/time + material allowance
						$90,235	
Contingency	10%					$9,023	
Total Annual Cost						**$99,258**	

Bunker Hill **DATE: 08/24/2000**
AMD Mitigation Concepts **PROJECT NO.: 152215.FS.02**
4.4: Improve Existing Diversion (Increase Pipeline Capacity) **ESTIMATE BY: D. Hedglin**
Order of Magnitude Cost Opinion

DESCRIPTION	QTY	UNIT	TOTAL UNIT COST	TOTAL COST	COMMENTS
New Pipeline					
Clear & Grub New Road	1,330	LF	8.62	$11,458	asm 30'w & 50'/hour
Grade, Fill & Compact New Road	1,330	LF	38.16	$50,756	
Base Course on New Road	493	CY	24.92	$12,277	
Erosion & Sedimentation Control	1	LS	41,643.58	$41,644	$/LF allowance for ditches, culverts, silt fences, sed ponds, etc
54" Pipeline in New Road	1,400	LF	218.69	$306,159	including earthwork & fittings
Remove & Dispose of 36" CMP Pipe	1,400	LF	8.59	$12,020	earthwork included above, remove, haul to disposal site, dispose
Thrust Block	1	EA	3,789.51	$3,790	
Air Vent	1	EA	1,286.19	$1,286	
Cut-off Trench Seepage Walls	14	EA	3,200.00	$44,800	
Modifications to Existing Diversion Structure					
Diversion/Care of Water	1	LS	20,000.00	$20,000	
Excavate for New Structure	150	CY	17.23	$2,585	
Native Backfill Around Structure	60	CY	13.30	$798	
Raise Existing Spillway on Dam	1	LS	23,299.89	$23,300	
Excavate for Screen Structure	70	CY	17.23	$1,206	
Native Backfill Around Screen Structure	20	CY	13.30	$266	
Backfill Riprap Overflow Spillway	325	CY	39.95	$12,984	
Construct Screen Intake Structure	45	CY	552.24	$24,851	
Construct Transition Structure	30	CY	552.24	$16,567	
Bar Screen	1	LS	22,659.98	$22,660	
Foundation Grout Curtain	1,500	LF	40.00	$60,000	
Excavation	833	CY	17.23	$14,358	
Gravel pad for concrete pad	50	CY	20.00	$1,000	
Concrete base pad, 8+ thick	70	CY	300.00	$21,000	
Sheetpile Wall for Cutoff	2,250	SQ	30.00	$67,500	
Native Backfill around Sheetpiles	1,800	CY	13.30	$23,940	
Riprap Cover	625	CY	28.62	$17,884	
Collector Pipe & Gabions					
Excavation	675	CY	17.23	$11,630	
Imported Bed, Zone & Backfill	563	CY	31.62	$17,789	
Waste	675	CY	3.29	$2,220	
36" Perf. Collector Pipe	450	LF	68.62	$30,878	
Regrade Stream	1	LS	30,152.64	$30,153	
Gabion Sediment Traps	150	CY	183.25	$27,487	
Bureau of Reclamation Stilling Basin					
Structure Complete	1	LS	151,690.24	$151,690	
SUBTOTAL				**$1,086,936**	
MISC ALLOWANCE	**10%**			**$108,694**	
SUBTOTAL				**$1,195,630**	
CONTINGENCY	**50%**			**$597,815**	
SUBTOTAL				**$1,793,445**	
MOBILIZATION	**15%**			**$269,017**	
CONSTRUCTION TOTAL				**$2,062,461**	
SALES TAX ON MATERIALS	**5.0%**			**$26,794**	
ENGINEERING AND SUPPORT	**20%**			**$412,492**	
CONST MANAGEMENT	**8%**			**$164,997**	
CAPITAL TOTAL (ROUNDED)				**$2,670,000**	
ANNUAL O&M COST			**$99,300**		
NPV OF ANNUAL O&M COSTS (30 YEARS @ 7% INTEREST)				**$1,232,000**	
TOTAL 30-YEAR PRESENT WORTH COST @ 7% INTEREST				**$3,902,000**	

NOTES:
Misc Allowance markup is to include items known to exist but cannot be quantified at this time.
Contingency is for scope changes that are presently unforeseen.
Mobilization includes bonds, insurance, temporary facilities, health & safety, demobilization, etc.

O & M COST ESTIMATE DETAILS

Tasks	Qty	Unit	Material Unit Cost	Labor Unit Cost	Equip Unit Cost	Total Cost	Comments
Annual Costs							
Inspection	1	YR	0	1,600	320	$1,920	asm 4 times/year & 8hrs/time @ $50/hr labor & $10 for pickup
Road Maintenance & Repairs	1	YR	0	1,492	672	$2,164	asm 1 time/year & 8hrs/time + material allowance
Pipeline & Structure Maint. & Repairs	1	YR	0	46,550	39,600	$86,150	asm 12 times/year & 8hrs/time + material allowance
						$90,235	
Contingency	10%					$9,023	
Total Annual Cost						**$99,258**	

Bunker Hill **DATE: 08/24/2000**
AMD Mitigation Concepts **PROJECT NO.: 152215.FS.02**
4.3: Improve Existing Diversions (Improve Seal, Decrease Weir Overflow)
Order of Magnitude Cost Opinion **ESTIMATE BY: D. Hedglin**

DESCRIPTION	QTY	UNIT	TOTAL UNIT COST	TOTAL COST	COMMENTS
Modifications to Existing Diversion Structure					
Diversion/Care of Water	1	LS	20,000.00	$20,000	
Excavate for New Structure	150	CY	17.23	$2,585	
Native Backfill Around Structure	60	CY	13.30	$798	
Raise Existing Spillway on Dam	1	LS	23,299.89	$23,300	allowance
Excavate for Screen Structure	70	CY	17.23	$1,206	
Native Backfill Around Screen Structure	20	CY	13.30	$266	
Backfill Riprap Overflow Spillway	325	CY	39.95	$12,984	
Construct Screen Intake Structure	45	CY	552.24	$24,851	
Construct Transition Structure	30	CY	552.24	$16,567	
Bar Screen	1	LS	22,659.98	$22,660	
Foundation Grout Curtain	1,500	LF	40.00	$60,000	
Excavation	833	CY	17.23	$14,358	
Gravel pad for concrete pad	50	CY	20.00	$1,000	
Concrete base pad, 8+ thick	70	CY	300.00	$21,000	
Riprap Cover	625	CY	28.62	$17,884	
SUBTOTAL				**$239,459**	
MISC ALLOWANCE	**10%**			**$23,946**	
SUBTOTAL				**$263,405**	
CONTINGENCY	**50%**			**$131,703**	
SUBTOTAL				**$395,108**	
MOBILIZATION	**15%**			**$59,266**	
CONSTRUCTION TOTAL				**$454,374**	
SALES TAX ON MATERIALS	**5.0%**			**$5,113**	
ENGINEERING AND SUPPORT	**20%**			**$90,875**	
CONST MANAGEMENT	**8%**			**$36,350**	
CAPITAL TOTAL (ROUNDED)				**$590,000**	
ANNUAL O&M COST			**$99,300**		
NPV OF ANNUAL O&M COSTS (30 YEARS @ 7% INTEREST)				**$1,232,000**	
TOTAL 30-YEAR PRESENT WORTH COST @ 7% INTEREST				**$1,822,000**	

NOTES:
Misc Allowance markup is to include items known to exist but cannot be quantified at this time.
Contingency is for scope changes that are presently unforeseen.
Mobilization includes bonds, insurance, temporary facilities, health & safety, demobilization, etc.

O & M COST ESTIMATE DETAILS

Tasks	Qty	Unit	Material Unit Cost	Labor Unit Cost	Equip Unit Cost	Total Cost	Comments
Annual Costs							
Inspection	1	YR	0	400	80	$480	asm 1 times/year & 8hrs/time @ $50/hr labor & $10 for pickup
Road Maintenance & Repairs	1	YR	0	0	0	$0	
Pipeline & Structure Maint. & Repairs	1	YR	0	0	0	$0	
						$480	
Contingency	10%					$48	
Total Annual Cost						**$528**	

Bunker Hill
AMD Mitigation Concepts
2.2.2: Improve Phil Sheridan Diversion Rehabilitation
Order of Magnitude Cost Opinion

DATE: 08/24/2000
PROJECT NO.: 152215.FS.02
ESTIMATE BY: D. Hedglin
T. Pyle

DESCRIPTION	QTY	TOTAL UNIT COST	TOTAL COST	COMMENTS
Foundation Grout Curtain	1,500	40.00	$60,000	
Sheetpile Wall for Cutoff	3,000	30.00	$90,000	
Dig/Drill/Install Collection Drains for Groundwater	50	120.00	$6,000	
SUBTOTAL			**$156,000**	
MISC ALLOWANCE	**10%**		**$15,600**	
SUBTOTAL			**$171,600**	
CONTINGENCY	**50%**		**$85,800**	
SUBTOTAL			**$257,400**	
MOBILIZATION	**15%**		**$38,610**	
CONSTRUCTION TOTAL			**$296,010**	
SALES TAX ON MATERIALS	**5.0%**		**$1,925**	
ENGINEERING AND SUPPORT	**20%**		**$59,202**	
CONST MANAGEMENT	**8%**		**$23,681**	
CAPITAL TOTAL (ROUNDED)			**$380,000**	
ANNUAL O&M COST		**$500**		
NPV OF ANNUAL O&M COSTS (30 YEARS @ 7% INTEREST)			**$6,000**	
TOTAL 30-YEAR PRESENT WORTH COST @ 7% INTEREST			**$386,000**	

NOTES:

Misc Allowance markup is to include items known to exist but cannot be quantified at this time.
Contingency is for scope changes that are presently unforeseen.
Mobilization includes bonds, insurance, temporary facilities, health & safety, demobilization, etc.

O & M COST ESTIMATE DETAILS

Tasks	Qty	Unit	Material Unit Cost	Labor Unit Cost	Equip Unit Cost	Total Cost	Comments
Annual Costs							
Inspection	1	YR	0	3,200	320	$3,520	asm 8 times/year & 8hrs/time @ $50/hr labor & $10 for pickup
Road Maintenance & Repairs	1	YR	1,000	3,724	3,168	$7,892	asm 1 time/year & 8hrs/time + material allowance
Pipeline & Structure Maint. & Repairs	1	YR	2,000	7,448	6,336	$15,784	asm 4 times/year & 8hrs/time + material allowance
						$27,196	
Contingency	10%					$2,720	
Total Annual Cost						**$29,916**	

Bunker Hill **DATE: 08/24/2000**
AMD Mitigation Concepts **PROJECT NO.: 152215.FS.02**
3.1: South Fork Diversion **ESTIMATE BY: D. Hedglin**
Order of Magnitude Cost Opinion

DESCRIPTION	QTY	UNIT	TOTAL UNIT COST	TOTAL COST	COMMENTS	
Site Access Road						
Clear & Grub New Road	1,330	LF	8.62	$11,458	asm 30'w & 50'/hour	
Grade, Fill & Compact New Road	1,330	LF	38.16	$50,756		
Base Course on New Road	493	CY	24.92	$12,277		
Grade & Improve Existing Road	800	LF	28.90	$23,118		
Erosion & Sedimentation Control	1	LS	41,643.58	$41,644	$/LF allowance for ditches, culverts, silt fences, sed ponds, etc	
Diversion Structure						**$65.38**
Diversion/Care of Water	1	LS	10,000.00	$10,000		
Excavate for Sheetpile Dam	900	CY	17.23	$15,507		
Native Backfill Around Sheetpiles	900	CY	13.30	$11,970		
Sheetpile Wall for Cutoff	1,100	SF	30.00	$33,000		
Excavate for Screen Structure	70	CY	17.23	$1,206		
Native Backfill Around Screen Structure	20	CY	13.30	$266		
Backfill Riprap Overflow Spillway	325	CY	39.95	$12,984		
Construct Screen Intake Structure	15	CY	552.24	$8,284		
Construct Transition Structure	15	CY	552.24	$8,284		
Foundation Grout Curtain	750	LF	40.00	$30,000		
Bar Screen	1	LS	10,329.99	$10,330		
Collector Pipe & Gabions						
Excavation	300	CY	17.23	$5,169		
Imported Bed, Zone & Backfill	250	CY	31.62	$7,906		
Waste	300	CY	3.29	$986		
36" Perf. Collector Pipe	200	LF	68.62	$13,724		
Regrade Stream	1	LS	20,676.10	$20,676		
Gabion Sediment Traps	50	CY	183.25	$9,162		
Pipeline & Access Road						
36" Pipeline in Imp Road	850	LF	127.24	$108,152	including earthwork & fittings	
36" Pipeline in New Road	1,350	LF	127.24	$171,771	including earthwork & fittings	
Stream Crossing	1	EA	4,579.02	$4,579		
Thrust Block	1	EA	822.38	$822		
Air Vent	3	EA	586.19	$1,759		
Cut-Off Trench Seepage Walls	22	EA	2,100.00	$46,200	asm 7cy @ $300/cy	
Thrust Block	2	EA	3,789.51	$7,579		
Bureau of Reclamation Stilling Basin						
Structure Complete	2	LS	67,230.08	$134,460	based on Lake Tapps design & estimate	
SUBTOTAL				**$814,028**		
MISC ALLOWANCE	**10%**			**$81,403**		
SUBTOTAL				**$895,431**		
CONTINGENCY	**40%**			**$358,173**		
SUBTOTAL				**$1,253,604**		
MOBILIZATION	**15%**			**$188,041**		
CONSTRUCTION TOTAL				**$1,441,644**		
SALES TAX ON MATERIALS	**5.0%**			**$20,664**		
ENGINEERING AND SUPPORT	**20%**			**$288,329**		
CONST MANAGEMENT	**8%**			**$115,332**		
CAPITAL TOTAL (ROUNDED)				**$1,870,000**		
ANNUAL O&M COST			**$29,900**			
NPV OF ANNUAL O&M COSTS (30 YEARS @ 7% INTEREST)				**$371,000**		
TOTAL 30-YEAR PRESENT WORTH COST @ 7% INTEREST				**$2,241,000**		

NOTES:
Misc Allowance markup is to include items known to exist but cannot be quantified at this time.
Contingency is for scope changes that are presently unforeseen.
Mobilization includes bonds, insurance, temporary facilities, health & safety, demobilization, etc.

O & M COST ESTIMATE DETAILS

Tasks	Qty	Unit	Material Unit Cost	Labor Unit Cost	Equip Unit Cost	Total Cost	Comments
Annual Costs							
Inspection	1	YR	0	400	80	$480	asm 1 time/year & 8hrs/time @ $50/hr labor & $10 for pickup
Road Maintenance & Repairs	1	YR	500	4,477	2,016	$6,993	asm 13time/year & 8hrs/time + material allowance
Pipeline & Structure Maint. & Repairs	1	YR	0	0	3,168	$3,168	asm 1 times/year & 8hrs/time + material allowance
						$10,641	
Contingency	10%					$1,064	
Total Annual Cost						**$11,705**	

Bunker Hill **DATE: 08/24/2000**
AMD Mitigation Concepts **PROJECT NO.: 152215.FS.02**
2.3: Sidehill Diversion above Guy Cave **ESTIMATE BY: D. Hedglin**
Order of Magnitude Cost Opinion

DESCRIPTION	QTY	UNIT	TOTAL UNIT COST	TOTAL COST	COMMENTS
Access Roads					
Clear & Grub	940	LF	8.62	$8,098	asm 30'w & 50'/hour
Grade, Fill & Compact	940	LF	76.32	$71,745	60% rock
Crushed Surfacing Base Course	348	CY	21.65	$7,537	
Erosion matting & mulch on all disturbed cut slopes	47,000	SF	1.00	$47,000	jute mat & hydroseed-allow
Ditch Lining System	940	LF	47.90	$45,024	
Construct Screen Intake Structure	20	CY	500.90	$10,018	
Erosion & Sedimentation Control	1	LS	9,400.00	$9,400	$/LF allowance for ditches, culverts, silt fences, sed ponds, etc
SUBTOTAL				**$198,823**	
MISC ALLOWANCE	**10%**			**$19,882**	
SUBTOTAL				**$218,705**	
CONTINGENCY	**50%**			**$109,352**	
SUBTOTAL				**$328,057**	
MOBILIZATION	**15%**			**$49,209**	
CONSTRUCTION TOTAL				**$377,266**	
SALES TAX ON MATERIALS	**5.0%**			**$2,306**	
ENGINEERING AND SUPPORT	**20%**			**$75,453**	
CONST MANAGEMENT	**8%**			**$30,181**	
CAPITAL TOTAL (ROUNDED)				**$490,000**	
ANNUAL O&M COST			**$11,700**		
NPV OF ANNUAL O&M COSTS (30 YEARS @ 7% INTEREST)				**$145,000**	
TOTAL 30-YEAR PRESENT WORTH COST @ 7% INTEREST				**$635,000**	

NOTES:
Misc Allowance markup is to include items known to exist but cannot be quantified at this time.
Contingency is for scope changes that are presently unforeseen.
Mobilization includes bonds, insurance, temporary facilities, health & safety, demobilization, etc.

Bunker Hill — **DATE: 08/24/2000**
AMD Mitigation Concepts — **PROJECT NO.: 152215.FS.02**
2.1: West Fork Diversion — **ESTIMATE BY: D. Hedglin**
Order of Magnitude Cost Opinion — **T. Pyle**

DESCRIPTION	QTY	UNIT	TOTAL UNIT COST	TOTAL COST	COMMENTS
Site Access Road					
Clear & Grub New Road	3,500	LF	8.62	$30,153	asm 30'w & 50'/hour
Grade, Fill & Compact New Road	3,500	LF	76.32	$267,137	encounter rock
Base Course on New Road	1,296	CY	24.92	$32,307	
Grade & Improve Existing Road	400	LF	28.90	$11,559	
Erosion & Sedimentation Control	1	LS	47,054.48	$47,054	$/LF allowance for ditches, culverts, silt fences, sed ponds, etc
Diversion Structure					
Diversion/Care of Water	1	LS	10,000.00	$10,000	
Excavate for Sheetpile Dam	1,800	CY	17.23	$31,014	
Native Backfill Around Sheetpiles	1,800	CY	13.30	$23,940	
Sheetpile Wall for Cutoff	2,250	SF	30.00	$67,500	
Excavate for Screen Structure	70	CY	17.23	$1,206	
Native Backfill Around Screen Structure	20	CY	13.30	$266	
Backfill Riprap Overflow Spillway	325	CY	39.95	$12,984	
Construct Screen Intake Structure	15	CY	552.24	$8,284	
Construct Transition Structure	15	CY	552.24	$8,284	
Foundation Grout Curtain	1,500	LF	40.00	$60,000	Includes diamond drilling, grout pipe, pressure testing, etc.
Bar Screen	1	LS	10,329.99	$10,330	
Collector Pipe & Gabions					
Excavation	300	CY	17.23	$5,169	
Imported Bed, Zone & Backfill	250	CY	31.62	$7,906	
Waste	300	CY	3.29	$986	
36" Perf. Collector Pipe	200	LF	68.62	$13,724	
Regrade Stream	1	LS	20,676.10	$20,676	
Gabion Sediment Traps	50	CY	183.25	$9,162	
Pipeline & Access Road					
36" Pipeline in Imp Road	750	LF	127.24	$95,430	including earthwork & fittings
30" Pipeline in New Road	750	LF	117.24	$87,928	including earthwork & fittings
36" Pipeline in Unimp Road	1,700	LF	241.71	$410,912	including earthwork & fittings
36" Overland Pipe	150	LF	214.48	$32,171	including earthwork, supports & fittings
42" Slip Pipe for Overland Pipe	40	LF	127.24	$5,090	including earthwork, supports & fittings
Anchor Block	2	EA	4,061.89	$8,124	asm 6cy & 5hrs to form, rebar, place
Anchor Fitting	2	EA	1,172.38	$2,345	allowance
Slip Joint Gasket	1	EA	1,186.19	$1,186	based on quote for Lake Tapps outfall
Thrust Block	7	EA	822.38	$5,757	
Air Vent	2	EA	586.19	$1,172	
Cut-Off Trench Seepage Walls	30	EA	2,100.00	$63,000	asm 7cy @ $300/cy
22 1/2 Degree Elbow	10	EA	2,572.38	$25,724	
Bureau of Reclamation Stilling Basin					
Structure Complete	4	LS	67,230.08	$268,920	based on Lake Tapps design & estimate
SUBTOTAL				**$1,687,400**	
MISC ALLOWANCE	**10%**			**$168,740**	
SUBTOTAL				**$1,856,140**	
CONTINGENCY	**30%**			**$556,842**	
SUBTOTAL				**$2,412,983**	
MOBILIZATION	**15%**			**$361,947**	
CONSTRUCTION TOTAL				**$2,774,930**	
SALES TAX ON MATERIALS	**5.0%**			**$33,487**	
ENGINEERING AND SUPPORT	**20%**			**$554,986**	
CONST MANAGEMENT	**8%**			**$221,994**	
CAPITAL TOTAL (ROUNDED)				**$3,590,000**	
ANNUAL O&M COST			**$27,700**		
NPV OF ANNUAL O&M COSTS (30 YEARS @ 7% INTEREST)				**$344,000**	
TOTAL 30-YEAR PRESENT WORTH COST @ 7% INTEREST				**$3,934,000**	

NOTES:
Misc Allowance markup is to include items known to exist but cannot be quantified at this time.
Contingency is for scope changes that are presently unforeseen.
Mobilization includes bonds, insurance, temporary facilities, health & safety, demobilization, etc.

Bunker Hill — **DATE: 08/24/2000**
AMD Mitigation Concepts — **PROJECT NO.: 152215.FS.02**
2.2.1: Rehabilitate Phil Sheridan Diversion — **ESTIMATE BY: D. Hedglin**
Order of Magnitude Cost Opinion — **T. Pyle**

DESCRIPTION	QTY	UNIT	TOTAL UNIT COST	TOTAL COST	COMMENTS
Open Phil Sheridan Raises					
Site Access Road					
Grade & Improve Existing Road	200	LF	28.90	$5,779	
Erosion & Sedimentation Control	1	LS	5,328.72	$5,329	$/LF allowance for ditches, culverts, silt fences, sed ponds, etc
Raise #1					
Open Up Raise #1	100	CY	107.69	$10,769	
Sink 6' Casing from Surface to Rock Line	25	LF	228.92	$5,723	
Prefabricated Steel Inlet Structure	1	LS	10,000.00	$10,000	
Native Backfill Around Screen Structure	100	CY	17.23	$1,723	
Place Riprap	100	CY	26.65	$2,665	
Raise #2					
Open Up Raise #2	100	CY	107.69	$10,769	
Sink 10' Casing from Surface to Rock Line	25	CY	2,500.00	$62,500	
Native Backfill Around Screen Structure	100	CY	17.23	$1,723	
Construct Screen Intake Structure	20	CY	500.90	$10,018	
Screens for Inlet Structure	2	LS	10,659.98	$21,320	
Regrade Stream	1	LS	10,338.05	$10,338	
Place Riprap	100	CY	26.65	$2,665	
Drift Construction					
Site Access Road					
Clear & Grub New Road for Access	150	LF	8.62	$1,292	
Grade, Fill & Compact New Road	150	LF	76.32	$11,449	$/LF allowance for ditches, culverts, silt fences, sed ponds, etc
Base Course on New Road	56	CY	24.92	$1,385	
Erosion & Sedimentation Control	1	LS	7,410.90	$7,411	
Proposed Drift Construction					
Drift Advancement	300	LF	500.00	$150,000	Based on costs provided by Bill Hudson
Access Road and Staging Area	1	LS	15,000.00	$15,000	Based on costs provided by Bill Hudson
Diversion/Care of Water	1	LS	20,000.00	$20,000	
Bulkhead/Bracing for new portal area	1	LS	25,000.00	$25,000	
Concrete Collar with Steel Bulkhead Dam	8	CY	566.25	$4,530	
HDPE Diversion Pipeline					
42" HDPE Pipeline in adit	300	LF	264.48	$79,343	including supports & fittings
36" HDPE buried in Unimp Road	100	LF	241.71	$24,171	including earthwork & fittings
Anchor Block	2	EA	4,061.89	$8,124	asm 6cy & 5hrs to form, rebar, place
Cut-Off Trench Seepage Walls	1	EA	2,100.00	$2,100	asm 7cy @ $500/cy
Concentric Reducer 42" by 36"	1	EA	2,572.38	$2,572	

SUBTOTAL			**$513,697**
MISC ALLOWANCE	**10%**		**$51,370**
SUBTOTAL			**$565,067**
CONTINGENCY	**50%**		**$282,534**
SUBTOTAL			**$847,601**
MOBILIZATION	**15%**		**$127,140**
CONSTRUCTION TOTAL			**$974,741**
SALES TAX ON MATERIALS	**5.0%**		**$1,710**
ENGINEERING AND SUPPORT	**20%**		**$194,948**
CONST MANAGEMENT	**8%**		**$77,979**
CAPITAL TOTAL (ROUNDED)			**$1,250,000**
ANNUAL O&M COST		**$18,200**	
NPV OF ANNUAL O&M COSTS (30 YEARS @ 7% INTEREST)			**$226,000**
TOTAL 30-YEAR PRESENT WORTH COST @ 7% INTEREST			**$1,476,000**

NOTES:
Misc Allowance markup is to include items known to exist but cannot be quantified at this time.
Contingency is for scope changes that are presently unforeseen.
Mobilization includes bonds, insurance, temporary facilities, health & safety, demobilization, etc.

O & M COST ESTIMATE DETAILS

Tasks	Qty		Unit Cost	Total Cost	Comments
Annual Costs					
Packer Inspection and Maintenance	21	Each	400	$8,400	$400/hole @ 21 holes
				$8,400	
Contingency	10%			$840	
Total Annual Cost				**$9,240**	

Bunker Hill **DATE: 08/24/2000**
AMD Mitigation Concepts **PROJECT NO.: 152215.FS.02**
6.1: Plug Drill Holes **ESTIMATE BY: D. Hedglin**
Order of Magnitude Cost Opinion

DESCRIPTION	QTY	UNIT	TOTAL UNIT COST	TOTAL COST	COMMENTS
Plug Holes					
Tunnel Clearing	1	LS	10,822.00	$10,822	2 week w/4 man crew & equipment
Add anchor flange for high pressure hole	1	LS	10,000.00	$10,000	
Plug Low Pressure Hole	20	EA	1,392.64	$27,853	1 day w/ 3 man crew
Plug High Pressure Hole	1	EA	22,926.40	$22,926	
SUBTOTAL				**$71,601**	
MISC ALLOWANCE	**10%**			**$7,160**	
SUBTOTAL				**$78,761**	
CONTINGENCY	**30%**			**$23,628**	
SUBTOTAL				**$102,390**	
MOBILIZATION	**15%**			**$15,358**	
CONSTRUCTION TOTAL				**$117,748**	
SALES TAX ON MATERIALS	**5.0%**			**$600**	
ENGINEERING AND SUPPORT	**20%**			**$23,550**	
CONST MANAGEMENT	**8%**			**$9,420**	
CAPITAL TOTAL (ROUNDED)				**$150,000**	
ANNUAL O&M COST			**$9,200**		
NPV OF ANNUAL O&M COSTS (30 YEARS @ 7% INTEREST)				**$114,000**	
TOTAL 30-YEAR PRESENT WORTH COST @ 7% INTEREST				**$264,000**	

NOTES:

Misc Allowance markup is to include items known to exist but cannot be quantified at this time.
Contingency is for scope changes that are presently unforeseen.
Mobilization includes bonds, insurance, temporary facilities, health & safety, demobilization, etc.

O & M COST ESTIMATE DETAILS

Tasks	Qty	Unit	Material Unit Cost	Labor Unit Cost	Equip Unit Cost	Total Cost	Comments
Annual Costs							
Inspection	1	YR	0	1,800	240	$2,040	asm 3 times/year & 8hrs/time @ $50/hr labor & $10 for pickup
Road Maintenance & Repairs	1	YR	1,000	1,492	672	$3,164	asm 1 time/year & 8hrs/time + material allowance
Pipeline & Structure Maint. & Repairs	1	YR	1,000	5,586	4,752	$11,338	asm 3 times/year & 8hrs/time + material allowance
						$16,542	
Contingency	10%					$1,654	
Total Annual Cost						**$18,197**	

O & M COST ESTIMATE DETAILS

Tasks	Qty	Unit	Material Unit Cost	Labor Unit Cost	Equip Unit Cost	Total Cost	Comments
Annual Costs							
Inspection	1	YR	0	1,600	320	$1,920	asm 4 times/year & 8hrs/time @ $50/hr labor & $10 for pickup
Road Maintenance & Repairs	1	YR	1,000	4,477	2,016	$7,493	asm 3 time/year & 8hrs/time + material allowance
Pipeline & Structure Maint. & Repairs	1	YR	2,000	7,448	6,336	$15,784	asm 4 times/year & 8hrs/time + material allowance
						$25,197	
Contingency	10%					$2,520	
Total Annual Cost						**$27,717**	

Alternative 2
Option A

Bunker Hill — **DATE: 11/22/2000**
Acid Mine Drainage — **PROJECT NO.: 152215.FS.02**
Sludge CIA Disposal Beds - Future Closure Cost — **ESTIMATE BY: D. Bunte**
Order of Magnitude Cost Opinion — **N. Gulensoy**

DESCRIPTION	QTY	UNIT	TOTAL UNIT COST	TOTAL COST
Sludge Disposal Bed Closure (per each)				
Cell Closure Allowance	3.80	AC	137,500.00	$522,500
SUBTOTAL				**$522,500**
MISC ALLOWANCE	**10%**			**$52,250**
SUBTOTAL				**$574,750**
CONTINGENCY	**30%**			**$172,425**
SUBTOTAL				**$747,175**
MOBILIZATION	**15%**			**$112,076**
CONSTRUCTION TOTAL				**$859,251**
SALES TAX ON MATERIALS	**5.0%**			**$11,875**
ENGINEERING AND SUPPORT	**20%**			**$171,850**
CONSTRUCTION MANAGEMENT	**8%**			**$68,740**
CAPITAL TOTAL (ROUNDED)				**$1,110,000**
ANNUAL O&M COST (considered incidental to rest of CIA)			**$0**	

NOTES:
Misc Allowance markup is to include items known to exist but cannot be quantified at this time.
Contingency is for scope changes that are presently unforeseen.
Mobilization includes bonds, insurance, temporary facilities, health & safety, demobilization, etc.

NOTE: The above cost opinion is in November 2000 dollars and does not include escalation. The order of magnitude cost opinion shown has been prepared for guidance in project evaluation at the time of preparation. The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope, final schedule and other variable factors. As a result, the final project costs will vary from those presented above. Because of these factors, funding needs must be carefully reviewed prior to making specific financial decisions or establishing final budgets.

Alternative 2
Option A

Bunker Hill
Acid Mine Drainage
Disposal of Raw Sludge in CIA Disposal Beds
Order of Magnitude Cost Opinion

DATE: 11/22/2000
PROJECT NO.: 152215.FS.02
ESTIMATE BY: D. Bunte
N. Gulensoy

DESCRIPTION	QTY	UNIT	TOTAL UNIT COST	TOTAL COST
Sitework/Yard Piping				
6" HDPE Sludge Pipeline in Trench	800	LF	21.54	$17,233
6" HDPE Leachate Pipeline in Trench	800	LF	21.54	$17,233
Sludge Pumping				
Prefab Metal Bldg w/Concrete Floor	216	SF	150.00	$32,400
Paint	1	LS	5,000.00	$5,000
Pump, 30hp	2	EA	14,810.06	$29,620
Standby Pump, 30hp	1	EA	14,810.06	$14,810
Gland Seal Water Pump	1	EA	7,948.38	$7,948
Electrical/I&C	1	LS	17,955.71	$17,956
Sludge Disposal Bed (per each)				
Excavation	25,000	C. Y.	3.00	$75,000
Subgrade Preparation	5	Acres	3,000.00	$15,000
Subgrade Stabilization	10,500	C. Y.	4.00	$42,000
Liner Protection Sand	8250	C. Y.	10.00	$82,500
Drain Rock	1,950	C. Y.	18.00	$35,100
Ditch Lining Geotextile	21,200	S. Y.	1.65	$34,980
G C L	18,100	S. Y.	4.05	$73,305
H D P E Geomembrane	18,100	S. Y.	5.40	$97,740
H D P E Pipe, 10"	550	L. F.	23.00	$12,650
Erosion Control Matting	11800	S.Y.	1.50	$17,700
Perf Pipe, 4"	2000	L. F.	2.00	$4,000
Perf Pipe, 6"	580	L. F.	3.00	$1,740
HDPE Pipe, 6"	130	L. F.	2.50	$325
Strip Drains	700	L. F.	1.75	$1,225
Valves, 6" Knife Gate	2	Each	700	$1,400
Valves, 10" Knife Gate	6	Each	1,000	$6,000
Air/Vacuum Release Valve	1	Each	2,000	$2,000
Valve Vault	6	Each	1,950	$11,700
Water Tight Manhole	1	Each	3,500	$3,500
Vertical Filtrate Drains	6	Each	4,000	$24,000
Cleanouts	2	Each	750	$1,500
Perimeter Road Embankment (not reduced)	43500	C. Y.	10	$435,000
Chain Link Fence and Gates (not reduced)	2000	L.F.	12	$24,000
Crushed Rock Surfacing (not reduced)	1500	C. Y.	15	$22,500
SUBTOTAL				**$1,167,065**
MISC ALLOWANCE	**10%**			**$116,706**
SUBTOTAL				**$1,283,771**
CONTINGENCY	**30%**			**$385,131**
SUBTOTAL				**$1,668,903**
MOBILIZATION	**15%**			**$250,335**
CONSTRUCTION TOTAL				**$1,919,238**
SALES TAX ON MATERIALS	**5.0%**			**$28,216**
ENGINEERING AND SUPPORT	**20%**			**$383,848**
CONSTRUCTION MANAGEMENT	**8%**			**$153,539**
CAPITAL COST FIRST BED (ROUNDED)				**$2,480,000**
CAPITAL COST FOR NEW CELLS IN FUTURE YEARS (DOES NOT INCLUDE PUMPING AND PIPING COST)				
Sludge Disposal Bed (per each)				
Excavation	25,000	C. Y.	3.00	$75,000
Subgrade Preparation	5	Acres	3,000.00	$15,000

Alternative 2
Option B

O & M COST ESTIMATE DETAILS

Description	Qty	Unit	Unit Cost	Total Cost
Annual Costs				
Belt Press Operator/Mechanic	1	YR	100,000	$100,000
Belt Press Repair Parts	1	YR	17,200	$17,200
Chemical Conditioning Polymer	1	YR	20,000	$20,000
Operation Costs	16,000	kWHR	0	$800
			Subtotal	**$138,000**
Contingency	10%			$13,800
Total Annual Cost				**$151,800**

Alternative 2
Option B

Bunker Hill — **DATE: 08/24/2000**
Acid Mine Drainage — **PROJECT NO.: 152215.FS.02**
Dewatering with Belt Filter Press — **ESTIMATE BY: D. Bunte**
Order of Magnitude Cost Opinion — **N. Gulensoy**

DESCRIPTION	QTY	UNIT	TOTAL UNIT COST	TOTAL COST
Belt Filter Press				
Earthwork & Concrete for Slab	0	LS	$0	$0
Misc Metals	1	LS	$0	$0
Building	4,000	SF	$130	$520,000
Paint	1	LS	$20,000	$20,000
Belt Press	4	EA	$260,540	$1,042,161
Booster Pump	1	EA	$6,793	$6,793
Air Compressor	1	EA	$5,638	$5,638
Conveyor	4	EA	$37,910	$151,640
Storage Hopper	2	EA	$38,997	$77,994
Electrical/I&C	1	LS	$0	$0
Haul to Off-Site Landfill				
Load	0	CY	$0	$0
Misc	0	LS	$0	$0
SUBTOTAL				**$1,824,227**
MISC ALLOWANCE	**10%**			**$182,423**
SUBTOTAL				**$2,006,649**
CONTINGENCY	**30%**			**$601,995**
SUBTOTAL				**$2,608,644**
MOBILIZATION	**15%**			**$391,297**
CONSTRUCTION TOTAL				**$2,999,941**
SALES TAX ON MATERIALS	**5.0%**			**$87,299**
ENGINEERING AND SUPPORT	**20%**			**$599,988**
CONSTRUCTION MANAGEMENT	**8%**			**$239,995**
FILTER PRESS CAPITAL TOTAL (ROUNDED)				**$3,930,000**
FILTER PRESS ANNUAL O&M COST			**$152,000**	
30-YEAR NPV OF FILTER PRESS ANNUAL O&M COST				**$1,886,000**
HAUL AND DISPOSE OFFSITE ANNUAL O&M COST			**$593,000**	
30-YEAR NPV OF HAUL AND DISPOSE OFFSITE				**$7,359,000**
TOTAL 30-YEAR PRESENT WORTH COST @ 7% INTEREST				**$13,175,000**

NOTES:
Misc Allowance markup is to include items known to exist but cannot be quantified at this time.
Contingency is for scope changes that are presently unforeseen.
Mobilization includes bonds, insurance, temporary facilities, health & safety, demobilization, etc.

NOTE: The above cost opinion is in August 2000 dollars and does not include escalation.
The order of magnitude cost opinion shown has been prepared for guidance in project evaluation at the time of preparation. The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope, final schedule and other variable factors. As a result, the final project costs will vary from those presented above. Because of these factors, funding needs must be carefully reviewed prior to making specific financial decisions or establishing final budgets.

Alternative 2
Option B

O & M COST ESTIMATE DETAILS

Description	Qty	Unit	Unit Cost	Total Cost	Comments
Annual Costs					
Haul & Dispose	12,400	TN	43.5	$539,400	Average cost for three regional landfills. Cost range from $35 to $52/ton
			Subtotal	**$539,400**	
Contingency	10%			$53,940	
Total Annual Cost				**$593,000**	

Alternative 2
Sludge Management Option C

ANNUAL O&M COSTS CALCULATIONS
Series of Expenditures

Interest Rate	**7.00%**
Net Present Value	**$889,000**

Year	Annual Cost	Factor	NPV
0	NA	1.0000	NA
1	$71,604	0.9346	$66,919
2	$71,604	0.8734	$62,541
3	$71,604	0.8163	$58,450
4	$71,604	0.7629	$54,626
5	$71,604	0.7130	$51,052
6	$71,604	0.6663	$47,713
7	$71,604	0.6227	$44,591
8	$71,604	0.5820	$41,674
9	$71,604	0.5439	$38,948
10	$71,604	0.5083	$36,400
11	$71,604	0.4751	$34,018
12	$71,604	0.4440	$31,793
13	$71,604	0.4150	$29,713
14	$71,604	0.3878	$27,769
15	$71,604	0.3624	$25,952
16	$71,604	0.3387	$24,255
17	$71,604	0.3166	$22,668
18	$71,604	0.2959	$21,185
19	$71,604	0.2765	$19,799
20	$71,604	0.2584	$18,504
21	$71,604	0.2415	$17,293
22	$71,604	0.2257	$16,162
23	$71,604	0.2109	$15,105
24	$71,604	0.1971	$14,116
25	$71,604	0.1842	$13,193
26	$71,604	0.1722	$12,330
27	$71,604	0.1609	$11,523
28	$71,604	0.1504	$10,769
29	$71,604	0.1406	$10,065
30	$71,604	0.1314	$9,406

PERIODIC COSTS CALCULATIONS
Single Expenditure at Year XX

Interest Rate	**7.00%**
Net Present Value	**$11,260,000**

Year	Investment	Factor	NPV	
0	$6,690,000	1.0000	$6,690,000	initial bed construction
1	$0	0.9346	$0	
2	$1,900,000	0.8734	$1,659,534	closure of existing bed
3	$0	0.8163	$0	
4	$0	0.7629	$0	
5	$0	0.7130	$0	
6	$0	0.6663	$0	
7	$0	0.6227	$0	
8	$0	0.5820	$0	
9	$0	0.5439	$0	
10	$2,580,000	0.5083	$1,311,541	new bed
11	$1,110,000	0.4751	$527,353	closure
12	$0	0.4440	$0	
13	$0	0.4150	$0	
14	$0	0.3878	$0	
15	$0	0.3624	$0	
16	$0	0.3387	$0	
17	$0	0.3166	$0	
18	$0	0.2959	$0	
19	$0	0.2765	$0	
20	$2,580,000	0.2584	$666,721	new bed
21	$1,110,000	0.2415	$268,080	closure
22	$0	0.2257	$0	
23	$0	0.2109	$0	
24	$0	0.1971	$0	
25	$0	0.1842	$0	
26	$0	0.1722	$0	
27	$0	0.1609	$0	
28	$0	0.1504	$0	
29	$0	0.1406	$0	
30	$0	0.1314	$0	
31	$1,110,000	0.1228	$136,278	closure

Alternative 2
Option C

Bunker Hill — **DATE: 11/22/2000**
Acid Mine Drainage — **PROJECT NO.: 152215.FS.02**
Smelter Closure Area Disposal Beds - Future Closure Cost — **ESTIMATE BY: D. Bunte**
Order of Magnitude Cost Opinion — **N. Gulensoy**

DESCRIPTION	QTY	UNIT	TOTAL UNIT COST	TOTAL COST
Sludge Disposal Bed Closure (per each)				
Cell Closure Allowance	3.80	AC	137,500.00	$522,500
SUBTOTAL				**$522,500**
MISC ALLOWANCE	**10%**			**$52,250**
SUBTOTAL				**$574,750**
CONTINGENCY	**30%**			**$172,425**
SUBTOTAL				**$747,175**
MOBILIZATION	**15%**			**$112,076**
CONSTRUCTION TOTAL				**$859,251**
SALES TAX ON MATERIALS	**5.0%**			**$11,875**
ENGINEERING AND SUPPORT	**20%**			**$171,850**
CONSTRUCTION MANAGEMENT	**8%**			**$68,740**
CAPITAL TOTAL (ROUNDED)				**$1,110,000**
ANNUAL O&M COST (considered incidental to operating sludge bed)			**$0**	

NOTES:
Misc Allowance markup is to include items known to exist but cannot be quantified at this time.
Contingency is for scope changes that are presently unforeseen.
Mobilization includes bonds, insurance, temporary facilities, health & safety, demobilization, etc.

NOTE: The above cost opinion is in November 2000 dollars and does not include escalation. The order of magnitude cost opinion shown has been prepared for guidance in project evaluation at the time of preparation. The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope, final schedule and other variable factors. As a result, the final project costs will vary from those presented above. Because of these factors, funding needs must be carefully reviewed prior to making specific financial decisions or establishing final budgets.

Alternative 2
Option C

O & M COST ESTIMATE DETAILS

Description	Qty	Unit	UNIT COST	Total Cost
Annual Costs				
Pump Station & Pipeline				
Operation Labor	1	YR	$33,000	$33,000
Pump & Pipeline Maintenance & Repairs	1	YR	$10,430	$10,430
Power Cost for Pumping & Misc	65,000	kWHR	$0.05	$3,250
Groundwater/Surface Water Monitoring				
System Inspection & Sampling	48	HR	$88	$4,224
Sample Shipping	4	EA	$66	$264
Supplies	4	EA	$220	$880
Indicator Analyses (quarterly)	8	EA	$297	$2,376
Metals Analyses (semiannually)	6	EA	$220	$1,320
Reporting	20	HR	$110	$2,200
Filtrate Discharge System Inspect/Clean	4	EA	$1,100	$4,400
Roads Maintenance	1	EA	$2,750	$2,750
			Subtotal	**$65,094**
Contingency	10%			$6,509
Total Annual Cost				**$71,604**

Alternative 2
Option C

Bunker Hill — **DATE: 11/22/2000**
Acid Mine Drainage — **PROJECT NO.: 152215.FS.02**
Closure of Existing CIA Sludge Pond — **ESTIMATE BY: D. Bunte**
Order of Magnitude Cost Opinion — **N. Gulensoy**

DESCRIPTION	QTY	UNIT	TOTAL UNIT COST	TOTAL COST
Closure of Existing CIA Sludge Pond				
Cell Closure Allowance	6.50	AC	137,500.00	$893,750
SUBTOTAL				**$893,750**
MISC ALLOWANCE	**10%**			**$89,375**
SUBTOTAL				**$983,125**
CONTINGENCY	**30%**			**$294,938**
SUBTOTAL				**$1,278,063**
MOBILIZATION	**15%**			**$191,709**
CONSTRUCTION TOTAL				**$1,469,772**
SALES TAX ON MATERIALS	**5.0%**			**$20,313**
ENGINEERING AND SUPPORT	**20%**			**$293,954**
CONSTRUCTION MANAGEMENT	**8%**			**$117,582**
CAPITAL TOTAL (ROUNDED)				**$1,900,000**
ANNUAL O&M COST (considered incidental to rest of CIA)			**$0**	

NOTES:

Misc Allowance markup is to include items known to exist but cannot be quantified at this time.
Contingency is for scope changes that are presently unforeseen.
Mobilization includes bonds, insurance, temporary facilities, health & safety, demobilization, etc.

NOTE: The above cost opinion is in November 2000 dollars and does not include escalation. The order of magnitude cost opinion shown has been prepared for guidance in project evaluation at the time of preparation. The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope, final schedule and other variable factors. As a result, the final project costs will vary from those presented above. Because of these factors, funding needs must be carefully reviewed prior to making specific financial decisions or establishing final budgets.

Alterative 2
Option D

SLUDGE LANDFILL O & M COST ESTIMATE DETAILS

Description	Qty	Unit	UNIT COST	Total Cost
Annual Costs				
Remove, Load, Decon Truck, Haul & Unload	6,800	CY	$11	$74,800
Groundwater/Surface Water Monitoring				
System Inspection & Sampling	48	HR	$88	$4,224
Sample Shipping	4	EA	$66	$264
Supplies	4	EA	$220	$880
Indicator Analyses (quarterly)	8	EA	$297	$2,376
Metals Analyses (semiannually)	6	EA	$220	$1,320
Reporting	20	HR	$110	$2,200
Filtrate Discharge System Inspect/Clean	4	EA	$1,100	$4,400
Roads Maintenance	1	EA	$2,750	$2,750
			Subtotal	**$93,214**
Contingency	10%			$9,321
Total Annual Cost				**$102,535**

Alternative 2
Option D

Bunker Hill — **DATE: 11/29/2000**
Acid Mine Drainage — **PROJECT NO.: 152215.FS.02**
Onsite Landfill - Smelter Closure Area — **ESTIMATE BY: D. Hedglin**
Order of Magnitude Cost Opinion

DESCRIPTION	QTY	UNIT	TOTAL UNIT COST	TOTAL COST
Sitework				
Clear and Grub	20	AC	3,000.00	$60,000
Site Prep Excavation	300,000	CY	3.30	$990,000
Site Prep Fill	300,000	CY	1.10	$330,000
Pipeline				
6" HDPE Gravity Pipeline in Trench	2,500	LF	22.50	$56,249
Manhole	8	EA	3,850.00	$32,083
Landfill Construction				
Excavation	58,000	CY	3.30	$191,400
Subgrade Preparation	13	AC	3,300.00	$41,910
Subgrade Stabilization	20,537	CY	4.40	$90,363
Embankment Fill	63,265	CY	11.00	$695,915
Liner Protection Sand	18,000	CY	19.80	$356,400
Drain Rock	5,100	CY	19.80	$100,980
Ditch Lining Geotextile	35,400	SY	1.82	$64,251
G C L	35,400	SY	4.46	$157,707
H D P E Geomembrane	35,400	SY	5.94	$210,276
H D P E Pipe, 12"	2,000	LF	28.60	$57,200
Erosion Control Matting	19,500	SY	1.65	$32,175
Perf Pipe, 6"	650	LF	3.30	$2,145
Strip Drains	1,180	LF	1.93	$2,272
Filtrate Penetration Sump (Allowance)	1	EA	27,500.00	$27,500
HDPE Pipe, 6"	150	LF	2.75	$413
Water Tight Manhole	1	EA	3,850.00	$3,850
Cleanouts	2	EA	825.00	$1,650
Chain Link Fence and Gates	3,060	LF	13.20	$40,392
Groundwater Monitoring Wells	4	EA	6,600.00	$26,400
Crushed Rock Surfacing	2,270	CY	16.50	$37,455
SUBTOTAL				**$3,608,985**
MISC ALLOWANCE	**10%**			**$360,899**
SUBTOTAL				**$3,969,884**
CONTINGENCY	**15%**			**$595,483**
SUBTOTAL				**$4,565,366**
MOBILIZATION	**15%**			**$684,805**
CONSTRUCTION TOTAL				**$5,250,171**
SALES TAX ON MATERIALS	**5%**			**$49,693**
ENGINEERING AND SUPPORT	**20%**			**$1,050,034**
CONSTRUCTION MANAGEMENT	**8%**			**$420,014**
CAPITAL TOTAL (ROUNDED)				**$6,770,000**

Alternative 2
Option D

Bunker Hill — **DATE: 11/29/2000**
Acid Mine Drainage — **PROJECT NO.: 152215.FS.02**
Onsite Landfill - Smelter Closure Area — **ESTIMATE BY: D. Hedglin**
Order of Magnitude Cost Opinion

DESCRIPTION	QTY	UNIT	TOTAL UNIT COST	TOTAL COST
ANNUAL O&M COST			$103,000	
CAPITAL COST OF CLOSURE @ YEAR 31			$2,263,000	
NPV OF ANNUAL O&M COSTS (30 YEARS @ 7% INTEREST)				$1,272,000
NPV OF CLOSURE COST (YEAR 31 @ 7% INTEREST)				$278,000
TOTAL 30-YEAR PRESENT WORTH COST @ 7% INTEREST				$8,320,000

NOTES:

Landfill post-closure costs are not included here since they extend beyond the 30 year period.
Misc Allowance markup is to include items known to exist but cannot be quantified at this time.
Contingency is for scope changes that are presently unforeseen.
Mobilization includes bonds, insurance, temporary facilities, health & safety, demobilization, etc.

NOTE: The above cost opinion is in November 2000 dollars and does not include escalation. The order of magnitude cost opinion shown has been prepared for guidance in project evaluation at the time of preparation. The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope, final schedule and other variable factors. As a result, the final project costs will vary from those presented above. Because of these factors, funding needs must be carefully reviewed prior to making specific financial decisions or establishing final budgets.

Alternatives 3 and 4
Option A

Bunker Hill — **DATE: 11/22/2000**
Acid Mine Drainage — **PROJECT NO.: 152215.FS.02**
Closure of Existing Sludge Pond on CIA — **ESTIMATE BY: D. Bunte**
Order of Magnitude Cost Opinion — **N. Gulensoy**

DESCRIPTION	QTY	UNIT	TOTAL UNIT COST	TOTAL COST
Closure of Existing Sludge Pond on CIA				
Cell Closure Allowance	6.50	AC	137,500.00	$893,750
SUBTOTAL				**$893,750**
MISC ALLOWANCE	**10%**			**$89,375**
SUBTOTAL				**$983,125**
CONTINGENCY	**30%**			**$294,938**
SUBTOTAL				**$1,278,063**
MOBILIZATION	**15%**			**$191,709**
CONSTRUCTION TOTAL				**$1,469,772**
SALES TAX ON MATERIALS	**5.0%**			**$20,313**
ENGINEERING AND SUPPORT	**20%**			**$293,954**
CONSTRUCTION MANAGEMENT	**8%**			**$117,582**
CAPITAL TOTAL (ROUNDED)				**$1,900,000**
ANNUAL O&M COST (considered incidental to rest of CIA)			**$0**	

NOTES:
Misc Allowance markup is to include items known to exist but cannot be quantified at this time.
Contingency is for scope changes that are presently unforeseen.
Mobilization includes bonds, insurance, temporary facilities, health & safety, demobilization, etc.

NOTE: The above cost opinion is in November 2000 dollars and does not include escalation. The order of magnitude cost opinion shown has been prepared for guidance in project evaluation at the time of preparation. The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope, final schedule and other variable factors. As a result, the final project costs will vary from those presented above. Because of these factors, funding needs must be carefully reviewed prior to making specific financial decisions or establishing final budgets.

Alternatives 3 and 4
Option A

Bunker Hill — **DATE: 11/22/2000**
Acid Mine Drainage — **PROJECT NO.: 152215.FS.02**
Sludge CIA Disposal Beds - Future Closure Cost — **ESTIMATE BY: D. Bunte**
Order of Magnitude Cost Opinion (Quantity reduced by 10%) — **N. Gulensoy**

DESCRIPTION	QTY	UNIT	TOTAL UNIT COST	TOTAL COST
Sludge Disposal Bed Closure (per each)				
Cell Closure Allowance	3.42	AC	137,500.00	$470,250
SUBTOTAL				**$470,250**
MISC ALLOWANCE	**10%**			**$47,025**
SUBTOTAL				**$517,275**
CONTINGENCY	**30%**			**$155,183**
SUBTOTAL				**$672,458**
MOBILIZATION	**15%**			**$100,869**
CONSTRUCTION TOTAL				**$773,326**
SALES TAX ON MATERIALS	**5.0%**			**$10,688**
ENGINEERING AND SUPPORT	**20%**			**$154,665**
CONSTRUCTION MANAGEMENT	**8%**			**$61,866**
CAPITAL TOTAL (ROUNDED)				**$1,000,000**
ANNUAL O&M COST (considered incidental to rest of CIA)			**$0**	

NOTES:
Misc Allowance markup is to include items known to exist but cannot be quantified at this time.
Contingency is for scope changes that are presently unforeseen.
Mobilization includes bonds, insurance, temporary facilities, health & safety, demobilization, etc.

NOTE: The above cost opinion is in November 2000 dollars and does not include escalation. The order of magnitude cost opinion shown has been prepared for guidance in project evaluation at the time of preparation. The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope, final schedule and other variable factors. As a result, the final project costs will vary from those presented above. Because of these factors, funding needs must be carefully reviewed prior to making specific financial decisions or establishing final budgets.

Alternatives 3 and 4
Option A

Bunker Hill — **DATE: 11/22/2000**
Acid Mine Drainage — **PROJECT NO.: 152215.FS.02**
Disposal of Raw Sludge in CIA Disposal Beds — **ESTIMATE BY: D. Bunte**
Order of Magnitude Cost Opinion (Quantity reduced by 10%) — **N. Gulensoy**

DESCRIPTION	QTY	QTY Reduced by 10%	UNIT	TOTAL UNIT COST	TOTAL COST
Sitework/Yard Piping					
6" HDPE Sludge Pipeline in Trench	800		LF	21.54	$17,233
6" HDPE Leachate Pipeline in Trench	800		LF	21.54	$17,233
Sludge Pumping					
Prefab Metal Bldg w/Concrete Floor	216		SF	150.00	$32,400
Paint	1		LS	5,000.00	$5,000
Pump, 30hp	2		EA	14,810.06	$29,620
Standby Pump, 30hp	1		EA	14,810.06	$14,810
Gland Seal Water Pump	1		EA	7,948.38	$7,948
Electrical/I&C	1		LS	17,955.71	$17,956
Sludge Disposal Bed (per each)					
Excavation	25,000	22,500	C. Y.	3.00	$67,500
Subgrade Preparation	5	5	Acres	3,000.00	$13,500
Subgrade Stabilization	10,500	9,450	C. Y.	4.00	$37,800
Liner Protection Sand	8250	7,425	C. Y.	10.00	$74,250
Drain Rock	1,950	1,755	C. Y.	18.00	$31,590
Ditch Lining Geotextile	21,200	19,080	S. Y.	1.65	$31,482
G C L	18,100	16,290	S. Y.	4.05	$65,975
H D P E Geomembrane	18,100	16,290	S. Y.	5.40	$87,966
H D P E Pipe, 10"	550	495	L. F.	23.00	$11,385
Erosion Control Matting	11800	10,620	S.Y.	1.50	$15,930
Perf Pipe, 4"	2000	1,800	L. F.	2.00	$3,600
Perf Pipe, 6"	580	522	L. F.	3.00	$1,566
HDPE Pipe, 6"	130	117	L. F.	2.50	$293
Strip Drains	700	630	L. F.	1.75	$1,103
Valves, 6" Knife Gate	2		Each	700	$1,400
Valves, 10" Knife Gate	6		Each	1,000	$6,000
Air/Vacuum Release Valve	1		Each	2,000	$2,000
Valve Vault	6		Each	1,950	$11,700
Water Tight Manhole	1		Each	3,500	$3,500
Vertical Filtrate Drains	6		Each	4,000	$24,000
Cleanouts	2		Each	750	$1,500
Perimeter Road Embankment (not reduced)	43500	43,500	C. Y.	10	$435,000
Chain Link Fence and Gates (not reduced)	2000	2,000	L.F.	12	$24,000
Crushed Rock Surfacing (not reduced)	1500	1,500	C. Y.	15	$22,500
SUBTOTAL					**$1,117,738**
MISC ALLOWANCE	**10%**				**$111,774**
SUBTOTAL					**$1,229,512**
CONTINGENCY	**30%**				**$368,854**
SUBTOTAL					**$1,598,366**
MOBILIZATION	**15%**				**$239,755**
CONSTRUCTION TOTAL					**$1,838,121**
SALES TAX ON MATERIALS	**5.0%**				**$28,216**
ENGINEERING AND SUPPORT	**20%**				**$367,624**
CONSTRUCTION MANAGEMENT	**8%**				**$147,050**
CAPITAL COST FIRST BED (ROUNDED)					**$2,380,000**
CAPITAL COST FOR NEW CELLS IN FUTURE YEARS (DOES NOT INCLUDE PUMPING AND PIPING COST)					
Sludge Disposal Bed (per each)					
Excavation	25,000	22,500	C. Y.	3.00	$67,500
Subgrade Preparation	5	5	Acres	3,000.00	$13,500

Alternative 5
Option B

Bunker Hill — **DATE: 08/24/2000**
Acid Mine Drainage — **PROJECT NO.: 152215.FS.02**
Dewatering with Belt Filter Press — **ESTIMATE BY: D. Bunte**
Order of Magnitude Cost Opinion (Quantity reduced by 20%) — **N. Gulensoy**

DESCRIPTION	QTY	UNIT	TOTAL UNIT COST	TOTAL COST
Belt Filter Press				
Earthwork & Concrete for Slab	0	LS	$0	$0
Misc Metals	1	LS	$0	$0
Building	3,499	SF	$130	$454,839
Paint	1	LS	$17,494	$17,494
Belt Press	4	EA	$227,892	$911,567
Booster Pump	1	EA	$5,942	$5,942
Air Compressor	1	EA	$4,932	$4,932
Conveyor	4	EA	$33,160	$132,638
Storage Hopper	2	EA	$34,110	$68,220
Electrical/I&C	1	LS	$0	$0
Haul to Off-Site Landfill				
Load	0	CY	$0	$0
Misc	0	LS	$0	$0

SUBTOTAL			**$1,595,632**
MISC ALLOWANCE	**10%**		**$159,563**
SUBTOTAL			**$1,755,195**
CONTINGENCY	**30%**		**$526,559**
SUBTOTAL			**$2,281,754**
MOBILIZATION	**15%**		**$342,263**
CONSTRUCTION TOTAL			**$2,624,017**
SALES TAX ON MATERIALS	**5.0%**		**$84,041**
ENGINEERING AND SUPPORT	**20%**		**$524,803**
CONSTRUCTION MANAGEMENT	**8%**		**$209,921**
FILTER PRESS CAPITAL TOTAL (ROUNDED)			**$3,440,000**
FILTER PRESS ANNUAL O&M COST		**$143,000**	
30-YEAR NPV OF FILTER PRESS ANNUAL O&M COST			**$1,774,000**
HAUL AND DISPOSE OFFSITE ANNUAL O&M COST		**$475,000**	
30-YEAR NPV OF HAUL AND DISPOSE OFFSITE			**$5,894,000**
TOTAL 30-YEAR PRESENT WORTH COST @ 7% INTEREST			**$11,108,000**

NOTES:
Misc Allowance markup is to include items known to exist but cannot be quantified at this time.
Contingency is for scope changes that are presently unforeseen.
Mobilization includes bonds, insurance, temporary facilities, health & safety, demobilization, etc.

NOTE: The above cost opinion is in August 2000 dollars and does not include escalation. The order of magnitude cost opinion shown has been prepared for guidance in project evaluation at the time of preparation. The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope, final schedule and other variable factors. As a result, the final project costs will vary from those presented above. Because of these factors, funding needs must be carefully reviewed prior to making specific financial decisions or establishing final budgets.

Alternatives 3 and 4
Sludge Management Option A

ANNUAL O&M COSTS CALCULATIONS
Series of Expenditures

Interest Rate	**7.00%**
Net Present Value	**$518,477**

Year	Annual Cost	Factor	NPV
0	NA	1.0000	NA
1	$41,782	0.9346	$39,049
2	$41,782	0.8734	$36,494
3	$41,782	0.8163	$34,107
4	$41,782	0.7629	$31,875
5	$41,782	0.7130	$29,790
6	$41,782	0.6663	$27,841
7	$41,782	0.6227	$26,020
8	$41,782	0.5820	$24,318
9	$41,782	0.5439	$22,727
10	$41,782	0.5083	$21,240
11	$41,782	0.4751	$19,850
12	$41,782	0.4440	$18,552
13	$41,782	0.4150	$17,338
14	$41,782	0.3878	$16,204
15	$41,782	0.3624	$15,144
16	$41,782	0.3387	$14,153
17	$41,782	0.3166	$13,227
18	$41,782	0.2959	$12,362
19	$41,782	0.2765	$11,553
20	$41,782	0.2584	$10,797
21	$41,782	0.2415	$10,091
22	$41,782	0.2257	$9,431
23	$41,782	0.2109	$8,814
24	$41,782	0.1971	$8,237
25	$41,782	0.1842	$7,698
26	$41,782	0.1722	$7,195
27	$41,782	0.1609	$6,724
28	$41,782	0.1504	$6,284
29	$41,782	0.1406	$5,873
30	$41,782	0.1314	$5,489

PERIODIC COSTS CALCULATIONS
Single Expenditure at Year XX

Interest Rate	**7.00%**
Net Present Value	**$6,473,791**

Year	Investment	Factor	NPV	
0	$2,380,000	1.0000	$2,380,000	initial bed construction
1	$0	0.9346	$0	
2	$1,900,000	0.8734	$1,659,534	closure of existing bed
3	$0	0.8163	$0	
4	$0	0.7629	$0	
5	$0	0.7130	$0	
6	$0	0.6663	$0	
7	$0	0.6227	$0	
8	$0	0.5820	$0	
9	$0	0.5439	$0	
10	$2,080,000	0.5083	$1,057,367	new bed
11	$1,000,000	0.4751	$475,093	closure
12	$0	0.4440	$0	
13	$0	0.4150	$0	
14	$0	0.3878	$0	
15	$0	0.3624	$0	
16	$0	0.3387	$0	
17	$0	0.3166	$0	
18	$0	0.2959	$0	
19	$0	0.2765	$0	
20	$2,080,000	0.2584	$537,512	new bed
21	$1,000,000	0.2415	$241,513	closure
22	$0	0.2257	$0	
23	$0	0.2109	$0	
24	$0	0.1971	$0	
25	$0	0.1842	$0	
26	$0	0.1722	$0	
27	$0	0.1609	$0	
28	$0	0.1504	$0	
29	$0	0.1406	$0	
30	$0	0.1314	$0	
31	$1,000,000	0.1228	$122,773	closure

Alternatives 3 and 4
Option A

Bunker Hill | **DATE: 11/22/2000**
Acid Mine Drainage | **PROJECT NO.: 152215.FS.02**
Disposal of Raw Sludge in CIA Disposal Beds | **ESTIMATE BY: D. Bunte**
Order of Magnitude Cost Opinion (Quantity reduced by 10%) | **N. Gulensoy**

DESCRIPTION	QTY	QTY Reduced by 10%	UNIT	TOTAL UNIT COST	TOTAL COST
Subgrade Stabilization	10,500	9,450	C. Y.	4.00	$37,800
Liner Protection Sand	8250	7,425	C. Y.	10.00	$74,250
Drain Rock	1,950	1,755	C. Y.	18.00	$31,590
Ditch Lining Geotextile	21,200	19,080	S. Y.	1.65	$31,482
G C L	18,100	16,290	S. Y.	4.05	$65,975
H D P E Geomembrane	18,100	16,290	S. Y.	5.40	$87,966
H D P E Pipe, 10"	550	495	L. F.	23.00	$11,385
Erosion Control Matting	11800	10,620	S.Y.	1.50	$15,930
Perf Pipe, 4"	2000	1,800	L. F.	2.00	$3,600
Perf Pipe, 6"	580	522	L. F.	3.00	$1,566
HDPE Pipe, 6"	130	117	L. F.	2.50	$293
Strip Drains	700	630	L. F.	1.75	$1,103
Valves, 6" Knife Gate	2		Each	700.00	$1,400
Valves, 10" Knife Gate	6		Each	1,000.00	$6,000
Air/Vacuum Release Valve	1		Each	2,000.00	$2,000
Valve Vault	6		Each	1,950.00	$11,700
Water Tight Manhole	1		Each	3,500.00	$3,500
Vertical Filtrate Drains	6		Each	4,000.00	$24,000
Cleanouts	2		Each	750.00	$1,500
Perimeter Road Embankment (not reduced)	28275	28,275	C. Y.	10	$282,750
Chain Link Fence and Gates (not reduced)	1000	1,000	L.F.	12	$12,000
Crushed Rock Surfacing (not reduced)	1500	1,500	C. Y.	15	$22,500
SUBTOTAL					**$975,539**
MISC ALLOWANCE	**10%**				**$97,554**
SUBTOTAL					**$1,073,092**
CONTINGENCY	**30%**				**$321,928**
SUBTOTAL					**$1,395,020**
MOBILIZATION	**15%**				**$209,253**
CONSTRUCTION TOTAL					**$1,604,273**
SALES TAX ON MATERIALS	**5.0%**				**$25,622**
ENGINEERING AND SUPPORT	**20%**				**$320,855**
CONSTRUCTION MANAGEMENT	**8%**				**$128,342**
CAPITAL COST SUBSEQUENT BEDS TOTAL (ROUNDED)					**$2,080,000**
ANNUAL O&M COST FOR OPERATING BED				**$42,000**	
NPV OF ANNUAL O&M COSTS (30 YEARS @ 7% INTEREST)					**$518,000**
NPV OF INITIAL AND SUBSEQUENT BEDS & CLOSURES CAPITAL COSTS @ 7% INTEREST					**$6,474,000**
TOTAL 30-YEAR PRESENT WORTH COST @ 7% INTEREST					**$6,992,000**

NOTES:
Misc Allowance markup is to include items known to exist but cannot be quantified at this time.
Contingency is for scope changes that are presently unforeseen.
Mobilization includes bonds, insurance, temporary facilities, health & safety, demobilization, etc.

NOTE: The above cost opinion is in November 2000 dollars and does not include escalation. The order of magnitude cost opinion shown has been prepared for guidance in project evaluation at the time of preparation. The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope, final schedule and other variable factors. As a result, the final project costs will vary from those presented above. Because of these factors, funding needs must be carefully reviewed prior to making specific financial decisions or establishing final budgets.

Alternatives 3 and 4
Option A
O & M COST ESTIMATE DETAILS

Description	Qty	Unit	Unit Cost	Total Cost
Annual Costs				
Pump Station & Pipeline				
Operation Labor	1	YR	22,500	$22,500
Pump & Pipeline Maintenance & Repairs	1	YR	8,534	$8,534
Power Cost for Pumping & Misc (Quantity reduced by 10%)	9,000	kWHR	0	$450
Filtrate Discharge System Inspect/Clean	4	EA	1,000	$4,000
Roads Maintenance	1	EA	2,500	$2,500
			Subtotal	**$37,984**
Contingency	10%			$3,798
Total Annual Cost				**$41,782**

Alternatives 3 and 4
Option B

O & M COST ESTIMATE DETAILS (Quantity reduced by 10%)

Description	Qty	Unit	Unit Cost	Total Cost
Annual Costs				
Belt Press Operator/Mechanic (fixed)	1	YR	100,000	$100,000
Belt Press Repair Parts (reduced by 10%)	1	YR	15,480	$15,480
Chemical Conditioning Polymer (reduced by 10%)	1	YR	18,000	$18,000
Operation Costs (reduced by 10%)	14,400	kWHR	0	$720
			Subtotal	**$134,200**
Contingency	10%			$13,420
Total Annual Cost				**$147,620**

Alternatives 3 and 4
Option B

O & M COST ESTIMATE DETAILS (Quantity reduced by 10%)

Description	Qty	Unit	Unit Cost	Total Cost	Comments
Annual Costs					
Haul & Dispose	11,160	TN	43.5	$485,460	Based on Alt 2 unit cost
				$485,460	
Contingency	10%			$48,546	
Total Annual Cost				**$534,000**	

Alternatives 3 and 4
Option B

Bunker Hill — **DATE: 08/24/2000**
Acid Mine Drainage — **PROJECT NO.: 152215.FS.02**
Dewatering with Belt Filter Press — **ESTIMATE BY: D. Bunte**
Order of Magnitude Cost Opinion (Quantity reduced by 10%) — **N. Gulensoy**

DESCRIPTION	QTY	UNIT	TOTAL UNIT COST	TOTAL COST
Belt Filter Press				
Earthwork & Concrete for Slab	0	LS	$0	$0
Misc Metals	1	LS	$0	$0
Building	3,755	SF	$130	$488,145
Paint	1	LS	$18,775	$18,775
Belt Press	4	EA	$244,580	$978,319
Booster Pump	1	EA	$6,377	$6,377
Air Compressor	1	EA	$5,293	$5,293
Conveyor	4	EA	$35,588	$142,351
Storage Hopper	2	EA	$36,608	$73,216
Electrical/I&C	1	LS	$0	$0
Haul to Off-Site Landfill				
Load	0	CY	$0	$0
Misc	0	LS	$0	$0
SUBTOTAL				**$1,712,475**
MISC ALLOWANCE	**10%**			**$171,248**
SUBTOTAL				**$1,883,723**
CONTINGENCY	**30%**			**$565,117**
SUBTOTAL				**$2,448,839**
MOBILIZATION	**15%**			**$367,326**
CONSTRUCTION TOTAL				**$2,816,165**
SALES TAX ON MATERIALS	**5.0%**			**$85,707**
ENGINEERING AND SUPPORT	**20%**			**$563,233**
CONSTRUCTION MANAGEMENT	**8%**			**$225,293**
FILTER PRESS CAPITAL TOTAL (ROUNDED)				**$3,690,000**
FILTER PRESS ANNUAL O&M COST			**$148,000**	
30-YEAR NPV OF FILTER PRESS ANNUAL O&M COST				**$1,837,000**
HAUL AND DISPOSE OFFSITE ANNUAL O&M COST			**$534,000**	
30-YEAR NPV OF HAUL AND DISPOSE OFFSITE				**$6,626,000**
TOTAL 30-YEAR PRESENT WORTH COST @ 7% INTEREST				**$12,153,000**

NOTES:
Misc Allowance markup is to include items known to exist but cannot be quantified at this time.
Contingency is for scope changes that are presently unforeseen.
Mobilization includes bonds, insurance, temporary facilities, health & safety, demobilization, etc.

NOTE: The above cost opinion is in August 2000 dollars and does not include escalation.
The order of magnitude cost opinion shown has been prepared for guidance in project evaluation at the time of preparation. The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope, final schedule and other variable factors. As a result, the final project costs will vary from those presented above. Because of these factors, funding needs must be carefully reviewed prior to making specific financial decisions or establishing final budgets.

Alternatives 3 and 4
Option C

Bunker Hill — **DATE: 11/22/2000**
Acid Mine Drainage — **PROJECT NO.: 152215.FS.02**
Close Existing CIA Disposal Bed — **ESTIMATE BY: D. Bunte**
Order of Magnitude Cost Opinion — **N. Gulensoy**

DESCRIPTION	QTY	UNIT	TOTAL UNIT COST	TOTAL COST
Closure of Existing Sludge Bed on CIA				
Cell Closure Allowance	6.50	AC	137,500.00	$893,750
SUBTOTAL				**$893,750**
MISC ALLOWANCE	**10%**			**$89,375**
SUBTOTAL				**$983,125**
CONTINGENCY	**30%**			**$294,938**
SUBTOTAL				**$1,278,063**
MOBILIZATION	**15%**			**$191,709**
CONSTRUCTION TOTAL				**$1,469,772**
SALES TAX ON MATERIALS	**5.0%**			**$20,313**
ENGINEERING AND SUPPORT	**20%**			**$293,954**
CONSTRUCTION MANAGEMENT	**8%**			**$117,582**
CAPITAL TOTAL (ROUNDED)				**$1,900,000**
ANNUAL O&M COST (considered incidental to rest of CIA)			**$0**	

NOTES:

Misc Allowance markup is to include items known to exist but cannot be quantified at this time.
Contingency is for scope changes that are presently unforeseen.
Mobilization includes bonds, insurance, temporary facilities, health & safety, demobilization, etc.

NOTE: The above cost opinion is in November 2000 dollars and does not include escalation. The order of magnitude cost opinion shown has been prepared for guidance in project evaluation at the time of preparation. The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope, final schedule and other variable factors. As a result, the final project costs will vary from those presented above. Because of these factors, funding needs must be carefully reviewed prior to making specific financial decisions or establishing final budgets.

Alternatives 3 and 4
Option C

O & M COST ESTIMATE DETAILS

Description	Qty	Unit	UNIT COST	Total Cost
Annual Costs				
Pump Station & Pipeline				
Operation Labor	1	YR	$29,700	$29,700
Pump & Pipeline Maintenance & Repairs	1	YR	$9,387	$9,387
Power Cost for Pumping & Misc (Quantity reduced by 10%)	58,500	kWHR	$0.06	$3,218
Groundwater/Surface Water Monitoring				
System Inspection & Sampling	48	HR	$88	$4,224
Sample Shipping	4	EA	$66	$264
Supplies	4	EA	$220	$880
Indicator Analyses (quarterly)	8	EA	$297	$2,376
Metals Analyses (semiannually)	6	EA	$220	$1,320
Reporting	20	HR	$110	$2,200
Filtrate Discharge System Inspect/Clean	4	EA	$1,100	$4,400
Roads Maintenance	1	EA	$2,750	$2,750
			Subtotal	**$60,719**
Contingency	10%			$6,072
Total Annual Cost				**$66,791**

Alternatives 3 and 4
Sludge Management Option C

ANNUAL O&M COSTS CALCULATIONS
Series of Expenditures

Interest Rate	**7.00%**
Net Present Value	**$828,807**

Year	Annual Cost	Factor	NPV
0	NA	1.0000	NA
1	$66,791	0.9346	$62,421
2	$66,791	0.8734	$58,337
3	$66,791	0.8163	$54,521
4	$66,791	0.7629	$50,954
5	$66,791	0.7130	$47,621
6	$66,791	0.6663	$44,505
7	$66,791	0.6227	$41,594
8	$66,791	0.5820	$38,873
9	$66,791	0.5439	$36,330
10	$66,791	0.5083	$33,953
11	$66,791	0.4751	$31,732
12	$66,791	0.4440	$29,656
13	$66,791	0.4150	$27,716
14	$66,791	0.3878	$25,903
15	$66,791	0.3624	$24,208
16	$66,791	0.3387	$22,624
17	$66,791	0.3166	$21,144
18	$66,791	0.2959	$19,761
19	$66,791	0.2765	$18,468
20	$66,791	0.2584	$17,260
21	$66,791	0.2415	$16,131
22	$66,791	0.2257	$15,076
23	$66,791	0.2109	$14,089
24	$66,791	0.1971	$13,168
25	$66,791	0.1842	$12,306
26	$66,791	0.1722	$11,501
27	$66,791	0.1609	$10,749
28	$66,791	0.1504	$10,045
29	$66,791	0.1406	$9,388
30	$66,791	0.1314	$8,774

PERIODIC COSTS CALCULATIONS
Single Expenditure at Year XX

Interest Rate	**7.00%**
Net Present Value	**$10,937,495**

Year	Investment	Factor	NPV	
0	$6,560,000	1.0000	$6,560,000	initial bed construction
1	$0	0.9346	$0	
2	$1,900,000	0.8734	$1,659,534	closure of existing bed
3	$0	0.8163	$0	
4	$0	0.7629	$0	
5	$0	0.7130	$0	
6	$0	0.6663	$0	
7	$0	0.6227	$0	
8	$0	0.5820	$0	
9	$0	0.5439	$0	
10	$2,450,000	0.5083	$1,245,456	new bed
11	$1,000,000	0.4751	$475,093	closure
12	$0	0.4440	$0	
13	$0	0.4150	$0	
14	$0	0.3878	$0	
15	$0	0.3624	$0	
16	$0	0.3387	$0	
17	$0	0.3166	$0	
18	$0	0.2959	$0	
19	$0	0.2765	$0	
20	$2,450,000	0.2584	$633,127	new bed
21	$1,000,000	0.2415	$241,513	closure
22	$0	0.2257	$0	
23	$0	0.2109	$0	
24	$0	0.1971	$0	
25	$0	0.1842	$0	
26	$0	0.1722	$0	
27	$0	0.1609	$0	
28	$0	0.1504	$0	
29	$0	0.1406	$0	
30	$0	0.1314	$0	
31	$1,000,000	0.1228	$122,773	closure

Alternative 3 and 4
Option C

Bunker Hill — **DATE: 11/22/2000**
Acid Mine Drainage — **PROJECT NO.: 152215.FS.02**
Smelter Closure Area Disposal Beds - Future Closure Cost — **ESTIMATE BY: D. Bunte**
Order of Magnitude Cost Opinion (Quantity reduced by 10%) — **N. Gulensoy**

DESCRIPTION	QTY	UNIT	TOTAL UNIT COST	TOTAL COST
Sludge Disposal Bed Closure (per each)				
Cell Closure Allowance	3.42	AC	137,500.00	$470,250
SUBTOTAL				**$470,250**
MISC ALLOWANCE	**10%**			**$47,025**
SUBTOTAL				**$517,275**
CONTINGENCY	**30%**			**$155,183**
SUBTOTAL				**$672,458**
MOBILIZATION	**15%**			**$100,869**
CONSTRUCTION TOTAL				**$773,326**
SALES TAX ON MATERIALS	**5.0%**			**$10,688**
ENGINEERING AND SUPPORT	**20%**			**$154,665**
CONSTRUCTION MANAGEMENT	**8%**			**$61,866**
CAPITAL TOTAL (ROUNDED)				**$1,000,000**
ANNUAL O&M COST (considered incidental to operating sludge bed)			**$0**	

NOTES:
Misc Allowance markup is to include items known to exist but cannot be quantified at this time.
Contingency is for scope changes that are presently unforeseen.
Mobilization includes bonds, insurance, temporary facilities, health & safety, demobilization, etc.

NOTE: The above cost opinion is in November 2000 dollars and does not include escalation. The order of magnitude cost opinion shown has been prepared for guidance in project evaluation at the time of preparation. The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope, final schedule and other variable factors. As a result, the final project costs will vary from those presented above. Because of these factors, funding needs must be carefully reviewed prior to making specific financial decisions or establishing final budgets.

Alternative 3 and 4
Option C

Bunker Hill — **DATE: 11/29/2000**
Acid Mine Drainage — **PROJECT NO.: 152215.FS.02**
Disposal of Raw Sludge in Smelter Closure Area Disposal Beds — **ESTIMATE BY: D. Bunte**
Order of Magnitude Cost Opinion (Quantity reduced by 10%) — **N. Gulensoy**

DESCRIPTION	QTY	QTY Reduced by 10%	UNIT	TOTAL UNIT COST	TOTAL COST
Sitework/Yard Piping					
Clear & Grub	20		AC	3,000.00	$60,000
Site Prep Cut	300,000	270,000	CY	3.30	$990,000
Site Prep Fill	300,000	270,000	CY	1.10	$330,000
6" HDPE Sludge Pipeline in Trench	6,400		LF	31.78	$203,421
6" HDPE Leachate Pipeline in Trench	2,500		LF	24.70	$61,749
Leachate pipe tie in to pump	1		LS	2,000.00	$2,000
Manholes	7		EA	3,850.00	$26,950
Sludge Pumping					
Prefab Metal Bldg w/Concrete Floor	500		SF	165.00	$82,500
Paint	1		LS	5,500.00	$5,500
Pump, 30hp	4		EA	15,380.27	$61,521
Standby Pump, 30hp	1		EA	15,380.27	$15,380
Gland Seal Water Pump	1		EA	8,136.01	$8,136
Electrical/I&C	1		LS	32,400.00	$32,400
6" Check Valve	4		EA	1,897.78	$7,591
6" Gate Valve	4		EA	1,897.78	$7,591
6" HDPE Pipe in Trench	200		LF	22.50	$4,500
Flushing Hookups	1		LS	5,500.00	$5,500
Pipeline Cleanout Pig Station	1		LS	27,500.00	$27,500
Sludge Disposal Bed (per each)					
Excavation	25,000	22,500	C. Y.	3.30	$74,250
Subgrade Preparation	5	5	Acres	3,300.00	$14,850
Subgrade Stabilization	10,500	9,450	C. Y.	4.40	$41,580
Liner Protection Sand	8250	7,425	C. Y.	19.80	$147,015
Drain Rock	1,950	1,755	C. Y.	19.80	$34,749
Ditch Lining Geotextile	21,200	19,080	S. Y.	1.82	$34,630
G C L	18,100	16,290	S. Y.	4.46	$72,572
H D P E Geomembrane	18,100	16,290	S. Y.	5.94	$96,763
H D P E Pipe, 10"	550	495	L. F.	25.30	$12,524
Erosion Control Matting	11800	10,620	S.Y.	1.65	$17,523
Perf Pipe, 4"	2000	1,800	L. F.	2.20	$3,960
Perf Pipe, 6"	580	522	L. F.	3.30	$1,723
HDPE Pipe, 6"	130	117	L. F.	2.75	$322
Strip Drains	700	630	L. F.	1.93	$1,213
Valves, 6" Knife Gate	2		Each	770.00	$1,540
Valves, 10" Knife Gate	6		Each	1,100.00	$6,600
Air/Vacuum Release Valve	1		Each	2,200.00	$2,200
Valve Vault	6		Each	2,145.00	$12,870
Water Tight Manhole	1		Each	3,850.00	$3,850
Vertical Filtrate Drains	6		Each	4,400.00	$26,400
Cleanouts	2		Each	825.00	$1,650
Perimeter Road Embankment (not reduced)	43500	43,500	C. Y.	11.00	$478,500
Chain Link Fence and Gates (not reduced)	2000	2,000	L.F.	13.20	$26,400
Groundwater Monitoring Wells	2		Each	6,600.00	$13,200
Crushed Rock Surfacing (not reduced)	1500	1,500	C. Y.	16.50	$24,750
SUBTOTAL					**$3,083,872**
MISC ALLOWANCE	**10%**				**$308,387**
SUBTOTAL					**$3,392,259**
CONTINGENCY	**30%**				**$1,017,678**
SUBTOTAL					**$4,409,937**
MOBILIZATION	**15%**				**$661,491**
CONSTRUCTION TOTAL					**$5,071,428**
SALES TAX ON MATERIALS	**5.0%**				**$63,650**
ENGINEERING AND SUPPORT	**20%**				**$1,014,286**
CONSTRUCTION MANAGEMENT	**8%**				**$405,714**
CAPITAL COST FIRST BED (ROUNDED)					**$6,560,000**

Alternative 3 and 4
Option C

Bunker Hill — **DATE: 11/29/2000**
Acid Mine Drainage — **PROJECT NO.: 152215.FS.02**
Disposal of Raw Sludge in Smelter Closure Area Disposal Beds — **ESTIMATE BY: D. Bunte**
Order of Magnitude Cost Opinion (Quantity reduced by 10%) — **N. Gulensoy**

DESCRIPTION	QTY	QTY Reduced by 10%	UNIT	TOTAL UNIT COST	TOTAL COST
CAPITAL COST FOR NEW CELLS IN FUTURE YEARS (DOES NOT INCLUDE PUMPING AND PIPING COST)					
Sludge Disposal Bed (per each)					
Excavation	25,000	22,500	C. Y.	3.30	$74,250
Subgrade Preparation	5	5	Acres	3,300.00	$14,850
Subgrade Stabilization	10,500	9,450	C. Y.	4.40	$41,580
Liner Protection Sand	8250	7,425	C. Y.	19.80	$147,015
Drain Rock	1,950	1,755	C. Y.	19.80	$34,749
Ditch Lining Geotextile	21,200	19,080	S. Y.	1.82	$34,630
G C L	18,100	16,290	S. Y.	4.46	$72,572
H D P E Geomembrane	18,100	16,290	S. Y.	5.94	$96,763
H D P E Pipe, 10"	550	495	L. F.	25.30	$12,524
Erosion Control Matting	11800	10,620	S.Y.	1.65	$17,523
Perf Pipe, 4"	2000	1,800	L. F.	2.20	$3,960
Perf Pipe, 6"	580	522	L. F.	3.30	$1,723
HDPE Pipe, 6"	130	117	L. F.	2.75	$322
Strip Drains	700	630	L. F.	1.93	$1,213
Valves, 6" Knife Gate	2		Each	770.00	$0
Valves, 10" Knife Gate	6		Each	1,100.00	$0
Air/Vacuum Release Valve	1		Each	2,200.00	$0
Valve Vault	6		Each	2,145.00	$0
Water Tight Manhole	1		Each	3,850.00	$0
Vertical Filtrate Drains	6		Each	4,400.00	$0
Cleanouts	2		Each	825.00	$0
Perimeter Road Embankment (not reduced)	28275	28,275	C. Y.	11.00	$311,025
Chain Link Fence and Gates (not reduced)	1000	1,000	L.F.	13.20	$13,200
Groundwater Monitoring Wells (not reduced)	2		Each	6,600.00	$13,200
Crushed Rock Surfacing (not reduced)	1500	1,500	C. Y.	16.50	$24,750

SUBTOTAL			**$1,151,632**
MISC ALLOWANCE	**10%**		**$115,163**
SUBTOTAL			**$1,266,796**
CONTINGENCY	**30%**		**$380,039**
SUBTOTAL			**$1,646,834**
MOBILIZATION	**15%**		**$247,025**
CONSTRUCTION TOTAL			**$1,893,859**
SALES TAX ON MATERIALS	**5.0%**		**$27,572**
ENGINEERING AND SUPPORT	**20%**		**$378,772**
CONSTRUCTION MANAGEMENT	**8%**		**$151,509**
CAPITAL COST SUBSEQUENT BEDS TOTAL (ROUNDED)			**$2,450,000**
ANNUAL O&M COST FOR OPERATING BED		**$67,000**	
NPV OF ANNUAL O&M COSTS (30 YEARS @ 7% INTEREST)			**$829,000**
NPV OF INITIAL AND SUBSEQUENT BEDS & CLOSURES CAPITAL COSTS @ 7% INTEREST			**$10,937,000**
TOTAL 30-YEAR PRESENT WORTH COST @ 7% INTEREST			**$11,766,000**

NOTES:
Misc Allowance markup is to include items known to exist but cannot be quantified at this time.
Contingency is for scope changes that are presently unforeseen.
Mobilization includes bonds, insurance, temporary facilities, health & safety, demobilization, etc.

NOTE: The above cost opinion is in November 2000 dollars and does not include escalation. The order of magnitude cost opinion shown has been prepared for guidance in project evaluation at the time of preparation. The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope, final schedule and other variable factors. As a result, the final project costs will vary from those presented above. Because of these factors, funding needs must be carefully reviewed prior to making specific financial decisions or establishing final budgets.

Alternatives 3 and 4
Option D

SLUDGE DRYING BEDS O & M COST ESTIMATE DETAILS

Description	Qty	Unit	Unit Cost	Total Cost
Annual Costs				
Pump Station & Pipeline				
Operation Labor	1	YR	$24,750	$24,750
Pump & Pipeline Maintenance & Repairs	1	YR	$9,696	$9,696
Power Cost for Pumping & Misc	18,000	kWHR	$0.06	$990
Filtrate Discharge System Inspect/Clean	4	EA	$1,100	$4,400
Roads Maintenance	1	EA	$2,750	$2,750
				$42,586
Contingency	10%			$4,259
Total Annual Cost				**$46,844**

Alternative 3 and 4
Option D

Bunker Hill — **DATE: 12/16/1998**
Acid Mine Drainage — **PROJECT NO.: 148562.02.01**
Dewatering in CIA Sludge Drying Beds — **ESTIMATE BY: D. Hedglin**
Order of Magnitude Cost Opinion (Reduced by 10%)

DESCRIPTION	QTY	QTY Reduced by 10%	UNIT	TOTAL UNIT COST	TOTAL COST
		0.9			
Sitework/Yard Piping					
6" HDPE Sludge Pipeline in Trench	800		LF	21.54	$17,233
6" HDPE Leachate Pipeline in Trench	800		LF	21.54	$17,233
Sludge Pumping					
Prefab Metal Bldg w/Concrete Floor	216		SF	150.00	$32,400
Paint	1		LS	5,000.00	$5,000
Pump, 30hp	2		EA	14,810.06	$29,620
Standby Pump, 30hp	1		EA	14,810.06	$14,810
Gland Seal Water Pump	1		EA	7,948.38	$7,948
Electrical/I&C	1		LS	17,955.71	$17,956
Sludge Drying Bed					
Excavation	7000	6300	C. Y.	3.00	$18,900
Subgrade Preparation	2.6	2.34	Acres	3,000.00	$7,020
Subgrade Stabilization	4200	3780	C. Y.	4.00	$15,120
Liner Protection Sand	5,000	4500	C. Y.	10.00	$45,000
Drain Rock	1250	1125	C. Y.	18.00	$20,250
Ditch Lining Geotextile	2,000	1800	S. Y.	1.65	$2,970
G C L	10,000	9000	S. Y.	4.05	$36,450
H D P E Geomembrane	10,500	9450	S. Y.	5.40	$51,030
H D P E Pipe, 10"	450	405	L. F.	23.00	$9,315
Erosion Control Matting	8,000	7200	S.Y.	1.50	$10,800
Perf Pipe, 4"	1600	1440	L. F.	2.00	$2,880
Perf Pipe, 6"	400	360	L. F.	3.00	$1,080
HDPE Pipe, 6"	250	225	L. F.	2.50	$563
Strip Drains	850	765	L. F.	1.75	$1,339
Valves, 6" Knife Gate	2		Each	700	$1,400
Valves, 10" Knife Gate	4		Each	1,000.00	$4,000
Air/Vacuum Release Valve	1		Each	2,000.00	$2,000
Valve Vault	6		Each	1,950.00	$11,700
Water Tight Manhole	2		Each	3,500.00	$7,000
Vertical Filtrate Drains	8		Each	4,000.00	$32,000
Cleanouts	4		Each	750.00	$3,000
Perimeter Road Embankment	8000		C. Y.	10.00	$80,000
Chain Link Fence and Gates	2000		L.F.	12.00	$24,000
Groundwater Monitoring Wells	2		Each	6,000.00	$12,000
Access Road (CCP)	500		L.F.	50.00	$25,000
Crushed Rock Surfacing	1500		C. Y.	15.00	$22,500
Decontamination Station	1		LS	200,000.00	$200,000
SUBTOTAL					**$789,516**
MISC ALLOWANCE	**10%**				**$78,952**
SUBTOTAL					**$868,468**
CONTINGENCY	**15%**				**$130,270**
SUBTOTAL					**$998,738**
MOBILIZATION	**15%**				**$149,811**
CONSTRUCTION TOTAL					**$1,148,548**
SALES TAX ON MATERIALS	**5.0%**				**$13,777**
ENGINEERING AND SUPPORT	**20%**				**$229,710**
CONSTRUCTION MANAGEMENT	**8%**				**$91,884**

Alteratives 3 and 4
Option D

SLUDGE LANDFILL O & M COST ESTIMATE DETAILS

Description	Qty	Unit	UNIT COST	Total Cost
Annual Costs				
Remove, Load, Decon Truck, Haul & Unload	6,120	CY	$11	$67,320
Groundwater/Surface Water Monitoring				
System Inspection & Sampling	48	HR	$88	$4,224
Sample Shipping	4	EA	$66	$264
Supplies	4	EA	$220	$880
Indicator Analyses (quarterly)	8	EA	$297	$2,376
Metals Analyses (semiannually)	6	EA	$220	$1,320
Reporting	20	HR	$110	$2,200
Filtrate Discharge System Inspect/Clean	4	EA	$1,100	$4,400
Roads Maintenance	1	EA	$2,750	$2,750
			Subtotal	**$85,734**
Contingency	10%			$8,573
Total Annual Cost				**$94,307**

Alternative 3 and 4
Option D

Bunker Hill | **DATE: 11/29/2000**
Acid Mine Drainage | **PROJECT NO.: 152215.FS.02**
Onsite Landfill - Smelter Closure Area | **ESTIMATE BY: D. Hedglin**
Order of Magnitude Cost Opinion

DESCRIPTION	QTY	QTY Reduced by 10%	UNIT	TOTAL UNIT COST	TOTAL COST
		0.90			
Sitework					
Clear and Grub	20		AC	3,000.00	$60,000
Site Prep Excavation	300,000	270,000	CY	3.30	$891,000
Site Prep Fill	300,000	270,000	CY	1.10	$297,000
Pipeline					
6" HDPE Gravity Pipeline in Trench	2,500		LF	22.50	$56,249
Manhole	8		EA	3,850.00	$32,083
Landfill Construction					
Excavation	58,000	52,200	CY	3.30	$172,260
Subgrade Preparation	13	11	AC	3,300.00	$37,719
Subgrade Stabilization	20,537	18,483	CY	4.40	$81,327
Embankment Fill	63,265	56,939	CY	11.00	$626,324
Liner Protection Sand	18,000	16,200	CY	19.80	$320,760
Drain Rock	5,100	4,590	CY	19.80	$90,882
Ditch Lining Geotextile	35,400	31,860	SY	1.82	$57,826
G C L	35,400	31,860	SY	4.46	$141,936
H D P E Geomembrane	35,400	31,860	SY	5.94	$189,248
H D P E Pipe, 12"	2,000	1,800	LF	28.60	$51,480
Erosion Control Matting	19,500	17,550	SY	1.65	$28,958
Perf Pipe, 6"	650	585	LF	3.30	$1,931
Strip Drains	1,180	1,062	LF	1.93	$2,044
Filtrate Penetration Sump (Allowance)	1		EA	27,500.00	$27,500
HDPE Pipe, 6"	150	135	LF	2.75	$371
Water Tight Manhole	1		EA	3,850.00	$3,850
Cleanouts	2		EA	825.00	$1,650
Chain Link Fence and Gates	3,060		LF	13.20	$40,392
Groundwater Monitoring Wells	4		EA	6,600.00	$26,400
Crushed Rock Surfacing	2,270		CY	16.50	$37,455
SUBTOTAL					**$3,276,645**
MISC ALLOWANCE	**10%**				**$327,664**
SUBTOTAL					**$3,604,309**
CONTINGENCY	**15%**				**$540,646**
SUBTOTAL					**$4,144,955**
MOBILIZATION	**15%**				**$621,743**
CONSTRUCTION TOTAL					**$4,766,699**
SALES TAX ON MATERIALS	**5%**				**$45,140**
ENGINEERING AND SUPPORT	**20%**				**$953,340**
CONSTRUCTION MANAGEMENT	**8%**				**$381,336**
CAPITAL TOTAL (ROUNDED)					**$6,147,000**
ANNUAL O&M COST				**$94,000**	

Alternative 3 and 4
Option D

Bunker Hill — **DATE: 11/29/2000**
Acid Mine Drainage — **PROJECT NO.: 152215.FS.02**
Onsite Landfill - Smelter Closure Area — **ESTIMATE BY: D. Hedglin**
Order of Magnitude Cost Opinion

DESCRIPTION	QTY	QTY Reduced by 10%	UNIT	TOTAL UNIT COST	TOTAL COST
		0.90			
CAPITAL COST OF CLOSURE @ YEAR 31				$1,960,000	
NPV OF ANNUAL O&M COSTS (30 YEARS @ 7% INTEREST)					$1,170,000
NPV OF CLOSURE COST (YEAR 31 @ 7% INTEREST)					$241,000
TOTAL 30-YEAR PRESENT WORTH COST @ 7% INTEREST					$7,558,000

NOTES:

Landfill post-closure costs are not included here since they extend beyond the 30 year period.
Misc Allowance markup is to include items known to exist but cannot be quantified at this time.
Contingency is for scope changes that are presently unforeseen.
Mobilization includes bonds, insurance, temporary facilities, health & safety, demobilization, etc.

NOTE: The above cost opinion is in November 2000 dollars and does not include escalation. The order of magnitude cost opinion shown has been prepared for guidance in project evaluation at the time of preparation. The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope, final schedule and other variable factors. As a result, the final project costs will vary from those presented above. Because of these factors, funding needs must be carefully reviewed prior to making specific financial decisions or establishing final budgets.

Alternative 3 and 4
Option D

Bunker Hill | **DATE: 12/16/1998**
Acid Mine Drainage | **PROJECT NO.: 148562.02.01**
Dewatering in CIA Sludge Drying Beds | **ESTIMATE BY: D. Hedglin**
Order of Magnitude Cost Opinion (Reduced by 10%)

DESCRIPTION	QTY	QTY Reduced by 10%	UNIT	TOTAL UNIT COST	TOTAL COST
		0.9			
CAPITAL TOTAL (ROUNDED)					**$1,484,000**

Alternative 3 and 4
Option D

Bunker Hill — **DATE: 12/16/1998**
Acid Mine Drainage — **PROJECT NO.: 148562.02.01**
Dewatering in CIA Sludge Drying Beds — **ESTIMATE BY: D. Hedglin**
Order of Magnitude Cost Opinion (Reduced by 10%)

DESCRIPTION	QTY	QTY Reduced by 10%	UNIT	TOTAL UNIT COST	TOTAL COST
		0.9			
ANNUAL O&M COST				$47,000	
NPV OF ANNUAL O&M COSTS (30 YEARS @ 7% INTEREST)					$581,000
TOTAL 30-YEAR PRESENT WORTH COST @ 7% INTEREST					$2,065,000

NOTES:
Misc Allowance markup is to include items known to exist but cannot be quantified at this time.
Contingency is for scope changes that are presently unforeseen.
Mobilization includes bonds, insurance, temporary facilities, health & safety, demobilization, etc.

NOTE: The above cost opinion is in December 1998 dollars and does not include escalation. The order of magnitude cost opinion shown has been prepared for guidance in project evaluation at the time of preparation. The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope, final schedule and other variable factors. As a result, the final project costs will vary from those presented above. Because of these factors, funding needs must be carefully reviewed prior to making specific financial decisions or establishing final budgets.

Alternative 5
Option A

Bunker Hill — **DATE: 11/22/2000**
Acid Mine Drainage — **PROJECT NO.: 152215.FS.02**
Sludge CIA Disposal Beds - Future Closure Cost — **ESTIMATE BY: D. Bunte**
Order of Magnitude Cost Opinion (Quantity reduced by 20%) — **N. Gulensoy**

DESCRIPTION	QTY	UNIT	TOTAL UNIT COST	TOTAL COST
Sludge Disposal Bed Closure (per each)				
Cell Closure Allowance	3.04	AC	137,500.00	$418,000
SUBTOTAL				**$418,000**
MISC ALLOWANCE	**10%**			**$41,800**
SUBTOTAL				**$459,800**
CONTINGENCY	**30%**			**$137,940**
SUBTOTAL				**$597,740**
MOBILIZATION	**15%**			**$89,661**
CONSTRUCTION TOTAL				**$687,401**
SALES TAX ON MATERIALS	**5.0%**			**$9,500**
ENGINEERING AND SUPPORT	**20%**			**$137,480**
CONSTRUCTION MANAGEMENT	**8%**			**$54,992**
CAPITAL TOTAL (ROUNDED)				**$890,000**
ANNUAL O&M COST (considered incidental to rest of CIA)			**$0**	

NOTES:
Misc Allowance markup is to include items known to exist but cannot be quantified at this time.
Contingency is for scope changes that are presently unforeseen.
Mobilization includes bonds, insurance, temporary facilities, health & safety, demobilization, etc.

NOTE: The above cost opinion is in November 2000 dollars and does not include escalation. The order of magnitude cost opinion shown has been prepared for guidance in project evaluation at the time of preparation. The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope, final schedule and other variable factors. As a result, the final project costs will vary from those presented above. Because of these factors, funding needs must be carefully reviewed prior to making specific financial decisions or establishing final budgets.

Alternative 5
Option A

Bunker Hill — **DATE: 11/22/2000**
Acid Mine Drainage — **PROJECT NO.: 152215.FS.02**
Closure of Existing Sludge Pond on CIA — **ESTIMATE BY: D. Bunte**
Order of Magnitude Cost Opinion — **N. Gulensoy**

DESCRIPTION	QTY	UNIT	TOTAL UNIT COST	TOTAL COST
Closure of Existing Sludge Pond on CIA				
Cell Closure Allowance	6.50	AC	137,500.00	$893,750
SUBTOTAL				**$893,750**
MISC ALLOWANCE	**10%**			**$89,375**
SUBTOTAL				**$983,125**
CONTINGENCY	**30%**			**$294,938**
SUBTOTAL				**$1,278,063**
MOBILIZATION	**15%**			**$191,709**
CONSTRUCTION TOTAL				**$1,469,772**
SALES TAX ON MATERIALS	**5.0%**			**$20,313**
ENGINEERING AND SUPPORT	**20%**			**$293,954**
CONSTRUCTION MANAGEMENT	**8%**			**$117,582**
CAPITAL TOTAL (ROUNDED)				**$1,900,000**
ANNUAL O&M COST (considered incidental to rest of CIA)			**$0**	

NOTES:
Misc Allowance markup is to include items known to exist but cannot be quantified at this time.
Contingency is for scope changes that are presently unforeseen.
Mobilization includes bonds, insurance, temporary facilities, health & safety, demobilization, etc.

NOTE: The above cost opinion is in November 2000 dollars and does not include escalation. The order of magnitude cost opinion shown has been prepared for guidance in project evaluation at the time of preparation. The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope, final schedule and other variable factors. As a result, the final project costs will vary from those presented above. Because of these factors, funding needs must be carefully reviewed prior to making specific financial decisions or establishing final budgets.

Alternative 5
Option A
O & M COST ESTIMATE DETAILS

Description	Qty	Unit	Unit Cost	Total Cost
Annual Costs				
Pump Station & Pipeline				
Operation Labor	1	YR	20,000	$20,000
Pump & Pipeline Maintenance & Repairs	1	YR	7,586	$7,586
Power Cost for Pumping & Misc (Quantity reduced by 20%)	8,000	kWHR	0	$400
Filtrate Discharge System Inspect/Clean	4	EA	1,000	$4,000
Roads Maintenance	1	EA	2,500	$2,500
			Subtotal	**$34,486**
Contingency	10%			$3,449
Total Annual Cost				**$37,934**

Alternative 5
Option A

Bunker Hill
Acid Mine Drainage
Disposal of Raw Sludge in CIA Disposal Beds
Order of Magnitude Cost Opinion (Quantity reduced by 20%)

DATE: 11/22/2000
PROJECT NO.: 152215.FS.02
ESTIMATE BY: D. Bunte
N. Gulensoy

DESCRIPTION	QTY	QTY Reduced by 20%	UNIT	TOTAL UNIT COST	TOTAL COST
Sitework/Yard Piping					
6" HDPE Sludge Pipeline in Trench	800		LF	21.54	$17,233
6" HDPE Leachate Pipeline in Trench	800		LF	21.54	$17,233
Sludge Pumping					
Prefab Metal Bldg w/Concrete Floor	216		SF	150.00	$32,400
Paint	1		LS	5,000.00	$5,000
Pump, 30hp	2		EA	14,810.06	$29,620
Standby Pump, 30hp	1		EA	14,810.06	$14,810
Gland Seal Water Pump	1		EA	7,948.38	$7,948
Electrical/I&C	1		LS	17,955.71	$17,956
Sludge Disposal Bed (per each)					
Excavation	25,000	20,000	C. Y.	3.00	$60,000
Subgrade Preparation	5	4	Acres	3,000.00	$12,000
Subgrade Stabilization	10,500	8,400	C. Y.	4.00	$33,600
Liner Protection Sand	8250	6,600	C. Y.	10.00	$66,000
Drain Rock	1,950	1,560	C. Y.	18.00	$28,080
Ditch Lining Geotextile	21,200	16,960	S. Y.	1.65	$27,984
G C L	18,100	14,480	S. Y.	4.05	$58,644
H D P E Geomembrane	18,100	14,480	S. Y.	5.40	$78,192
H D P E Pipe, 10"	550	440	L. F.	23.00	$10,120
Erosion Control Matting	11800	9,440	S.Y.	1.50	$14,160
Perf Pipe, 4"	2000	1,600	L. F.	2.00	$3,200
Perf Pipe, 6"	580	464	L. F.	3.00	$1,392
HDPE Pipe, 6"	130	104	L. F.	2.50	$260
Strip Drains	700	560	L. F.	1.75	$980
Valves, 6" Knife Gate	2		Each	700	$1,400
Valves, 10" Knife Gate	6		Each	1,000	$6,000
Air/Vacuum Release Valve	1		Each	2,000	$2,000
Valve Vault	6		Each	1,950	$11,700
Water Tight Manhole	1		Each	3,500	$3,500
Vertical Filtrate Drains	6		Each	4,000	$24,000
Cleanouts	2		Each	750	$1,500
Perimeter Road Embankment (not reduced)	43500	43,500	C. Y.	10	$435,000
Chain Link Fence and Gates (not reduced)	2000	2,000	L.F.	12	$24,000
Crushed Rock Surfacing (not reduced)	1500	1,500	C. Y.	15	$22,500
SUBTOTAL					**$1,068,412**
MISC ALLOWANCE	**10%**				**$106,841**
SUBTOTAL					**$1,175,253**
CONTINGENCY	**30%**				**$352,576**
SUBTOTAL					**$1,527,829**
MOBILIZATION	**15%**				**$229,174**
CONSTRUCTION TOTAL					**$1,757,003**
SALES TAX ON MATERIALS	**5.0%**				**$28,216**
ENGINEERING AND SUPPORT	**20%**				**$351,401**
CONSTRUCTION MANAGEMENT	**8%**				**$140,560**
CAPITAL COST FIRST BED (ROUNDED)					**$2,280,000**
CAPITAL COST FOR NEW CELLS IN FUTURE YEARS (DOES NOT INCLUDE PUMPING AND PIPING COST)					
Sludge Disposal Bed (per each)					
Excavation	25,000	20,000	C. Y.	3.00	$60,000
Subgrade Preparation	5	4	Acres	3,000.00	$12,000

Alternative 5
Sludge Management Option A

ANNUAL O&M COSTS CALCULATIONS
Series of Expenditures

Interest Rate	**7.00%**
Net Present Value	**$470,727**

Year	Annual Cost	Factor	NPV
0	NA	1.0000	NA
1	$37,934	0.9346	$35,452
2	$37,934	0.8734	$33,133
3	$37,934	0.8163	$30,966
4	$37,934	0.7629	$28,940
5	$37,934	0.7130	$27,047
6	$37,934	0.6663	$25,277
7	$37,934	0.6227	$23,623
8	$37,934	0.5820	$22,078
9	$37,934	0.5439	$20,634
10	$37,934	0.5083	$19,284
11	$37,934	0.4751	$18,022
12	$37,934	0.4440	$16,843
13	$37,934	0.4150	$15,741
14	$37,934	0.3878	$14,712
15	$37,934	0.3624	$13,749
16	$37,934	0.3387	$12,850
17	$37,934	0.3166	$12,009
18	$37,934	0.2959	$11,223
19	$37,934	0.2765	$10,489
20	$37,934	0.2584	$9,803
21	$37,934	0.2415	$9,162
22	$37,934	0.2257	$8,562
23	$37,934	0.2109	$8,002
24	$37,934	0.1971	$7,479
25	$37,934	0.1842	$6,989
26	$37,934	0.1722	$6,532
27	$37,934	0.1609	$6,105
28	$37,934	0.1504	$5,705
29	$37,934	0.1406	$5,332
30	$37,934	0.1314	$4,983

PERIODIC COSTS CALCULATIONS
Single Expenditure at Year XX

Interest Rate	**7.00%**
Net Present Value	**$6,204,782**

Year	Investment	Factor	NPV	
0	$2,280,000	1.0000	$2,280,000	initial bed construction
1	$0	0.9346	$0	
2	$1,900,000	0.8734	$1,659,534	closure of existing bed
3	$0	0.8163	$0	
4	$0	0.7629	$0	
5	$0	0.7130	$0	
6	$0	0.6663	$0	
7	$0	0.6227	$0	
8	$0	0.5820	$0	
9	$0	0.5439	$0	
10	$1,980,000	0.5083	$1,006,532	new bed
11	$890,000	0.4751	$422,833	closure
12	$0	0.4440	$0	
13	$0	0.4150	$0	
14	$0	0.3878	$0	
15	$0	0.3624	$0	
16	$0	0.3387	$0	
17	$0	0.3166	$0	
18	$0	0.2959	$0	
19	$0	0.2765	$0	
20	$1,980,000	0.2584	$511,670	new bed
21	$890,000	0.2415	$214,947	closure
22	$0	0.2257	$0	
23	$0	0.2109	$0	
24	$0	0.1971	$0	
25	$0	0.1842	$0	
26	$0	0.1722	$0	
27	$0	0.1609	$0	
28	$0	0.1504	$0	
29	$0	0.1406	$0	
30	$0	0.1314	$0	
31	$890,000	0.1228	$109,268	closure

Alternative 5
Option A

Bunker Hill
Acid Mine Drainage
Disposal of Raw Sludge in CIA Disposal Beds
Order of Magnitude Cost Opinion (Quantity reduced by 20%)

DATE: 11/22/2000
PROJECT NO.: 152215.FS.02
ESTIMATE BY: D. Bunte
N. Gulensoy

DESCRIPTION	QTY	QTY Reduced by 20%	UNIT	TOTAL UNIT COST	TOTAL COST
Subgrade Stabilization	10,500	8,400	C. Y.	4.00	$33,600
Liner Protection Sand	8250	6,600	C. Y.	10.00	$66,000
Drain Rock	1,950	1,560	C. Y.	18.00	$28,080
Ditch Lining Geotextile	21,200	16,960	S. Y.	1.65	$27,984
G C L	18,100	14,480	S. Y.	4.05	$58,644
H D P E Geomembrane	18,100	14,480	S. Y.	5.40	$78,192
H D P E Pipe, 10"	550	440	L. F.	23.00	$10,120
Erosion Control Matting	11800	9,440	S.Y.	1.50	$14,160
Perf Pipe, 4"	2000	1,600	L. F.	2.00	$3,200
Perf Pipe, 6"	580	464	L. F.	3.00	$1,392
HDPE Pipe, 6"	130	104	L. F.	2.50	$260
Strip Drains	700	560	L. F.	1.75	$980
Valves, 6" Knife Gate	2		Each	700.00	$1,400
Valves, 10" Knife Gate	6		Each	1,000.00	$6,000
Air/Vacuum Release Valve	1		Each	2,000.00	$2,000
Valve Vault	6		Each	1,950.00	$11,700
Water Tight Manhole	1		Each	3,500.00	$3,500
Vertical Filtrate Drains	6		Each	4,000.00	$24,000
Cleanouts	2		Each	750.00	$1,500
Perimeter Road Embankment (not reduced)	28275	28,275	C. Y.	10	$282,750
Chain Link Fence and Gates (not reduced)	1000	1,000	L.F.	12	$12,000
Crushed Rock Surfacing (not reduced)	1500	1,500	C. Y.	15	$22,500
SUBTOTAL					**$926,212**
MISC ALLOWANCE	**10%**				**$92,621**
SUBTOTAL					**$1,018,833**
CONTINGENCY	**30%**				**$305,650**
SUBTOTAL					**$1,324,483**
MOBILIZATION	**15%**				**$198,672**
CONSTRUCTION TOTAL					**$1,523,156**
SALES TAX ON MATERIALS	**5.0%**				**$25,622**
ENGINEERING AND SUPPORT	**20%**				**$304,631**
CONSTRUCTION MANAGEMENT	**8%**				**$121,852**
CAPITAL COST SUBSEQUENT BEDS TOTAL (ROUNDED)					**$1,980,000**
ANNUAL O&M COST FOR OPERATING BED				**$38,000**	
NPV OF ANNUAL O&M COSTS (30 YEARS @ 7% INTEREST)					**$471,000**
NPV OF INITIAL AND SUBSEQUENT BEDS & CLOSURES CAPITAL COSTS @ 7% INTEREST					**$6,205,000**
TOTAL 30-YEAR PRESENT WORTH COST @ 7% INTEREST					**$6,676,000**

NOTES:
Misc Allowance markup is to include items known to exist but cannot be quantified at this time.
Contingency is for scope changes that are presently unforeseen.
Mobilization includes bonds, insurance, temporary facilities, health & safety, demobilization, etc.

NOTE: The above cost opinion is in November 2000 dollars and does not include escalation. The order of magnitude cost opinion shown has been prepared for guidance in project evaluation at the time of preparation. The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope, final schedule and other variable factors. As a result, the final project costs will vary from those presented above. Because of these factors, funding needs must be carefully reviewed prior to making specific financial decisions or establishing final budgets.

Alternative 2
Option A

Bunker Hill
Acid Mine Drainage
Disposal of Raw Sludge in CIA Disposal Beds
Order of Magnitude Cost Opinion

DATE: 11/22/2000
PROJECT NO.: 152215.FS.02
ESTIMATE BY: D. Bunte
N. Gulensoy

DESCRIPTION	QTY	UNIT	TOTAL UNIT COST	TOTAL COST
Subgrade Stabilization	10,500	C. Y.	4.00	$42,000
Liner Protection Sand	8250	C. Y.	10.00	$82,500
Drain Rock	1,950	C. Y.	18.00	$35,100
Ditch Lining Geotextile	21,200	S. Y.	1.65	$34,980
G C L	18,100	S. Y.	4.05	$73,305
H D P E Geomembrane	18,100	S. Y.	5.40	$97,740
H D P E Pipe, 10"	550	L. F.	23.00	$12,650
Erosion Control Matting	11800	S.Y.	1.50	$17,700
Perf Pipe, 4"	2000	L. F.	2.00	$4,000
Perf Pipe, 6"	580	L. F.	3.00	$1,740
HDPE Pipe, 6"	130	L. F.	2.50	$325
Strip Drains	700	L. F.	1.75	$1,225
Valves, 6" Knife Gate	2	Each	700.00	$1,400
Valves, 10" Knife Gate	6	Each	1,000.00	$6,000
Air/Vacuum Release Valve	1	Each	2,000.00	$2,000
Valve Vault	6	Each	1,950.00	$11,700
Water Tight Manhole	1	Each	3,500.00	$3,500
Vertical Filtrate Drains	6	Each	4,000.00	$24,000
Cleanouts	2	Each	750.00	$1,500
Perimeter Road Embankment (not reduced)	28275	C. Y.	10	$282,750
Chain Link Fence and Gates (not reduced)	1000	L.F.	12	$12,000
Crushed Rock Surfacing (not reduced)	1500	C. Y.	15	$22,500
SUBTOTAL				**$1,024,865**
MISC ALLOWANCE	**10%**			**$102,487**
SUBTOTAL				**$1,127,352**
CONTINGENCY	**30%**			**$338,205**
SUBTOTAL				**$1,465,557**
MOBILIZATION	**15%**			**$219,834**
CONSTRUCTION TOTAL				**$1,685,390**
SALES TAX ON MATERIALS	**5.0%**			**$25,622**
ENGINEERING AND SUPPORT	**20%**			**$337,078**
CONSTRUCTION MANAGEMENT	**8%**			**$134,831**
CAPITAL COST SUBSEQUENT BEDS TOTAL (ROUNDED)				**$2,180,000**
ANNUAL O&M COST FOR OPERATING BED			**$46,000**	
NPV OF ANNUAL O&M COSTS (30 YEARS @ 7% INTEREST)				**$566,000**
NPV OF INITIAL AND SUBSEQUENT BEDS & CLOSURES CAPITAL COSTS @ 7% INTEREST				**$6,743,000**
TOTAL 30-YEAR PRESENT WORTH COST @ 7% INTEREST				**$7,309,000**

NOTES:
Misc Allowance markup is to include items known to exist but cannot be quantified at this time.
Contingency is for scope changes that are presently unforeseen.
Mobilization includes bonds, insurance, temporary facilities, health & safety, demobilization, etc.

NOTE: The above cost opinion is in November 2000 dollars and does not include escalation. The order of magnitude cost opinion shown has been prepared for guidance in project evaluation at the time of preparation. The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope, final schedule and other variable factors. As a result, the final project costs will vary from those presented above. Because of these factors, funding needs must be carefully reviewed prior to making specific financial decisions or establishing final budgets.

Alternative 5
Option B

O & M COST ESTIMATE DETAILS (Quantity reduced by 20%)

Description	Qty	Unit	Unit Cost	Total Cost
Annual Costs				
Belt Press Operator/Mechanic (fixed)	1	YR	100,000	$100,000
Belt Press Repair Parts (reduced by 20%)	1	YR	13,760	$13,760
Chemical Conditioning Polymer (reduced by 20%)	1	YR	16,000	$16,000
Operation Costs (reduced by 20%)	12,800	kWHR	0	$640
			Subtotal	**$130,400**
Contingency	10%			$13,040
Total Annual Cost				**$143,440**

Alternative 5
Option B

Bunker Hill — **DATE: 08/24/2000**
Acid Mine Drainage — **PROJECT NO.: 152215.FS.02**
Dewatering with Belt Filter Press — **ESTIMATE BY: D. Bunte**
Order of Magnitude Cost Opinion (Quantity reduced by 20%) — **N. Gulensoy**

DESCRIPTION	QTY	UNIT	TOTAL UNIT COST	TOTAL COST
Belt Filter Press				
Earthwork & Concrete for Slab	0	LS	$0	$0
Misc Metals	1	LS	$0	$0
Building	3,499	SF	$130	$454,839
Paint	1	LS	$17,494	$17,494
Belt Press	4	EA	$227,892	$911,567
Booster Pump	1	EA	$5,942	$5,942
Air Compressor	1	EA	$4,932	$4,932
Conveyor	4	EA	$33,160	$132,638
Storage Hopper	2	EA	$34,110	$68,220
Electrical/I&C	1	LS	$0	$0
Haul to Off-Site Landfill				
Load	0	CY	$0	$0
Misc	0	LS	$0	$0

SUBTOTAL			**$1,595,632**
MISC ALLOWANCE	**10%**		**$159,563**
SUBTOTAL			**$1,755,195**
CONTINGENCY	**30%**		**$526,559**
SUBTOTAL			**$2,281,754**
MOBILIZATION	**15%**		**$342,263**
CONSTRUCTION TOTAL			**$2,624,017**
SALES TAX ON MATERIALS	**5.0%**		**$84,041**
ENGINEERING AND SUPPORT	**20%**		**$524,803**
CONSTRUCTION MANAGEMENT	**8%**		**$209,921**
FILTER PRESS CAPITAL TOTAL (ROUNDED)			**$3,440,000**
FILTER PRESS ANNUAL O&M COST		**$143,000**	
30-YEAR NPV OF FILTER PRESS ANNUAL O&M COST			**$1,774,000**
HAUL AND DISPOSE OFFSITE ANNUAL O&M COST		**$475,000**	
30-YEAR NPV OF HAUL AND DISPOSE OFFSITE			**$5,894,000**
TOTAL 30-YEAR PRESENT WORTH COST @ 7% INTEREST			**$11,108,000**

NOTES:
Misc Allowance markup is to include items known to exist but cannot be quantified at this time.
Contingency is for scope changes that are presently unforeseen.
Mobilization includes bonds, insurance, temporary facilities, health & safety, demobilization, etc.

NOTE: The above cost opinion is in August 2000 dollars and does not include escalation. The order of magnitude cost opinion shown has been prepared for guidance in project evaluation at the time of preparation. The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope, final schedule and other variable factors. As a result, the final project costs will vary from those presented above. Because of these factors, funding needs must be carefully reviewed prior to making specific financial decisions or establishing final budgets.

Alternative 5
Option B

O & M COST ESTIMATE DETAILS (Quantity reduced by 20%)

Description	Qty	Unit	Unit Cost	Total Cost	Comments
Annual Costs					
Haul & Dispose	9,920	TN	43.5	$431,520	Based on Alt 2, reduced by 20%
				$431,520	
Contingency	10%			$43,152	
Total Annual Cost				**$475,000**	

Alternative 5
Option C

Bunker Hill — **DATE: 11/22/2000**
Acid Mine Drainage — **PROJECT NO.: 152215.FS.02**
Closure of Existing Sludge Bed on CIA — **ESTIMATE BY: D. Bunte**
Order of Magnitude Cost Opinion — **N. Gulensoy**

DESCRIPTION	QTY	UNIT	TOTAL UNIT COST	TOTAL COST
Closure of Existing Sludge Bed on CIA				
Cell Closure Allowance	6.50	AC	137,500.00	$893,750
SUBTOTAL				**$893,750**
MISC ALLOWANCE	**10%**			**$89,375**
SUBTOTAL				**$983,125**
CONTINGENCY	**30%**			**$294,938**
SUBTOTAL				**$1,278,063**
MOBILIZATION	**15%**			**$191,709**
CONSTRUCTION TOTAL				**$1,469,772**
SALES TAX ON MATERIALS	**5.0%**			**$20,313**
ENGINEERING AND SUPPORT	**20%**			**$293,954**
CONSTRUCTION MANAGEMENT	**8%**			**$117,582**
CAPITAL TOTAL (ROUNDED)				**$1,900,000**
ANNUAL O&M COST (considered incidental to rest of CIA)			**$0**	

NOTES:

Misc Allowance markup is to include items known to exist but cannot be quantified at this time.
Contingency is for scope changes that are presently unforeseen.
Mobilization includes bonds, insurance, temporary facilities, health & safety, demobilization, etc.

NOTE: The above cost opinion is in November 2000 dollars and does not include escalation. The order of magnitude cost opinion shown has been prepared for guidance in project evaluation at the time of preparation. The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope, final schedule and other variable factors. As a result, the final project costs will vary from those presented above. Because of these factors, funding needs must be carefully reviewed prior to making specific financial decisions or establishing final budgets.

Alternative 5
Option C

Bunker Hill — **DATE: 11/29/2000**
Acid Mine Drainage — **PROJECT NO.: 152215.FS.02**
Smelter Closure Area Sludge Disposal Beds - Future Closure Cost — **ESTIMATE BY: D. Bunte**
Order of Magnitude Cost Opinion (Quantity reduced by 20%) — **N. Gulensoy**

DESCRIPTION	QTY	UNIT	TOTAL UNIT COST	TOTAL COST
Sludge Disposal Bed Closure (per each)				
Cell Closure Allowance	3.04	AC	137,500.00	$418,000
SUBTOTAL				**$418,000**
MISC ALLOWANCE	**10%**			**$41,800**
SUBTOTAL				**$459,800**
CONTINGENCY	**30%**			**$137,940**
SUBTOTAL				**$597,740**
MOBILIZATION	**15%**			**$89,661**
CONSTRUCTION TOTAL				**$687,401**
SALES TAX ON MATERIALS	**5.0%**			**$9,500**
ENGINEERING AND SUPPORT	**20%**			**$137,480**
CONSTRUCTION MANAGEMENT	**8%**			**$54,992**
CAPITAL TOTAL (ROUNDED)				**$890,000**
ANNUAL O&M COST (considered incidental to operating sludge bed)			**$0**	

NOTES:
Misc Allowance markup is to include items known to exist but cannot be quantified at this time.
Contingency is for scope changes that are presently unforeseen.
Mobilization includes bonds, insurance, temporary facilities, health & safety, demobilization, etc.

NOTE: The above cost opinion is in November 2000 dollars and does not include escalation. The order of magnitude cost opinion shown has been prepared for guidance in project evaluation at the time of preparation. The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope, final schedule and other variable factors. As a result, the final project costs will vary from those presented above. Because of these factors, funding needs must be carefully reviewed prior to making specific financial decisions or establishing final budgets.

Alternative 5
Sludge Management Option C

ANNUAL O&M COSTS CALCULATIONS
Series of Expenditures

Interest Rate	**7.00%**
Net Present Value	**$764,645**

Year	Annual Cost	Factor	NPV
0	NA	1.0000	NA
1	$61,620	0.9346	$57,589
2	$61,620	0.8734	$53,821
3	$61,620	0.8163	$50,300
4	$61,620	0.7629	$47,010
5	$61,620	0.7130	$43,934
6	$61,620	0.6663	$41,060
7	$61,620	0.6227	$38,374
8	$61,620	0.5820	$35,863
9	$61,620	0.5439	$33,517
10	$61,620	0.5083	$31,324
11	$61,620	0.4751	$29,275
12	$61,620	0.4440	$27,360
13	$61,620	0.4150	$25,570
14	$61,620	0.3878	$23,897
15	$61,620	0.3624	$22,334
16	$61,620	0.3387	$20,873
17	$61,620	0.3166	$19,507
18	$61,620	0.2959	$18,231
19	$61,620	0.2765	$17,038
20	$61,620	0.2584	$15,924
21	$61,620	0.2415	$14,882
22	$61,620	0.2257	$13,908
23	$61,620	0.2109	$12,999
24	$61,620	0.1971	$12,148
25	$61,620	0.1842	$11,353
26	$61,620	0.1722	$10,611
27	$61,620	0.1609	$9,917
28	$61,620	0.1504	$9,268
29	$61,620	0.1406	$8,661
30	$61,620	0.1314	$8,095

PERIODIC COSTS CALCULATIONS
Single Expenditure at Year XX

Interest Rate	**7.00%**
Net Present Value	**$10,605,483**

Year	Investment	Factor	NPV	
0	$6,420,000	1.0000	$6,420,000	initial bed construction
1	$0	0.9346	$0	
2	$1,900,000	0.8734	$1,659,534	closure of existing bed
3	$0	0.8163	$0	
4	$0	0.7629	$0	
5	$0	0.7130	$0	
6	$0	0.6663	$0	
7	$0	0.6227	$0	
8	$0	0.5820	$0	
9	$0	0.5439	$0	
10	$2,320,000	0.5083	$1,179,370	new bed
11	$890,000	0.4751	$422,833	closure
12	$0	0.4440	$0	
13	$0	0.4150	$0	
14	$0	0.3878	$0	
15	$0	0.3624	$0	
16	$0	0.3387	$0	
17	$0	0.3166	$0	
18	$0	0.2959	$0	
19	$0	0.2765	$0	
20	$2,320,000	0.2584	$599,532	new bed
21	$890,000	0.2415	$214,947	closure
22	$0	0.2257	$0	
23	$0	0.2109	$0	
24	$0	0.1971	$0	
25	$0	0.1842	$0	
26	$0	0.1722	$0	
27	$0	0.1609	$0	
28	$0	0.1504	$0	
29	$0	0.1406	$0	
30	$0	0.1314	$0	
31	$890,000	0.1228	$109,268	closure

Alternative 5
Option C

O & M COST ESTIMATE DETAILS

Description	Qty	Unit	UNIT COST	Total Cost
Annual Costs				
Pump Station & Pipeline				
Operation Labor	1	YR	$26,400	$26,400
Pump & Pipeline Maintenance & Repairs	1	YR	$8,344	$8,344
Power Cost for Pumping & Misc (Quantity reduced by 20%)	52,000	kWHR	$0.06	$2,860
Groundwater/Surface Water Monitoring				
System Inspection & Sampling	48	HR	$88	$4,224
Sample Shipping	4	EA	$66	$264
Supplies	4	EA	$220	$880
Indicator Analyses (quarterly)	8	EA	$297	$2,376
Metals Analyses (semiannually)	6	EA	$220	$1,320
Reporting	20	HR	$110	$2,200
Filtrate Discharge System Inspect/Clean	4	EA	$1,100	$4,400
Roads Maintenance	1	EA	$2,750	$2,750
			Subtotal	**$56,018**
Contingency	10%			$5,602
Total Annual Cost				**$61,620**

Alternative 5
Option C

Bunker Hill — **DATE: 11/29/2000**
Acid Mine Drainage — **PROJECT NO.: 152215.FS.02**
Disposal of Raw Sludge in Smelter Closure Area Disposal Beds — **ESTIMATE BY: D. Bunte**
Order of Magnitude Cost Opinion (Quantity reduced by 20%) — **N. Gulensoy**

DESCRIPTION	QTY	QTY Reduced by 20%	UNIT	TOTAL UNIT COST	TOTAL COST
Sitework/Yard Piping					
Clear & Grub	20		AC	3,000.00	$60,000
Site Prep Cut	300,000	240,000	CY	3.30	$990,000
Site Prep Fill	300,000	240,000	CY	1.10	$330,000
6" HDPE Sludge Pipeline in Trench	6,400		LF	31.78	$203,421
6" HDPE Leachate Pipeline in Trench	2,500		LF	24.70	$61,749
Leachate pipe tie in to pump	1		LS	2,000.00	$2,000
Manholes	7		EA	3,850.00	$26,950
Sludge Pumping					
Prefab Metal Bldg w/Concrete Floor	500		SF	165.00	$82,500
Paint	1		LS	5,500.00	$5,500
Pump, 30hp	4		EA	15,380.27	$61,521
Standby Pump, 30hp	1		EA	15,380.27	$15,380
Gland Seal Water Pump	1		EA	8,136.01	$8,136
Electrical/I&C	1		LS	32,400.00	$32,400
6" Check Valve	4		EA	1,897.78	$7,591
6" Gate Valve	4		EA	1,897.78	$7,591
6" HDPE Pipe in Trench	200		LF	22.50	$4,500
Flushing Hookups	1		LS	5,500.00	$5,500
Pipeline Cleanout Pig Station	1		LS	27,500.00	$27,500
Sludge Disposal Bed (per each)					
Excavation	25,000	20,000	C. Y.	3.30	$66,000
Subgrade Preparation	5	4	Acres	3,300.00	$13,200
Subgrade Stabilization	10,500	8,400	C. Y.	4.40	$36,960
Liner Protection Sand	8250	6,600	C. Y.	19.80	$130,680
Drain Rock	1,950	1,560	C. Y.	19.80	$30,888
Ditch Lining Geotextile	21,200	16,960	S. Y.	1.82	$30,782
G C L	18,100	14,480	S. Y.	4.46	$64,508
H D P E Geomembrane	18,100	14,480	S. Y.	5.94	$86,011
H D P E Pipe, 10"	550	440	L. F.	25.30	$11,132
Erosion Control Matting	11800	9,440	S.Y.	1.65	$15,576
Perf Pipe, 4"	2000	1,600	L. F.	2.20	$3,520
Perf Pipe, 6"	580	464	L. F.	3.30	$1,531
HDPE Pipe, 6"	130	104	L. F.	2.75	$286
Strip Drains	700	560	L. F.	1.93	$1,078
Valves, 6" Knife Gate	2		Each	770.00	$1,540
Valves, 10" Knife Gate	6		Each	1,100.00	$6,600
Air/Vacuum Release Valve	1		Each	2,200.00	$2,200
Valve Vault	6		Each	2,145.00	$12,870
Water Tight Manhole	1		Each	3,850.00	$3,850
Vertical Filtrate Drains	6		Each	4,400.00	$26,400
Cleanouts	2		Each	825.00	$1,650
Perimeter Road Embankment (not reduce	43500	43,500	C. Y.	11.00	$478,500
Chain Link Fence and Gates (not reduced)	2000	2,000	L.F.	13.20	$26,400
Groundwater Monitoring Wells	2		Each	6,600.00	$13,200
Crushed Rock Surfacing (not reduced)	1500	1,500	C. Y.	16.50	$24,750
SUBTOTAL					**$3,022,353**
MISC ALLOWANCE	**10%**				**$302,235**
SUBTOTAL					**$3,324,588**
CONTINGENCY	**30%**				**$997,377**
SUBTOTAL					**$4,321,965**
MOBILIZATION	**15%**				**$648,295**
CONSTRUCTION TOTAL					**$4,970,260**
SALES TAX ON MATERIALS	**5.0%**				**$60,650**
ENGINEERING AND SUPPORT	**20%**				**$994,052**
CONSTRUCTION MANAGEMENT	**8%**				**$397,621**
CAPITAL COST FIRST BED (ROUNDED)					**$6,420,000**

Alternative 5
Option C

Bunker Hill | **DATE: 11/29/2000**
Acid Mine Drainage | **PROJECT NO.: 152215.FS.02**
Disposal of Raw Sludge in Smelter Closure Area Disposal Beds | **ESTIMATE BY: D. Bunte**
Order of Magnitude Cost Opinion (Quantity reduced by 20%) | **N. Gulensoy**

DESCRIPTION	QTY	QTY Reduced by 20%	UNIT	TOTAL UNIT COST	TOTAL COST
CAPITAL COST FOR NEW CELLS IN FUTURE YEARS (DOES NOT INCLUDE PUMPING AND PIPING COST)					
Sludge Disposal Bed (per each)					
Excavation	25,000	20,000	C. Y.	3.30	$66,000
Subgrade Preparation	5	4	Acres	3,300.00	$13,200
Subgrade Stabilization	10,500	8,400	C. Y.	4.40	$36,960
Liner Protection Sand	8250	6,600	C. Y.	19.80	$130,680
Drain Rock	1,950	1,560	C. Y.	19.80	$30,888
Ditch Lining Geotextile	21,200	16,960	S. Y.	1.82	$30,782
G C L	18,100	14,480	S. Y.	4.46	$64,508
H D P E Geomembrane	18,100	14,480	S. Y.	5.94	$86,011
H D P E Pipe, 10"	550	440	L. F.	25.30	$11,132
Erosion Control Matting	11800	9,440	S.Y.	1.65	$15,576
Perf Pipe, 4"	2000	1,600	L. F.	2.20	$3,520
Perf Pipe, 6"	580	464	L. F.	3.30	$1,531
HDPE Pipe, 6"	130	104	L. F.	2.75	$286
Strip Drains	700	560	L. F.	1.93	$1,078
Valves, 6" Knife Gate	2		Each	770.00	$0
Valves, 10" Knife Gate	6		Each	1,100.00	$0
Air/Vacuum Release Valve	1		Each	2,200.00	$0
Valve Vault	6		Each	2,145.00	$0
Water Tight Manhole	1		Each	3,850.00	$0
Vertical Filtrate Drains	6		Each	4,400.00	$0
Cleanouts	2		Each	825.00	$0
Perimeter Road Embankment (not reduce	28275	28,275	C. Y.	11.00	$311,025
Chain Link Fence and Gates (not reduced)	1000	1,000	L.F.	13.20	$13,200
Groundwater Monitoring Wells	2		Each	6,600.00	$13,200
Crushed Rock Surfacing (not reduced)	1500	1,500	C. Y.	16.50	$24,750

SUBTOTAL		**$1,090,113**
MISC ALLOWANCE	**10%**	**$109,011**
SUBTOTAL		**$1,199,125**
CONTINGENCY	**30%**	**$359,737**
SUBTOTAL		**$1,558,862**
MOBILIZATION	**15%**	**$233,829**
CONSTRUCTION TOTAL		**$1,792,691**
SALES TAX ON MATERIALS	**5.0%**	**$27,572**
ENGINEERING AND SUPPORT	**20%**	**$358,538**
CONSTRUCTION MANAGEMENT	**8%**	**$143,415**
CAPITAL COST SUBSEQUENT BEDS TOTAL (ROUNDED)		**$2,320,000**
ANNUAL O&M COST FOR OPERATING BED	**$62,000**	
NPV OF ANNUAL O&M COSTS (30 YEARS @ 7% INTEREST)		**$765,000**
NPV OF INITIAL AND SUBSEQUENT BEDS & CLOSURES CAPITAL COSTS @ 7% INTEREST		**$10,605,000**
TOTAL 30-YEAR PRESENT WORTH COST @ 7% INTEREST		**$11,370,000**

NOTES:
Misc Allowance markup is to include items known to exist but cannot be quantified at this time.
Contingency is for scope changes that are presently unforeseen.
Mobilization includes bonds, insurance, temporary facilities, health & safety, demobilization, etc.

NOTE: The above cost opinion is in November 2000 dollars and does not include escalation. The order of magnitude cost opinion shown has been prepared for guidance in project evaluation at the time of preparation. The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope, final schedule and other variable factors. As a result, the final project costs will vary from those presented above. Because of these factors, funding needs must be carefully reviewed prior to making specific financial decisions or establishing final budgets.

Alternative 2
Option D

SLUDGE DRYING BEDS O & M COST ESTIMATE DETAILS

Description	Qty	Unit	Unit Cost	Total Cost
Annual Costs				
Pump Station & Pipeline				
Operation Labor	1	YR	$22,000	$22,000
Pump & Pipeline Maintenance & Repairs	1	YR	$8,618	$8,618
Power Cost for Pumping & Misc	16,000	kWHR	$0.06	$880
Filtrate Discharge System Inspect/Clean	4	EA	$1,100	$4,400
Roads Maintenance	1	EA	$2,750	$2,750
			Subtotal	**$38,648**
Contingency	10%			$3,865
Total Annual Cost				**$42,513**

Alternative 5
Option D

Bunker Hill | **DATE: 12/16/1998**
Acid Mine Drainage | **PROJECT NO.: 148562.02.01**
Dewatering in Sludge Drying Beds | **ESTIMATE BY: D. Hedglin**
Order of Magnitude Cost Opinion (Reduced by 20%)

DESCRIPTION	QTY	QTY Reduced by 20%	UNIT	TOTAL UNIT COST	TOTAL COST
		0.8			
Sitework/Yard Piping					
6" HDPE Sludge Pipeline in Trench	800		LF	21.54	$17,233
6" HDPE Leachate Pipeline in Trench	800		LF	21.54	$17,233
Sludge Pumping					
Prefab Metal Bldg w/Concrete Floor	216		SF	150.00	$32,400
Paint	1		LS	5,000.00	$5,000
Pump, 30hp	2		EA	14,810.06	$29,620
Standby Pump, 30hp	1		EA	14,810.06	$14,810
Gland Seal Water Pump	1		EA	7,948.38	$7,948
Electrical/I&C	1		LS	17,955.71	$17,956
Sludge Drying Bed					
Excavation	7000	5600	C. Y.	3.00	$16,800
Subgrade Preparation	2.6	2.08	Acres	3,000.00	$6,240
Subgrade Stabilization	4200	3360	C. Y.	4.00	$13,440
Liner Protection Sand	5,000	4000	C. Y.	10.00	$40,000
Drain Rock	1250	1000	C. Y.	18.00	$18,000
Ditch Lining Geotextile	2,000	1600	S. Y.	1.65	$2,640
G C L	10,000	8000	S. Y.	4.05	$32,400
H D P E Geomembrane	10,500	8400	S. Y.	5.40	$45,360
H D P E Pipe, 10"	450	360	L. F.	23.00	$8,280
Erosion Control Matting	8,000	6400	S.Y.	1.50	$9,600
Perf Pipe, 4"	1600	1280	L. F.	2.00	$2,560
Perf Pipe, 6"	400	320	L. F.	3.00	$960
HDPE Pipe, 6"	250	200	L. F.	2.50	$500
Strip Drains	850	680	L. F.	1.75	$1,190
Valves, 6" Knife Gate	2		Each	700	$1,400
Valves, 10" Knife Gate	4		Each	1,000.00	$4,000
Air/Vacuum Release Valve	1		Each	2,000.00	$2,000
Valve Vault	6		Each	1,950.00	$11,700
Water Tight Manhole	2		Each	3,500.00	$7,000
Vertical Filtrate Drains	8		Each	4,000.00	$32,000
Cleanouts	4		Each	750.00	$3,000
Perimeter Road Embankment	8000		C. Y.	10.00	$80,000
Chain Link Fence and Gates	2000		L.F.	12.00	$24,000
Access Road (CCP)	500		L.F.	50.00	$25,000
Crushed Rock Surfacing	1500		C. Y.	15.00	$22,500
Decontamination Station	1		LS	200,000.00	$200,000
SUBTOTAL					**$752,770**
MISC ALLOWANCE	**10%**				**$75,277**
SUBTOTAL					**$828,047**
CONTINGENCY	**15%**				**$124,207**
SUBTOTAL					**$952,254**
MOBILIZATION	**15%**				**$142,838**
CONSTRUCTION TOTAL					**$1,095,092**
SALES TAX ON MATERIALS	**5.0%**				**$12,859**
ENGINEERING AND SUPPORT	**20%**				**$219,018**
CONSTRUCTION MANAGEMENT	**8%**				**$87,607**

Alterative 5
Option D

SLUDGE LANDFILL O & M COST ESTIMATE DETAILS

Description	Qty	Unit	UNIT COST	Total Cost
Annual Costs				
Remove, Load, Decon Truck, Haul & Unload	5,440	CY	$11	$59,840
Groundwater/Surface Water Monitoring				
System Inspection & Sampling	48	HR	$88	$4,224
Sample Shipping	4	EA	$66	$264
Supplies	4	EA	$220	$880
Indicator Analyses (quarterly)	8	EA	$297	$2,376
Metals Analyses (semiannually)	6	EA	$220	$1,320
Reporting	20	HR	$110	$2,200
Filtrate Discharge System Inspect/Clean	4	EA	$1,100	$4,400
Roads Maintenance	1	EA	$2,750	$2,750
			Subtotal	**$78,254**
Contingency	10%			$7,825
Total Annual Cost				**$86,079**

Alternative 5
Option D

Bunker Hill | **DATE: 11/29/2000**
Acid Mine Drainage | **PROJECT NO.: 152215.FS.02**
Onsite Landfill - Smelter Closure Area | **ESTIMATE BY: D. Hedglin**
Order of Magnitude Cost Opinion

DESCRIPTION	QTY	QTY Reduced by 20%	UNIT	TOTAL UNIT COST	TOTAL COST
		0.80			
Sitework					
Clear and Grub	20		AC	3,000.00	$60,000
Site Prep Excavation	300,000	240,000	CY	3.30	$792,000
Site Prep Fill	300,000	240,000	CY	1.10	$264,000
Pipeline					
6" HDPE Gravity Pipeline in Trench	2,500		LF	22.50	$56,249
Manhole	8		EA	3,850.00	$32,083
Landfill Construction					
Excavation	58,000	46,400	CY	3.30	$153,120
Subgrade Preparation	12.7	10.2	AC	3,300.00	$33,528
Subgrade Stabilization	20,537	16,430	CY	4.40	$72,290
Embankment Fill	63,265	50,612	CY	11.00	$556,732
Liner Protection Sand	18,000	14,400	CY	19.80	$285,120
Drain Rock	5,100	4,080	CY	19.80	$80,784
Ditch Lining Geotextile	35,400	28,320	SY	1.82	$51,401
G C L	35,400	28,320	SY	4.46	$126,166
H D P E Geomembrane	35,400	28,320	SY	5.94	$168,221
H D P E Pipe, 12"	2,000	1,600	LF	28.60	$45,760
Erosion Control Matting	19,500	15,600	SY	1.65	$25,740
Perf Pipe, 6"	650	520	LF	3.30	$1,716
Strip Drains	1,180	944	LF	1.93	$1,817
Filtrate Penetration Sump (Allowance)	1		EA	27,500.00	$27,500
HDPE Pipe, 6"	150	120	LF	2.75	$330
Water Tight Manhole	1		EA	3,850.00	$3,850
Cleanouts	2		EA	825.00	$1,650
Chain Link Fence and Gates	3,060		LF	13.20	$40,392
Groundwater Monitoring Wells	4		EA	6,600.00	$26,400
Crushed Rock Surfacing	2,270		CY	16.50	$37,455
SUBTOTAL					**$2,944,304**
MISC ALLOWANCE	**10%**				**$294,430**
SUBTOTAL					**$3,238,734**
CONTINGENCY	**15%**				**$485,810**
SUBTOTAL					**$3,724,545**
MOBILIZATION	**15%**				**$558,682**
CONSTRUCTION TOTAL					**$4,283,226**
SALES TAX ON MATERIALS	**5%**				**$40,586**
ENGINEERING AND SUPPORT	**20%**				**$856,645**
CONSTRUCTION MANAGEMENT	**8%**				**$342,658**
CAPITAL TOTAL (ROUNDED)					**$5,523,000**

Alternative 5
Option D

Bunker Hill — **DATE: 11/22/2000**
Acid Mine Drainage — **PROJECT NO.: 152215.FS.02**
Closure of Existing Sludge Bed on CIA — **ESTIMATE BY: D. Bunte**
Order of Magnitude Cost Opinion — **N. Gulensoy**

DESCRIPTION	QTY	UNIT	TOTAL UNIT COST	TOTAL COST
Closure of Existing Sludge Bed on CIA				
Cell Closure Allowance	6.50	AC	137,500.00	$893,750
SUBTOTAL				**$893,750**
MISC ALLOWANCE	**10%**			**$89,375**
SUBTOTAL				**$983,125**
CONTINGENCY	**30%**			**$294,938**
SUBTOTAL				**$1,278,063**
MOBILIZATION	**15%**			**$191,709**
CONSTRUCTION TOTAL				**$1,469,772**
SALES TAX ON MATERIALS	**5.0%**			**$20,313**
ENGINEERING AND SUPPORT	**20%**			**$293,954**
CONSTRUCTION MANAGEMENT	**8%**			**$117,582**
CAPITAL TOTAL (ROUNDED)				**$1,900,000**
ANNUAL O&M COST (considered incidental to rest of CIA)			**$0**	

NOTES:

Misc Allowance markup is to include items known to exist but cannot be quantified at this time.
Contingency is for scope changes that are presently unforeseen.
Mobilization includes bonds, insurance, temporary facilities, health & safety, demobilization, etc.

NOTE: The above cost opinion is in November 2000 dollars and does not include escalation. The order of magnitude cost opinion shown has been prepared for guidance in project evaluation at the time of preparation. The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope, final schedule and other variable factors. As a result, the final project costs will vary from those presented above. Because of these factors, funding needs must be carefully reviewed prior to making specific financial decisions or establishing final budgets.

Alternative 5
Option D

Bunker Hill — **DATE: 11/29/2000**
Acid Mine Drainage — **PROJECT NO.: 152215.FS.02**
Onsite Landfill - Smelter Closure Area — **ESTIMATE BY: D. Hedglin**
Order of Magnitude Cost Opinion

DESCRIPTION	QTY	QTY Reduced by 20%	UNIT	TOTAL UNIT COST	TOTAL COST
		0.80			
ANNUAL O&M COST				$86,000	
CAPITAL COST OF CLOSURE @ YEAR 31				$1,818,000	
NPV OF ANNUAL O&M COSTS (30 YEARS @ 7% INTEREST)					$1,068,000
NPV OF CLOSURE COST (YEAR 31 @ 7% INTEREST)					$223,000
TOTAL 30-YEAR PRESENT WORTH COST @ 7% INTEREST					$6,814,000

NOTES:

Landfill post-closure costs are not included here since they extend beyond the 30 year period.
Misc Allowance markup is to include items known to exist but cannot be quantified at this time.
Contingency is for scope changes that are presently unforeseen.
Mobilization includes bonds, insurance, temporary facilities, health & safety, demobilization, etc.

NOTE: The above cost opinion is in November 2000 dollars and does not include escalation. The order of magnitude cost opinion shown has been prepared for guidance in project evaluation at the time of preparation. The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope, final schedule and other variable factors. As a result, the final project costs will vary from those presented above. Because of these factors, funding needs must be carefully reviewed prior to making specific financial decisions or establishing final budgets.

Alternative 5
Option D

Bunker Hill — **DATE: 12/16/1998**
Acid Mine Drainage — **PROJECT NO.: 148562.02.01**
Dewatering in Sludge Drying Beds — **ESTIMATE BY: D. Hedglin**
Order of Magnitude Cost Opinion (Reduced by 20%)

DESCRIPTION	QTY	QTY Reduced by 20%	UNIT	TOTAL UNIT COST	TOTAL COST
		0.8			
CAPITAL TOTAL (ROUNDED)					$1,415,000
ANNUAL O&M COST				$43,000	
NPV OF ANNUAL O&M COSTS (30 YEARS @ 7% INTEREST)					$528,000
TOTAL 30-YEAR PRESENT WORTH COST @ 7% INTEREST					$1,943,000

NOTES:
Misc Allowance markup is to include items known to exist but cannot be quantified at this time.
Contingency is for scope changes that are presently unforeseen.
Mobilization includes bonds, insurance, temporary facilities, health & safety, demobilization, etc.

NOTE: The above cost opinion is in December 1998 dollars and does not include escalation. The order of magnitude cost opinion shown has been prepared for guidance in project evaluation at the time of preparation. The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope, final schedule and other variable factors. As a result, the final project costs will vary from those presented above. Because of these factors, funding needs must be carefully reviewed prior to making specific financial decisions or establishing final budgets.

Alternative 2
Option A

Bunker Hill — **DATE: 11/22/2000**
Acid Mine Drainage — **PROJECT NO.: 152215.FS.02**
Closure of Existing CIA Sludge Pond — **ESTIMATE BY: D. Bunte**
Order of Magnitude Cost Opinion — **N. Gulensoy**

DESCRIPTION	QTY	UNIT	TOTAL UNIT COST	TOTAL COST
Closure of Existing Sludge Pond on CIA				
Cell Closure Allowance	6.50	AC	137,500.00	$893,750
SUBTOTAL				**$893,750**
MISC ALLOWANCE	**10%**			**$89,375**
SUBTOTAL				**$983,125**
CONTINGENCY	**30%**			**$294,938**
SUBTOTAL				**$1,278,063**
MOBILIZATION	**15%**			**$191,709**
CONSTRUCTION TOTAL				**$1,469,772**
SALES TAX ON MATERIALS	**5.0%**			**$20,313**
ENGINEERING AND SUPPORT	**20%**			**$293,954**
CONSTRUCTION MANAGEMENT	**8%**			**$117,582**
CAPITAL TOTAL (ROUNDED)				**$1,900,000**
ANNUAL O&M COST (considered incidental to rest of CIA)			**$0**	

NOTES:
Misc Allowance markup is to include items known to exist but cannot be quantified at this time.
Contingency is for scope changes that are presently unforeseen.
Mobilization includes bonds, insurance, temporary facilities, health & safety, demobilization, etc.

NOTE: The above cost opinion is in November 2000 dollars and does not include escalation. The order of magnitude cost opinion shown has been prepared for guidance in project evaluation at the time of preparation. The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope, final schedule and other variable factors. As a result, the final project costs will vary from those presented above. Because of these factors, funding needs must be carefully reviewed prior to making specific financial decisions or establishing final budgets.

Alternative 2
Sludge Management Option A

ANNUAL O&M COSTS CALCULATIONS
Series of Expenditures

Interest Rate	**7.00%**
Net Present Value	**$566,227**

Year	Annual Cost	Factor	NPV
0	NA	1.0000	NA
1	$45,630	0.9346	$42,645
2	$45,630	0.8734	$39,855
3	$45,630	0.8163	$37,248
4	$45,630	0.7629	$34,811
5	$45,630	0.7130	$32,534
6	$45,630	0.6663	$30,405
7	$45,630	0.6227	$28,416
8	$45,630	0.5820	$26,557
9	$45,630	0.5439	$24,820
10	$45,630	0.5083	$23,196
11	$45,630	0.4751	$21,679
12	$45,630	0.4440	$20,260
13	$45,630	0.4150	$18,935
14	$45,630	0.3878	$17,696
15	$45,630	0.3624	$16,538
16	$45,630	0.3387	$15,457
17	$45,630	0.3166	$14,445
18	$45,630	0.2959	$13,500
19	$45,630	0.2765	$12,617
20	$45,630	0.2584	$11,792
21	$45,630	0.2415	$11,020
22	$45,630	0.2257	$10,299
23	$45,630	0.2109	$9,626
24	$45,630	0.1971	$8,996
25	$45,630	0.1842	$8,407
26	$45,630	0.1722	$7,857
27	$45,630	0.1609	$7,343
28	$45,630	0.1504	$6,863
29	$45,630	0.1406	$6,414
30	$45,630	0.1314	$5,994

PERIODIC COSTS CALCULATIONS
Single Expenditure at Year XX

Interest Rate	**7.00%**
Net Present Value	**$6,742,799**

Year	Investment	Factor	NPV	
0	$2,480,000	1.0000	$2,480,000	initial bed construction
1	$0	0.9346	$0	
2	$1,900,000	0.8734	$1,659,534	closure of existing bed
3	$0	0.8163	$0	
4	$0	0.7629	$0	
5	$0	0.7130	$0	
6	$0	0.6663	$0	
7	$0	0.6227	$0	
8	$0	0.5820	$0	
9	$0	0.5439	$0	
10	$2,180,000	0.5083	$1,108,201	new bed
11	$1,110,000	0.4751	$527,353	closure
12	$0	0.4440	$0	
13	$0	0.4150	$0	
14	$0	0.3878	$0	
15	$0	0.3624	$0	
16	$0	0.3387	$0	
17	$0	0.3166	$0	
18	$0	0.2959	$0	
19	$0	0.2765	$0	
20	$2,180,000	0.2584	$563,353	new bed
21	$1,110,000	0.2415	$268,080	closure
22	$0	0.2257	$0	
23	$0	0.2109	$0	
24	$0	0.1971	$0	
25	$0	0.1842	$0	
26	$0	0.1722	$0	
27	$0	0.1609	$0	
28	$0	0.1504	$0	
29	$0	0.1406	$0	
30	$0	0.1314	$0	
31	$1,110,000	0.1228	$136,278	closure

Alternative 2
Option A
O & M COST ESTIMATE DETAILS

Description	Qty	Unit	Unit Cost	Total Cost
Annual Costs				
Pump Station & Pipeline				
Operation Labor	1	YR	25,000	$25,000
Pump & Pipeline Maintenance & Repairs	1	YR	9,482	$9,482
Power Cost for Pumping & Misc	10,000	kWHR	0.05	$500
Filtrate Discharge System Inspect/Clean	4	EA	1,000	$4,000
Roads Maintenance	1	EA	2,500	$2,500
			Subtotal	**$41,482**
Contingency	10%			$4,148
Total Annual Cost				**$45,630**

Diversions Costs
Bunker Hill — **DATE: 08/24/2000**
Acid Mine Drainage: Storage — **PROJECT NO.: 152215.FS.02**
9 Level AMD Diversion Installation (Costs below are for two diversion locations) — **ESTIMATE BY: J. Winters**
Order of Magnitude Cost Opinion — **N.Gulensoy**

DESCRIPTION	QTY	UNIT	TOTAL UNIT COST	TOTAL COST	COMMENTS
Rock work					
Construct new 3'x3'x30'lg channel	20	CY	504.49	$10,090	Assumes no cross cut tunneling to reach a raise for diversion. One diversion will be located at No. 2 Shaft. Second diversion location will be on the Barney Drift, exact location is not known.
Diversion Gates and Flumes					
Diversion gates w/electric operator	4	EA	6,407.50	$25,630	See quote from Plasti-Fab 1/3/00 + markup
Exstg and new channel prep for gates	4	EA	1,513.46	$6,054	
Gate installation	4	EA	1,112.88	$4,452	
Cut-throat (trapezoidal) flumes	4	EA	6,000.00	$24,000	Price is for trapezoidal flume. Decide during final design which flume type to use. See quote from Plasti-Fab of 1/7/00. PlastiFab says cutthroat flume accuracy not repeatble. They have discontinued active sales.
Isco flowmeter on each flume	4	EA	4,106.52	$16,426	See eqmt quote from Whitney Eqmt.
Flume installation	4	EA	1,669.32	$6,677	Some (<1CY) minor amt of rock work in existing channel.
Extend 480 v power to gates from 9 Level	600	LF	17.83	$10,700	Assume motor starter w/in 300 ft of gate location.
Extend 120 v power to flowmeters from 9 Level	600	LF	12.13	$7,277	
TWSP (#16) wire in conduit for flowmeter	10,000	LF	4.62	$46,169	Two wires: 8000 lf in mine tunnel & 2000 lf buried from gates to CTP
Control wire(#12) for gate operators	10,000	LF	7.56	$75,644	Eight wires: 8000 lf in mine tunnel & 2000 lf buried from gates to CTP
Diversion pipe in No. 2 Shaft and in the Barney Drift					
12 dia HDPE pipe (SDR 17)	840	LF	68.52	$57,553	Pipe mounted inside a 50 deg mine shaft. Access for installation off mine shaft lift system. Each diversion pipe 420 ft long
Pipe riser clamp brackets (SST)	40	EA	870.54	$34,822	SST Clamp with base plate and epoxy anchor bolts. Installed at 20 OC along pipe
SST sheet metal inlet box/funnel to riser pipe	2	EA	2,500.00	$5,000	3'x3' box with one side open and hopper bottom. Outlet pipe on bottom fits up to HPDE pipe.
Installation of inlet box and attachment to pipe	2	EA	1,912.90	$3,826	Box will require some structural support beams
SUBTOTAL				**$334,319**	
MISC ALLOWANCE	**10%**			**$33,432**	
SUBTOTAL				**$367,751**	
CONTINGENCY	**30%**			**$110,325**	
SUBTOTAL				**$478,077**	
MOBILIZATION	**15%**			**$71,712**	
CONSTRUCTION TOTAL				**$549,788**	
SALES TAX ON MATERIALS	**5.0%**			**$6,906**	
ENGINEERING AND SUPPORT	**20%**			**$109,958**	
CONST MANAGEMENT	**8%**			**$43,983**	
CAPITAL TOTAL (ROUNDED)				**$710,000**	

Diversions Costs
Bunker Hill — **DATE: 08/24/2000**
Acid Mine Drainage: Storage — **PROJECT NO.: 152215.FS.02**
9 Level AMD Diversion Installation (Costs below are for two diversion locations) — **ESTIMATE BY: J. Winters**
Order of Magnitude Cost Opinion — **N.Gulensoy**

DESCRIPTION	QTY	UNIT	TOTAL UNIT COST	TOTAL COST	COMMENTS
ANNUAL O&M COST			$0		**O & M cost for diversion equipment included with AMD pump O&M.
NPV OF ANNUAL O&M COSTS (30 YEARS @ 7% INTEREST)				$0	
TOTAL 30-YEAR PRESENT WORTH COST @ 7% INTEREST				$710,000	

NOTE: The above cost opinion is in February 2000 dollars and does not include escalation. The order of magnitude cost opinion shown has been prepared for guidance in project evaluation at the time of preparation. The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope, final schedule and other variable factors. As a result, the final project costs will vary from those presented above. Because of these factors, funding needs must be carefully reviewed prior to making specific financial decisions or establishing final budgets.

Diversions Costs
Bunker Hill — **DATE: 08/24/2000**
Acid Mine Drainage: Storage — **PROJECT NO.: 152215.FS.02**
9 Level AMD Diversion Installation (Costs below are for two diversion locations) — **ESTIMATE BY: J. Winters**
Order of Magnitude Cost Opinion — **N.Gulensoy**

DESCRIPTION	QTY	UNIT	TOTAL UNIT COST	TOTAL COST	COMMENTS
Rock work					
Construct new 3'x3'x30'lg channel	20	CY	504.49	$10,090	Assumes no cross cut tunneling to reach a raise for diversion. One diversion will be located at No. 2 Shaft. Second diversion location will be on the Barney Drift, exact location is not known.
Diversion Gates and Flumes					
Diversion gates w/electric operator	4	EA	6,407.50	$25,630	See quote from Plasti-Fab 1/3/00 + markup
Exstg and new channel prep for gates	4	EA	1,513.46	$6,054	
Gate installation	4	EA	1,112.88	$4,452	
Cut-throat (trapezoidal) flumes	4	EA	6,000.00	$24,000	Price is for trapezoidal flume. Decide during final design which flume type to use. See quote from Plasti-Fab of 1/7/00. PlastiFab says cutthroat flume accuracy not repeatble. They have discontinued active sales.
Isco flowmeter on each flume	4	EA	4,106.52	$16,426	See eqmt quote from Whitney Eqmt.
Flume installation	4	EA	1,669.32	$6,677	Some (<1CY) minor amt of rock work in existing channel.
Extend 480 v power to gates from 9 Level	600	LF	17.83	$10,700	Assume motor starter w/in 300 ft of gate location.
Extend 120 v power to flowmeters from 9 Level	600	LF	12.13	$7,277	
TWSP (#16) wire in conduit for flowmeter	10,000	LF	4.62	$46,169	Two wires: 8000 lf in mine tunnel & 2000 lf buried from gates to CTP
Control wire(#12) for gate operators	10,000	LF	7.56	$75,644	Eight wires: 8000 lf in mine tunnel & 2000 lf buried from gates to CTP
Diversion pipe in No. 2 Shaft and in the Barney Drift					
12 dia HDPE pipe (SDR 17)	840	LF	68.52	$57,553	Pipe mounted inside a 50 deg mine shaft. Access for installation off mine shaft lift system. Each diversion pipe 420 ft long
Pipe riser clamp brackets (SST)	40	EA	870.54	$34,822	SST Clamp with base plate and epoxy anchor bolts. Installed at 20 OC along pipe
SST sheet metal inlet box/funnel to riser pipe	2	EA	2,500.00	$5,000	3'x3' box with one side open and hopper bottom. Outlet pipe on bottom fits up to HPDE pipe.
Installation of inlet box and attachment to pipe	2	EA	1,912.90	$3,826	Box will require some structural support beams
SUBTOTAL				**$334,319**	
MISC ALLOWANCE	**10%**			**$33,432**	
SUBTOTAL				**$367,751**	
CONTINGENCY	**30%**			**$110,325**	
SUBTOTAL				**$478,077**	
MOBILIZATION	**15%**			**$71,712**	
CONSTRUCTION TOTAL				**$549,788**	
SALES TAX ON MATERIALS	**5.0%**			**$6,906**	
ENGINEERING AND SUPPORT	**20%**			**$109,958**	
CONST MANAGEMENT	**8%**			**$43,983**	
CAPITAL TOTAL (ROUNDED)				**$710,000**	

Diversions Costs
Bunker Hill — **DATE: 08/24/2000**
Acid Mine Drainage: Storage — **PROJECT NO.: 152215.FS.02**
9 Level AMD Diversion Installation (Costs below are for two diversion locations) — **ESTIMATE BY: J. Winters**
Order of Magnitude Cost Opinion — **N.Gulensoy**

DESCRIPTION	QTY	UNIT	TOTAL UNIT COST	TOTAL COST	COMMENTS
ANNUAL O&M COST			$0		**O & M cost for diversion equipment included with AMD pump O&M.
NPV OF ANNUAL O&M COSTS (30 YEARS @ 7% INTEREST)				$0	
TOTAL 30-YEAR PRESENT WORTH COST @ 7% INTEREST				$710,000	

NOTE: The above cost opinion is in February 2000 dollars and does not include escalation. The order of magnitude cost opinion shown has been prepared for guidance in project evaluation at the time of preparation. The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope, final schedule and other variable factors. As a result, the final project costs will vary from those presented above. Because of these factors, funding needs must be carefully reviewed prior to making specific financial decisions or establishing final budgets.

O&M Costs
Storage from 30 feet below 11 Level and up
Bunker Hill
Acid Mine Drainage: Storage

DATE: 08/24/2000
PROJECT NO.: 152215.FS.02
ESTIMATE BY: J. Winters
N.Gulensoy

O & M COST ESTIMATE DETAILS

Tasks	Qty	Unit	Material Unit Cost	Labor Unit Cost	Equip Unit Cost	Total Cost	Comments
Annual Costs							
Mucking out diversion and main channels	1	YR		10,000		$10,000	Allowance.
Maintenance of electrical system for pumps	1	YR		50,000		$10,000	Allowance.
Diversion system maintenance	1	YR	2,000	4,800		$6,800	allowance $2k materials and 16hrs/mo for 6 months
Pumping System Inspection	365	HR	0	50		$18,250	asm 1 hr/day, 365 days/yr @ $50/hr labor
Pump removal and replacement	1	YR	5,000	22,385	672	$28,057	asm 1 time/year & 120hrs/time + material allowance
Pump maintenance	1	YR	20,000	18,620	3,168	$41,788	asm 1 time/year & 80hrs/time + material allowance
						$114,896	
Contingency	10%					$11,490	
Total Annual Cost						**$126,385**	

NOTE:
Pumping cost of extra minewater above11 Level is not included in this cost estimate due to infrequent pumping and unknown quantities of water.

Two 700 gpm pumps (constant speed) & Storage from 30 feet below 11 Level and up

Bunker Hill — **DATE: 08/24/2000**
Acid Mine Drainage: Storage — **PROJECT NO.: 152215.FS.02**
9 Level AMD Pumping Installation — **ESTIMATE BY: J. Winters**
Order of Magnitude Cost Opinion — **N.Gulensoy**

DESCRIPTION	QTY	UNIT	TOTAL UNIT COST	TOTAL COST	COMMENTS
Demolition					
Remove exstg pipe in No. 2 Shaft	1	LS	50,000.00	$50,000	Allowance.
Remove existing centrifugal pump (700 gpm)	1	LS	4,328.72	$4,329	Allowance. Assume 2 days. No materials.
Pump & Pipe Installation					
Upgrade electrical system into mine at 9 Level	1	ls	100,000.00	$100,000	Allowance.
New 12-inch dia throttling valve	1	LS	14,749.16	$14,749	Allowance $1000/ dia inch. Butterfly valve w/SSTdisk, seat and trim. Gear operator.
New 8' magnetic flowmeter	1	LS	7,632.78	$7,633	Assume $750/dia inch for meter. Need 8x12 reducer on each side of meter
Install 400 ft of 12" dia SST pipe (9 Level to 11 Level)	400	lf	156.87	$62,749	Pipe mtl quote from Alaska copper & Brass ($57.50/lf plus added $10/lf for flanged ends) = $67.50/lf + GC markup
New pipe riser clamps and base 20 ft OC	20	ea	452.24	$9,045	Pipe inside No. 2 Shaft from 9 to 11 Levels. Single pipe serves both 11 Level pumps.
Motor starters for 11 level Pump A	1	ls	24,576.43	$24,576	ANM quote from 1/10/00. Cost for 1,900 gpm scenario is adjusted for 700 & 700 gpm combination.
New Pump A (700 & 700 gpm vertical turbine, submersible)	1	LS	38,670.46	$38,670	SST impeller and trim. Quote due from ANM on 1/10/00. Cost for 1,900 gpm scenario is adjusted for 700 & 700 gpm combination. Each pump will be rated for 700 gpm at 460 ft.
Skid/rail car cost for submersible pump A.	1	ls	27,628.80	$27,629	ANM quote from 1/10/00. Cart will be designed to hold two pumps. Cost for 1,900 gpm scenario is adjusted for 700 & 700 gpm combination.
Power cable for two 150 HP Pumps (Pump A type)	500	lf	38.50	$19,248	Cost for 1,900 gpm scenario is adjusted for 700 & 700 gpm combination.
Wire for pump control back to CTP	11,000	lf	13.42	$147,583	Wire and conduit. Assume ten # 12 wires plus two TWSP #16
Bubbler level control system mounted at 11 Level	1	ls	3,300.00	$3,300	Bubbler tube extends to 12 Level. Cost shown is an allowance $ amount.
New pump & diversion gate control panel at CTP	1	ls	33,000.00	$33,000	Allowance. $30k installed. Panel will include pump control, gate control, flowmeter readings from pumps and cutthroat flumes.
Valves					
Check valves	1	ls	8,952.61	$8,953	12" size. Style not selected yet. Assumed SST valve. Assume $500/inch dia for valve cost and $2000 to install it. Cost for 1,900 gpm scenario is adjusted for 700 & 700 gpm combination.
Air release valves	1	ls	1,738.83	$1,739	2" APCO 144 DAT w/SST float. Cost for 1,900 gpm scenario is adjusted for 700 & 700 gpm combination.
Isolation valves	1	ls	19,828.68	$19,829	Assumed $15000 for 300 psi rated SST BTV. Cost for 1,900 gpm scenario is adjusted for 700 & 700 gpm combination.
Check valve spare	1	ea	6,126.12	$6,126	

Two 700 gpm pumps (constant speed) & Storage from 30 feet below 11 Level and up

Bunker Hill — **DATE: 08/24/2000**
Acid Mine Drainage: Storage — **PROJECT NO.: 152215.FS.02**
9 Level AMD Pumping Installation — **ESTIMATE BY: J. Winters**
Order of Magnitude Cost Opinion — **N.Gulensoy**

DESCRIPTION	QTY	UNIT	TOTAL UNIT COST	TOTAL COST	COMMENTS
SUBTOTAL				$579,158	
MISC ALLOWANCE	10%			$57,916	
SUBTOTAL				$637,074	
CONTINGENCY	30%			$191,122	
SUBTOTAL				$828,196	
MOBILIZATION	15%			$124,229	
CONSTRUCTION TOTAL				$952,425	
SALES TAX ON MATERIALS	5.0%			$18,370	
ENGINEERING AND SUPPORT	20%			$190,485	
CONST MANAGEMENT	8%			$76,194	
CAPITAL TOTAL (ROUNDED)				$1,240,000	
ANNUAL O&M COST			$126,000		
NPV OF ANNUAL O&M COSTS (30 YEARS @ 7% INTEREST)				$1,564,000	
TOTAL 30-YEAR PRESENT WORTH COST @ 7% INTEREST				$2,804,000	

NOTE: The above cost opinion is in February 2000 dollars and does not include escalation. The order of magnitude cost opinion shown has been prepared for guidance in project evaluation at the time of preparation. The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope, final schedule and other variable factors. As a result, the final project costs will vary from those presented above. Because of these factors, funding needs must be carefully reviewed prior to making specific financial decisions or establishing final budgets.

O & M COST ESTIMATE DETAILS

Description	Qty	Unit	Material Unit Cost	Labor Unit Cost	Equip Unit Cost	Total Cost	Comments
Annual Costs							
Operation Costs	1	YR	0	509,000	0	$509,000	Based on existing plant O&M costs calculated over 12/98 to 9/00; excludes outside analytical services & non routine maintenance
Maintenance Costs @ 2%	1	YR	0	90,707	0	$90,707	asm 2% of subtotal after allowance of HDS upgrade
HDS Effluent Pump Station	1	YR	46,800	0	0	$46,800	
Media Filters	1	YR	97,500	0	0	$97,500	
Backwash Pumping	1	YR	8,775	0	0	$8,775	
Building (not incl HDS)	1	YR	0	2,400	0	$2,400	
						$755,182	
Contingency	10%					$75,518	
Subtotal						**$831,000**	
Lime Savings Estimated at 20% Reduction in Lime Use						($68,000)	Annual lime cost without mitigations estimated at $335,000/year
Total Annual Cost With Savings						**$763,000**	
NPV of Annual O&M Costs (30 years @ 7%)						**$9,468,000**	

Bunker Hill
Mine Water
Upgrade HDS Plant & Add Media Filters (2,500gpm) (Equivalent to Phase I CTP Masterplan)
Order of Magnitude Cost Opinion

DATE: 11/29/2000
PROJECT NO.: 152215.FS.02
ESTIMATE BY: D. Hedglin

DESCRIPTION	QTY	UNIT	TOTAL UNIT COST	TOTAL COST	COMMENTS
HDS (Hydroxide)					
Sitework/Yard Piping					
Fencing	500	LF	10.00	$5,000	allowance
Gravel Surfacing & Misc	1	LS	25,000.00	$25,000	allowance
Connections & Relocations of Existing Piping	1	LS	30,000.00	$30,000	allowance
AMD Coarse Filter					
Earthwork & Concrete for Slab & Sump	1	LS	6,000.00	$6,000	10cy @ $600
2500gpm Self-Cleaning Filter	2	EA	16,563.04	$33,126	quote + frt + markup
Appurtenances for Filter	2	EA	21,738.95	$43,478	4-valves, fittings, misc
Electrical for Filter	2	EA	5,000.00	$10,000	allowance
Cleaning Debris Bin	2	LS	1,000.00	$2,000	Fiberglass tank due to pH 2
Structural Steel Tank Support System	1	LS	5,000.00	$5,000	allowance
Supernatant Pump	1	EA	10,000.00	$10,000	Low pH
Mechanical for Pump	1	LS	5,000.00	$5,000	slab, FG tank, concrete sump, pH 2 reqs FG & acid rest conc
					$114,604
Lime Feed System					
Earthwork & Concrete for Slab, Curbs, Sumps, etc	1	LS	79,488.00	$79,488	apx 200cy @ $400/cy
Retaining Wall to Accommodate New Tank	550	SF	25.00	$13,750	55'x 8'H + 2' below grade, CIP cantelever
Earthwork for Retaining Wall	1	LS	6,814.27	$6,814	
Paint	1	LS	50,000.00	$50,000	allowance for subcontract
Lime Silo, 21'x 48' h, Conical, Coated Steel	1	EA	179,040.98	$179,041	quote + 5%frt, rep, sp pts + 10%mu, esca;ated
Screw Feeder, 9" dia x 20' long	2	EA	14,774.78	$29,550	quote + 5%frt, rep, sp pts + 10%mu, esca;ated
Lime Slaker, Grit Screen & Screw, Controls	2	EA	74,816.42	$149,633	quote + 5%frt, rep, sp pts + 10%mu, esca;ated
Lime Slurry Storage Tank, 43000gal	1	EA	34,015.95	$34,016	
Lime Slurry Storage Tank Mixer, 15hp	2	EA	17,190.11	$34,380	
Slurry Circulation Pumps, 100gpm, 50' tdh	4	EA	16,901.45	$67,606	
Slurry Transfer Pumps, 100gpm, 50' tdh	4	EA	16,901.45	$67,606	same as above
Grit Bin	2	EA	2,183.17	$4,366	allowance
Clean, Refurbish, Upgrade Existing System	1	LS	24,653.63	$24,654	allow hours & misc parts i.e. bin vents,etc
Truck Unloading Improvements	1	LS	10,000.00	$10,000	ACP, curbing, etc - allowance
Lime Slurry Piping, 2" GE Steel	1,000	LF	20.20	$20,205	incl cplgs, ftgs, etc, on pipe rack
Piping Rack	250	LF	25.00	$6,250	allowance
Reactor A (Sludge Conditioning Tank)					
Earthwork & Concrete for Slab	1	LS	19,872.00	$19,872	apx 50cy @ $400/cy
Elevated Platform for Reactor A&B	1	LS	60,000.00	$60,000	asm 40x20 @ $75/sf high level and to support reactor A
Paint	1	LS	10,000.00	$10,000	allowance for subcontract
Sludge Conditioning Tank, 2500gal FRP	1	EA	42,694.85	$42,695	quote + 5% infla. + 5%frt + 10%mu

Bunker Hill
Mine Water
Upgrade HDS Plant & Add Media Filters (2,500gpm) (Equivalent to Phase I CTP Masterplan)
Order of Magnitude Cost Opinion

DATE: 11/29/2000
PROJECT NO.: 152215.FS.02
ESTIMATE BY: D. Hedglin

DESCRIPTION	QTY	UNIT	TOTAL UNIT COST	TOTAL COST	COMMENTS
Mixer, 3hp	1	EA	13,802.75	$13,803	quote + 5% infla. + 5%frt + 10%mu
Inlet Piping, 24" SDR 15.5	120	LF	193.68	$23,242	constrained schedule & access w/obstacles, ftgs, valves, connections, etc
Inlet Piping, 18" SDR 15.5	120	LF	146.95	$17,634	constrained schedule & access w/obstacles, ftgs, valves, connections, etc
Valves, vaults, etc	1	LS	50,000.00	$50,000	allowance
Neutralization/Oxidation System					
Distribution Piping, 24" HDPE	170	LF	193.68	$32,926	constrained schedule & access w/obstacles, ftgs, valves, connections, etc
Retaining Wall to Accommodate New Tank	450	SF	25.00	$11,250	45'x 8'H + 2' below grade, CIP cantelever
Earthwork for Retaining Wall	1	LS	6,814.27	$6,814	
Earthwork & Concrete for Slab	1	LS	65,577.60	$65,578	apx 165cy @ $400/cy
Paint	1	LS	50,000.00	$50,000	allowance for subcontract
Aeration Tank (Reactor B), 75,000gal Steel Tank	1	EA	37,500.00	$37,500	revised to $.50/gal
Submerged Turbine Aerator/Mixer	1	EA	73,520.37	$73,520	use same a 5000gpm estimate
Positive Displacement Blower	1	EA	13,205.04	$13,205	
Pipe Supports, Hangers, etc	1	LS	2,500.00	$2,500	allowance
Automated Polymer Make-up & Feed System					
Earthwork & Concrete for Slab	1	LS	0.00	$0	in bldg
Paint	1	LS	5,000.00	$5,000	allowance for subcontract
Polymer Make-up System	2	EA	10,216.52	$20,433	
Polymer Make-up Tank, 2000gal	1	EA	3,973.95	$3,974	
Mixer	2	EA	2,337.07	$4,674	corrected hours
Transfer Pump, 20gpm	2	EA	3,273.75	$6,548	corrected hours
Polymer Feed Tank, 2000gal	1	EA	3,973.95	$3,974	
Variable Speed Gear Pump, 1gpm	2	EA	4,210.43	$8,421	
Piping to Feed Point	100	LF	19.90	$1,990	
Thickener					
Clean & Decommission Existing Floc System	1	LS	1,774.62	$1,775	
Replace Weir	1	LS	28,860.00	$28,860	quote + frt & markup=$19/lf & allow for removal & replacement
Groundwater Test & Empty Tank	1	LS	10,000.00	$10,000	allowance
Replace Thickener Rake System Complete	1	LS	146,934.08	$146,934	quote + frt & markup
E-DUC Feed & Floc System & Center Well Mods	1	LS	45,933.63	$45,934	quote + frt & markup + add'l parts for mods
Surface Prep & Coat	1	LS	100,000.00	$100,000	allowance for interior walls & mechanism
Sludge Wasting & Recycle Pumps					
Earthwork & Concrete for Slab	1	LS	79,488.00	$79,488	apx 200cy @ $400/cy
Remove Existing Pumps	1	LS	2,474.40	$2,474	
Paint	1	LS	20,000.00	$20,000	allowance for subcontract

Bunker Hill
Mine Water
Upgrade HDS Plant & Add Media Filters (2,500gpm) (Equivalent to Phase I CTP Masterplan)
Order of Magnitude Cost Opinion

DATE: 11/29/2000
PROJECT NO.: 152215.FS.02
ESTIMATE BY: D. Hedglin

DESCRIPTION	QTY	UNIT	TOTAL UNIT COST	TOTAL COST	COMMENTS
Sludge Recycle Pump, 400gpm	2	EA	14,616.89	$29,234	new cost for smaller pump
Sludge Recycle Pump, 800gpm	2	EA	22,047.87	$44,096	new cost for smaller pump
Sludge Waste Pump, 400gpm, 200' tdh	2	EA	26,380.15	$52,760	new cost for larger pump
Sludge Recycle Piping, 8" DI	600	LF	68.47	$41,084	including ftgs, valves, etc, revised cost
Sludge Wasting Piping, 6" DI	400	LF	54.78	$21,912	including ftgs, valves, etc, revised cost
I&C and Electrical					
Total I&C	1	LS	108,103.26	$108,103	use 5% of above
Generator & Fuel Tank	1	EA	352,246.48	$352,246	same as 5000gpm + escalation
New Magnetic Flowmeter in Existing Vault	1	EA	10,268.68	$10,269	24"
Parshall Flume @ Effluent	1	EA	3,037.37	$3,037	12"
Electrical	1	LS	210,857.68	$210,858	use 8% of above
Building Extension					
Addition to Existing Building	900	SF	150.00	$135,000	added size for additional pumps
Existing Plant Demolition					
Earthwork	1	LS	7,314.27	$7,314	
Concrete Slab & Footings	100	CY	255.36	$25,536	assume 18" avg thickness to account for ftgs, etc
Relocate Existing Filtration Bldg, etc	1	LS	34,071.36	$34,071	60' x 30' x 10' eave ht metal bldg-remove contents, dismantle & re-erect
Repairs, Touchup, etc	1	LS	5,000.00	$5,000	allowance for some painting, sealants, doors, etc
Water	1	LS	4,234.70	$4,235	sink, emer. Shower, hose bibbs, piping & service
Sanitary	1	LS	1,917.35	$1,917	toilet, piping & service
Drains	1	LS	2,117.35	$2,117	
HVAC	1	LS	1,617.35	$1,617	reinstall unit heaters
Electrical	1	LS	4,933.48	$4,933	reinstall, fixtures, panels, wiring, etc
Tertiary Media Filters					
HDS Pump Station Complete	1	LS	70,000.00	$70,000	cost by DAH
Water Reuse Pump Station Complete	1	LS	30,000.00	$30,000	cost by DAH
Distribution Piping	500	LF	35.00	$17,500	4" plastic, below grade
Media Filter System	1	LS	566,834.08	$566,834	quote=430000 + 10% frt + 10% mu & 100hrs to install
Liquid Polymer System	0	LS	47,634.41	$0	Not required per JS 11/28/2000
Backwash Pumping Complete	1	LS	133,461.22	$133,461	Bob York spreadsheet + 10% OH&P, scaled to 2500gpm + escalation to 2(
Dirty Backwash Storage Tank, 30,000gal	1	EA	22,500.00	$22,500	$.75/gal
Dirty Backwash Storage Tank Mixer	1	EA	3,737.46	$3,737	allowance
Dirty Backwash Return Pump	1	EA	13,885.36	$13,885	allowance
Clean Backwash Supply Tank, 30,000gal	1	EA	22,500.00	$22,500	$.75/gal
Clean Backwash Supply Pump	1	EA	13,885.36	$13,885	

Bunker Hill
Mine Water
Upgrade HDS Plant & Add Media Filters (2,500gpm) (Equivalent to Phase I CTP Masterplan)
Order of Magnitude Cost Opinion

DATE: 11/29/2000
PROJECT NO.: 152215.FS.02
ESTIMATE BY: D. Hedglin

DESCRIPTION	QTY	UNIT	TOTAL UNIT COST	TOTAL COST	COMMENTS
Building Complete	1	LS	318,750.00	$318,750	85'x 50 @ $75/sf
Electrical/I&C	1	LS	0.00	$0	included
Mechanical	1	LS	0.00	$0	included
Backflow Preventer	1	EA	10,000.00	$10,000	allowance
Distribution Piping	1,000	LF	23.00	$23,000	2" plastic
Paint	1	LS	5,000.00	$5,000	misc painting allowance
SUBTOTAL				**$4,319,374**	
MISC ALLOWANCE	**5%**			**$215,969**	
SUBTOTAL				**$4,535,343**	
CONTINGENCY	**20%**			**$907,069**	
SUBTOTAL				**$5,442,411**	
MOBILIZATION	**15%**			**$816,362**	
CONSTRUCTION TOTAL				**$6,258,773**	
SALES TAX ON MATERIALS	**5.0%**			**$186,656**	
ENGINEERING AND SUPPORT	**20%**			**$1,251,755**	
CONSTRUCTION MANAGEMENT	**8%**			**$500,702**	
CAPITAL TOTAL (ROUNDED)				**$8,198,000**	
ANNUAL O&M COST			**$763,000**		
NPV OF ANNUAL O&M COSTS (30 YEARS @ 7% INTEREST)				**$9,468,000**	
TOTAL 30-YEAR PRESENT WORTH COST @ 7% INTEREST				**$17,666,000**	

NOTES:

Misc Allowance markup is to include items known to exist but cannot be quantified at this time.
Contingency is for scope changes that are presently unforeseen.
Mobilization includes bonds, insurance, temporary facilities, health & safety, demobilization, etc.

NOTE: The above cost opinion is in October 2000 dollars and does not include escalation. The order of magnitude cost opinion shown has been prepared for guidance in project evaluation at the time of preparation. The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope, final schedule and other variable factors. As a result, the final project costs will vary from those presented above. Because of these factors, funding needs must be carefully reviewed prior to making specific financial decisions or establishing final budgets.

Bunker Hill
Mine Water
Upgrade HDS Plant & Add Media Filters (2,500gpm) (Equivalent to Phase I CTP Masterplan)
Order of Magnitude Cost Opinion

DATE: 11/29/2000
PROJECT NO.: 152215.FS.02
ESTIMATE BY: D. Hedglin

DESCRIPTION	QTY	UNIT	TOTAL UNIT COST	TOTAL COST	COMMENTS
HDS (Hydroxide)					
Sitework/Yard Piping					
Fencing	500	LF	10.00	$5,000	allowance
Gravel Surfacing & Misc	1	LS	25,000.00	$25,000	allowance
Connections & Relocations of Existing Piping	1	LS	30,000.00	$30,000	allowance
AMD Coarse Filter					
Earthwork & Concrete for Slab & Sump	1	LS	6,000.00	$6,000	10cy @ $600
2500gpm Self-Cleaning Filter	2	EA	16,563.04	$33,126	quote + frt + markup
Appurtenances for Filter	2	EA	21,738.95	$43,478	4-valves, fittings, misc
Electrical for Filter	2	EA	5,000.00	$10,000	allowance
Cleaning Debris Bin	2	LS	1,000.00	$2,000	Fiberglass tank due to pH 2
Structural Steel Tank Support System	1	LS	5,000.00	$5,000	allowance
Supernatant Pump	1	EA	10,000.00	$10,000	Low pH
Mechanical for Pump	1	LS	5,000.00	$5,000	slab, FG tank, concrete sump, pH 2 reqs FG & acid rest conc
					$114,604
Lime Feed System					
Earthwork & Concrete for Slab, Curbs, Sumps, etc	1	LS	79,488.00	$79,488	apx 200cy @ $400/cy
Retaining Wall to Accommodate New Tank	550	SF	25.00	$13,750	55'x 8'H + 2' below grade, CIP cantelever
Earthwork for Retaining Wall	1	LS	6,814.27	$6,814	
Paint	1	LS	50,000.00	$50,000	allowance for subcontract
Lime Silo, 21'x 48' h, Conical, Coated Steel	1	EA	179,040.98	$179,041	quote + 5%frt, rep, sp pts + 10%mu, esca;ated
Screw Feeder, 9" dia x 20' long	2	EA	14,774.78	$29,550	quote + 5%frt, rep, sp pts + 10%mu, esca;ated
Lime Slaker, Grit Screen & Screw, Controls	2	EA	74,816.42	$149,633	quote + 5%frt, rep, sp pts + 10%mu, esca;ated
Lime Slurry Storage Tank, 43000gal	1	EA	34,015.95	$34,016	
Lime Slurry Storage Tank Mixer, 15hp	2	EA	17,190.11	$34,380	
Slurry Circulation Pumps, 100gpm, 50' tdh	4	EA	16,901.45	$67,606	
Slurry Transfer Pumps, 100gpm, 50' tdh	4	EA	16,901.45	$67,606	same as above
Grit Bin	2	EA	2,183.17	$4,366	allowance
Clean, Refurbish, Upgrade Existing System	1	LS	24,653.63	$24,654	allow hours & misc parts i.e. bin vents,etc
Truck Unloading Improvements	1	LS	10,000.00	$10,000	ACP, curbing, etc - allowance
Lime Slurry Piping, 2" GE Steel	1,000	LF	20.20	$20,205	incl cplgs, ftgs, etc, on pipe rack
Piping Rack	250	LF	25.00	$6,250	allowance
Reactor A (Sludge Conditioning Tank)					
Earthwork & Concrete for Slab	1	LS	19,872.00	$19,872	apx 50cy @ $400/cy
Elevated Platform for Reactor A&B	1	LS	60,000.00	$60,000	asm 40x20 @ $75/sf high level and to support reactor A
Paint	1	LS	10,000.00	$10,000	allowance for subcontract
Sludge Conditioning Tank, 2500gal FRP	1	EA	42,694.85	$42,695	quote + 5% infla. + 5%frt + 10%mu

Bunker Hill
Mine Water
Upgrade HDS Plant & Add Media Filters (2,500gpm) (Equivalent to Phase I CTP Masterplan)
Order of Magnitude Cost Opinion

DATE: 11/29/2000
PROJECT NO.: 152215.FS.02
ESTIMATE BY: D. Hedglin

DESCRIPTION	QTY	UNIT	TOTAL UNIT COST	TOTAL COST	COMMENTS
Mixer, 3hp	1	EA	13,802.75	$13,803	quote + 5% infla. + 5%frt + 10%mu
Inlet Piping, 24" SDR 15.5	120	LF	193.68	$23,242	constrained schedule & access w/obstacles, ftgs, valves, connections, etc
Inlet Piping, 18" SDR 15.5	120	LF	146.95	$17,634	constrained schedule & access w/obstacles, ftgs, valves, connections, etc
Valves, vaults, etc	1	LS	50,000.00	$50,000	allowance
Neutralization/Oxidation System					
Distribution Piping, 24" HDPE	170	LF	193.68	$32,926	constrained schedule & access w/obstacles, ftgs, valves, connections, etc
Retaining Wall to Accommodate New Tank	450	SF	25.00	$11,250	45'x 8'H + 2' below grade, CIP cantelever
Earthwork for Retaining Wall	1	LS	6,814.27	$6,814	
Earthwork & Concrete for Slab	1	LS	65,577.60	$65,578	apx 165cy @ $400/cy
Paint	1	LS	50,000.00	$50,000	allowance for subcontract
Aeration Tank (Reactor B), 75,000gal Steel Tank	1	EA	37,500.00	$37,500	revised to $.50/gal
Submerged Turbine Aerator/Mixer	1	EA	73,520.37	$73,520	use same a 5000gpm estimate
Positive Displacement Blower	1	EA	13,205.04	$13,205	
Pipe Supports, Hangers, etc	1	LS	2,500.00	$2,500	allowance
Automated Polymer Make-up & Feed System					
Earthwork & Concrete for Slab	1	LS	0.00	$0	in bldg
Paint	1	LS	5,000.00	$5,000	allowance for subcontract
Polymer Make-up System	2	EA	10,216.52	$20,433	
Polymer Make-up Tank, 2000gal	1	EA	3,973.95	$3,974	
Mixer	2	EA	2,337.07	$4,674	corrected hours
Transfer Pump, 20gpm	2	EA	3,273.75	$6,548	corrected hours
Polymer Feed Tank, 2000gal	1	EA	3,973.95	$3,974	
Variable Speed Gear Pump, 1gpm	2	EA	4,210.43	$8,421	
Piping to Feed Point	100	LF	19.90	$1,990	
Thickener					
Clean & Decommission Existing Floc System	1	LS	1,774.62	$1,775	
Replace Weir	1	LS	28,860.00	$28,860	quote + frt & markup=$19/lf & allow for removal & replacement
Groundwater Test & Empty Tank	1	LS	10,000.00	$10,000	allowance
Replace Thickener Rake System Complete	1	LS	146,934.08	$146,934	quote + frt & markup
E-DUC Feed & Floc System & Center Well Mods	1	LS	45,933.63	$45,934	quote + frt & markup + add'l parts for mods
Surface Prep & Coat	1	LS	100,000.00	$100,000	allowance for interior walls & mechanism
Sludge Wasting & Recycle Pumps					
Earthwork & Concrete for Slab	1	LS	79,488.00	$79,488	apx 200cy @ $400/cy
Remove Existing Pumps	1	LS	2,474.40	$2,474	
Paint	1	LS	20,000.00	$20,000	allowance for subcontract

Bunker Hill
Mine Water
Upgrade HDS Plant & Add Media Filters (2,500gpm) (Equivalent to Phase I CTP Masterplan)
Order of Magnitude Cost Opinion

DATE: 11/29/2000
PROJECT NO.: 152215.FS.02
ESTIMATE BY: D. Hedglin

DESCRIPTION	QTY	UNIT	TOTAL UNIT COST	TOTAL COST	COMMENTS
Sludge Recycle Pump, 400gpm	2	EA	14,616.89	$29,234	new cost for smaller pump
Sludge Recycle Pump, 800gpm	2	EA	22,047.87	$44,096	new cost for smaller pump
Sludge Waste Pump, 400gpm, 200' tdh	2	EA	26,380.15	$52,760	new cost for larger pump
Sludge Recycle Piping, 8" DI	600	LF	68.47	$41,084	including ftgs, valves, etc, revised cost
Sludge Wasting Piping, 6" DI	400	LF	54.78	$21,912	including ftgs, valves, etc, revised cost
I&C and Electrical					
Total I&C	1	LS	108,103.26	$108,103	use 5% of above
Generator & Fuel Tank	1	EA	352,246.48	$352,246	same as 5000gpm + escalation
New Magnetic Flowmeter in Existing Vault	1	EA	10,268.68	$10,269	24"
Parshall Flume @ Effluent	1	EA	3,037.37	$3,037	12"
Electrical	1	LS	210,857.68	$210,858	use 8% of above
Building Extension					
Addition to Existing Building	900	SF	150.00	$135,000	added size for additional pumps
Existing Plant Demolition					
Earthwork	1	LS	7,314.27	$7,314	
Concrete Slab & Footings	100	CY	255.36	$25,536	assume 18" avg thickness to account for ftgs, etc
Relocate Existing Filtration Bldg, etc	1	LS	34,071.36	$34,071	60' x 30' x 10' eave ht metal bldg-remove contents, dismantle & re-erect
Repairs, Touchup, etc	1	LS	5,000.00	$5,000	allowance for some painting, sealants, doors, etc
Water	1	LS	4,234.70	$4,235	sink, emer. Shower, hose bibbs, piping & service
Sanitary	1	LS	1,917.35	$1,917	toilet, piping & service
Drains	1	LS	2,117.35	$2,117	
HVAC	1	LS	1,617.35	$1,617	reinstall unit heaters
Electrical	1	LS	4,933.48	$4,933	reinstall, fixtures, panels, wiring, etc
Tertiary Media Filters					
HDS Pump Station Complete	1	LS	70,000.00	$70,000	cost by DAH
Water Reuse Pump Station Complete	1	LS	30,000.00	$30,000	cost by DAH
Distribution Piping	500	LF	35.00	$17,500	4" plastic, below grade
Media Filter System	1	LS	566,834.08	$566,834	quote=430000 + 10% frt + 10% mu & 100hrs to install
Liquid Polymer System	0	LS	47,634.41	$0	Not required per JS 11/28/2000
Backwash Pumping Complete	1	LS	133,461.22	$133,461	Bob York spreadsheet + 10% OH&P, scaled to 2500gpm + escalation to 2(
Dirty Backwash Storage Tank, 30,000gal	1	EA	22,500.00	$22,500	$.75/gal
Dirty Backwash Storage Tank Mixer	1	EA	3,737.46	$3,737	allowance
Dirty Backwash Return Pump	1	EA	13,885.36	$13,885	allowance
Clean Backwash Supply Tank, 30,000gal	1	EA	22,500.00	$22,500	$.75/gal
Clean Backwash Supply Pump	1	EA	13,885.36	$13,885	

Bunker Hill
Mine Water
Upgrade HDS Plant & Add Media Filters (2,500gpm) (Equivalent to Phase I CTP Masterplan)
Order of Magnitude Cost Opinion

DATE: 11/29/2000
PROJECT NO.: 152215.FS.02
ESTIMATE BY: D. Hedglin

DESCRIPTION	QTY	UNIT	TOTAL UNIT COST	TOTAL COST	COMMENTS
Building Complete	1	LS	318,750.00	$318,750	85'x 50 @ $75/sf
Electrical/I&C	1	LS	0.00	$0	included
Mechanical	1	LS	0.00	$0	included
Backflow Preventer	1	EA	10,000.00	$10,000	allowance
Distribution Piping	1,000	LF	23.00	$23,000	2" plastic
Paint	1	LS	5,000.00	$5,000	misc painting allowance
SUBTOTAL				**$4,319,374**	
MISC ALLOWANCE	**5%**			**$215,969**	
SUBTOTAL				**$4,535,343**	
CONTINGENCY	**20%**			**$907,069**	
SUBTOTAL				**$5,442,411**	
MOBILIZATION	**15%**			**$816,362**	
CONSTRUCTION TOTAL				**$6,258,773**	
SALES TAX ON MATERIALS	**5.0%**			**$186,656**	
ENGINEERING AND SUPPORT	**20%**			**$1,251,755**	
CONSTRUCTION MANAGEMENT	**8%**			**$500,702**	
CAPITAL TOTAL (ROUNDED)				**$8,198,000**	
ANNUAL O&M COST			**$797,000**		
NPV OF ANNUAL O&M COSTS (30 YEARS @ 7% INTEREST)				**$9,890,000**	
TOTAL 30-YEAR PRESENT WORTH COST @ 7% INTEREST				**$18,088,000**	

NOTES:

Misc Allowance markup is to include items known to exist but cannot be quantified at this time.
Contingency is for scope changes that are presently unforeseen.
Mobilization includes bonds, insurance, temporary facilities, health & safety, demobilization, etc.

NOTE: The above cost opinion is in October 2000 dollars and does not include escalation.
The order of magnitude cost opinion shown has been prepared for guidance in project evaluation at the time of preparation. The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope, final schedule and other variable factors. As a result, the final project costs will vary from those presented above. Because of these factors, funding needs must be carefully reviewed prior to making specific financial decisions or establishing final budgets.

O & M COST ESTIMATE DETAILS

Description	Qty	Unit	Material Unit Cost	Labor Unit Cost	Equip Unit Cost	Total Cost	Comments
Annual Costs (5,000 gpm)							
Operation Costs	1	YR	0	509,000	0	$509,000	Based on existing plant O&M costs calculated over 12/98 to 9/00; excludes outside analytical services & non routine maintenance
Maintenance Costs @ 2%	1	YR	0	107,421	0	$107,421	asm 2% of subtotal after allowance of HDS upgrade, phase 1 & 2
HDS Effluent Pump Station	1	YR	46,800	0	0	$46,800	
Media Filters	1	YR	97,500	0	0	$97,500	
Polymer System	0	YR	6,825	0	0	$0	not required
Polymer	0	YR	52,634	0	0	$0	not required
Backwash Pumping	1	YR	8,775	0	0	$8,775	
Building (not incl HDS)	1	YR	0	2,400	0	$2,400	asm $.50/SF
						$771,896	
Contingency	10%					$77,190	
Total Annual Cost						**$849,000**	
NPV of Annual O&M Costs (30 years @ 7%)						**$10,535,000**	

Bunker Hill — **DATE: 11/01/2000**
Mine Water — **PROJECT NO.: 152215.FS.02**
Upgrade HDS Plant & Add Media Filters (2,500gpm) Phase 1 — **ESTIMATE BY: D. Hedglin**
Order of Magnitude Cost Opinion

DESCRIPTION	QTY	UNIT	TOTAL UNIT COST	TOTAL COST	COMMENTS
HDS (Hydroxide)					
Sitework/Yard Piping					
Fencing	500	LF	10.00	$5,000	allowance
Gravel Surfacing & Misc	1	LS	25,000.00	$25,000	allowance
Connections & Relocations of Existing Piping	1	LS	30,000.00	$30,000	allowance
AMD Coarse Filter					
Earthwork & Concrete for Slab & Sump	1	LS	6,000.00	$6,000	10cy @ $600
2500gpm Self-Cleaning Filter	2	EA	16,563.04	$33,126	quote + frt + markup
Appurtenances for Filter	2	EA	21,738.95	$43,478	4-valves, fittings, misc
Electrical for Filter	2	EA	5,000.00	$10,000	allowance
Cleaning Debris Bin	2	LS	1,000.00	$2,000	Fiberglass tank due to pH 2
Structural Steel Tank Support System	1	LS	5,000.00	$5,000	allowance
Supernatant Pump	1	EA	10,000.00	$10,000	Low pH
Mechanical for Pump	1	LS	5,000.00	$5,000	slab, FG tank, concrete sump, pH 2 reqs FG & acid rest conc
					$114,604
Lime Feed System					
Earthwork & Concrete for Slab, Curbs, Sumps, etc	1	LS	79,488.00	$79,488	apx 200cy @ $400/cy
Retaining Wall to Accommodate New Tank	550	SF	25.00	$13,750	55'x 8'H + 2' below grade, CIP cantelever
Earthwork for Retaining Wall	1	LS	6,814.27	$6,814	
Paint	1	LS	50,000.00	$50,000	allowance for subcontract
Lime Silo, 21'x 48' h, Conical, Coated Steel	1	EA	179,040.98	$179,041	quote + 5%frt, rep, sp pts + 10%mu, esca;ated
Screw Feeder, 9" dia x 20' long	2	EA	14,774.78	$29,550	quote + 5%frt, rep, sp pts + 10%mu, esca;ated
Lime Slaker, Grit Screen & Screw, Controls	2	EA	74,816.42	$149,633	quote + 5%frt, rep, sp pts + 10%mu, esca;ated
Lime Slurry Storage Tank, 43000gal	1	EA	34,015.95	$34,016	
Lime Slurry Storage Tank Mixer, 15hp	2	EA	17,190.11	$34,380	
Slurry Circulation Pumps, 100gpm, 50' tdh	4	EA	16,901.45	$67,606	
Slurry Transfer Pumps, 100gpm, 50' tdh	4	EA	16,901.45	$67,606	same as above
Grit Bin	2	EA	2,183.17	$4,366	allowance
Clean, Refurbish, Upgrade Existing System	1	LS	24,653.63	$24,654	allow hours & misc parts i.e. bin vents,etc
Truck Unloading Improvements	1	LS	10,000.00	$10,000	ACP, curbing, etc - allowance
Lime Slurry Piping, 2" GE Steel	1,000	LF	20.20	$20,205	incl cplgs, ftgs, etc, on pipe rack
Piping Rack	250	LF	25.00	$6,250	allowance
Reactor A (Sludge Conditioning Tank)					
Earthwork & Concrete for Slab	1	LS	19,872.00	$19,872	apx 50cy @ $400/cy
Elevated Platform for Reactor A&B	1	LS	60,000.00	$60,000	asm 40x20 @ $75/sf high level and to support reactor A
Paint	1	LS	10,000.00	$10,000	allowance for subcontract
Sludge Conditioning Tank, 2500gal FRP	1	EA	42,694.85	$42,695	quote + 5% infla. + 5%frt + 10%mu

Bunker Hill **DATE: 11/01/2000**
Mine Water **PROJECT NO.: 152215.FS.02**
Upgrade HDS Plant & Add Media Filters (2,500gpm) Phase 1 **ESTIMATE BY: D. Hedglin**
Order of Magnitude Cost Opinion

DESCRIPTION	QTY	UNIT	TOTAL UNIT COST	TOTAL COST	COMMENTS
Mixer, 3hp	1	EA	13,802.75	$13,803	quote + 5% infla. + 5%frt + 10%mu
Inlet Piping, 24" SDR 15.5	120	LF	193.68	$23,242	constrained schedule & access w/obstacles, ftgs, valves, connections, etc
Inlet Piping, 18" SDR 15.5	120	LF	146.95	$17,634	constrained schedule & access w/obstacles, ftgs, valves, connections, etc
Valves, vaults, etc	1	LS	50,000.00	$50,000	allowance
Neutralization/Oxidation System					
Distribution Piping, 24" HDPE	170	LF	193.68	$32,926	constrained schedule & access w/obstacles, ftgs, valves, connections, etc
Retaining Wall to Accommodate New Tank	450	SF	25.00	$11,250	45'x 8'H + 2' below grade, CIP cantelever
Earthwork for Retaining Wall	1	LS	6,814.27	$6,814	
Earthwork & Concrete for Slab	1	LS	65,577.60	$65,578	apx 165cy @ $400/cy
Paint	1	LS	50,000.00	$50,000	allowance for subcontract
Aeration Tank (Reactor B), 75,000gal Steel Tank	1	EA	37,500.00	$37,500	revised to $.50/gal
Submerged Turbine Aerator/Mixer	1	EA	73,520.37	$73,520	use same a 5000gpm estimate
Positive Displacement Blower	1	EA	13,205.04	$13,205	
Pipe Supports, Hangers, etc	1	LS	2,500.00	$2,500	allowance
Automated Polymer Make-up & Feed System					
Earthwork & Concrete for Slab	1	LS	0.00	$0	in bldg
Paint	1	LS	5,000.00	$5,000	allowance for subcontract
Polymer Make-up System	2	EA	10,216.52	$20,433	
Polymer Make-up Tank, 2000gal	1	EA	3,973.95	$3,974	
Mixer	2	EA	2,337.07	$4,674	corrected hours
Transfer Pump, 20gpm	2	EA	3,273.75	$6,548	corrected hours
Polymer Feed Tank, 2000gal	1	EA	3,973.95	$3,974	
Variable Speed Gear Pump, 1gpm	2	EA	4,210.43	$8,421	
Piping to Feed Point	100	LF	19.90	$1,990	
Thickener					
Clean & Decommission Existing Floc System	1	LS	1,774.62	$1,775	
Replace Weir	1	LS	28,860.00	$28,860	quote + frt & markup=$19/lf & allow for removal & replacement
Groundwater Test & Empty Tank	1	LS	10,000.00	$10,000	allowance
Replace Thickener Rake System Complete	1	LS	146,934.08	$146,934	quote + frt & markup
E-DUC Feed & Floc System & Center Well Mods	1	LS	45,933.63	$45,934	quote + frt & markup + add'l parts for mods
Surface Prep & Coat	1	LS	100,000.00	$100,000	allowance for interior walls & mechanism
Sludge Wasting & Recycle Pumps					
Earthwork & Concrete for Slab	1	LS	79,488.00	$79,488	apx 200cy @ $400/cy
Remove Existing Pumps	1	LS	2,474.40	$2,474	
Paint	1	LS	20,000.00	$20,000	allowance for subcontract

Bunker Hill **DATE: 11/01/2000**
Mine Water **PROJECT NO.: 152215.FS.02**
Upgrade HDS Plant & Add Media Filters (2,500gpm) Phase 1 **ESTIMATE BY: D. Hedglin**
Order of Magnitude Cost Opinion

DESCRIPTION	QTY	UNIT	TOTAL UNIT COST	TOTAL COST	COMMENTS
Sludge Recycle Pump, 400gpm	2	EA	14,616.89	$29,234	new cost for smaller pump
Sludge Recycle Pump, 800gpm	2	EA	22,047.87	$44,096	new cost for smaller pump
Sludge Waste Pump, 400gpm, 200' tdh	2	EA	26,380.15	$52,760	new cost for larger pump
Sludge Recycle Piping, 8" DI	600	LF	68.47	$41,084	including ftgs, valves, etc, revised cost
Sludge Wasting Piping, 6" DI	400	LF	54.78	$21,912	including ftgs, valves, etc, revised cost
I&C and Electrical					
Total I&C	1	LS	108,103.26	$108,103	use 5% of above, enough?????
Generator & Fuel Tank	1	EA	352,246.48	$352,246	same as 5000gpm + escalation
New Magnetic Flowmeter in Existing Vault	1	EA	10,268.68	$10,269	24"
Parshall Flume @ Effluent	1	EA	3,037.37	$3,037	12"
Electrical	1	LS	210,857.68	$210,858	use 8% of above
Building Extension					
Addition to Existing Building	900	SF	150.00	$135,000	added size for additional pumps
Existing Plant Demolition					
Earthwork	1	LS	7,314.27	$7,314	
Concrete Slab & Footings	100	CY	255.36	$25,536	assume 18" avg thickness to account for ftgs, etc
Relocate Existing Filtration Bldg, etc	1	LS	34,071.36	$34,071	60' x 30' x 10' eave ht metal bldg-remove contents, dismantle & re-erect
Repairs, Touchup, etc	1	LS	5,000.00	$5,000	allowance for some painting, sealants, doors, etc
Water	1	LS	4,234.70	$4,235	sink, emer. Shower, hose bibbs, piping & service
Sanitary	1	LS	1,917.35	$1,917	toilet, piping & service
Drains	1	LS	2,117.35	$2,117	
HVAC	1	LS	1,617.35	$1,617	reinstall unit heaters
Electrical	1	LS	4,933.48	$4,933	reinstall, fixtures, panels, wiring, etc
Tertiary Media Filters					
HDS Pump Station Complete	1	LS	70,000.00	$70,000	cost by DAH
Water Reuse Pump Station Complete	1	LS	30,000.00	$30,000	cost by DAH
Distribution Piping	500	LF	35.00	$17,500	4" plastic, below grade
Media Filter System	1	LS	566,834.08	$566,834	quote=430000 + 10% frt + 10% mu & 100hrs to install
Liquid Polymer System	0	LS	47,634.41	$0	Not required as per JS 11/28/2000
Backwash Pumping Complete	1	LS	133,461.22	$133,461	Bob York spreadsheet + 10% OH&P, scaled to 2500gpm + escalation to 2(
Dirty Backwash Storage Tank, 30,000gal	1	EA	22,500.00	$22,500	$.75/gal
Dirty Backwash Storage Tank Mixer	1	EA	3,737.46	$3,737	allowance
Dirty Backwash Return Pump	1	EA	13,885.36	$13,885	allowance
Clean Backwash Supply Tank, 30,000gal	1	EA	22,500.00	$22,500	$.75/gal
Clean Backwash Supply Pump	1	EA	13,885.36	$13,885	

Bunker Hill **DATE: 11/01/2000**
Mine Water **PROJECT NO.: 152215.FS.02**
Upgrade HDS Plant & Add Media Filters (2,500gpm) Phase 1 **ESTIMATE BY: D. Hedglin**
Order of Magnitude Cost Opinion

DESCRIPTION	QTY	UNIT	TOTAL UNIT COST	TOTAL COST	COMMENTS
Building Complete	1	LS	318,750.00	$318,750	85'x 50 @ $75/sf
Electrical/I&C	1	LS	0.00	$0	included
Mechanical	1	LS	0.00	$0	included
Backflow Preventer	1	EA	10,000.00	$10,000	allowance
Distribution Piping	1,000	LF	23.00	$23,000	2" plastic
Paint	1	LS	5,000.00	$5,000	misc painting allowance
SUBTOTAL				**$4,319,374**	
MISC ALLOWANCE	**5%**			**$215,969**	
SUBTOTAL				**$4,535,343**	
CONTINGENCY	**20%**			**$907,069**	
SUBTOTAL				**$5,442,411**	
MOBILIZATION	**15%**			**$816,362**	
CONSTRUCTION TOTAL				**$6,258,773**	
SALES TAX ON MATERIALS	**5.0%**			**$186,656**	
ENGINEERING AND SUPPORT	**20%**			**$1,251,755**	
CONSTRUCTION MANAGEMENT	**8%**			**$500,702**	
CAPITAL TOTAL (ROUNDED)				**$8,198,000**	
ANNUAL O&M COST			**$849,000**		
NPV OF ANNUAL O&M COSTS (30 YEARS @ 7% INTEREST)				**$10,535,000**	
TOTAL 30-YEAR PRESENT WORTH COST @ 7% INTEREST				**$18,733,000**	

NOTES:

Misc Allowance markup is to include items known to exist but cannot be quantified at this time.
Contingency is for scope changes that are presently unforeseen.
Mobilization includes bonds, insurance, temporary facilities, health & safety, demobilization, etc.

NOTE: The above cost opinion is in October 2000 dollars and does not include escalation.
The order of magnitude cost opinion shown has been prepared for guidance in project evaluation at the time of preparation. The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope, final schedule and other variable factors. As a result, the final project costs will vary from those presented above. Because of these factors, funding needs must be carefully reviewed prior to making specific financial decisions or establishing final budgets.

Bunker Hill
Mine Water
Upgrade HDS Plant & Add Media Filters (5,000gpm) (Equivalent to Phase 2 of CTP Masterplan)
Order of Magnitude Cost Opinion

DATE: 11/29/2000
PROJECT NO.: 152215.FS.02
ESTIMATE BY: D. Hedglin

DESCRIPTION	QTY	UNIT	TOTAL UNIT COST	TOTAL COST	COMMENTS
Improvements					
Remove Reactor A	1	LS	2,810.04	$2,810	
Remove Aeration Basin, Ret Wall, Stairs, etc	1	LS	127,767.60	$127,768	6000cy @ 200cy/hr
Remove Flocculation Basin	1	LS	18,733.63	$18,734	allow 40hrs
Remove Associated Piping	1	LS	1,873.36	$1,873	
Remove Associated Electrical	1	LS	1,873.36	$1,873	
Regrade Area	1	LS	1,703.57	$1,704	
Connections & Relocations of Existing Piping	1	LS	5,000.00	$5,000	allowance
New Reactor B					**same as ph 1**
Earthwork & Concrete for Slab	1	LS	19,872.00	$19,872	apx 50cy @ $400/cy
Elevated Platform	1	LS	35,000.00	$35,000	asm 35x20 addition @ $50/sf
Paint	1	LS	10,000.00	$10,000	allowance for subcontract
Aeration Tank (Reactor B), 75,000gal Steel Tank	1	EA	37,500.00	$37,500	
Submerged Turbine Aerator/Mixer	1	EA	73,527.30	$73,527	use same a 5000gpm estimate
Positive Displacement Blower	1	EA	13,205.04	$13,205	
Outlet Piping, 24" DI	200	LF	104.78	$20,956	
Pipe Rack & Walkway	200	LF	243.47	$48,695	
Reactor A					
Modify Reactor A to Feed Both B Reactors	1	LS	10,000.00	$10,000	allowance
Piping to All B Reactors to Operate in Series or Parallel	1	LS	5,000.00	$5,000	allowance
Sludge Recycle Pump, 400gpm	2	EA	14,618.10	$29,236	
Filtration					
Media Filter System	1	LS	132,000.00	$132,000	Bob York spreadsheet + 10% OH&P
Expand Filtration Building	1	LS	165,000.00	$165,000	Bob York spreadsheet + 10% OH&P

Bunker Hill
Mine Water
Upgrade HDS Plant & Add Media Filters (5,000gpm) (Equivalent to Phase 2 of CTP Masterplan)
Order of Magnitude Cost Opinion

DATE: 11/29/2000
PROJECT NO.: 152215.FS.02
ESTIMATE BY: D. Hedglin

DESCRIPTION	QTY	UNIT	TOTAL UNIT COST	TOTAL COST	COMMENTS
Electrical/I&C	1	LS	0.00	$0	included
Mechanical	1	LS	0.00	$0	included
Paint	1	LS	0.00	$0	included
SUBTOTAL				**$759,753**	
MISC ALLOWANCE	**10%**			**$75,975**	greater uncertainty of quantities & detail
SUBTOTAL				**$835,728**	
CONTINGENCY	**25%**			**$208,932**	greater uncertainty of scope & remodeling
SUBTOTAL				**$1,044,660**	
MOBILIZATION	**0%**			**$0**	included in phase 1 cost
CONSTRUCTION TOTAL				**$1,044,660**	
SALES TAX	**5.0%**			**$26,116**	50% materials
ENGINEERING	**20%**			**$208,932**	
CONSTRUCTION MANAGEMENT	**8%**			**$83,573**	
CAPITAL TOTAL (ROUNDED)				**$1,363,000**	
ANNUAL O&M COST			**$849,000**		
NPV OF ANNUAL O&M COSTS (30 YEARS @ 7%)				**$10,535,000**	
TOTAL PROJECT COST FOR PHASE 2				**$11,898,000**	
TOTAL CAPITAL COST FOR 5000 GPM OPTION (PHASE 1 + PHASE 2)				**$9,561,000**	
ANNUAL O&M COST			**$849,000**		
TOTAL NPV OF ANNUAL O&M COST (30 YEARS @ 7%)				**$10,535,000**	
TOTAL PROJECT COST FOR 5000 GPM OPTION				**$20,096,000**	

Bunker Hill
Mine Water
Upgrade HDS Plant & Add Media Filters (5,000gpm) (Equivalent to Phase 2 of CTP Masterplan)
Order of Magnitude Cost Opinion

DATE: 11/29/2000
PROJECT NO.: 152215.FS.02
ESTIMATE BY: D. Hedglin

DESCRIPTION	QTY	UNIT	TOTAL UNIT COST	TOTAL COST	COMMENTS

NOTES:

Misc Allowance markup is to include items known to exist but cannot be quantified at this time.
Contingency is for scope changes that are presently unforeseen.
Mobilization includes bonds, insurance, temporary facilities, health & safety, demobilization, etc. and is included in phase 1 costs

NOTE: The above cost opinion is in October 2000 dollars and does not include escalation. The order of magnitude cost opinion shown has been prepared for guidance in project evaluation at the time of preparation. The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope, final schedule and other variable factors. As a result, the final project costs will vary from those presented above. Because of these factors, funding needs must be carefully reviewed prior to making specific financial decisions or establishing final budgets.

Bunker Hill
Mine Water
Upgrade HDS Plant & Add Media Filters (5,000gpm) (Equivalent to Phase 2 of CTP Masterplan)
Order of Magnitude Cost Opinion

DATE: 11/29/2000
PROJECT NO.: 152215.FS.02
ESTIMATE BY: D. Hedglin

DESCRIPTION	QTY	UNIT	TOTAL UNIT COST	TOTAL COST	COMMENTS
Improvements					
Remove Reactor A	1	LS	2,810.04	$2,810	
Remove Aeration Basin, Ret Wall, Stairs, etc	1	LS	127,767.60	$127,768	6000cy @ 200cy/hr
Remove Flocculation Basin	1	LS	18,733.63	$18,734	allow 40hrs
Remove Associated Piping	1	LS	1,873.36	$1,873	
Remove Associated Electrical	1	LS	1,873.36	$1,873	
Regrade Area	1	LS	1,703.57	$1,704	
Connections & Relocations of Existing Piping	1	LS	5,000.00	$5,000	allowance
New Reactor B					**same as ph 1**
Earthwork & Concrete for Slab	1	LS	19,872.00	$19,872	apx 50cy @ $400/cy
Elevated Platform	1	LS	35,000.00	$35,000	asm 35x20 addition @ $50/sf
Paint	1	LS	10,000.00	$10,000	allowance for subcontract
Aeration Tank (Reactor B), 75,000gal Steel Tank	1	EA	37,500.00	$37,500	
Submerged Turbine Aerator/Mixer	1	EA	73,527.30	$73,527	use same a 5000gpm estimate
Positive Displacement Blower	1	EA	13,205.04	$13,205	
Outlet Piping, 24" DI	200	LF	104.78	$20,956	
Pipe Rack & Walkway	200	LF	243.47	$48,695	
Reactor A					
Modify Reactor A to Feed Both B Reactors	1	LS	10,000.00	$10,000	allowance
Piping to All B Reactors to Operate in Series or Parallel	1	LS	5,000.00	$5,000	allowance
Sludge Recycle Pump, 400gpm	2	EA	14,618.10	$29,236	
Filtration					
Media Filter System	1	LS	132,000.00	$132,000	Bob York spreadsheet + 10% OH&P
Expand Filtration Building	1	LS	165,000.00	$165,000	Bob York spreadsheet + 10% OH&P

Bunker Hill
Mine Water
Upgrade HDS Plant & Add Media Filters (5,000gpm) (Equivalent to Phase 2 of CTP Masterplan)
Order of Magnitude Cost Opinion

DATE: 11/29/2000
PROJECT NO.: 152215.FS.02
ESTIMATE BY: D. Hedglin

DESCRIPTION	QTY	UNIT	TOTAL UNIT COST	TOTAL COST	COMMENTS
Electrical/I&C	1	LS	0.00	$0	included
Mechanical	1	LS	0.00	$0	included
Paint	1	LS	0.00	$0	included
SUBTOTAL				**$759,753**	
MISC ALLOWANCE	**10%**			**$75,975**	greater uncertainty of quantities & detail
SUBTOTAL				**$835,728**	
CONTINGENCY	**25%**			**$208,932**	greater uncertainty of scope & remodeling
SUBTOTAL				**$1,044,660**	
MOBILIZATION	**0%**			**$0**	included in phase 1 cost
CONSTRUCTION TOTAL				**$1,044,660**	
SALES TAX	**5.0%**			**$26,116**	50% materials
ENGINEERING	**20%**			**$208,932**	
CONSTRUCTION MANAGEMENT	**8%**			**$83,573**	
CAPITAL TOTAL (ROUNDED)				**$1,363,000**	
ANNUAL O&M COST			**$849,000**		
NPV OF ANNUAL O&M COSTS (30 YEARS @ 7%)				**$10,535,000**	
TOTAL PROJECT COST FOR PHASE 2				**$11,898,000**	
TOTAL CAPITAL COST FOR 5000 GPM OPTION (PHASE 1 + PHASE 2)				**$9,561,000**	
ANNUAL O&M COST			**$849,000**		
TOTAL NPV OF ANNUAL O&M COST (30 YEARS @ 7%)				**$10,535,000**	
TOTAL PROJECT COST FOR 5000 GPM OPTION				**$20,096,000**	

Bunker Hill
Mine Water
Upgrade HDS Plant & Add Media Filters (5,000gpm) (Equivalent to Phase 2 of CTP Masterplan)
Order of Magnitude Cost Opinion

DATE: 11/29/2000
PROJECT NO.: 152215.FS.02
ESTIMATE BY: D. Hedglin

DESCRIPTION	QTY	UNIT	TOTAL UNIT COST	TOTAL COST	COMMENTS

NOTES:

Misc Allowance markup is to include items known to exist but cannot be quantified at this time.
Contingency is for scope changes that are presently unforeseen.
Mobilization includes bonds, insurance, temporary facilities, health & safety, demobilization, etc. and is included in phase 1 costs

NOTE: The above cost opinion is in October 2000 dollars and does not include escalation. The order of magnitude cost opinion shown has been prepared for guidance in project evaluation at the time of preparation. The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope, final schedule and other variable factors. As a result, the final project costs will vary from those presented above. Because of these factors, funding needs must be carefully reviewed prior to making specific financial decisions or establishing final budgets.

Existing 20-Inch HDPE Pipeline from Mine Yard to Lined Pond O&M Costs

	Qty	Unit	Material Unit Cost	Labor Unit Cost	Equip Unit Cost	Total Cost	Comments
Annual Costs							
Inspection	2	Each	0	674	288	$1,924	2 times/year & 4hrs/time each with 2 laborers with pickup
Pigging	2	Each				$56,000	2 times per year at $28,000 each lump sum based on the USACE estimate of 8/1/00 for the pipeline from mine yard to lined pond
Camera	2	YR	2,000			$4,000	2 times/year (subcontracted out)
						$61,924	
Contingency	10%					$6,192	
Total Annual Cost						**$68,116**	

Notes

Camera costs = 1,000/day times 2 days each time (Big Sky Industrial 509/624-4949)

Bunker Hill
Future Pipeline to CTP
Order of Magnitude Cost Opinion

DATE: 03/03/2000
PROJECT NO.: 152215.RS.06
ESTIMATE BY: D. Hedglin

DESCRIPTION	QTY	UNIT	TOTAL UNIT COST	TOTAL COST	COMMENTS
Pigging/Camera Station					
818 LA Utility Vault Company Vault (8 feet deep)	1	EA	4,584.51	$4,585	
30 degree SDR 17 HDPE (wrapped in fiberglass)	1	EA	3,072.38	$3,072	
20-inch ORBE knife-gate valve	1	EA	6,572.38	$6,572	
Link-Seals	2	EA	1,072.38	$2,145	
Electrofusion couplers	2	EA	1,472.38	$2,945	
Stainless steel flanges	2	EA	3,572.38	$7,145	
Pig Launching Station (see pipeline O&M plan)	1	EA	8,144.75	$8,145	based on past estimate
Pipeline					
20-inch diameter SDR 17 HDPE	800	LF	52.90	$42,316	R2-38
Excavation	1,312	CY	8.62	$11,301	5' of cover, utility obstructions, concrete debris, etc
Bed & Zone	397	CY	31.62	$12,541	
Native Backfill	847	CY	13.30	$11,258	
Waste	465	CY	4.93	$2,295	
Remove & Dispose of Box Culvert (Asbestos)	1	LS	6,892.03	$6,892	allow 2 days & local disposal
Tee connection to 24-inch existing line	1	EA	6,579.02	$6,579	cut, fab tee, install
McKinley Avenue paved road crossing (standard 2 lane road with shoulders)	1	LS	800.00	$800	28'x 13' @ @20/sy
Bunker Creek Crossing (assume 20 feet wide)	1	LS	5,307.52	$5,308	cofferdams, temp diversion, dewatering, open cut,etc
Electrofusion couplers	5	EA	1,472.38	$7,362	
Stainless steel flanges	5	EA	3,572.38	$17,862	
SUBTOTAL				**$159,121**	
MISC ALLOWANCE	**10%**			**$15,912**	
SUBTOTAL				**$175,033**	
CONTINGENCY	**30%**			**$52,510**	
SUBTOTAL				**$227,543**	
MOBILIZATION	**15%**			**$34,131**	
CONSTRUCTION TOTAL				**$261,675**	
SALES TAX ON MATERIALS	**5.0%**			**$3,977**	
ENGINEERING AND SUPPORT	**20%**			**$52,335**	
CONST MANAGEMENT	**8%**			**$20,934**	
CAPITAL TOTAL (ROUNDED)				**$340,000**	
ANNUAL O&M COST			**$37,000**		
NPV OF ANNUAL O&M COSTS (30 YEARS @ 7% INTEREST)				**$459,000**	
TOTAL 30-YEAR PRESENT WORTH COST @ 7% INTEREST				**$799,000**	

NOTES:

Misc Allowance markup is to include items known to exist but cannot be quantified at this time.
Contingency is for scope changes that are presently unforeseen.
Mobilization includes bonds, insurance, temporary facilities, health & safety, demobilization, etc.

Assumptions

Pipe is buried 5-feet deep
Incidentals to consider include:
Excavation through several abandoned utilities and live utilities
Excavating through sections of concrete demolition waste (quantity unknown)
Remove and dispose of an old box culvert (asbestos removal)

	Qty	Unit	Material Unit Cost	Labor Unit Cost	Equip Unit Cost	Total Cost	Comments
Annual Costs							
Inspection	2	Each	0	674	288	$1,924	2 times/year & 4hrs/time each with 2 laborers with pickup
Pigging	2	Each				$28,000	2 times per year at $14,000 each lump sum based on 1/2 the USACE estimate of 8/1/00 for the pipeline from mine yard to lined pond of $28,000 each
Camera	2	YR	2,000			$4,000	2 times/year (subcontracted out)
						$33,924	
Contingency	10%					$3,392	
Total Annual Cost						**$37,316**	

Notes

Camera costs = 1,000/day times 2 days each time (Big Sky Industrial 509/624-4949)

KT Portal Channel and Flume Cleaning Costs

	Qty	Unit	Total Unit Cost	Total Cost	Comments
Annual Costs					
Inspection and Cleanout	12	Month	1,875	$22,500	Based on USACE cost of $1,875/month for existing cleanout work
Contingency	10%			$2,250	
Total Annual Cost				**$24,750**	

Existing 20-Inch HDPE Pipeline from Mine Yard to Lined Pond O&M Costs

	Qty	Unit	Material Unit Cost	Labor Unit Cost	Equip Unit Cost	Total Cost	Comments
Annual Costs							
Inspection	2	Each	0	674	288	$1,924	2 times/year & 4hrs/time each with 2 laborers with pickup
Pigging	2	Each				$56,000	2 times per year at $28,000 each lump sum based on the USACE estimate of 8/1/00 for the pipeline from mine yard to lined pond
Camera	2	YR	2,000			$4,000	2 times/year (subcontracted out)
						$61,924	
Contingency	10%					$6,192	
Total Annual Cost						**$68,116**	

Notes

Camera costs = 1,000/day times 2 days each time (Big Sky Industrial 509/624-4949)

Existing Mine Water Collection System O&M Costs

	Qty	Unit	Total Unit Cost	Total Cost	Comments
Annual Costs					
Mine Operation Labor	52	Week		$320,840	Weekly cost based on estimate of existing mine owner incurred cost. Includes a crew of a foreman, hoistman, backup hoistman, and 3-man repair crew. Total labor at $4,410/week and a benefits package at $1,760/week = $6,170/week total
Power	12	Month		$102,000	Power cost estimated for existing mine operations
Level Repair and Maintenance	1	Year	81,000	$81,000	9, 10, and 11 level areas necessary for mine water control
Compressor Maintenance	1	Year	20,000	$20,000	Compressor maintenance costs
Hoist Maintenance	1	Year	160,000	$160,000	Cherry Hoist, #2 Hoist, and #1 Temporary Hoist
Pumps and Pipe Columns	1	Year	100,000	$100,000	Maintenance of mine dewatering pumps in #2 Shaft, #1 Shaft, 9 Level Pumps, and piping
Electrical System Maintenance	1 Year		40,000	$40,000	
Subtotal				**$823,840**	
Contingency	15%			**$123,576**	15% contingency for repairs and maintenance
Allowance	15%			**$123,576**	15% allowance for unaccounted for costs
Total Annual Cost				**$1,070,992**	

Historical CTP O&M Costs

	Qty	Unit	Material Unit Cost	Labor Unit Cost	Equip Unit Cost	Total Unit Cost	Total Cost	Comments
June 1998 thru May 1999								
Jun-98	1	Month					$44,335	From EPA Cost Record
Jul-98	1	Month					$73,829	From EPA Cost Record
Aug-98	1	Month					$40,436	From EPA Cost Record
Sep-98	1	Month					$33,517	From EPA Cost Record
Oct-98	1	Month					$72,233	From EPA Cost Record
Nov-98	1	Month					$39,582	From EPA Cost Record
Dec-98	1	Month					$37,083	From EPA Cost Record
Jan-99	1	Month					$46,206	From EPA Cost Record
Feb-99	1	Month					$62,474	From EPA Cost Record
Mar-99	1	Month					$81,237	From EPA Cost Record
Apr-99	1	Month					$32,128	From EPA Cost Record
May-99	1	Month					$58,806	From EPA Cost Record
							$621,866	
Jun-99	1	Month					$77,378	From EPA Cost Record
Jul-99	1	Month					$30,478	From EPA Cost Record
Aug-99	1	Month					$116,559	From EPA Cost Record
Sep-99	1	Month					$100,556	From EPA Cost Record
Oct-99	1	Month					$44,459	From EPA Cost Record
Nov-99	1	Month					$50,342	From EPA Cost Record
Dec-99	1	Month					$56,221	From EPA Cost Record
Jan-00	1	Month					$57,592	From EPA Cost Record
Feb-00	1	Month					$34,511	From EPA Cost Record
Mar-00	1	Month					$41,880	From EPA Cost Record
Apr-00	1	Month					$50,910	From EPA Cost Record
May-00	1	Month					$80,357	From EPA Cost Record
							$741,243	
						2-Year Average =	**$681,555**	

Note: Treatment costs vary year-to-year depending on mine water flow rates and unplanned maintenance requirements.
More unplanned maintenance was conducted during the June 1999 to May 2000 period than the previous 12 months.

O&M Costs
Existing Lined Pond
Bunker Hill
Acid Mine Drainage: Storage

DATE: 01/11/2001
PROJECT NO.: 152215.FS.02
ESTIMATE BY: D. Hedglin

O & M COST ESTIMATE DETAILS

Tasks	Qty	Unit	Material Unit Cost	Labor Unit Cost	Equip Unit Cost	Total Cost	Comments
Annual Costs							
Inspect Pond and Remove Debris	2	YR		4,000		$8,000	assume 2 times/year - 8 hours @ $250 to remove & dispose
Pond Repair & Maintenance	1	YR		18,000		$18,000	fence, gate, road, liner, and misc. maintenance
Pumping System Inspection	8	HR	0	50		$400	minimal pump operatiion-assume 2-4hr inspections/ year @ $50
Pumping System Operation	1	HR	0	50		$50	allow for power for minimal use
Pump maintenance	1	YR	500.00	800	0	$1,300	minimal pump operatiion-assume 2-8hr repairs/ year @ $50
						$27,750	
Contingency	10%					$2,775	
Total Annual Cost						**$30,525**	

NOTE:

ALTERNATIVES 3 AND 4
Bunker Hill Mine Water RI/FS
Performance Monitoring Costs

Tasks	Qty	Unit	Material Unit Cost	Labor Unit Cost	Equip Unit Cost	Annual Cost	Comments
Annual Costs							
KT Portal (flow and chemistry) (Years 1 through 30)							
KT Flow Data Management & Reporting	1	MO	0	800	0	$9,600	Monthly data management; asm 10 hrs/month (1 person) @ $80/hr labor
KT Sampling and Analysis	1	WK	300	0	0	$15,600	Weekly sample collection; asm analysis cost of $300/sample for Cd, Pb, Zn, SO4, LD/SF
Sample Collection Supplies	1	YR	500	0	0	$500	Allowance
Sample Shipment	1	YR	500	0	0	$500	Allowance
Subtotal						**$16,600**	
Allowance	10%					**$1,660**	
Total Annual Cost						**$18,260**	
CTP (flow and chemistry) (Years 1 through 30)							
	1	Day	150	0	0	$54,750	Total, Cd, Pb, and Zn low level analysis
Subtotal						**$54,750**	
Allowance	10%					**$5,475**	
Total Annual Cost						**$60,225**	
Surface Streams (flow only) (Years 1 through 10)							
Automatic Flow Recorder Data Download	1	MO	0	1,280	0	$15,360	Monthly data download from 3 flow recorders and 8 piezometers; asm 16 hrs/month (2 persons, 1 field day) @ $80/hr labor
Flow Data Recording & Management for surface water diversions	1	MO	0	320	0	$3,840	Monthly data management; asm 4 hrs/month (1 person) @ $80/hr labor
Data management & reporting for existing piezometers	1	MO	0	640	0	$7,680	Monthly data management and reporting; asm 8 hrs/month (1 person) @ $80/hr labor
Subtotal						**$26,880**	
Allowance	10%					**$2,688**	
Total Annual Cost						**$29,568**	
In-Mine (flow and chemistry) (Years 1 through 10)							
Sample Collection	15	Event	0	3,840	0	$57,600	15 events, 48 hrs/event (3 persons, 2 field days) @ $80/hr labor
Sample Collection Materials	15	Event	0	0	0	$2,000	Allowance
Sample Preparation and Packaging	15	Event	0	2,560	0	$38,400	15 events, 32 hrs/event (2 persons, 2 days) @ $80/hr labor
Sample Shipment	15	Event	100	0		$1,500	
Sample Analysis	15	Event	5,600	0	0	$84,000	15 events, 14 samples/event, $400/sample for analytical (total and dissolved metals, sulfate, lime demand, solids formed, TSS)
Data management, interpretation, QA/QC and reporting	15	Event	0	640	0	$9,600	15 events, 8 hrs/event, @ $80/hr labor
Subtotal						**$193,100**	
Allowance	10%					**$19,310**	
Total Annual Cost						**$212,410**	

ALTERNATIVE 1
Bunker Hill Mine Water RI/FS
Performance Monitoring Costs

Tasks	Qty	Unit	Material Unit Cost	Labor Unit Cost	Equip Unit Cost	Annual Cost	Comments
Annual Costs (All Costs are for Years 1 through 4)							
KT Portal (flow and chemistry) (Years 1 through 4)							
KT Flow Data Management & Reporting	1	MO	0	800	0	$9,600	Monthly data management; asm 10 hrs/month (1 person) @ $80/hr labor
KT Sampling and Analysis	1	WK	300	0	0	$15,600	Weekly sample collection; asm analysis cost of $300/sample for Cd, Pb, Zn, SO4, LD/SF
Sample Collection Supplies	1	YR	500	0	0	$500	Allowance
Sample Shipment	1	YR	500	0	0	$500	Allowance
Subtotal						**$16,600**	
Allowance	10%					**$1,660**	
Total Annual Cost						**$18,260**	
CTP (flow and chemistry) (Years 1 through 4)							
	1	Day	150	0	0	$54,750	Total, Cd, Pb, and Zn low level analysis
Subtotal						**$54,750**	
Allowance	10%					**$5,475**	
Total Annual Cost						**$60,225**	
TOTAL ANNUAL COST (YEARS 1 THROUGH 4)						**$78,485**	

Alternative 5A
Cost Summary

Alternative 5A
Phased Mitigations/Treatment with Plugging of Near-Stream Workings (with CIA Sludge Disposal Beds)
Interest = 7%

Remedy Component	Capital Cost ($)	Annual O&M Cost ($/yr)
AMD Mitigations	12,060,000	222,000
AMD Collection	0	1,071,000
AMD Conveyance	340,000	130,000
AMD Storage	1,950,000	157,000
AMD Treatment	8,198,000	763,000
Sludge Management[1]	6,205,000	38,000
Performance Monitoring[2]	0	158,000
Totals	**28,753,000**	**2,539,000**
30-Year NPV of O&M		**31,507,000**
Total 30-Year Present Worth	**60,260,000**	

[1]The capital cost is the present worth of capital expenditures which occur during the 30-year time period. See the sludge option NPV calculation summary sheet for details.

[2]The monitoring annual O&M cost is the annualized amount of the 30-year net present value , since annual costs vary over the 30-year period. See the monitoring summary sheet for details.

AMD Mitigations	Capital	O&M
West Fork Milo Creek Diversion	3,590,000	28,000
Rehabilitate Phil Sheridan Diversion	1,250,000	18,000
Plug Drill Holes	150,000	9,000
Plug Small Hopes	360,000	500
Plug/Bypass Inez Shaft	650,000	500
Improve Phil Sheridan Diversion	380,000	500
Sidehill Diversions above Guy Cave	490,000	12,000
South Fork Diversion	1,870,000	30,000
Bypass Bunker Hill Dam	60,000	24,000
Improve Existing Mainstem Milo Diversion, Seal/Decrease Subflow	590,000	99,000
Improve Existing Mainstem Milo Diversion, Increase Capacity	2,670,000	Accounted For Above
Subtotal	12,060,000	222,000

AMD Collection	Capital	O&M
Existing In Mine System	0	1,071,000
Subtotal	0	1,071,000

AMD Conveyance	Capital	O&M
Existing Concrete Channel	0	25,000
Existing HDPE Pipeline	0	68,000
New HDPE Pipeline to CTP	340,000	37,000
Subtotal	340,000	130,000

AMD Storage	Capital	O&M
In-Mine Gravity Diversion System	710,000	Included in Extraction System
New Mine Pool Extraction System	1,240,000	126,000
Existing Lined Pond	0	31,000
Subtotal	1,950,000	157,000

AMD Treatment	Capital	O&M
Upgraded 2,500 gpm CTP with Media Filters	8,198,000	763,000
Subtotal	8,198,000	763,000

Sludge Management	NPV of Capital	O&M
CIA Sludge Disposal Beds	4,545,000	38,000
Close Existing CIA Disposal Bed (Yr 2)	1,660,000	0
Subtotal	6,205,000	38,000

Performance Monitoring	Capital	O&M
KT Portal (Years 1 -30)	0	18,000
CTP (Years 1-30)	0	60,000
Surface (Years 1 - 5)	0	30,000
In-Mine (Years 1-5)	0	212,000
Subtotal	0	320,000
	Annualized O&M (Yrs 1-30)	157,969

NEXT

Alternative 5B
Cost Summary

Alternative 5B
Phased Mitigations/Treatment with Plugging of Near-Stream Workings (with Mechanical Dewatering and Offsite Sludge Disposal)
Interest = 7%

Remedy Component	Capital Cost ($)	Annual O&M Cost ($/yr)
AMD Mitigations	12,060,000	222,000
AMD Collection	0	1,071,000
AMD Conveyance	340,000	130,000
AMD Storage	1,950,000	157,000
AMD Treatment	8,198,000	763,000
Sludge Management[1]	5,100,000	618,000
Performance Monitoring[2]	0	158,000
Totals	**27,648,000**	**3,119,000**
30-Year NPV of O&M		**38,704,000**
Total 30-Year Present Worth	**66,352,000**	

[1]The capital cost is the present worth of capital expenditures which occur during the 30-year time period. See the sludge option NPV calculation summary sheet for details.

[2]The monitoring annual O&M cost is the annualized amount of the 30-year net present value , since annual costs vary over the 30-year period. See the monitoring summary sheet for details.

AMD Mitigations	Capital	O&M
West Fork Milo Creek Diversion	3,590,000	28,000
Rehabilitate Phil Sheridan Diversion	1,250,000	18,000
Plug Drill Holes	150,000	9,000
Plug Small Hopes	360,000	500
Plug/Bypass Inez Shaft	650,000	500
Improve Phil Sheridan Diversion	380,000	500
Sidehill Diversions above Guy Cave	490,000	12,000
South Fork Diversion	1,870,000	30,000
Bypass Bunker Hill Dam	60,000	24,000
Improve Existing Mainstem Milo Diversion, Seal/Decrease Subflow	590,000	99,000
Improve Existing Mainstem Milo Diversion, Increase Capacity	2,670,000	Accounted For Above
Subtotal	12,060,000	222,000

AMD Collection	Capital	O&M
Existing In Mine System	0	1,071,000
Subtotal	0	1,071,000

AMD Conveyance	Capital	O&M
Existing Concrete Channel	0	25,000
Existing HDPE Pipeline	0	68,000
New HDPE Pipeline to CTP	340,000	37,000
Subtotal	340,000	130,000

AMD Storage	Capital	O&M
In-Mine Gravity Diversion System	710,000	Included in Extraction System
New Mine Pool Extraction System	1,240,000	126,000
Existing Lined Pond	0	31,000
Subtotal	1,950,000	157,000

AMD Treatment	Capital	O&M
Upgraded 2,500 gpm CTP with Media Filters	8,198,000	763,000
Subtotal	8,198,000	763,000

Sludge Management	NPV of Capital	O&M
Mechanical Dewatering System	3,440,000	143,000
Offsite Haulage and Disposal		475,000
Close Existing CIA Disposal Bed (Yr 2)	1,660,000	0
Subtotal	5,100,000	618,000

Performance Monitoring	Capital	O&M
KT Portal (Years 1 -30)	0	18,000
CTP (Years 1-30)	0	60,000
Surface (Years 1 - 5)	0	30,000
In-Mine (Years 1-5)	0	212,000
Subtotal	0	320,000
	Annualized O&M (Yrs 1-30)	157,969

NEXT

Alternative 5C
Cost Summary

Alternative 5C
Phased Mitigations/Treatment with Plugging of Near-Stream Workings (with Smelter Closure Area Sludge Disposal Beds)
Interest = 7%

Remedy Component	Capital Cost ($)	Annual O&M Cost ($/yr)
AMD Mitigations	12,060,000	222,000
AMD Collection	0	1,071,000
AMD Conveyance	340,000	130,000
AMD Storage	1,950,000	157,000
AMD Treatment	8,198,000	763,000
Sludge Management[1]	10,605,000	62,000
Performance Monitoring[2]	0	158,000
Totals	**33,153,000**	**2,563,000**
30-Year NPV of O&M		**31,804,000**
Total 30-Year Present Worth	**64,957,000**	

[1]The capital cost is the present worth of capital expenditures which occur during the 30-year time period. See the sludge option NPV calculation summary sheet for details.

[2]The monitoring annual O&M cost is the annualized amount of the 30-year net present value , since annual costs vary over the 30-year period. See the monitoring summary sheet for details.

AMD Mitigations	Capital	O&M
West Fork Milo Creek Diversion	3,590,000	28,000
Rehabilitate Phil Sheridan Diversion	1,250,000	18,000
Plug Drill Holes	150,000	9,000
Plug Small Hopes	360,000	500
Plug/Bypass Inez Shaft	650,000	500
Improve Phil Sheridan Diversion	380,000	500
Sidehill Diversions above Guy Cave	490,000	12,000
South Fork Diversion	1,870,000	30,000
Bypass Bunker Hill Dam	60,000	24,000
Improve Existing Mainstem Milo Diversion, Seal/Decrease Subflow	590,000	99,000
Improve Existing Mainstem Milo Diversion, Increase Capacity	2,670,000	Accounted For Above
Subtotal	12,060,000	222,000

AMD Collection	Capital	O&M
Existing In Mine System	0	1,071,000
Subtotal	0	1,071,000

AMD Conveyance	Capital	O&M
Existing Concrete Channel	0	25,000
Existing HDPE Pipeline	0	68,000
New HDPE Pipeline to CTP	340,000	37,000
Subtotal	340,000	130,000

AMD Storage	Capital	O&M
In-Mine Gravity Diversion System	710,000	Included in Extraction System
New Mine Pool Extraction System	1,240,000	126,000
Existing Lined Pond	0	31,000
Subtotal	1,950,000	157,000

AMD Treatment	Capital	O&M
Upgraded 2,500 gpm CTP with Media Filters	8,198,000	763,000
Subtotal	8,198,000	763,000

Sludge Management	NPV of Capital	O&M
Smelter Closure Area Sludge Disposal Beds	8,945,000	62,000
Close Existing CIA Disposal Bed (Yr 2)	1,660,000	0
Subtotal	10,605,000	62,000

Performance Monitoring	Capital	O&M
KT Portal (Years 1 -30)	0	18,000
CTP (Years 1-30)	0	60,000
Surface (Years 1 - 5)	0	30,000
In-Mine (Years 1-5)	0	212,000
Subtotal	0	320,000
	Annualized O&M (Yrs 1-30)	157,969

NEXT

Alternative 5D
Cost Summary

Alternative 5D
Phased Mitigations/Treatment with Plugging of Near-Stream Workings (with CIA Sludge Drying Beds and Smelter Closure Area Landfill)
Interest = 7%

Remedy Component	Capital Cost ($)	Annual O&M Cost ($/yr)
AMD Mitigations	12,060,000	222,000
AMD Collection	0	1,071,000
AMD Conveyance	340,000	130,000
AMD Storage	1,950,000	157,000
AMD Treatment	8,198,000	763,000
Sludge Management[1]	8,821,000	129,000
Performance Monitoring[2]	0	158,000
Totals	**31,369,000**	**2,630,000**
30-Year NPV of O&M		**32,636,000**
Total 30-Year Present Worth	**64,005,000**	

[1]The capital cost is the present worth of capital expenditures which occur during the 30-year time period. See the sludge option NPV calculation summary sheet for details.

[2]The monitoring annual O&M cost is the annualized amount of the 30-year net present value , since annual costs vary over the 30-year period. See the monitoring summary sheet for details.

AMD Mitigations	Capital	O&M
West Fork Milo Creek Diversion	3,590,000	28,000
Rehabilitate Phil Sheridan Diversion	1,250,000	18,000
Plug Drill Holes	150,000	9,000
Plug Small Hopes	360,000	500
Plug/Bypass Inez Shaft	650,000	500
Improve Phil Sheridan Diversion	380,000	500
Sidehill Diversions above Guy Cave	490,000	12,000
South Fork Diversion	1,870,000	30,000
Bypass Bunker Hill Dam	60,000	24,000
Improve Existing Mainstem Milo Diversion, Seal/Decrease Subflow	590,000	99,000
Improve Existing Mainstem Milo Diversion, Increase Capacity	2,670,000	Accounted For Above
Subtotal	12,060,000	222,000

AMD Collection	Capital	O&M
Existing In Mine System	0	1,071,000
Subtotal	0	1,071,000

AMD Conveyance	Capital	O&M
Existing Concrete Channel	0	25,000
Existing HDPE Pipeline	0	68,000
New HDPE Pipeline to CTP	340,000	37,000
Subtotal	340,000	130,000

AMD Storage	Capital	O&M
In-Mine Gravity Diversion System	710,000	Included in Extraction System
New Mine Pool Extraction System	1,240,000	126,000
Existing Lined Pond	0	31,000
Subtotal	1,950,000	157,000

AMD Treatment	Capital	O&M
Upgraded 2,500 gpm CTP with Media Filters	8,198,000	763,000
Subtotal	8,198,000	763,000

Sludge Management	NPV of Capital	O&M
Smelter Closure Area Landfill	5,523,000	86,000
Landfill Closure (Yr 31)	223,000	0
CIA Sludge Drying Beds	1,415,000	43,000
Close Existing CIA Disposal Bed (Yr 2)	1,660,000	0
Subtotal	8,821,000	129,000

Performance Monitoring	Capital	O&M
KT Portal (Years 1 -30)	0	18,000
CTP (Years 1-30)	0	60,000
Surface (Years 1 - 5)	0	30,000
In-Mine (Years 1-5)	0	212,000
Subtotal	0	320,000
	Annualized O&M (Yrs 1-30)	157,969

NEXT

O & M COST ESTIMATE DETAILS

Tasks	Qty	Unit	Material Unit Cost	Labor Unit Cost	Equip Unit Cost	Total Cost	Comments
Annual Costs							
Inspection	1	YR	0	1,600	320	$1,920	asm 4 times/year & 8hrs/time @ $50/hr labor & $10 for pickup
Road Maintenance & Repairs	1	YR	1,000	4,477	2,016	$7,493	asm 3 time/year & 8hrs/time + material allowance
Pipeline & Structure Maint. & Repairs	1	YR	2,000	7,448	6,336	$15,784	asm 4 times/year & 8hrs/time + material allowance
						$25,197	
Contingency	10%					$2,520	
Total Annual Cost						**$27,717**	

Bunker Hill — **DATE: 08/24/2000**
AMD Mitigation Concepts — **PROJECT NO.: 152215.FS.02**
2.1: West Fork Diversion — **ESTIMATE BY: D. Hedglin**
Order of Magnitude Cost Opinion — **T. Pyle**

DESCRIPTION	QTY	UNIT	TOTAL UNIT COST	TOTAL COST	COMMENTS
Site Access Road					
Clear & Grub New Road	3,500	LF	8.62	$30,153	asm 30'w & 50'/hour
Grade, Fill & Compact New Road	3,500	LF	76.32	$267,137	encounter rock
Base Course on New Road	1,296	CY	24.92	$32,307	
Grade & Improve Existing Road	400	LF	28.90	$11,559	
Erosion & Sedimentation Control	1	LS	47,054.48	$47,054	$/LF allowance for ditches, culverts, silt fences, sed ponds, etc
Diversion Structure					
Diversion/Care of Water	1	LS	10,000.00	$10,000	
Excavate for Sheetpile Dam	1,800	CY	17.23	$31,014	
Native Backfill Around Sheetpiles	1,800	CY	13.30	$23,940	
Sheetpile Wall for Cutoff	2,250	SF	30.00	$67,500	
Excavate for Screen Structure	70	CY	17.23	$1,206	
Native Backfill Around Screen Structure	20	CY	13.30	$266	
Backfill Riprap Overflow Spillway	325	CY	39.95	$12,984	
Construct Screen Intake Structure	15	CY	552.24	$8,284	
Construct Transition Structure	15	CY	552.24	$8,284	
Foundation Grout Curtain	1,500	LF	40.00	$60,000	Includes diamond drilling, grout pipe, pressure testing, etc.
Bar Screen	1	LS	10,329.99	$10,330	
Collector Pipe & Gabions					
Excavation	300	CY	17.23	$5,169	
Imported Bed, Zone & Backfill	250	CY	31.62	$7,906	
Waste	300	CY	3.29	$986	
36" Perf. Collector Pipe	200	LF	68.62	$13,724	
Regrade Stream	1	LS	20,676.10	$20,676	
Gabion Sediment Traps	50	CY	183.25	$9,162	
Pipeline & Access Road					
36" Pipeline in Imp Road	750	LF	127.24	$95,430	including earthwork & fittings
30" Pipeline in New Road	750	LF	117.24	$87,928	including earthwork & fittings
36" Pipeline in Unimp Road	1,700	LF	241.71	$410,912	including earthwork & fittings
36" Overland Pipe	150	LF	214.48	$32,171	including earthwork, supports & fittings
42" Slip Pipe for Overland Pipe	40	LF	127.24	$5,090	including earthwork, supports & fittings
Anchor Block	2	EA	4,061.89	$8,124	asm 6cy & 5hrs to form, rebar, place
Anchor Fitting	2	EA	1,172.38	$2,345	allowance
Slip Joint Gasket	1	EA	1,186.19	$1,186	based on quote for Lake Tapps outfall
Thrust Block	7	EA	822.38	$5,757	
Air Vent	2	EA	586.19	$1,172	
Cut-Off Trench Seepage Walls	30	EA	2,100.00	$63,000	asm 7cy @ $300/cy
22 1/2 Degree Elbow	10	EA	2,572.38	$25,724	
Bureau of Reclamation Stilling Basin					
Structure Complete	4	LS	67,230.08	$268,920	based on Lake Tapps design & estimate
SUBTOTAL				**$1,687,400**	
MISC ALLOWANCE	**10%**			**$168,740**	
SUBTOTAL				**$1,856,140**	
CONTINGENCY	**30%**			**$556,842**	
SUBTOTAL				**$2,412,983**	
MOBILIZATION	**15%**			**$361,947**	
CONSTRUCTION TOTAL				**$2,774,930**	
SALES TAX ON MATERIALS	**5.0%**			**$33,487**	
ENGINEERING AND SUPPORT	**20%**			**$554,986**	
CONST MANAGEMENT	**8%**			**$221,994**	
CAPITAL TOTAL (ROUNDED)				**$3,590,000**	
ANNUAL O&M COST			**$27,700**		
NPV OF ANNUAL O&M COSTS (30 YEARS @ 7% INTEREST)				**$344,000**	
TOTAL 30-YEAR PRESENT WORTH COST @ 7% INTEREST				**$3,934,000**	

NOTES:
Misc Allowance markup is to include items known to exist but cannot be quantified at this time.
Contingency is for scope changes that are presently unforeseen.
Mobilization includes bonds, insurance, temporary facilities, health & safety, demobilization, etc.

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