Draft

COMO BASIN, FISHER CREEK AND GLENGARRY ADIT RESPONSE ACTION ENGINEERING EVALUATION/COST ANALYSIS NEW WORLD MINING DISTRICT RESPONSE AND RESTORATION PROJECT

Prepared For:

USDA Forest Service
Northern Region
Missoula, Montana

Prepared By:

Maxim Technologies, Inc.
851 Bridger Drive
P.O. Box 1413
Bozeman, Montana 59715

June 2002

EXECUTIVE SUMMARY

Maxim Technologies, Inc. (Maxim) prepared this Response Action Engineering Evaluation/Cost Analysis (EE/CA) for the United States Department of Agriculture Forest Service (USDA-FS). This report presents an engineering evaluation and cost analysis of response alternatives for response and restoration work proposed for the Glengarry Adit, Como Basin, and remaining mine waste dumps in the Fisher Creek drainage. These historic mine sites are located in the New World Mining District (District), which is located in Park County, north of Cooke City, Montana. The primary environmental issues at these sites are associated with impacts from historic mining and more recent mineral exploration activities. Human health and environmental issues are related to elevated levels of base-metal contaminants present in mine wastes, disturbed soils, and acidic water discharging from mine openings.

The District is located at elevations ranging from 2,400 meters (7,900 feet) to over 3,200 meters (10,400 feet) above sea level and is snow-covered for much of the year. The District covers an area of about 100 square kilometers (40 square miles) with historic mining disturbances affecting about 20 hectares (50 acres). The topography of the District is mountainous, with the dominant topographic features created by glacial erosion. The headwaters of Fisher Creek are located at or near tree line.

This EE/CA was developed using the "non-time-critical removal" process that is outlined in the *Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)*, as amended in 1986, and the updated National Oil and Hazardous Substances Pollution Contingency Plan. The USDA-FS has identified the Como Basin/Glengarry Adit/Fisher Creek Response Action to address the immediate threat to human health and the environment posed by metal-rich soils exposed during mineral exploration activity, by historic mining and associated mine wastes, and by the contaminated discharge from the underground workings of the Glengarry mine.

Response activities for the Como Basin/Glengarry Adit/Fisher Creek represent the third response action proposed during this multi-year project. Previous response actions include the Selective Source Response Action and McLaren Pit Response Action. The Glengarry Adit is ranked No. 15 and the Como Basin is ranked No. 27 in the priority listing of contaminated sites located on District Property.

Existing data from surface water, groundwater, in-stream sediment, and metal-loading to surface waters were reviewed and summarized to plan response activities and evaluate risks to human health and the aquatic environment. In addition, material samples collected from numerous waste rock dumps in Fisher Creek and disturbed soils in the Como Basin were analyzed for heavy metals and acid-base characteristics. Heavy metals associated with these waste rock sources can affect human health through inhalation or ingestion. Metals may also be toxic to plant growth, preventing reestablishment of plant cover on the waste rock. Sediment containing heavy metals can erode from mine waste, impacting surrounding land and potentially enter surface water drainages. Water percolating through mine waste can carry dissolved concentrations of heavy metals into groundwater, which, in some areas, discharges to surface water. Percolation of water through sulfide-rich mine waste lowers pH, which promotes solubility of most metals.

A comparison of disturbed soils, waste rock, water, and in-stream sediment data with background concentrations and regulatory standards indicates several metals are contaminants of concern at this site: aluminum, cadmium, copper, iron, lead, and zinc. A human health risk evaluation based on *Risk-Based Cleanup Guidelines for Abandoned Mine Sites* (Tetra Tech, 1996) found there to be no unacceptable risks to human health from these contaminants in the Como Basin and Fisher Creek based on a recreational use scenario. A comparison of metals levels to literature guidelines and state aquatic water quality standards indicates that aluminum, cadmium, copper, iron, lead, and zinc pose risk to organisms in the aquatic environment. In addition, arsenic, copper, and lead occur at phytotoxic levels in disturbed and metal-rich soils in the Como Basin and waste rock dumps in the Fisher Creek drainage.

Three separate source areas were evaluated in this study and include: the Como Basin Source Area, the Fisher Creek Source Area, and the Glengarry Adit Source area. The Como Basin and Fisher Creek source areas are similar in that they both contain metal-rich soils and/or mine waste rock deposits as a principal source of sulfide-bearing material that is oxidized to form an acidic, metal-laden leachate, which in turn is mobilized and impacts the quality of surface water and groundwater. These two areas differ in scale in that the Como Basin Source Area is a large area (2.23 hectares) that contains disturbed and metal-rich soils (as much as 190,174 cubic meters) in contact with an underlying massive sulfide mineral deposit. The Como Basin also includes the switchbacks on the Lulu Pass road as it climbs northward from the Glengarry Adit and through the Como Basin. This portion of the road exhibits severe erosion problems that expose mineralized soil and rock. The Fisher Creek Source Area contains numerous small, scattered waste rock piles in the Fisher Creek drainage and other small, but locally severe erosional problems. Total volume of waste rock in the Fisher Creek Source Area is estimated to be 16,840 cubic meters scattered over a combined area of about 2.9 hectares (7.1 acres).

The third source area evaluated is the Glengarry Adit Source Area, where contaminated water flows into underground workings from four principal sources that combine and flow through the mine discharging contaminated surface water into the upper Fisher Creek watershed.

The objectives of the Como Basin/Glengarry Adit/Fisher Creek Response Action are:

- Minimize phytotoxicity resulting from high concentrations of copper and low pH in disturbed and metal-rich soils present in the Como Basin and outlying waste rock areas

- Prevent soluble metal contaminants or metals contaminated solid materials in the disturbed and metal-rich soils and mine waste from migrating into adjacent surface watercourses, to the extent practicable.

- Reduce or eliminate concentrated runoff and discharges that generate sediment and/or metals contamination to adjacent surface water and groundwater, to the extent practicable.

- Prevent potential exposure through the food chain to metal contaminants from acid discharges, waste rock, metal-rich soils and mineralized bedrock to the extent practicable.

- Mitigate, contain, or divert mine water inflows and consequent outflows to surface water.

- Prevent or limit future releases and mitigate the environmental effect of past releases of hazardous substances, pollutants or contaminants.

- Identify applicable or relevant and appropriate requirements (ARARs) for response actions and evaluate how each alternative complies with ARARs.

- Take into consideration the desirability of preserving the existing undeveloped character of the District and surrounding area when selecting response and restoration actions.

Cleanup goals were identified for metals posing risk at the site. Groundwater and surface water goals are the State of Montana water quality standards. Solid media goals are based on in-stream sediment and soil guidelines found in the literature.

After screening a variety of response technologies and process options, several alternatives were developed for detailed analysis. The alternatives were evaluated for effectiveness, implementability, and cost. Table ES-1 lists the Como Basin Source Area Alternatives. Table ES-2 lists the Fisher Creek Source Area Alternatives, and Table ES-3 list the Glengarry Adit Source Area Alternatives.

TABLE ES-1
RESPONSE ACTION ALTERNATIVES FOR THE COMO BASIN SOURCE AREA
New World Mining District Response and Restoration Project
Como Basin/Glengarry Adit/Fisher Creek Response Action

Alternative		Response Technology/Process Options
CB-1	No Action	None
CB-2A	In-Situ Treatment of Select Soil Material with Shallow Amendment	Regrading and compaction of disturbed and metal-rich soils in-situ, amendment of the upper 30 cm of the regraded surface with lime, and revegetation.
CB-2B	In-Situ Treatment of Select Soil Material with Deep Amendment	Regrading and compaction of disturbed and metal-rich soils in-situ, amendment of the upper meter of the regraded surface with lime, and revegetation.
CB-2C	In Situ Treatment of Metal-Rich Soil Material	Excavation of unconsolidated metal-rich soils, lime amendment of excavated materials, replacing and regrading amended soils, and revegetation.
CB-3A	In-Situ Treatment with Soil Cap	Regrading metal-rich soils in-situ, shallow amendment (upper 30 cm), constructing a soil cap, and revegetation
CB-3B	In-Situ Treatment with Geomembrane Liner and Amended Soil Cap	Regrading metal-rich soils in-situ, constructing a geomembrane liner with a drain layer and an amended soil cap, and revegetation.
CB-3C	In-Situ Treatment with Geomembrane Liner and Soil Cap	Regrading metal-rich soils in-situ, constructing a geomembrane liner with a drain layer and an imported soil cap, and revegetation.

Note: Except for No Action, all alternatives considered for the Como Basin include repairing the erosion problems in the channels below the Como Basin and the erosion problems associated with the switchbacks on the portion of the Lulu Pass Road that climbs from the Glengarry Adit through the Como Basin.

TABLE ES-2
RESPONSE ACTION ALTERNATIVES FOR THE FISHER CREEK SOURCE AREA
New World Mining District Response and Restoration Project
Como Basin/Glengarry Adit/Fisher Creek Response Action

Alternative		Response Technology/Process Options
FC-1	No Action	None
FC-2	In-Situ Treatment of Waste Rock with Shallow Amendment	Grading and compaction of waste rock in-situ, amendment of the upper 30 cm of the regraded surface with lime, and revegetation.
FC-3	Surface Controls	Grading waste rock in-situ, constructing runon and runoff controls.
FC-4	Total Removal and Disposal in an On-Site Repository	Total removal and disposal of waste rock in the SB-4B (B) repository.

TABLE ES-3
RESPONSE ACTION ALTERNATIVES FOR THE GLENGARRY ADIT SOURCE AREA
New World Mining District Response and Restoration Project
Como Basin/Glengarry Adit/Fisher Creek Response Action

Alternative		Response Technology/Process Options
GA-1	No Action	None
GA- 2	Grout Curtain Around Como Raise Collar; Backfill and Plug Como Raise	Drilling and pressure grouting around the collar of the Como Raise to construct a grout curtain; plugging and backfilling the raise. Eliminates or minimizes highly contaminated water flow from the Como Basin into the second Glengarry raise.
GA-3	Grout the Short Raise Above Bulkhead	Drilling and pressure grouting the structure at the top of the first raise to produce a grout curtain that eliminates or minimizes flow.
GA-4	Grout the 1050 Roof Leak	Drilling and pressure grouting of the roof leak to produce a grout curtain that eliminates or minimizes flow.
GA-5	Backfill Various Portions of the Glengarry Drift	Backfilling various portions of the Glengarry Mine with cemented backfill with a waste rock aggregate for structural support and strength needed to help protect grout curtains and reduce or minimize flow along a particular portion of the drift. ➢ 5A - backfilling the drift in the Fisher Mountain Porphyry only (fill will begin at the first plug and end at the portal plug). ➢ 5B - backfilling the drift in the Precambrian Granite only. ➢ 5C- backfilling the entire drift.
GA-6	Plug the Glengarry Drift at Critical Locations	Construct three watertight concrete plugs within the Glengarry Drift. Two plugs near the Precambrian Granite/Fisher Mountain Porphyry contact and another plug near the portal.

COMO BASIN SOURCE AREA ALTERNATIVES

The alternatives evaluated present a range of effectiveness. The overall effectiveness of the No Action alternative is poor. Under existing conditions, metals will continue to migrate from metal-rich soils in the Como Basin into surface water and groundwater. While slopes are stable in the Como Basin as a result of Crown Butte Mines, Inc.'s (CBMI) reclamation, poorly vegetated metal-rich soils will continue to erode unabated into Fisher Creek. Vegetation condition and cover in the Como Basin will likely continue to decline over time as acidic conditions in the regraded and amended surface soil increase, causing a reduction in vegetation cover and vigor.

In terms of reducing contaminant seepage and migration from the Como Basin, Alternative CB-3C is the most effective of the alternatives evaluated. This is because practically all of the metal-rich soils of the basin would be capped by a geomembrane liner, and thereby protected from infiltrating waters. In this alternative, an imported soil cover placed over the liner promotes vegetation growth. Alternative CB-3B is as effective or only somewhat less effective than Alternative CB-3C, as most of the metal-rich soils are protected under the liner, and metal-rich soils are completely neutralized and amended to produce an amended soil cap. Alternative CB-3A is much less effective because the imported soil cap, although providing a substrate for vegetation reestablishment, does not decrease either the rate of infiltration nor substantially diminish risk of contaminant migration out of metal-rich soils.

The overall effectiveness of Alternative CB-2C may be as effective as CB-3B in controlling contaminant migration from metal-rich soils in the Como Basin. Under this alternative, seepage would not be eliminated but rather would become nearly neutral and will not contain significant metals concentrations or low pH. Alternative CB-2C however requires excavation, treatment, and replacement of a very large volume of material (190,174 cubic meters). Alternatives CB-2B and CB-2A are progressively less effective because smaller volumes of metal-rich soil material are amended, the seepage rate would remain about the same as existing conditions, and non-amended soils will likely still release contaminants to the environment. From this point of view, with the exception of the benefits of an imported soil cover, Alternative CB-3A will probably be a little more effective than Alternative CB-2A.

Based on a recreational use scenario, there are no unacceptable human health risks associated with the Como Basin metal-rich soils. The greatest risk to the environment comes from degraded surface and groundwater quality and its impact to aquatic life. The Como Basin alternatives involving a geomembrane as part of a composite cover will significantly reduce metal and acidity loading to Fisher Creek from tributaries draining the basin, particularly during high flow conditions.

Metal-rich soil in the Como Basin, however, is not the only source of contamination in the headwaters of Fisher Creek. It has been demonstrated that sulfide minerals in bedrock are a major, naturally occurring source of metals and acid rock drainage, and impact a surface water tributary flowing from the northeast flank of Fisher Mountain as well as the tributary flowing from the Como Basin. In addition, there is a significant (perhaps as much as 40%) contaminated groundwater component that enters Fisher Creek between the Glengarry mine and surface water-sampling Station SW-3. Cleaning up or preventing seepage and impacted surface water flows from metal-rich soils of the Como Basin at the headwaters of Fisher Creek will, however, significantly reduce the contribution of metal and acidity loading from mining and exploration related sources in the Como Basin. This is particularly true during high flow conditions when the component of contamination from these basin sources is the largest.

None of the alternatives reduce the volume or toxicity of contaminants but all the alternatives, except No Action, reduce the mobility and loading of contaminants to some degree. Alternatives CB-2A, CB-2B, CB-2C, CB-3A, and CB-3B rely on treatment of soils with a neutralizing amendment to reduce mobility. Alternatives CB-3A and CB-3C also use an imported soil cover to reduce mobility. Alternatives CB-3B and CB-3C use a geomembrane liner as a part of a composite cover system to reduce mobility. Alternative CB-2C achieves the greatest reduction in mobility through treatment, but again this alternative requires moving and treating a very large volume of metal-rich soil. Reduction in plant toxicity through treatment or soil placement is achieved by all the alternatives except for No Action.

All the alternatives are implementable, and technically and administratively feasible. Essential project components such as equipment, materials, and construction expertise, although distant from the site, are available. However, there is the potential for incomplete mixing of neutralizing amendments for those alternatives where mixing is required for the alternative to be effective, especially Alternative CB-2C.

The presence of such a large volume of material in the Como Basin (190,174 cubic meters) precluded further consideration of a total removal alternative. This alternative was evaluated in detail for the McLaren Pit Response Action, which has a similar amount of unconsolidated wastes, and total removal was not found to offer any distinct advantage because of the massive sulfide deposit that underlies waste rock in the McLaren Pit. Total removal cost about three times higher than the capping alternatives considered for the McLaren Pit.

All of the alternatives evaluated provide some measure of mitigation to man-caused mining impacts. Given what is known about the source of metals impacts in Fisher Creek and the fact that natural sources contribute a considerable metals load to the creek via groundwater and surface water pathways, completely eliminating metals impacts from mining related sources will not be possible. However, Alternatives CB-3B and CB-3C would be the most effective at reducing mining-related acid and metals impacts, particularly with regards to loading. Each of these alternatives uses a geomembrane liner in a composite cover system to isolate metal-rich soil and reduce mobility of contaminants.

With Alternative CB-3C, metals-rich soils would be protected from contact with surface water below a liner, and would likely minimize contaminant mobility and migration into Fisher Creek. Both Alternatives CB-3B and CB-3C will meet most project ARARs with the exception of surface water and groundwater quality. However, Alternative CB-3C will require both locating and developing a local source of soil material, or excavating and transporting borrow from the SB-4B repository site, both of which require disturbing an undisturbed site.

Alternative CB-3B should not present significantly more difficulty in the establishment of a vegetative cover as compared with Alternative CB-3C as long as procedures for revegetation established by the USDA-FS are followed. Alternative CB-3B has fully amended metals-rich soil above the liner, which should pose no significant additional risk for contaminant migration over alternative CB-3C. This is particularly true for the Como Basin given the relatively low level of contaminant concentrations in metal-rich soils.

FISHER CREEK SOURCE AREA

The Fisher Creek Source area contains a number of small scattered waste rock piles in the upper Fisher Creek drainage and other small, but locally severe erosional problems. Many of the small to intermediate size dumps that exhibited the greatest potential to impact surface water and groundwater in Fisher Creek were removed in 2001 as part of the Selective Source Response Action (Tredennic, Spaulding, and Small Como dumps). Under existing conditions, metals migrate from outlying waste rock dumps at the headwaters of Fisher Creek into surface water and groundwater. While slopes are stable in the small outlying waste because of the length of time they have been in-place, the largely unvegetated waste rock dumps will continue to erode unabated into Fisher Creek. The Glengarry and Gold Dust waste rock dumps are the two largest dumps remaining in the Fisher Creek drainage, accounting for about 85% of the total mine waste remaining in the drainage.

Some of the same process options from the Como Basin analysis (Table ES-1) also apply to the remaining waste rock dumps in Fisher Creek (Table ES-2). The alternatives developed from these process options are similar to those proposed for the Como Basin, with several exceptions. First, because the dumps are scattered over a wide area with difficult access to many of the dumps, covering the small waste dumps with a geocomposite is not practical or cost effective. Therefore, the CB-3 alternatives are not considered for the Fisher Creek Source Area. Of the CB-2 alternatives (*in-situ* treatment), only shallow amendment with lime (CB-2A) is considered appropriate for the small, scattered waste rock dumps due to site constraints and access limitations (i.e. most of the sites are on steep slopes that constrains lime mixing with equipment). Total removal to the SB-4 repository is considered appropriate for the Fisher Creek Source Area and was developed as an alternative. Also an additional alternative was developed, surface controls for surface water runon and runoff, as this process option lends itself to being potentially effective at mitigating water quality impacts with a minimum impact to access roads and adjacent lands. Surface controls would include a variety of best management practices to reduce or eliminate surface water runon from flowing across mine waste, reduce or eliminate erosion generated in mine waste areas from moving to offsite areas, and reduce the amount infiltration from precipitation falling on waste dumps. Best management practices include constructing diversion ditches along the waste rock dump margins, constructing sediment basins downslope of waste dumps, and regrading waste rock to provide positive drainage. Surface controls could also include temporary measures such as installing silt fence and straw bale dikes to reduce or eliminated sediment produced from waste dumps.

Overall, *in-situ* treatment (Alternative FC-2) would be effective in providing suitable soil conditions for revegetation in the short-term, and a corresponding reduction in mobility of metal contaminants. However, because site conditions limit the depth of waste treatment, untreated wastes will remain at the dump sites. Under certain conditions, generally during moderate to extreme weather, untreated wastes could become saturated and release contaminants to the environment. There is also the potential for the treated surface of the waste to reacidify due to capillary rise of acid from underlying untreated wastes, resulting in a reduction in vegetation cover and vigor. Such a mechanism would likely cause the waste dump to revert to pre-treatment conditions.

Surface controls (Alternative FC-3) would be effective in reducing impacts that result from surface water runon encountering waste. Diversion of runon at dumps where this problem occurs is a simple, straightforward approach to reducing mobility of contaminants. However, maintenance of diversion structures over time would be required. Precipitation that falls directly on the dumps will continue to leach through the unvegetated dumps, creating the potential for contaminants to move off-site into area surface and groundwater. To some degree, regrading of the waste rock dumps can enhance surface water runoff.

Alternative FC-4, total removal, is the most effective and most costly of the alternatives considered. This alternative calls for moving the mine wastes to an on-site repository, part of which has been previously constructed. The No Action Alternative does not address surface water impacts, nor does it provide any controls on contaminant migration.

GLENGARRY ADIT SOURCE AREA

The third source area evaluated is the Glengarry Adit Source Area, where contaminated water flows into underground workings from four principal sources that combine and flow down the drift to the portal. Water discharged from the portal flows directly into surface waters of Fisher Creek and also leaches through a sulfide-bearing waste rock dump located at the portal. Clean-up goals for the Glengarry Adit are all based on eliminating or minimizing contaminated inflows and outflows from the mine. Alternatives that use engineering controls to plug, contain, or divert water flows and eliminate or minimize contaminated discharges were developed to meet these goals.

The No Action Alternative involves leaving the Glengarry Mine in its existing condition. Overall effectiveness of no action is poor. Under existing conditions, acidic water, dissolved metals, and sediment will continue to flow from the mine portal and into Fisher Creek.

From the point of view of contaminant concentration and loading, the principal source of metals and low pH water inflow into the Glengarry Mine arises from water flowing along the colluvial/bedrock contact in the Como Basin that flows down the second raise (8 to 38 liters per minute). Alternative GA-2 effectively reduces the influx of metal-laden water into the Glengarry Mine and Fisher Creek by providing multiple barriers to contaminated water entering and flowing down the second raise. The grout curtain encircling the raise collar will provide a barrier to keep shallow subsurface water flowing along the colluvial/bedrock contact from entering the raise, and cement and bentonite plugs will provide a very tight seal within the raise and below the massive sulfide-bearing portion of the Meagher Limestone. Backfilling the raise will also act as a barrier to water movement, and will eliminate the chance of future collapse of rock around the grout curtain and plug areas that could result in leakage past the plugs or failure of the grout curtain.

Other significant sources of inflow are the flow from the top of the first raise (38 to 64 liters per minute) and flow from the 1050 fracture system (10 to 50 liters per minute). These two inflow sources contribute two orders of magnitude less metals concentrations than the Como raise, but contribute a considerable iron and zinc load and exceed water quality standards. Water leakage from both these structures would be considerably reduced or eliminated if Alternatives GA-3 (grouting of fracture system at the top of the first, short raise) and GA-4 (grouting of the 1050 Roof Leak) were implemented.

If grouting for Alternatives GA-3 and GA-4 are only partially successful, implementation of these two alternatives is still likely to be effective in substantially reducing flow into the mine. However, the effectiveness of Alternative GA-3 directly depends on the success of locating and sealing the fracture system above the first raise. If Alternatives GA-2 and GA-6 are selected, Alternative GA-3 becomes unnecessary.

Implementing Alternative GA-5 (backfilling various portions of the underground workings) ensures no further ground movement will occur in the rock surrounding the Glengarry workings. This alternative provides structural stability and support to areas grouted and plugged under Alternatives GA-4 and GA-6. The relative impermeability of backfill will also significantly reduce flow through the backfilled portions of the workings.

Alternative GA-6 is the most effective of the alternatives in that it seals the underground workings with a series of plugs. Water draining down the raises and entering the Glengarry drift will be stopped in the very dry and low permeability rock of the Precambrian granite. A third plug located near the portal will block Fisher Mountain Porphyry water that drains into the drift between the portal and the porphyry contact. This alternative should be very effective in eliminating or minimizing outflow from the mine and into Fisher Creek.

PREFERRED ALTERNATIVE

Loading analysis suggests that metals loading from the Glengarry Adit is most significant (more than 90 % of the total load as measured in Fisher Creek immediately below the mine site) during low flow conditions from September to late June. Metals loading from the Como Basin is most significant (about 20% of the total load in Fisher Creek immediately below the Glengarry mine) during high flow conditions in late June through August. Loading for many constituents during low flow is about a factor of 10 lower than that during high flow. Metal loading from the tributary draining undisturbed ground on the northeast flank of Fisher Mountain contributes about 14% of the copper load to Fisher Creek during high flow conditions. This metal load is though to be the result of natural ARD. Based on this analysis, it would seem appropriate to complete the most desirable response action on both the Como Basin and Glengarry Adit Source Areas in order to minimize contaminant migration into Fisher Creek on a year-round basis. The combination of both should significantly and positively impact water quality, particularly with respect to metal and acidity loading, in the upper reaches of Fisher Creek, and will likely have some positive impacts on groundwater.

A response action targeting the smaller waste rock dumps that remain in the Fisher Creek Source Area is of lower importance in terms of metals loading to Fisher Creek. Only the Glengarry waste rock dump appears from metals loading analyses to have a significant impact on water quality in Fisher Creek. Some water quality degradation from the Gold Dust waste rock dump in the form of increased acidity (pH of 5.5) has also been documented, primarily due to infiltration of water from the Gold Dust Adit through the waste rock dump. Although there are metal analyses available indicating seepage through the waste rock dump carries high metals concentrations and low pH, there is no identified metal impact to the tributary to Fisher Creek (FCT-4) above or below the dump site. There are no unacceptable residual risks to human health at these sites.

Because of the foregoing, the preferred alternative for the Como Basin/Glengarry Adit/Fisher Creek Response Action is a combination of the alternatives discussed for each of the separate source areas. Only by combining the alternatives discussed will substantial improvements in water quality be realized in Fisher Creek. The preferred alternative for each of the three source areas is discussed below.

COMO BASIN SOURCE AREA

All the alternatives evaluated for the Como Basin provide some measure of mitigation to man-caused mining impacts. Given what is known about the source of metals impacts in Fisher Creek and the fact that natural sources contribute a considerable metals load to the creek via groundwater and surface water pathways, eliminating metals impacts from mining related activities will not allow achievement of state water quality standards. However, Alternatives CB-3B and CB-3C would be the most effective at reducing mining-related metals loading impacts to Fisher Creek. Each of these sub-alternatives uses a geomembrane liner in a composite cover system to confine and reduce the mobility of contaminants present in soils in the basin. Alternative CB-3B should not be significantly more difficult in establishing vegetation as compared with Alternative CB-3C as long as procedures established by the USDA-FS are followed. Alternative CB-3C would require obtaining a local source of soil material, which involves disturbance and reclamation of a borrow site. For these reasons, Alternative CB-3B is the preferred alternative for the Como Basin Source Area. The total cost to implement this alternative is $1,918,000.

FISHER CREEK SOURCE AREA

Except for the Glengarry and the Gold Dust waste rock dumps, there appears to be little impact from the remaining waste rock dumps located in Fisher Creek. There are no identified human health risks, and environmental risks appear to be associated with waste rock that is in contact with surface water and/or groundwater. This is the case at the Glengarry Dump, where loading of contaminants was determined to make up nearly 15% of the load delivered to Fisher Creek during high flow conditions. Part of the reason for this is the location of the dump at the mouth of the Glengarry Adit, where flows discharging from the adit eventually infiltrate through the waste rock dump. Another reason is the location of the dump as a cross-valley fill in the Fisher Creek drainage, where it is prone to nearly constant contact with Fisher Creek and fluctuating groundwater levels that are influenced or controlled by Fisher Creek. The Glengarry Dump accounts for about 59% of the remaining waste rock in Fisher Creek.

The Gold Dust site is somewhat similar to the Glengarry Dump in that the Gold Dust waste rock sits at the mouth of the adit, and discharge from the adit flows across the dump before entering a tributary to Fisher Creek. The dump is also one of the larger remaining dumps in Fisher Creek, constituting 26% of the waste rock left in the remaining dumps. Together, the Glengarry and Gold Dust waste rock dumps contain 85% of the waste rock in Fisher Creek.

Other waste rock dumps and their associated mine sites lie topographically above the valley bottom and present little threat to surface or groundwater quality (except for a brief period during active snowmelt). Some of the sites, in addition to being high and dry, are also considered to be cultural or historic resources (e.g. Homestake Mine, Gold Dust Adit).

Because of the nominal nature of recognized impacts from remaining dumps in Fisher Creek, and because the Glengarry and Gold Dust waste dumps constitute 85% of the waste rock, the preferred alternative for the Fisher Creek Source Area is Alternative FC-3 for all waste dumps except the Glengarry and Gold Dust dumps. Alternative FC-4, total removal to the SB-4B(B) repository, is selected for these two dumps. For most of the remaining waste rock dumps, the impacts of building roads and moving equipment onto the sites for removal or treatment would be greater than that of leaving them in place. Alternative FC-3, surface controls, appears to be suitable for implementation at other waste rock dumps, where runon controls may be sufficient to reduce the majority of environmental impacts, especially with regard to surface water quality.

GLENGARRY ADIT SOURCE AREA

The most effective means of closure for the Glengarry Mine involves a combination of alternatives that attempt to minimize mobility of contaminants as inflow and outflow from the mine. These alternatives are also selected for implementability, as they offer the most in terms of long-term effectiveness and permanence, and provide for the maximum protection of the environment. Although there is some need for backfilling intervals of the workings around grout curtains or plugs to ensure structural stability, the combination of the evaluated alternatives has been selected to minimize redundancy. For these reasons, the following alternatives have been selected:

- GA-2, a surface grout curtain around the raise collar with a concrete plug in the raise below the Meagher limestone and backfilling the raise.

- GA-4, a grout curtain around the 1050 roof leak.

- GA-5A, backfilling the drift with cemented backfill in the Fisher Mountain Porphyry portion of the drift, and

- GA-6, placement of two watertight plugs and a portal plug in the Glengarry drift.

Alternative GA-3 has not been selected as it has the least chance for success, is the most dangerous to implement, and can be eliminated with the plug set in the Precambrian granite (Alternative GA-6). This will backup and confine water from the first raise into a very dry portion of the mine, and will keep water from the Precambrian granite from mixing with that from the Fisher Mountain Intrusive.

Closure of the Glengarry Mine would preferably be executed as a two-year program that allows for testing and monitoring the success of the first season of work. Alternatives GA-2, GA-4, and part of Alternative GA-6 would be completed the first year, allowing monitoring of flow reductions during the winter and spring of the following year. Monitoring would allow for any adjustments to be made before the second season of work is done. Backfilling the drift (GA-5) and setting the remaining portal plug (GA-6) would be completed the second season of work. Estimated cost of the preferred alternative for the Glengarry Source Area is $2,666,000.

COMBINED ALTERNATIVE - IMPACTS TO LOADING

Upper Fisher Creek is characterized by highly variable flow with rapidly increasing flow rates and short periods of sustained flow during snowmelt. As much as 90% of Fisher Creek's discharge volume occurs between mid May and early August. Discharge rates near the upper reaches of Fisher Creek range from less than 0.3 m^3/s (1.0 cfs) in late winter to over 1.4 m^3/s (150 cfs) during peak runoff.

Metals loading investigations by Amacher (1998) and Kimball and others (1999) indicate that a few distinct surface water sources in the upper 500 meters of Fisher Creek supply the majority of the contaminant load to the creek. Results of Amacher's investigation indicate that the major sources of metals loading into Fisher Creek are:

- Outflow from the Glengarry Adit (F-8A)
- A tributary draining the northeastern flank of Fisher Mountain (FCT-12)
- A tributary draining the Como basin (FCT-11)
- Seepage from the Glengarry Adit waste rock dump (FC-2)

In general, the loading studies agree about the major inflow sources that contribute metals to Fisher Creek. Roughly half of the sources contributing metal loading into the creek have been identified as surface sources, with estimates ranging from 40 to 60%; the remainder being groundwater or subsurface flows. Subsurface flows will prove difficult to remediate, as these flows do not seem to be associated with any particular mining-related activity, and could very well represent natural acidic drainage.

Amacher (1998) and Kimball and others (1999) noted that the relative contribution of the four major sources varied considerably from spring runoff to base flow conditions. The majority of contaminant loading to Fisher Creek occurs under peak flow conditions (by a factor of 10). Comparison of loads indicates that while the Glengarry Adit dominates water chemistry during low flow conditions, tributaries FCT-11 and FCT-12 contribute the majority of the annual load during high flow conditions.

In May, under base flow conditions, Glengarry Adit discharge (FC-2) accounts for most of the dissolved copper load to upper Fisher Creek. As snowmelt begins in June and proceeds into July, runoff from Fisher Mountain (FCT-12) and Como Basin (FCT-11) accounts for most of dissolved copper load. In the fall, the Glengarry Adit again accounts for the majority of copper load. Metals load contribution from groundwater is significant during spring runoff, but cannot be quantified with the available data.

Using copper and iron as examples, based on the combined predicted affect for the preferred alternative for each of three source areas (composite cover on Como Basin soils, closure of the Glengarry adit and removal of the Glengarry waste rock dump), copper loading to Fisher Creek could be reduced by as much as 90% during low flow at a point immediately below the present location of the Glengarry waste rock dump, and by a considerably smaller amount at SW-3. This is true because there is no or very little flow in the tributaries from Fisher Mountain or the Como Basin (or two other small tributaries) under base-flow conditions and approximately 90% of the load then comes from the Glengarry adit and seepage through the waste rock dump. The remaining load is from groundwater sources that report to surface water flow measured at SW-3. During these flow conditions, both Kimball and Amacher's studies indicate that groundwater inflow to Fisher Creek between the Glengarry Mine and SW-3 contributes at least 35 to 45% of the total load to SW-3.

The total estimated load reduction for the preferred alternative, using three estimates of adit closure efficiency of 100, 50 and 20%, show that copper removal will likely range from 8 to 40%, depending upon the amount of load rerouted by the adit closure into preexisting fractures that in turn report to Fisher Creek. Using the total annual load data for copper (2,132 lbs/year under high flow conditions or 149.4 lbs/year under low flow conditions), and assuming annual flow of 3 months per year at high flow and 9 months per year at low flow, the preferred alternative could remove as few as 18 pounds (20% efficiency) or as much as 146 pounds (100% efficiency) of copper per year. Similarly for iron loading, the calculated estimates show that iron removal will likely range from 8 to 49%, depending upon adit closure efficiency. Using the total annual load data for iron (8,876 lbs/year under high flow conditions or 1,255 lbs/year under low flow conditions), and assuming annual flow at 3 months per year at high flow and 9 months per year at low flow, the preferred alternative could remove as few as 94 pounds (20% efficiency) or as much as 1,462 pounds (100% efficiency) of copper per year.

COMBINED ALTERNATIVE COST

Table ES-4 presents the combined alternative cost for the preferred alternative. For Alternative FC-3 Modified, the cost of the removal and disposal of the Glengarry Dump in the SB-4B(B) repository was estimated to be 70% of the total estimated cost for Alternative FC-4, and then added to the FC-3 total cost. This cost is conservative because Alternative GA-5A will use approximately 25% of the Glengarry Dump for the backfill of the Glengarry drift.

TABLE ES-4
SUMMARY OF ESTIMATED COSTS FOR THE PREFERRED ALTERNATIVE
New World Mining District Response and Restoration Project
Como Basin/Glengarry Adit/Fisher Creek Response Action

Preferred Alternative	Cost
Como Basin Source Area – CB-3B	$ 1,918,000
Fisher Creek Source Area – FC-3 (Modified for removal of the Glengarry and Gold Dust Waste Rock Dumps)	$ 2,010,000
Glengarry Adit Source Area (Combination of GA-2, GA-4, GA-5A, and GA-6)	$ 2,666,000
TOTAL ESTIMATED RESPONSE ACTION COST	**$ 6,594,000**

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LIST OF ACRONYMS AND ABBREVIATIONS

ABP	Acid-Base Potential
AIMSS	Abandoned and Inactive Mines Scoring System
ARARs	Applicable or Relevant and Appropriate Requirements
ARD	Acid Rock Drainage
ATSDR	Agency for Toxic Substances and Disease Registry
BMP	best management practice
CBMI	Crown Butte Mines, Inc.
CDM	Camp, Dresser and McKee
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
COC	Contaminant of Concern
CFR	Code of Federal Regulations
cfs	cubic feet per second
cy	cubic yard
District	New World Mining District
DNRC	Montana Department of Natural Resources and Conservation
EE/CA	Engineering Evaluation/Cost Analysis
EPA	U.S. Department of the Interior Environmental Protection Agency
EQ	Ecological Impact Quotient
ER-M	Effect Range- Median
gpm	gallons per minute
Ha	hectare
HDPE	High Density Polyethylene
HEAST	Health Effects Assessment Summary Tables
HELP Model	Hydrologic Evaluation of Landfill Performance Model
HHS	human health hazard
HQ	Hazard Quotient
HRS	Hazard Ranking System
IRIS	EPA's Integrated Risk Information System
LAI	Leaf area index
LCS	Leachate Collection System
lpm	liters per minute
Maxim	Maxim Technologies, Inc.
MCL	Maximum Contaminant Level
MCLG	Maximum Contaminant Level Goal
MDEQ	Montana Department of Environmental Quality
MPDES	Montana Pollutant Discharge Elimination System
MWCB	Mine Waste Cleanup Bureau
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
mm	millimeter
µg/L	micrograms per liter
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
ppm	parts per million
PRSC	Post Removal Site Control
PRAOs	Preliminary Removal Action Objectives
RCRA	Resource Conservation and Recovery Act
SAP	Sampling and Analysis Plan
SMP	Shoemaker, McLean, and Pratt

s.u.	standard units
TCLP	Toxicity Characteristics Leaching Procedure
URS	URS Operating Services
USDA-FS	United States Department of Agriculture Forest Service

1.0 INTRODUCTION

Maxim Technologies, Inc. (Maxim) developed this Engineering Evaluation/Cost Analysis (EE/CA) for the United States Department of Agriculture Forest Service (USDA-FS). The purpose of this report is to present an engineering evaluation and cost analysis of alternatives for the New World Mining District Response and Restoration Project proposed for the headwaters of Fisher Creek in the vicinity of the Glengarry Adit, Como Basin, and mine wastes present in dumps located in the upper portion of the Fisher Creek drainage. These sites are located in the New World Mining District (District). Response activities will address environmental media affected by historic gold, silver, copper, and lead mining and will be implemented over the life of the project, which is expected to be completed by 2007. The District is located north of Cooke City, Montana, in the Beartooth Mountains (Figure 1). Mining disturbances are primarily situated on lands managed or controlled by the USDA-FS.

The primary environmental issues within the District are associated with impacts from historic mining and more recent mineral exploration activities that occurred since prospecting in the area was initiated in about 1869. Human health and environmental issues are related to elevated levels of heavy metal contaminants present in mine waste piles, open pits, acidic water discharging from mine openings, and sediments.

1.1 PURPOSE

The purpose of this EE/CA is to screen, develop, and evaluate potential response action alternatives that would be used for cleanup of historic mining wastes located in the Fisher Creek drainage. This EE/CA was developed using the "non-time-critical removal" process outlined in the *Comprehensive Environmental Response, Compensation, and Liability Act* (CERCLA), as amended in 1986, and the updated National Oil and Hazardous Substances Pollution Contingency Plan (NCP). Figure 2 displays the non-time critical removal process as it applies to the New World Mining District Response and Restoration Project. A non-time-critical removal action is implemented by the lead agency to respond to "the cleanup or removal of released hazardous substances from the environment… as may be necessary to prevent, minimize, or mitigate damage to the public health or welfare or to the environment…" (EPA, 1993).

Numerous investigators collected the data used to support this EE/CA. The most recent data was collected in 2001. Site data were used to assess risks posed by acid mine drainage and metal loading from historic disturbances in the Como Basin, the underground mine workings of the Glengarry Mine, and mine waste rock dumps present in the Fisher Creek drainage. These same data were also used to evaluate the potential effectiveness of removal, in situ treatment, capping methods in the Como Basin massive sulfide deposit areas, and various mine closure options in alleviating the risks present at the site. Finally, cost estimates were developed for each alternative for comparative purposes. Following receipt of public comment on the preferred response action alternative identified in this document, the USDA-FS will finalize the selection of an alternative in the decision document for the response action, an Action Memorandum.

1.2 OBJECTIVES

The geographic area included for study in this EE/CA is the Fisher Creek watershed from the topographic divide at Lulu Pass to the confluence of Lady of the Lake Creek. This EE/CA will focus on four major components that impact the Fisher Creek drainage:

- Disturbed acidic and metal-rich soils in the Como Basin that overlie and have been derived from an underlying near-surface massive sulfide deposit.

- The Glengarry Adit that discharges poor quality water into Fisher Creek from sources in the Como Basin and various underground inflows that drain through the Glengarry underground workings.

- Mine wastes present in waste rock dumps within Fisher Creek.

- Erosion problems (mining and road related) occurring between the Como Basin and the Glengarry Adit.

Observed and measured environmental impacts from these sources include: contaminated surface and groundwater; contaminated adit discharges to surface water; seepage from acidic and metal-laden natural soils and waste rock; and severe erosion along roads and streams. These impacts are indicative of the physical transport of metal-rich soils, seasonally heavy sediment loading to surface waters, and physical instability of slopes and stream gradients, both from erosion by surface water and traffic along established roadways.

1.3 REPORT ORGANIZATION

This EE/CA is arranged in eight sections. Following this introductory section, the history of the district and descriptions of the site's geologic, hydrologic, and climatic characteristics are presented in Section 2.0. Section 3.0 presents pertinent data used to characterize contaminant sources and pathways of contaminant movement within Fisher Creek, the Como Basin, the underground workings of the Glengarry Mine, and other mine wastes, including contaminated surface and groundwater sources. Section 4.0 summarizes human health and ecologic risks associated with mining wastes and recreational use of the sites. Section 5.0 outlines the response action scope, preliminary removal action objectives (PRAOs), and goals for the site. The PRAOs were developed by the USDA-FS and goals were identified based on both applicable or relevant and appropriate requirements (ARARs) or applicable cleanup guidelines. In Section 6.0, response action technologies and process options are screened and potentially applicable removal alternatives are developed. Section 7.0 presents a detailed analysis of alternatives using NCP evaluation criteria. Section 8.0 compares the alternatives against three primary criteria: effectiveness, implementability, and cost.

Figures and tables are incorporated into the text of the report. References cited in the document are listed at the end of the text. Several appendices that contain supporting documentation are included at the end of the document.

Figure 1 - Project Vicinity Map

Figure 2 - Non-Time Critical Removal Process Schematic

2.0 SITE DESCRIPTION AND BACKGROUND

The New World Mining District includes both National Forest and private lands in a historic metal mining area located in the Beartooth Mountains, near Cooke City, Montana (Figure 1). This historic mining district contains both mining related and natural features that are pertinent to mine waste cleanup activities. These features include: massive sulfide deposits exposed at the surface; regionally distributed geologic units and deposits enriched in pyrite and chalcopyrite; abandoned mines; hard rock mining wastes; acid discharges from both mine wastes and abandoned mine workings; and natural acid rock drainage (ARD). Human health and environmental issues are related to elevated levels of metals present in various mineralized geologic units, mine wastes, acidic water discharging from mine openings, and contaminated stream sediments.

2.1 PROJECT BACKGROUND

On August 12, 1996, the United States signed a Settlement Agreement (Agreement) with Crown Butte Mining, Inc. (CBMI) to purchase CBMI's interests in the District. This transfer of property to the U.S. government effectively ended CBMI's proposed mine development plans and provided $22.5 million to clean up historic mining impacts on certain properties in the District. In June 1998, a Consent Decree (Decree) was signed by all interested parties and was approved by the United States District Court for the District of Montana. The Decree finalized the terms of the Agreement and made available the funds that are being used for mine cleanup. Monies available for cleanup are to be first spent on District Property, which, as defined in the Decree, includes all property or interests in property that CBMI relinquished to the United States (Figure 1). If funds are available after District Property is cleaned up to the satisfaction of the United States, other mining disturbances in the District may be addressed.

Mitigation of impacts from acid-generating historic mining wastes has been an objective of investigators in the District since the 1970's. One of the first to investigate revegetation in the District was the USDA-FS Intermountain Research Station (Brown et al., 1995; 1996). This research has focused on reclaiming high elevation mine disturbances, with emphasis on specific issues associated with species selection, fertilization, planting season, organic amendments, acid soil amendments, and surface soil treatments. Some reclamation work was completed voluntarily by CBMI on District Property. In 1991, CBMI began surface restoration work to reclaim the historic McLaren open pit mine disturbance and areas disturbed by exploration activity in the Como Basin. Reclamation activities in the McLaren Pit included surface recontouring, up-gradient diversion ditches, construction of lined runon and runoff control ditches, treating acid soils with a lime amendment, and fertilizing and seeding with native grasses. In both the McLaren and Como Basin areas, as many exploration drill holes (CBMI and pre-CBMI) as could be located were plugged and abandoned using bentonite chips and cement caps.

In 1995, the United States Environmental Protection Agency (EPA) began a site investigation after the initial announcement of the property transfer from CBMI. The EPA investigation involved installing monitoring wells, surface water sampling, groundwater monitoring, and completing a groundwater tracer study. The results of these studies were published in two technical reports (URS, 1996; 1998) and included a description of the following: a review of all previous surface water and groundwater data collected by the Montana Department of Natural Resources and Conservation, USDA-FS, CBMI, EPA, and URS; an evaluation of the data collected during the 1996, 1997 and 1998 field season; and an overall evaluation of the complete data set with respect to adequacy for restoration and reclamation of historic abandoned mines.

From 1993 to 1996, CBMI reclaimed eleven other waste rock dumps in Fisher Creek and reclaimed the Como Basin by using a combination of regrading, amending surface soils (upper 30 cm) with lime, and fertilizing, seeding, and mulching. In the Como Basin, the entire area covered by disturbed soils was regraded by CBMI. Unfortunately, revegetation was not very successful, probably in part due to both inadequate lime amendment and failure to fertilize in subsequent years following the initial fertilizer treatment. Lined and armored diversion ditches were constructed around the raise collar and along the upgradient margin of the disturbed ground overlying the deposit. These diversions were somewhat effective in diverting water flow from the Glengarry workings and subsequent sampling documented that flow volumes and loading from the Glengarry adit were substantially reduced.

The USDA-FS assisted CBMI in October 1998 in completing and submitting a Support Document and Implementation Plan to support the CBMI petition for temporary modification of water quality standards. The Support Document and Implementation Plan was submitted to the State of Montana Board of Environmental Review on January 22, 1999, and a rule was approved on June 4, 1999. The petition for temporary standards was necessary to temporarily modify surface water quality standards for Daisy and Fisher Creeks and a headwater portion of the Stillwater River so that improvements to water quality could be achieved by implementation of the response and restoration project.

Major work completed during the first three years of cleanup activity initiated by the USDA-FS was associated with the Selective Source Response Action (Maxim, 2001a). Construction activities associated with this response action, were initiated in 2001 and will be completed in 2002, and involve removing approximately 24,500 cubic meters (32,000 cubic yards) of waste rock and mill tailings from seven mine waste areas in the Fisher Creek and Soda Butte Creek drainages, disposing of these wastes in an engineered repository, and revegetating about 1.9 hectares (4.6 acres) of the former waste areas. The waste areas cleaned up and the volume of waste permanently disposed represent about 9% of the impacted area and about 8% of the waste located on District Property. Mine wastes included in this first cleanup action were the Tredennic, Spaulding, and Small Como waste rock dumps, and the former Rommel and Soda Butte tailings ponds.

The second proposed response action for the district is the McLaren Pit Response Action (Maxim, 2001b). This proposed action involves consolidation of waste rock dumps from the Daisy Creek headwaters area into the McLaren Pit, and isolating the consolidated wastes with an impermeable liner. The waste dumps slated for consolidation into the pit are the McLaren Pit Spoils and the Multicolor Dump. Approximately 18,000 cubic meters (24,000 cubic yards) of waste rock are contained in the dumps, which cover about 1.4 hectares (3.5 acres) of disturbance. An additional 137,000 cubic meters (180,000 cubic yards) of waste rock located in the former McLaren Pit will be covered with the impermeable cap.

2.2 SITE LOCATION AND DESCRIPTION

The New World Mining District falls within the boundaries of the Gallatin and Custer National Forests and lies adjacent to Yellowstone National Park’s northeastern-most corner. The Absaroka-Beartooth Wilderness Area bounds the District to the north and east. To the south of the District is the Montana-Wyoming state line and public lands administered by the Shoshone National Forest. The District lies entirely within Park County, Montana.

The communities of Cooke City and Silver Gate, Montana are the only population centers near the District. The neighboring communities of Mammoth, Wyoming and Gardiner, Montana are located about 80 kilometers (km) (50 miles) to the west. Red Lodge, Montana is about 105 km (65 miles) to the northeast via the Beartooth Highway (US Highway 212), and Cody, Wyoming is located 100 km (60 miles) to the southeast via the Chief Joseph Scenic Byway, or Sunlight Basin road.

The District is located at elevations ranging from 2,400 meters (7,900 feet) to over 3,200 meters (10,400 feet) above mean sea level, the site is snow-covered for much of the year. Only one route of travel is open on a year-round basis to the District, the highway between Mammoth and Cooke City. The Sunlight Basin road allows access to the District from northwestern Wyoming during the spring, summer and fall but only allows access to within a few miles of the District in winter. The Beartooth Highway is closed during winter, as is Highway 212 from Cooke City eastward to Pilot Creek near the Montana-Wyoming state line.

The District covers an area of about 100 square kilometers (40 square miles). Historic mining disturbances affect about 20 hectares (50 acres) according to measurements made by the USDA-FS Interagency Spatial Analysis Center. The topography of the District is mountainous, with the dominant topographic features created by glacial erosion and glacial deposits. The stream valleys are U-shaped, broad, and underlain at shallow depths by bedrock, while the ridges are steep, rock covered, and narrow. Much of the District is located at or near tree line, especially in the Fisher Mountain area where the major historic mining disturbances are located.

The District is situated at the headwaters of three tributaries of the Yellowstone River: the Clark's Fork of the Yellowstone, the Stillwater, and the Lamar. The Lamar River flows through Yellowstone Park. Headwaters tributaries in the District that feed these three branches of the Yellowstone are Fisher Creek, Daisy Creek and Miller Creek. The other major named tributary streams in the District include Goose, Sheep, Lady of the Lake, Republic, Woody, and Soda Butte (Figure 1).

2.3 MINING HISTORY

Mining exploration in the District began in 1864 when prospectors from the mining camp of Virginia City explored the area. The earliest placer and lode deposits were prospected in 1869. In 1876, the Eastern Montana Mining and Smelting Company constructed a smelter in the Cooke City area and a portable smelter was reported to be in operation in the Miller Creek drainage. In 1883 the Republic Smelter was built for the reduction of silver-lead ore. It was located on the western end of town, on the south side of Soda Butte Creek. During these early years of development, the District was a part of the Crow Reservation. When the U.S. government withdrew this land from the reservation and put it into public ownership in 1882, interest in mining in the District heightened with the filing of 1,450 claims (Wolle, 1963).

Mining activity fluctuated greatly between 1882 and the late 1920's, hampered primarily by the lack of a railroad to ship ore and supplies, and the long and severe winters. Numerous smelters were built, although most only operated for a few years at a time. Gold was mined on Henderson Mountain beginning in 1888. During 1893 and 1894, gold was mined from underground workings and an open pit on Henderson Mountain (Reed, 1950). A road over Lulu Pass was built during 1905-1906 to reach a copper lode in the area of Goose Lake (URS, 1996).

A number of small mining companies operated underground mines that were developed in the early 1920s. The Glengarry Mining Company operated a flotation mill in the upper Fisher Creek drainage in the 1920s to process copper-gold ores from the Spaulding Tunnels located on the south side of Scotch Bonnet Mountain (Figure 3) (Reed, 1950). Later, in the mid-1920's, the Glengarry Mining Company drove an adit, the Glengarry Adit (Figure 3), from the base of Lulu Pass in the Fisher Creek drainage to intercept ore at depth along the mineralized structure of the Spaulding Tunnels. No ore-grade mineralization was encountered in this adit (Lovering, 1929). Prior to 1934, a southwest heading was driven from an underground location in the Glengarry Adit beneath the Como Basin, and a raise driven to surface in the massive sulfide of the Como deposit.

The Tredennick Mines were operated by the Tredennick Development Company on claims located on the southeast flank of Scotch Bonnet Mountain (Figure 3). The workings consist of three principal adits with about 419 meters (1,375 feet) of combined workings. The middle adit intercepted a narrow zone of copper-gold mineralization at the contact with Precambrian basement and the gabbro of the Scotch Bonnet intrusive complex. No significant production has occurred from any of the Tredennick workings (Lovering, 1929).

The Gold Dust Adit is located on the southwest side of the Fisher Creek Valley, near the break in slope forming the flank of Henderson Mountain (Figure 3). The adit was driven by Western Smelting and Power Company between 1920 and 1925 and drifts to the southwest for about 700 meters (2,300 feet). No production is recorded from the adit. By 1925, the estimated production of the District was $215,000 in gold, silver, copper, and lead (Wolle, 1963).

In 1933, a gold-copper-silver mining operation, the McLaren Mine, was developed on the west side of Fisher Mountain. Milling of the ore produced from this mine was done in Cooke City at the Cooke City Mill. The Cooke City Mill was a gravity/flotation mill that produced a concentrate that was then shipped through Yellowstone National Park to a railhead in Gardiner, Montana. With the destruction of the McLaren Mill by fire in 1953, mining in the District ceased. Total metal production from the New World District is 62,311 ounces of gold; 692,386 ounces of silver; 1,963,800 pounds of copper; 3,242,615 pounds of lead; and 920,200 pounds of zinc (Lovering, 1929; Reed, 1950; Eyrich, 1969; Wolle, 1963; Krohn and Weist, 1977). Nearly all of the gold and copper came from the McLaren Mine. Most of the lead, zinc, and a large portion of the silver came from mines in the Republic District south of Cooke City.

Extensive exploration of the area by a number of major mining companies for sedimentary rock-hosted massive sulfide, porphyry copper, and molybdenum continued from 1974 until 1996, with CBMI as the last major company to hold an interest in district. CBMI executed exploratory drilling programs in the District from 1987 to 1993.

2.4 DISTRICT GEOLOGY

The geology of the mineral deposits of the New World District was mapped and described by Lovering (1929) and the geology of the Cooke City Quadrangle was mapped by Elliott (1979). Reed (1950) described many of the mines and summarized production from the District. Additional information on alteration and mineralization in the District is available from theses by Eyrich (1969), Johnson and Meinert (1991), and guidebook articles by Johnson (1992) and Elliot et al (1992).

Precambrian basement rocks, predominantly granitic gneisses, are exposed over much of the northern and eastern part of the New World District, including the valley floor along upper Fisher Creek (Figure 4). Paleozoic sedimentary rocks consisting of sandstone, siltstone, shale, limestone, and dolomite unconformably overlie these basement rocks (i.e., Como Basin, southwest flank of Sheep Mountain, and northeast flank of Henderson Mountain). These sedimentary rocks generally dip gently to the southwest and are intruded by Tertiary (Eocene) felsic calc-alkaline stocks, laccoliths, sills, and dikes.

Figure 3 – Location Map showing Mines, Dumps, and Adits

Figure 4 – Geologic Map of the New World Mining District

There are four principle plutons in the New World District; from north to south these are: Scotch Bonnet Diorite, Fisher Mountain Intrusive Complex, Homestake Stock, and Henderson Mountain Stock. The upper Fisher Creek drainage lies between the intrusives of Scotch Bonnet and Fisher Mountain. Fisher Mountain and Homestake Intrusive complexes (Figure 4) exhibit concentrically zoned, porphyry-style alteration characterized by quartz-sericite-pyrite-chalcopyrite alteration assemblages. The intrusives were explored in the 1960s-1980s for porphyry copper and molybdenum.

Gold-copper-silver deposits in the New World District are of three principal types: 1) tabular, stratabound, skarn and massive sulfide replacement deposits hosted by the Meagher Limestone Formation of Cambrian-age (i.e., Como, McLaren, and Miller Creek deposits); 2) replacement (i.e., Fisher Mountain deposit) and vein-type mineralization along high angle faults and fractures (i.e. Spaulding and Tredennick deposits); and 3) sulfide and oxide replacement deposits of limestone clasts in diatreme and intrusion breccias (i.e., Fisher Mountain Intrusive Complex and Homestake Breccia Pipe deposit – the target of the Gold Dust adit). Late stage vein and replacement deposits of lead, zinc and silver that occur more peripheral to the district are also genetically related to these two stocks.

2.5 MINERALIZATION IN THE COMO BASIN/UPPER FISHER CREEK AREAS

Mineralization in the Como Basin and upper Fisher Creek areas is spatially, temporally, and genetically related to the emplacement and alteration of the Fisher Mountain Intrusive Complex. The following mineralized areas are discussed in this section: Como deposit, Fisher Mountain deposit, Small Como adit, and deposits associated with the Spaulding, Glengarry, Tredennick and Gold Dust Mines. Figure 4 is a geologic map of upper Fisher Creek and Figure 5 shows a stratigraphic section. Figure 6 is a cross-section through the Como Deposit. The line of section for Figure 6 is shown on Figure 7.

2.5.1 COMO DEPOSIT

The Como Basin and the Como sulfide deposit are located on the north side of Fisher Mountain (Figure 4). The gold-copper-silver-bearing skarn and massive sulfide replacement deposits of the Como Basin are stratabound and hosted primarily in the Cambrian Meagher Limestone (Figures 4, 5, and 6). The deposit occurs and is genetically related to hydrothermal alteration within the Fisher Mountain Intrusive Complex, which is in high-angle intrusive contact with the adjacent Cambrian-age sediments.

The block of Cambrian sediments in this area is completely surrounded by intrusive rocks of the Fisher Mountain complex to the south and east, and by intrusive rocks of the Lulu Pass dacite porphyry to the north and west (Figure 4). Based on relations described below from exposures in the Glengarry Mine, this block unconformably overlies Precambrian basement rocks. The resulting deposit is tabular, stratabound, and occurs within the gently southwesterly dipping (5-18 degrees) Meagher Limestone at distances from 0-180 meters (0-600 feet) north from the intrusive contact. The deposit is circular in plan view with a diameter of about 180 meters (600 feet) and is as much as 27 meters (100 feet) thick (Figure 6). The deposit varies in thickness from 0-27 meters (0 to 100 feet, the total thickness of the Meagher Limestone), is thickest in the sediments nearest the contact with the intrusive stock, and thins to selective bed replacement as distance from the intrusive stock increases to the north. The northern portion of the deposit has been removed by glacial and recent post-glacial erosion. The sulfide content of the massive sulfide ore is quite variable ranging from about 10 to 75%, and averages about 35%.

Fracture controlled stockwork vein-type mineralization occurs in the upper seven meters (20 feet) of the underlying Wolsey Shale (Elliot 1992) and considerable mineralization occurs in intrusion breccias containing numerous Meagher Limestone breccia clasts within and near the contact of the Fisher Mountain intrusive complex (Johnson and Meinert, 1994).

The massive sulfide replacement deposit in the Como Basin either outcrops at the surface or is covered with thin deposits of unconsolidated soil mixed with colluvial or slope-wash material. Much of the soil is weathered in place. Soil overlying the massive sulfide, replaced limestone of the Meagher Formation is rich in sulfide, skarn, and clay minerals.

Actual historical underground mining disturbances in the Como Basin consists of a raise to surface from the Glengarry Mine, a short adit driven in the northwest portion of the Como Basin (Small Como Adit), the three Spaulding Tunnels located on the south flank of Scotch Bonnet Mountain north of the Como Basin, and three very short adits (Cowboy Tunnel, Ice Tunnel, and the Blacksmith Tunnel) driven on the north flank of Fisher Mountain (above the Como Basin) (Figure 7). In addition, the collar of the raise from the Glengarry mine was accessed by very shallow (<20' deep) underground workings driven in a 5-foot thick bed of massive sulfide. Maps prepared by McLaren Gold Mines in 1938 also show a number of scattered prospect pits and trenches in the south central portion of the Como Basin area. Based on historical records and the extent of these early disturbances, it appears that, with the exception of the Spaulding Tunnels, no significant amount of material was ever mined or shipped from the Como Basin area.

In addition to historic mining, surface disturbances (2.23 Ha) in the Como Basin have also occurred as the result of at least three periods of exploration drilling (Figure 7), and associated access road and drill pad construction in the Como deposit area (Figure 7, and Figure 8 photo). The first two periods of exploration core drilling were completed in the 1970's and early 1980's by Bear Creek Exploration (an exploration subsidiary of Kennecott Minerals, 69 holes) and then by Ranchers Exploration (48 holes). Both companies grid drilled the Como deposit on about 25-foot centers. Bear Creek core holes were completed with a steel casing set just into bedrock and left in place with or without a welded cap. Ranchers Exploration core holes were left open upon completion, and the casing was removed. Crown Butte Mines completed about 2,553 meters (8,376 feet) of drilling in 48 holes (both core and reverse circulation drilling). Only about twelve of the Crown Butte drill holes were located and subsequently abandoned by backfilling the drill holes with bentonite prior to regrading the disturbed area.

Re-contouring of the Como deposit area obliterated the location of almost all exploration drill holes and no further remediation of the open holes is possible. Several observations can be made regarding the impact of open drill holes in the Como deposit area. All of the holes mentioned here were drilled for exploration purpose to evaluate mineralization in the Meagher Limestone hosted massive sulfide deposit. Because of this, most holes are shallow (<125 feet) and were drilled through the Meagher Limestone and are completed in the relatively impermeable underlying Wolsey Shale. Therefore, shallow ground water is not likely to flow into deeper bedrock formations through the Wolsey shale, which is some 55 meters thick. Lateral flow in the bedrock Meagher Limestone is also probably restricted because of intense silicification and recrystallization of the limestone by the mineralizing hydrothermal solutions. This is fairly well document by observations in the three shallowest horizontal levels of underground working in the Glengarry raise (at 35, 70 and 125 feet below the surface). Each of these drifts is driven in Meagher Limestone with or without crosscutting intrusive rocks. Fracture flow observed in the shallow underground workings ranged from 0.002 to 0.1 gpm indicating very low fracture permeability. By contrast, flow in the Como Basin along the colluvial-bedrock contact was observed to be about 10 gpm where it was intersected by the raise collar and flowed down the raise (a three order of magnitude difference in flow rates). In addition most of the copper contamination flowing from the Glengarry portal was identified as coming from this later source.

Figure 5 Generalized stratigraphic section of the New World District.

Figure 6 - Cross section of the Como deposit – Figure 13 1990 Year End Report Noranda.

FIGURE 7 – Glengarry Adit and Como Basin Vicinity Map

Figure 7 page 2

Figure 8. Photo of Exploration Disturbances on Fisher Mountain

The Small Como Adit was a collapsed adit in the northwest portion of the Como Basin (Figure 7). The portal was backfilled with rock and the small waste rock dump removed as part of a 2001 Selective Source Removal Action (Maxim, 2001a). Closure of the site was accomplished by regrading the slope following waste rock removal, and revegetating the removal area.

2.5.2 FISHER MOUNTAIN DEPOSIT

The Fisher Mountain Deposit is located between the Como and McLaren Deposits. It differs from other deposits in the district in several respects. The formation and localization of this deposit is controlled by the location of the laterally extensive Crown Butte Fault zone and its proximity to the Fisher Mountain Intrusive Complex. The deposit consists of both sulfide-rich fracture fillings along the fault, and quartz-pyrite replacement deposits in the Pilgrim Limestone on the west side of the fault, high on the northwest flank of Fisher Mountain. The deposit is blind (not exposed on the surface) and was never mined, so there are no wastes associated with this deposit. As such, this deposit has the potential to be a groundwater migration pathway into the Como Basin area for mineral-rich, acidic water. Mineralization in the fault zone contains as much as 90% sulfides, most of which is unconsolidated.

The northern part of the McLaren deposit is bounded and down-dropped along the Crown Butte Fault (Figure 4). The Crown Butte fault is a major north-south trending dip-slip fault within the New World District. Sedimentary rocks to the west of the fault in the vicinity of the McLaren deposit have been down-dropped as much as 85 meters (280 feet) relative to the same units to the east.

2.5.3 Spaulding Tunnels

Prior to 1925, the Glengarry Mining Company initially had operations on the south-facing flank of Scotch Bonnet Mountain, immediately northeast of Lulu Pass (Figures 3 and 7). On old historic mine maps these workings are called the Spaulding Tunnels. The Spaulding Tunnels consist of three short adits at different elevations, the lower two of which are connected by a winze.

In 1990, Crown Butte Mines, Inc. drilled five reverse circulation holes in the vicinity of the Spaulding Tunnels. The mineralization in the vicinity of the workings was found to contain very large breccia fragments (greater than 50 feet in diameter) of sedimentary rocks within the northern extension of the Crown Butte Fault Zone.

At some time in the past, the upper adit (95 meters, 310 feet long) and lower adit (96 meters, 315 feet long) portals were backfilled with waste rock. The middle adit (60 meters, 200 feet long) was accessible for about the first 15 meters (50 feet), where a cave had blocked the workings. The lower Spaulding adit has, at least recently, discharged a small amount of water (0.4 to 7.5 liters per minute [lpm], 0.1 to 2.0 gallons per minute [gpm]). Waste rock dumps at the Upper, Middle and Lower Spaulding adits were removed during August 2001 for the Selective Source Response Action (Maxim, 2001a) and disposed in the SB-4B on-site repository. In spite of these recently completed reclamation activities, these workings remain as potential conduits for groundwater migration into the Como Basin and upper Fisher Creek along the Crown Butte Fault.

2.5.4 Glengarry Adit

Subsequent to the development of the Spaulding workings, the Glengarry Adit, was driven by the Glengarry mining Company, from about one-half mile east-southeast of the Spaulding workings, and lower down (9,320 feet in elevation) in the Fisher Creek drainage (Figure 3). This adit was actively being driven in 1925 (Lovering, 1929). The adit was driven some 700 meters (2,300 feet) towards Lulu Pass and attempted to intercept mineralization beneath the Spaulding Tunnels (Figure 3). No mineralization was found at the level of the Glengarry Adit (Lovering, 1929).

In the early 1930's (workings appear on maps dating 1934), the southwest drift of the Glengarry Adit was driven some 183 meters (600 feet) to come in under mineralization identified at the surface in the Como Deposit (Figures 3 and 4). Two sets of raises were driven from this drift. The second set of raises came to surface in the base of the Como deposit (about 130 meters, 425 vertical feet). The first set of raises appears from old maps to have been abandoned after raising some 15 meters (50 feet) above the floor of the drift. Both sets of raises at least seasonally make a considerable amount of water (as much as 38 liters per minute, 10 gpm) that flows out of the Glengarry Adit and into upper Fisher Creek.

The Glengarry Adit was partially re-opened by the Montana Bureau of Mines and Geology for the Montana Department of Natural Resources and Conservation (DNRC) in the mid-1970's to evaluate the mine for possible closure (DNRC, 1974). The USDA-FS reopened the Glengarry Adit in 2000, and the raise to surface in the Como Basin was partially reopened in 2001. Reopening work and a description of conditions found in the raise are discussed below.

2.5.5 TREDENNICK MINES

The Tredennick Mines were operated by the Tredennick Development Company on claims located on the southeast flank of Scotch Bonnet Mountain (Figure 3). The workings consist of three principal adits with about 418 meters (1,375 feet) of combined workings. The upper adit is short and only drives about 38 meters (125 feet) to the northeast along a narrow pyrite-rich vein in Precambrian granite, beneath a topographic bench capped by Flathead Sandstone. The middle adit (128 meters, 420 feet long) intercepted a narrow zone of copper-gold mineralization at the contact with Precambrian basement and the gabbro of the Scotch Bonnet intrusive complex. The lower adit with more extensive workings (246 meters, 810 feet) was attempting to drive to the north-northeast to intercept mineralization beneath the middle adit workings at depth. The adit was not completed to its targeted distance, and therefore drives for all of its length in unmineralized or weakly mineralized rock. Although these three mines are named the same, they occur in distinctly different mineralized zones. A number of other short adits lying at higher elevations on Scotch Bonnet Mountain were also affiliated with the Tredennick Mines. No significant production has occurred from any of the Tredennick workings.

Adit seeps and mine wastes were present at all three adit portals. Waste rock dumps at the Upper, Middle and Lower Tredennick adits was removed during August and September of 2001 for the Selective Source Response Action (Maxim, 2001a) and disposed in the SB-4B repository.

Closure of the upper, middle, and lower waste rock dumps was accomplished by regrading and revegetating the removal area. The upper portal was backfilled with rock. As a result of these recently completed reclamation activities, these workings remain to be potential conduits for groundwater migration into upper Fisher Creek.

2.5.6 GOLD DUST ADIT

The Gold Dust Adit is located on the southwest side of the Fisher Creek Valley, near the break in slope forming the flank of Henderson Mountain (Figure 3). Western Smelting and Power Company owned and operated the Gold Dust Adit as one of its three mines driven in Henderson Mountain to explore copper-gold-silver mineralization in the vicinity of what was later to be identified as the Homestake Breccia Pipe (Figure 4). The adit was driven between 1920 and 1925 and drifts to the southwest for about 700 meters (2,300 feet). About 457 meters (1,500 feet) from the portal, the adit splits into two headings: one that continues to the southwest, and another that trends in a more southerly direction. No production is recorded from the mine. A waste rock dump is present at the portal of the Gold Dust Adit that contains approximately 4,330 cubic meters (5,700 cubic yards) of material.

CBMI rehabilitated the Gold Dust Adit portal and underground workings to construct drill stations. In 1992 and 1993 angle holes were drilled from these stations to delineate mineralization in the lower portion of the breccia pipe. The mine portal and underground workings were rehabilitated to gain access and to cut four new drill stations. The mine was mapped geologically during the rehabilitation work and water sources were identified and sampled. Approximately 7,111 meters (23,331 feet) of drilling were completed in 23 drill holes. Drill holes that were making water when drilled were closed with mechanical packers. The portal was closed with a series of lagged timber sets and a locking steel gate. The mine made water prior to being rehabilitated by CBMI and continues to make a similar amount of water today.

Water presently flows from the portal of the Gold Dust Adit at an average rate of about 41 liters per minute (10 gpm). Water quality is not degraded in the workings, but water quality deteriorates (lower pH) as water flows over the top of, and seeps through the waste rock dump at the mine portal. There are no metal analyses of seepage through the waste rock dump, however, samples from the adjacent tributary of Fisher Creek show no metal impacts up or downstream of the waste rock dump.

2.6 REOPENING THE GLENGARRY MINE

The Glengarry Mine was rehabilitated for assessment purposes under response and restoration activities initiated by the USDA-FS, because it is one of the principal sources of metals loading in the headwaters of Fisher Creek. Eighty seven to 215 lpm (23 to 57 gpm) of low pH, iron-, zinc-, and copper-bearing water discharges from the Glengarry Adit into Fisher Creek.

The Glengarry Mine consists of 933 meters (3,060 feet) of drifting and two nearly vertical raises. One of the raises extends 130 meters (425 feet) upward and surfaces in the Como Basin at the foot of the north flank of Fisher Mountain. The top of this raise passes through the massive sulfide deposit in the Meagher Limestone formation.

The Glengarry drift was reopened for assessment in September and October 2000. During this phase of reopening and assessment, accumulated debris and ferricrete mud two to five feet deep were removed from the drift beginning at the portal and extending back to a "Y" intersection 470 meters (1540 feet) in from the portal. The two branches of the "Y" were made accessible, but debris and ferricrete were not removed from the drift beyond the intersection. The Glengarry workings were surveyed and a planimetric map produced (Figure 9).

In the heading extending southwest from the "Y" intersection, two raises are present. At 570 meters (1,875 feet) in from the portal, a three-compartment timbered raise extending vertically upward was encountered. Timber debris cluttered the bottoms of the raise compartments and approximately 68 lpm (18 gpm) of water flowed down the raise. A map dating from the 1930's shows this raise extending upward approximately 15 meters (50 feet).

At the end of the southwest heading, 655 meters (2,150 feet) in from the portal, a timbered two-compartment raise extending vertically upward was encountered. Approximately 1.0 to 2.0 gpm of water were observed flowing from the bottom of this second raise. A substantial air flow came down the raise on warm days. Access into the bottom of the raise was blocked by timber lagging as well as sand and gravel five feet deep in the drift. The map dating from the 1930s shows the second raise extending vertically to the surface.

The following year, in June 2001, the second raise that extends into the Como Basin was reopened and repaired to a depth below the base of the Meagher Limestone. The second raise consisted of two square-set compartments. Old ladders and debris were removed from the north compartment. New ladders and landings were installed down to a depth of 65 meters (215 feet) below the surface. Three separate short horizontal workings were encountered in the Meagher Limestone at 10 meters (35 feet), 23 meters (75 feet), and 30 meters (100 feet) below the surface. A small room with two pneumatic hoists was also encountered at 65 meters down. No significant water inflows were encountered below the middle of the Meagher Limestone at about 14 meters (47 feet) below the surface.

Figure 9 – Glengarry Adit

Figure 9 back page

Each horizontal level and the raise down to 65 meters were surveyed and the geology was mapped. Water inflows were measured and sampled at the collar of the raise and at each horizontal level during July and August 2001. Water was also sampled at the contact of overburden with bedrock (Park Shale) in the exposed wall of the excavation during re-construction of the raise collar.

Later in 2001, debris was removed from below the first raise in the Glengarry drift, and temporary ladders were installed up the middle compartment of the first raise. The purpose of this work was to determine whether the top of the raise was open or if it extended beyond the 50 feet shown on the 1930's map. Debris was removed, and aluminum ladders were nailed in place extending approximately 8 meters (25 feet) up the center compartment. From there a round timber bulkhead was seen at the same elevation as the other two bulkheads in the adjacent compartments. Removing the bulkheads to determine what was above them or to identify the source of the water inflow was considered too dangerous.

All of the accessible workings were mapped planimetrically for spatial control and then geologically to identify geologic units, structures, mineralization and points of water inflow. These data, together with the geologic logs of adjacent exploration holes drilled by CBMI, were used to develop a model of the geology around the raise. At least two intrusions and two faults within close proximity to the raise were identified and can be correlated both vertically and laterally. Cross sections looking north and looking west depict the geology around to the raise (Figure 9).

2.7 CLIMATE

The New World District has a continental climate modified by the mountain setting. It is characterized by large daily and annual temperature ranges and marked differences in precipitation, temperature, and wind patterns over distances of only a few kilometers.

Precipitation and temperature data have been collected periodically at Cooke City from 1967 through 1995 (EarthInfo, 1996). The Cooke City station is located at an elevation of 2273.8 meters (7,460 feet). The average annual precipitation for the period of record is 645 millimeters (mm) (25.38 inches). Temperatures are coldest in January with an average minimum of -16.5ºC (2.4ºF) and an average maximum temperature of –4.8ºC (23.3ºF.) Temperatures are warmest in July with an average minimum temperature of 3.3ºC (37.9ºF) and an average maximum temperature of 22.8ºC (73.1ºF.)

Precipitation and temperature vary with elevation, and freezing conditions can occur any day of the year. Precipitation records from a Natural Resources Conservation Service SNOTEL Station TX06 at an elevation of 2,770 meters (9,100 feet) in the Fisher Creek drainage indicate that the average annual precipitation at this location is 1,500 mm (60 inches). Fifty percent of the annual precipitation occurs between October and February, with January being the highest average precipitation month (14.4 percent) and August having the lowest average monthly precipitation (3.9 percent) (URS, 1998). Average annual snowfall at higher elevations is about 13 meters (500 inches) (USDA, 1975).

A meteorological station was maintained in upper Fisher Creek near the proposed mill site for various periods during exploration activities by CBMI. Data collected from this site for the period May 1992 through August 1993 indicate an average wind speed of 2.4 meters/second (5.4 miles/hour) and a prevailing direction from the northwest (Gelhaus, 1993).

2.8 HYDROLOGY AND HYDROGEOLOGY

Surface water resources in the District are comprised of three separate watersheds: Daisy Creek (a tributary of the Stillwater River), Fisher Creek (a tributary of the Clarks Fork of the Yellowstone River), and Miller Creek (a tributary of Soda Butte Creek and the Lamar River) (Figure 1).

The upper portion of the Fisher Creek drainage basin collects water from the east side of Lulu Pass, the north and east flank of Fisher Mountain, the south flank of Scotch Bonnet and Sheep Mountains and from the Como Basin. Fisher Creek flows southeastward from its origin below Lulu Pass and is joined by a few small-unnamed tributaries in the stretch from the Glengarry Adit to below the east flank of Henderson Mountain. Further downstream (southeast), Fisher Creek is joined by Lady of the Lake Creek and the Broadwater River, both of which flow from the north. Below the confluence with the Broadwater, the river becomes the Clarks Fork of the Yellowstone. From here the Clarks Fork flows east through the Sunlight Basin in Wyoming, and out through the mountain front, where it turns north and joins the Yellowstone River near Laurel, Montana.

The drainage basin of Upper Fisher Creek (Figure 3 Study Area) comprises 970 hectares (2,400 acres). Upper Fisher Creek is characterized by rapidly increasing flow rates and short periods of sustained flow during snowmelt. As much as 90% of Fisher Creek's discharge volume occurs between mid May and early August. Discharge rates near the upper reaches of Fisher Creek range from less than one cfs in late winter to over 50 cfs during peak snowmelt. During the period 1989 to 2001 at Station CFY-2, which is located just above the confluence of Lady of the Lake Creek, measured flows in Fisher Creek range over four orders of magnitude, from 2.6 cubic meters per second (m^3/s) (91 cfs) to 0.003 m^3/s (0.091 cfs). Fisher Creek water quality is impacted by a combination of acid rock drainage from the Como Basin massive sulfide deposit , outflow from the Glengarry Mine workings, by other smaller waste dumps in the Fisher Creek headwaters and by naturally occurring acid rock drainage (URS, 1998).

Surface water discharge in the area is quite variable and seasonally dependent. All three of the principal watersheds within the District exhibit rapid flow response to snowmelt and summer precipitation events. Rain on snow events typically produce major spring and early summer peak runoff events. Significant diurnal variations in flow also occur, particularly during peak snowmelt periods. Although a substantial number of summer and fall flow measurements have been made in the Fisher Creek drainage, winter and spring flow measurements have largely been restricted to those made at selected locations during the 1974-75 hydrograph year, a few late spring measurements made in 1995 (URS, 1998), and a few measurements made in January and late April by the USDA-FS (Maxim, 2002, 2001c, 2000).

Groundwater occurs in two hydro-stratigraphic units in upper Fisher Creek: surficial unconsolidated alluvial and colluvial deposits localized along drainages and fractured bedrock. Unconsolidated deposits that host groundwater consist primarily of as much as a 16 meter (55 feet) thick layer of alluvial/colluvial material covering the Como Basin (more typically 1.5 to 10 meters and average 3.4 meters), narrow strips of alluvial/colluvial material deposited parallel to tributary streams that feed the upper portion of Fisher Creek, and a broader expanse of alluvial valley fill downstream of the Glengarry Adit portal. Groundwater within unconsolidated sediments is recharged by direct infiltration of surface runoff and in some areas by discharge from bedrock fractures. Groundwater flow within unconsolidated material is parallel to topographic slope. Most alluvial groundwater discharges to Fisher Creek.

Recharge to bedrock occurs primarily as direct infiltration of snowmelt and runoff into fractures. In the Como Basin, groundwater from overlying colluvium infiltrates directly into bedrock. Significant fluctuations in groundwater levels in monitoring wells completed in bedrock are observed as a result of this annual spring recharge event. The regional hydraulic gradient in bedrock is expected to follow topography from Lulu Pass, Fisher Mountain, and Scotch Bonnet Mountain toward Fisher Creek. A man-made recharge source is present where near-surface colluvial groundwater flows down the Como raise into bedrock exposed in the Glengarry workings (Figure 9).

The primary porosity of bedrock units throughout the District is limited. As a result, unfractured bedrock transmits very little groundwater flow. Aquifer tests on wells completed in Precambrian granite within the Como Basin yielded an average hydraulic conductivity estimate of 5 x 10^{-5} centimeters per second (cm/sec) (Kirk, 1995). A packer test in Tertiary intrusive rocks in the District yielded hydraulic conductivity estimates ranging from 1 x 10^{-4} to 3 x 10^{-5} cm/sec (Kirk, 1995). These values reflect fractured areas of rock. Unfractured rocks of these types would be expected to exhibit much lower hydraulic conductivity values.

Hydraulic conductivity values are largely reflective of the degree of fracturing and interconnectedness of fractures in the bedrock. For example, during one pumping test performed on well MW-5P located in the Miller Creek drainage at the base of Daisy Pass (Huntingdon, 1995), drawdown of approximately one meter (3 feet) was measured after it was pumped for 150 minutes at 397 lpm (105 gpm), and little if any draw down was observed in the observation wells. Well MW-5P is completed in Wolsey shale within a zone of fractures along the Crown Butte Fault. Observation wells MW-5B and MW-5C are completed within approximately 100 feet of the pumping well. During one test, Aquifer transmissivity could not be quantified by the pumping test but it did demonstrate that fractures associated with faults are capable of transmitting large volumes of groundwater in the plane of the fault, but, at least in this case, very little at right angles to the fault. A pump test was also conducted on well MW-11P, located 427 meters (1,400 feet) north of well MW-5P. This well is completed in less fractured Meagher limestone and Wolsey shale. The pump testing of this well demonstrated that unfractured bedrock is much less transmissive. Well MW-11P went dry with 5 meters (17 feet) of drawdown after pumping for two minutes at 11 lpm (3 gpm) (Huntingdon, 1995).

Fractures in bedrock create a high degree of anisotropy that controls local and regional groundwater flow. Although the regional hydraulic gradient generally follows topography, anisotropy due to fracture orientation creates preferential flow paths that often cut across potentiometric gradients. A groundwater tracer study conducted in the area in 1997 and 1998 (URS, 1998) demonstrated that groundwater can flow quite rapidly across topographic divides between drainage basins. The groundwater tracer data further demonstrated that there is large north-south component of flow near the Crown Butte fault. Groundwater velocity along fracture traces is probably several orders of magnitude greater than within unfractured bedrock.

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3.0 SOURCE, NATURE, AND EXTENT OF CONTAMINATION

Numerous environmental samples have been collected from mine wastes and mine discharges present in the headwaters of Fisher Creek to identify the source, nature and extent of contamination. The data used to support this EE/CA include the following: geochemical analyses of mine waste samples collected from waste rock dumps; water quality information from surface water, adit discharges, and groundwater sources; geochemical loading calculations; modeling of precipitation through soil and waste; and, stream sediment data.

The examination of source, nature, and extent of contamination in the Fisher Creek watershed begins with a discussion of the conceptual model. Details and supporting information concerning specific sources are contained in subsequent sections.

3.1 CONCEPTUAL MODEL

This section describes the current conceptual model for contaminant sources and movement of metal contaminants into Fisher Creek. Presentation of this conceptual model provides a framework for reviewing environmental impacts and understanding the benefits and consequences of potential cleanup alternatives. The conceptual model covers surface and groundwater flow, hydrogeology, and fate and transport of metal contaminants. Two block diagrams present major elements of the conceptual model for the Fisher Creek headwaters upstream of the Gold Dust Adit tributary (Figure 10) and for the Como Basin and Glengarry Adit (Figure 11).

The majority of precipitation within the area falls as snow in the fall, winter, and spring. Precipitation as rain occurs in early summer. The drainage area that comprises the disturbed soils of the Como Basin is about 7 hectares (17.4 acres) and is shown on Figure 7. The drainage basin for upper Fisher Creek is 970 hectares (2,400 acres) and is shown on Figure 3. Upper Fisher Creek is characterized by rapidly increasing flow rates and short periods of sustained flow during the snowmelt event. As much as 90 percent of Fisher Creek's discharge volume occurs between mid May and early August. Fisher Creek and its tributaries receive base flow from groundwater seepage from unconsolidated sediments and fractured bedrock. Discharge from adits at the Glengarry, Gold Dust, Spaulding Tunnels, and Tredennick mine sites contribute varying amounts of flow to Fisher Creek.

Recharge to groundwater in unconsolidated sediments comes from direct infiltration of snowmelt, runoff, and discharge of water as springs from bedrock adjacent to or beneath alluvial material. Alluvial groundwater discharges to underlying bedrock in the Como Basin through infiltration into fractures and direct drainage into the Como raise. Downstream of the Como Basin, shallow colluvial-hosted groundwater discharges directly to Fisher Creek. Recharge to bedrock occurs primarily as direct infiltration of snowmelt and runoff, particularly where fractures or faults are exposed at the surface, such as along the Crown Butte fault. In the Como Basin, groundwater from the overlying colluvium infiltrates directly into bedrock.

The portion of the Como Basin disturbed by exploration activities accounts for a significant portion of the District's total waste rock. However, in-situ massive sulfide deposits within the basin are the ultimate source of contaminants. This massive sulfide deposit is thinly veneered by weathered in-place metal-rich soils and colluvium in the Como Basin (Figure 11). The Como deposit contains some 750,000 million metric tons of in-place, massive sulfide and replacement deposits present in the Meagher Limestone at depths from 0 to 30 meters (0-100 feet).

Massive sulfide deposits are exposed to atmospheric oxygen within mine workings and along natural faults and fractures. The deposits are enriched in sulfide minerals, principally pyrite and chalcopyrite, with varying amounts of base and precious metals (gold (Au), silver (Ag), copper (Cu), lead (Pb), zinc (Zn), molybdenum (Mo), tellurium (Te), among others). When exposed to oxygen, in either mine workings or in oxidizing groundwater occupying shallow bedrock fractures, these sulfide minerals oxidize, releasing sulfate, iron, and acidity, which in turn increases the solubility of metals. In deeper bedrock fractures, iron is transported in a reduced state (Fe^{2+}), a state in which it is about three orders of magnitude more soluble than in the oxidized state (Fe^{3+}). Because of this relationship, reduced groundwater can carry very large amounts of iron, that is rapidly and readily oxidized and precipitated when it comes into contact with atmospheric oxygen in either mine workings or as seeps or springs. This is likely the reason so much oxidized iron as iron hydroxides is present in underground workings, in ferricrete deposit associated with springs, and in terrace deposits, as shallow groundwater flows into creeks throughout the New World District. Surface water runoff and shallow groundwater ultimately transport these metals to streams (Figure 10).

The principal mechanisms of transport of contaminants within the mining district include the following:

- Physical erosion, transport and deposition of materials by runoff and surface water.
- Dissolution of contaminants into surface runoff, from primary mineralization or secondary sedimentary deposits.
- Infiltration of runoff containing dissolved metals into soil and groundwater.
- Movement of contaminated water through open underground mine workings and improperly abandoned exploratory borings.
- Contaminated groundwater discharge into surface water.
- Contaminated surface water inflow to groundwater.
- Precipitation of iron and aluminum mineral phases with adsorption of trace metals in Fisher Creek along its flow path.
- Scouring of secondary minerals and remobilization metals.

Physical erosion of materials occurs where waste rock, metal-rich soils, or roadbed material is exposed at the surface, such as at mine dumps at the mouth of the Glengarry and Gold Dust adits or disturbed soils in the Como Basin. Surface runoff carries metal-laden sediments to stream channels, where sediments are entrained in the bedload of the stream. Mobility of metals in the streambed is dependent on the chemistry of water in the stream.

Metals will dissolve into surface water flowing across metal-laden material exposed at the surface. Metal bearing minerals in surficial materials are generally oxidized by exposure to water and atmospheric oxygen, which releases soluble metal salts that are highly mobile under acidic conditions. In addition, slope-wash from snowmelt or rain exposed to contaminated surface material will dissolve metals and transport them laterally to an adjacent stream or downward into underlying soil and groundwater. This occurs where sulfides are exposed at the surface (such as in the Glengarry waste rock dump) or in surface disturbances of metal-rich soils overlying sulfide mineralization (such as in the Como Basin).

Groundwater can enter underground mine workings where the workings intersect saturated bedrock fractures transmitting groundwater (Figures 10 and 11). The addition of atmospheric oxygen within the workings can enhance the dissolution of metals. Mine workings frequently act as conduits for groundwater, allowing water collected underground to discharge directly to surface water. This has

Figure 10 – Big Block

Figure 11 – Small Block

occurred within the Glengarry, Gold Dust, Tredennick and Spaulding Tunnels as well as other underground workings in the District.

Groundwater can transport dissolved contaminants to surface water at seeps and springs (such as along Fisher Creek between the Glengarry Adit and surface water site SW-3) or anywhere else where groundwater directly discharges to Fisher Creek (Figure 10). Surface water can also transport metals to groundwater as it infiltrates into the ground.

One of the principal controls of water quality in the lower reaches of Fisher Creek is precipitation of iron and aluminum oxyhydroxide minerals, with co-precipitation and adsorption of metals to these mineral phases. These reactions control the concentration of metals in the stream, maintaining equilibrium between secondary metal oxyhydroxides and dissolved metals in the overlying water column. Although removing the major source of contaminants present in seepage from the Como Basin and Glengarry Adit discharges by implementing response and reclamation alternatives would significantly reduce metal and acidity loading to Fisher Creek, it may not have the impact on water quality as measured by concentration at intermediate distances downstream. However, cleaning up these sources will reduce the load in the upper reaches of Fisher Creek and likely considerably improve water quality in the lower reaches of the stream as well.

The mechanisms described above contribute to the degradation of water quality in Fisher Creek. Metals loading investigations by Kimball and others (1999) and Amacher (1998) indicate that four distinct surface water sources in the upper 500 meters of Fisher Creek supply the majority of the contaminant load to the creek (Figure 10). The four surface water sources are:

- Outflow from the Glengarry Adit (F-8A)
- A tributary draining the northeastern flank of Fisher Mountain (FCT-12)
- A tributary draining the Como Basin (FCT-11)
- Seepage from the Glengarry Adit waste rock dump (FC-2)

Amacher (1998) determined that two other tributaries draining runoff from Fisher Mountain (FCT-1 and FCT-14) also contribute an appreciable portion of copper load to Fisher Creek (Figure 10). The flow of FCT-11 contributes all of the runoff from the Como Basin, flowing seasonally above a low permeability ferricrete surface. As a result, the flow of water from FCT-11 is representative of seepage flow and chemistry for the Como Basin. The remaining load of contaminants reporting to Station SW-3 can be attributed to the influx and mixing of groundwater along Fisher Creek, but it is difficult to identify specific areas where groundwater with low pH and high metals are discharging. This significant groundwater component is estimated to represent as much as 40% of the total load to Fisher Creek during high flow. Therefore, removal of key surface water sources may not result in full restoration of water quality. There should, however, be substantial reductions of metal and acidity loading from source areas.

There is considerable temporal variation in the relative contribution of the four major sources from snowmelt to base-flow conditions. In late April and early May, under base-flow conditions, the Glengarry Adit accounts for most of the dissolved copper load to upper Fisher Creek. As snowmelt begins in May and proceeds into July, runoff from Fisher Mountain and Como Basin account for most of the dissolved copper load. In the fall, the Glengarry Adit again accounts for majority of the copper load. Portions of the water flow from each of these sources flows onto and infiltrates into the Glengarry waste rock dump before rejoining Fisher Creek. Through the snowmelt season, the load contribution for metals from groundwater is significant and of a much larger magnitude than during lower flow periods. On an annual basis, the largest point sources high in the drainage (Glengarry Adit, FCT-11, FCT-12, and the

Glengarry waste rock dump) contribute about 65 to 70% of the total copper load at surface water Station SW-3.

As water flows down Fisher Creek, less acidic surface and groundwater with more alkalinity enters Fisher Creek and changes the chemistry of the water, raising the pH and diluting metal concentrations. As a result, settling of colloidal metals and co-precipitation of dissolved metals with ferric-hydroxides produce an overall improvement of water quality so that water quality impacts at CFY-2 are very minor for most of the year. Since the cleanup project began in 1999, no temporary standards have been exceeded at this downstream station. Since 1999, copper concentrations have fallen below chronic aquatic standards during winter base flow conditions at Station CFY-2 and zinc concentrations are below both the chronic and acute aquatic standards. During base flow conditions in the fall, only copper has exceeded acute or chronic aquatic standards at this station.

3.2 MINING RELATED CONTAMINANT SOURCES IN FISHER CREEK

Contaminant source areas included in the Como Basin/Glengarry Adit/Fisher Creek Response Action were inventoried and prioritized using the Abandoned and Inactive Mines Scoring System (AIMSS). This modified hazard ranking system (HRS) was developed for the Montana Department of Environmental Quality (MDEQ) Mine Waste Cleanup Bureau (Pioneer, 1995) to prioritize abandoned mine sites in Montana. AIMSS scoring was completed on about 190 source areas using data collected in 1996, 1999, 2000, and 2001. Table 3-1 lists the sites located in the Fisher Creek Drainage. Appendix A contains the site inventory forms.

The AIMSS system ranks waste sources relative to each other using site-specific data and the HRS scoring algorithm. In preparing these AIMSS rankings, four distinct exposure pathways were evaluated -- groundwater, surface water, air, and direct contact. For each exposure pathway, three factors are evaluated: 1) likelihood of release; 2) waste characteristics; and, 3) potential receptors. The scores for the three factors are multiplied to derive a pathway score. Pathway scores are weighted more heavily toward certain situations and types of impacts. Higher weights are ascribed to the following: observed releases to groundwater and surface water, especially where an exceedance of a standard is documented; sources that are closer to a population base; and, high contaminant concentrations, large contaminant quantities, and/or large areas of disturbance.

As shown in Table 3-1, the highest ranked source area in Fisher Creek is the Glengarry Dump, which ranks as No. 15 in the prioritized list of sites located on District Property. Several of the sites in Fisher Creek that are shown in the table were reclaimed for the Selective Source Response Action (Maxim, 2001a) including: Lower, Middle, and Upper Spaulding Dumps; Lower, Middle, and Upper Tredennick Dumps; and, Small Como Dump. The Gold Dust Mine and Dump is ranked No. 24, and the Como Basin is ranked No. 27. The Gold Dust is ranked slightly higher than the Como Basin because of the adit discharge, which increased considerably the groundwater pathway score (Table 3-1). Over half of the dumps are ranked lower than No. 70, which is the rank where all pathway scores are less than 1,000 and the total score is less than 0.01. The Glengarry Dump total score is 0.76.

Table 3-1
Fischer Creek Source Area Ranking
New World Mining District Response and Restoration Project
Glengarry/Como/Fisher Creek Response Action EE/CA

Site No.	Site Name	Other Name	Material Type	Volume (cubic meters)	Area (hectares)	Mine Drainage	Flow (GPM)	Ground Water Pathway	Surface Water Pathway	Air Pathway	Direct Contact Pathway	Total Score	Rank
FCSI-96-2A	Glengarry Dump	Lower Glengarry	waste	9880	0.43	adit, toeseep	20	30599.19	45272.86	10.94	34.50	0.7592	15
FCSI-99-1	Sheep Mountain Dump One		waste	140	0.05	adit, toeseep	10	27621.06	1077.57	1989.84	167.06	0.3086	21
FCSI-96-4	Glengarry Adit and Mill Site	Lower Glengarry	waste	380	0.23	adit, toeseep	5	7196.83	16535.51	488.62	40.22	0.2426	22
FCSI-96-8	Lower Spaulding Dump		reclaimed	2000	0.13	cladit	2	10910.38	10914.66	1262.51	49.89	0.2314	23
FCSI-96-1A	Gold Dust Mine and Dump	Gold Dust	waste	4330	0.22	adit, toeseep	15	14656.89	6223.54	60.29	5.27	0.2095	24
FCSI-96-5	Lower Trendennic Dump One		reclaimed	2610	0.16	cladit, toeseep	5	7581.55	6085.50	171.62	15.28	0.1385	26
FCSI-99-11	Como Basin	Lulu, Upper Lulu Adit	disturbed	22040	3.43	none	0	6314.86	5928.05	48.80	38.51	0.1233	27
FCSI-99-70	Henderson Mountain Dump Nine		waste	150	0.17	none	0	6231.53	158.64	2929.45	245.98	0.0957	31
FCSI-99-71	Henderson Mountain Dump Ten		waste	110	0.02	adit	1	9060.25	163.49	301.90	25.36	0.0955	32
FCSI-96-7	Upper and Middle Spaulding Dump	Upper Glengarry Mine	reclaimed	560	0.11	none	0	4561.46	3103.74	1219.43	69.53	0.0895	33
FCSI-99-74	Henderson Mountain Dump Fourteen	Elizabeth Mine	waste	90	0.28	none	0	6006.60	83.79	1547.28	130.20	0.0777	35
FCSI-96-15-2	Upper Trendennic Dump Two	Commonwealth #1	reclaimed	240	0.03	seep	1	4393.67	3027.49	157.65	8.86	0.0759	36
FCSI-99-101	Henderson Mountain Dump Nine-A		waste	80	0.08	none	0	3252.31	45.76	2816.60	234.99	0.0635	38
FCSI-99-53	Henderson Mountain Dump Four		waste	60	0.11	none	0	2558.21	47.59	2929.45	245.98	0.0578	40
FCSI-99-76	Sheep Mountain Shaft and Dump	Sheep Mountain Shaft	waste	50	0.04	none	0	4218.90	164.57	1012.96	85.06	0.0548	42
FCSI-99-62	Henderson Mountain Dump Six		waste	150	0.04	none	0	4461.58	82.87	153.03	12.87	0.0471	44
FCSI-96-6	Middle Trendennic Dump One	Manhattan	reclaimed	620	0.11	cladit, toeseep	2	1984.21	1728.76	467.99	39.99	0.0422	45
FCSI-96-18	East Henderson Pit	Schiller #1	waste	10	0.03	none	0	2741.85	51.04	942.50	79.09	0.0381	49
FCSI-99-68	Henderson Mountain Dump Seven	Fisher Creek No. 1	waste	210	0.04	adit	2	3466.95	63.62	117.48	10.00	0.0366	51
FCSI-99-102	Henderson Mountain Dump Seven-A		waste	50	0.04	none	0	3255.77	46.52	281.66	23.50	0.0361	53
FCSI-99-43	Homestake Mine Dump		waste	140	0.23	none	0	2068.69	52.68	972.86	81.66	0.0318	54
FCSI-99-78	Sheep Mountain Dump Two		waste	20	0.01	none	0	1406.30	54.86	1012.96	85.06	0.0256	59
FCSI-99-18	Middle Trendennic Dump Two		waste	10	0.00	none	0	1406.30	274.28	101.30	8.51	0.0179	62
FCSI-99-20	Middle Trendennic Dump Three		waste	10	0.00	none	0	1406.30	274.28	101.30	8.51	0.0179	62
FCSI-99-77	Sheep Mountain Pit		waste	20	0.00	none	0	1406.30	54.86	101.30	8.51	0.0157	64
FCSI-99-104	Henderson Mountain Dump Eight-A		waste	20	0.08	none	0	1084.10	152.53	281.66	23.50	0.0154	65
FCSI-99-73	Henderson Mountain Dump Thirteen	Fisher Creek No. 1	waste	40	0.03	adit	6	1140.54	18.10	97.29	8.17	0.0126	66
FCSI-99-39	Henderson Mountain Dump Two	Silver Queen	waste	30	0.05	none	0	1001.42	25.58	157.48	13.18	0.0120	67
FCSI-99-103	Henderson Mountain Dump Five-A		waste	20	0.00	none	0	1084.10	15.25	28.17	2.35	0.0113	68
FCSI-96-15-1	Upper Trendennic Dump One	Commonwealth #1	reclaimed	80	0.02	adit, toeseep	1	439.81	303.31	157.65	8.86	0.0091	70
FCSI-96-17	Homestake Adit and Dump	Homestake #2	waste	320	0.11	none	0	702.62	19.18	118.05	9.25	0.0085	73
FCSI-96-15-4	Upper Trendennic Dump Four	Commonwealth #2	reclaimed	50	0.02	none	0	439.32	221.97	157.65	8.86	0.0083	74
FCSI-99-38	Henderson Mountain Dump One		waste	20	0.01	none	0	333.81	8.53	157.48	13.18	0.0051	77
FCSI-96-16	Homestake Pit		waste	80	0.08	none	0	379.35	9.94	61.18	4.99	0.0046	78
FCSI-96-15-3	Upper Trendennic Dump Three	Commonwealth #2	reclaimed	10	0.02	none	0	146.44	134.53	157.65	8.86	0.0045	79

Table 3-1
Fischer Creek Source Area Ranking
New World Mining District Response and Restoration Project
Glengarry/Como/Fisher Creek Response Action EE/CA

Site No.	Site Name	Other Name	Material Type	Volume (cubic meters)	Area (hectares)	Mine Drainage	Flow (GPM)	Ground Water Pathway	Surface Water Pathway	Air Pathway	Direct Contact Pathway	Total Score	Rank
FCSI-96-15-5	Upper Trendennic Dump Five	Commonwealth #2	reclaimed	10	0.03	none	0	146.44	134.53	157.65	8.86	0.0045	79
FCSI-99-69	Henderson Mountain Dump Eight	Kingfisher	waste	60	0.16	none	0	151.74	3.86	237.88	19.97	0.0041	82
FCSI-99-61	Henderson Mountain Dump Five	Schiller Lode #2	waste	10	0.05	none	0	283.08	5.27	97.29	8.17	0.0039	83
FCSI-99-24	Lower Trendennic Dump Two		waste	30	0.00	cladit, toeseep	1	253.58	9.49	5.84	0.51	0.0027	85
FCSI-99-59	Chicago Mill Site		ore/slag	30	0.52	none	0	48.74	10.11	186.78	6.84	0.0025	87
FCSI-99-75	Henderson Mountain Dump Twelve	International	waste	20	0.01	none	0	206.87	13.17	0.97	0.82	0.0022	89
FCSI-99-12	Scotch Bonnet Dump Two		waste	80	0.02	none	0	114.49	6.56	40.37	3.49	0.0016	91
FCSI-99-105	Sheep Mountain Dumps		waste	30	0.08	none	0	100.18	5.86	36.09	3.05	0.0015	92
FCSI-99-72	Henderson Mountain Dump Eleven		waste	20	0.06	none	0	59.51	1.51	27.94	2.35	0.0009	94
FCSI-99-49	Fisher Creek Dump One		waste	20	0.03	none	0	50.77	0.91	16.78	1.46	0.0007	95
FCSI-96-9	Small Como Dump		reclaimed	310	0.10	none	0	17.90	41.26	5.94	0.27	0.0007	96
FCSI-99-26	Fisher Creek Trench One		waste	40	0.01	none	0	32.90	10.72	0.66	0.04	0.0004	97
FCSI-99-52	Fisher Creek Dump Three		waste	0	0.02	none	0	15.23	2.73	16.78	1.46	0.0004	99
FCSI-99-35	Fisher Mountain Dump Three		reclaimed	0	0.49	nfv	0	4.25	0.01	12.71	11.18	0.0003	100
FCSI-99-36	Fisher Mountain Dump Four		reclaimed	0	0.67	nfv	0	4.25	0.01	12.71	11.18	0.0003	100
FCSI-99-23	Glengarry Trench		trench	0	0.01	none	0	21.35	0.03	3.33	2.59	0.0003	102
FCSI-99-54	Fisher Creek Dump Four		waste	0	0.04	none	0	5.08	0.91	16.78	1.46	0.0002	103
FCSI-96-14	Upper Glengarry Dump		waste	80	0.02	none	0	9.16	7.56	3.58	0.28	0.0002	104
FCSI-96-10	Fisher Mountain Trench One		reclaimed	0	0.53	nfv	0	0.35	0.01	10.25	9.08	0.0002	105
FCSI-99-29	Fisher Mountain Trench Two		reclaimed	0	0.06	nfv	0	4.25	0.01	1.27	1.12	0.0001	108
FCSI-99-32	Fisher Mountain Dump One		reclaimed	0	0.02	nfv	0	4.25	0.01	1.27	1.12	0.0001	108
FCSI-99-33	Fisher Mountain Dump Two		reclaimed	0	0.02	nfv	0	4.25	0.01	1.27	1.12	0.0001	108
FCSI-99-51	Fisher Creek Dump Two		native	0	0.01	none	0	4.25	0.08	0.97	0.82	0.0001	111
FCSI-96-11	Fisher Mountain Pit		reclaimed	0	0.02	nfv	0	0.50	0.01	1.52	1.33	0.0000	112
FCSI-99-65	Fisher Creek Trench Two		trench	0	0.06	none	0	0.00	0.00	0.00	0.27	0.0000	114
FCSI-99-8	Scotch Bonnet Dump One		natural	0	0.00	none	0	0.00	0.00	0.00	0.03	0.0000	117

3.3 MINE WASTE INVESTIGATION RESULTS

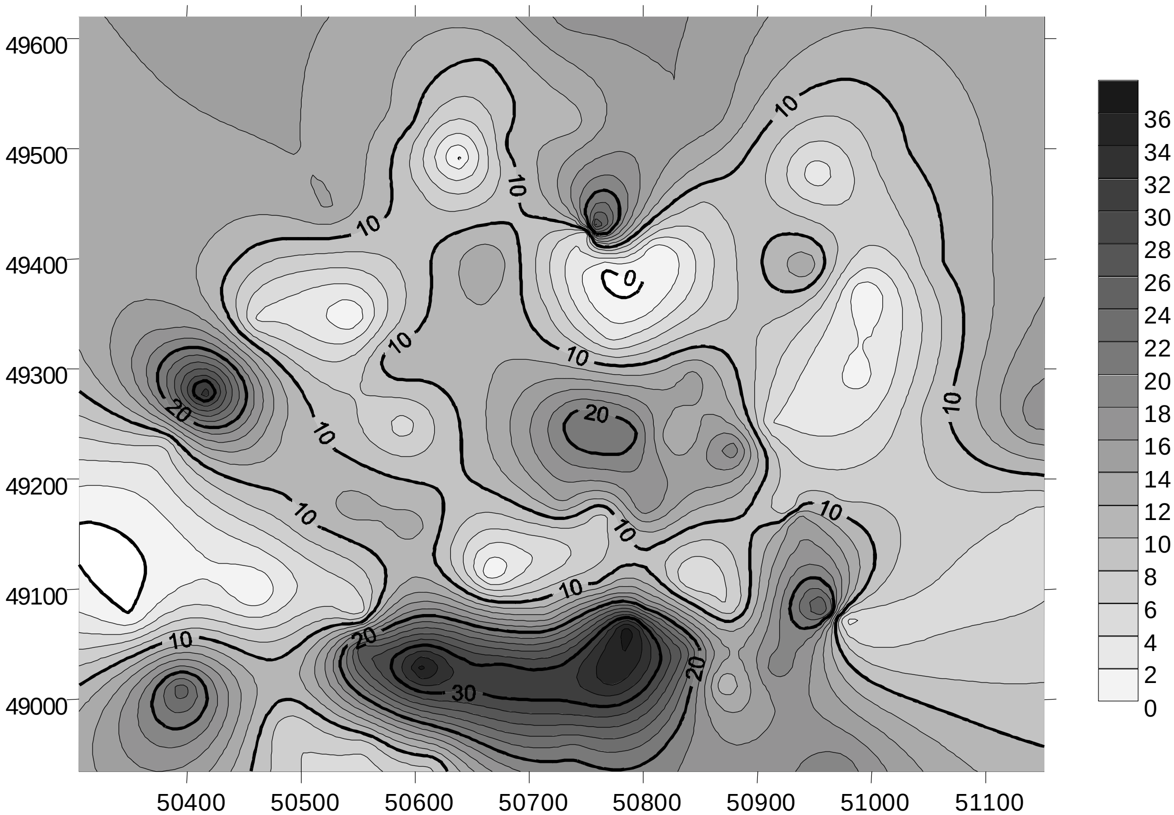
Waste rock samples were collected from many of the dumps in Fisher Creek in 1999, 2000, and 2001 by Maxim, and in 1996 by George Furniss on behalf of CBMI. Mine waste samples were collected from the dumps following standard operating procedures referenced in the Site-Wide Sampling and Analysis Plan (SAP) (Maxim, 1999b). Samples were collected from hand dug test pits using a shovel. Subsample test pits were dug to a depth of about 18 inches. Field quality control (QC) samples were collected at a frequency of 5% of natural samples. Laboratory quality control samples included duplicates and matrix spikes. Quality assurance was completed according to the quality assurance project plan presented in the Site-Wide SAP. Composite samples were analyzed for saturated paste pH and electrical conductivity, total metals, sulfur fractionation, and lime requirement. All samples were analyzed according to methods presented in the Site-Wide SAP. Analytical results for samples collected from the mine waste dumps in the Fisher Creek drainage are shown in Table 3-2.

Dump volumes and areas are listed in Table 3-1 and dump locations are shown in Figure 3. Volumes were calculated from field reconnaissance and area estimates were interpreted from aerial photography by the Gallatin National Forest Interagency Spatial Analysis Center in Bozeman, Montana.

The volume of sulfide and metal-rich soil and colluvial material overlying the Como deposit was calculated from CBMI borehole data. Approximately 92 drill holes were used for this calculation. The disturbed area overlying the deposit covers approximately 2.23 Ha (5.5 acres) with a thickness of unconsolidated material ranging from 0 to 11 meters (0 to 35 feet). The volume calculated for these unconsolidated materials was 190,174 cubic meters (248,700 cubic yards). Drill hole data was also used to construct a structure contour map of the top of bedrock underlying the unconsolidated colluvial/soil material (Figure 12) and an isopach map of the thickness of the unconsolidated material (Figure 13). The structure contour map in general depicts the erosional surface of the bedrock (mostly covered by colluvial materials) sloping 18% to 28% to the northeast. The bedrock slope is similar to the existing surface topography. Geomorphic features identified as paleo channels or drainage pathways are identified on the bedrock surface; these features are also very closely aligned with the present surface drainages within the Como Basin (Figure 12). In general, the thickest material is located along the axis of the identified channels, and along the southern margin of the basin near the break in slope between the basin margin and Fisher Mountain to the south (Figure 13).

Geochemical data for 37 composite waste material samples from the Fisher Creek waste rock dumps (excluding the Como Basin) are summarized in Table 3-2. These wastes have higher than background concentrations of arsenic, copper, lead, and zinc. Acid-base potential data for these samples suggests that wastes in Fisher Creek are moderately to strongly acidic, with paste pH values as low as 2.0 and lime requirements ranging from less than 1.0 to 1,850 tons/1,000 tons as calcium carbonate ($CaCO_3$). Total sulfur contents ranges from 0.03 to 45.6%. The maximum lime requirement and total sulfur measurement was made on a sample collected from the Glengarry Dump. A modest amount of lime, on average 40 tons per 1000 tons, would be needed to adjust the pH of the waste rock materials to 7.0 standard units (s.u).

Geochemical data for five composite soil and colluvial material samples from the Como Basin are summarized in Table 3-3. These samples have high concentrations of aluminum and copper, with lesser concentrations of arsenic, lead, and zinc. Concentrations of copper, arsenic and lead exceed background concentrations in some samples. Cadmium, chromium, mercury, and silver were near or below detection limits in the samples. Acid-base potential data for these samples suggests that soils in the Como Basin are moderately to strongly acidic, with paste pH values as low as 2.2 and lime requirements ranging from 7 to 70 tons/1,000 tons as calcium carbonate ($CaCO_3$). Total sulfur contents ranges from 0.2 to 2.1%, with roughly equal amounts of reduced sulfide (nitric acid soluble) and oxidized sulfate, and slightly lower amounts of jarositic sulfur (hydrochloric acid soluble). A modest amount of lime, an average 38 tons per 1000 tons, would be needed to adjust the pH of the waste rock materials to 7.0 s.u. Some of the total sulfur present in the Como Basin was measured in the residual fraction, which indicates that the minerals present in the samples have low reactivity in the strong acids used to digest the pyritic and sulfate sulfur fractions. These data, and the data in Table 3-2, indicate that disturbed soils in the Como Basin and mine wastes in Fisher Creek have the potential to produce acidic, metalliferous water.



Contour interval is 2

Isopach Map Of Colluvium

Como Basin
Figure 12

TABLE 3-2
CHEMICAL CHARACTERISTICS OF FISHER CREEK WASTE ROCK DUMP SAMPLES
New World Mining District - Response and Restoration Project

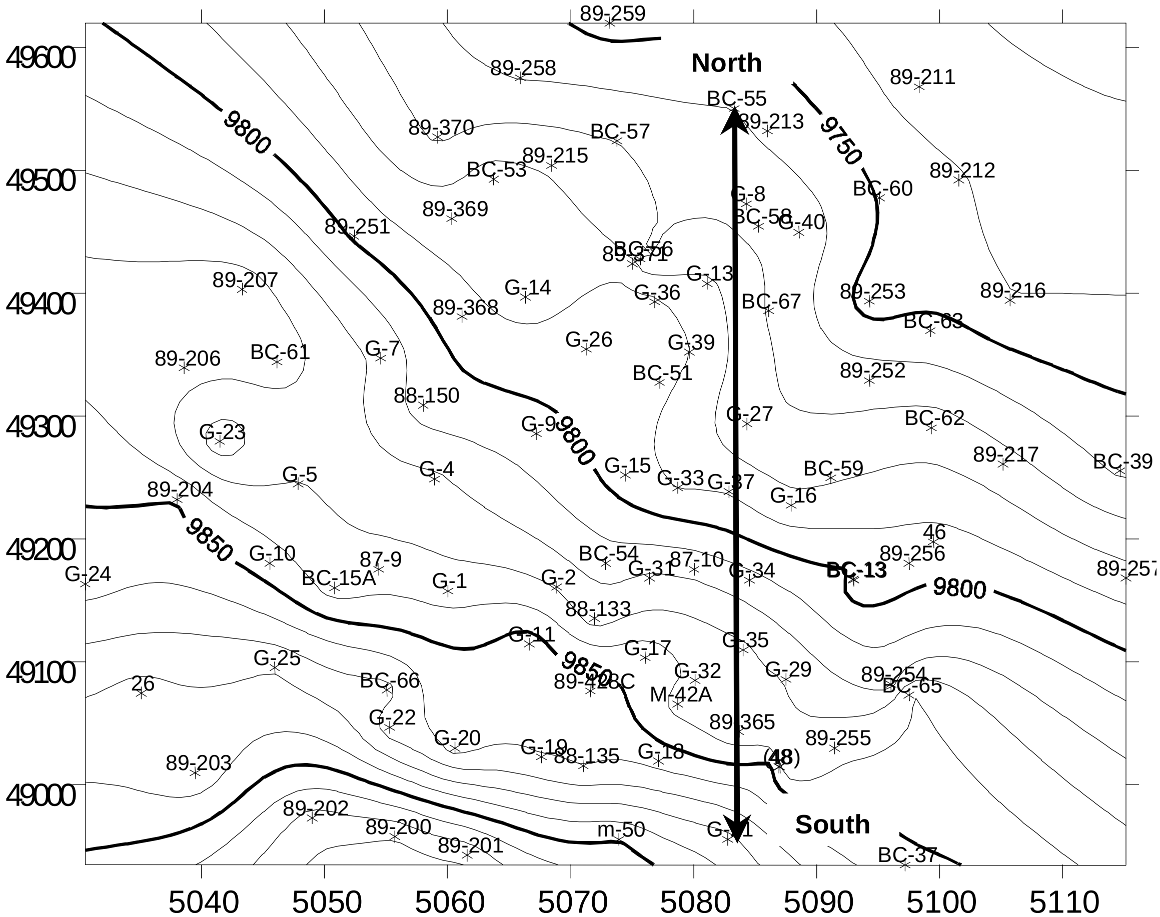
Site No.	Site Name	Sample Date	Stat Group	pH (su)	EC (mmhos/cm)	Ag (mg/Kg)	Flag	As (mg/Kg)	Flag	Cd (mg/Kg)	Flag	Cr (mg/Kg)	Flag	Cu (mg/Kg)	Flag	Hg (mg/Kg)	Flag	Pb (mg/Kg)
FCSI-96-1A	Gold Dust Mine and Dump	8/26/96	5	5.4	3.69	20	<	10		2	<	9		144		0.69		46
FCSI-96-1A	Gold Dust Mine and Dump	08/09/93	5					40.3	J	0.8		14.1		180		1.15	J	68.32
FCSI-96-1A	Gold Dust Mine and Dump	08/09/93	5					34.9	J	0.5	<	20.4		98.4		0.256	J	51.2
FCSI-96-1B	Gold Dust Mine and Dump	8/26/96	5	7	2.07	20	<	21		2		12		283		0.5	<	37
FCSI-96-9	Small Como Dump	8/26/96	9	7.3	1.17	20	<	3		6		5	<	178		0.75		18
FCSI-96-16	Homestake Pit	8/26/96	10	6	2.7	20	<	140		27		5	<	2420		0.5	<	218
FCSI-96-17	Homestake Adit and Dump	8/26/96	10	7	0.7	20	<	50		11		5	<	642		0.5	<	54
FCSI-96-17	Homestake Adit and Dump	08/09/93	10					16.7	J	0.6		21		1140		0.378	J	79.8
FCSI-99-26-01	Fisher Creek Trench One	08/11/99	10	3.7	0.09	20	<	4		3		8		1320		0.5	<	35
FCSI-99-38/39-01	Henderson Mountain Dump One	08/10/99	10	5.1	2.31	20	<	17		13		5	<	376		1.01		900
FCSI-99-49,52,54-01	Fisher Creek Dump One	08/09/99	10	3.9	0.07	20	<	50		11		18		202		0.5	<	76
FCSI-99-53/99-70	Henderson Mountain Dump Four	08/18/99	10	4.1	0.29	20	<	60		19		18		576		0.5	<	1600
FCSI-99-62-01	Henderson Mountain Dump Six	08/09/99	10	3.5	0.68	20	<	27		6		8		53		0.74		874
FCSI-99-68	Henderson Mountain Dump Seven	08/10/93	10					207	J	3.26		1.17	<	449		1.98		920
FCSI-99-68	Henderson Mountain Dump Seven	08/10/93	10					82.3	J	0.49	<	19.2	J	255		0.055		213
FCSI-99-69-01	Henderson Mountain Dump Eight	08/10/99	10	5.1	3.36	20	<	19		12.4		5	<	178		0.5	<	154
FCSI-99-71	Henderson Mountain Dump Ten	08/18/99	10	6.9	0.38	20	<	120		40		25		973		1.71		1560
FCSI-99-72-01	Henderson Mountain Dump Eleven	08/10/99	10	3	0.12	20	<	28		15		5	<	248		0.5	<	166
FCSI-99-74-01	Henderson Mountain Dump Fourteen	08/09/99	10	3	0.42	20	<	73		27		5	<	335		1.8		819
FCSI-96-10	Fisher Mountain Trench One	8/26/96	12	4.4	0.48	20	<	50		3		5	<	151		0.5	<	60
FCSI-96-11	Fisher Mountain Pit	8/26/96	12	4.1	0.15	20	<	50		8		5	<	99		0.5	<	83
FCSI-96-2A	Glengarry Dump	8/26/96	14	3.2	3.31	20	<	18		2		5	<	280		0.59		65
FCSI-96-2A	Glengarry Dump	08/09/93	14					50.2	J	0.5	<	4.67		421		2.14	J	109
FCSI-96-2A	Glengarry Dump	08/09/93	14					53.6	J	3.6		1.38	<	1260		0.038	J	116
FCSI-96-2B	Glengarry Dump	8/26/96	14	3.4	3.52	20	<	5		2	<	5	<	215		0.66		30
FCSI-96-2C	Glengarry Dump	8/26/96	14	3.2	3.63	20	<	21		3		5	<	400		0.72		53
FCSI-96-4	Glengarry Adit and Mill Site	8/26/96	14	3.2	0.7	20	<	130		47		6	<	1650		3		140
FCSI-96-18	East Henderson Pit	8/26/96	103	2.8	1.27	122		90		22		5	<	602		1.5		5210
FCSI-99-1-01	Sheep Mountain Dump One	08/11/99	104	2.8	1.27	119		167		21		5	<	869		1.47		11000
FCSI-99-105-01	Sheep Mountain Dumps	08/11/99	104	4.2	0.12	20	<	33		15		5	<	140		0.5	<	208
FCSI-99-12	Scotch Bonnet Dump Two	08/18/99	105	3.5	0.17	20	<	160		29		5	<	538		0.5	<	217
FCSI-99-12	Scotch Bonnet Dump Two	08/18/99	105	2.8	0.19	20	<	50		15		29		228		0.69		75
FCSI-99-59-01	Chicago Mill Site	08/09/99	106	8.4	2.05	20	<	45		2	<	5	<	11		0.5	<	20
FCSI-99-59-02	Chicago Mill Site	08/09/99	106	7.3	0.97	36		24		39		6	<	8520		1.2		101
FCSI-99-59-03	Chicago Mill Site	08/09/99	106	7	0.39	20	<	2	<	3		5	<	19		0.5	<	20
FCSI-99-104-1	Henderson Mountain Dump Eight-A	08/10/99	112	2	9.57	20	<	11		18		5	<	1110		0.5	<	1590
FCSI-96-14	Upper Glengarry Dump	8/26/96	140	3	0.38	20	<	9		8		5	<	244		0.58		54
Mine Waste	**- Average**					**27.23**		**53.30**		**11.92**		**8.67**		**724.52**		**0.83**		**730.82**
	- Minimum					**20**		**2**		**0.49**		**1.17**		**11**		**0.038**		**18**
	- Maximum					**122**		**207**		**47**		**29**		**8520**		**3**		**11000**
BACKGROUND																		
FCSI-96-3A		8/26/96	99	4.2	0.18	20	<	3		2	<	51		108		0.5	<	47
FCSI-96-3B		8/26/96	99	4.4	0.09	20	<	6		2	<	5	<	126		0.5	<	39
FCSI-96-19		8/26/96	99	4	0.23	20	<	4		7		5	<	20		0.5	<	43
DCSI-96-5		8/26/96	99	4.4	0.28	20	<	8		13		8		85		0.5	<	81
DCSI-96-5B		8/26/96	99	6	0.97	20	<	2	<	2	<	5	<	10	<	0.5	<	20
MCSI-96-8		8/26/96	99	2.2	0.46	20	<	14.7		2.89		5	<	26.9		0.5	<	75.3
Background	**- Average**					**20.00**		**6.28**		**4.82**		**13.17**		**62.65**		**0.50**		**50.88**
Mine Waste	**- Minimum**					**20.00**		**2.00**		**0.49**		**1.17**		**11.00**		**0.04**		**18.00**
Background	**- Median**					**20.00**		**5.00**		**2.45**		**5.00**		**55.95**		**0.50**		**45.00**

TABLE 3-2
CHEMICAL CHARACTERISTICS OF FISHER CREEK WASTE ROCK DUMP SAMPLES
New World Mining District - Response and Restoration Project

Site No.	Site Name	Sample Date	Flag	Zn (mg/Kg)	Flag	NP (t/1000t)	Flag	Total S (%)	Sulfate S (%)	Flag	Pyritic S (%)	Flag	Jarosite S (%)	Flag	Resid S (%)	Flag	ABP (t/1000t)	AP (t/1000t)	Flag	SMP_pH
FCSI-96-1A	Gold Dust Mine and Dump	8/26/96		42		24		2.92	0.1	<	0.8		0.1	<	2.2		-64	88	<	6.6
FCSI-96-1A	Gold Dust Mine and Dump	08/09/93	J	66.1		0.35		0.27	0.12		0.04				0.11					
FCSI-96-1A	Gold Dust Mine and Dump	08/09/93	J	83.3		61.6		4.67	0.01	<	2.06				2.83					
FCSI-96-1B	Gold Dust Mine and Dump	8/26/96		98		50		4.38	0.1	<	1.6		0.1	<	2.8		-87	137	<	
FCSI-96-9	Small Como Dump	8/26/96		35		50		0.45	0.1	<	0.1		0.1	<	0.4		34	16		
FCSI-96-16	Homestake Pit	8/26/96		233		38		1.1	0.1	<	0.1	<	0.1	<	1.1		4	34		7.1
FCSI-96-17	Homestake Adit and Dump	8/26/96		58		17		0.31	0.1	<	0.1	<	0.1	<	0.3		7.3	9.7		
FCSI-96-17	Homestake Adit and Dump	08/09/93		162		29		1.01	0.02		0.32				0.67					
FCSI-99-26-01	Fisher Creek Trench One	08/11/99		43		1	<	0.05	0.1	<	0.1	<	0.1	<	0.1	<	0	3	<	6.1
FCSI-99-38/39-01	Henderson Mountain Dump One	08/10/99		398		14		1.17	0.1	<	0.1		0.1	<	1.1		-23	37		6.5
FCSI-99-49,52,54-01	Fisher Creek Dump One	08/09/99		92		1	<	0.19	0.1	<	0.1	<	0.1	<	0.2		-5.9	5.9		5.9
FCSI-99-53/99-70	Henderson Mountain Dump Four	08/18/99		342		2		0.27	0.1	<	0.1	<	0.1		0.2		-5.7	7.7		6.3
FCSI-99-62-01	Henderson Mountain Dump Six	08/09/99		222		1	<	0.14	0.1	<	0.1	<	0.1	<	0.1		-4.4	4.4		6.4
FCSI-99-68	Henderson Mountain Dump Seven	08/10/93		732		-3.57		6.64	0.72		2.91				3.01					
FCSI-99-68	Henderson Mountain Dump Seven	08/10/93		188		3.81		0.25	0.1		0.03				0.14					
FCSI-99-69-01	Henderson Mountain Dump Eight	08/10/99		173		10		1.69	0.3		0.7		0.2		0.5		-32	42		6.3
FCSI-99-71	Henderson Mountain Dump Ten	08/18/99		1600		92		0.44	0.1	<	0.1	<	0.1	<	0.4		78	14		
FCSI-99-72-01	Henderson Mountain Dump Eleven	08/10/99		64		1	<	0.44	0.1	<	0.1		0.2		0.1		-12	12		5.5
FCSI-99-74-01	Henderson Mountain Dump Fourteen	08/09/99		172		1	<	0.67	0.1	<	0.1	<	0.1		0.6		-20	20		5.6
FCSI-96-10	Fisher Mountain Trench One	8/26/96		16		3	<	0.03	0.1	<	0.1	<	0.1	<	0.1		-3.1	3.1		5.9
FCSI-96-11	Fisher Mountain Pit	8/26/96		14		3	<	0.41	0.1		0.1		0.1		0.1		-8.6	8.6		5.8
FCSI-96-2A	Glengarry Dump	8/26/96		39		3	<	0.75	0.1	<	0.2		0.2		0.4		-22	22		5.6
FCSI-96-2A	Glengarry Dump	08/09/93	J	29.1		-1.68		0.77	0.23		0.16				0.38					
FCSI-96-2A	Glengarry Dump	08/09/93	J	50.1		-4.79		45.6	0.31		0.01	<			47.2					
FCSI-96-2B	Glengarry Dump	8/26/96		42		3	<	1.62	0.1	<	0.6		0.3		0.7		-48	48		5.9
FCSI-96-2C	Glengarry Dump	8/26/96		54		3	<	0.87	0.1		0.2		0.3		0.3		-22	22		5.4
FCSI-96-4	Glengarry Adit and Mill Site	8/26/96		73		3	<	0.46	0.1		0.1		0.2		0.1		-9.7	9.7		5.6
FCSI-96-18	East Henderson Pit	8/26/96		2250		3	<	1.22	0.1	<	0.2		0.1		0.9		-37	37		5.9
FCSI-99-1-01	Sheep Mountain Dump One	08/11/99		1020		1	<	1.72	0.1	<	0.2		0.2		1.3		-52	52		5.3
FCSI-99-105-01	Sheep Mountain Dumps	08/11/99		82		4		0.32	0.1	<	0.1	<	0.1	<	0.3		-6	10		6.4
FCSI-99-12	Scotch Bonnet Dump Two	08/18/99		118		1	<	0.38	0.1	<	0.1	<	0.1		0.3		-11	11		5.7
FCSI-99-12	Scotch Bonnet Dump Two	08/18/99		48		1	<	0.4	0.1	<	0.1	<	0.1		0.3		-12	12		5.1
FCSI-99-59-01	Chicago Mill Site	08/09/99	<	10	<	21		0.1	0.1		0.1		0.1		0.1	<	21	3	<	
FCSI-99-59-02	Chicago Mill Site	08/09/99		294		37		3.61	0.1	<	0.1		0.1	<	3.5		-76	113		
FCSI-99-59-03	Chicago Mill Site	08/09/99	<	10.9		1	<	0.53	0.1	<	0.1	<	0.1	<	0.5		-17	17		
FCSI-99-104-1	Henderson Mountain Dump Eight-A	08/10/99		87		1	<	6.44	0.1	<	0.1	<	0.3		6.1		-199	199		3.9
FCSI-96-14	Upper Glengarry Dump	8/26/96		10		3	<	0.49	0.1	<	0.1		0.1	<	0.4		-15	15		5.2
Mine Waste	**- Average**			**244.61**		**12.91**		**2.51**	**0.13**		**0.33**		**0.14**		**2.16**		**-21.60**	**33.77**		**5.83**
	- Minimum			**10**		**-4.79**		**0.03**	**0.01**		**0.01**		**0.1**		**0.1**		**-199**	**3**		**3.9**
	- Maximum			**2250**		**92**		**45.6**	**0.72**		**2.91**		**0.3**		**47.2**		**78**	**199**		**7.1**
BACKGROUND																				
FCSI-96-3A		8/26/96		112		3	<	0.05	0.1	<	0.1	<	0.1	<	0.1	<	-1.6	1.6		5.8
FCSI-96-3B		8/26/96		18		3	<	0.05	0.1	<	0.1	<	0.1	<	0.1	<	-1.6	1.6		6.6
FCSI-96-19		8/26/96		5	<	3	<	0.33	0.1		0.1		0.1		0.1	<	-6.4	6.4		6.3
DCSI-96-5		8/26/96		23		6		0.44	0.1		0.1		0.1	<	0.2		-5	113		5.6
DCSI-96-5B		8/26/96	<	5	<	3	<	0.22	0.1	<	0.1	<	0.1	<	0.2		-6.9	6.9		7
MCSI-96-8		8/26/96		24.8		2	<	0.19	0.1	<	0.1	<	0.1		0.1		-5.2	5.2		3.4
Background	**- Average**			**31.30**		**3.33**		**0.21**	**0.10**		**0.10**		**0.10**		**0.13**			**22.45**		**5.78**
Mine Waste	**- Minimum**			**10.00**		**-4.79**		**0.03**	**0.01**		**0.01**		**0.10**		**0.10**			**3.00**		**3.90**
Background	**- Median**			**20.50**		**3.00**		**0.21**	**0.10**		**0.10**		**0.10**		**0.10**			**5.80**		**6.05**

TABLE 3-2
CHEMICAL CHARACTERISTICS OF FISHER CREEK WASTE ROCK DUMP SAMPLES
New World Mining District - Response and Restoration Project

Site No.	Site Name	Sample Date	Flag	SMP lime (t/1000t) formula	Lime Req (t/1000t) lab	Lime Req (t/1000t) office	HNO3 lime	HCL lime	Resid lime	NP
FCSI-96-1A	Gold Dust Mine and Dump	8/26/96		1.78	113	89.4	25.0	0.0	68.8	24.0
FCSI-96-1A	Gold Dust Mine and Dump	08/09/93				5.4	1.3	0.0	3.4	0.4
FCSI-96-1A	Gold Dust Mine and Dump	08/09/93				114.0	64.4	0.0	88.4	61.6
FCSI-96-1B	Gold Dust Mine and Dump	8/26/96		5.74	171	116.6	50.0	0.0	87.5	50.0
FCSI-96-9	Small Como Dump	8/26/96	(1)	0.00	20	-43.0	3.1	0.0	12.5	50.0
FCSI-96-16	Homestake Pit	8/26/96	(1)	0.00	43	-0.6	3.1	0.0	34.4	38.0
FCSI-96-17	Homestake Adit and Dump	8/26/96	(1)	0.00	12	-5.6	3.1	0.0	9.4	17.0
FCSI-96-17	Homestake Adit and Dump	08/09/93				2.4	10.0	0.0	20.9	29.0
FCSI-99-26-01	Fisher Creek Trench One	08/11/99		4.45	9.6	9.5	3.1	0.0	0.0	0.0
FCSI-99-38/39-01	Henderson Mountain Dump One	08/10/99		2.31	50	32.3	3.1	0.0	34.4	14.0
FCSI-99-49,52,54-01	Fisher Creek Dump One	08/09/99		5.74	15	18.9	3.1	0.0	6.3	0.0
FCSI-99-53/99-70	Henderson Mountain Dump Four	08/18/99		3.52	15	16.5	3.1	2.3	6.3	2.0
FCSI-99-62-01	Henderson Mountain Dump Six	08/09/99		2.98	10	11.5	3.1	0.0	3.1	0.0
FCSI-99-68	Henderson Mountain Dump Seven	08/10/93				235.7	90.9	0.0	94.1	-3.6
FCSI-99-68	Henderson Mountain Dump Seven	08/10/93				1.9	0.9	0.0	4.4	3.8
FCSI-99-69-01	Henderson Mountain Dump Eight	08/10/99		3.52	58	44.6	21.9	4.7	15.6	10.0
FCSI-99-71	Henderson Mountain Dump Ten	08/18/99	(1)	0.00	17	-95.5	3.1	0.0	12.5	92.0
FCSI-99-72-01	Henderson Mountain Dump Eleven	08/10/99		7.79	28	23.4	3.1	4.7	3.1	0.0
FCSI-99-74-01	Henderson Mountain Dump Fourteen	08/09/99		7.12	32	39.2	3.1	2.3	18.8	0.0
FCSI-96-10	Fisher Mountain Trench One	8/26/96		5.74	11	15.0	3.1	0.0	3.1	0.0
FCSI-96-11	Fisher Mountain Pit	8/26/96		6.23	21	18.5	3.1	2.3	3.1	0.0
FCSI-96-2A	Glengarry Dump	8/26/96		7.12	39	38.2	6.3	4.7	12.5	0.0
FCSI-96-2A	Glengarry Dump	08/09/93				23.2	5.0	0.0	11.9	-1.7
FCSI-96-2A	Glengarry Dump	08/09/93				1850.1	0.3	0.0	1475.0	-4.8
FCSI-96-2B	Glengarry Dump	8/26/96		5.74	68	66.7	18.8	7.0	21.9	0.0
FCSI-96-2C	Glengarry Dump	8/26/96		8.41	41	38.8	6.3	7.0	9.4	0.0
FCSI-96-4	Glengarry Adit and Mill Site	8/26/96		7.12	24	22.6	3.1	4.7	3.1	0.0
FCSI-96-18	East Henderson Pit	8/26/96		5.74	54	53.1	6.3	2.3	28.1	0.0
FCSI-99-1-01	Sheep Mountain Dump One	08/11/99		8.90	80	75.6	6.3	4.7	40.6	0.0
FCSI-99-105-01	Sheep Mountain Dumps	08/11/99		2.98	17	14.4	3.1	0.0	9.4	4.0
FCSI-99-12	Scotch Bonnet Dump Two	08/18/99		6.68	25	26.9	3.1	2.3	9.4	0.0
FCSI-99-12	Scotch Bonnet Dump Two	08/18/99		10.06	31	31.1	3.1	2.3	9.4	0.0
FCSI-99-59-01	Chicago Mill Site	08/09/99	(1)	0.00	3	-19.4	3.1	2.3	0.0	21.0
FCSI-99-59-02	Chicago Mill Site	08/09/99	(1)	0.00	141	94.4	3.1	0.0	109.4	37.0
FCSI-99-59-03	Chicago Mill Site	08/09/99	(1)	0.00	21	23.4	3.1	0.0	15.6	0.0
FCSI-99-104-1	Henderson Mountain Dump Eight-A	08/10/99		16.15	249	271.2	3.1	7.0	190.6	0.0
FCSI-96-14	Upper Glengarry Dump	8/26/96		9.52	35	31.4	3.1	0.0	12.5	0.0
Mine Waste	**- Average**				**48.45**	**40.05**				
	- Minimum				**3**	**-95.46875**				
	- Maximum				**249**	**1850.128**				
BACKGROUND										
FCSI-96-3A		8/26/96		6.23	12	11.7	3.1	0.0	0.0	0.0
FCSI-96-3B		8/26/96		1.78	5	6.1	3.1	0.0	0.0	0.0
FCSI-96-19		8/26/96		3.52	14	11.2	3.1	2.3	0.0	0.0
DCSI-96-5		8/26/96		7.12	25	13.1	3.1	0.0	6.3	6.0
DCSI-96-5B		8/26/96	(1)	0.00	8.6	11.7	3.1	0.0	6.3	0.0
MCSI-96-8		8/26/96		18.91	6.4	34.4	3.1	2.3	3.1	0.0
Background	**- Average**				**11.83**					
Mine Waste	**- Minimum**				**3.00**					
Background	**- Median**				**10.30**					



STRUCTURE CONTOUR MAP ON BEDROCK

Como Basin

North/South Section on Figure 6

Figure 13

TABLE 3-3
CHEMICAL CHARACTERISTICS OF DISTURBED SOILS IN THE COMO BASIN
New World Mining District Response and Restoration Project
Como Basin/Glengarry Adit/Fisher Creek Response Action

ANALYTE	COMO #2	COMO #3	COMO #4	COMO #5	COMO #6	MEAN
Aluminum Dry Basis (mg/kg)	5,960	5,980	8,360	6,560	6,690	6,710
Arsenic Dry Basis (mg/kg)	17	16	70	80	80	52.6
Cadmium Dry Basis (mg/kg)	2	2	2	2	2	2
Copper Dry Basis (mg/kg)	235	270	1910	1290	760	893
Lead Dry Basis (mg/kg)	161	269	71	123	120	148.8
Zinc Dry Basis (mg/kg)	118	507	122	127	90	192.8
Acid Base Potential (T/kT)	-9.8	12.1	-30	-56	-34	-23.54
pH Saturated Paste (s.u.)	2.8	7.0	3.5	2.8	2.2	--
SMP Buffer pH (s.u.)	4.9	--	4.6	3.6	3.3	--
Lime Requirement (T/kT)	31	7.4	38	70	42	37.68

Notes - mg/kg = milligrams per kilogram; T/kT = tons per 1,000 tons; s.u. = standard units
-- indicates not applicable

3.4 SURFACE WATER

A large volume of data has been produced on water chemistry of Fisher Creek. The efforts to document and evaluate Fisher Creek water quality began in 1973 when the Montana DNRC began a three year study to assess water quality and discharge characteristics related to mine disturbances at the headwaters of Fisher Creek (Montana DNRC, 1977). Crown Butte Mines, Inc, in conjunction with their application for a hard rock mining permit, began comprehensive surface and groundwater quality monitoring and discharge measurements in the Fisher Creek drainage basin in 1989 that continued through 1996. The most comprehensive data were collected during the 1974-1975 hydrograph year. The USDA-FS, under the direction of Mike Amacher, conducted comprehensive water quality studies from 1989 through 1993. More recent efforts by the USGS (Kimball and others, 1999), EPA, and the USDA-FS continue to build on the database and understanding of Fisher Creek water chemistry.

The conclusions reached by these various studies are complimentary and point to dynamic and complicated water chemistry. In Fisher Creek, chemistry is controlled not only by seasonal climatic events, but also by elements such as rock-water interactions at the headwaters, discharge from mine-related disturbances, equilibrium between mineral precipitants and trace elements within the creek, and reaction with stream sediments deposited along Fisher Creek. As a basis for evaluating the influence of different sources of contaminants, and the processes that affect contaminant concentrations in Fisher Creek, a conceptual hydrogeochemical model has been developed for the drainage.

3.4.1 SURFACE WATER QUALITY

Surface water quality in Fisher Creek is impacted by runoff from the Como Basin, mine waste dumps, and other disturbances, as well as discharges from adits, seeps, and natural and impacted groundwater that carry high metal loads. Mean concentrations of selected parameters for the 1989-2001 period for sample sites located in the Fisher Creek drainage are summarized in Table 3-4. Sampling stations are shown on Figure 3.

TABLE 3-4
Mean Surface Water Concentrations Of Selected Parameters
New World Mining District Response and Restoration Project
Como Basin/Glengarry Adit/Fisher Creek Response Action

Location	Total Recoverable Metals (milligrams/liter)								pH[1] (su)
	Al	Cd	Cr	Cu	Fe	Pb	Mn	Zn	
Glengarry Adit (F-8A) [2]	5.8	0.0004	--	1.18	48.5	0.021	3.64	0.27	3.1
Gold Dust Adit (F-28) [2]	<0.1	0.0001	--	0.004	0.35	>0.001	0.073	0.01	7.9
Fisher Creek @ SW-3[3]	2.56	0.0008	0.008	0.675	5.094	0.005	0.758	0.109	3.6
Temporary Standard @ SW-3	4.54	0.002	--	1.256	9.259	0.01	1.718	0.225	2.1
Fisher Creek @ CFY-2[3]	0.114	0.0001	0.006	0.36	0.148	0.001	0.022	0.017	7.8
Temporary Standard @ CFY-2	0.47	--	--	0.11	0.75	0.002	0.082	0.044	5.7
Chronic Aquatic Life Standard [4]	0.087	0.0014	0.089	.0052	1.0	0.003	--	0.067	--

Notes:
(1) pH in standard units
(2) Data from June or July 2001
(3) Mean concentrations calculated from available data in project database - 1989 – 2001
(4) Hardness based criteria (Al, Cd, Cu, Pb, and Zn) calculated using hardness of 50 mg/L.
-- Not analyzed or not applicable

The headwaters of Fisher Creek are comprised of the Glengarry Adit (F-8A) and two surface tributaries that drain the Como Basin (FCT-11) and the northeast flank of Fisher Mountain (FCT-12) (Figure 10). At the Glengarry Adit, FCT-11 drains the Como Basin and joins Fisher Creek immediately to the northeast of the portal. FCT-12 drains a mineralized but unmined portion of Fisher Mountain and enters immediately to the southwest of the Glengarry Adit. The first routinely sampled surface water station downgradient of the headwaters is SW-3 (Figure 10). Water quality data for FCT-11 and FCT-12 are presented in Tables 3-5 and 3-6, respectively. Water quality analyses for the Glengarry Adit are presented in Table 3-4.

Additional surface water quality data for Fisher Creek have been collected at other intermediary surface water sites at various times of the year, over a number of years by a number of sources. These data are available on the Internet from the New World project database at **http://www.fs.fed.us/rl/gallatin**.

Table 3-5 Flow and Water Quality Data (mg/l) from Surface Water Site FCT-11											
SiteCode	SampDate	pHLab	Flow (gpm)	AlTrc	AsTrc	CdTrc	CuTrc	FeTrc	MnTrc	PbTrc	ZnTrc
FCT-11	6/14/1994	3.9	736.1	4.4	0.002	0.0002	0.57	9.27	0.3	0.019	0.049
FCT-11	8/30/1994	3.4	1.39	5	0.001	0.0004	0.25	3.68	0.69	0.002	0.088
FCT-11	7/13/1995	3.7	1458.7	2.8	0.001	0.0003	0.862	2.58	0.36	0.002	0.048
FCT-11	6/5/1996	5.8	3.14	0.1		0.0001	0.006	0.14	0.009	0.003	0.05
FCT-11	6/12/1996	5.2	11.2				0.014	0.14			0.01
FCT-11	6/20/1996	5.5	62.8	0.1		0.0001	0.018	0.22	0.018	0.003	0.01
FCT-11	6/26/1996	5.3	112.2				0.024	0.07			0.01
FCT-11	7/2/1996	3.8	884.2				0.529	3.45			0.05
FCT-11	7/12/1996	3.6	1072.7	1.8		0.0001	0.451	1.64	0.164	0.003	0.03
FCT-11	7/18/1996	3.5	598.3				0.568	1.97			0.05
FCT-11	7/25/1996	3.5	449.3				0.513	1.83			0.05
FCT-11-1	8/7/1996	5	27.8	0.3			0.003	0.01			0.02
FCT-11-2	8/7/1996	3.3		5.6			1.02	11.1			0.11
FCT-11-3	8/7/1996	4.3	15	0.3			0.003	0.01			0.03
FCT-11-4	8/7/1996	3.6	150	3.2			0.389	6.37			0.08
FCT-11-5	8/7/1996	4	125	2.5			0.65	0.63			0.04
FCT-11-6	8/7/1996	5.3	0.007	0.1			0.003	0.01			0.04
FCT-11-7	8/8/1996	5.5	50	0.1			0.013	0.21			0.02
FCT-11-8	8/8/1996	5.9	19.74	0.7			0.429	0.47			0.02
FCT-11	8/21/1996		116.7				0.28	2.26			0.04
FCT-11	9/11/1996	3.3	9.43	3.8		0.0003	0.243	2.67	0.421	0.003	0.08
FCT-11	9/11/1996	3.7	9.43	3.22		0.0005	0.25	2.35	0.381	0.003	0.07
FCT-11-4	9/11/1996	3.2	9.42	4.8		0.0003	0.158	6.52	0.539	0.003	0.11
FCT-11-5	9/11/1996	3.6	2.61	2.4		0.0001	0.382	0.05	0.204	0.003	0.03
FCT-11-1	9/12/1996	3.7	6.73	0.6		0.0001	0.003	0.01	0.054	0.003	0.04
FCT-11-3	9/12/1996	4	0.94	0.4		0.0001	0.002	0.01	0.018	0.003	0.02
FCT-11-7	9/12/1996	5.5	3.14	0.1		0.0001	0.018	0.05	0.01	0.003	0.04
FCT-11-7	9/12/1996	6	3.14	0.1		0.0001	0.017	0.06	0.01	0.003	0.04
FCT-11-8	9/12/1996	4.2	4.5	1.6		0.0001	0.644	0.04	0.114	0.003	0.04
FCT-11A	10/8/1996			0.566	0.005	0.002	0.007	0.052	0.062	0.003	0.0285
FCT-11	7/8/1997		1317.3	3.2	0.01	0.005	0.385	5.58	0.133	0.003	0.0247
FCT-11-4	7/8/1997			1.01	0.01	0.005	0.103	2.05	0.106	0.0088	0.0236
FCT-11-5	7/8/1997			3.67	0.01	0.005	0.01	4.55	0.191	0.003	0.0248
FCT-11	5/12/1998	4.2	73.2	2			0.354	0.326	0.139		0.0249
FCT-11	5/29/1998	4.2	326.7	1.51			0.347	0.622	0.121		0.024
FCT-11	7/25/2001	3.8		3.8	<0.005	0.0004	0.39	2.17	0.41	<0.003	0.07
Standard				0.087	0.018	0.0025	0.0093	0.03	0.05	0.0032	0.12

Table 3-6 Flow and Water Quality Data (mg/l) from Surface Water Site FCT-12

SiteCode	SampDate	pHLab	Flow gpm	AlTrc	AsTrc	CdTrc	CuTrc	FeTrc	MnTrc	PbTrc	ZnTrc
FCT-12	6/14/1994	4.2	493.7183	1	0.001	0.0001	0.63	0.11	0.03	0.003	0.025
FCT-12	8/30/1994	4.2	0.048883	1	0.001	0.0001	0.72	0.07	0.1	0.003	0.026
FCT-12	6/28/1995	4.1	0	1.5	0.001	0.0002	0.72	0.23	0.03	0.002	0.029
FCT-12	7/13/1995	4.2	728.3567	1	0.001	0.0001	0.548	0.16	0.03	0.002	0.027
FCT-12	7/13/1995	4.2	728.3567	1.16	0.001	0.0002	0.625	0.117	0.0269	0.0016	0.0267
FCT-12	8/4/1995	4.1	50.69167								
FCT-12	9/26/1995	3.4	1.46649	1.3	0.001	0.0001	0.75	0.28	0.11	0.002	0.042
FCT-12	5/21/1996	4	0.635479	1.2		0.0001	0.55	0.33	0.088	0.005	0.07
FCT-12	5/29/1996	4.3	1.026543	1.2		0.0001	0.558	0.06	0.091	0.003	0.04
FCT-12	6/5/1996	4.3	54.74896	1		0.0001	0.484	0.02	0.069	0.003	0.03
FCT-12	6/12/1996	3.9	689.2503				0.621	0.05			0.04
FCT-12	6/20/1996	4.2	223.1998	1.1		0.0002	0.581	0.07	0.029	0.003	0.02
FCT-12	6/26/1996	4	0				0.665	0.12			0.02
FCT-12	7/2/1996	4	659.9205				0.541	0.1			0.03
FCT-12	7/12/1996	4	488.83	1		0.0001	0.584	0.09	0.025	0.003	0.01
FCT-12	7/18/1996	3.8	494.696				0.611	0.06			0.04
FCT-12	7/25/1996	3.9	41.55055				0.711	0.07			0.05
FCT-12	8/21/1996	3.9	4.8883				0.59	0.05			0.04
FCT-12	9/11/1996	4.3	3.42181	1.2		0.0001	0.672	0.02	0.103	0.003	0.04
FCT-12	9/11/1996	3.9	3.42181	1.2		0.0001	0.64	0.02	0.1	0.003	0.04
FCT-12A	10/8/1996			2.19	0.005	0.002		0.284	0.103	0.0078	0.0413
FCT-12	7/8/1997		859.3631	0.992	0.01	0.005	0.01	0.1	0.0229	0.003	0.02
FCT-12-2	7/8/1997		106.0761	1.87	0.01	0.005	0.523	0.484	0.032	0.003	0.02
FCT-12-3	7/8/1997		12.31852	6.1	0.0102	0.005	0.805	20.9	0.754	1.16	0.649
FCT-12	5/12/1998	4.4	9.7766	1.01				0.1	0.0944		0.0291
FCT-12	5/29/1998	4.4	37.63991	0.807				0.1	0.0655		0.0218
Standard				0.087	0.018	0.0025	0.0093	0.03	0.05	0.0032	0.12

3.4.2 Surface Water Geochemistry

Changes in flow and chemistry between the Fisher Creek headwaters and Station SW-3 show that metal enriched groundwater discharges to Fisher Creek and increases both metal loads and flow along the upper reach of the drainage. Changes in water quality below Station SW-3 result from increasing flow and related dilution, increasing contributions from impacted and natural groundwater, and precipitation of metal oxides with co-precipitation and sorption of other trace elements. At Station CFY-2 (Figure 3), these processes have neutralized much of the acidity and removed or reduced the concentration of metals added in the upper reaches so that regulatory standards are typically exceeded only under high flow conditions. Any evaluation of the effectiveness of mine waste removal and elimination of drainage from the Glengarry Adit must be considered within this conceptual hydrogeochemical framework.

3.4.3 Loading Analysis

Upper Fisher Creek is characterized by rapidly increasing flow rates and short periods of sustained flow during snowmelt. As much as 90% of Fisher Creek's total annual discharge volume occurs between mid May and early August. Discharge rates near the upper reaches of Fisher Creek range from less than 0.3 m^3/s (1 cfs) in late winter to over 1.4 m^3/s (150 cfs) during peak snowmelt.

Most contaminants entering upper Fisher Creek reach peak concentrations during late winter when flows are lowest and dilution is at a minimum. At downstream locations, however, concentrations of some constituents rise with increasing discharge rates, despite the enhanced dilution under high flow conditions, indicating that much of the load moves further down Fisher Creek during high flow. Comparison of loads indicate that while the Glengarry Adit dominates water chemistry during low flow conditions, tributaries FCT-11 and FCT-12 contribute the majority of the annual load during high flow.

Metals loading investigations by Amacher (1998) and Kimball and others (1999) indicate that a few distinct surface water sources in the upper 500 meters of Fisher Creek supply the majority of the contaminant load to the creek. Amacher (1998) compiled water quality and flow data for various springs, seeps, adits, tributaries, and the main channel of Fisher Creek collected as part of baseline studies for the CBMI project between1989 to 1996. Twenty direct inputs were identified and the data were used to quantify sources of metals to Fisher Creek. Results of Amacher's investigation are summarized in Table 3-7, and indicate that the major sources of metals loading into Fisher Creek are:

- Outflow from the Glengarry Adit (F-8A)
- A tributary draining the northeastern flank of Fisher Mountain (FCT-12)
- A tributary draining the Como basin (FCT-11)
- Seepage from the Glengarry Adit waste rock dump (FC-2)

Amacher determined that these four sources contribute nearly 70 percent of the copper load, 67 percent of the aluminum load, 75 percent of the manganese load, and 95 percent of the iron load into Fisher Creek at base-flow conditions. Two additional tributaries from Fisher Mountain (FCT-1 and FCT-14) contribute an additional 20 percent of the copper load.

Amacher (1998) noted that the relative contribution of the four major sources varied considerably from spring runoff to base flow conditions. In May, under base flow conditions, Glengarry Adit discharge (F-8A) accounts for most of the dissolved copper load to upper Fisher Creek. As snowmelt begins in June and proceeds into July, runoff from Fisher Mountain (FCT-12) and Como Basin (FCT-11) accounts for most of dissolved copper load. In the fall, the Glengarry Adit again accounts for the majority of copper load. Metals load contribution from groundwater is large during spring runoff. These are significant sources of loading and if they can be reduced by removal actions from these source areas would represent a significant improvement of metal loading (and acidity) to Fisher Creek.

TABLE 3-7
MEAN CONTRIBUTIONS OF METAL LOADS IN FISHER CREEK FROM MAJOR SOURCES*
New World Mining District Response and Restoration Project
Como Basin/Glengarry Adit/Fisher Creek Response Action

Source	Description	Mn%	Fe%	Cu%	Al%	SO4%
F-8A	Glengarry Adit	39.9	65.3	20.2	15	9.3
FCT-12	Runoff from Fisher mountain	1.1	0.4	14.3	6.4	1.8
FCT-11	Runoff from the Como Pit	19.7	16.8	21.1	25.5	8.2
FC-2	Seepage from waste rock dump in front of Glengarry Adit	14.4	12.9	13.8	20	8.6
Total		75.1	95.4	69.4	66.9	27.9

Note: Load data are mean values from periods of both high and low flow.

Kimball and others (1999) conducted an investigation of metals loading in Fisher Creek in August 1997. The main objectives of their study were to identify and quantify the sources of metal loading in Fisher Creek and describe the geochemical processes that affect metal concentrations in the creek. These objectives were met by combining tracer injection with synoptic surface water sampling of Fisher Creek. Study results indicate that at least 60 percent of the sources contributing metal loading into Fisher Creek are surface water sources, including discharge from the Glengarry Adit (F-8A), seepage from the waste rock dump in front of the adit (FC-2), and the tributary draining the Como Basin (FCT-11. The study concluded that the remaining metal load (40 percent) during their August sampling event was from diffuse groundwater discharge to Fisher Creek.

According to Kimball and others (1999), water in Fisher Creek changes in response to the chemistry of inflows and can be divided into three distinct study reaches. The first reach of Fisher Creek (upstream from the Glengarry Adit) is acidic, indicating that the Como deposit and natural weathering of the disseminated sulfides in the Fisher Mountain Intrusive Complex are sources of acidity to Fisher Creek. Downstream acidic inflows, however, appear to have a greater affect on resulting stream chemistry. The second geochemical reach is between 263 meters, where the Glengarry Adit inflow causes the lowest pH and the highest metal concentrations, and about 1,715 meters downstream from the headwaters of Fisher Creek. The mixing of acidic mainstream flow and near-neutral pH tributary inflow in the second reach results in a gradual increase in pH with distance downstream. In the third study reach, downstream of 1,715 meters, inflow of neutral pH water from adjacent wetlands and water draining carbonate rock sources results in a substantial increase in pH (greater than 5.0) in Fisher Creek.

Among the inflows investigated by Kimball, discharge from the Glengarry Adit (F-8A) was the most acidic and contained the highest concentration of metals. Three samples of surface water draining from the waste rock dump in front of the adit were also found to have a pH of 4 and very high concentrations of metals. A third group of inflows from the porphyritic country rock had a slightly less acidic pH (5.0) and lower metal concentrations, and may represent more natural drainage of the porphyritic country rock.

Two groups of inflows had higher pH values. The first group included inflows that had low metal concentrations and appeared unaffected by mining, occurring along much of the study reach between 492 meters and 1412 meters downstream of the headwaters of Fisher Creek. A second group of higher pH inflow waters rich in calcium (> 3,500 mg/L) occur downstream from 1,750 meters and include flows from the Gold Dust Adit and inflows at the start of the wetland area adjacent to the stream. Regulated metal concentrations decrease downstream as a result of dilution and co-precipitation with ferrihydroxides.

In addition, Kimball and others (1999) determined that the two largest sources of iron loading to Fisher Creek were discharge from Glengarry Adit (F-8A) and the tributary draining the Como Basin (FCT-11). Iron precipitation is widely observed along the creek and plays an important role in controlling the concentration of metals in downstream reaches where higher pH is observed. About 60% of aluminum, copper, manganese, and zinc loads were accounted for by concentrations in surface inflows. The remaining 40% were assumed to be coming from groundwater discharge to the creek. Kimball and others (1999) established that most of the surface water load of metals to Fisher Creek occurs in the upper 700 meters. They noted an increase in load in the reach between 1,582 meters and 1,750 meters, and conclude that it was due to groundwater input. A considerable increase in calcium, aluminum, and copper was noted further downstream between 1,876 meters to 1,936 meters. This area likely drains carbonate outcrops on the southwest side of the valley, but the source(s) of aluminum and copper are not clear.

Table 3-8 shows a comparison of loading for aluminum, iron, and copper for stations FTC 11, 12, and the Glengarry Adit (F-8A), in order of increasing total flow using the data collected between 1994 and 1997. The diminishing percentage of load contributed by the Glengarry Adit under increasing flow conditions is evident in this data shown in Table 3-8. For aluminum and copper, the adit may contribute as little as 10% of total load from these three sources under high flow conditions.

Table 3-8 Flow and Water Quality Data (% of total) - FCT-11, FCT-12, and Glengarry Adit
Como Basin/Glengarry Adit/Fisher Creek Response Action EE/CA
New World Mining District Response and Restoration Project

	Flow in %			Al %			Cu%			Fe%		
Date	**FCT 11**	**FCT 12**	**Adit**	**FCT 11**	**FCT 12**	**Adit**	**FCT 11**	**FCT 12**	**Adit**	**FCT 11**	**FCT 12**	**Adit**
8/30/1994	3.2	0.1	96.7		no data		0.60	0.06	99.33	0.3	0.0	99.7
9/11/1996	14.1	5.1	80.7	6.1	0.7	93.2	1.66	1.66	96.68	0.9	0.0	99.1
6/5/1996	4.0	70.5	25.4	0.2	32.7	67.2	0.05	73.01	26.94	0.1	0.2	99.7
8/21/1996	71.6	3.0	25.4				17.05	1.50	81.44	9.6	0.0	90.4
6/20/1996	20.2	71.7	8.1	1.3	50.6	48.1	0.60	68.57	30.83	1.1	1.2	97.7
7/25/1996	82.5	7.6	9.9				35.00	4.49	60.52	15.4	0.1	84.6
6/12/1996	1.5	91.4	7.1				0.03	81.01	18.96	0.1	1.5	98.5
7/18/1996	53.2	44.0	2.8				39.67	35.29	25.04	32.3	0.8	66.9
6/14/1994	57.5	38.6	3.9	78.6	12.0	9.4	50.95	37.77	11.28	70.1	0.6	29.3
7/8/1997	84.1	6.8	9.1	70.9	3.3	25.8	79.62	8.71	11.67	45.4	0.3	54.2
7/12/1996	66.6	30.3	3.1	64.5	16.3	19.1	48.72	28.75	22.52	38.4	1.0	60.7
7/2/1996	53.4	39.8	6.8				42.49	32.43	25.08	39.3	0.9	59.8

A streamflow hydrograph analysis (URS, 1998) summarized total annual load by source, as a percentage of total load at Station SW-3. Neglecting iron, which is actively precipitating as a ferrihydroxide along the stream reach from F-8A to SW3, and aluminum, which may also be precipitating as an oxide, the net contribution of surface sources F-8A, FCT-11, and FCT-12 ranges from 36% for copper to 44% for sulfate (Table 3-9). These data suggests that groundwater contribution of load above SW-3 could be as high as 60 percent. This analysis also demonstrates that the Glengarry Adit alone contributes less than 30% of the annual load, compelling evidence for the need to eliminate loads from FCT-11 and/or FCT-12 for water quality to improve substantially in Fisher Creek.

TABLE 3-9
FCT-11, FCT-12, and Glengarry Adit (F-8A) Loading Contributions to Fisher Creek at Station SW-3
Como Basin/Glengarry Adit/Fisher Creek Response Action EE/CA
New World Mining District Response and Restoration Project

Total Annual Load (1995 –1996)	Copper	Aluminum	Iron	Sulfate	Acid as $CaCO_3$
Glengarry Adit (F-8A) lbs/year	367	1,203	5,358	55,517	27,290
Fisher Creek Trib. FCT-11 lbs/year	249	1,314	1,104	26,615	8,344
Fisher Creek Trib. FCT-12 lbs/year	157	287	18	4,662	3,376
Fisher Creek SW-3 lbs/year	2,132	5,911	8,876	192,997	76,971
F-8A % of total at SW-3	17%	20%	60%	28%	35%
FCT-11 % of total at SW-3	12%	22%	12%	14%	11%
FCT-12 % of total at SW-3	7%	5%	0.02%	2%	4%
F-8A + FCT-11 + FCT-12 % of total at SW-3	36%	47%	72%	44%	50%

Note: Data Source – UOS, 1998.

3.4.4 SURFACE WATER SUMMARY

In general, all of the loading studies agree about the major water inflow sources that contribute metals to Fisher Creek. Roughly half of the sources contributing metal loading into the creek have been identified as surface sources, with estimates of their combined contributions ranging from 40 to 60% of the total load. Subsurface flows will prove difficult to remediate, as these flows do not seem to be associated with any particular mining-related activity, and could represent natural acidic drainage.

Mineral precipitation and sorption processes control metal concentrations in the downstream reaches of Fisher Creek, as influenced by changes in chemical equilibrium resulting from dilution, addition of alkalinity and increasing pH. The total load of copper in kilograms per day (kg/day) measured in lower Fisher Creek is substantially lower than the cumulative load of copper in the upper reaches of the drainage. Similar trends are also seen for other metals, which are removed from the water as precipitated and sorbed solids. This is supported by results of thermodynamic modeling of mineral solubility using PHREEQC (pH redox equations computer model) for water from selected stations (Parkhurst, 1995). Because these geochemical reactions control metal concentrations in the stream (especially below Station SW-3), a simple mass balance cannot accurately predict the effect of remedial actions on metals concentrations at any one location within the drainage. Such prediction is also constrained by lack of specific information on groundwater loading of contaminants. For example, eliminating the Glengarry Adit as a source will lead to a decrease in loading of metals in the upper reaches, an increase in pH, and a reduction of sulfate concentrations. Under baseflow conditions, when the adit outflow dominates surface water chemistry in upper Fisher Creek, eliminating drainage from the adit will significantly change the concentration prior to the addition of metals from groundwater inflows.

The concentration of metals in the upper drainage will ultimately be controlled by equilibrium with secondary mineral precipitates, even if the modified load reduces concentrations to levels below the threshold of mineral precipitation. This will be true as long as the water column is in equilibrium with impacted sediments. Metals will redissolve or desorb to reestablish equilibrium between the water column and stream sediment. Because the majority of load, and subsequent mineral precipitation, occurs under high flow conditions, it is unlikely that significant changes in water quality will be observed unless surface flows from FCT-11 and FCT-12 are altered. The greatest reduction in load (as much as 60% to 70%, measured below the Glengarry waste rock dump) would result from control of all three contaminant sources, the Glengarry Adit, FCT-11, and/or FCT-12. Reduced loading near the headwaters of Fisher Creek may produce significant improvements downsteam where concentrations are more strongly influenced by higher flows.

3.4.5 Semi-Quantitative Loading Analysis

A cursory semi-quantitative load analysis was conducted based on the observations developed in the preceding sections. The results indicate the relative magnitude of changes that might be anticipated and are not meant to be an accurate numerical characterization of absolute changes to loading that might result from source control on the project site.

As discussed in detail above, metals loading investigations by Amacher (1998) and Kimball and others (1999) indicate that a few distinct surface water sources in the upper 500 meters of Fisher Creek supply the majority of the contaminant load to the creek. Most contaminants entering upper Fisher Creek reach peak concentrations (not load) during late winter when flows are lowest and dilution is at a minimum. Comparison of loads indicates that while the Glengarry Adit dominates water chemistry during low flow conditions, tributaries FCT-11 and FCT-12 contribute the majority of the annual load during high flow conditions. As can be seen from Amacher and Kimball's data presented above, these loading sources are significant sources of metals and acidity to Fisher Creek, and, if they could be reduced, would represent significant improvements to water quality.

Using copper as an example, and by assuming loading can be reduced or eliminated from three of the four source areas (Como Basin, Glengarry Adit, and the Glengarry waste rock dump) copper loading might be reasonably expected to be reduced by as much as 80 to 90% during low flow (early August through late-May, approximately 9 months of the year) at a point immediately below the present location of the Glengarry waste rock dump, and by a lesser amount at SW-3. The large magnitude of the estimated reduction is due to there being no flow or a very low flow of surface water from the tributaries (FCT-11, FCT-12, and other smaller surface water inflows) under low flow conditions. Therefore, eliminating the flow from the Glengarry adit and removal of the waste rock dump might reduce the copper load to Fisher Creek by as much as 80-90% below the Glengarry dump, and by as much as 40% at SW-3 during low flow. The remaining copper load reporting further downstream at SW-3 is contained in other smaller surface water flows, but primarily as diffuse groundwater sources that recharge surface water flow measured at SW-3.

During high flow (late-May through late July, approximately 3 months of the year) the potential reduction in loading by control of the source areas is less certain, due to multiple sources of loading. However, at high flow reductions in copper loading as large as 50% might be expected below the present location of the Glengarry waste rock dump and as large as 20% at SW-3. This could occur if the Glengarry Adit was closed to eliminate flow and the Glengarry waste rock dump was removed. These sources, at higher flow, contribute 20.2% and 13.8% of the load respectively (Amacher, 1998). In addition, the load from the tributary that drains the Como Basin contributes about 21.1% of the load, and any method that would reduce the load from this source would result in a significant improvement in water quality (Amacher, 1998). If the load from the Como Basin could be reduced by as much as 80%, then the combined reduction of load reporting to the point below the Glengarry dump would be about 20%. During these high flow conditions, both Kimball and Amacher's studies indicate that groundwater inflow to Fisher Creek below the Glengarry Mine contributes as much as 35 to 45% of the total load to SW-3. Therefore, the total reduction by controlling loading in these three source areas might be as large as about 20% at SW-3. Loading From FCT-12 appears to be coming from undisturbed ground and may be a measure of natural acidity and metal loading and very difficult to control. Regardless of the absolute accuracy of these numbers, this analysis suggests that reduction in loading from the three above-mentioned sources would result in a significant improvement to water quality in Fisher Creek.

3.5 STREAM SEDIMENT DATA

Sediment data and background levels are summarized in Table 3-10. Stream sediment data were collected from Fisher Creek and the Clarks Fork of the Yellowstone in 1996 by CDM (1997). At most sites, samples were collected during high and low flow conditions.

TABLE 3-10
MEAN CONCENTRATIONS OF SELECTED ELEMENTS IN STREAM SEDIMENT
New World Mining District Response and Restoration Project
Como Basin/Glengarry Adit/Fisher Creek Response Action

Location	Ag	As	Ba	Cd	Cr	Cu
SW-3 (Fisher Creek)	43	24	1,821	2	142	310
SW-4 (Fisher Creek)	0.5	5	1,443	0.3	16	1,176
CFY-1 (Clarks Fork)	--	4	1,644	1	28	1,370
SW-6 (Clarks Fork)	--	1	1,723	1	35	1,162
Average	**21**	**8.5**	**1,658**	**1.1**	**55**	**1,004**
Background Concentration*	**--**	**2**	**72**	**5**	**13**	**63**
Location	**Fe**	**Mn**	**Ni**	**Pb**	**Sb**	**Zn**
SW-3 (Fisher Creek)	85,274	816	6.9	45	2.5	73
SW-4 (Fisher Creek)	61,264	1,868	16	78	3.7	143
CFY-1 (Clarks Fork)	59,365	3,368	24	84	0.9	255
SW-6 (Clarks Fork)	58,302	3,092	11	69	0.3	263
Average	**66,051**	**2,286**	**14**	**69**	**2.1**	**183**
Background Concentration*	**17,100**	**461**	**24**	**51**	**5**	**31**

Notes: Analysis by X-ray fluorescence; all values are rounded in mg/kg; data source: CDM (1997).
-- Not detected or not available.
* From soil sample collected near Glengarry Mine by Pioneer (1995) or mean concentrations from five natural samples collected by Furniss.

Sixteen elements were analyzed using X-ray fluorescence. Of these 16 elements, 11 correspond to elements for which comparison background data are available from native soils collected from the Glengarry Mine area (Pioneer, 1995). Sediment data indicate that arsenic, barium, chromium, copper, iron, manganese, and zinc concentrations are more than three times higher than background soil concentrations.

3.6 GROUNDWATER

Groundwater chemistry and flow characteristics are not as well documented as surface water chemistry in Fisher Creek, but some efforts have been made at comparisons (URS, 1998). Water level measurements indicate that the potentiometric surface in bedrock wells in the Como Basin is directly influenced by snowmelt. Water levels in some wells may fluctuate by as much as 60 feet over the hydrograph year. Increasing water levels lag behind snowmelt and maximum surface water flow in the upper basin by as little as two to three weeks. Recent groundwater tracer studies (URS, 1998) indicate that bedrock flow is fracture controlled and that flow directions are not necessarily coincident with obvious surface hydrographic divides or other topographic features.

Comparison of groundwater chemistry for wells completed in various bedrock units (Table 3-11) suggest several populations of water, the quality of which is controlled by the host aquifer. Water quality is most degraded in wells completed in sedimentary rock within the Como Basin and in rocks of the mineralized Fisher Mountain Intrusive Complex.

TABLE 3-11
CONCENTRATIONS OF SELECTED PARAMETERS IN GROUNDWATER
New World Mining District Response and Restoration Project
Como Basin/Glengarry Adit/Fisher Creek Response Action

Well Designation	pH(1) (standard units)	Average Dissolved Metals(2) (milligrams per liter)						
		Al	Cd	Cu	Fe	Mn	Pb	Zn
EPA-11(3)	3.6	3.0	0.014	0.293	320	13.45	0.179	1.29
Tracer-4(3)	3.4	1.2	0.0005	0.295	105.5	8.46	0.010	1.76
Tracer-5(3)	3.5	22.4	0.0017	5.07	54.95	0.86	0.004	0.38
MW-1(4)	3.1	1.2	0.0021	0.396	37.63	3.3	0.021	0.22
EPA-12(5)	5.7	0.1	0.0011	0.004	22.36	1.46	0.002	0.03
Tracer-6(5)	5.9	0.3	0.0008	0.150	19.3	3.09	0.001	0.06
MW-9A(6)	5.6	0.1	0.0002	0.006	0.26	0.009	0.002	0.03
MW-9B(7)	6.3	0.1	0.0001	0.002	1.027	0.337	0.001	0.035
MW-10A(6)	5.7	0.1	0.0002	0.014	0.032	0.23	0.001	0.015
MW-10B(7)	7.3	0.1	0.0001	0.005	2.79	0.265	0.001	0.015
MW-11(7)	5.1	0.16	0.0005	0.007	0.209	0.017	0.004	0.02
SB-16(7)	7.2	0.1	0.0001	0.012	0.65	0.18	0.001	0.01
Standard(8)	--	--	0.005	1.3	0.3	0.05	0.015	2.1

Notes:
(1) Minimum pH measured
(2) Data from Maxim, 2002
(3) Well completed in Fisher Mountain Intrusive
(4) Well completed in Wolsey Shale
(5) Well completed in Scotch Bonnet Diorite
(6) Well completed in alluvium
(7) Well completed in Precambrian granite
(8) Montana DEQ, WQB-7 (MDEQ, 2002)
-- Indicates not measured or not applicable

Wells completed in late stage tertiary dikes, intruded along fractures, have a distinctive chemical fingerprint with high iron and zinc but low copper values. Wells completed in alluvium and granite exhibit the lowest concentrations of contaminants.

Water flow from mine adits in the Fisher Creek drainage is also considered groundwater flow. Mines that have outflows include: Glengarry Adit; lower Spaulding; lower, middle, and upper Tredennick; Sheep Mountain #1; and, Gold Dust Adit. The most prominent groundwater outflow in the Fisher Creek drainage is the Glengarry Adit. Water quality data from these discharges are presented in Table 3-12.

Table 3-12
Water Quality and Flow Data for Seepage from Underground Mines in Fisher Creek

Sample ID	FCSI-96-5	FCSI-96-6	FCSI-96-15	F-8A	FCSI-99-1	FCSI-96-8	FCSI-96-1A		
Location	L. Tredennick	M. Tredennick #1	U. Tredennick	Glengarry*	Sheep Mnt#1	L Spalding	Gold Dust	Standard	
METALS (mg/l)									
Al total rec	<0.1	**0.2**	**0.3**	**9.5**	**0.4**	**3.3**	<0.1	0.087	AL Chron
As total rec	<0.003	<0.003	<0.005	0.005	<0.003	0.007	<0.003	0.018	HH SW
Cd total rec	0.0002	0.0001	0.0004	0.0016	0.0002	0.0013	<0.0001	0.0025	AL Chron
Cu total rec	0.004	**0.082**	**0.051**	**3.357**	**0.035**	**13**	0.004	0.0093	AL Chron
Fe total rec	0.12	**0.97**	0.22	**531**	**1.01**	**165**	**0.35**	0.3	HH SW
Pb total rec	0.001	0.003	**0.038**	**0.021**	**0.015**	**0.012**	<0.001	0.0032	AL Chron
Mn total rec	**0.074**	**0.064**	**0.069**		**0.069**	**4.69**	**0.073**	0.05	HH SW
Mo total rec	<0.01	<0.01	<0.01		<0.01	<0.01	<0.01		
Zn total rec	0.04	0.04	0.06	**0.428**	0.05	**0.42**	0.01	0.12	AL Chron
LAB SAMPLING (mg/l)									
Sulfate as SO_4	49	23			17	**769**	**451**	500	
Hardness as $CaCO_3$	99	21			31	302	595		
Electrical Conductivity **	211	67	296	1042	76				
Total Dissolved Solids	163	82	83	544	85				
Total Suspended Solids	<10	<10	<4		21				
FIELD SAMPLING									
Temp °C	5.6	3.7	5.6		5.3	4.8	4.6		
pH, su	**5.26**	**4.66**	**5.26**	**3.1**	6.92	**2.6**	7.54	6.5	
SC, ms	72.7	55.08	72.7	929	66.13	1651	1005		
Turb, FTU	1	2	1		3	27	6		
ORP, mv	296	268			274	544	286		
Cu, mg/l	0.02	0.05			<0.01	11.6	<0.01		
Fe(t), mg/l	0.16	<0.01			<0.01	139.5	0.34		
Fe+2, mg/l	0.04	n/d			n/d	3.5	0.01		
DO, mg/l	8.9	8.6	8.9		8.2	10.6	8.5		
Flow, gpm	0.6	3.14	0.6	10-38	0.6	<0.1-2	30		
	L Tredennick	M. Tredennick #1	U Tredennick	Glengarry	Sheep Mnt#1	L Spalding	Gold Dust	Standard	

*average all samples collected; data range 20-48 #scripts **Bold**-well out of compliance

** EC in mmlos/cm

*** pH in standard units

mg/l = milligrams per liter

gpm = gallons per minute

3.6.2 GLENGARRY ADIT FLOW AND CHEMISTRY

Groundwater quantity and quality has been measured in outflow from the Glengarry Adit for a number of years (Table 3-12). Outflow volume documented since 1989 has ranged from 57 lpm (15 gpm) to 848 lpm (224 gpm) and averages about 212 lpm (56 gpm).

Until 2000, when the USDA-FS completed a program to drain and access the Glengarry Adit, little was known about water quality and quantity entering the Glengarry workings. Historic mine maps indicated a hydrologic connection with the Como Basin, but insufficient data were available to determine an appropriate approach for closure. In the fall of 2000, the hydrogeology of the adit was mapped and a series of water flow and chemistry sampling stations were established (Figure 9). Changes in water flow and chemistry, both for inflows and on the adit floor, have been measured since October 2000 at these stations. To understand the hydrogeochemistry of the adit, flow was measured and samples were collected from each source of inflowing water. Flow measurements were also made, and samples were collected, both up and downgradient of each principal inflow.

A total of five sampling events have been completed in the Glengarry workings (Table 3-13). Events were timed to catch key points of peak and low flow in the hydrograph year. Of the five events, sampling in October 2000, June 2001, and October 2001 were the most comprehensive in terms of the number of stations and the parameters studied. Limited access during specific sampling events produced incomplete sampling records, primarily for the sampling events in April 2001 and on June 25, 2001.

Flow data from each sampling event is summarized in the graphs shown in Figure 14. Total flow from the adit, as measured at the adit portal (Station F-8A+0), ranged from less than 38 lpm (10 gpm) to 189 lpm (50 gpm). Sampling during October of 2000 indicated that the water flowing into the Glengarry Mine comes from essentially three point sources and one diffuse source. Figure 15 is a graph depicting the various points of inflow into the Glengarry Mine and the cumulative flow curve. The point sources are the 1050 roof leak (F-8A+12), a major roof leak 320 meters (1050 feet) in from the portal; the bulkhead at top of the first short raise about 12 meters (40 feet) above the drift level (Short Raise, F8A+15); and the top of the second raise (Como raise, F-8A+16) where the raise collars in the Como Basin. The diffuse source is a collection of small, fracture-controlled roof leaks (F-8A+1, F-8A+2, and F-8A+4) developed in the bedrock between the portal and the major roof leak at 320 meters (1050 feet). Each of these sources is described in detail below and their locations are shown on Figure 9.

The **Como raise** (F-8A+16), which collars in the Como Basin, contributes 3.8 lpm (1 gpm) to 41 lpm (11 gpm) of inflow. During snowmelt, most of the flow is derived from water passing through the colluvial material exposed at the surface in the Como Basin and flowing along the bedrock/colluvial surface, into and down the raise. This seasonal water flow is characterized by a pH of 3.0, 100 to 400 milligrams per liter (mg/l) iron, and 8 to 40 mg/l copper.

The **short raise** (F-8A+15) has a fairly constant flow in the range of 26 lpm (7 gpm) to 68 lpm (18 gpm) although lower flows occur in the spring prior to snowmelt. The water is characterized by a pH of 3.1 to 3.3, 47 to 93 mg/l iron, and below detection to 0.32 mg/l copper. Manganese ranging from 5 to 7 mg/l is typical of both raises.

The **1050 roof leak** (F-8A+12) varies seasonally from 9 to 49 lpm (2.4 to 13 gpm) and is characterized by a pH of 4 to 5, 24 to 123 mg/l iron, and 0.0014 to 0.05 mg/l copper. Concentrations of aluminum (4 to 24 mg/l), arsenic (0.016 mg/l), and cadmium (0.0015 to 0.0032 mg/l), in water discharging from this structure are higher than concentrations in water discharging from the raises or diffuse leaks.

The **diffuse roof leaks** dry-up in the winter but collectively contribute up to 57 lpm (15 gpm) during snowmelt. These leaks exhibit a pH of 3 to 6, 2 to 10 mg/l iron, and 0.001 to 0.006 mg/l copper.

Table 3-13. GLENGARRY MINE, UNDERGROUND WATER QUALITY DATA (2000-2001)

			FIELD PARAMETER				INORGANICS				METALS																				NUTRIENTS			
Station	Description	Sample Date	Flow (gpm)	Redox mV	pH	SC mmhos	Elec Cond	pH	S	Solids (dissolved)	Al (dissolved)	Al Total	As (dissolved)	As Total	Cd (dissolved)	Cd Total	Cu (dissolved)	Cu Total	Fe (dissolved)	Fe Total	Pb (dissolved)	Pb Total	Mn (dissolved)	Mn Total	Mo (dissolved)	Mo Total	Ni (dissolved)	Ni Total	Zn (dissolved)	Zn Total	Nitrate	Nitrate+ Nitrite	Nitrite	Phos Total
SW-3		9/17/2000	0.218		3.3		458			221		3.1			0.0006			0.76		22		0.003		1.5						0.15				
SW-3		10/5/2000	0.18		3.5					198																								
SW-3		10/11/2000	0.321		3.32					180																								
SW-3		10/12/2000	0.221		3.46					122																								
SW-3		10/19/2000			3	276	418	2.9		243		2.9				<0.0001		0.67		7.84		0.007		1.29						0.39				
F-8A-0	**Portal**	**10/6/00**	**38.15**	**400**	**3.19**	**520**	**1110**	**4.3**		**605**		**6.6**		**0.012**		**0.0013**		**0.7**		**121**		**0.055**		**4.87**				**0.06**		**0.27**		**<0.05**		**0.42**
F-8A-1 120'	**Fracture**	**10/6/00**	**36.35**	**220**	**4.64**	**110**	**239**	**5.9**		**112**		**0.5**		**0.001**		**0.0002**		**0.058**		**11**		**0.002**		**0.76**				**0.01**		**0.06**		**<0.05**		**0.03**
F-8A-2 130'	**Fracture**	**10/6/00**	**nd**	**410**	**3.16**	**540**	**1180**	**4.2**		**618**		**7.6**		**0.016**		**0.0014**		**0.74**		**132**		**0.059**		**5.33**				**0.06**		**0.28**		**<0.05**		**0.32**
F-8A-4 400'	**Fracture**	**10/6/00**	**3.15**	**380**	**4.02**	**100**	**225**	**4.9**		**130**		**0.2**		**0.001**		**0.0005**		**0.012**		**1.57**		**0.012**		**0.68**				**0.01**		**0.07**		**<0.05**		**0.09**
F-8A-5 410'	**Floor**	**10/6/00**	**27.82**	**410**	**3.13**	**600**	**1260**	**4.1**		**615**		**9.8**		**0.024**		**0.0017**		**0.86**		**177**		**0.076**		**6.02**				**0.07**		**0.31**		**<0.05**		**0.36**
F-8A-7 550'	**Floor**	**10/6/00**	**29.17**	**400**	**3.14**	**600**	**1330**	**3.9**		**699**		**8.7**		**0.025**		**0.0018**		**0.95**		**187**		**0.096**		**6.24**				**0.07**		**0.34**		**<0.05**		**0.2**
F-8A-8 600'	**Floor**	**10/6/00**	**34.56**	**405**	**3.11**	**630**	**1320**	**4.1**		**711**		**10.2**		**0.028**		**0.0018**		**0.95**		**201**		**0.085**		**6.08**				**0.07**		**0.35**		**<0.05**		**0.52**
F-8A-10	**Fracture**	**10/6/00**	**nd**	**290**	**4.57**	**280**	**773**	**5.1**		**395**		**0.7**		**0.005**		**<0.0001**		**<0.001**		**10.6**		**<0.001**		**3.94**				**0.03**		**0.22**		**<0.05**		**0.12**
F-8A-12 1050'	**Fracture**	**10/6/00**	**13.00**	**290**	**4.15**	**500**	**1280**	**5.1**		**787**		**4**		**0.017**		**0.0032**		**0.048**		**23.9**		**0.08**		**6.02**				**0.09**		**0.42**		**<0.05**		**0.09**
F-8A-13 1060'	**Floor**	**10/6/00**	**16.15**	**700**	**3.06**	**700**	**1380**	**3.9**		**727**		**1.1**		**0.02**		**0.001**		**1.53**		**37.9**		**0.11**		**6.83**				**0.08**		**0.35**		**<0.05**		**0.41**
F-8A-14 1500'	**Floor**	**10/6/00**	**19.75**	**680**	**3.02**	**680**	**1380**	**3.9**		**723**		**0.7**		**0.013**		**0.0009**		**1.45**		**20.5**		**0.045**		**6.86**				**0.07**		**0.3**		**<0.05**		**0.21**
F-8A-15	**Raise**	**10/11/00**	**18**	**–**	**3.3**	**–**	**1360**	**3.3**		**741**		**0.3**		**0.007**		**0.0004**		**0.015**		**75.4**		**0.044**		**4.53**				**0.06**		**0.24**		**<0.05**		**0.14**
F-8A-16	**Raise**	**10/11/00**	**1**	**–**	**3.1**	**–**	**1340**	**3.1**		**688**		**6.1**		**0.01**		**0.001**		**1.98**		**74.8**		**0.032**		**5.61**				**0.07**		**0.32**		**<0.05**		**0.19**
F-8A+17	**Floor**	**10/16/00**	**nd**	**–**	**3.48**	**–**	**974**	**3.8**		**863**		**4.6**		**<0.003**		**0.0051**		**3.06**		**13.5**		**0.008**		**2.06**				**0.05**		**0.08**		**<0.05**		**0.02**
SW-3		4/21/2001	0.103		3.74	562	463	3.4		255		2.6				0.001		0.74		6.21		0.006		1.12						0.12				
F-8A-0	**Portal**	**4/24/01**	**9.40**	**–**	**3.25**	**957**	**1010**	**3.1**	**<4**	**553**	**5.2**	**5.6**	**<0.003**	**0.004**	**0.0011**	**0.0019**	**0.18**	**0.19**	**41.4**	**35.8**	**0.03**	**0.033**	**3.91**	**4.29**	**<0.001**	**0.001**	**0.04**	**0.05**	**0.25**	**0.29**	**0.05**	**0.05**	**<0.05**	**0.14**
F-8A-12 1050'	**Fracture**	**4/24/01**	**2.40**	**–**	**4**	**972**	**1147**	**4.1**	**9**	**820**	**16.4**	**18.1**	**0.02**	**0.02**	**0.0021**	**0.0023**	**0.008**	**0.001**	**119**	**117**	**0.063**	**0.059**	**5.52**	**6.08**	**<0.001**	**<0.001**	**0.07**	**0.08**	**0.45**	**0.55**	**<0.05**	**<0.05**	**<0.05**	**0.39**
F-8A-14 1500'	**Floor**	**4/24/01**	**6.73**	**–**	**3.17**	**1150**	**1176**	**3.1**	**<4**	**699**	**1.4**	**1.5**	**<0.003**	**<0.003**	**0.0005**	**0.0005**	**0.31**	**0.32**	**35.9**	**27.5**	**0.034**	**0.04**	**4.75**	**5.21**	**<0.001**	**<0.001**	**0.05**	**0.06**	**0.24**	**0.27**	**<0.05**	**<0.05**	**<0.05**	**0.11**
F-8A-15	**Raise**	**4/24/01**	**–**	**–**	**3.24**	**1194**	**1323**	**3.1**	**<4**	**815**	**0.4**	**0.4**	**<0.003**	**0.004**	**0.0005**	**0.0005**	**0.016**	**<0.01**	**55.6**	**47**	**0.051**	**0.063**	**4.77**	**5.29**	**<0.001**	**<0.001**	**0.06**	**0.06**	**0.27**	**0.31**	**<0.05**	**<0.05**	**<0.05**	**0.12**
F-8A-16	**Raise**	**4/24/01**	**–**		**3.0**	**1069**	**983**	**3**	**<4**	**546**	**2.2**	**2.5**	**<0.003**	**<0.003**	**0.0004**	**0.0004**	**0.72**	**0.81**	**20.6**	**15**	**0.013**	**0.013**	**4.61**	**5.07**	**<0.001**	**<0.001**	**0.05**	**0.04**	**0.18**	**0.18**	**<0.05**	**<0.05**	**<0.05**	**0.11**

Table 3-13. GLENGARRY MINE, UNDERGROUND WATER QUALITY DATA (2000-2001)

			FIELD PARAMETER				INORGANICS				METALS																				NUTRIENTS			
Station	Description	Sample Date	Flow (gpm)	Redox mV	pH	SC mmhos	Elec Cond	pH	S	Solids (dissolved)	Al (dissolved)	Al Total	As (dissolved)	As Total	Cd (dissolved)	Cd Total	Cu (dissolved)	Cu Total	Fe (dissolved)	Fe Total	Pb (dissolved)	Pb Total	Mn (dissolved)	Mn Total	Mo (dissolved)	Mo Total	Ni (dissolved)	Ni Total	Zn (dissolved)	Zn Total	Nitrate	Nitrate+ Nitrite	Nitrite	Phos Total
SW-3		6/11/2001			3.05		152	3.9		73	1.5	1.7	<0.003	<0.003	<0.0001	<0.0001	0.46	0.48	1.74	1.92	<0.003	<0.003	0.18	0.2	<0.01	<0.01	<0.02	<0.02	0.06	0.06				
F-8A-0		6/11/01	34.6		2.68						5.8	5.8	0.003	0.004	0.0004	0.0004	1.14	1.18	47.7	48.5	0.019	0.021	3.39	3.64	<0.01	<0.01	0.04	0.04	0.27	0.27				
F-8A-1		6/11/01					228	4.8	<4	140	0.3	0.5	<0.003	<0.003	<0.0001	<0.0001	0.054	0.06	9.68	12.7	<0.003	<0.003	0.74	0.74	<0.01	<0.01	<0.02	<0.02	0.15	0.16				
F-8A-4		6/11/01					210	4.2	<4	146	1.6	1.8	<0.003	<0.003	0.0002	0.0002	0.022	0.022	8.76	13.7	0.008	0.015	0.78	0.78	<0.01	<0.01	<0.02	<0.02	0.11	0.12				
F-8A-7		6/11/01	27.8		2.88				<4		8.3	9.2	0.005	0.008	0.0006	0.0007	1.59	1.64	71.4	87.3	0.029	0.033	4.55	4.81	<0.01	<0.01	0.06	0.06	0.36	0.37				
F-8A-9		6/11/01		257	4.31																													
F-8A-10		6/11/01		163	4.01		652	4.6	<4	355	2.5	2.6	0.004	0.006	<0.0001	<0.0001	0.007	0.007	48.9	48.9	<0.003	<0.003	2.99	3.01	<0.01	<0.01	0.03	0.03	0.23	0.23				
F-8A-11		6/11/01		163	4.46																													
F-8A-12		6/11/01	11.7		3.72				<4		14.2	15.6	0.018	0.018	0.0014	0.0015	0.002	0.004	107	111	0.05	0.058	4.71	5.09	<0.01	<0.01	0.07	0.07	0.45	0.49				
F-8A-13		6/11/01	14.8		2.81				<4		7.7	8.1	0.004	0.005	0.0006	0.0006	3.23	3.34	81.1	95	0.028	0.033	5.32	5.6	<0.01	<0.01	0.07	0.06	0.38	0.39				
F-8A-14		6/11/01	17.1						<4		7.9	8.3	0.004	0.008	0.0007	0.0007	3.52	3.5	86.3	101	0.027	0.037	5.6	5.74	<0.01	<0.01	0.07	0.07	0.39	0.4				
F-8A-15		6/11/01	16.6	412	3.21	562												0.32		73.5										0.3				
F-8A-16		6/11/01			2.77				<4		15.2	17.8	0.007	0.008	0.0015	0.0015	7.1	7.96	116	129	0.018	0.018	6.34	7.24	<0.01	<0.01	0.08	0.08	0.48	0.6				
F-8A-18		8/17/01					3610	2.2		2830		88.4		0.025		0.01		53.7		392		0.057		18.6		<0.01				2.86				
F-8A-19		8/17/01					3210	2.2		2490		68		<0.003		0.012		46.5		343		0.005		19.4		<0.01				3.75				
SW-3		10/11/2001	0.27		3.29	324.8	353	3.5		185		2.4		<0.003		0.0011		0.67		5.79		0.004		0.87						0.15				
F-8A-0		10/13/01					1010	3.2		540	6	6.7	<0.003	0.005	0.0011	0.0011	0.54	0.61	47.1	56.6	0.025	0.034	3.9	4.21					0.31	0.32				
F-8A-12		10/13/01		304	3.31	828.2	1050	4.1		735	19.2	23.5	0.011	0.016	0.0022	0.0025	0.034	0.035	115	123	0.059	0.071	4.61	4.68					0.46	0.47				
F-8A-14		10/13/01		435	2.64	1108	1260	3		690	2.5	2.9	<0.003	0.004	0.0008	0.0008	1.15	1.22	58	58.9	0.028	0.036	5.45	5.48					0.36	0.33				
F-8A-15		10/13/01		414	3.11	1015	1310	3.2		638	0.3	0.3	<0.003	0.006	0.0004	0.0004	0.015	0.013	80	92.6	0.031	0.049	4.7	4.91					0.28	0.27				
F-8A-16		10/13/01		501	2.52	1131	1160	2.9		651	5.8	7.5	<0.003	<0.003	0.0013	0.0016	2.93	3.44	41.8	49.5	0.009	0.012	6.24	7.33					0.43	0.46				

* Spectrophotometry field data

Flow relationships in the Glengarry Adit for October of 2000 are presented in Figure 15. The October 2000 and June 23, 2001 monitoring events caught periods of relatively high flow, between 132 lpm (35 gpm) and 189 lpm (50 gpm) at the adit portal. The long-term average flow at the portal is 212 lpm (56 gpm). Flow from the fracture at the 1050 roof leak is relatively consistent between sampling events, ranging from 11 lpm (3 gpm) to 49 lpm (13 gpm) except under the lowest flow of 9 lpm (2.4 gpm) observed in the late winter April 2001 event. Flow through the raises is more seasonal, with flows that exceed that of the fracture during peak recharge and very little flow during the low flow period in late winter. Comparison of flow volumes between stations, during the more complete monitoring events (Figure 14), shows the adit loses water along two stretches, near the contact of the Precambrian and intrusive rocks and in a zone between 400 and 600 feet from the adit portal. The magnitude of loss is small relative to total flow from the adit, and is most evident under high flow, recharge conditions.

3.6.3 GLENGARRY ADIT CONCENTRATION TRENDS

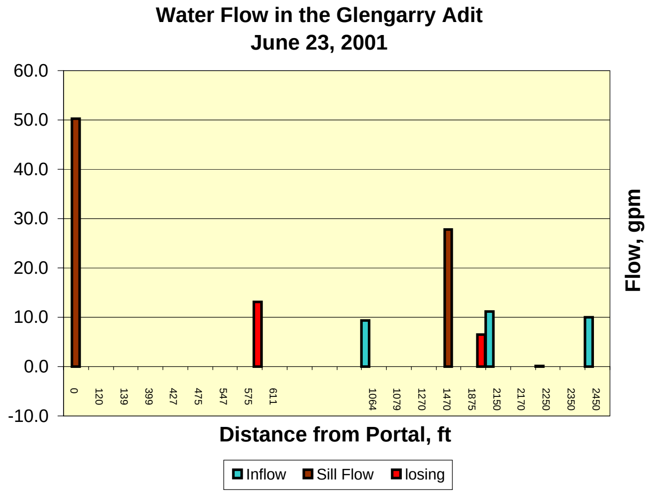
Variation in contaminant concentrations between sampling locations and different sampling events in the Glengarry Adit are summarized by element (arsenic, copper, and iron) in Table 3-13 and Figures 16, 17, and 18. Changes in concentration occur between inflow sources, due to differences in the chemistry of each inflow, and along the floor of the adit as the result of changes in dilution and mineral precipitation. Changes in concentration also occur seasonally within each source and the relative volume contributed by each source changes over time. Although these variations contribute to dynamic and complex trends in concentration, some general conclusions can be drawn.

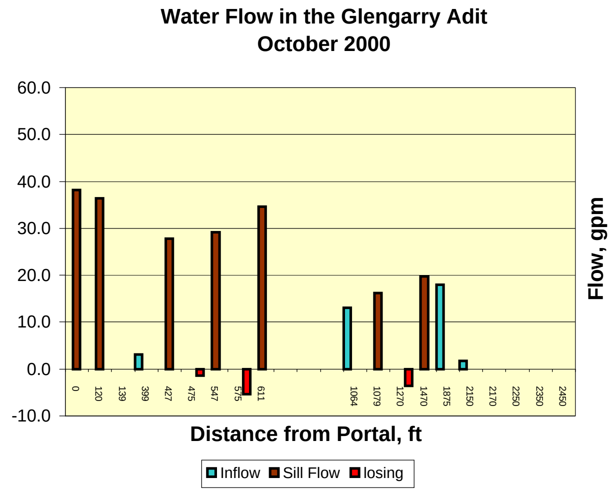
Trends in concentration on the adit floor (solid data point symbols and solid lines on Figures 16-18) are strongly driven by the changes in flow through the raises under all but the lowest flow conditions. This is because concentration and volume of flow through the 1050 roof fracture are relatively consistent, and the contribution through the diffuse fracture zone is relatively minor. The October 2000 event shows distinctly different trends in concentration for most elements, when compared with other sampling events, most likely due to the fact that the adit had only recently been dewatered and rehabilitated and had not yet achieved hydrogeochemical equilibrium.

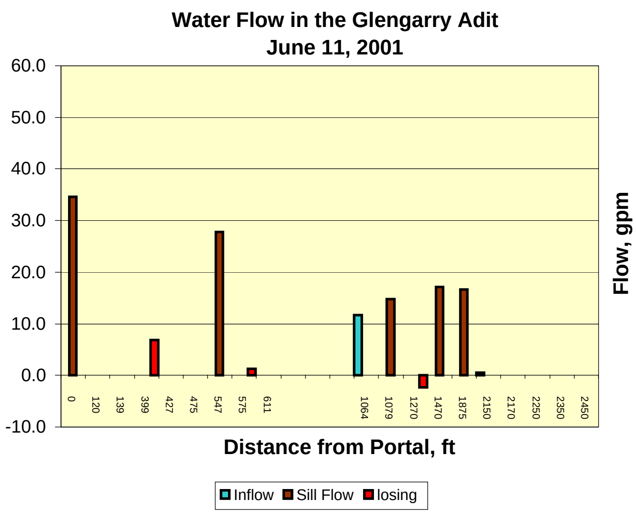
Water (open data point symbols and dashed lines on Figures 16-18) collected from the raise immediately below the Como Basin (F-8A-16) contains very high concentrations of arsenic (Figure 16), copper (Figure 17), aluminum, cadmium, iron (Figure 18), manganese, and zinc (Table 3-13), which reflect high rates of oxidation in the massive sulfide mineralization of the Como deposit and release of aluminum from clay and feldspar alteration minerals. With the exception of inflow from the surface to the raise, flow values for these near-surface fracture controlled inflows are very low and range from 0.11 to 0.34 lpm (0.03 to 0.1 gpm). This low apparent transmissivity may be due to strong silicification and low fracture density observed in the Meagher Limestone. Elevated concentrations of metals in water at the top of the raise do not correspond directly to metal concentrations measured at the base of the raise, however, suggesting that significant dilution or attenuation occurs between the upper workings and the adit. The metals arsenic, aluminum, and cadmium are highest in concentration in flows from the 1050 roof leak. High concentrations of copper and manganese are observed in flow from the Como raise, and in lower concentrations in the short raise. Iron, lead, and zinc concentrations vary with flow, at times having a higher concentration in water from the raise than the 1050 roof leak, and at other times having lower concentrations than the roof leak.

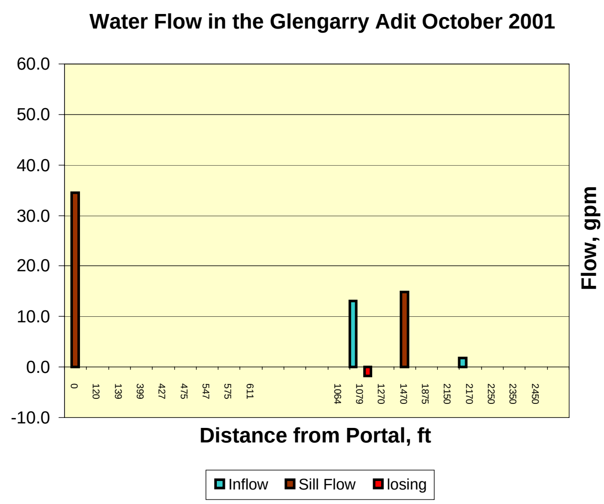
Figure 14. Comparison of Flow Measurements in the Glengarry Adit by Sampling Event

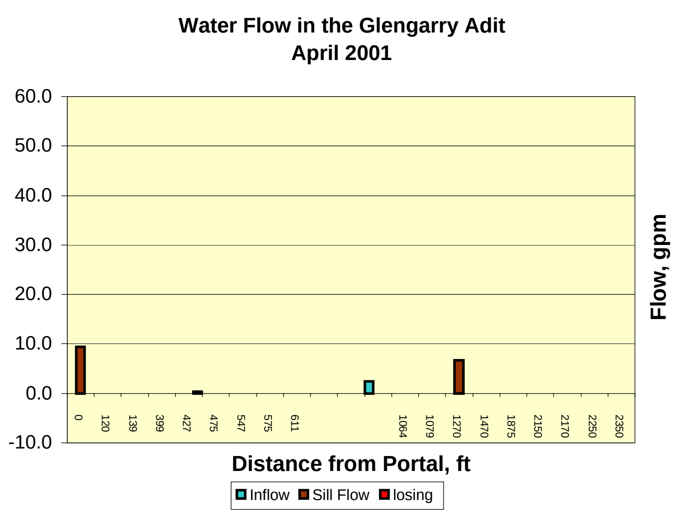
(arranged by total flow volume)











newworld/massloading/Flow_data.xls

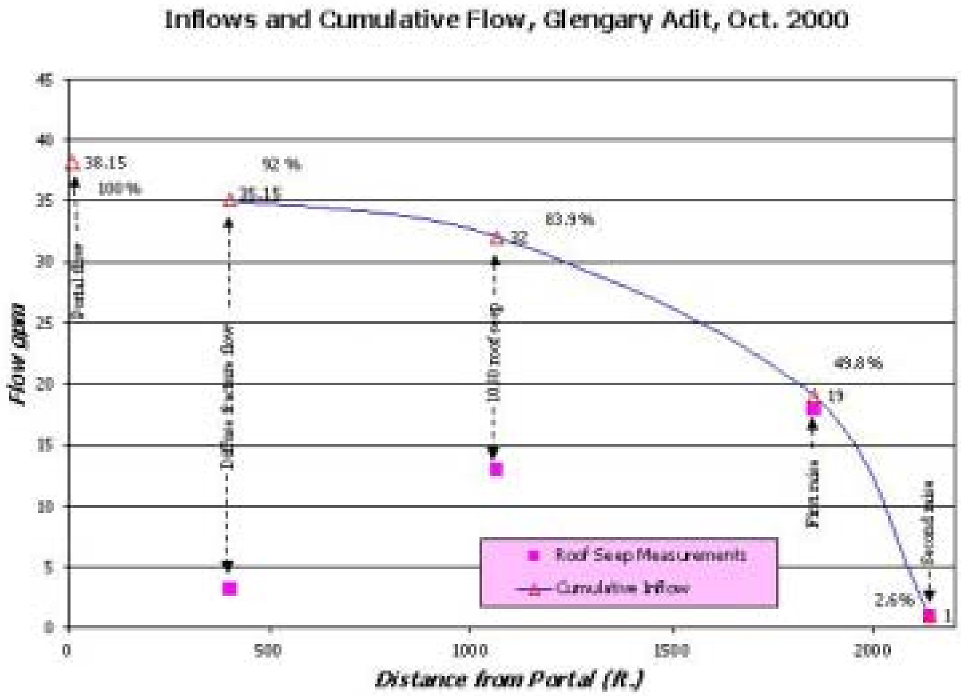


Figure 15. Water Flow in the Glengarry Adit, October 2000

Figure 16. As Concentration with distance from Glengarry Portal

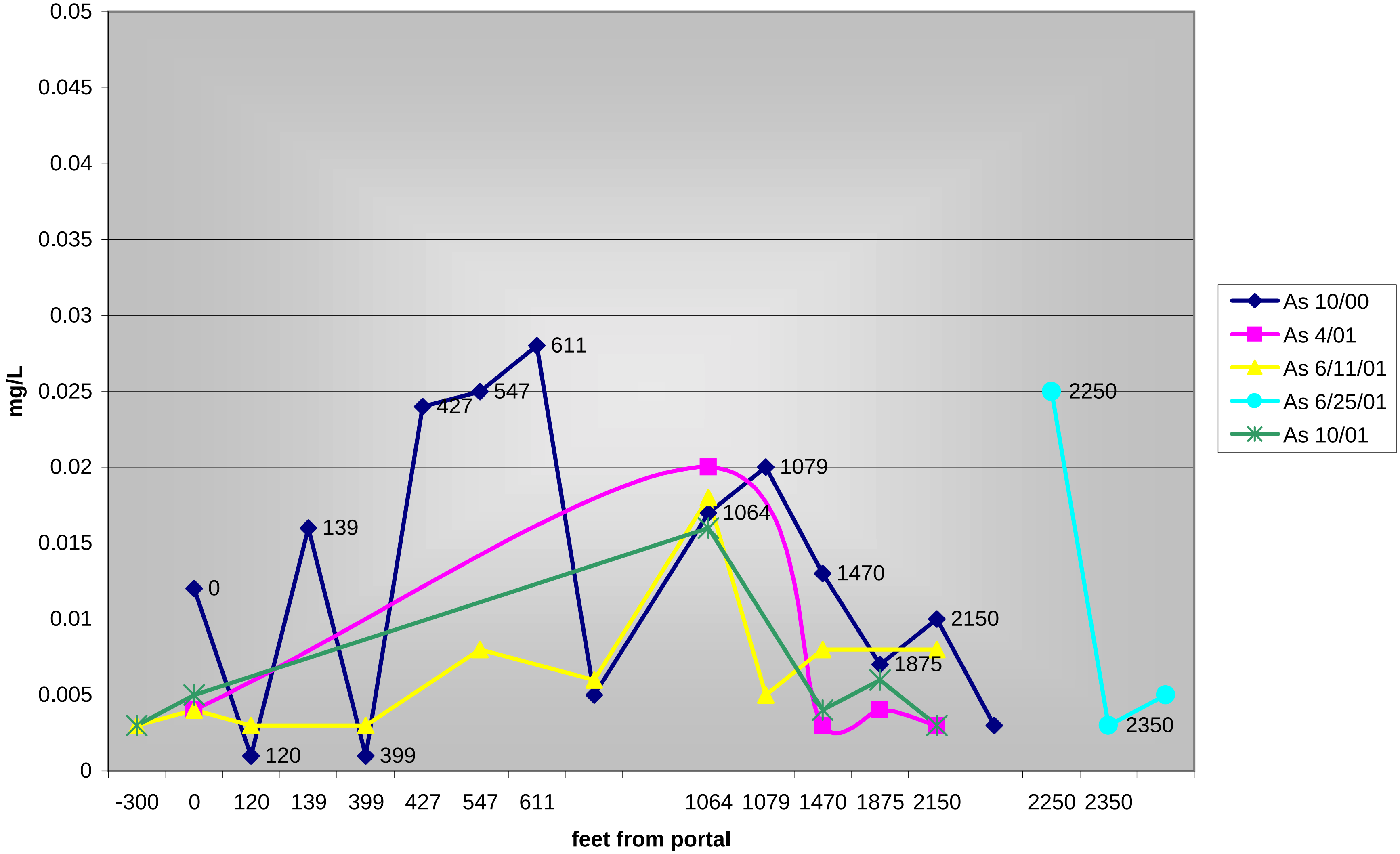


Figure 17. Cu Concentration with distance from Glengarry Portal

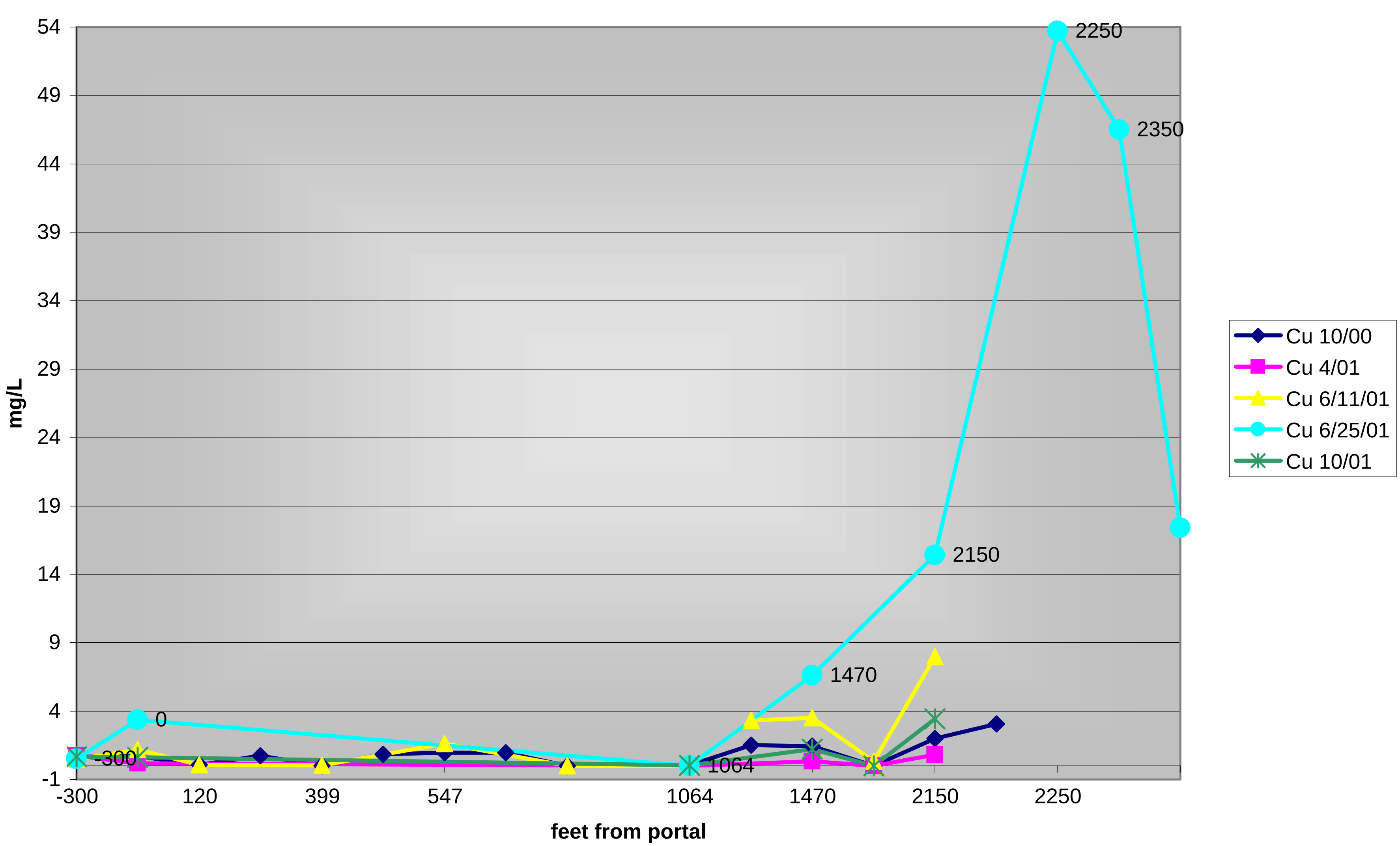
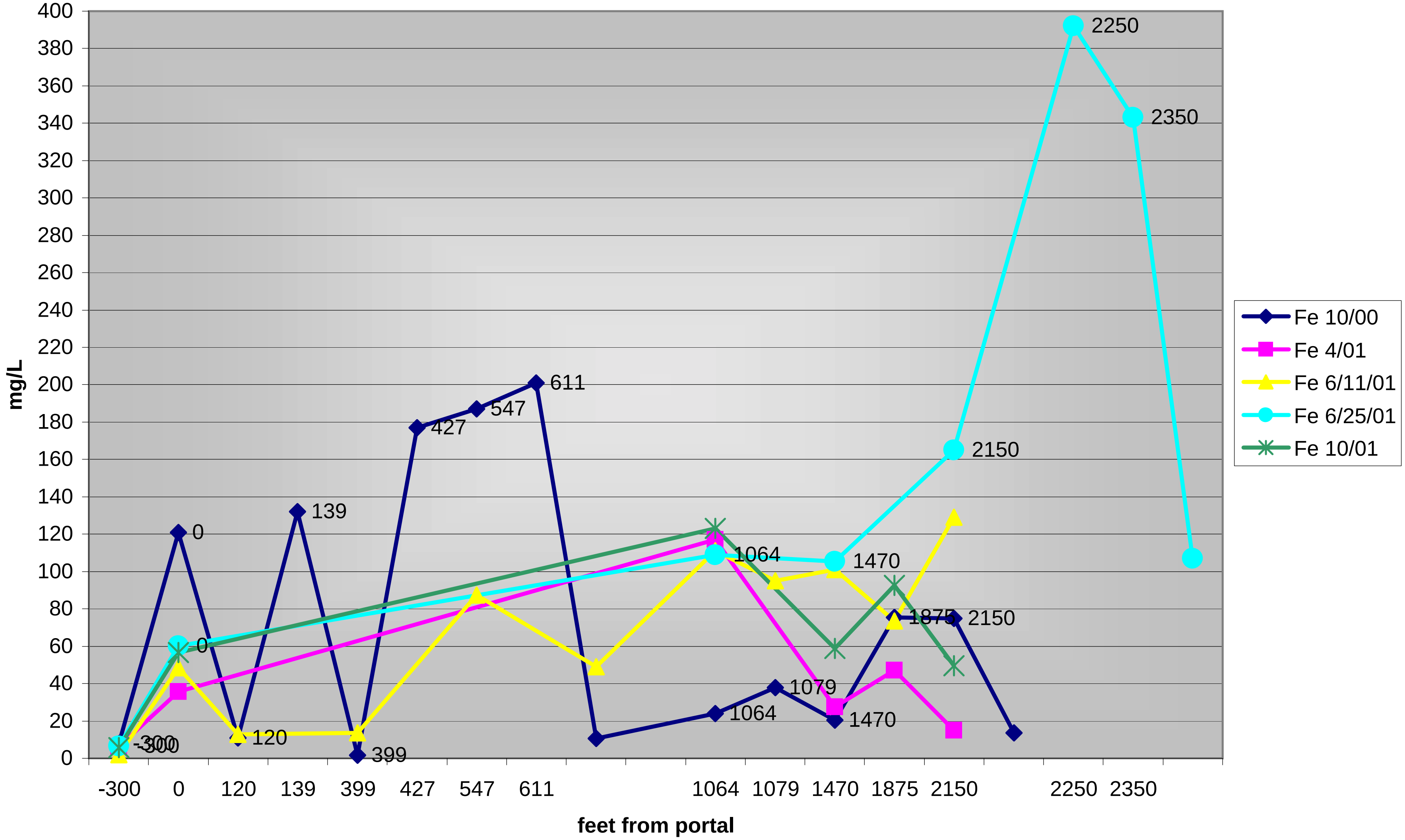


Figure 18. Fe Concentration with distance from Glengarry Portal



Groundwater chemistry in various wells in the Como Basin can be linked to water entering the workings of the Glengarry Adit. Of the three major sources of water entering the Glengarry Adit, the 1050 roof leak is most similar to water in wells completed in late tertiary dikes. Water entering the adit from the first raise also shows characteristics similar to water in wells completed in late tertiary dikes, but appears to be influenced by a component of water originating from mineralized sediments during peak flow. Water entering the adit through the second raise has a direct surface connection with the Como Basin disturbed area. The chemistry of this water reflects equilibrium with sulfide-rich sediment.

3.6.4 GLENGARRY ADIT LOAD TRENDS

Dynamic changes in metals concentration in water discharging from the adit make it difficult to evaluate potential improvements in water quality in the long term. A mass load approach, which evaluates the mass of metals in water discharging from each source over time in kilograms per day, provides a clearer basis for identifying significant sources of contaminants.

Relatively consistent patterns of loading are evident for the April, June, and October 2001 sampling events for most parameters. Figures 19 (arsenic), 20 (copper), and 21 (iron) are good examples of these patterns for the different sampling events. For these parameters, the October 2000 event shows very different loading characteristics than those of the other sampling events, reflecting dis-equilibrium in the adit immediately after the adit was dewatered. Of particular interest is that most parameters in the October 2000 event show a net gain in load that cannot be accounted for with the identified sources. This most likely reflects dewatering of recently excavated sediments along the adit floor. In the remaining four events, most parameters show an unaccounted net loss in load that likely reflects precipitation of oxide minerals and related co-precipitation/sorption (Figures 19 to 21).

Load analysis shows that the vast majority of loading into the adit comes from the raises and the 1050 roof leak, and not the diffuse fractures. Comparison of loading sources between elements shows that the Glengarry receives several orders of magnitude more copper from the top of the Como raise than from all the other in-flow sources combined. The raises also contribute more manganese load as well. The 1050 roof leak contributes more arsenic, aluminum, and cadmium load than the raises. In addition, the two raises and the 1050 roof leak each contribute at least an order of magnitude more iron loading than do the diffuse roof leaks. Comparison of the percent contribution of inflows, relative to outflow, shows that roughly equal loads of iron, lead, and zinc are released by the raises and the 1050 fracture, varying depending upon flow. These results clearly show that control of discharge from the Como raises and the 1050 roof leak are most important in reducing contaminant loading from the Glengarry Adit.

3.7 SEVERE EROSIONAL ISSUES IN THE COMO BASIN AND UPPER FISHER CREEK SOURCE AREAS

Several severe erosional problems exist in the Como Basin and Fisher Creek Source areas, where the east-facing slope below the basin has been subject to erosion due to down-cutting of the drainages leading out of the upper basin, and vehicle traffic in the vicinity of the Lulu Pass road. Erosion in these areas contributes sediment to Fisher Creek with above background metals concentrations (See stations SW-3 and SW-4 in Table 3-10).

Erosion problems in the headwaters of Fisher Creek (Figure 22) include:

- Erosion and channel incision associated with a constructed surface water diversion channel on the north flank of Fischer Mountain that diverts surface water flow around the Como Basin;
- Two natural channels that originate in the Como Basin and are incised and erode unconsolidated colluvial deposits as the channels descend the steep, east-facing slope below the basin, and
- Switchbacks on the Lulu Pass road down the steep east-facing slope from the Como Basin to the Glengarry Adit portal, which have been eroded by vehicle traffic and off-road travel.

3.7.1 DIVERSION CHANNEL

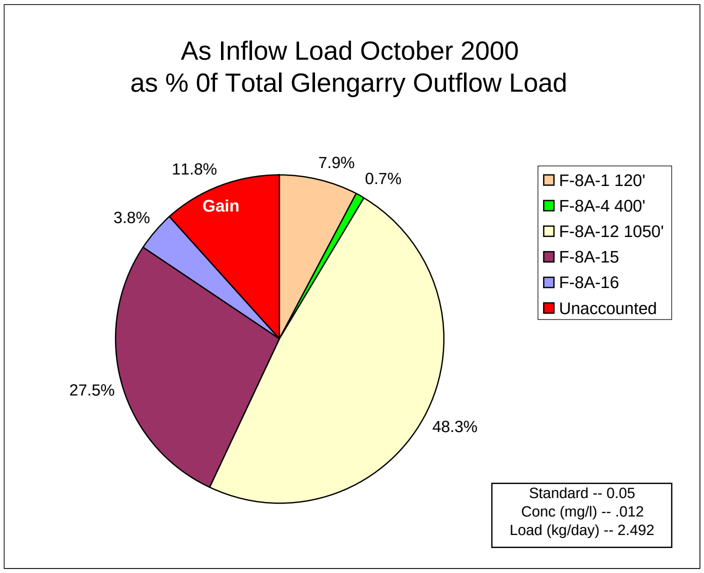
A surface water diversion channel was constructed by CBMI on the south side of the Como Basin (Figure 22). The purpose of the diversion is to prevent runoff from the north slope of Fischer Mountain from directly impacting the Como Basin. Runoff is diverted to the eastern border of the basin and then discharges into the most easterly channel that drains the Como Basin. The eastern half of the diversion channel appears to have been overloaded during peak runoff events as indicated by erosion of the down-slope bank. Channel capacity should probably be expanded on the eastern half of this diversion ditch. Another problem with this channel is riprap that armors the channel ends on a relatively steep slope, and the existing surface water channel is being down-cut by increased high-energy water flow.

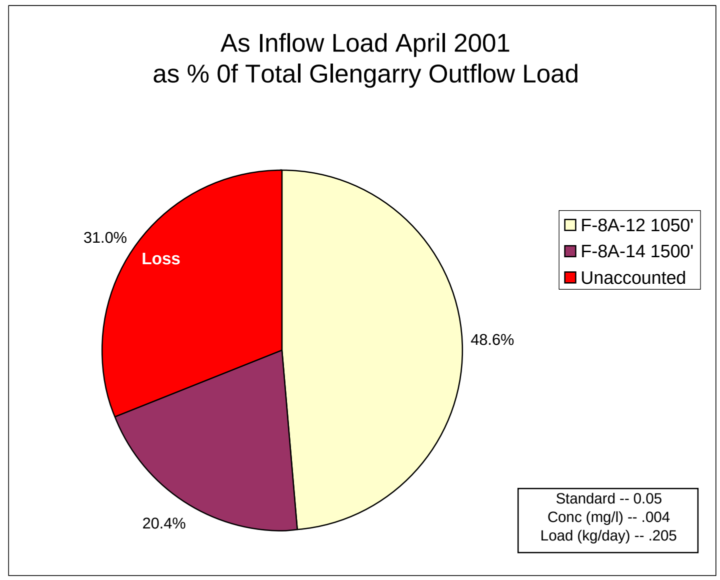
3.7.2 CHANNEL EROSION

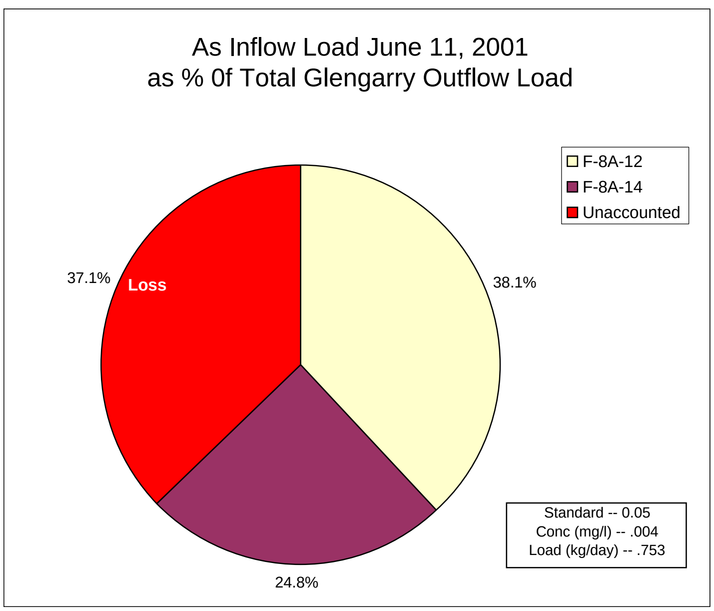
Channel erosion is occurring in the two main channels that originate in the Como Basin as well as the continuation of these channels down the steep east-facing slope that ends at the Glengarry Adit (Figure 22). The channel that originates with the diversion ditch turns to the east at the east edge of the basin and is the more southerly of the two main channels as it descends the east-facing slope. This channel is heavily eroded for its entire upper portion (about 300 meters) but is in relatively stable condition for the remainder of its descent (about 330 meters). In the Como Basin, the channel has incised as much as 1.3 meters and, after it starts to descend the east-facing slope with grades up to 50 percent, the incision is as great as two meters. Well-lithified ferricrete deposits are exposed by erosion in many places in the streambed from the Como Basin to the Glengarry Adit and below. These ferricrete deposits are acting as a temporary base-level that limits further vertical erosion. However, this means that during high flow events and snowmelt, excess water in these channels causes severe lateral erosion of colluvial slope-wash materials.

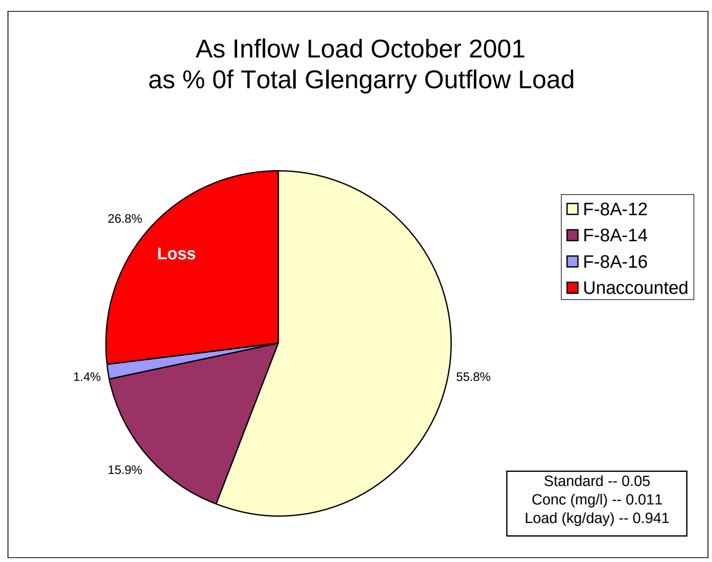
After the steepest grades on the headwall are passed and the grade begins to moderate, the stream braids into two or three channels for about 100 meters. In this reach the channels are not incised but are still subject to erosion. Near the end of the braided reach, the grade moderates again and there is an area of sediment deposition where locally overbank fans have been deposited. Below the depositional area the channels rejoin and the channel bed appears to be relatively stable to the base of the slope.

The more northerly channel originates in the western portion of the Como Basin where the upper portion of the channel has been rebuilt by CBMI (Figure 22). From this point to the base of the slope, much of the channel has been impacted by erosion. The initial 150 meters of channel, on a moderate eight percent slope, is only lightly eroded, and channel reconstruction is not necessary in this reach. At the point where the channel is joined by the channel originating near the former Small Como dump, there is a sediment deposit (estimated to contain up to 200 cubic meters of sediment) that was deposited Figure 19 – Arsenic Inflow Load as % of Total Glengarry Outflow Load - loading data Aspie



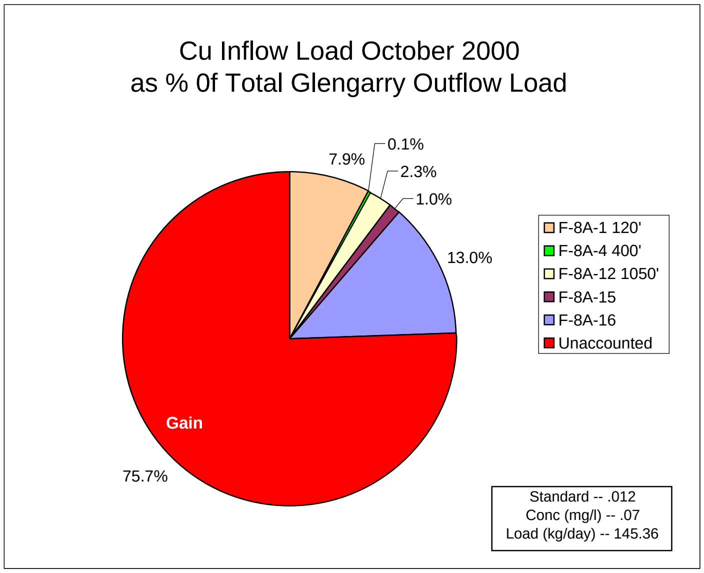


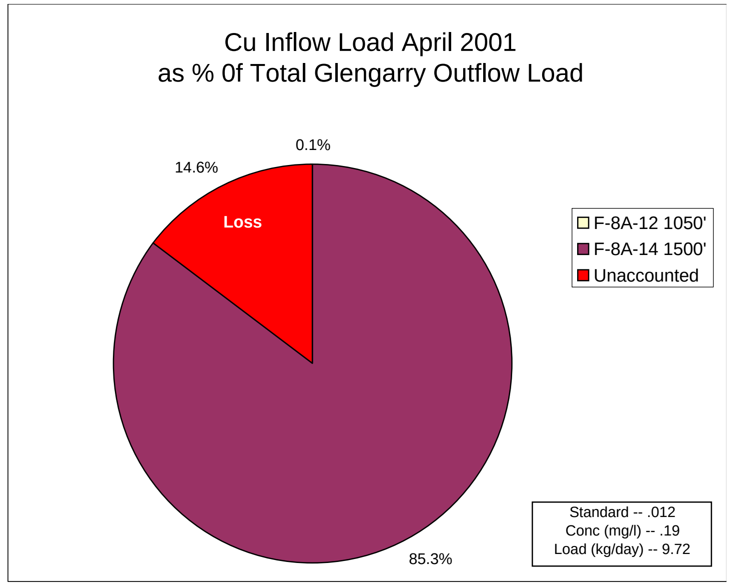


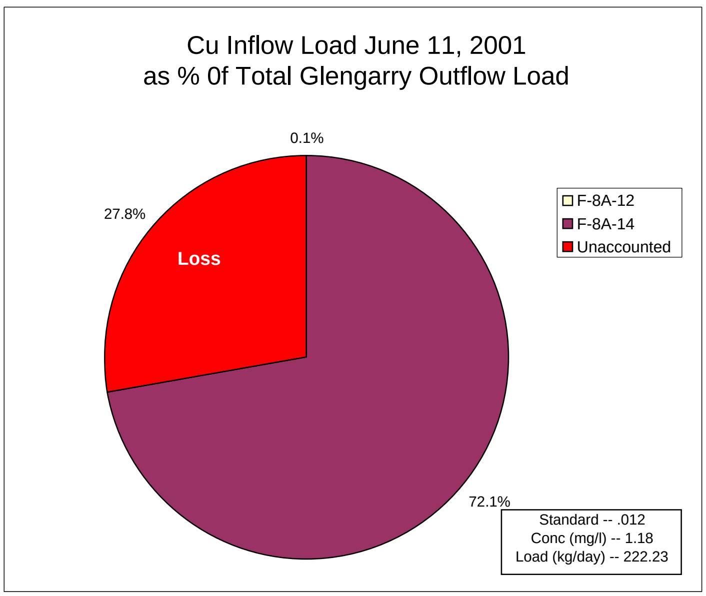


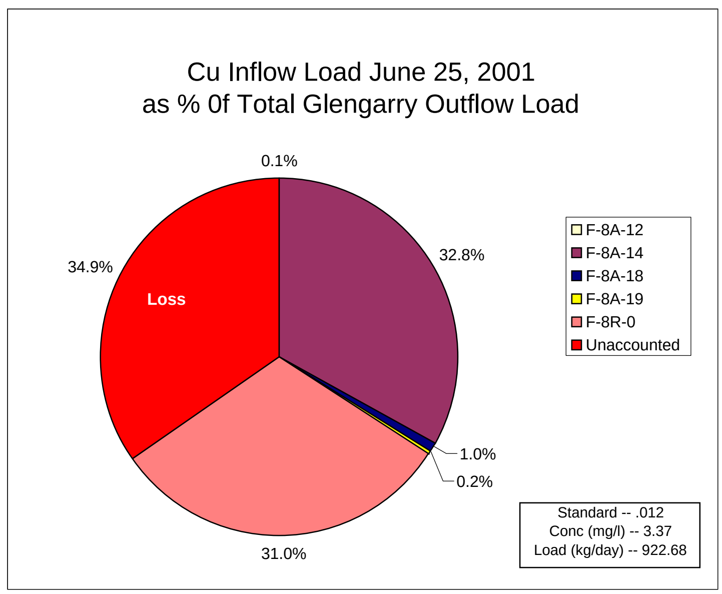
F-8A-1 120'	Diffuse fracture flow
F-8A-4 400	Diffuse fracture flow
F-8A-12 1050	1050 Roof leak
F-8A-14	Floor, sum of 1st & 2nd raises
F-8A-15	First raise
F-8A-16	Second raise
F-8A-18	Intermediate Como raise
F-8A-19	Intermediate Como raise
F-8R-0	Como raise collar

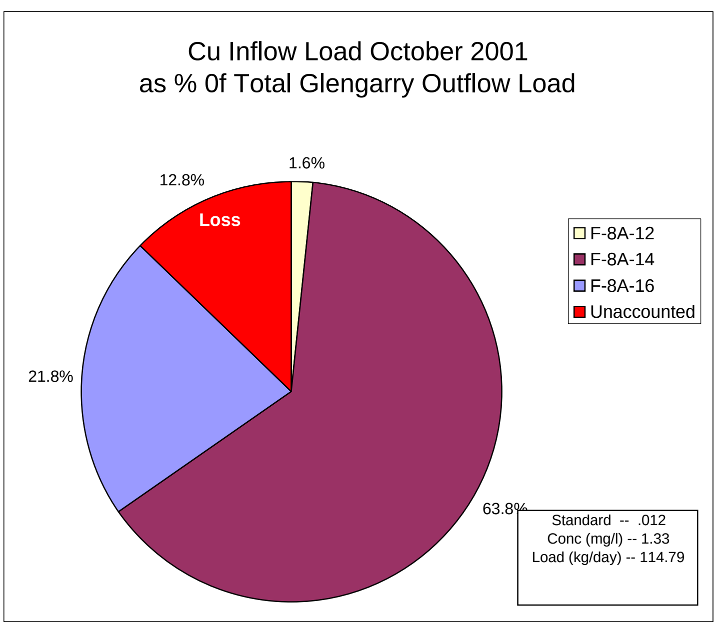
Arsenic Inflow Load as % of Total Glengarry Outflow Load
New World Mining District Response and Restoration Project
FIGURE 19





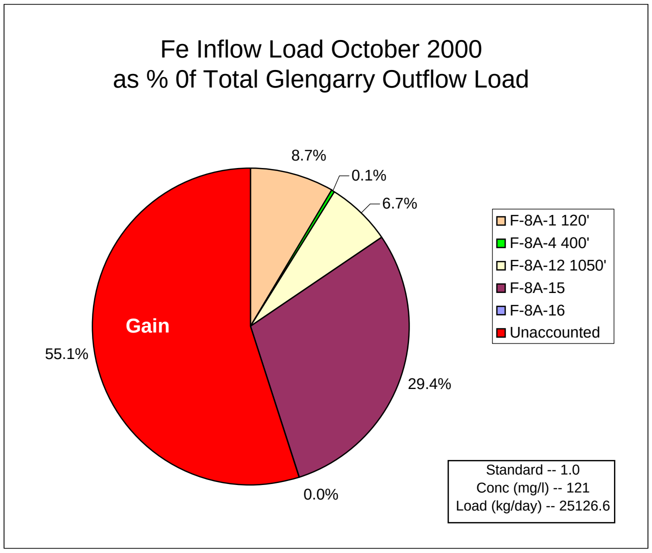


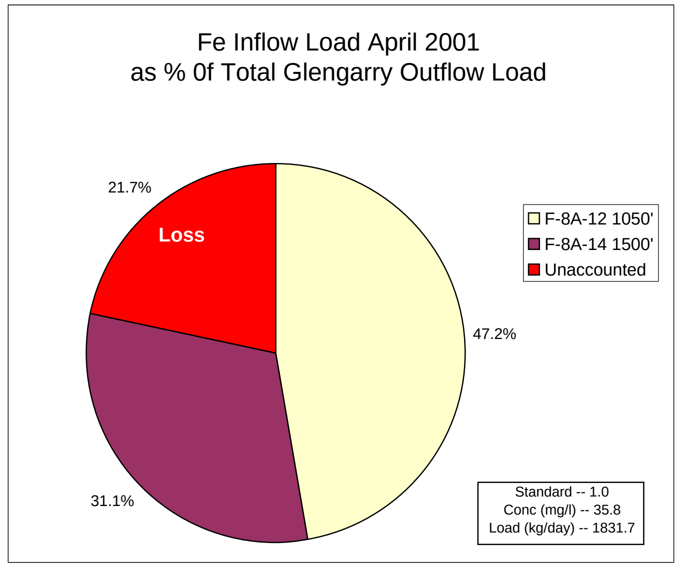


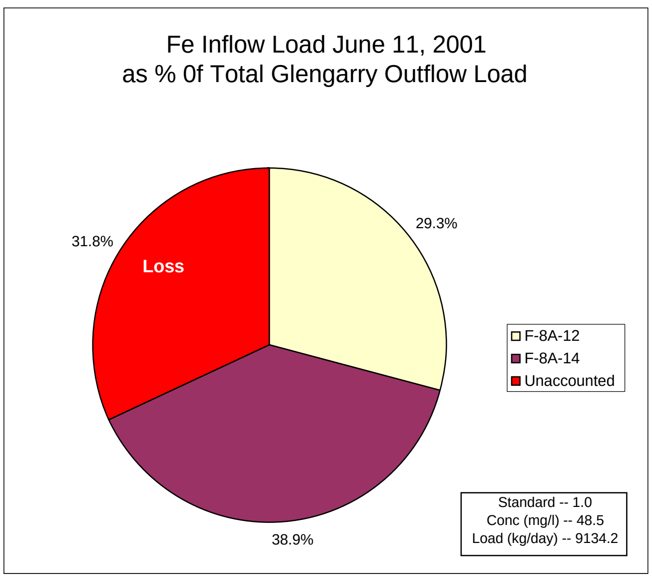


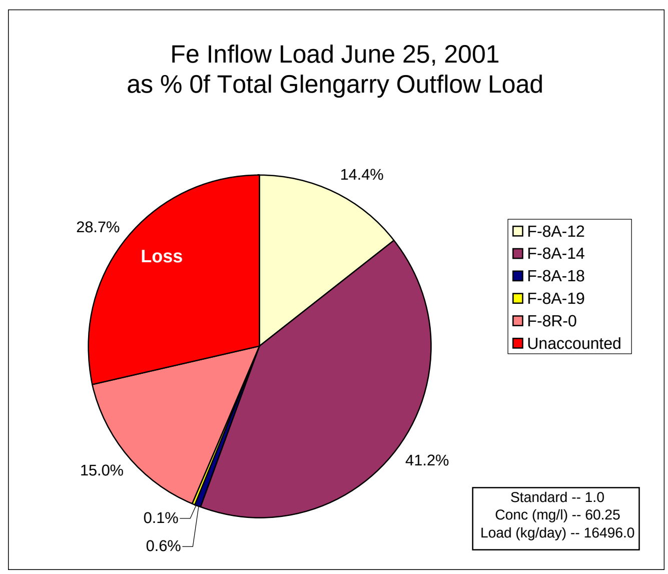
F-8A-1 120'	Diffuse fracture flow
F-8A-4 400	Diffuse fracture flow
F-8A-12 1050	1050 Roof leak
F-8A-14	Floor, sum of 1st & 2nd raises
F-8A-15	First raise
F-8A-16	Second raise
F-8A-18	Intermediate Como raise
F-8A-19	Intermediate Como raise
F-8R-0	Como raise collar

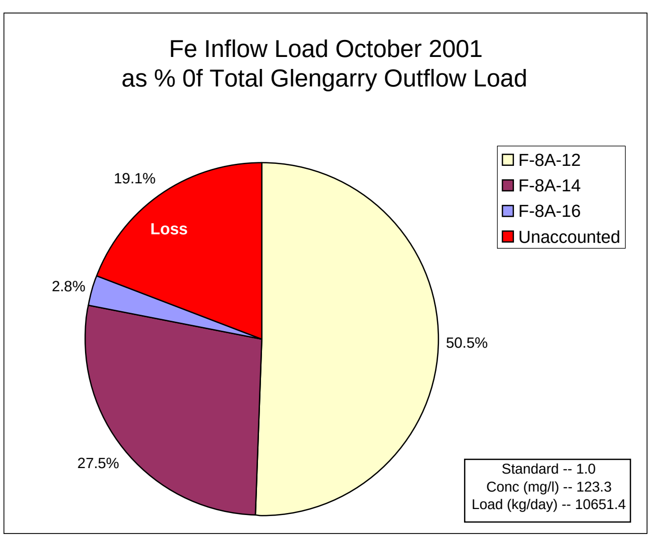
Copper Inflow Load as % of Glengarry Outflow Load
New World Mining District
Response and Restoration Project
FIGURE 20











F-8A-1 120'	Diffuse fracture flow
F-8A-4 400	Diffuse fracture flow
F-8A-12 1050	1050 Roof leak
F-8A-14	Floor, sum of 1st & 2nd raises
F-8A-15	First raise
F-8A-16	Second raise
F-8A-18	Intermediate Como raise
F-8A-19	Intermediate Como raise
F-8R-0	Como raise collar

Iron Inflow Load as % of Total Glengarry Outflow Load
New World Mining District
Response and Restoration Project
FIGURE 21

Figure 22 – Erosion Areas in the Headwaters of Fisher Creek

behind a road berm that crosses the drainage because a culvert is plugged. The roadway has since been removed but the deposit remains. Starting at sediment deposit and continuing downstream, the channel eroded enough to require rebuilding. The heaviest erosion is on the steep (50 percent) slope of the headwall of the east-facing slope. After about 180 meters, the slope moderates and the flow separates into two channels for about 60 meters until it reaches a breached dike where the channels are forced together. This braided reach and the 35 meters of channel below the dike are in relatively good shape and do not need rebuilding although the breached dike should be reclaimed to minimize sediment contribution to the channel. The remaining 300 meters of channel has experienced some erosion and erosion protection measures should be considered. A limiting factor for construction in this lower reach is the five-meter high, steep slopes on either side of the channel.

There is also a small channel that originates near the headwall of the east-facing slope on the south side of the Lulu Pass Road. This channel has been subject to heavy erosion for about 60 meters before it enters the north-channel.

3.7.3 LULU PASS ROAD EROSION

The Lulu Pass Road is a county road located just north of the north-channel, adjacent to the Glengarry Adit portal, where it begins its ascent of the steep, east-facing slope below Como Basin (Figure 22). Once it reaches the Como Basin it traverses the north side of the basin and continues on the short distance to Lulu Pass. The main track of the road has about seven major switch-backs on the steep, east-facing slope. On this slope there are numerous side tracks that are caused by off road vehicle traffic. Drainage and erosion are major issues on this portion of the road. The Lulu Pass Road will remain open to the public in the long-term, but may need to be closed when construction and reclamation occurs along the road.

3.8 SOURCES AND EVIDENCE FOR PRE-MINING ACID ROCK DRAINAGE

A number of pre-mining sources, some of which are introduced and described above, have been identified as probable natural occurrences of acid rock drainage (ARD). Considerable evidence provides convincing support for the conclusion that some of these sources existed prior to mining. Absolute quantification of the amount of contamination attributable to these pre-mining sources is difficult, however, and has been the subject of considerable investigation (Runnells, 1992; Furniss and Hinman, 1998; Lovering, 1929). Probable natural background sources of ARD at New World include: metal-enriched, massive sulfide deposits; mineralized zones in bedrock; disseminated sulfides contained within very large masses of intrusive rocks; fracture and fault controlled mineralization; anomalous metal concentrations in native soils; groundwater migration through sulfide and metal-bearing bedrock units; transported and deposited metal-bearing sulfide sediments; chemical precipitates along tributary drainages and in over-bank sediments; ferricrete deposits; and, metal-enriched bogs.

3.8.1 BEDROCK SOURCES

In the New World Mining District, there are five known deposits that consist of gold-copper-silver mineralization hosted in massive sulfide-rich (pyrite and chalcopyrite-bearing) sedimentary replacement deposits. The total amount of this material identified by past exploratory drilling in the vicinity of Fisher Mountain and at the northern end of Henderson Mountain is quite large (CBMI, unpublished data). Approximately 12,000,000 tons were identified as geologic reserves, or zones of contiguous ore grade or near-ore grade mineralization. These massive sulfide deposits average about 35% total sulfides by weight and range between 10% and 60% total sulfides. Oxidation of sulfides in the presence of oxygen and water produces sulfuric acid and releases metals trapped in the sulfide structures, as shown in the following set of chemical equations.

$2FeS_2 + 2H_2O + O_2 = 2\,Fe^{++} + 4H^+ + SO_4^{2-}$
pyrite + water + oxygen = iron (in solution) + acid + sulfate (in solution)
pyrite + water + air = metal + acid + salt + heat

Most metals are very soluble in acidic waters, and therefore, when sulfide-bearing rocks weather or oxidize, they have the potential to release acid and metals to the environment unless other minerals are available to neutralize the acidic water (such as limestone). Unconsolidated materials weather and oxidize more rapidly, and typically generate a higher load of acidity, metals, and sulfate, but it has long been recognized that as long as adequate oxygen and water are present, sulfide oxidation occurs in undisturbed materials as well. Indeed, in-situ oxidation has provided an important prospecting tool that has led to the discovery of many ore bodies.

Two of the five deposits at New World are exposed at the surface, and have probably been exposed to surface weathering and leaching by infiltrating meteoric waters for the last 10,000 years since glaciers last eroded the topography (Lovering, 1929). These deposits are the McLaren deposit, located at the headwaters of Daisy Creek on the southwest flank of Fisher Mountain, and the Como deposit located in the Como Basin immediately east of Lulu Pass at the north end of Fisher Mountain. These deposits occur as replacement mineralization in the Meagher Limestone. Bedrock is intensely fractured and faulted based on detailed drilling investigations conducted by CBMI. The deposits are cut by the major Crown Butte fault zone, which runs essentially north to south throughout the entire New World District over a zone about 15 meters (50 feet) wide (Figure 4).

Ample material has been exposed to weathering at the surface since post-glacial times that has undoubtedly produced a considerable amount of historic ARD. In the Fisher Creek drainage, this is evidenced by large aprons and terraces of ferricrete that have been deposited downgradient and downstream of exposed surface deposits. Elsewhere, terraces of ferricrete, some as much as 5 meters (15 feet) thick, have been deposited from seeps and springs adjacent to the Fisher Creek channel. In addition, large fluctuations in groundwater have been measured in bedrock wells developed within the Como Basin that clearly demonstrate that most of the mineralized Meagher Limestone is subjected to periodic (at least annual) oxidation and flushing events that remove stored acidity and metals that accumulate during the oxidation period.

Intrusive (igneous) rock that comprises Fisher Mountain (Fisher Mountain Intrusive Complex) and the northern end of Henderson Mountain (the Homestake Stock and Intrusive Complex) was extensively altered by hydrothermal activity some 40 million years ago. The alteration is so classic and widespread that these two intrusive bodies were explored as potential molybdenum and copper-porphyry deposits (large tonnage, low-grade deposits) in the 1970’s and 1980’s. The type of alteration present within these stocks is named for the assemblage of minerals that make up the alteration, *quartz-sericite-pyrite*. In the New World District, there are very large volumes of rock that contain disseminated sulfides, pre-dominantly pyrite, chalcopyrite, and molybdenite (iron, copper, and molybdenum sulfides, respectively). These very large volumes (conservatively 200,000,000 tons) of altered intrusive rocks contain between 2 and 4 percent disseminated sulfides (with larger amounts on fractures and faults. Rocks containing as little as 0.3% pyrite are potentially acid generating depending on the neutralization potential of the host rock. Altered granitic intrusive rocks like those found in the New World District contain very little neutralization potential. These intrusive rocks have been exposed to weathering since the retreat of the last glaciers some 10,000 years ago, and are unquestionably a source of acid and metal loading to ground and surface waters.

Fractures and faults throughout the district have been mined and thoroughly prospected in the past for metals. These fractures systems contain abundant sulfide mineralization and metals (gold, copper, silver, lead, and zinc, as well as other metals) as vein and fracture-fillings that extend out from the altered intrusive centers. Fracture systems within the intrusives themselves have been identified by geophysical techniques (conductivity, resistivity, and induced polarization) and drilled to examine the style, type, and grade of mineralization present. These fracture systems were observed to contain as much as 30 to 40% sulfides. These fracture systems also represent the major conduits for water movement in the district where the rock is most permeable in the plane of the fractures and most groundwater is stored in secondary porosity zones created by fractures. The Crown Butte Fault zone in the subsurface beneath Fisher Mountain contains a deposit called the “Fisher Mountain Zone” where the fault and the adjacent Pilgrim Limestone are completely replaced by massive sulfide (generally in excess of 80% sulfide). This deposit was shown to be over 365 meters (1,200 feet) long (north-south along the fault), is as much as 15 meters (50 feet) wide, and 60 meters (200 feet) high in the plane of the fault in mineral exploration studies, and lies only about 60 meters below the crest of the mountain in the plane of the fault. This fault zone has been shown to have very high permeability by pump-testing in the Miller Creek drainage (CBMI, unpublished data) along the fault zone, and by dye tracer studies conducted by the EPA, where dyes introduced near the fault on Fisher Mountain showed up in the Miller and Fisher Creek drainages (URS, 1998).

3.8.2 Soil Anomalies

One of the most common techniques used by mining companies to explore for deposits hidden beneath soil covers is to sample soils for anomalous naturally occurring concentrations of metals. During the porphyry copper exploration period (1970-1986), a number of mining companies explored the New World District for a large tonnage, low-grade copper and molybdenum deposit. These companies included Kennecott, Rancher Exploration, Gulf Mineral Resources and Amoco Mineral Resources. These companies identified many areas within the District where the soils were anomalously enriched in copper, lead, and zinc, and a number of these areas were subsequently drilled for their porphyry potential. Crown Butte Mines, Inc. duplicated some of the better soil anomalies on Henderson Mountain and obtained copper values in soils as large as 200 parts per million (ppm). Lead and zinc anomalies were also identified.

3.8.3 Groundwater Migration from Mineralized Ground

There is abundant evidence of acidic, metal-laden water exiting from mineralized ground and depositing secondary mineralization throughout the District. Some of these deposits include actively forming chemical precipitates such as aluminum-iron hydroxides (with associated trace metals) that are present as rusty or white coatings on streambeds and boulder/sediment substrates of the Fisher Creek and Daisy Creek drainages (Amacher, 1998). These deposits are evidence of active ferricrete formation (iron-oxide precipitation and cementation of sediments) that result from active weathering of sulfide rich deposits. Transport of dissolved weathering products by surface water and groundwater, subsequent dilution and neutralization, and mineral precipitation causes ferricrete deposits to form.

Groundwater migration from sulfide and metal-bearing bedrock units into surface water and groundwater supplying base flow to Fisher Creek is another source of metal and acid contamination (Amacher, 1998; Kimball and others, 1999).

In addition, a number of seeps and springs from the New World District are acidic and contain large metal loads. These are described in detail in CBMI's environmental baseline studies (CBMI, 1990). Several of these seeps and springs originate in areas that are not obviously mineralized and lie outside of areas affected by historic mining or prospecting activities. In a paper by Runnels and others (1992), two such seeps are described. The results of the chemical analysis of these seeps and springs show very low pH and anomalous metal concentrations present in undisturbed areas (Table 3-14).

TABLE 3-14
RANGES OF CHEMICAL CONCENTRATIONS IN SPRING WATERS FROM UNDISTURBED SITES IN THE NEW WORLD MINING DISTRICT

Location/ Type of Water Sampled	Rock Type	pH	Concentration, mg/L			
			Cu	Zn	Pb	Cd
Park County, Montana (two springs)	Igneous/ sedimentary contact	2.73 - 3.93	0.30 - 7.9	0.07 - 1.1	<0.01	<0.0002 - 0.003

Note: Data from Runnels (1992)

3.8.4 Transported and Redeposited Sediments

Sediments have been transported downstream of the Como Basin site and redeposited as channel fill and overbank deposits along Fisher Creek. These sediments are locally sulfide and metal-enriched. The distribution of these sediments was mapped and inventoried by Hydrometrics (1990) and by CDM (1997). Remobilized sediments are considered secondary sources in terms of their contribution to overall loading in Fisher Creek, and are therefore not addressed as part of this EE/CA. These sources could be considered for removal at some future time. The composition of these sediments is described above in Section 3.4.

In addition, glacial tills in both the Fisher and Daisy Creek valleys were drilled for various geotechnical purposes and as monitor wells. Glacial tills above the water table are oxidized and contain abundant iron oxides and hydroxides. In a zone of fluctuating water within the till, sulfide minerals are partially oxidized while sediments below the water table in the glacial till contain abundant pyrite. Geotechnical bore holes in Fisher Creek collected samples of pyritic glacial till over intervals as thick as 50 feet with pyrite contents estimated to be as high as 20%.

3.8.5 Ferricrete Deposits

Ferricrete deposits are alluvial, colluvial, or talus deposits that are cemented by iron-manganese-aluminum oxide and hydroxides. The cementing agent (hydroxides) dehydrates over time to form a well-lithified material that typically resembles an iron oxide or rust-cemented breccia. These deposits contain anomalous amounts of other metals that are associated with and adsorbed to or co-precipitated with the iron hydroxides. Ferricrete deposits have been, and continue to be deposited along the hydrologic gradient below the Como Basin, and elsewhere, wherever seeps and springs containing acidic and metal laden waters come to surface.

Active, historic, and ancient deposition of these chemical precipitates was described by T. S. Lovering, a geologist with the USGS, during field studies of the New World District conducted early in the last century (Lovering, 1929). Excerpted from that report is the following:

> *"Talus breccias cemented by limonite cover may acres near the headwaters of the Clarks Fork of the Yellowstone (Fisher Creek). Large pyritic deposits occur near by, and both surface and groundwater move from the sulfides to the breccias, where deposition of iron hydroxide is going on actively", and*
>
> *"Talus and gravel have been thoroughly cemented by iron hydroxide in many places near Red Mountain (Fisher Mountain), and areas covering many acres may be found on its western and eastern flanks."*

Furniss and Hinman (1998) mapped ferricrete deposits in the New World District (Figure 23), which are relatively common in the upper reaches of the Fisher Creek and Daisy Creek. In the course of their mapping, they locally identified logs and other organic debris contained in these ferricrete deposits. Organic materials were collected from these ferricrete deposits for radiocarbon dating (Figure 23).

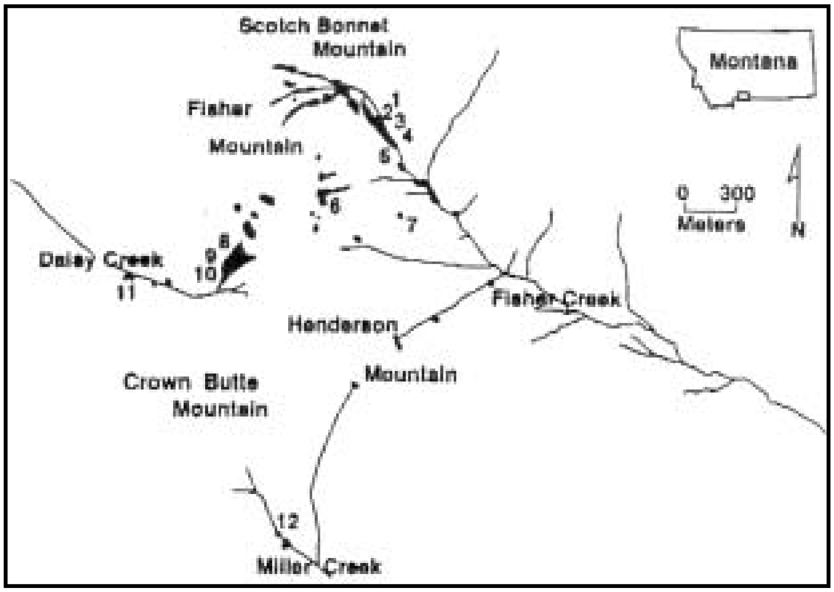


Figure 23. Location of mapped ferricrete deposits in the New World Mining District, Montana. Numbers indicate ferricrete sample locations with radiometric dates. Data from Furniss and Hinman (1998).

The dates reported from these samples range from 310 to 8,740 years before present (Table 3-15) (Furniss and Hinman, 1998). These dates are clear evidence that acid rock drainage and metal contamination was naturally occurring in each of these drainages, for approximately the last 9,000 years, long before historical mining activities.

Furniss and Hinman (1998) also chemically analyzed ancient and recent hydroxide cemented material and precipitates. The mean and range of compositions for several elements from each of these types of deposits are shown in Table 3-16. These data clearly indicate that not only were these ferricrete deposits formed long ago, but chemically they also contained anomalous metal concentrations, similar to those of modern chemical precipitates and ferricretes that form from ARD.

3.8.6 BOGS

There are a number of metal-rich bogs developed in conjunction with seeps and springs in both the Daisy and Fisher Creek drainages. These bogs are typically discolored (brown and gray) masses of dead and decaying organic material admixed and interbedded with sediments. They contain abundant anomalous metal concentrations (usually iron and manganese, but locally copper). A particularly large bog occurs in the Fisher Creek drainage below the Glengarry Mine, and another occurs on the northeast flank of Fisher Mountain in an area that is undisturbed by mining.

TABLE 3-15
RADIOCARBON DATES FOR WOOD COLLECTED FROM FERRICRETE DEPOSITS IN THE NEW WORLD DISTRICT(1)

Sample Location(2)	Analytical Method(3)	Radiocarbon Date (years before present.)
1	B	6,800 ± 70
2	B	8,690 ± 80
3	B	5,810 ± 80
	B	6,920 ± 80
	B	7,030 ± 60
	B	7,170 ± 70
	B	7,170 ± 70
4	B	5,970 ± 150
	B	8,270 ± 70
5	B	30 ± 50
	B	60 ± 70
	B	100 ± 100
	B	550 ± 80
	B	890 ± 70
6	A	4,000 ± 60
7	B	1,670 ± 40
8	A	8,620 ± 60
9	B	310 ± 110
10	A	8,700 ± 50
	A	8,840 ± 50
11	A	6,490 ± 60
12	B	2,050 ± 50

(1) Data from Furniss and Hinman (1998)
(2) Radiocarbon dates in stratigraphic order where more than one date shown
(3) A = accelerator mass spectrometer; B = beta decay

TABLE 3-16
COMPOSITION OF IRON-OXYHYDROXIDES COLLECTED FROM ANCIENT AND MODERN FERRICRETE DEPOSITS

Element	Concentration (milligrams per gram)			
	Mean Ancient Samples	Mean Modern Samples	Range Ancient Samples	Range Modern Samples
Sulfur	6.90	32.00	0.80 – 17.40 (n=30)	1.60 – 49.80 (n=4)
Aluminum	10.80	63.00	0.33 – 55.80 (n=30)	0.750 – 141.0 (n=5)
Copper	2.58	5.80	0.08 – 12.60 (n=30)	0.075 – 21.1 (n=5)
Iron	239.00	236.00	21.8 – 446.0(n=30)	69.10 – 394.0 (n=5)
Lead	0.13	0.14	0.01 – 1.04 (n=17)	0.12 – 0.16 (n=3)
Magnesium	1.75	1.95	0.16 – 4.10 (n=11)	1.0 – 2.9 (n=2)
Manganese	1.10	0.27	0.01 – 8.01 (n=15)	0.06 – 0.64 (n=4)
Phosphorous	1.80	1.20	0.16 – 10.6 (n=25)	0.76 – 2.0 (n=4)
Potassium	1.24	3.20	0.23 – 2.6 (n-9)	1.3 – 5.0 (n=2)
Zinc	0.20	0.27	0.01 – 2.1 (n=25)	0.001 – 0.75 (n=4)

Notes: Data from Furniss and Hinman (1998)
Samples analyzed by strong acid leach digestion (nitric acid/hydrogen peroxide) and inductively coupled plasma emission spectrophotometry (ICP) (US EPA Method 3050)
(n = number of samples)

Lovering (1929) describes an unusual copper bog as follows.

> *"The alluvium near the lower Glengarry Adit carries spongy nuggets of native copper. Trenches several feet deep expose gravel and slope wash interbedded with a little black mud. Some of the gravel is clean and some contains limonite, but no native copper has been found in it. The dark mud usually contains native copper, but nowhere iron stained. The copper bearing layers do not make up more than 5-8 per cent of the section exposed in the cuts, but …"* and *"The deposit rests in a recently glaciated valley and must be of very late origin. The copper-bearing mud contains blackened blades of grass, partly decomposed twigs, and other organic material that has now lost all form…the conclusion is reached that metallic copper has been precipitated from these solutions by organic material."*

3.9 HYDROLOGIC EVALUATION OF COMO PIT BACKFILL

The Hydrologic Evaluation of Landfill Performance (HELP) model was used to estimate the amount of seepage (infiltration) percolating through unconsolidated metal-rich soil material in the Como Basin. The HELP model is a quasi-two-dimensional hydrologic model developed by the U.S. Army Corps of Engineers for the EPA that models water movement across, into, through, and out of landfills. The HELP Users Guide (Schroeder et. al., 1994) states, "The primary purpose of the model is to assist in the comparison of design alternatives as judged by their water balances." The analysis presented in this section characterizes current conditions in the Como Basin. In addition to infiltration analysis, another intent of the HELP analysis was to compare values calculated for infiltration and runoff with flow measurements made at surface water Station FCT-11, which flows out of the Como Basin.

In the Como Basin, nearby bedrock wells demonstrate significant large-scale static water level fluctuations of as much as 21 meters (68 feet). These wells include MW-1 (14.6 meters, 48 feet of fluctuation), EPA-11 (20.7 meters, 68 feet), and EPA-12 (16.5 meters, 54 feet) (Figure 3). No monitor wells are completed in Como Basin colluvium. It is estimated that water levels in the unconsolidated material in the Como Basin fluctuate on the order of 0.6 to 1.0 meters (2-3 feet) in elevation as is observed in the similar geologic setting of the McLaren Pit. This fluctuation suggests that the sulfide-bearing metal-rich soils of the Como Basin may be subject to periodic oxidation with subsequent flushing of infiltration through unconsolidated material. As a result of oxidation and chemical reaction with the metal-rich soils in the basin, water that has percolated through unconsolidated materials may contain considerable acidity and metal concentrations, and is a known source of groundwater and surface water contamination.

By quantifying the source of water (i.e. infiltration or groundwater inflows) in the Como Basin, impacts to Fisher Creek can be determined. Due to the limited quantity of detailed, long-term hydrogeologic and climatic data available, the HELP3 model was chosen as the most appropriate model for calculation of a water balance for unconsolidated material in the Como Basin. Since there are no wells completed in the Como Basin colluvium, the model cannot be calibrated. Without site-specific data, the McLaren Pit HELP3 model layout and design (Maxim, 2001b) was followed for the purposes of the Como Basin model, but Como Basin site-specific dimensions were used.

The following input parameters were considered in the HELP3 model for the Como Basin. Values used for each of these input parameters are discussed in Appendix B.

- Climatic information, including daily precipitation, daily solar radiation, and daily mean temperature
- Evapotranspiration information, including maximum leaf area index (LAI), and starting and ending dates for growing season
- Design information, including layer types and thickness
- Soil material properties in each layer, including porosity, field capacity, wilting point, saturated hydraulic conductivity, initial water content, and SCS curve number.

Soil material properties for unconsolidated materials in the Como Basin were taken from the Help Model for the McLaren Pit (Maxim, 2001b). Four samples of unconsolidated material from the McLaren Pit were collected and submitted for unsaturated hydraulic characteristics testing. In addition, a series of infiltration tests were also conducted at the McLaren Pit in 2000.

A physical model domain was created using an average depth of 3.4 meters (132 inches) of metal-rich soils underlain by approximately 15 centimeters (6 inches) of a barrier soil layer. The actual thickness of unconsolidated material varies from 0 to 35 feet. The barrier soil layer (relatively impermeable layer) was included to model the more limited flow potential from fracture controlled secondary permeability within the bedrock system underlying the Como Basin. Unsaturated hydraulic characteristics for the bedrock system were taken from literature values (Tindall, 1999). Model input parameters are summarized in Table 3-17. Results of HELP modeling are presented in Table 3-18. Seepage under existing conditions through Como Basin metal-rich soils is about 21.4 inches per year of about 6.1 gallons per minute (23 liters per minute).

TABLE 3-17
SUMMARY OF HELP3 MODEL INPUT PARAMETERS SELECTED FOR SOIL MATERIAL
New World Mining District Response and Restoration Project
Como Basin/Glengarry Adit/Fisher Creek Response Action

Parameter	Waste rock	Barrier Soil Layer
Layer Type	Vertical Percolation	Barrier Soil
Layer Thickness (inches)	132 total	6
Porosity	0.4820	0.10
Field Capacity (vol/vol)	0.2950	0.0031
Wilting Point (vol/vol)	0.1770	0.0030
Saturated Hydraulic Conductivity (cm/sec)	0.99E-3	1E-7
Initial Water content (vol/vol)	0.377	0.1

TABLE 3-18
COMO BASIN HELP MODELING EXISTING CONDITIONS
New World Mining District Response and Restoration Project
Como Basin/Glengarry Adit/Fisher Creek Response Action

Condition	Annual Precipitation (inches)	Evapo-Transpiration (inches/yr)	Runoff (inches/yr)	Seepage (inches/yr)	Seepage (gpm for 2.23 Ha)
Existing	54.07	15.8	16.8	21.4	6.1

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4.0 RISK EVALUATION

A streamlined risk evaluation process is used to assess threats to human health and the environment associated with exposure to mine wastes in Fisher Creek. Risks are evaluated using site-specific chemical concentration data, applicable exposure scenarios, and pertinent risk-based cleanup guidelines or ecological criteria. This streamlined risk evaluation examines risks under existing site conditions, assuming no cleanup activities are performed at the site.

4.1 STREAMLINED HUMAN HEALTH RISK EVALUATION

Risk-based guidelines were developed for abandoned mine sites under a recreational scenario (Tetra Tech, 1995). A *User's Guide*, prepared for use by Montana's Mine Waste Cleanup Bureau (MWCB), summarizes the risk-based guidelines and describes how they were developed (Tetra-Tech, 1996). Although this risk evaluation method is not an EPA risk assessment process, it provides a basis to determine risks posed to humans using abandoned mine waste sites for recreational activities.

The streamlined human health risk evaluation involves four steps: (1) selection of contaminants of concern (COCs); (2) completion of an exposure assessment; (3) performance of a toxicity assessment; and (4) completion of risk characterization. These tasks are accomplished by evaluating available site data to select COCs, identifying applicable human populations and exposure routes, reviewing toxicity data, and characterizing overall risk by comparing COC concentrations in soil and surface water to previously derived, risk-based cleanup guidelines.

4.1.1 CONTAMINANTS OF CONCERN

COCs are contaminants that pose significant potential risks to human health or the environment. Surface water data collected at the site from 1989 through 2001 (Table 3-4) were evaluated to identify the COCs for this media. Samples collected from waste rock sources in Fisher Creek (Table 3-2) were evaluated to determine COCs for soil, and samples collected from stream sediments in 1996 were used to determine COCs for stream sediment (Table 3-10).

Standard EPA criteria that must be collectively satisfied to establish a COC are the following: (1) is associated with mining wastes present at the site; (2) has an average concentration at least three times average background levels; and (3) has been measured at concentrations above the detection limit in at least 20% of the samples analyzed. Based on these criteria, arsenic, cadmium, copper, lead, and zinc were identified as contaminants of concern for waste rock. Contaminants in stream sediment include arsenic, chromium, copper, iron, and zinc.

For surface water risk, background data are not meaningful. Therefore, COCs were identified if average site concentrations exceeded the most restrictive water quality standard, the chronic aquatic standard for metallic contaminants. Average concentrations for chromium do not exceed the most restrictive water quality standard. Arsenic has historically not been detected in surface water above practical quantification limits (Maxim, 1998). Mean concentrations of aluminum, copper, iron, lead, and zinc at Station SW-3 on Fisher Creek exceed the chronic water quality standards and are, therefore, considered COCs. However, aluminum and iron in surface water are not considered a risk to human health and will only be considered in the ecological risk portion of this evaluation. Iron only affects the aesthetics of water; no human health standards have been listed for aluminum by the MDEQ (MDEQ, 2001).

4.1.2 Exposure Assessment

An exposure assessment identifies potentially exposed human populations, exposure pathways, and typical exposure durations. Analytical results for soil and water samples are then used to estimate COC concentrations at exposure points and the potential intake of contaminants. Current human exposure to site-related contaminants in soil and surface water is via seasonal recreational activities on and near the dump sites in Fisher Creek. There is currently no residential use of District Property.

The risk evaluation assumed four types of recreation populations: fishermen, hunters, gold panners/rock-hounds, and ATV/motorcycle riders. Evaluated exposure pathways included soil and water ingestion, dermal contact, dust inhalation, and fish consumption. The assessment assumed a moderate to high level of recreational use. The types of activities, exposure pathways, and use levels considered in the recreational scenario are consistent with current recreational uses of District Property. Consequently, the recreational scenario exposure assessment is comparable and applicable to current human exposure at the site.

4.1.3 Toxicity Assessment

A toxicity assessment provides information on the potential for COCs to cause carcinogenic and non-carcinogenic adverse health effects. Toxicity values for COCs are derived from dose-response evaluations performed by EPA. Sources of toxicity data include EPA's Integrated Risk Information System (IRIS), Agency for Toxic Substances and Disease Registry (ATSDR) toxicological profiles, Health Effects Assessment Summary Tables (HEAST), and EPA criteria documents. Individual toxicity profiles for each COC are provided in the reference document (Tetra-Tech, 1996). Arsenic and cadmium at the site are the only COCs that are carcinogens.

4.1.4 Risk Characterization

Findings of the recreational scenario exposure assessment were combined with toxicity data for the COCs to characterize health risks posed to each population through various exposure routes (Tetra Tech, 1995, 1996). The maximum calculated risks were for: (1) a rock-hound/gold panner (soil contact and surface water ingestion); (2) a fisherman (soil contact, surface water ingestion, and fish consumption); and (3) an ATV/motorcycle rider (soil contact, dust inhalation).

To ensure the protection of the majority of recreational visitors, MWCB also developed a set of conservative, risk-based cleanup guidelines for abandoned mine sites based on the lowest cleanup concentration calculated for the various types of exposure and the possibility of multiple exposure routes. The guidelines thus account for visitors participating in several activities and metals exposure routes from both soil and surface water. The conservative, risk-based cleanup guidelines for soil and water are presented in Tables 4-1 and 4-2. The guidelines for each medium are based on a hazard quotient (HQ) of 1.0, where a HQ is the ratio of a chemical exposure concentration to a reference dose that represents a threshold level for human health effects. An HQ greater than 1.0 may cause adverse health effects.

TABLE 4-1
Hazard Quotients For Recreational Visitors Exposed To Soil Ingestion And Dust Inhalation
New World Mining District Response and Restoration Project
Como Basin/Glengarry Adit/Fisher Creek Response Action

Contaminant of Concern	Average Waste Rock Concentration (mg/kg) (1)	Average Stream Sediment Concentration (mg/kg) (2)	Soil Ingestion/Dust Inhalation Guideline (mg/kg)(3)	Hazard Quotient(4)
Arsenic	53	21	700	0.07
Cadmium	12	1.5	19,500	0.0006
Chromium	9	69	735,000 (2,920)(5)	0.00009 (0.02)
Copper	725	1,744	27,100	0.06
Lead	731	114	1,100	0.66
Zinc	245	357	220,000	0.002

Notes: (1) Data from Table 3-2; mg/kg = milligrams/kilogram.
(2) Data from CDM (1997).
(3) Guidelines recalculated from Tetra Tech, (1996). The guidelines are based on a Hazard Index of 0.5 or an increased cancer risk of $5x10^{-4}$.
(4) Hazard quotient calculated for the greater of the waste rock or in-stream sediment concentration.
(5) Guideline based on chromium III risk and chromium VI risk (in parenthesis).

TABLE 4-2
Hazard Quotients for Recreational Visitors Exposed to Water and Fish Ingestion
New World Mining District Response and Restoration Project
Como Basin/Glengarry Adit/Fisher Creek Response Action

Contaminant of Concern	Average Water Concentration (micrograms/liter) (1)	Water and Fish Ingestion Guideline (micrograms/liter)(2)	Hazard Quotient
Arsenic	2	65	0.031
Cadmium	1	66.5	0.015
Chromium	7.8	100,246(3)	0.00008
Copper	675	472	1.4
Lead	5	47.1	0.11
Zinc	109	17.2	6.4

Notes: (1) Data from Table 3-4 - mean concentration at SW-3 for period 1989-2001
(2) Guidelines recalculated from Tetra Tech, (1996). The guidelines are based on a Hazard Index of 0.5 or an increased cancer risk of $5x10^{-4}$.
(3) Guideline based on chromium III risk.

Potential health risks for the site are characterized by comparing the risk-based concentrations in Tables 4-1 and 4-2 to site-specific soil and surface water quality data. The solid medium chemistry data used for the comparison are the average values presented in Table 3-2 and 3-10. The calculation of the hazard quotient was performed using the greater of the two media values for each constituent. The water quality data used for the calculation are the mean concentrations shown in Table 3-4 at Station SW-3, which is on

Fisher Creek below the Glengarry Adit. The total hazard quotient, which is calculated in Table 4-3, includes the soil ingestion/dust inhalation and water ingestion/fish ingestion routes.

TABLE 4-3
Total Hazard Quotients (HQ) for the Recreational Land Use Scenario
New World Mining District Response and Restoration Project
Como Basin/Glengarry Adit/Fisher Creek Response Action

Contaminant of Concern	Soil Ingestion/Dust Inhalation HQ	Water Ingestion/Fish Ingestion HQ	Total HQ for Contaminant
Arsenic	0.07	0.031	0.041
Cadmium	0.0006	0.015	0.016
Chromium	0.02*	0.00008	0.02
Copper	0.06	1.4	1.46
Lead	0.66	0.11	0.77
Zinc	0.002	6.4	6.4

Notes: * Assumes risk associated with chromium VI

The total hazard quotients for arsenic, cadmium, chromium, and lead do not exceed 1.0, which indicates that these COCs do not pose a human health risk for this Response Action. The total hazard quotient for copper is 1.46 and for zinc is 6.4, which is primarily due to the water component of the calculation. This suggests that copper and zinc are human health concerns based on the risk assessment performed by Tetra Tech (1996). In this risk assessment, almost the entire risk of copper and zinc in surface water is posed by ingestion of fish taken from the stream by recreationists. Because there are currently no fish in Fisher Creek at Station SW-3 where the risk calculation is applicable, the risk of exposure to copper and zinc in surface water is probably not a concern in Fisher Creek. Therefore, based on these limited data, there are no unacceptable human health risks associated with the remaining waste dumps in Fisher Creek under a recreational use scenario.

4.2 STREAMLINED ECOLOGICAL RISK EVALUATION

The streamlined ecological risk evaluation was completed to assess the potential risk that mine wastes at the site pose to plants and animals. The evaluation was performed by comparing concentrations of COCs in surface water, sediment, and soil at the site with ecological criteria and standards available in toxicity literature and risk-based EPA guidance. The key guidance documents used were EPA's *Ecological Risk Assessment Guidance for Superfund* (EPA, 1997), *Risk Assessment Guidance for Superfund, Volume II, Environmental Evaluation Manual* (EPA, 1989a), and *Ecological Assessment of Hazardous Waste Site* (EPA, 1989b). Because there are no site-specific ecological risk data available, this evaluation, although executed in a quantitative manner, is only intended to be qualitative.

Because this streamlined ecological risk evaluation focuses on COCs, no evaluation was done with respect to the physical habitat present in the District nor was an assessment made toward how other factors may have affected aquatic or terrestrial populations. The presence or absence of appropriate habitat for animals, spawning beds for fish, or the health of wetlands and riparian areas, while it may affect the presence, diversity, or nature of aquatic and terrestrial populations, are not considered under the non-time-critical removal process evaluation of risk. A use attainability study is the mechanism that would assess the nature of the contamination in conjunction with other habitat factors.

The ecological risk evaluation, like the human health risk evaluation, estimates the effects of taking no action at the site and involves four steps: 1) identification of COCs; 2) exposure assessment; 3) ecological effects assessment; and 4) risk characterization. These steps are completed by evaluating currently available site data to select the COCs, identifying species and exposure routes of concern, assessing ecological toxicity of the COCs, and characterizing overall risk by integrating the results of the exposure and toxicity assessments.

4.2.1 Contaminants of Concern

COCs at the site were identified in Section 4.1.1 as aluminum, arsenic, cadmium, chromium, copper, iron, lead, and zinc. All of these contaminants have the potential to pose ecological risks.

4.2.2 Exposure Assessment

Two groups of ecological receptors have been identified as potentially being affected by site contamination. The first group includes aquatic life and wetlands in Fisher Creek located down-gradient of the source areas. These receptors are of concern because Fisher Creek provides habitat for aquatic organisms, possibly including spawning areas for fish migrating from the Clarks Fork of the Yellowstone. Wetlands are of concern because they typically support a diverse ecological community. The second group of receptors is native terrestrial plants at the site whose ability to grow in soil or mine waste is limited by relatively high concentrations of certain metals and low pH. Potentially adverse exposures of aquatic life and terrestrial plants can be quasi-quantitatively assessed by comparing site-specific surface water, sediment, and soil data to toxicity-based criteria and standards for the respective media. Exposure pathways for aquatic life include: 1) direct exposure of aquatic organisms to metals in surface water that exceed toxicity thresholds; 2) exposure of aquatic organisms (e.g., insect larvae, fish embryos) to sediment pore water that is toxic due to contaminants in the sediments; and 3) ingestion of aquatic species (e.g., insects) that have accumulated contaminants to the extent that they are toxic to predators (e.g., fish). Native terrestrial plants could be exposed to phytotoxic effects related to elevated concentrations of metals in soil or mine wastes at the site.

4.2.3 Ecological Effects Assessment

The COCs are known to have toxic effects on plants and animals (EPA, 1986; Long and Morgan, 1991; Kabata-Pendias and Pendias, 1992). No ecological effects data have been collected from the site, and no site-specific toxicity tests have been performed. As a result, this streamlined risk evaluation assesses potential ecological effects using existing and proposed ecological criteria and guidelines. The criteria and guidelines used to evaluate ecological risks from surface water, sediment, and phytotoxic soil at the site are listed in Table 4-4.

TABLE 4-4
Ecological Assessment Guidelines
New World Mining District Response and Restoration Project
Como Basin/Glengarry Adit/Fisher Creek Response Action

Contaminant	Surface Water (1) (micrograms/liter)	Sediment (2) (milligrams/kilogram)	Phytotoxic Soil (3) (milligrams/kilogram)
Aluminum	87	--	--
Arsenic	150	85	15-50
Cadmium	1.4(4)	9	3-8
Chromium (as III)	117	--	--
Copper	5.3(4)	390	60-125
Iron	1,000	--	--
Lead	3.2(4)	110	100-400
Zinc	67(4)	270	70-400

Notes:
(1) Chronic aquatic life standards from WQB-7, Montana Numeric Water Quality Standards (MDEQ, 1998).
(2) Effect Range - Median from Long and Morgan (1991).
(3) Concentration ranges from Kabata-Pendias and Pendias (1992).
(4) Chronic standard at total hardness of 50 mg/L.
- - Criteria not currently available

Surface water criteria are the Chronic Aquatic Life Standards promulgated by the State of Montana (MDEQ, 2002). Criteria for chromium (III), copper, lead, and zinc are calculated as a function of water hardness while aluminum, arsenic, and iron criteria are fixed numerical standards. Sediment guidelines consist of Effect Range - Median (ER-M) values generated from the pool of national fresh water and marine sediment toxicity information (Long and Morgan, 1991). Guidelines for soil phytotoxicity are from Kabata-Pendias and Pendias (1992). The availability of contaminants to plants and the potential for plant toxicity depends on many factors including soil pH, soil texture, nutrients, and plant species. Applicable guidelines are currently not available for aluminum, chromium, and iron in sediment and soil.

4.2.4 RISK CHARACTERIZATION

This section integrates the ecological exposure and ecological effects assessments to provide a screening level estimate of potential adverse ecological impacts to aquatic life and native terrestrial plants. This was accomplished by calculating ecologic-impact quotients (EQs), which are analogous to the HQs calculated for human exposures. Site-specific surface water and soil data used in this evaluation are summarized in Tables 3-2, 3-4, and 3-10. Mean concentrations are reported for surface water samples that were collected and analyzed between 1989 and 2001 according to EPA procedures. Waste rock samples were collected in 1993, 1996, 1999, and 2000. The EQs were generated for each COC in surface water by dividing mean concentrations at Station SW-3 in Fisher Creek (Table 3-4) by the chronic water quality criteria (Table 4-4). For soils, EQs are generated by dividing the average values from Table 3-2 by the soil phytotoxicity values in Table 4-4. Adverse ecological impacts may occur if an EQ value is 1.0 or greater. Results of the EQ calculations are presented in Table 4-5 and are discussed below.

4.2.4.1 Surface Water - Aquatic Life

For this scenario, surface water quality data are compared to chronic aquatic life criteria. This comparison is limited because EPA water quality criteria are not species-specific but were developed to protect 95 percent of the species tested and may not protect the most sensitive species, which may or may not be present in Fisher Creek. In addition, toxicity to the most sensitive species may not in itself be a limiting factor for the maintenance of a healthy, viable fishery and/or other aquatic organisms. The calculated EQ values indicate the potential for aquatic life impacts (EQs greater than 1.0) for aluminum, copper, iron, lead, and zinc in surface water (Table 4-5).

TABLE 4-5
ECOLOGICAL – IMPACT QUOTIENTS (EQ)
New World Mining District Response and Restoration Project
Como Basin/Glengarry Adit/Fisher Creek Response Action

Contaminant	Surface Water		Sediment		Phytotoxic Soil1		Total EQ
	Conc(2) (µg/liter)	EQ	Conc(2) (mg/kg)	EQ	Conc(2) (mg/kg)	EQ	
Aluminum	2,559	29	--	--	--	--	29
Arsenic	2	0.01	21	0.25	53	1.06	1.32
Cadmium	0.8	0.6	9	1.0	12	1.5	3.1
Chromium	7.8	0.07	69	--	9	--	0.07
Copper	675	127	1,744	4.47	725	5.8	137
Iron	5,094	5.09	--	--	--	--	5.09
Lead	5	1.6	114	1.04	731	1.8	4.44
Zinc	109	1.6	357	1.32	245	0.6	3.52

Note: (1) Based on high range of average concentration in Table 4-4
(2) Concentration from Tables 3-2, 3-4, and 3-10.
-- Not calculated or not detected, toxicity data unavailable.

4.2.4.2 Sediment - Aquatic Life

Stream sediment concentration data are compared to sediment ER-M values determined by Long and Morgan (1991). This comparison is not definitive because sediment quality values are preliminary and are not species-specific. The guidelines represent sediment toxicity to the most sensitive species, which may or may not be present in Fisher Creek, and toxicity to the most sensitive species may not preclude a healthy aquatic community. EQ values in Table 4-5 indicate the potential for aquatic life impacts due to cadmium, copper, lead, and zinc in stream sediment.

4.2.4.3 Soil Phytotoxicity - Native Terrestrial Plants

Soil concentration data are compared to the lower values in the range of phytotoxicity guidelines. This comparison is limited because phytotoxicity ranges are not species-specific and thus represent toxicity to species that may or may not be present at the site. Additionally, other characteristics of waste materials, such as soil pH, texture, or nutrient deficiencies, may limit growth of terrestrial plants directly, or in combination with substrate toxicity. EQ values in Table 4-5 indicate the potential for impacts to terrestrial plant communities due to arsenic, cadmium, copper, and lead in soil at the site. Although no data are available to document the release of these metals from waste rock and the subsequent uptake by vegetation, it is likely that a phytotoxic effect is occurring due to low pH. Low pH increases the mobility and bioavailability of metals except for arsenic, which is more mobile at more neutral pH levels.

In summary, most of the ecological risk at this site is in the surface water environment with the contaminants of greatest concern being aluminum and copper. Arsenic, cadmium, copper, and lead appear to be phytotoxic in waste rock.

5.0 RESPONSE ACTION SCOPE, GOALS, AND OBJECTIVES

The risk evaluation demonstrated that none of the contaminants of concern present in surface water and waste rock in the Fisher Creek drainage pose a significant risk to human health related to ingestion and inhalation. Environmental risks associated with mine dumps appear in surface water and groundwater due to migration of contaminants from the mine dumps. These contaminants (aluminum, copper, iron, lead, and zinc) present ecological risks to aquatic life. Cadmium, copper, lead, and zinc are contaminants in stream sediment that present risks to aquatic life. Phytotoxicity is a concern in mine waste due to excessive arsenic, cadmium, copper, and lead concentrations and low pH values.

This section of the EE/CA presents the scope of the Glengarry/Como Basin/Fisher Creek Response Action and Removal Action Objectives (RAOs) to meet project goals and applicable or relevant and appropriate requirements (ARARs).

5.1 SCOPE OF THE RESPONSE ACTION

This is the second response action proposed for Fisher Creek. The first response action was the Selective Source Response Action conducted in 2001 and involved removal of selected waste rock dumps located in the headwaters of Fisher Creek that were in direct contact with surface water or groundwater.

The scope of this response action is directed at eliminating or reducing uncontrolled releases of metals from remaining mining-related sources in Fisher Creek. Mining-related sources in the Fisher Creek drainage include mine waste dumps at 43 sites, including the largest dumps at the Glengarry and Gold Dust adits, disturbed soils in the Como Basin, and the Glengarry Adit discharge. Mine waste at these remaining sites consists of about 16,840 cubic meters of waste rock over an area of 2.9 hectares. Disturbed soils in the Como Basin encompass about 2.2 hectares (5.5 acres), and were primarily disturbed for the construction of exploration drilling roads. These disturbed soils, along with metal-rich unconsolidated materials, overly the mineralized Meagher Limestone Formation and contain sulfides and enriched metals from this massive sulfide deposit and weathering products of the Fisher Mountain Porphyry. Metals loading investigations by Kimball and others (1999) and Amacher (1998) indicate that four distinct surface water sources in the upper 500 m of Fisher Creek supply the majority of the contaminant load to the creek (Figure 11).

By addressing releases from metals-enriched mine wastes and disturbed soils, some reduction in contaminant concentrations are expected in surface water, groundwater, and new stream sediment accumulation as a result of removing or controlling these primary sources of mining-related metals contamination in Fisher Creek. However, this response action does not directly address groundwater contamination, as source controls are expected to address mining-related surface water impacts.

This response action only addresses the discharge from the Glengarry Adit from a source control approach. The source control approach is considered to be a first step in attempting to reduce contaminant loading from point sources. Source control is preferred to water treatment as a first step in mitigating impacts to water quality in Fisher Creek, as water treatment options evaluated in a separate study by the USDA-FS (Unifield, 2000) indicates that construction and operation of an passive and active water treatment systems would be difficult and expensive. Passive treatment systems are less expensive than active treatment systems, but large flow variations and low water temperatures raise uncertainties relative to effectiveness and maintenance requirements. Because there are eight other adit discharges in the Fisher Creek drainage that could impact water quality (in addition to the Glengarry discharge), water treatment of these discharges and any remaining Glengarry discharge will be considered further in a subsequent response action EE/CA.

5.2 REMOVAL ACTION OBJECTIVES

As outlined in the Overall Project Work Plan (Maxim, 1999a), the overall goals for the response and restoration project are: 1) assure the achievement of the highest and best water quality practicably attainable on District Property, considering the natural geology, hydrology, and background conditions in the District; and 2) mitigate environmental impacts that are a result of historic mining. Based on the risk evaluation, the primary goal of the Como Basin/Glengarry Adit/Fisher Creek Response Action is to protect the environment by reducing the migration of contaminants into the environment.

The overall scope of the project is described in the Consent Decree (pp. 12-13, §VII.7(a)), which directs the project work to address the following:

- Releases or threats of release of hazardous substances, pollutants or contaminants that are related to District Property.
- Natural resources lost as a result of, or injured or destroyed by, releases or threats of release of hazardous substances, pollutants or contaminants that are released to District Property.
- Conditions affecting water quality and natural resources in Miller, Fisher, and Daisy creeks, and their tributaries.

The Overall Project Work Plan (Maxim, 1999a) identifies 11 objectives to achieve project goals. The plan also recommends supplementing those objectives to correspond to response actions proposed for a given year. Project specific RAOs are:

- Minimize phytotoxicity resulting from high concentrations of copper and low pH in waste rock dumps.
- Prevent soluble contaminants or contaminated solid materials from migrating into adjacent drainages to the extent practicable.
- Reduce or eliminate concentrated runoff and discharges that generate sediment and/or metals contamination to adjacent surface water and groundwater to the extent practicable.
- Prevent potential exposure through the food chain to metal contaminants from acid discharges and waste rock, to the extent practicable.
- Prevent or limit future releases and mitigate the environmental effect of past releases of hazardous substances, pollutants or contaminants.
- Comply with ARARs to the extent practicable, considering the exigencies of the circumstances.
- Take into consideration the desirability of preserving the existing undeveloped character of the District and surrounding area when selecting response and restoration actions.

5.3 ARAR-BASED RESPONSE GOALS

Response action goals are primarily contaminant-based concentrations that are set by federal or state laws and regulations. For this project overall, the primary contaminant-specific ARARs apply to groundwater and surface water. There are no contaminant-specific ARARs for soil media. A preliminary list of ARARs is presented in Appendix C. The USDA-FS will issue final ARARs in the Action Memorandum, which documents the decision involved with the selection of the preferred response alternative.

5.3.1 SURFACE WATER

Aquatic life standards and human health standards are common ARARs for surface water. Generally, the more stringent of the two standards is identified as the ARAR-based reclamation goal. Because the aquatic life standards are more stringent than the human health standards for COCs, and ecological risks predominate at this site, aquatic standards represent the surface water ARARs for this site. These goals are presented in Table 5-1. Those goals that are hardness dependent have been calculated based on a hardness of 50 mg/L. Hardness in Fisher Creek generally ranges from 25 to 55 mg/L at stations SW-3 and CFY-2, the two stations that bracket the portion of the site included in this response action. Enforcement of cleanup goals may be executed at specific water quality stations, in which case the cleanup standard for the hardness dependent contaminants should be calculated based on the hardness at those specific stations.

TABLE 5-1
ARAR-BASED RECLAMATION GOALS FOR SURFACE WATER
New World Mining District Response and Restoration Project
Como Basin/Glengarry Adit/Fisher Creek Response Action

	Total Recoverable Metals (micrograms/liter)[1]					
	Al	Cr	Cu	Fe	Pb	Zn
Goal	87	117	5.3	1,000	3.2	67

Notes: (1) Standards are in terms of total recoverable concentrations. Hardness based criteria are calculated for hardness = 50 milligrams/liter.

CBMI, with the support of the USDA-FS, petitioned the State of Montana Board of Environmental Review (Board) for temporary modification of water quality standards for certain stream segments in the District. The temporary standards are necessary so that improvements to water quality may be achieved by implementation of the response and restoration project. A rule allowing temporary standards on specific reaches of Fisher Creek, Daisy Creek, and the headwaters of the Stillwater River was approved by the Board on June 4, 1999.

Although cleanup actions need not immediately achieve surface water quality standards for B-1 streams, the most restrictive standards (Table 5-1) remain the ultimate cleanup goals for the District. Temporary standards are listed in Table 3-4.

5.3.2 GROUNDWATER

ARAR-based reclamation goals for groundwater are Montana Human Health Standards. Using these standards, ARAR-based goals for COCs in groundwater are shown in Table 5-2. Site-specific groundwater quality data are available for the District, particularly the Como Basin, and average dissolved concentrations of cadmium, copper, iron, lead, manganese, and zinc exceed these standards.

TABLE 5-2
ARAR-BASED RECLAMATION GOALS FOR GROUNDWATER
New World Mining District Response and Restoration Project
Como Basin/Glengarry Adit/Fisher Creek Response Action

Chemical	Type (1)	Concentration (µg/L)
Arsenic	HHS (MCL)	18 (50)
Cadmium	HHS/MCL	5
Copper	HHS/MCL	1,300
Lead	HHS/MCL	15
Manganese	MCL	50(2)
Zinc	HHS (MCL)	2,100 (5,000)

Notes: (1) HHS = Human Health Standard (MDEQ, 2002); MCL = Maximum Contaminant Level (EPA, 1996)
(2) Secondary standard for taste, odor, color.
µg/L = micrograms per liter

5.4 SOIL CLEANUP GUIDELINES

As presented in Section 4.1, there are no unacceptable human health risks associated with mine wastes in Fisher Creek. Recreational cleanup goals for solid mine wastes have been adopted by MDEQ in the form of cleanup guidelines. Cleanup guidelines for COCs in the District are listed in Table 5-3.

Ecological risk from waste dumps included in the Como Basin/Glengarry Adit/Fisher Creek Response Action is likely due to arsenic, copper, lead, and zinc phytotoxicity. Because high metals concentrations, in conjunction with low soil pH, limit plant establishment on waste dumps, other criteria could apply to soil cleanup in the District. Reclamation criteria have been adopted for the Remedial Action underway on the Streamside Tailings Operable Unit near Butte, Montana. These criteria also are listed in Table 5-3 along with phytotoxicity data from the literature. Finally, in lieu of removing metals from the soil, amending the soil to neutralize potential acid generation, may reduce phytotoxicity without reducing metals concentrations. These soil cleanup guidelines should be balanced with the goals for the response project rather than used as absolute numerical criteria.

TABLE 5-3
CLEANUP GUIDELINES FOR MINE WASTE
New World Mining District Response and Restoration Project
Como Basin/Glengarry Adit/Fisher Creek Response Action

	Total Metals (milligrams/kilogram)[1]				
	As	**Cd**	**Cu**	**Pb**	**Zn**
Human Health Guideline[1]	700	19,500	27,100	1,100	220,000
Reclamation Criteria[2]	<30	<4	<100	<100	<250
Phytotoxicity Guideline[3]	15-50	3-8	60-125	100-400	70-400

Notes: (1) Guidelines recalculated from Tetra Tech, (1996). The guidelines are based on a Hazard Index of 0.5 or an increased cancer risk of $5x10^{-5}$ for the recreational visitor scenario.

(2) Criteria used for backfill materials at the Silver Bow Creek/Butte Area Streamside Tailings Operable Unit Remedial Action (Arco, 1997). Allan, find reference

(3) Concentration ranges from Kabata-Pendias (1992).

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6.0 SCREENING AND DEVELOPMENT OF RESPONSE ALTERNATIVES

The description of the source, nature, and extent of contamination (Section 3); the conceptual model that portrays contaminant sources, release mechanisms, and exposure pathways (Section 3.1); and the RAOs developed for this phase of the project (Section 5.0) provide the basis for screening and development of response alternatives for disturbed acidic and metal-rich soils in the Como Basin, for waste rock dumps located in Fisher Creek, and for the Glengarry Adit discharge. The process presented in this section follows EPA guidance for non-time-critical removal actions (EPA, 1993) by first identifying potential response technologies and process options, screening these options through consideration of practical applications of the technologies to the scope of the removal action, and then assembling the remaining technologies and options into response alternatives.

This section of the report presents the potential response technologies, screens the technologies, and then develops the remaining technologies into alternatives. The alternatives are then evaluated in detail against three primary criteria in Section 7.0.

6.1 RESPONSE TECHNOLOGY AND PROCESS OPTION SCREENING

The purpose of identifying and screening technology types and process options is to eliminate those technologies that are obviously unfeasible or ineffective, while retaining potentially effective options. General source control response actions and process options are specifically applied to the mitigation of contaminant release from the disturbed acidic soils of the Como Basin and other waste rock dump sources in the Fisher Creek valley. In addition, response actions and process options for decreasing or stopping the flow of contaminated water from the Glengarry Adit are also evaluated. A source control approach is considered a first step in attempting to reduce contaminant loading from point sources.

No evaluation was conducted for technologies that directly address contaminated groundwater or transported, contaminated stream sediments, as these environmental media may be addressed in future response actions. Addressing environmental impacts associated with disturbed soils, waste rock dumps, and the adit discharge presumes that some reduction in contaminant concentrations will occur in surface water, groundwater, and newly transported stream sediment as a result of removing or controlling these sources of contamination. Stemming the flow of acidic and metal-laden waters from the Glengarry Adit will also lead to a direct improvement in resulting surface water quality in the receiving waters of Fisher Creek Improvements in surface water and groundwater quality are expected to result from implementation of all of the other response actions; however, the absolute amount of improvement is difficult to quantify and is expected to be quite variable between specific response actions. Because there are eight other adit discharges in the Fisher Creek drainage in addition to the Glengarry discharge that could impact water quality, water treatment of these discharges and any remaining Glengarry discharge will be considered further in a subsequent response action EE/CA.

General response actions potentially capable of achieving RAOs and goals for Fisher Creek are screened for applicability in Table 6-1. Response actions include no action, institutional controls, engineering controls, excavation and treatment, in-situ treatment, and migration treatment. The general response actions, technology types, and process options are discussed in text following the table. Screening comments are found in Table 6-1, and the logic and reasons for removing technologies or process options by screening also are discussed in the text. Technologies and options retained for alternative development are shaded in Table 6-1.

TABLE 6-1
Response Technology Screening Summary
New World Mining District Response and Restoration Project
Como Basin/Glengarry Adit/Fisher Creek Response Action

General Response Action	Response Technology	Process Option	Description	Screening Comment
NO ACTION	None	Not Applicable	No Action	Retained for comparison with other options.
INSTITUTIONAL CONTROLS	Access Restrictions	Fencing and Gates	Install fences around contaminated areas to limit access. Gating of access roads or mine portals	Potentially effective in conjunction with other technologies; readily implementable; not considered as a stand-alone alternative.
		Land Use Controls	Legal restrictions to control current and future land use	Potentially effective in conjunction with other technologies; readily implementable; not considered as a stand-alone alternative
		Portal Closures	Close mine portals with backfill, plugging or installation of locking bared gates. Also necessary for public safety.	Potentially effective closure option, readily implementable; may be considered as a stand-alone alternative or used in conjunction with other technologies; readily implementable.
ENGINEERING CONTROLS	Underground Flow Control	Near Surface Grout Curtain (portal or collar)	Drilling unconsolidated surficial material and or near surface fractured rock and filling fractures and porous voids using high- or low-pressure cement or bentonite grouting techniques to prevent infiltration or seepage.	Reduces infiltration into near-surface fractures and workings; may minimize seepage of water from workings into adjacent fractures; readily implementable; best when used in conjunction with backfill of workings for optimum structural support.
		Flowing Fracture Grout Curtain	Drilling fractured rock zones and filling fractures using high-pressure cement or bentonite grouting techniques. To stem or divert water flow.	Effective in stopping or reducing flow through fractures adjacent to workings. Diverts flow around workings. Implementable; best when used with backfill for optimum structural support.
		Cemented Backfill of Workings	Placing aggregate based cemented backfill along sections of raise or drift for structural support and strength and to restrict flow along workings.	Effective as structural support to prevent collapse; significantly restricts flow when installed tight to back or circling; readily implementable.
		Acid Resistant Cement Tunnel Plugs	Placing a high strength, acid-resistant concrete plug to block and seal workings in raises or drifts to act as a seal or barrier to groundwater flow	Effective as a barrier or seal to water flow along workings or isolating select areas of underground workings in order to prevent the mixing of groundwater; readily implementable, most effective when used with backfill (but not required).

Note: Shading indicates technology or process option retained for further consideration.

TABLE 6-1 (continued)
Response Technology Screening Summary
New World Mining District Response and Restoration Project
Como Basin/Glengarry Adit/Fisher Creek Response Action

General Response Action	Response Technology	Process Option	Description	Screening Comment
ENGINEERING CONTROLS (continued)	Containment	Soil Cover	Native or imported soil used to cover waste; soil vegetated; covers contaminant source to prevent direct contact and reduces infiltration.	Reduces surface infiltration by evapotranspiration; Not effective in early spring or late fall when plants are dormant, or under conditions of peak infiltration; acid wastes may contaminate soil cover; readily implementable.
		Multi-layered Cap	Geomembrane layer covered with growth media and vegetation in contaminated surface areas.	Effective in isolating wastes from infiltration; site characteristics key to success; readily implementable; not cost effective for small sites.
		Asphalt or Concrete Cover	Apply asphalt or concrete over areas of exposed ore/waste rock.	Limited feasibility due to cracking over the long term under thermal extremes; long-term maintenance required.
	Surface Controls	Consolidation	Consolidate mine waste into single area.	Consolidation of small outlying mine dumps into larger areas of disturbance; readily implementable.
		Grading and Compaction	Grading and compaction of waste dump surfaces to reduce slopes for managing runoff, erosion and surface infiltration.	Grading alone does not reduce contaminant mobility; potentially effective if combined with other process options; compaction helps to reduce infiltration to some degree: readily implementable.
		Revegetation	Seed mine waste with adaptive plants; controls or reduces water infiltration by evapotranspiration and controls erosion.	Effective in stabilizing wastes which do not contain phytotoxic contaminant concentrations; acid soils affect plant establishment; readily implementable.
		Erosion Protection Runon / Runoff Control	Erosion resistant materials and/or commercial fabrics placed over mine wastes; storm-water diversion structures constructed to channel water away from mine wastes; lined and armored surface channels to maximize runoff from waste surfaces.	Potentially effective at reducing lateral contaminant migration; does not reduce contaminant mobility; potentially effective if combined with other process options; readily implementable.

TABLE 6-1 (continued)
Response Technology Screening Summary
New World Mining District Response and Restoration Project
Como Basin/Glengarry Adit/Fisher Creek Response Action

ENGINEERING CONTROLS (continued)	In Situ Capping	Soil Cover	Cover mine wastes with a soil cover.	Potentially effective. Increase water storage capacity and supports revegetation efforts. Readily implementable.
		Composite Cover	Cover mine waste with composite cover; geomembrane and growth media cover system design.	Potentially effective. Increase water storage capacity and supports revegetation efforts. Readily implementable.
	On-site Disposal	Composite Cover Repository with Leachate Collection System	Excavate mine waste and dispose in on-site repository with composite cover and leachate collection system; liners included in both cover system and at base of repository.	Potentially effective. Increase water storage capacity and supports revegetation efforts. Readily implementable.
		Existing Containment Facility	Excavate mine waste and dispose in on-site repository.	Potentially effective; on-site repository is in-place and has additional storage capacity; readily implementable.
	Off-site Disposal	RCRA Landfill	Excavate mine waste and dispose in RCRA-C permitted facility.	Potentially effective because contaminant sources would be removed; high costs associated with transportation, and disposal fees; implementable.
		Solid Waste Landfill	Excavate mine waste and dispose in non-hazardous solid waste facility.	Not feasible due to an administrative policy by the USDA that does not allow disposal of mining wastes at a solid waste facility. Potentially effective for non-hazardous materials or residue from other treatment options; readily implementable; cost very high due to long haul distances and disposal fees.

Note: Shading indicates technology or process option retained for further consideration.

TABLE 6-1 (continued)
Response Technology Screening Summary
New World Mining District Response and Restoration Project
Como Basin/Glengarry Adit/Fisher Creek Response Action

General Response Action	Response Technology	Process Option	Description	Screening Comment
EXCAVATION & TREATMENT	Reprocessing	Milling and Smelting	Excavate and either treat on-site to ship a concentrate or haul mine waste to operating mill and/or smelter for extraction of precious and non-precious metals.	Potentially effective if economic concentrations of metals are present; probably not cost effective to ship all wastes but if a concentrate is produced and shipped, this would partially remove contaminants. Reduces toxicity of the remaining wastes and improves quality and texture of waste rock remaining on-site for reclamation use. High capital costs.
	Fixation/ Stabilization	Cement/ Pozzolan Additive	Solidify mine waste with non-leachable cement or pozzolan.	Extensive treatability testing and proper disposal of stabilized material would be required. Potentially implementable but cost prohibitive.
		Lime Fixation	Mine waste treated with lime amendments to reduce mobility of metals.	Lime treatment of mine waste is a demonstrated technology in Montana. Effectiveness limited by depth of mixing. Arsenic mobility may increase.
	Physical/ Chemical Treatment	Soil Washing	Separate hazardous constituents from solid media via dissolution & precipitation.	Not effective for waste rock; potential exists to increase mobility by providing partial dissolution of contaminants; implementable; high cost.
		Acid Extraction	Mobilize hazardous constituents via acid leaching & recover by precipitation.	Effectiveness is questionable. Sulfides would only be acid soluble under extreme temperature & pressure; high cost.
		Alkaline Leaching	Use alkaline solution to leach contaminants from solid media in heap, vat, or agitated vessel.	Effectiveness not well documented for arsenic; not readily implementable; high cost.
		Fluidized Bed Reactor/Rotary Kiln/Multi-Health Kiln	Concentrate hazardous constituents into small volume by volatilization of metals & formation of metallic oxide particulates.	Further treatment required to treat process by-product. Potentially implementable; cost prohibitive.
		Vitrification	Extremely high temperature used to melt and/or volatilize all components of the solid media. Molten material containing contaminants is rapidly cooled to form vitrified, non-leachable product.	Not readily implementable for solid wastes; extensive treatability testing required; emission controls necessary; cost prohibitive.

Note: Shading indicates technology or process option retained for further consideration.

TABLE 6-1 (continued)
Response Technology Screening Summary
New World Mining District Response and Restoration Project
Como Basin/Glengarry Adit/Fisher Creek Response Action

General Response Action	Response Technology	Process Option	Description	Screening Comment
IN-SITU TREATMENT	Physical/ Chemical Treatment	Lime Fixation	Mine waste treated in-situ with lime amendments to reduce mobility of metals.	Lime treatment of mine waste is a demonstrated technology in Montana. Effectiveness is limited by depth of mixing. Arsenic mobility may increase.
		Solidification	Solidifying agents used in conjunction with deep soil mixing techniques to promote a physical or chemical change in mobility of contaminants.	Extensive treatability testing required. Potentially implementable; cost prohibitive.
		Soil Flushing	Acid/base reagents or chelating agents injected into solid media to solubilize metals. Pregnant solution with contaminants is extracted using dewatering techniques.	Effectiveness unknown; innovative process currently in pilot stage. Likely cost prohibitive.
		Reactive Barrier Wall	Construction of a downgradient hollow core permeable wall, hollow portion of the wall is filled with reactive treatment agents (iron-fillings, organic material, etc) through which contaminated water flows	Migration treatment technique, effective at removing metals and raising pH depending on filler material used, requires on-going maintenance, potentially expensive but effective and implementable
	Thermal Treatment	Vitrification	Contaminated solid media subjected to extremely high temperature in-situ. Rapid cooling vitrifies material into non-leachable product.	Potentially implementable but would require extensive pilot testing; site layout not ideal at certain sites due to steep slopes and lack of adequate access; cost prohibitive.

Note: Shading indicates technology or process option retained for further consideration.

6.1.1 No Action

No action involves no further response or monitoring. No action is generally used as a baseline against which other response options are compared so ***the no action alternative is retained*** for detailed analysis.

6.1.2 Institutional Controls

Institutional controls are used to restrict or control access to or use of a site. Land use and access restrictions are potentially applicable institutional controls. Land use restrictions would limit the possible future uses of the land through the local forest management plan. Institutional controls involving access restrictions via mine portal closures, fencing and gates and/or land use controls do not achieve a clean-up goal. However, in addition to limiting access, these controls can provide for long-term public safety. ***Institutional controls are retained*** to complement clean up and safety actions and will be combined with other process options.

6.1.3 Engineering Controls

Engineering controls are used to reduce the mobility of contaminants by establishing barriers that limit contaminant exposure, reduce contaminant reactivity, and prevent or limit migration or flow of contaminated surface or groundwater. Engineering controls typically include containment, capping, runon/runoff controls, revegetation and/or disposal. In underground applications, the engineering controls presented, are used to stem water flow or provide structural support or strength to materials or workings. These underground engineering controls may include grout curtains, cemented backfill, or cement plugs. Engineering controls generally do not reduce the volume or toxicity of hazardous materials. ***Engineering controls are retained.***

6.1.3.1 Underground Flow Control

Underground flow control technologies are used as contaminant source and migration control measures. They are used eliminate, minimize or divert contaminated water flows from either entering or leaving underground mine workings. By doing so, they minimize the impacts of discharging contaminated water to surface water flows. Typically these flow controls do not reduce the toxicity or volume of the water because underground flows are usually diverted to other pathways, typically the pathways used before the underground workings were excavated. Methods, such as grout curtains around flowing fracture systems or near-surface workings and cemented backfills for structural support, reduced water flow along workings. Cement plugs that act as barriers or seals to groundwater flow are appropriate alternatives when underground flows need to be controlled, diverted or eliminated. Each of these alternatives uses common underground mining practices, with equipment that is readily available, and site- or application-specific designs. ***Underground flow techniques are retained*** as a possible response action.

6.1.3.2 Containment

Containment technologies are used as source control measures. These technologies are designed to eliminate direct contact and fugitive releases of contaminated materials. In addition, such controls are used to divert and minimize infiltration of surface water/precipitation that may contribute to erosion and/or leachate formation. The cap or cover design is a function of the degree of hazard posed by the contaminated media and may vary from a simple soil cover to a multi-layered cap.

Capping is an appropriate alternative when contaminated materials are left on-site. A site-appropriate capping design is dependent on the relative toxicity and mobility of the contaminants and their demonstrated impacts to human health and/or environment. Capping also is an option when excavation and disposal or treatment actions are cost prohibitive. Capping of mine/mill wastes is a standard construction practice, uses standard equipment, and employs standard design methods. ***Containment process options are retained*** as a possible response action.

6.1.3.3 Surface Controls

Surface controls are used to minimize contaminant release and migration. Surface controls alone may not be appropriate in areas where direct human contact is a primary concern. In these instances, surface controls are commonly integrated with containment to provide further protection. Surface control process options are directed at controlling water and wind erosion, and transport of contaminated materials. These options include consolidation, grading, revegetation, and erosion controls.

Consolidation involves grouping wastes of similar type in a common area for more efficient management or treatment. Consolidation may be important in the upper Fisher Creek drainage area where multiple smaller waste sources are present nearby and could be consolidated.

Grading and compaction are used to reshape and compact waste areas in order to reduce slopes, manage the runon/runoff and infiltration of surface water, and control erosion. Depending on site conditions, periodic maintenance may be necessary to control subsidence and erosion problems after closure. Grading of the material in the disturbed area in the Como Basin and other outlying waste rock dumps may be an important surface control in the Fisher Creek drainage.

Revegetation involves adding soil amendments to a limited depth in the waste in order to provide nutrients and organic materials to establish vegetation. Revegetation is essential to controlling water and wind erosion processes and minimizing infiltration of water through plant evapotranspiration processes. Revegetation generally involves the selection of appropriate plant species, preparation of the seeding area, seeding and/or planting, mulching and/or chemical stabilization, and fertilization. Depending on the success of revegetation, the site may require maintenance in order to establish a self-sustaining plant community.

In addition, neutralizing agents and/or additives to improve pH conditions and/or the water storage capacity of the waste may be appropriate. Neutralizing agents such as lime product, kiln dust, or limestone can be mixed to varying depths, or throughout the entire volume of waste materials.

Erosion protection includes using erosion resistant materials to control water and wind impact on the contaminated media surface. Processes include surface water diversions, application of mulch and natural or synthetic fabric mats, and rip rap. Erosion resistant materials are strategically placed based on knowledge of drainage area characteristics, slopes, vegetation types and densities, soil texture, and precipitation data.

Surface control process options are retained for inclusion into response alternatives. These process options would not be effective in controlling the release of hazardous substances alone. ***Addition of***

neutralizing agents is also retained, as this process option is considered to be quite effective in controlling pH and the release of metals.

6.1.3.4 On-Site Disposal

On-site disposal can be used as a permanent source control measure. Contaminated media failing to meet toxicity characteristic leaching procedure (TCLP) criteria may require disposal in a RCRA hazardous waste-type repository and could be subject to RCRA landfill closure performance standards. Solid wastes from the beneficiation of ores and minerals, however, are not considered hazardous wastes under RCRA regulations (CFR 261.4 (b) (7). This reclamation technology involves placing the untreated or treated contaminated materials in an engineered repository located on-site. An on-site repository was selected as the preferred alternative in the initial response action proposed for the District (Maxim, 2001b). This repository was constructed in 2001 and partially filled with mining wastes. Capacity exists to contain additional mine wastes and would be suitable for mine smaller waste rock dumps scattered about in the Fisher Creek watershed. ***On-site disposal technologies are retained*** for further analysis.

6.1.3.5 Off-site Disposal

Off-site disposal involves excavating the contaminated materials and transporting them to an existing engineered repository permitted to accept such materials. Off-site disposal options include a centralized repository constructed for disposal of mine waste -- for example, a RCRA-permitted repository or a solid waste landfill. Materials classified as hazardous waste as defined in RCRA would require disposal in a RCRA-permitted facility. Less toxic materials could possibly be disposed of in a permitted solid waste or sanitary landfill. The ***off-site disposal alternative is not retained*** for further analysis.

Off-site disposal was evaluated in detail in the initial response action considered for the District (Maxim 2001a), but was dropped because of high cost. Off-site disposal at a *solid waste facility is not retained* because the USDA has made an administrative policy decision that does not allow disposal of mining wastes at a solid waste facility. Also in this regard, there is a general reluctance of these facilities to accept mining wastes and there remains a liability to the government if such a facility were used.

6.1.4 Excavation and Treatment

Excavation and treatment processes involve the removal of the contaminated materials and subsequent treatment to reduce toxicity and/or volume. Treatment processes may involve a variety of techniques including chemical, physical or thermal methods. These methods are used to concentrate metal contaminants for additional treatment or recovery of economic constituents (reprocessing) or to reduce the toxicity of hazardous constituents.

6.1.4.1 Reprocessing

Reprocessing involves excavation and either on-site processing and shipping of a concentrate, or direct transportation of all contaminated materials to an existing mill or smelter for processing and recovery of valuable metals. Reprocessing of mine/mill wastes from outside sources is not commonly practiced due to the low concentrations of metals in source materials, operating permits limiting processing of off-site materials, and liability issues. Applicability of this option is dependent on the concentration of economically viable elements and the ability and willingness of an off-site facility to process the material and dispose of waste. The Como Basin sulfide-rich and metal-bearing soil material is, however, known to contain valuable gold, copper, and silver credits.

Reprocessing of the wastes greatly reduces contaminant content and acidity of the wastes and improves the texture and chemistry of remaining waste rock so that it might be used for reclamation purposes. A preliminary cost analysis was prepared for the McLaren Pit Response Action EE/CA (Maxim, 2001b) for reprocessing waste rock in the McLaren Pit. The principal costs involved are capital costs for the equipment used in the processing facility, the cost of which cannot be recovered from the valuable metals in a small tonnage of rock. Another costly element of this alternative is in the failure of the smelter to return full value of the contained metals, because of smelter penalties associated with particular aspects of the ore (high iron, low silica). The cost of reprocessing these materials was found to be prohibitive for the analysis of the McLaren Pit waste rock materials. Based on the McLaren pit analysis, the cost of reprocessing the similar volume of lower-grade Como Basin materials also would be prohibitively expensive. ***On-site reprocessing is not retained*** for further evaluation due to high capital costs.

6.1.4.2 Fixation/Stabilization

Fixation/stabilization technologies employ treatment processes that chemically alter the contaminant to reduce its mobility or toxicity (fixation) or physically treat the contaminant by encapsulating it with an inert material (stabilization). The technology involves mixing materials with binding agents under specific conditions to form a stable matrix. For inorganic contaminants, fixation/stabilization employs a reagent or combination of reagents to promote a chemical and/or physical change in order to reduce the mobility. Fixation of acid-generating mine wastes with additives that raise the pH of the waste have been used widely in the last 25 years to reduce the mobility of metals. These additives include lime (calcium oxide), limestone (calcium carbonate), and calcium hydroxide. Other stabilization methods, such as phosphate addition (e.g., Envirobond) and the Dow manganese oxide passivation method have not been proven to be successful under field conditions and are not considered further. The in-situ process may use shallow surface, deep mixing, or complete incorporation techniques to achieve the best integration of the fixation agents with contaminated media. Fixation with a lime or other neutralizing amendment works because the contaminants of concern (acid rock drainage and some metals (Cu, Pb, Zn)) are mobilized in an oxidizing-acidic environment. The mobility of arsenic may be increased by neutralizing the wastes.

In sulfide bearing rocks, sulfide minerals are oxidized and release metals and sulfuric acid. The solubility and rate of release of these metals is greatly increased by the acidic conditions. The addition of lime as a neutralizing agent prevents the formation of acidic conditions and thereby restricts oxidation rate of the sulfide and the rate of metal release. Stabilization processes commonly use pozzolan/cement as additives. Obviously, the ability to ensure adequate mixing is a critical limitation for any amendment approach.

Fixation with lime is retained for further consideration. ***Stabilization using pozzolans is not retained*** due to higher costs associated with the process and large volume of materials.

6.1.4.3 Physical/Chemical Treatment

Physical treatment processes use physical characteristics to concentrate constituents into a smaller volume for disposal or further treatment. Chemical treatment processes treat contaminants by adding a chemical reagent that removes or fixates the contaminant. Chemical treatment processes reduce toxicity and/or mobility of contaminants in solid media. Chemical treatment processes generally work in conjunction with physical processes to flush the contaminated media with water, acids, bases, or surfactants. Potentially applicable physical/chemical treatment processes include flotation (an ore beneficiation process use to concentrate sulfides), soil washing, acid extraction, vitrification, alkaline leaching, and concentration by volitization.

Soil washing is an innovative treatment process that consists of washing the contaminated media with water in a heap, vat, or agitated vessel to dissolve water-soluble contaminants. Soil washing requires that contaminants be readily soluble in water and sized sufficiently small so that dissolution can be achieved in a practical retention time. Dissolved metal constituents contained in the wash solution are precipitated as insoluble compounds, and the treated solids are dewatered before additional treatment or disposal. Precipitates form a sludge that requires additional treatment such as dewatering or stabilization prior to disposal. At New World, this process would remove sulfate salts, but would not remove relatively insoluble oxide and sulfide minerals.

Acid extraction applies an acidic solution to the contaminated media in a heap, vat, or agitated vessel. Depending on temperature, pressure, and acid concentration, varying quantities of the metal constituents present in the contaminated media would be dissolved. A broader range of contaminants can be expected to be acid soluble at ambient conditions using acid extraction versus soil washing; however, sulfide compounds may only be acid soluble under extreme conditions of temperature and pressure. Dissolved contaminants are subsequently precipitated for additional treatment and/or disposal.

Alkaline leaching is similar to acid extraction in which a leaching solution, i.e., ammonia, lime, or caustic soda, is applied to the contaminated media in a heap, vat, or agitated vessel. Alkaline leaching is potentially effective for leaching the majority of metals from contaminated media; however, removal of arsenic is not well documented. Alkaline addition to promote formation of oxide armor on sulfide minerals would be expected to reduce arsenic release from arsenic-bearing sulfide minerals. Arsenic-bearing salts, or sorbed arsenic species, would tend to leach under alkaline conditions and could therefore be removed. These process options are ***not retained*** for further consideration due to associated high costs and large volumes of material to be treated.

Thermal treatment technologies apply heat to contaminated media in order to volatilize and oxidize metals. This process renders the contaminated media amenable to additional processing or it produces an inert product via vitrification. Potentially applicable thermal processes, which volatilize metals and form metallic oxide particulates, include the fluidized bed reactor, rotary kiln, and multi-hearth kiln. High temperature vitrification is another thermal treatment technology that essentially melts or volatilizes the contaminated media. Volatile contaminants and gaseous oxides of sulfur are driven off as gases and the non-volatile component is vitrified when it cools. ***Thermal treatment is not retained*** for further consideration due to its high cost and large volume of material to be treated.

6.1.5 IN-SITU TREATMENT

In-situ treatment involves treating contaminated materials in place with the objective of reducing mobility and toxicity of problem constituents. In-situ treatments provide less control than excavation and treatment options because it affords less efficient mixing of additives. In-situ treatment technologies include physical/chemical and thermal treatment processes. Physical/chemical treatment technologies include Lime Fixation, Solidification, Soil Flushing, and Reactive Barrier Wall, while thermal treatment technology relies on the process of vitrification.

6.1.5.1 Physical/Chemical Treatment

In-situ stabilization/solidification is similar to conventional stabilization in that a solidifying or chemical precipitating agent (or combination of agents) is used to create a chemical or physical change in the mobility and/or toxicity of the contaminants. Mine waste treatment with additives that raise the pH of the waste has been used widely and successfully in the last 25 years to reduce the mobility of metals. These additives include lime (calcium oxide), limestone (calcium carbonate), kiln dust, and calcium hydroxide. The in-situ process uses both surface and deep mixing techniques to achieve the best integration of the solidifying agents with the contaminated media. ***In-situ fixation with lime is retained*** for further consideration.

Soil flushing is an innovative process that injects an acidic or basic reagent or chelating agent into contaminated media to solubilize metals. Dissolved metals are extracted using established dewatering techniques, and the extracted solution is treated to recover metals or is disposed as aqueous waste. Low permeability materials may hinder proper circulation, solution reaction, and ultimate recovery. Currently, soil flushing has only been demonstrated at a pilot scale. ***Soil flushing is not retained*** for further consideration because of the difficulty in implementing this technology at disperse sites that are situated in less than ideal environmental settings. The cost of this technology is expected to be high.

A ***Reactive Barrier Wall*** treatment technology is presented here as a migration and treatment control for infiltration or percolation waters that have been contaminated by passage through disturbed soils or waste materials. Some surface and/or groundwater components would also be treated by this treatment technology, because it could not be separated from contaminated waters at the point of treatment. A permeable barrier wall is constructed downgradient of the contamination source, to force surface and/or groundwater to flow through the wall. The wall is constructed as a thick and hollow wall that is filled with reactive material (iron filings, organic material, limestone or various other reactive agents) that reacts with contaminated water as it flows through the wall. The wall is isolated from atmospheric conditions and thermal stresses with a cover of low permeability material. Contaminants including sulfate, nitrate, and a variety of metals have been successfully removed in this way. Reactive barrier walls have been shown to be effective in the treatment of migrating contaminated groundwater on both pilot and full-scale field-testing projects, and a dozen or more are currently in use on various projects at the present time. There is established EPA guidance for their application. They are cost effective to construct and an excellent method to treat contaminated surface or groundwater along its migration pathway. Long-term maintenance is required as the agent filling the wall must be replaced periodically over time as it loses its reactive properties or becomes plugged with precipitated contaminants.

The University of Waterloo holds the patent for the reactive barrier technology for treating acidic mine waters. Reactive barriers consists of four main components; an organic carbon source, a bacterial source, a neutralizing source, and a non-reactive porous medium. The organic source is usually made up of composted leaf mulch, composted municipal sewage waste, sawdust, composted manure and delignified cellulose, either placed alone or in some sort of a mixture. The bacterial source consists of sulfate reducing bacteria that are either cultured and grown in a laboratory or obtained from natural occurring sources. The neutralizing source is usually limestone and usually added at approximately 1-2% by volume or 2-7% by weight. Sand or gravel is mixed with the mixture to increase permeability of the mixture and is usually 5-10% by volume. The permeability of the mixture is an important parameter that must be considered while designing a reactive wall. The mixtures should be designed such that the permeability is the same as, or slightly greater than, that of the surrounding soil or aquifer material. The permeability usually ranges from 10^{-3} cm/sec to 10^{-4} cm/sec. Because of this low permeability, the systems are best designed for treating small volumes of groundwater. Large volumes of contaminated surface water such as are seasonally present in the Como basin, could not be handled by any reasonably sized barrier wall. In order for the sulfate reducing bacteria to be effective, a clay cap (typically 25 to 40 cm of clay) needs to be placed on the barrier to prevent diffusion of oxygen and allow reducing conditions to develop. Bacteria are tolerant to a temperature range of 23 to 150 °F. The optimum temperature range for sulfate reducing bacteria is 60 to 80 °F. Low temperatures, such as are present for rather long periods of time at the New World project site would reduce the efficiency and applicability of the bacteria media in the reactive barriers drastically.

A detailed pilot-scale study would be required in order to evaluate the effectiveness and applicability of this technology at the New World Site. A better understanding of the groundwater flow and velocity is also needed to accurately design this remedial system.

Reactive barrier walls are not retained as a migration pathway treatment process, as active source control options should be applied and monitored for success prior to implementing migration control treatment. Reactive barrier walls may best be considered as a second level treatment option if primary source controls do not provide the level of contaminant control desired.

6.1.5.2 Thermal Treatment

In-situ vitrification is an innovative process used to melt contaminated solid media in place to immobilize metals into a glass-like, inert, non-leachable solid matrix. Vitrification requires significant energy to generate sufficient current to force the solid media to act as a continuous electrical conductor. This technology is seriously inhibited by high-moisture content. Gases generated by the process must be collected and treated in an off-gas treatment system. In-situ vitrification has only been demonstrated at the pilot scale, and treatment costs are extremely high compared to other treatment technologies.

Thermal Treatment is not retained for further consideration because of the difficulty in implementing this technology at disperse sites that are situated in less than ideal environmental settings. The cost of this technology is expected to be high.

6.2 RESPONSE ALTERNATIVE DEVELOPMENT

The most promising technologies and process options that were identified and retained through the screening process are summarized in Table 6-2. These options appear to be effective and readily implementable for a reasonable cost and will be used to develop response action alternatives for further consideration.

EPA guidance for non-time-critical removal actions suggests that only the most qualified technologies that apply to the media or source of contamination be evaluated in detail in the EE/CA. Using this guidance, response action alternatives for the Como Basin/Glengarry Adit/Fisher Creek Response Action were developed by combining reclamation technologies and process options such that each alternative fulfilled in whole or part the RAOs and goals for the project. The No Action alternative is the one exception to this statement but the No Action alternative is used in the detailed analysis as a baseline against which the other alternatives can be compared. Assembling the alternatives was accomplished by combining process options so that each alternative either offered a distinct benefit over another alternative, or provided a different approach to meeting the RAOs and goals. The alternatives also cover a reasonable range of costs, an important factor that will be considered in the detailed analysis.

TABLE 6-2
Process Options Retained From Technology Screening
New World Mining District Response and Restoration Project
Como Basin/Glengarry Adit/Fisher Creek Response Action

General Response Action	Response Technology	Process Option
No Action	None	Not Applicable
Institutional Controls	Access Restrictions	Fencing/Signage
		Land Use Controls
		Portal Closures and/or Gates
Engineering Source Controls	Underground Flow Control	Near-surface Grout Curtain (portal or collar)
		Flowing Fracture Grout Curtain
		Cemented Backfill of Workings
		Acid Resistant Cement Tunnel Plugs
	Surface Controls	Grading/Compaction
		Revegetation
		Erosion Protection, Runon/Runoff Control
	In-Situ Capping and Containment	Soil Cover
		Multi-layered Cap: Composite Geomembrane and Amended Waste Cover
		Composite Geomembrane and Soil Cover
	On-Site Disposal	Disposal in an On-Site Repository with Leachate Collection System
Excavation and Treatment	Fixation/Stabilization	Lime Fixation
In-Situ Treatment	Physical/Chemical Treatment	Lime Fixation

There are two distinct types of problems being addressed in this particular response action, one pertains to the migration of contaminants from mining wastes and metal-rich soils, and the other pertains to contaminated inflow into an underground mine that subsequently flows into and contaminates surface water and groundwater. Both are very important with respect to overall contaminant loading to Fisher Creek based on the loading analysis presented in Section 3.4. That analysis indicates that during low flow the Glengarry Adit is the larger source of metal loading to Fisher Creek (>90%); during high flow the Glengarry Adit contributes less than 10% of the total copper load, and tributaries FCT-11 and FCT-12 become the most significant source of metals loading to Fisher Creek.

There is a considerable difference in the scale of the proposed response actions between the Como Basin and remaining smaller dumps in Fisher Creek, particularly the size and volume of material present in each. The Como Basin consists of a 2.23 hectare site with 190,174 cubic meters of metal-rich soils. Waste rock dumps at the remaining mine sites in the Fisher Creek drainage disturb about 2.9 hectares at over 43 small, scattered sites. Because of these two diverse settings and the difference in scale of areas to be reclaimed, response alternatives discussed in this EE/CA have been grouped for the following three source areas:

- Como Basin Source Area (metal-rich soils)
- Fisher Creek Source Area (small outlying waste rock dumps in the Fisher Creek watershed)
- Glengarry Adit (inflow of contaminants in groundwater and outflow into surface water)

6.2.1 Como Basin Source Area Response Alternative Development

Table 6-3 lists response action alternatives that will be considered in the detailed analysis for the Como Basin Source Area. Also listed in Table 6-3 are the process options and technologies that constitute each alternative. A brief description of each of the alternatives is presented below. A schematic representation of the alternatives is shown in Figure 24.

CB-1 *No Action*

CB-2 *In-Situ Treatment of Disturbed and Metal-Rich Soil* - In-situ treatment combines the three surface control process options with in-situ lime fixation. This alternative involves regrading metal-rich soils in the Como Basin to a stable configuration, amending various amounts of material with a neutralizing lime amendment, and then revegetating the amended soils. Three sub-alternatives propose to amend different amounts of the metal-rich soils in the basin (Figure 24). Alternative 2A proposes to amend disturbed soils in the upper 30 cm. Alternative 2B proposes to amend disturbed soils to a depth of 1.0 meter. Alternative 2C proposes to excavate and amend all unconsolidated, metal-rich soil material within the disturbed area of the Como Basin. Engineering controls including grading, compaction, surface water diversion, lime amendment, and revegetation are common to the sub-alternatives.

CB-3 *In Situ treatment with a Cap* – There are three variations of this alternative for the Como Basin. Common to each of the three sub-alternatives is regrading of metal-rich soils, amending the soils with nutrients and organics, and revegetation. The sub-alternatives differ in the cap/cover design placed on the waste rock materials.

- *Alternative* 3A – *In-Situ Treatment with Soil Cap:* In this alternative the upper 30 cm (1 foot) will be amended with lime, and regraded soils will be capped with 60 cm (2 feet) of imported soil. Soil will be obtained from the SC-4B(I) repository site or other nearby, suitable source.

- *Alternative* 3B – *In-Situ Treatment with Geomembrane Cover and Amended Soil Cap:* In this alternative, disturbed and metal-rich soil will be capped with a geomembrane liner and a geocomposite drain layer. The drain layer will be covered with one meter of amended soil.

- *Alternative* 3C *– In-Situ Treatment with Geomembrane Cover and Soil Cap:* In this alternative, the shallow amended and regraded surface will be capped with a geomembrane liner and a geocomposite drain layer. The drain layer will be covered with one meter of imported soil obtained from the SB-4B(I) repository site or other nearby, suitable source.

TABLE 6-3
RESPONSE ACTION ALTERNATIVES FOR THE COMO BASIN SOURCE AREA
New World Mining District Response and Restoration Project
Como Basin/Glengarry Adit/Fisher Creek Response Action

Alternative		Response Technology/Process Options
CB-1	No Action	None
CB-2A	In-Situ Treatment of Select Soil Material with Shallow Amendment	Regrading and compaction of disturbed and metal-rich soils in-situ, amendment of the upper 30 cm of the regraded surface with lime, and revegetation.
CB-2B	In-Situ Treatment of Select Soil Material with Deep Amendment	Regrading and compaction of disturbed and metal-rich soils in-situ, amendment of the upper meter of the regraded surface with lime, and revegetation.
CB-2C	In Situ Treatment of Metal-Rich Soil Material	Excavation of unconsolidated metal-rich soils, lime amendment of excavated materials, replacing and regrading amended soils, and revegetation.
CB-3A	In-Situ Treatment with Soil Cap	Regrading metal-rich soils in-situ, shallow amendment (upper 30 cm), constructing a soil cap, and revegetation
CB-3B	In-Situ Treatment with Geomembrane Liner and Amended Soil Cap	Regrading metal-rich soils in-situ, constructing a geomembrane liner with a drain layer and an amended soil cap, and revegetation.
CB-3C	In-Situ Treatment with Geomembrane Liner and Soil Cap	Regrading metal-rich soils in-situ, constructing a geomembrane liner with a drain layer and an imported soil cap, and revegetation.

Note: Except for No Action, all the alternatives considered for the Como Basin include repairing the erosion problems in the channels below the Como Basin and the erosion problems associated with the switchbacks on the portion of the Lulu Pass Road that climbs from the Glengarry Adit through the Como Basin.

Total removal to an on-site repository was not considered a viable option for the Como Basin due to the large volume of metal-rich soils that would require excavation and disposal. This alternative was evaluated in detail for the McLaren Pit Response Action EE/CA (Maxim, 2001b), and did not prove to have any advantage over in-situ options due to the massive sulfide deposit in the McLaren pit that would be exposed in a removal of overlying metal-rich waste rock. This same situation applies to the Como Basin.

Figure 24

Figure 24 – Back Page

6.2.2 FISHER CREEK SOURCE AREA RESPONSE ALTERNATIVE DEVELOPMENT

There are 43 small, scattered, waste rock dumps in Fisher Creek. Not all the process options retained (Table 6-2) apply to the Fisher Creek area. Response action alternatives developed for the Fisher Creek area (Table 6-4) are similar to these developed for the Como Basin area (Table 6-3) with several exceptions. First, because the dumps are scattered over a wide area, and due to the difficult access to many of the dumps, covering the small waste dumps with a geocomposite liner system is not practical or cost effective. Therefore, the CB-3 alternatives are not considered for the Fisher Creek Source Area. Of the CB-2 alternatives, only shallow amendment with lime (CB-2A) is considered appropriate for the remaining waste rock dumps due to site constraints and access limitations (i.e., most of the sites are on steep slopes that constrains lime mixing with equipment). Total removal to the SB-4B(I) repository area (On-site Disposal, Table 6-2), is considered appropriate for the Fisher Creek Source Area. One additional alternative is also considered appropriate, surface controls for runon and runoff (Table 6-2). The alternatives considered in the detailed analysis for the Fisher Creek Source Area are listed in Table 6-4.

TABLE 6-4
RESPONSE ACTION ALTERNATIVES FOR THE FISHER CREEK SOURCE AREA
New World Mining District Response and Restoration Project
Como Basin/Glengarry Adit/Fisher Creek Response Action

Alternative		Response Technology/Process Options
FC-1	No Action	None
FC-2	In-Situ Treatment of Waste Rock with Shallow Amendment	Grading and compaction of waste rock in-situ, amendment of the upper 30 cm of the regraded surface with lime, and revegetation.
FC-3	Surface Controls	Grading waste rock in-situ, constructing runon and runoff controls.
FC-4	Total Removal and Disposal in an On-Site Repository	Total removal and disposal of waste rock in the SB-4B(I) repository.

6.2.3 GLENGARRY ADIT RESPONSE ALTERNATIVE DEVELOPMENT

Table 6-5 lists response action alternatives that will be considered for contaminated inflow and outflow at the Glengarry Adit. Also listed in the table are the relevant process options and technologies that constitute each alternative.

Institutional controls in the form of a portal closure or gate for closure and safety purposes are assumed to be an essential part of all of the alternatives developed below. The response action alternatives, with the exception of the no action alternative, are all engineering controls designed to control contaminated underground water flows into and out of the Glengarry Mine.

TABLE 6-5
RESPONSE ACTION ALTERNATIVES FOR THE GLENGARRY ADIT SOURCE AREA
New World Mining District Response and Restoration Project
Como Basin/Glengarry Adit/Fisher Creek Response Action

Alternative		Response Technology/Process Options
GA-1	No Action	None
GA- 2	Grout Curtain Around Como Raise Collar; Backfill and Plug Como Raise	Drilling and pressure grouting around the collar of the Como Raise to construct a grout curtain; plugging and backfilling the raise. Eliminates or minimizes highly contaminated water flow from the Como Basin into the second Glengarry raise.
GA-3	Grout the Short Raise Above Bulkhead	Drilling and pressure grouting the structure at the top of the first raise to produce a grout curtain that eliminates or minimizes water flow.
GA-4	Grout the 1050 Roof Leak	Drilling and pressure grouting of the roof leak to produce a grout curtain that eliminates or minimizes water flow.
GA-5	Backfill Various Portions of the Glengarry Drift	Backfilling various portions of the Glengarry Mine with cemented backfill with a waste rock aggregate for structural support and strength needed to help protect grout curtains and reduce or minimize flow along a particular portion of the drift. ➢ 5A - backfilling the drift in the Fisher Mountain Porphyry only (fill will begin at the first plug and end at the portal plug). ➢ 5B - backfilling the drift in the Precambrian Granite only. ➢ 5C- backfilling the entire drift.
GA-6	Plug the Glengarry Drift at Critical Locations	Construct three water-tight concrete plugs within the Glengarry Drift. Two plugs near the Precambrian Granite/Fisher Mountain Porphyry contact and another plug near the portal.

7.0 DETAILED ANALYSIS OF RESPONSE ALTERNATIVES

Response alternatives developed in the previous section are analyzed and compared in detail in this section. Response alternatives represent a range of potential actions that can meet, to some degree, RAOs for this portion of the project, and achieve distinct levels of protectiveness to human health and the environment for a reasonable range of costs.

7.1 ORGANIZATION

The detailed analysis of alternatives presented in this section have been organized into alternatives for each of the three different source areas, the Como Basin, Fisher Creek, and the Glengarry Adit. For each of the source areas, a complete discussion of the applicable alternatives identified for each area in Section 6.0 is presented. These alternatives are evaluated as stand-alone alternatives; that is, a detailed analysis of a combination of alternatives from the three site areas is not done.

7.2 EVALUATION CRITERIA

The following three criteria will be used to evaluate response action alternatives:

1. Effectiveness
2. Implementability
3. Cost

According to EPA guidance for non-time-critical removal actions (EPA, 1993), the effectiveness of an alternative should be evaluated by the following criteria: overall protection of human health and the environment; compliance with ARARs; long-term effectiveness and permanence; reduction of toxicity, mobility, or volume through treatment; and, short-term effectiveness. The ability of each alternative to meet RAOs is considered when evaluating these criteria.

Implementability addresses the technical and administrative feasibility of implementing an alternative and the availability of various services and materials required to accomplish its implementation. Technical feasibility considerations include the applicability of the alternative to the waste source, availability of the required equipment and expertise to implement the alternative, and overall reliability of the alternative. Administrative feasibility evaluates logistical and scheduling constraints.

Evaluating the cost of alternatives involves developing conservative cost estimates based on the materials needed and the construction elements associated with implementing the alternative. These costs do not necessarily represent the cost that may actually be incurred during construction of the alternative because many design details are preliminary at this stage. However, a similar set of assumptions is used for all the alternatives so that the relative differences in cost between alternatives are fairly represented. Unit costs were developed by analyzing data available from USDA-FS and nationally published cost estimating guides. Where possible, cost data incorporate actual operating costs and unit costs that have been realized during similar reclamation projects. Unit costs are based on assessments of materials handling and procurement, site conditions, administrative and engineering costs, and a contingency.

In addition to the capital costs discussed above, post-removal site control (PRSC) costs are estimated for the alternatives. These PRSC costs were estimated using reasonable assumptions for likely and potential maintenance and monitoring requirements. PRSC Costs for the No Action Alternative were calculated using the same monitoring costs as the active alternatives, but without the costs for monitoring and maintenance of revegetation. Average annual PRSC costs are estimated for a 30-year period. The present worth for PRSC is calculated using a discount rate factor of 4.9% (OSWER, 1993). The details of this calculation are presented in Appendix D along with the detailed cost estimates.

The total estimated project cost for each alternative is the sum of the estimated capital cost, the estimated present worth PRSC cost, and engineering design and construction oversight costs which are calculated as a percentage of the estimated capital cost. In line with EPA guidance, the total estimated cost is expected to be within plus 50% and minus 30% of actual costs.

Costs presented in this section are based on waste volumes determined from Maxim's 1999 field investigation, and supplemented, corroborated, or modified by detailed volume calculations using CBMI drilling data. Areas were calculated from measurements made on aerial photographs. Summary cost tables are presented in the cost discussion for each alternative with the supporting unit cost spreadsheets presented in Appendix D.

7.3 COMO BASIN SOURCE AREA ALTERNATIVES

Alternatives for the Como Basin that resulted from the screening process developed in Section 6.0 include No Action (Alternative CB-1), *In-situ* Treatment (Alternative CB-2), and Capping in Place (Alternative CB-3). Except for No Action, all the alternatives considered for the Como Basin include repairing the erosion problems in the channels below the Como Basin and the erosion problems associated with the switchbacks on the portion of the Lulu Pass Road that climbs from the Glengarry Adit through the Como Basin. Erosion problems were fully described in Section 3.7.

7.3.1 NO ACTION – ALTERNATIVE CB-1

The No Action Alternative involves leaving the Como Basin in its existing condition. No further reclamation would be attempted at the site to control contaminant migration or to reduce toxicity or volume. Reclamation work done previously by CBMI in the Como Basin would be monitored, but no further investigations would be conducted. Monitoring of surface water would be conducted on a yearly basis.

7.3.1.1 <u>Effectiveness</u>

Overall effectiveness of the No Action Alternative is poor. Under existing conditions, metals will continue to migrate from the metal-rich soils of the Como Basin and into surface water and groundwater. The No Action Alternative does not address surface water impacts, nor does it provide any controls on contaminant migration via direct contact or particulate emissions. Toxicity, mobility, and volume of contaminants would not be reduced under the No Action Alternative, although contaminant sources will diminish over a very long period of time as oxidation of sulfides depletes the source.

Protection of the environment would not be achieved under this alternative. While slopes are stable in the Como Basin as a result of CBMI's reclamation, the poorly vegetated disturbed soils will continue to erode into Fisher Creek tributaries. The deteriorating condition of vegetation and cover in the Como Basin will likely continue to decline over time as acid conditions in the regraded and amended surface soil worsen.

The No Action Alternative is currently in compliance with both narrative and numeric temporary water quality standards at the three stations monitored in Fisher Creek. However, as these standards expire in 2014, the No Action Alternative is not expected to move water quality toward compliance with B-1 standards for these streams.

7.3.1.2 Implementability

This alternative is both technically and administratively feasible. It is not a viable means of controlling wastes that impact environmental receptors.

7.3.1.3 Cost

No capital costs would be incurred under this alternative. However, annual monitoring costs would be incurred for both surface water and groundwater monitoring. Long-term costs associated with the No Action Alternative are unknown since there is an on-going risk that mine wastes may erode, resulting in further damage to other resources and requiring action. There are also environmental costs associated with the No Action Alternative, including the loss of certain ecological functions. Using the PRSC costs presented in Appendix C, the total monitoring cost for monitoring over a 30-year period is about $37,300.

7.3.2 In Situ Treatment – Alternative CB-2

The principal process technology associated with this alternative involves in-place treatment of disturbed soils in the Como Basin with a neutralizing amendment. Other aspects of this alternative include regrading and compaction, addition of nutrients and organics, revegetation, and erosion control. The three sub-alternatives evaluated under this alternative consider the addition of a neutralizing amendment to varying amounts (or depths) of disturbed soil. Figure 24 shows a schematic of the alternative components and sub-alternatives. A description of the alternative is presented below, followed by the detailed analysis.

7.3.2.1 Alternative Task Description

- *Treat Metal-Rich Soils with Neutralizing Amendment*: A neutralizing amendment, such as agricultural limestone, lime kiln dust, or calcium oxide would be mixed into soils according to an average rate of 38 tons per 1,000 tons. The disturbed area of the Como Basin is about 2.23 Ha (5.5 acres) and contains a volume of about 190,174 cubic meters (248,700 cubic yards) of metal-rich soils. Treating the soils would require establishing sediment controls around the perimeter of the site, regrading metal-rich soils to a stable configuration, and constructing lined and armored surface water diversion ditches. Regrading would be done to blend with the surrounding topography.

    - *Alternative* CB-*2A* involves shallow lime amendment of the upper 30 cm (12 inches) of metal-rich soils in the Como Basin. This will involve amending approximately 6,660 cubic meters (8,710 cubic yards) or 3.5% of the total metal-rich soils present in the basin with about 635 metric tons (mtons) of lime and placing this material as a compacted layer across the surface of the disturbed area of the Como Basin.

- *Alternative* CB-*2B* involves deeper lime amendment of the upper 1.0 meter (40 inches) of disturbed soils. This will involve amending approximately 22,300 cubic meters (29,200 cubic yards) or 11.7% of the metal-rich soils present in the basin with about 2,100 metric tons of lime.

- *Alternative* CB-*2C* involves complete excavation of all metal-rich soil material (190,174 cubic meters, 248,700 cubic yards), amending the entire volume of material with a neutralizing amendment, and placing the amended material back into the excavation in the Como Basin. Neutralization of this entire volume of material with a lime amendment would require mixing approximately 17,990 mtons of lime.

TABLE 7-1
LIME REQUIREMENT FOR ALTERNATIVE CB-2
New World Mining District Response and Restoration Project
Como Basin/Glengarry Adit/Fisher Creek Response Action

Alternative	Area hectares (acres)	Volume (cubic meters)	Lime Req[1] (t/1000t)	Lime[2] (mtons)
CB-2A (30 cm amendment)	2.23 (5.5)	6,660	38	635
CB-2B (1 meter amendment)	2.23 (5.5)	22,300	38	2,100
CB-2C (total amendment)	2.23 (5.5)	190,174	38	17,990

Notes: 1 Lime requirement in tons of calcium carbonate equivalent amendment per 1000 tons soil.
2 Total lime in metric tons (mtons); total lime calculated according to the following formula: ([{volume cubic meters x 1.31} x 1.9 tons per cubic yard]/ 1000 tons soil per ton of lime) x lime rate) x 1.1 x 0.9 mtons/ton

7.3.2.2 Effectiveness

For Alternatives CB-2A and CB-2B, *in-situ* treatment would be only somewhat effective. This is because these alternatives limit the volume of metal-rich soil that would be treated, and untreated soil will remain at relatively shallow depths below the surface. Implementation of any one of the Alternative 2 sub-alternatives will not significantly affect the rate or volume of infiltration through the soil materials. For Alternatives CB-2A and CB-2B, water will be infiltrating and percolating through non-amended soil. Under certain conditions during moderate to extreme weather or during snowmelt, untreated soils will likely become saturated. Under these conditions, which can be expected to occur several times a year in the Como Basin, infiltrating water would flush accumulated contaminants to shallow groundwater and surface water.

The greatest positive impact of Alternatives CB-2A and CB-2B is the reduction of phytotoxicity at the soil surface, allowing establishment of vegetation. The vegetated cover uses water by evapotranspiration processes, reducing to a very limited extent the amount of infiltration through the soil profile. More importantly however, vegetative cover stabilizes the soil surface, prevents erosion and off-site transportation of metal-rich soils, and helps to reduce the amount of contaminant transport off-site in surface water. As each of the sub-alternatives in this analysis provides for successful revegetation, these benefits are also realized for Alternative CB-2C.

For Alternative CB-2C, in which all metal-rich soils are lime amended, it is presumed that most, if not all, of the contaminant migration from metal-rich soils could be eliminated within a short period of time. Although infiltration and percolation rates remain the same, treated soil material will not form acid that releases contaminants to shallow groundwater or surface water. Once existing oxidation products have been flushed from treated soils, and assuming that excess alkalinity will exist to buffer any future acidity, no further sulfide oxidation will occur.

For each of the Alternative CB-2 sub-alternatives, control of sulfide oxidation and infiltration through metal-rich soils will most likely only address a portion of contamination affecting groundwater impacted by sulfide mineralization in the Como Basin. Because the material underlying metal-rich soils in the Como Basin is made up of a large volume (707,318 metric tons) of an in-place massive sulfide deposit hosted in fractured and faulted bedrock, other sources of acid and metals remain unaffected by Alternative CB-2.

Compaction of the surface may very slightly lower the seepage rate through amended soils from that of the existing condition. This does not have any implication with respect to the water quality of the seepage; in fact, it is possible that the seepage rate would decrease but that the concentration of contaminants within the seepage could increase. This could occur because products of sulfide oxidation will continue to dissolve into seepage until the solubility of secondary minerals is reached. It is likely that solute load would be reduced to some extent by lime amendment, particularly for Alternative CB-2C, where the pH of amended soil will be raised above the critical threshold of pH 5.

Alternative CB-2A is similar to the reclamation program undertaken by CBMI in 1993 (Section 2.1). CBMI's program met with very limited success. Revegetation efforts have failed probably due to inadequate initial lime amendment and a failure to refertilize soils over time. Surface regrading is largely stable and diversion ditches have performed reasonably well, but diversion ditches should have been constructed further down the hill in order to minimize downstream surface erosion. Diversion of water flow down the Glengarry raise was partially successful in reducing flow and load from the Glengarry portal.

❖ *REMOVAL ACTION OBJECTIVES*

For each of the Alternative CB-2 sub-alternatives, *in-situ* treatment meets RAOs to varying degrees. By neutralizing the upper 30 cm of metal-rich soil to a more neutral pH (Alternative CB-2A), phytotoxicity of the soil will be reduced to the extent that plants will grow directly in the amended soil. Alternative CB-2B amends the disturbed surficial soil materials to a greater depth, allowing for the extension of roots to a greater depth. Revegetating the Como Basin will greatly reduce soluble metals that can migrate from the soils to surface water. Soluble metals will not be eliminated under Alternatives CB-2A and CB-2B because some portion of soil in the basin will remain untreated and in contact with infiltrating precipitation.

Alternative CB-2C should greatly decrease or virtually eliminate the formation of acid, and minimize the formation of soluble metals from unconsolidated soil as well as allow for vegetation to be established on the surface of the amended material. The RAO of reducing or eliminating concentrated runoff and sediment discharges will be met through the establishment of a viable vegetative cover. Potential exposure of metal contaminants to the food chain will be reduced to a large extent in the treated soil.

❖ *OVERALL PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT*

There are no unacceptable human health risks that remain in Fisher Creek according to the recreational risk analysis. *In-situ* treatment reduces the potential for further erosion and migration of contaminants by stabilizing metal-rich soils in the basin with vegetation. The amount of contaminated leachate formed, and its potential to migrate, varies between the Alternative CB-2 sub-alternatives based on the amount of metal-rich soil treated, with Alternative 2C being most effective and CB-2A being least effective.

Reductions in environmental exposure of contaminants to surface water and groundwater will be minimal due to the continued impacts from contaminated groundwater from both seepage through unamended metal-rich soils (Alternatives CB-2A and CB-2B) and natural sources of contaminated groundwater. Of the three sub-alternatives, Alternative CB-2C provides the highest level of protection to the environment.

❖ *COMPLIANCE WITH ARARS*

Compliance with ARARs will not be fully achieved under any of the Alternative CB-2 sub-alternatives. Temporary water quality standards are currently being met in Fisher Creek under existing conditions. However, contaminant-specific standards associated with the Montana Water Quality Act, will not be achieved under Alternative CB-2 without other cleanup actions. The reasons for this are several, including the presence of a large body of near-surface sulfide mineralization present in the Como Basin that contributes metal and pH impacts to groundwater and surface water. Groundwater migration out of these sulfide and metals-bearing bedrock units into surface water and groundwater supplying base flow to Fisher Creek below the Glengarry Adit portal is an additional potential and probably significant source of metals and acidity contamination to Fisher Creek. There are also sulfide and metal bearing sediments, as well as chemical precipitates that have been deposited along Fisher Creek that represent secondary sources of contamination. Finally, there are ferricrete deposits (iron and manganese oxide cemented colluvial deposits containing considerable metals concentrations) that have been and are being deposited downgradient of the Como Basin where surface water and seeps and springs containing metals-enriched groundwater are present.

Surface water quality at Station SW-3 will improve as a direct result of treating Como Basin soils under Alternative CB-2. While improvements in water quality are limited by control of water chemistry at Station SW-3 by mineral precipitates and metals sorption, erosion from revegetated areas would considerably reduce sediment loading that currently reports to Fisher Creek. Under higher flow conditions, some metals load from the Como Basin will be released due to saturation and seepage from non-amended wastes under Alternatives CB-2A and CB-2B. Copper and iron loading from the Como Basin would be considerably reduced if Alternative CB-2C is implemented, although arsenic loading may increase, as arsenic is more mobile in neutral pH environments. Arsenic is currently below the detection limit at the Glengarry Adit portal, but arsenic concentrations of a much as 0.018 mg/l have been measured in underground sampling stations and at the Como raise.

Groundwater quality in the Fisher Creek drainage varies considerably. With the exception of iron and manganese concentrations, groundwater in the Fisher Creek valley is in compliance with groundwater quality standards in both shallow alluvium and Precambrian granite water-bearing units. Iron and manganese are ubiquitous in the District, and concentrations of these two metals are believed to be partially controlled by natural sources in bedrock. Groundwater on the east flank of Fisher Mountain (sampled from well Tracer 5, which is completed in the Fisher Mountain Porphyry) exceeds contaminant-specific standards for copper, iron, and manganese and has an acidic pH. *In-situ* treatment of the Como Basin soils will likely have a positive effect on groundwater quality.

Contaminant-specific ARARs for ambient air are expected to be met under this alternative because metal-rich soils will be revegetated. Location-specific ARARs, particularly those associated with cultural and historic resources, are expected to be met, as there are no known cultural or historic features that would be impacted if this alternative is implemented. Requirements of the National Historic Preservation Act and the Archaeological and Historic Preservation Act will be met through consultation with the State Historic Preservation Office by the USDA-FS, and mitigation of cultural and historic impacts on the District as a whole.

Threatened and endangered species are present in or near the District. During development of the Draft Environmental Impact Statement for CBMI's proposed mine in the District, consultation with the U.S. Fish and Wildlife Service identified the grizzly bear, bald eagle, peregrine falcon, and gray wolf as threatened and endangered species that may be present in the project area. No critical habitat was designated or proposed in the project area. There is not expected to be any impact to threatened and endangered species because new disturbances will be limited to the Como Basin, no permanent facilities will be constructed, and construction and maintenance work will not be any greater than the current level of recreational use.

Other location-specific ARARs will be protected through substantive compliance with the requirements of laws related to streambeds and wetlands. The Floodplain and Floodway Management Act does not directly apply because the Como Basin is not in a designated 100-year floodplain. The Natural Streambed and Land Preservation Act (§§ 75-7-101 et seq., MCA) will be complied with by using earth and natural materials to construct diversion channels and to armor existing channels below the Como Basin that are currently exposed to severe erosion. Reconstructed streambed and banks will be designed to provide hydraulic stability. All disturbed areas will be managed during construction to minimize erosion. Protecting wetlands will be accomplished by avoiding, to the extent possible, adverse impacts to wetlands.

Action-specific ARARs are expected to be met by this alternative. Action-specific ARARs for storm water runoff will be complied with using best management practices (BMPs) in the Como Basin. Substantive MPDES permit regulations will be met, as no facilities require a discharge of waste to the environment. The Montana Water Quality Act will not be fully complied with under this alternative. as unamended metal-rich soils left by Alternatives CB-2A and CB-2B will likely be in contact with groundwater during periods of high water tables.

Because mine wastes are derived from the beneficiation and extraction of ores, District Property wastes generally are exempt from federal and state regulation under RCRA as a hazardous waste (42 U.S.C. 6921 (b) (3) (A)(iii)(1994); MCA § 75-10-401 et seq).

Revegetation requirements contained in the Surface Mining Control and Reclamation Act, Montana Strip and Underground Mine Reclamation Act and Metal Mining Act would be substantively met by regrading and amending soils. Native species have been selected through many years of USDA-FS research in the District. BMPs for seeding, planting, mulching, soil amendments, control of noxious weeds, and erosion control will also be followed under this alternative.

Hydrological regulations contained in the Montana Strip and Underground Mine Reclamation Act would be met as any changes to the hydrologic balance will be minimal. Other requirements for treating surface drainage, sediment control, construction and maintenance of sedimentation ponds, discharges from sedimentation ponds, and provisions for groundwater will be met by using best available technologies (BATs).

Action-specific State of Montana air quality regulations related to dust suppression and control during construction activities will be met using best management practices (BMPs).

Occupational Safety and Health Administration (OSHA) requirements would be met by requiring appropriate safety training for all on-site workers during construction. Site activities would be conducted under the guidance of a Health and Safety Plan for the site per OSHA 29 CFR 1910.120. Site personnel will have completed 40-hour hazardous waste operations and emergency response training and would be current with the 8-hour annual refresher training as required by OSHA 29 CFR 1910.120.

❖ *LONG-TERM EFFECTIVENESS AND PERMANENCE*

As the entire quantity of metal-rich soil materials in the Como Basin is not fully amended under Alternatives CB-2A and CB-2B, on-site treatment may not be a permanent solution. Acidity from non-amended soils lying below the amended zone has the potential to move upward into the treated zone through capillary action. This has occurred using a similar but more limited approach for the reclamation work completed in 1996 by CBMI. If this condition occurs, retreatment may be necessary, especially if vegetation is impacted through a reduction in cover or vigor. PRSC monitoring and maintenance will be essential to maintaining the effectiveness of these alternatives in the long-term. However, since all metal-rich soils are amended under Alternative CB-2C, long-term performance should be quite effective in minimizing contaminant migration from the basin.

❖ *REDUCTION OF TOXICITY, MOBILITY, OR VOLUME THROUGH TREATMENT*

There will be some variable amount of reduction in mobility depending on the sub-alternative selected but no reduction of toxicity or volume under this alternative. Reduction in the mobility of contaminants will be achieved through amendment with a neutralizing agent. Further reductions in mobility will vary between the sub-alternatives as the volume of soils amended is different. Alternative CB-2A (3.5% amended) and Alternative CB-2B (11.7% amended) would result in a lower reduction in mobility than Alternative CB-2C, in which all metal-rich soils are amended.

❖ *SHORT-TERM EFFECTIVENESS*

Implementation of either Alternative CB-2A or CB-2B should allow completion of the response action in a single construction season of not more than 60 days. Therefore, impacts associated with construction activities are considered short-term, and should not significantly impact human health. On-site workers will be protected by following a site specific Health and Safety Plan, employing appropriate personal protective equipment, and by following proper operating and safety procedures. Implementation of Alternative CB-2C will likely require at least two construction seasons to complete.

The major short-term impact to the surrounding community, residents, and wildlife involves increased vehicle traffic and temporary closures of some forest roads. An increase in traffic will occur during mobilization and demobilization of construction equipment. Transports and trucks that periodically travel to and from the site will supply materials. Additional trucks will be required to transport lime amendment, fertilizer, seed, and erosion control materials on a daily basis.
To construct Alternative CB-2A, 633 metric tons of neutralizing amendment will be hauled to the Como Basin site by truck over the course of the project. About 64 truck trips will be needed for this function over a period of 30 days. To construct Alternative CB-2B, 2,100 metric tons of neutralizing amendment will be hauled by truck over the course of the project. About 210 truck trips will be needed for this

function over a period of 30 to 60 days. To construct Alternative CB-2C, 17,990 metric tons of neutralizing amendment will be hauled by truck over the course of the project. About 720 additional truck trips will be needed for this function over a period of 90 days, assuming eight truck trips per day. Lime amendment materials could come from various locations in Montana or Wyoming.

Short-term road closures in the project area may be necessary, limiting access to the forest. Increased traffic may impact wildlife by either changing daily migration patterns or exposing wildlife to a higher potential for injury or death due to collisions with vehicles.

Short-term air quality impacts to the immediate environment may occur during regrading and mixing of neutralizing amendment. Control of fugitive dusts will require the use of best management practices. Dust control on designated truck routes is an expected requirement.

7.3.2.3 Implementability

In-situ treatment is both technically and administratively feasible. Key project components such as equipment, materials, and construction expertise, although distant from the site, are available and would allow the timely implementation and successful execution of the alternative.

Difficulties may be encountered with complete mixing of the lime amendment, especially for Alternative CB-2C. Specialized equipment such as a pug mill or other device may be required, and strict quality control measures will be needed to insure complete mixing.

7.3.2.4 Cost

Estimated costs for Alternative CB-2 are shown in Table 7-2. The detailed cost analysis can be found in Appendix D.

TABLE 7-2
SUMMARY OF TOTAL ESTIMATED COSTS FOR COMO BASIN ALTERNATIVE CB-2
New World Mining District Response and Restoration Project
Como Basin/Glengarry Adit/Fisher Creek Response Action

Item	Alt. CB-2A	Alt. CB-2B	Alt. CB-2C
Upgrade Access Roads	$14,074.00	$14,074.00	$14,074.00
Clear and Grub	$10,258.00	$10,258.00	$15,410.00
Excavate/Load/Haul/Place Soil	$36,322.47	$42,593.00	$1,141,044.00
Amend Waste	$39,246.00	$130,200.00	$1,155,380.00
Revegetation	$76,292.55	$76,292.55	$91,605.75
Misc. Site Work	$71,541.80	$71,541.80	$176,457.00
Reclaim Access Roads	$41,100.00	$41,100.00	$41,100.00
SUBTOTAL FOR ALL ITEMS:	$291,835.32	$389,059.85	$2,595,071.25
Mobilization (10%):	$29,183.53	$38,905.99	$259,507.13
Contingency (12%):	$35,020.24	$46,687.18	$311,408.55
TOTAL CONSTRUCTION ESTIMATE:	$356,039.09	$474,653.02	$3,165,986.93
Engineering Evaluation and Design (8%):	$28,483.13	$37,972.24	$253,278.95
Construction Oversight (5%):	$17,801.95	$23,732.65	$158,299.35
Present Worth Post-Removal Site Control Estimate:	$59,328.00	$59,328.00	$59,328.00
TOTAL ESTIMATED COST:	**$ 461,652.00**	**$595,685.91**	**$3,636,893.23**

7.3.3 Covering or Capping With or Without Lime Amendment – Alternative CB-3

This alternative involves construction of a cover or cap on the metal-rich soils with or without amendment in the Como Basin Source Area. There are three variations of this alternative. For each of the three sub-alternatives, regrading, nutrient and organic additions, and revegetation are common components. The three sub-alternatives differ in the cap design placed on the metal-rich soil materials and the amount of metal-rich soil amended with lime. A description of the alternative is presented below, followed by the detailed analysis. The components of this sub-alternative are presented graphically in Figure 24.

7.3.3.1 Alternative Task Description

- *Borrow Area Development*: A soil borrow area will be needed to supply cover materials for cap construction. Adequate soil materials are available at the SB-4B(I) repository area. The soil borrow area would likely be located at the (I) site, which is a hill composed of glacial till located east of the Lulu Pass road, about 0.8 kilometers (0.5 miles) north of US Highway 212. Because the haul distance (about 6 km or 3.7 miles), is considerable, there may be other nearby sources of suitable soil. Potential source areas for soil cap material will be considered in detail during the design phase of the project if Alternative CB-3 is selected. Development of the soil borrow area will involve excavating borrow to a depth of about 3 to 6 meters (10 to 20 feet). The area of disturbance will vary based on quantity of soil needed for each alternative. Construction elements will include developing sufficient access to the borrow site, clearing and grubbing vegetation, stockpiling topsoil, excavating borrow, regrading the borrow area, spreading stockpiled topsoil, revegetating the site with native grasses and forbs, and providing erosion controls.

- *Covering or Capping Wastes with or without Lime Amendment:*

  - *Alternative CB-3A – Shallow In-Situ Lime Amendment of Metal-Rich Soil with Soil Cover:* Metal-rich soil will be amended with a neutralizing amendment (such as agricultural limestone, lime kiln dust, or calcium oxide), compacted, graded, and shallow lime amended to a depth of 30 centimeters (12 inches). Total lime required (calcium carbonate equivalent) is 633 metric tons (Table 7-1). The cap for this alternative would be constructed with 60 centimeters of soil obtained from a local borrow area and transported to the Como Basin. The quantity of cap material needed is about 13,700 cubic meters (17,920 cubic yards)

  - *Alternative CB-3B – Non-amended Metal-Rich Soil Covered with a Geomembrane and an Amended Soil Cover:* Alternative CB-3B involves regrading of metal-rich soils *in-situ*. This alternative would use a synthetic liner in the cover system, consisting of a 60 mil HDPE geomembrane liner used as a barrier layer (Figure 24). The synthetic liner would be placed directly on regraded metal-rich soil. A drainage layer would be placed on top of the liner and the drainage layer covered with amended soil from the Como Basin. The amended soil cover thickness would be about one meter (3.3 feet) and would require about 2,100 mtons of lime. Adequate cover is needed to prevent the drainage layer from freezing and damaging or puncturing the liner.

  - *Alternative CB-3C - Non-amended Metal-Rich Soil Covered with a Geomembrane and an Imported Soil Cover:* Alternative CB-3C involves regrading of metal-rich soils *in-situ*. This alternative uses a 60 mil HDPE synthetic liner in the cover system as a barrier layer (Figure 24). The synthetic liner would be placed directly on the metal-rich soil. A geocomposite drainage layer and one meter of imported soil would be placed on top of the liner. The cover system for this sub-alternative requires about 22,300 cubic meters (29,200 cubic yards) of soil.

7.3.3.2 HELP Modeling

The Hydrologic Evaluation of Landfill Performance (HELP) model (Section 3.9) was used to compare the effectiveness of the Alternative CB-3 cover designs using average annual leachate generated as one measure of effectiveness. Detailed modeling results and a discussion of model parameters are presented in Appendix B.

Unsaturated hydraulic characteristics for each of the types of materials proposed for use in the cover were evaluated. For metal-rich soil, measured laboratory values of unsaturated hydraulic conductivity were used. Soil types were selected from general classes to match those that might be available on-site for reclamation purposes, a silty loam and silty clay. Drain material was assumed to be gravel. A published literature value for unsaturated hydraulic conductivity was used for the geomembrane in the model. Results of the HELP modeling for Alternative CB-3 sub-alternatives are shown in Table 7-3.

As expected, water percolation through metal-rich soil decreases considerably from Alternative CB-3A (without a geomembrane) to Alternatives CB-3B and CB-3C that use a geomembrane liner. The HELP model shows a dramatic decrease of percolation into metal-rich soil below the liner and, consequently, into mineralized bedrock. Some water will flow through the amended cap (Alternative CB-3B) or through the soil layer (Alternative CB-3C) and into the underlying drain layer, where it will flow laterally to the downgradient edge of the liner. This discharge is calculated by the HELP model and expressed as a large increase in runoff (Table 7-3). The effectiveness of the three CB-3 sub-alternatives is discussed in greater detail below.

TABLE 7-3
CONDITIONS FOR HELP MODELING OF INFILTRATION THROUGH COMO BASIN SOILS
New World Mining District Response and Restoration Project
Como Basin/Glengarry Adit/Fisher Creek Response Action

Condition	Annual Precipitation (inches)	Evapo-Transpiration (in/yr)	Runoff (in/yr)	Seepage (in/yr)	Seepage (gpm)
Existing Condition	54.07	15.8	16.8	21.4	6.1
CB-3A - 24 Inch Soil Barrier Layer	54.07	15.8	16.8	20.5	5.8
CB-3B and 3C Geomembrane under 36 inch Soil Layer	54.07	16.8	30.0	4.1	1.2

Covering the metal-rich soils of the basin with 24 or 36-inch thick cover of soil only reduces the seepage by a very small amount to 5.8 gpm (22 liters per minute). These numbers are the same because the thickness of soil offers no distinct advantage without a liner beneath. Placing a similar amount of soil material as a cap over a geomembrane cover significantly reduces the seepage to 0.87 and 1.2 gpm (3.3 and 4.5 lpm), respectively (Appendix B). Note that in this case, increasing the soil thickness over the liner actually increases seepage because more water is stored in the thicker cap. This corresponds to about 3.2 million gallons of seepage per year under existing conditions and 0.46 million gallons of seepage per year under the scenario with 24 inches of soil over a geomembrane cover, an 86% reduction in total annual seepage. This is a very significant reduction in seepage through the metal-rich soils of the Como Basin and the use of a geomembrane cover should significantly reduce long- and short-term loading from this source. It should be noted, however, that use of the geomembrane essentially doubles the amount of runoff from 16.8 inches under the existing condition to 30 inches.

7.3.3.3 <u>Effectiveness</u>

Alternative CB-3A will be only somewhat effective at limiting seepage of water through metal-rich soil. This is because only a limited volume of metal-rich soil is treated, and untreated soil remains at relatively shallow depths below the surface. Under certain conditions during moderate to extreme weather or during snowmelt conditions, untreated metal-rich soil will likely become saturated, and this water would flush accumulated contaminants to shallow groundwater and surface water. In addition, as shown by HELP modeling (Table 7-3), placing the soil cover in this sub-alternative does not significantly change the rate of percolation through metal-rich soil. This is because the soil's ability to retain or hold water is about the same as that of the metal-rich soil alone. During a rainfall event, coversoils take less time to become saturated and are thus more likely to transmit water to the underlying metal-rich soil.

The greatest positive impact of Alternative CB-3A is that, with the placement of the soil cover, the phytotoxic surface of metal-rich soil is covered with a growth media that allows for easier reestablishment of vegetation. Vegetation uses water by evapotranspiration processes, thereby reducing to a very limited extent the rate of infiltration through metal-rich soil. More importantly however, vegetation stabilizes the surface, preventing erosion and off-site transport of metal-rich soil, and helps to reduce the amount of contaminant transport in surface water. As each of the sub-alternatives in this analysis proposes a vegetated surface, this benefit is realized by the other Alternative CB-3 sub-alternatives.

Alternatives CB-3B, and CB-3C, are considerably more effective. This is principally because of the addition of the geomembrane in the cover. The geomembrane effectively eliminates the downward percolation of surface water into underlying material. These sub-alternatives also call for a lateral drain layer overlying the geomembrane, which allows water entering through the cover material to flow laterally along the membrane surface, discharging along the downgradient edge of the liner.

For Alternative CB-3B, where all metal-rich soils above the liner are lime amended, it is presumed that most of the contaminant migration from the amended soils could be eliminated. Metal-rich soils below the liner are protected from water infiltration by the liner. Metal-rich soils placed above the liner are amended such that the treated soil does not readily form acid or release contaminants to shallow groundwater or surface water.

For Alternative CB-3C, all metal-rich soils are below the liner and protected from infiltration. Material above the liner consists only of a lateral drain layer and coversoil. Under this closure option it is assumed that all contamination from metal-rich soils in the Como Basin could be protected from infiltrating surface water and precipitation, thereby eliminating contaminant leaching generated by percolation of water through metal-rich soil. Vegetation will be established, and will provide the benefits of a revegetated surface.

For each of the CB-3 sub-alternatives, it should be noted that beneath the unconsolidated metal-rich soil lays a large volume of in-place, sulfide-rich, fractured and faulted bedrock. Some undefined quantity of groundwater is known to flow laterally across this bedrock surface, and flows to surface water during some times of the year. Groundwater fracture flow in the underlying bedrock surrounding sulfide-rich bedrock is thought to be minimal based on observations within the Como raise and Glengarry Adit.

❖ *REMOVAL ACTION OBJECTIVES*

For each sub-alternative, capping meets RAOs to varying degrees. The RAO of reducing or eliminating concentrated runoff and sediment discharges will be met by each of the sub-alternatives through the establishment of a viable vegetative cover on a regraded surface. Each of the sub-alternatives reduces phytotoxicity by providing suitable conditions for establishment of vegetation.

In terms of infiltration and subsequent release and migration of contaminants, Alternative CB-3A is clearly inferior for the reasons described above under effectiveness, although some improvement (decrease) in contaminant migration from metal-rich soils could be expected, especially during drier periods. However, soluble metals and acidity will not be eliminated under Alternative CB-3A, because a large portion of the metal-rich soil in the basin will remain untreated and in contact with infiltrating precipitation.

Alternatives CB-3B and CB-3C will likely locally meet the RAO for migration of contaminants from metal-rich soils. These sub-alternatives should greatly decrease or virtually eliminate the formation of acid and minimize the formation of soluble metals. However, metal-rich soil in and around the Como Basin is not the only source of contaminants in the Fisher Creek headwaters area, as was described previously for Alternative CB-2.

Contaminant concentrations will likely be reduced in the upper reaches of Fisher Creek as a result of implementation of Alternatives CB-3B or CB-3C, and each of these alternatives will clearly perform better than Alternative CB-3A. Potential exposure to the food chain to metal contaminants will be reduced to a large extent in the treated or capped metal-rich soil materials.

❖ *OVERALL PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT*

There are no unacceptable human health risks that remain in Fisher Creek according to the recreational risk analysis. Alternative CB-3 reduces the potential for further erosion and migration of contaminants from source areas near surface water drainages by stabilizing metal-rich soils with vegetation. The amount of contaminated leachate formed and its potential to migrate varies between the three proposed sub-alternatives based on the amount of metal-rich soil treated and the specific capping design. In these terms, Alternative CB-3A performs more poorly than Alternatives CB-3B or CB-3C. Alternative CB-3C has an advantage of having all metal-rich soil material below the geomembrane liner, although metal-rich soil does not have the higher concentrations of contaminants or acidity that is present in other District Property wastes such as the Spaulding dumps.

Reductions in environmental exposure of contaminants to surface water and groundwater will be minimal due to contaminated groundwater from both seepage through unamended metal-rich soils (Alternative CB-3A) and natural sources of contaminated groundwater. Of the three sub-alternatives, Alternative CB-3B and CB-3C provides a high level of protection to the environment exposed to historic mining impacts.

❖ *COMPLIANCE WITH ARARS*

Compliance with ARARs will not be fully achieved under any of the Alternative CB-3 sub-alternatives. Temporary water quality standards are currently being met in Fisher Creek under existing conditions. However, contaminant-specific standards associated with the Montana Water Quality Act will not be achieved under Alternative CB-3 without other cleanup actions. The reasons for this are several, as discussed previously under Alternative CB-2.

Surface water quality at Station SW-3 will improve as a direct result of treating the Como Basin soils under Alternative CB-3. While improvements in water quality are limited by control of water chemistry at Station SW-3 by mineral precipitates and metals sorption, erosion from revegetated areas would considerably reduce sediment loading that currently reports to Fisher Creek. Copper and iron loading from the Como Basin would be considerably reduced if Alternative CB-3B or CB-3C is implemented because percolation of water through metal-rich soils would be reduced by over 85% from existing conditions.

Groundwater quality in the Fisher Creek drainage varies considerably. With the exception of iron and manganese concentrations, groundwater in the Fisher Creek valley bottom is in compliance with groundwater quality standards in both shallow alluvium and Precambrian granite water-bearing units. Iron and manganese are ubiquitous in the District, and concentrations of these two metals are believed to be partially controlled by natural sources in bedrock. Groundwater on the east flank of Fisher Mountain (sampled from well Tracer 5, which is completed in the Fisher Mountain Porphyry) exceeds groundwater contaminant-specific standards for copper, iron, and manganese and has an acidic pH. Capping of the Como Basin soils will likely have a positive effect on groundwater quality, especially under Alternative CB-3B or CB-3C because of the decreased amount of percolation through metal-rich soils. Alternative

CB-3A will not likely have much positive effect on groundwater quality because the amount of percolation through metal-rich soils would be relatively unchanged.

Contaminant-specific ARARs for ambient air are expected to be met under this alternative because metal-rich soils will be revegetated.

Location-specific ARARs, particularly those associated with cultural and historic resources, are expected to be met, as there are no known cultural or historic features that would be impacted if this alternative is implemented. Requirements of the National Historic Preservation Act and the Archaeological and Historic Preservation Act will be met through consultation with the State Historic Preservation Office by the USDA-FS, and mitigation of cultural and historic impacts on the District as a whole.

Threatened and endangered species are present in or near the District. During development of the Draft Environmental Impact Statement for CBMI's proposed mine in the District, consultation with the U.S. Fish and Wildlife Service identified the grizzly bear, bald eagle, peregrine falcon, and gray wolf as threatened and endangered species that may be present in the project area. No critical habitat was designated or proposed in the project area. There is not expected to be any impact to threatened and endangered species because new disturbances will be limited to the Como Basin, no permanent facilities will be constructed, and construction and maintenance work will not be any greater than the current level of recreational use.

Other location-specific ARARs will be protected through substantive compliance with the requirements of laws related to streambeds and wetlands. The Floodplain and Floodway Management Act does not directly apply because the Como Basin is not in a designated 100-year floodplain. The Natural Streambed and Land Preservation Act (§§ 75-7-101 et seq., MCA) will be complied with by using earth and natural materials to construct diversion channels and to armor existing channels below the Como Basin that are currently exposed to severe erosion. Reconstructed streambed and banks will be designed to provide hydraulic stability. All disturbed areas will be managed during construction to minimize erosion. Protecting wetlands will be accomplished by avoiding, to the extent possible, adverse impacts to wetlands.

Action-specific ARARs are expected to be met by this alternative. Action-specific ARARs for storm water runoff will be complied with using BMPs in the Como Basin. Substantive MPDES permit regulations will be met, as no facilities require a discharge of waste to the environment. The Montana Water Quality Act will not be fully complied with under this alternative as unamended metals-rich soils left beneath the liner or soil cover may be in contact with groundwater during periods of high water tables.

Because mine wastes are derived from the beneficiation and extraction of ores, District Property wastes generally are exempt from federal and state regulation under RCRA as a hazardous waste (42 U.S.C. 6921 (b) (3) (A)(iii)(1994); MCA § 75-10-401 et seq).

Revegetation requirements contained in the Surface Mining Control and Reclamation Act, Montana Strip and Underground Mine Reclamation Act and Metal Mining Act would be substantively met by regrading and amending treated soils. Native species have been selected through many years of USDA-FS research in the District on amended wastes. BMPs for seeding, planting, mulching, soil amendments, control of noxious weeds, and erosion control will also be followed under this alternative.

Hydrological regulations contained in the Montana Strip and Underground Mine Reclamation Act would be met by minimizing any changes to the hydrologic balance. While use of a geomembrane will locally change infiltration and runoff characteristics, these changes will not diminish flows in Fisher Creek. Other requirements for treating surface drainage, sediment control, construction and maintenance of sedimentation ponds, discharges from sedimentation ponds, and provisions for groundwater will be met by using BAT.

Action-specific State of Montana air quality regulations related to dust suppression and control during construction activities will be met using best management practices.

OSHA requirements would be met by requiring appropriate safety training for all on-site workers during construction phase. Site activities would be conducted under the guidance of a Health and Safety Plan for the site per OSHA 29 CFR 1910.120. Site personnel will have completed 40-hour hazardous waste operations and emergency response training and would be current with the 8-hour annual refresher training as required by OSHA 29 CFR 1910.120.

❖ *LONG-TERM EFFECTIVENESS AND PERMANENCE*

Under Alternative CB-3A, the volume of metal-rich soil in the Como Basin is not fully amended; on-site treatment with a soil cap may not be a permanent solution. Water will continue to migrate downward to some extent and acidity from non-amended metal-rich soil lying below the amended zone has the potential to move upward into the treated zone and the overlying soils through capillary action. If this condition occurs, retreatment may be necessary, especially if vegetation is impacted through a reduction in cover or vigor. PRSC monitoring and maintenance will be essential to maintaining the effectiveness of this alternative in the long-term.

Alternatives CB-3B and CB-3C should provide long-term effectiveness by using cover soil or adding enough neutralizing amendment to fully eliminate future acid production from metal-rich soil overlying the liner. Metal-rich soil below the liner in both sub-alternatives will also be protected from infiltrating waters by the liner.

For Alternatives CB-3B and CB-3C, geomembrane liners require proper installation and sequencing for the alternatives to be considered effective in the long-term. The multi-layer caps in these sub-alternatives could be impacted by environmental factors such as wetting/drying, freeze/thaw, and erosion, each of which could affect the long-term effectiveness of the capping alternatives. Continued PRSC monitoring and maintenance will be a factor in insuring long-term effectiveness.

❖ *REDUCTION OF TOXICITY, MOBILITY, OR VOLUME THROUGH TREATMENT*

The amount of reduction in mobility ranges considerably depending on the sub-alternative selected, but there will be no reduction of toxicity or volume under Alternative CB-3. Reduction in the mobility of contaminants will be achieved through treatment with a neutralizing amendment for Alternatives CB-3B (17%). Covering the metal-rich soil with a soil cap or placement of a geomembrane will also reduce mobility of contaminants because the HDPE liner will be a barrier to infiltrating water. With respect to mobility, Alternative CB-3A is the least effective and Alternatives CB-3B and CB-3C are more effective.

❖ *SHORT-TERM EFFECTIVENESS*

Implementation of Alternative CB-3A will probably allow for the completion of the response action in a single construction season of not more than 90 days. Therefore, impacts associated with construction activities are considered short-term, and should not significantly impact human health. On-site workers will be protected by following a site specific Health and Safety Plan, employing appropriate personal protective equipment and by following proper operating and safety procedures. Implementation of Alternatives 3B and 3C may require more than one construction season to complete due to the large amounts of materials that are required for the alternatives.

The major short-term impact to the surrounding community, residents, and wildlife involves increased vehicle traffic and temporary closures of some forest roads. An increase in traffic will occur during mobilization and demobilization of construction equipment. Transports and trucks that periodically travel to and from the site will supply materials. Much of the materials will be acquired on-site, with the exception of the lime amendment, and so much of the traffic associated with the project will occur on the Lulu Pass Road.

To construct Alternative CB-3A, 13,700 cubic meters of soil and 633 metric tons of neutralizing amendment will be hauled to the Como Basin by truck over the course of the project. About 860 truck trips will be needed for this function that will occur over a period of 90 days. To construct Alternative CB-3B, 2,100 metric tons of lime will be needed for cap construction. This will require up to 150 truckloads over a period of 60 days. Construction of Alternative CB-3C involves hauling about 20,070 cubic meters of coversoil in about 2,000 truckloads over a period of one three-month construction season. Lime amendment materials could come from a variety of sources in Montana and Wyoming.

Short-term road closures in the project area may be necessary, limiting access to the forest. Increased traffic may impact wildlife by either changing daily migration patterns or exposing wildlife to a higher potential for injury or death due to collisions with vehicles.

Short-term air quality impacts to the immediate environment may occur during regrading and mixing of neutralizing amendment. Control of fugitive dusts may thus require the use of BMPs. Dust control on designated truck routes is an expected requirement.

7.3.3.4 Implementability

Placing a multi-layer cap (soil, amended metal-rich soil, and/or a membrane) with or without *in-situ* lime amendment of metal-rich soil is both technically and administratively feasible. Key project components such as equipment, materials, and construction expertise, although distant from the site, are available and would allow the timely implementation and successful execution of the alternative. Geomembrane liner installation for Alternative CB-3B and CB-3C requires specialized equipment and labor including seam welders and seam test equipment. Quality Assurance/Quality Control for geomembrane liner installation is very strict, requiring experienced personnel and specialized equipment. Liners are available in-state, but available specialized labor may be limited. Lime amendment can be accomplished with conventional equipment although incorporation of lime may be best performed with specialized equipment.

There are some inherent difficulties with the placement of a geomembrane liner on the Como Basin site. Most of these difficulties have to do with the site itself. Although regrading will be completed prior to placement of the liner, some steep slope angles will remain that may make it difficult to place the cover system on the liner in a stable fashion. In addition, the liner will need to be keyed carefully to bedrock along its margins to minimize lateral infiltration into metal-rich soil. This may require a cut-off wall along the upgradient margin of the capped area in the Como Basin to prevent water from entering metal-rich soil. On the downgradient edge of the liner, the liner and the drainage layer must be terminated below grade to prevent any direct discharge to the surface. Alternatively, lateral flow along the liner could be diverted into constructed drainage pathways. Finally, a uniform and suitable depth of material must be placed over the liner to prevent damage to the liner by freezing and thawing. On steeper slopes, this cover material may locally need to be talus sized rock material rather than soil in order to hold the material on the liner.

7.3.3.5 Cost

A summary of the total estimated costs for Alternatives CB-3A, CB-3B, and CB-3C are shown on Table 7-4. The detailed cost analysis is contained in Appendix D.

TABLE 7-4
SUMMARY OF TOTAL ESTIMATED COSTS FOR COMO BASIN ALTERNATIVE CB-3
New World Mining District Response and Restoration Project
Como Basin/Glengarry Adit/Fisher Creek Response Action EE/CA

Item	Alt. CB-3A	Alt. CB-3B	Alt. CB-3C
Upgrade Roads	$14,074.50	$14,074.50	$14,074.50
Clearing and Grubbing	$10,258.00	$10,258.00	$10,258.00
Excavate/Load/Haul/Place Soil	$36,322.47	$133,800.00	$36,322.47
Amend Unconsolidated Soil	$39,246.00	$130,200.00	-
Install Geomembrane Liner	-	$552,148.00	$552,148.00
Drainage Layer	-	$129,375.00	$129,375.00
Cover Soil	$220,800.00	-	$323,494.08
Revegetate	$76,292.55	$76,292.55	$76,292.55
Reclaim Roads	$41,100.00	$41,100.00	$41,100.00
Misc. Construction	$174,541.80	$224,541.80	$224,541.80
SUBTOTAL FOR ALL ITEMS:	$612,635.32	$1,348,112.32	$1,407,606.40
Mobilization (10%):	$61,263.53	$134,811.23	$140,760.64
Contingency (12%):	$73,516.24	$161,773.48	$168,912.77
TOTAL CONSTRUCTION ESTIMATE:	$747,415.09	$1,644,697.03	$1,717,279.81
Engineering Evaluation and Design (8%):	$59,793.21	$131,575.76	$137,382.38
Construction Oversight (5%):	$37,370.75	$82,234.85	$85,863.99
Present Worth Post-Removal Site Control Estimate:	$59,328.00	$59,328.00	$59,328.00
TOTAL ESTIMATED COST:	**$903,907.05**	**$1,917,835.64**	**$1,999,854.18**

7.4 FISHER CREEK SOURCE AREA ALTERNATIVES

This section presents the detailed analysis of alternatives for the Fisher Creek Source Area. The Fisher Creek Source Area consists of 61 relatively small, scattered, outlying waste rock dumps located in the Fisher Creek watershed. These smaller waste rock dumps, identified in Table 3-1 and shown on Figure 3, contain acid-generating sulfides and heavy metal contaminants with potential contaminant migration issues similar to those of the metal-rich soils in the Como Basin Source Area

7.4.1 No Action - Alternative FC-1

The No Action Alternative involves leaving the Fisher Creek mine sites in the existing condition of unvegetated mine dumps. No reclamation would be accomplished at the site to control contaminant migration or reduce toxicity or volume. Periodic maintenance may be required if erosion of mine waste dumps increases to unacceptable levels or threatens other resources.

7.4.1.1 Effectiveness

The No Action Alternative does not address surface water impacts, nor does it provide any controls on contaminant migration via direct contact or particulate emissions. Toxicity, mobility, and volume of contaminants would not be reduced under the No Action Alternative. Protection of the environment would not be achieved under this alternative. Only one of the RAOs would be met for the site -- preserving the existing undeveloped character of the District and surrounding area. The No Action Alternative is currently in compliance with temporary water quality standards. However, as these standards expire in 15 years, a No Action Alternative is not expected to move water quality toward compliance with the B-1 standards.

7.4.1.2 Implementability

This alternative is both technically and administratively feasible. It is not a reliable means of controlling wastes that impact environmental receptors.

7.4.1.3 Cost

No capital costs would be incurred under this alternative. However, long term costs associated with no action are unknown since there is an on-going risk that unstable mine dumps may fail, resulting in damage to other resources and requiring action. In addition, there are external costs associated with no action, including the loss of certain ecological functions such as a healthy, viable aquatic community.

7.4.2 In-Situ Treatment - Alternative FC-2

Alternative FC-2 involves treating the wastes in-place with a neutralizing amendment. Figure 25 shows a schematic of the alternative components. A description of the alternative is presented below, followed by the detailed analysis.

7.4.2.1 Alternative Task Description

- *Road Improvement:* The existing condition of the majority of roads that access the dump sites is poor, except for the road to the Glengarry Dump and other dumps near the Lulu Pass Road. Road improvements will involve widening and grade reduction, cut and fill, and installing temporary culverts. Some sites may require new road construction, which will involve constructing a disturbed road width of 6 meters (20 feet), dozer grading to establish a 3.7-meter-wide (12 feet) travel width, and installing turnouts. Total disturbance associated with road improvements is expected to be 8.5 hectares (21 acres). All new access roads and some existing access roads will be fully reclaimed after the site activities are complete.

- *Site Preparation:* Clearing and grubbing; separating combustible and non-combustible debris; and, debris disposal.

- *Regrade Waste Dumps:* Mine waste dumps would be regraded to a stable configuration as allowed by site constraints. Wastes in contact with surface water would be pulled back so that the wastes are out of the surface water course. Regrading would be done to blend in with the surrounding topography.

- *Treat Waste with Neutralizing Amendment:* A neutralizing amendment, such as agricultural limestone, lime kiln dust, or calcium oxide, would be mixed into the top 30 cm (1 foot) of the waste at an average rate of 40 metric tons per thousand metric tons. The total lime required to amend the remaining dumps is 610 metric tons.

- *Revegetate Waste Dump Sites:* Following neutralization, prescriptions for revegetation will follow those developed by the USDA-FS Rocky Mountain Research Station specifically for revegetating amended mine wastes in the District. These prescriptions are summarized in the *1999 Revegetation Monitoring Report* (Maxim, 1999f). Revegetation prescriptions for mine waste specify amount and types of amendments recommended for organic matter, fertilizer, seeding, mulching, and use of erosion control.

- *PRSC*: Monitoring and maintenance of vegetation.

7.4.2.2 Effectiveness

Overall, *in-situ* treatment would be effective in providing suitable soil conditions for revegetation in the short-term, and a corresponding reduction in mobility of metal contaminants. However, because site conditions limit the depth of waste treatment, untreated wastes will remain at the sites. Under certain conditions, generally during moderate to extreme weather, untreated wastes could become saturated and release contaminants to the environment. There is also the potential for the treated surface of the waste to reacidify due to capillary rise of acid from underlying untreated wastes, resulting in a reduction in vegetation cover and vigor. Such a mechanism would likely cause the waste dump to revert to pre-treatment conditions.

❖ *REMOVAL ACTION OBJECTIVES*

In-situ treatment meets most of the RAOs to some extent. By neutralizing the upper 30 cm of waste to a pH of greater than 6.0 s.u., phytotoxicity of the waste will be reduced to the extent that plants will grow directly in the amended waste. Revegetating the waste dumps will greatly reduce the amount of water infiltration that dissolves metals and then migrates from the dumps to surface water. Soluble metals will not be eliminated because some portion of the wastes in the dump will remain untreated and in contact with infiltrating precipitation. The RAO of reducing or eliminating concentrated runoff and sediment discharges will be met through the establishment of a viable vegetative cover. Potential exposure of the food chain to metal contaminants will be reduced to a large extent in the treated waste dumps, except possibly for those animals that graze on vegetation growing in treated areas and burrowing animals that penetrate the amended waste layer.

Figure 25

Figure 25 back page

❖ *OVERALL PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT*

There are no identified unacceptable human health risks associated with the average concentration of metals present in waste at the remaining dump sites in Fisher Creek. *In-situ* treatment does provide a reasonable measure of control of exposure to contaminated materials and reduces risk to the environment. It reduces the potential for further erosion and migration of contaminants from source areas near surface water drainages by stabilizing the wastes with regrading and vegetation. Some risk remains to those dumps located proximal to surface water, such as the Glengarry and Gold Dust, because these dumps are more prone to exposure during flood events. In addition, some waste dump sites located in the valley of Fisher Creek may be saturated by groundwater during certain times of the year. This is not the case for the majority of dumps, however, because these dumps exist on the slopes of Henderson, Fisher, Sheep, and Scotch Bonnet Mountains. Other physical processes may affect the integrity of the treatment on the hillside dumps, including avalanches and severe rainstorms. While maintenance of treated dumps will reduce the risk of reclamation failure to some extent, maintenance will not prevent failure under extreme conditions that occur in a relatively short period of time (hours or days).

❖ *COMPLIANCE WITH ARARS*

Compliance with ARARs will not be fully achieved under Alternative FC-2. Temporary water quality standards are currently being met in Fisher Creek under existing conditions. However, contaminant-specific standards associated with the Montana Water Quality Act, will not be achieved under Alternative FC-2 without other cleanup actions.

Some improvement in water quality in Fisher Creek is expected because soluble concentrations of copper, iron, and zinc would be reduced and erosion from the revegetated waste dumps would be greatly reduced. Surface water quality along Fisher Creek should improve with the treatment of these dumps. However, contaminant-specific ARARs are not expected to be met in Fisher Creek if this alternative is implemented because the dumps treated *in situ* represent only a small quantity of the total contaminant sources present in the District.

Groundwater quality in the Fisher Creek drainage varies considerably. With the exception of iron and manganese concentrations, groundwater in the Fisher Creek valley is in compliance with groundwater quality standards in both shallow alluvium and Precambrian granite water-bearing units as shown by monitoring data collected in 2001 (Maxim 2002). Iron and manganese are ubiquitous in the District, and concentrations of these two metals are believed to be partially controlled by natural sources in bedrock. Groundwater on the east flank of Fisher Mountain (sampled from well Tracer 5, which is completed in the Fisher Mountain Porphyry) exceeds groundwater contaminant-specific standards for copper, iron, and manganese and has an acidic pH. Groundwater quality in the area of the Gold Dust Adit complies with groundwater quality criteria. *In-situ* treatment will likely have a positive effect on groundwater, although treatment of the small volume of waste included in this alternative is not anticipated to significantly affect overall groundwater quality.

Contaminant-specific ARARs for ambient air are expected to be met under this alternative because the wastes will be revegetated.

Location-specific ARARs, particularly those associated with cultural and historic resources, are expected to be met. Certain cultural and historic features may be affected if this alternative is implemented. Impacts to historic features may include removing timbers, metal debris, and trash; backfilling collapsed adits; and, regrading mine dumps. Historic structures and debris located adjacent to the dumps will be protected. Historic structures and debris that can be easily salvaged will be moved off the dumps and protected to represent elements of the former mining features. Requirements of the National Historic Preservation Act and the Archaeological and Historic Preservation Act will be met through consultation with the State Historic Preservation Office by the USDA-FS, and mitigation of cultural and historic impacts on the District as a whole.

Threatened and endangered species are present in or near the District. During development of the Draft Environmental Impact Statement for CBMI's proposed mine in the District, consultation with the U.S. Fish and Wildlife Service identified the grizzly bear, bald eagle, peregrine falcon, and gray wolf as threatened and endangered species that may be present in the project area. No critical habitat was designated or proposed in the project area. There is not expected to be any impact to threatened and endangered species because new disturbances will be limited to upgrading existing roads, no permanent facilities will be constructed, and construction and maintenance work will not be any greater than the current level of recreational use.

Other location-specific ARARs will be protected through substantive compliance with the requirements of laws related to streambeds and wetlands. The Floodplain and Floodway Management Act does not directly apply because the streams adjacent to the selected waste dumps are not in a designated 100-year floodplain. The Natural Streambed and Land Preservation Act (§§ 75-7-101 et seq., MCA) will be complied with at those sites where wastes are in contact with surface water because waste will be moved away from the stream, and the affected steambanks will be reconstructed with earth and natural materials and sufficiently protected with erosion control techniques so that the bed and banks are protected from flood erosion. Reconstructed streambed and banks will be designed to provide hydraulic stability. All disturbed areas will be managed during construction to minimize erosion. Protecting wetlands will be accomplished by avoiding, to the extent possible, adverse impacts to wetlands.

Action-specific ARARs are expected to be met by this alternative. Action-specific ARARs for storm water runoff will be complied with using BMPs at the treated dump sites. Substantive MPDES permit regulations will be met, as no facilities require a discharge of waste to the environment. The Montana Water Quality Act will not be fully complied with under this alternative. Unamended wastes will likely be in contact with groundwater from adit seeps and during periods of high water tables.

Because mine wastes are derived from the beneficiation and extraction of ores, District Property wastes generally are exempt from federal and state regulation under RCRA as a hazardous waste (42 U.S.C. 6921 (b) (3) (A)(iii)(1994); MCA § 75-10-401 et seq).

Revegetation requirements contained in the Surface Mining Control and Reclamation Act, Montana Strip and Underground Mine Reclamation Act and Metal Mining Act would be substantively met by regrading and amending treated sites. Native species have been selected through many years of USDA-FS research in the District on amended wastes. BMPs for seeding, planting, mulching, soil amendments, control of noxious weeds, and erosion control will also be followed under this alternative.

Hydrological regulations contained in the Montana Strip and Underground Mine Reclamation Act would be met by minimizing any changes to the hydrologic balance. Other requirements for treating surface drainage, sediment control, construction and maintenance of sedimentation ponds, discharges from sedimentation ponds, and provisions for groundwater will be met by using BATs.

Action-specific State of Montana air quality regulations related to dust suppression and control during construction activities will be met using\BMPs.

Occupational Safety and Health Administration requirements would be met by requiring appropriate safety training for all on-site workers during construction phase. Site activities would be conducted under the guidance of a Health and Safety Plan for the site per OSHA 29 CFR 1910.120. Site personnel will have completed 40-hour hazardous waste operations and emergency response training and would be current with the 8-hour annual refresher training as required by OSHA 29 CFR 1910.120.

❖ *LONG-TERM EFFECTIVENESS AND PERMANENCE*

Most of the waste rock dumps considered under this response action are very small. Because the entire package of waste materials at each dump site cannot be fully amended under this alternative, *in-situ* treatment may not be a permanent solution. Acidity from unamended wastes lying below the amended zone has the potential to move upward into the treated zone through capillary action. If this condition occurs, retreatment of the wastes may be necessary if vegetation is impacted through a reduction in cover or vigor. Amended wastes are also subject to erosion and unamended wastes may eventually resurface. PRSC monitoring and maintenance will be essential to maintaining the effectiveness of this alternative in the long-term.

❖ *REDUCTION OF TOXICITY, MOBILITY, OR VOLUME THROUGH TREATMENT*

There will be some reduction in mobility but no reduction of toxicity or volume under this alternative. Reduction in the mobility of contaminants will be achieved through treatment with a neutralizing amendment.

❖ *SHORT-TERM EFFECTIVENESS*

This alternative should allow completion of *in-situ* treatment in a single construction season of not more than 60 days. Therefore, impacts associated with construction activities are considered short-term and should not significantly impact human health. On-site workers will be protected by following a site specific Health and Safety Plan, employing appropriate personal protective equipment, and by following proper operating and safety procedures.

The major short-term impact to the surrounding community, residents, and wildlife involves increased vehicle traffic and temporary closures of some forest roads. An increase in traffic will occur during mobilization and demobilization of construction equipment.

Short-term road closures in the project area may be necessary, limiting access to the forest. Increased traffic may impact wildlife by either changing daily migration patterns or exposing wildlife to a higher potential for injury or death due to collisions with vehicles.

Short-term air quality impacts to the immediate environment may occur during regrading and mixing of neutralizing amendment. Control of fugitive dusts may thus require the use of BMPs. Dust control on designated truck routes is an expected requirement.

Road improvements needed to implement this alternative may have some short-term impacts on the watershed. Increased sedimentation may result from road improvements due to an increased sediment load from exposed and widened roads and deeper and wider borrow ditches. These impacts will be mitigated by implementing BMPs for storm water runoff.

7.4.2.3 Implementability

In-situ treatment is both technically and administratively feasible. Key project components such as equipment, materials, and construction expertise, although distant from the site, are available and would allow the timely implementation and successful execution of the alternative.

7.4.2.4 Cost

Estimated costs for Alternative FC-2 are shown in Table 7-5. The detailed cost analysis can be found in Appendix D. Total cost for this alternative is about $735,500. About 13% of that cost is associated with regrading and amending the dumps with a neutralizing amendment. About 16% of the cost is associated with upgrading and reclaiming the roads.

TABLE 7-5
SUMMARY OF TOTAL ESTIMATED COSTS FOR FISHER CREEK SITES ALTERNATIVE FC-2
New World Mining District Response and Restoration Project
Como Basin/Glengarry Adit/Fisher Creek Response Action EE/CA

Item	Alt. FC-2
Upgrade Access Roads	$79,755.50
Clear and Grub	$15,640.00
Excavate/Load/Haul/Place Soil	$64,328.80
Amend Waste	$37,758.00
Revegetation	$144,557.80
Misc. Site Work	$54,628.00
Reclaim Access Roads	$41,100.00
SUBTOTAL FOR ALL ITEMS:	$437,768.10
Mobilization (10%):	$43,776.81
Contingency (12%):	$53,532.17
TOTAL CONSTRUCTION ESTIMATE:	$550,085.08
Engineering Evaluation and Design (8%):	$44,006.81
Construction Oversight (5%):	$27,504.25
Present Worth Post-Removal Site Control Estimate:	$113,891.00
TOTAL ESTIMATED COST:	**$735,487.14**

7.4.3 Surface Controls – Alternative FC-3

Alternative FC-3 involves implementing surface controls at those dumps where runon and runoff move through waste rock or disturbed areas. Surface controls include a variety of best management practices to reduce or eliminate surface water runon from flowing across mine waste, reduce or eliminate erosion generated in mine waste areas from moving to offsite areas, and reduce the amount infiltration from precipitation falling on waste dumps. Best management practices include constructing diversion ditches along the waste rock dump margins, constructing sediment basins downslope of waste dumps, and regrading waste rock to provide positive drainage. Surface controls could also include temporary measures such as installing silt fence and straw bale dikes to reduce or eliminated sediment produced from waste dumps. Road improvements are not expected to be needed to implement this alternative, as small, tracked equipment could be used to access sites with poor road access. The addition of amendment and revegetation of the dump sites is not included in this alternative, as acid conditions in the waste dumps would not be changed from current conditions. Alternative FC-3 requires only a minimum amount of PRSC monitoring be conducted.

7.4.3.1 Effectiveness

Overall, surface controls provide minor improvements over existing conditions. Untreated wastes will remain at the sites, and these wastes could become saturated and release contaminants to the environment under certain conditions. Surface controls will reduce contaminant movement in surface water by reducing the amount of water that moves over and through the waste dumps.

❖ *REMOVAL ACTION OBJECTIVES*

Surface controls meet only a few of the RAOs. The RAO of reducing or eliminating concentrated runoff and sediment discharges will be met through the rerouting of surface water at the sites. Soluble metals will not be eliminated because wastes in the dumps will remain untreated and in contact with infiltrating precipitation.

❖ *OVERALL PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT*

There are no identified unacceptable human health risks associated with the average concentration of metals present in waste at the remaining dump sites in Fisher Creek. Surface controls provide a minor measure of control to exposure of contaminated materials and a minor reduction in risk to the environment. they also reduce the potential for further erosion and migration of contaminants from source areas near surface water drainages by stabilizing the wastes through regrading. Some risk remains to those dumps located proximal to surface water, such as the Glengarry and Gold Dust, because these dumps are more prone to exposure by flooding. In addition, waste dump sites located in the valley of Fisher Creek become saturated with groundwater during certain times of the year. This is not the case for the majority of dumps, however, because the majority of dumps lie on the slopes of Henderson, Sheep, Fisher, and Scotch Bonnet Mountains. Other physical processes may affect the integrity of this alternative on the hillside dumps, including avalanches and severe rainstorms. While maintenance of dumps will reduce the risk of failure to some extent, maintenance will not prevent failure under extreme conditions that occur in a relatively short period of time (hours or days).

❖ *COMPLIANCE WITH ARARS*

Compliance with ARARs will not be fully achieved under Alternative FC-3. Temporary water quality standards are currently being met in Fisher Creek under existing conditions. However, contaminant-specific standards associated with the Montana Water Quality Act, will not be achieved under Alternative FC-3 without other cleanup actions.

Some improvement in water quality in Fisher Creek is expected because soluble concentrations of copper, iron, and zinc would be reduced and erosion of the waste dumps would be reduced. Surface water quality at various stations along Fisher Creek may improve slightly. However, contaminant-specific ARARs are not expected to be met in Fisher Creek if this alternative is implemented because the dumps represent only a small quantity of the total contaminant sources present in Fisher Creek. For dumps located near-stream, wastes will be pulled back so that the dumps no longer toe into a stream. Under higher flow conditions at select sites, such as the Glengarry dump, some load is likely to be released due to saturation of wastes.

Groundwater quality in the Fisher Creek drainage varies considerably. With the exception of iron and manganese concentrations, groundwater in the Fisher Creek valley bottom is in compliance with groundwater quality standards in both shallow alluvium and Precambrian granite water-bearing units as shown by monitoring data collected in 2001 (Maxim 2002). Iron and manganese are ubiquitous in the district, and concentrations of these two metals are believed to partially controlled by natural sources in bedrock. Groundwater on the east flank of Fisher Mountain (sampled from well Tracer 5, which is completed in the Fisher Mountain Porphyry) exceeds groundwater contaminant-specific standards for copper, iron, and manganese and has an acidic pH. Groundwater quality in the area of the Gold Dust Adit complies with groundwater quality criteria. Surface controls will not likely have any effect on groundwater quality.

Contaminant-specific ARARs for ambient air are expected to be met under this alternative because the wastes will only be minimally disturbed.

Location-specific ARARs, particularly those associated with cultural and historic resources, are expected to be met. Certain cultural and historic features may be affected if this alternative is implemented. Impacts to historic features may result from regrading mine dumps, but these impacts are considered to be minimal under this alternative. Historic structures and debris located adjacent to the dumps will be protected. Historic structures and debris that can be easily salvaged will be moved off the dumps and protected to represent elements of the former mining features. Requirements of the National Historic Preservation Act and the Archaeological and Historic Preservation Act will be met through consultation with the State Historic Preservation Office by the USDA-FS, and mitigation of cultural and historic impacts on the District as a whole.

Threatened and endangered species are present in or near the District. During development of the Draft Environmental Impact Statement for CBMI's proposed mine in the District, consultation with the U.S. Fish and Wildlife Service identified the grizzly bear, bald eagle, peregrine falcon, and gray wolf as threatened and endangered species that may be present in the project area. No critical habitat was designated or proposed in the project area. There is not expected to be any impact to threatened and endangered species because new disturbances will be limited to upgrading existing roads, no permanent facilities will be constructed, and construction and maintenance work will not be any greater than the current level of recreational use.

Other location-specific ARARs will be protected through substantive compliance with the requirements of laws related to streambeds and wetlands. The Floodplain and Floodway Management Act does not directly apply because the streams adjacent to the selected waste dumps are not in a designated 100-year floodplain. The Natural Streambed and Land Preservation Act (§§ 75-7-101 et seq., MCA) will be complied with at those sites where wastes are in contact with surface water because waste will be moved away from the stream, and the affected steambanks will be reconstructed with earth and natural materials and sufficiently protected with erosion control techniques so that the bed and banks are protected from flood erosion. Reconstructed streambed and banks will be designed to provide hydraulic stability. All disturbed areas will be managed during construction to minimize erosion. Protecting wetlands will be accomplished by avoiding, to the extent possible, adverse impacts to wetlands.

Action-specific ARARs are expected to be met by this alternative. Action-specific ARARs for storm water runoff will be complied with using best management practices (BMPs) at the dump sites. Substantive MPDES permit regulations will be met, as no facilities require a discharge of waste to the environment. The Montana Water Quality Act will not be fully complied with under this alternative. Wastes will likely be in contact with groundwater during periods of high water tables.

Because mine wastes are derived from the beneficiation and extraction of ores, District Property wastes generally are exempt from federal and state regulation under RCRA as a hazardous waste (42 U.S.C. 6921 (b) (3) (A)(iii)(1994); MCA § 75-10-401 et seq).

Revegetation requirements contained in the Surface Mining Control and Reclamation Act, Montana Strip and Underground Mine Reclamation Act and Metal Mining Act would not be addressed under this alternative because revegetation would not be possible.

Hydrological regulations contained in the Montana Strip and Underground Mine Reclamation Act would be met because no changes to the hydrologic balance would occur. Other requirements for treating surface drainage, sediment control, construction and maintenance of sedimentation ponds, discharges from sedimentation ponds, and provisions for groundwater will be met by using BATs.

Action-specific State of Montana air quality regulations related to dust suppression and control during construction activities will be met using BMPs.

OSHA requirements would be met by requiring appropriate safety training for all on-site workers during construction phase. Site activities would be conducted under the guidance of a Health and Safety Plan for the site per OSHA 29 CFR 1910.120. Site personnel will have completed 40-hour hazardous waste operations and emergency response training and would be current with the 8-hour annual refresher training as required by OSHA 29 CFR 1910.120.

❖ *LONG-TERM EFFECTIVENESS AND PERMANENCE*

Most of the waste rock dumps considered under this response action are very small. Surface controls are not considered to be a permanent solution because the wastes are generally left unaltered, and unamended wastes would still be subject to erosion. PRSC monitoring and maintenance will be essential to maintaining the effectiveness of this alternative in the long-term.

❖ *REDUCTION OF TOXICITY, MOBILITY, OR VOLUME THROUGH TREATMENT*

There will be no reduction in mobility, toxicity, or volume under this alternative.

❖ *SHORT-TERM EFFECTIVENESS*

This alternative should allow completion in a single construction season of not more than 30 days. Therefore, impacts associated with construction activities are considered short-term and should not significantly impact human health. On-site workers will be protected by following a site-specific Health and Safety Plan, employing appropriate personal protective equipment and by following proper operating and safety procedures.

The major short-term impact to the surrounding community, residents, and wildlife involves increased vehicle traffic and temporary closures of some forest roads. An increase in traffic will occur during mobilization and demobilization of construction equipment.

Short-term road closures in the project area would not be necessary. Short-term air quality impacts to the immediate environment are not expected. Dust control on designated truck routes is an expected requirement.

Road improvements needed to implement this alternative may have some short-term impacts on the watershed. Increased sedimentation may result from road improvements due to an increased sediment load exposed widened roads and deeper and wider borrow ditches. These impacts will be mitigated by implementing BMPs for storm water runoff.

7.4.3.2 Implementability

Surface controls are technically and administratively feasible. Key project components such as equipment, materials, and construction expertise, are available and would allow the timely implementation and successful execution of the alternative.

7.4.3.3 Cost

Estimated costs for Alternative FC-3 are about $283,000. Appendix D contains the detailed cost estimate for this alternative.

7.4.4 On-Site Disposal - Alternative FC-4

Alternative FC-4 involves removal of waste rock from the dumps listed in Table 3-1 to the SB-4B(B) repository site, which is an on-site repository that was constructed specifically to dispose of mine wastes present in the District. Under Alternative FC-4, all dumps identified for removal will be fully removed. Figure 3 shows the dumps that will be removed. The haul route to the repository would be the Lulu Pass Road.

7.4.4.1 Alternative Task Description

The following work activities are included in the construction of Alternative FC-4:

- *Road Improvement:* The existing condition of the majority of roads that access the dump sites is poor, except for the road to the Glengarry Dump and other dumps near the Lulu Pass road. Road improvements will involve widening and grade reduction, cut and fill, and installing temporary culverts. Some sites may require new road construction, which will involve constructing a disturbed road width of 6 meters (20 feet), dozer grading to establish a 3.7-meter-wide (12 feet) travel width, and installing turnouts. Total disturbance associated with road improvements is expected to be 8.5 hectares (21 acres). All new access roads and some existing access roads will be fully reclaimed after the site activities are complete.

- *Site Preparation:* Clearing and grubbing; separating combustible and non-combustible debris; and, debris disposal.

- E*xcavate/Load Waste:* Excavate and load all waste from selected dumps. About 21,000 cubic meters (27,500 cy) of mine waste would be loaded onto haul trucks, assuming a swell factor of 15%.

- *Construct Repository:* The repository site at SB-4B(B) would be expanded to accept the additional volume of mine waste from the Fisher Creek dump sites. Expanding the repository would involve the following:

  - Salvaging soil from the disturbed area.
  - Excavating the area to a design depth of 1 m (3 feet) and stockpiling excavated materials.
  - Preparing the subgrade of the repository by compacting to a specified density.
  - Constructing runon and runoff control ditches around the perimeter of the repository.
  - Constructing a perimeter drainage trench to intercept subsurface flow.
  - Blasting rock from a nearby source to provide material for a rock toe.
  - Crushing rock from a nearby source to provide sand and gravel or importing this material from an off-site source.
  - Revegetating the repository cap with an appropriate seed mix and mulch.
  - Covering the cap with an erosion control blanket.

- *Haul Waste to Repository:* Truck wastes to the on-site repository and place and compact waste.

- *Regrade and Revegetate Mine Waste Dump Sites:* Regrade excavated areas; amend excavated surface with lime and fertilizer, seed, mulch, and cover with an erosion control blanket.

- *PRSC*: Monitoring and maintenance of vegetation on removal areas and at the repository; Monitoring of surface water and groundwater quality at the repository.

7.4.4.2 Effectiveness

Under this alternative, mine wastes are removed and disposed in an engineered on-site repository. Because wastes are isolated from the environment, this alternative is highly effective in controlling future migration of contaminants. The repository cap and liner system are the key design elements that isolates wastes from the environment. The cap provides a barrier that minimizes direct percolation of precipitation into the waste and therefore minimizes the amount of leachate that is generated within the waste. The bottom liner minimizes the seepage of leachate through the bottom of the repository, resulting in a low volume of leachate.

- *REMOVAL ACTION OBJECTIVES*

Removal of mine wastes to an on-site repository would meet RAOs to the maximum extent.

- *OVERALL PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT*

There are no identified unacceptable human health risks at the remaining dump sites in the Fisher Creek Valley. Alternative FC-4 would provide protection to the environment because contaminants would no longer be exposed at uncontrolled sites.

❖ *COMPLIANCE WITH ARARS*

Compliance with ARARs will not be fully achieved under Alternative FC-4. Temporary water quality standards are currently being met in Fisher Creek under existing conditions. However, contaminant-specific standards associated with the Montana Water Quality Act, will not be achieved under Alternative FC-4 without other cleanup actions.

Some improvement in water quality in Fisher Creek is expected because soluble concentrations of copper, iron, and zinc and erosion of contaminants from the removed waste dump areas would be eliminated. Surface water quality at various stations along Fisher Creek should improve with the removal of these dumps. However, contaminant-specific ARARs are not expected to be met in Fisher Creek if this alternative is implemented because the dumps removed represent only a small quantity of the total contaminant sources present in the District.

Groundwater quality in the Fisher Creek drainage varies considerably. With the exception of iron and manganese concentrations, groundwater in the Fisher Creek valley bottom is in compliance with groundwater quality standards in both shallow alluvium and Precambrian granite water-bearing units as shown by monitoring data collected in 2001 (Maxim 2002). Iron and manganese are ubiquitous in the District, and concentrations of these two metals are believed to partially controlled by natural sources in bedrock. Groundwater on the east flank of Fisher Mountain (sampled from well Tracer 5, which is completed in the Fisher Mountain Porphyry) exceeds groundwater contaminant-specific standards for copper, iron, and manganese and has an acidic pH. Groundwater quality in the area of the Gold Dust Adit complies with groundwater quality criteria. Removal of these source areas, however, should not degrade groundwater quality and may improve it in specific areas. The removal of the small volume of waste in this response action is not anticipated to significantly affect overall groundwater quality.

Contaminant-specific ARARs for ambient air are expected to be met under this alternative because the wastes will be capped in an engineered repository and the repository and removal areas revegetated. Although dust and problems with PM-10 airborne contaminants have not been investigated, air quality should improve to some extent because the unvegetated dumps will be removed.

Location-specific ARARs at the dump removal sites are expected to be met to a substantial degree. Certain cultural and historic features may be affected if this alternative is implemented. Impacts to historic features may include removing timbers, metal debris, and trash; backfilling collapsed adits; and, removing mine dumps. Historic structures and debris located adjacent to the dumps will be protected. Historic structures and debris that can be easily salvaged will be moved off the dumps and protected to represent elements of the former mining features. Requirements of the National Historic Preservation Act and the Archaeological and Historic Preservation Act will be met through consultation with the State Historic Preservation Office by the USDA-FS, and mitigation of cultural and historic impacts on the District as a whole.

Threatened and endangered species are present in or near the District. During development of the Draft Environmental Impact Statement for CBMI's proposed mine in the District, consultation with the U.S. Fish and Wildlife Service identified the grizzly bear, bald eagle, peregrine falcon, and gray wolf as threatened and endangered species that may be present in the project area. No critical habitat was designated or proposed in the project area. Threatened and endangered species are not expected to be impacted because new disturbances are limited to upgrading existing roads and expanding the exiting repository site. The response action will be completed in one construction season.

Other location-specific ARARs at the dump removal sites will be protected through substantive compliance with the requirements of laws related to streambeds, floodplains, and wetlands. The Floodplain and Floodway Management Act will be complied with because removals will not be conducted in a designated 100-year floodplain. The Natural Streambed and Land Preservation Act will be complied with at those sites where wastes are in contact with surface water. Affected areas will be reconstructed with earth and natural materials and sufficiently protected with erosion control techniques so that the bed and banks are protected from erosion. Protecting wetlands will be accomplished by avoiding, to the extent possible, adverse impacts to wetlands.

Action-specific ARARs are expected to be met by this alternative. Action-specific ARARs for storm water runoff will be complied with through the use of BMPs at the removal areas and at the repository.

It should be noted that mine and mill wastes are excluded from regulation under the Montana Solid Waste Management Act (75-10-214 (1)(b) MCA. Substantive requirements of this act are met at the repository site through siting and design criteria. Also, because mine wastes are derived from the beneficiation and extraction of ores, District Property wastes are exempt from federal and state regulation under RCRA as a hazardous waste (42 U.S.C. 6921 (b) (3) (A)(iii)(1994); MCA § 75-10-401 et seq).

Revegetation requirements contained in the Surface Mining Control and Reclamation Act, Montana Strip and Underground Mine Reclamation Act and Metal Mining Act would be substantively met by grading, backfilling, and topsoiling removal areas, and using primarily native species and matching species to surrounding habitat types. BMPs for seeding, planting, mulching, soil amendments, control of noxious weeds, and erosion control will also be followed under this alternative.

Action-specific State of Montana air quality regulations related to dust suppression and control during construction activities will be met using BMPs.

Occupational Safety and Health Administration requirements would be met by requiring appropriate safety training for all on-site workers during construction phase. Site activities would be conducted under the guidance of a Health and Safety Plan for the site per OSHA 29 CFR 1910.120. Site personnel will have completed 40-hour hazardous waste operations and emergency response training and would be current with the 8-hour annual refresher training as required by OSHA 29 CFR 1910.120.

❖ *LONG-TERM EFFECTIVENESS AND PERMANENCE*

Removing the wastes from current locations should be a permanent solution requiring little maintenance and providing long-term effectiveness at the waste sites. PRSC involving monitoring and maintenance will be done at the removal areas. Monitoring and maintenance will improve the chances for achieving long-term effectiveness.

❖ *REDUCTION OF TOXICITY, MOBILITY, OR VOLUME THROUGH TREATMENT*

There will be a considerable reduction in mobility but no reduction of toxicity or volume if on-site disposal is implemented. Reduction in the mobility of the contaminants would be achieved by removing wastes to a repository

❖ *SHORT-TERM EFFECTIVENESS*

This removal action should be completed in a single construction season of not more than 90 days. Therefore, impacts associated with construction activities are considered short-term, and should not significantly impact human health. On-site workers will be protected by following a site specific Health and Safety Plan, employing appropriate personal protective equipment and by following proper operating and safety procedures.

The major short-term impact to the surrounding community, residents, and wildlife involves increased vehicle traffic, road building and upgrade work associated with access to the mine sites, clearing ground for a repository, and temporary closures of some forest roads. An increase in traffic will occur during mobilization and demobilization of construction equipment.

Short-term road closures in the project area may be necessary, limiting access to the forest. To haul the waste to the repository, about 840 round-trip truck trips will be made on the Fisher Creek and Henderson Mountain roads. Increased traffic may impact wildlife by either changing daily migration patterns or exposing wildlife to a higher potential for injury or death due to collisions with vehicles.

Short-term air quality impacts to the immediate environment may occur during excavation and placement of wastes and development of access roads. Control of fugitive dusts may thus require the use of best management practices. Dust control on designated haul routes is an expected requirement.

Road improvements needed to implement this alternative may have some short-term impacts on the watershed. Increased sedimentation may result from road improvements due to an increased sediment load exposed widened roads and deeper and wider borrow ditches. These impacts will be mitigated by implementing best management practices for storm water runoff.

7.4.4.3 Implementability

Removal of wastes to an on-site repository is both technically and administratively feasible. Key project components such as equipment, materials, and construction expertise, although distant from the site, are available. Availability of these items will allow the timely implementation and successful execution of the alternative. Quality Assurance/Quality Control for geomembrane liner installation is very strict, requiring experienced personnel and specialized equipment. Liners are available in-state, but available specialized labor may be limited.

7.4.4.4 Cost

A summary of the total estimated costs for Alternatives FC-4 is shown in Table 7-6. The detailed cost analysis is contained in Appendix D.

TABLE 7-6
SUMMARY OF TOTAL ESTIMATED COSTS FOR FISHER CREEK SITES ALTERNATIVE FC-4
New World Mining District Response and Restoration Project
Como Basin/Glengarry Adit/Fisher Creek Response Action

Item	Alt. FC-4
Waste Removal, Haul and Place	$821,175.55
Repository Construction	$885,381.40
SUBTOTAL FOR ALL ITEMS:	$1,706,556.95
Mobilization (10%):	$170,655.70
Contingency (12%):	$204,786.83
TOTAL CONSTRUCTION ESTIMATE:	$2,081,999.48
Engineering Evaluation and Design (8%):	$166,559.96
Construction Oversight (5%):	$104,099.97
Present Worth Post-Removal Site Control Estimate:	$113,891.00
TOTAL ESTIMATED COST:	**$2,466,550.41**

7.5 GLENGARRY ADIT SOURCE AREA ALTERNATIVES

This section presents the detailed analysis of alternatives listed in Table 6-4.

7.5.1 No Action - Alternative GA-1

The No Action Alternative involves leaving the Glengarry Mine in its existing condition. No further closure actions or flow control measures would be attempted at the site to control contaminant migration from the mine to Fisher Creek or to reduce its toxicity or volume. The recently completed rehabilitation work would be abandoned and no further investigations would be conducted. Surface water monitoring would be conducted annually.

7.5.1.1 Effectiveness

Overall effectiveness of the No Action Alternative is poor. Under existing conditions, acidic water, dissolved metals and sediment will continue to flow from the portal and into Fisher Creek. The No Action Alternative does not address surface water or groundwater impacts, nor does it provide any controls on contaminant migration via direct contact or ingestion. Toxicity, mobility, and volume of contaminants would not be reduced under the No Action Alternative.

The No Action Alternative is currently in compliance with temporary water quality standards at the two principal stations monitored in Fisher Creek, SW-3 and CFY-2. However, as these standards expire in 2014, the No Action Alternative is not expected to move water quality toward compliance with the B-1 standards. Protection of the environment would not be achieved under this alternative.

7.5.1.2 Implementability

This alternative is both technically and administratively feasible. However, it is not a viable means of controlling the migration of contaminants that flow from the mine and that significantly impact environmental receptors.

7.5.1.3 Cost

No capital costs would be incurred under this alternative. However, annual monitoring costs would be incurred for both surface water and groundwater monitoring. There are external costs associated with no action, including the loss of certain ecological functions. Using the PRSC costs presented in Appendix D, the total monitoring cost for monitoring over a 30-year period is about $112,000.

7.5.2 Grout Curtain Around Como Raise Collar, Backfill and Plug Como Raise – Alternative GA- 2

Water sampling data collected during 2001 shows that, during seasonal snowmelt, nearly all copper loading measured in water exiting the Glengarry Adit enters the Glengarry Mine through the Como raise. Water that enters the raise flows along the colluvial/bedrock contact, within a few meters of the surface. The purpose of Alternative GA-2 is to prevent acidic and metals-laden colluvial groundwater from entering the Como raise. It appears that very little water enters the raise through bedrock fractures, therefore the grouting program will not attempt to grout deeply into bedrock.

Alternative GA-2 includes drilling a ring of vertical holes three to six meters away from the raise collar, each approximately 10 meters deep (Figure 26). The holes will begin at the surface, extend through colluvial soils and the Park Shale (bedrock), and terminate a few meters into the Meagher Limestone Formation (Figure 26). Grout under pressure will be pumped into the holes to form a nearly water-tight, cylindrical grout curtain around the collar of the raise. With this alternative, water flow along the colluvial/bedrock contact and into the Como raise will be significantly reduced and the raise will be supported for long-term stability. Upon completion of the grout curtain, the timbered Como raise will be filled with cemented gravel and fines up to a point approximately 50 meters below the surface (Figure 27).

7.5.2.1 Alternative GA-2 Task Description

The following work is included in the implementation of Alternative GA-2:

- *Engineering:* A surface-grouting program will be designed for fractured bedrock and soils in an acid-water environment. Using backfill borrow material from a source near the Como raise, a cemented backfill meeting strength and flow requirements will be designed. A concrete raise plug will be designed using either local materials or imported materials. A materials batching and handling system will specified along with quality controls to ensure successful completion of the project.

- *Drilling:* Approximately 15 primary drill holes and 15 secondary drill holes will be needed to encircle the collar of the Como raise with a grout curtain. The holes will extend from the surface to 10 meters deep, requiring a total of about 300 meters of drilling (Figure 26).

Figure 26

Figure 27

- *Grouting:* The bedrock will be pressure grouted with Portland cement, micro-fine cement, bentonite, or a combination of the three forming a grout curtain within the Park Shale and the top part of the Meagher Limestone. The decomposed bedrock and soils above the Park Formation will grouted with low pressure Portland cement, bentonite, or a combination of the two.

- *Backfilling the bottom portion of the raise:* A 15-centimeter pipe will be installed in the raise extending from the surface down 50 meters. A bulkhead will be constructed in the Glengarry drift near the Como raise to prevent backfill from flowing down the drift. A modestly cemented backfill will be batched on surface and gravity fed through the pipe from the surface downward. The raise will be backfilled to within 50 meters from the surface with the timbers left in place (Figure 27).

- *Raise Plug:* After the lower backfill material has set-up, the timber sets, lagging, ladders, and other debris will be removed from an interval between 45 and 50 meters below the surface. The bare ribs (mine walls) will be scaled and cleaned as necessary to ensure a tight contact between the concrete plug and the wall rock. Concrete will be batched on surface and fed down through the pipe to construct a plug approximately three meters thick. A bentonite cap approximately one meter thick will be placed on top of the concrete plug.

- *Backfilling the top portion of the raise:* The raise will be filled with cemented backfill from the bentonite cap to within a few meters of the surface. The near-surface timber cribbing will be removed, and the raise will be filled completely to the surface. The surface around the raise will be graded so that meteoric water drains away from the raise.

7.5.2.2 <u>Effectiveness</u>

Alternative GA-2 provides multiple barriers to contaminated water entering and flowing down the raise to the Glengarry Mine. The grout curtain encircling the raise collar and extending from the surface to 10 meters below the surface will provide a barrier to keep shallow subsurface water flowing along the colluvial/bedrock contact in the Como Basin from flowing into the raise. Cement and bentonite plugs will provide a very tight seal within the raise and below the massive sulfide-bearing portion of the Meagher Limestone. Backfill will contribute to Alternative GA-2 as a barrier to water movement. Furthermore, backfilling the raise will eliminate the chance of future spalling, loosening, and collapse of rock around the plugs that could result in leakage past the plugs or failure of the plugs.

As shallow groundwater entering the Como raise contributes such a large proportion of the metals load to the Glengarry Mine, Alternative GA-2 will dramatically reduce the influx of metal-laden water into the mine.

❖ *REMOVAL ACTION OBJECTIVES*

Implementation of Alternative GA-2 meets two of the RAOs for the project by preventing soluble contaminants from migrating into Fisher Creek, and preventing future releases of contaminants down the Como raise. Even though metals-tainted groundwater is prevented from flowing down the raise, these metals will continue to be generated and will likely eventually migrate to surface water.

❖ *OVERALL PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT*

This alternative, constructing a grout curtain around the collar of the Como raise and plugging and backfilling the raise, provides a reasonable measure for controlling exposure to contaminated water and reduces risk to the environment. It reduces the volume of metal-bearing water flowing directly down the raise, through the drift and out the Glengarry Adit into the headwaters of Fisher Creek by constructing a physical barrier to water movement.

Alternative 2 permanently diverts the flow of a considerable amount of copper, zinc, and iron-bearing water entering the Como raise and prevents it from discharging from the Glengarry Adit. The removal of up to 38 liters per minute of water flow exiting the adit will considerably lessen exposure of the environment to contaminated water.

❖ *COMPLIANCE WITH ARARS*

Compliance with ARARs will not be fully achieved under Alternative GA-2. While, temporary water quality standards are currently being met in Fisher Creek under existing conditions, contaminant-specific standards associated with the Montana Water Quality Act, will not be achieved without other cleanup actions.

Surface water quality at Station SW-3 will improve considerably as a direct result of plugging the Como raise. While improvements in water quality are limited by control of water chemistry at SW-3 by mineral precipitates and metals sorption, a considerable reduction in copper, zinc, and iron load will be realized with this alternative.

Groundwater quality will not likely be improved under this alternative, although, with the exception of iron and manganese concentrations, groundwater in Fisher Creek is in compliance with groundwater quality standards in both shallow alluvium and Precambrian granite water-bearing units, as shown by monitoring data collected in 2001 (Maxim 2002). Iron and manganese are ubiquitous in the District, and concentrations of these two metals are believed to be partially controlled by natural sources in bedrock. Contaminant-specific ARARs for ambient air will be met under this alternative, as air quality will not be impacted by construction operations.

Location-specific ARARs, particularly those associated with cultural and historic resources, will be met, as no cultural or historic features will be impacted if this alternative is implemented. Threatened and endangered species are present in or near the District will not be affected by this alternative as there will be no new disturbances, no permanent facilities, and implementation of the alternative will be completed in one season. No other location-specific ARARs apply.

Action-specific ARARs are expected to be met by this alternative. Action-specific ARARs for storm water runoff will be complied with using BMPs in the Como Basin. Substantive MPDES permit regulations will be met, as no facilities require a discharge of waste to the environment. The Montana Water Quality Act will not be fully complied with under this alternative as the Glengarry Adit will continue to discharge iron from other sources within the Glengarry Mine that exceeds standards. Other requirements for treating surface drainage, sediment control, construction and maintenance of sedimentation ponds, discharges from sedimentation ponds, and provisions for groundwater will be met by using BATs.

Action-specific State of Montana air quality regulations related to dust suppression and control during construction activities will be met using BMPs.

Occupational Safety and Health Administration requirements will be met by requiring appropriate safety training for all on-site workers during construction phase. Site activities would be conducted under the guidance of a Health and Safety Plan for the site per OSHA 29 CFR 1910.120. Site personnel will have completed 40-hour hazardous waste operations and emergency response training and would be current with the 8-hour annual refresher training as required by OSHA 29 CFR 1910.120.

❖ *LONG-TERM EFFECTIVENESS AND PERMANENCE*

Grouting in soils can potentially fail due to subsequent movement within the soil. This is particularly true on slopes and around open holes. Movement within the grouted soils could result in cracks within the top portion of the grout curtain, reducing its effectiveness. Backfilling the raise in conjunction with grouting will provide support and thereby significantly reduce the chance of soil movement near the top of the Como raise.

In a similar manner, the concrete plug within the raise will bear directly on a column of cemented fill and be poured tightly against clean rock, virtually eliminating the chance of settling, cracking, and subsequent leakage. The inclusion of the bentonite cap above the concrete plug further enhances the impermeability of the plug/backfill system. Completely backfilling the Como raise with cemented backfill will ensure the long-term stability of Alternative GA-2, thus maintaining the integrity of the grout curtain and plug system.

❖ *REDUCTION OF TOXICITY, MOBILITY, OR VOLUME THROUGH TREATMENT*

Alternative GA-2 will substantially reduce the mobility of metals. The Glengarry Mine will no longer be a well-connected plumbing system for transporting metals-laden water directly from the Como Basin to Fisher Creek. While there will be no reduction in toxicity or volume, the Glengarry Adit will be eliminated as a point-source discharge for the acidic metal-laden water from the Como Basin deposit.

❖ *SHORT-TERM EFFECTIVENESS*

No impacts to the community or the environment are expected with the implementation of this alternative. Only a limited amount of equipment and supplies will be required, all of which will travel on existing roads. Protection to workers will be afforded through standard work practices. Exposure to hazardous substances will be minimal, as all work will be conducted at the surface of the raise.

The effects of Alternative GA-2 will be immediate. From the time the grout curtain, concrete plug, and bentonite cap are in place, seasonal water flow down the raise will be almost completely eliminated. As water flow down the Como raise is reduced, metals loading exiting the Glengarry Adit and into Fisher Creek will also be significantly reduced. However, this water flow will likely be diverted into the Como Basin and flow along existing natural pathways through the unconsolidated material, and will still reach Fisher Creek.

7.5.2.3 Implementability

Grouting of colluvial and/or soil material and fractured bedrock to reduce permeability has been commonly used to stop groundwater in-flow at tunneling, dam, and construction sites for over a century (Houlsby, 1990). The proposed application in Alternative GA-2 is essentially the same.

Seasonal access is available to and around the site. If the grouting program is completed while snow is still actively melting from the Como Basin and subsurface water flow is active, the success of the grouting program can be monitored as grout is pumped into the raise and sets up. Grouting early in the construction season allows decisions concerning the need for additional (secondary and tertiary) holes to be made immediately.

The Como raise was rehabilitated down to 65 meters below the surface in 2001. The near-surface collapsed portion of the raise was excavated and cribbed to the surface and affords excellent access for plugging and backfilling activities. Transporting the backfill and concrete down the vertical raise will be straight-forward as no pumping is required. The lower portion of the raise will be backfilled prior to placing the plug; therefore, the concrete plug can be placed on cemented backfill for support with no concerns about settling. Plugging and backfilling present no serious technical difficulties.

7.5.2.4 Cost

TABLE 7-7
SUMMARY OF ALTERNATIVE GA-2 ESTIMATED COSTS

TASK	UNIT COST	UNITS	QUANTITY	COST
MOBILIZATION/DEMOBILIZATION				
Mobilization	$15,000	/ls	1	$15,000
Site clean-up, restoration	$10,000	/ls	1	$10,000
Demobilization	$15,000	/ls	1	$15,000
TOTAL				$40,000
EQUIPMENT				
Drill	$500	/day	30	$15,000
Generator	$125	/day	30	$3,750
Water truck	$200	/day	45	$9,000
Grout plant	$250	/day	30	$7,500
Ready-mix truck (2 @ 15 days ea.)	$500	/day	30	$15,000
Track excavator	$700	/day	20	$14,000
Pick-up trucks	$100	/day	45	$4,500
Miscellaneous plant (hoppers, pumps, etc.)	$100	/day	45	$4,500
TOTAL				$73,250
MATERIALS, SUPPLIES, and FUEL				
Fuel	$150	/day	45	$6,750
Cement	$165	/tonne	227	$37,500
Bentonite based grout	$220	/tonne	27	$6,000
15 cm Schd 40 pipe w/clamps, fittings	$49.21	/m˘	61	$3,000
Haul aggregate	$6.54	/m˘	765	$5,000
Pre-mix	$196	/m˘	24	$4,800
Bentonite	$83	/tonne	14	$1,125
Miscellaneous	$10,000	/ls	1	$10,000
TOTAL				$74,175
LABOR				
4 man crew (surface)	$2,400	/day	45	$108,000
2 man crew (U/G)	$1,200	/day	30	$36,000
TOTAL				$144,000
ALTERNATIVE 2 SUBTOTAL				$331,425
Contingency (12%)				$39,771
TOTAL CONSTRUCTION ESTIMATE				$371,196
Engineering Evaluation and Design (8%)				$29,696
Construction Oversight (5%)				$18,560
Present Worth Post-Removal Site Control Estimate				$112,300
TOTAL ESTIMATED COST FOR ALTERNATIVE 2				**$531,751**
Assumptions:				
Batch 11.5 m˘/hr: 920 m˘/(11.5 m˘/hr) = 80 hrs (w/2 trucks) .... assume 15 days w/delays & 2 trucks				
Drilling and grouting: 30 days				
Backfilling: 15 days (with 2 trucks)				
Backfill preparations: 15 days				

7.5.3 Grout Short Raise Above Bulkhead - Alternative GA-3

The first raise beyond the "Y" in the Glengarry drift is a three compartment, vertical raise. Each compartment extends vertically upward to a bulkhead about 12 meters above the track level in the drift. A map dating from the 1930's shows the raise extending about 15 meters above the track level, indicating that there is a space above the bulkheads. Between 38 and 64 liters per minute of metals laden water rains down through the bulkheads, apparently after entering the raise in the void space above the bulkheads. During the 2001 assessment, the bulkheads were not removed due to the danger of debris falling from above the bulkheads.

Alternative GA-3 targets what is most likely a geologic structure in bedrock transmitting groundwater, exposed in the space above the bulkheads by drilling several holes from a drill station within the drift (Figure 28). The drilling program will attempt to define the geologic structure above the bulkheads. The structure will be grouted to diminish or stop the inflows from entering the top of the raise. The Glengarry drift, up to a distance of 400 meters from the portal, is open to access by rubber-tired equipment no wider than 1.25 meters. The raise is another 175 meters beyond this point. Thus, Alternative GA-3 includes drift rehabilitation, as well as excavating a drill station, core drilling, and grouting.

7.5.3.1 Alternative Task Description

The following work is included in the implementation of Alternative GA-3:

- *Rehabilitate the Glengarry drift to 575 meters from the portal:* Timber sets will be removed in about 20 meters of the drift where horizontal stress has broken posts or where the timbers are rotten. In these areas, the back and ribs of the drift will be supported with roof bolts and chain-link screen. Approximately 200 cubic meters of ferricrete mud, clay, rock, and timber debris will be hauled to the portal using a one cubic yard load-haul-dump machine. Timber will be removed, and the debris will be transported to the waste repository.

- *Install utilities:* Prior to constructing the drill station, 550 meters of 5 cm compressed air pipe and 550 meters of 5 cm drill water pipe will be installed from the portal to the drill site. After the drill stations are excavated, electric cable will be installed to provide power to the core drill. If Alternative GA-2 is implemented, the natural ventilation through the Glengarry drift and Como raise will be interrupted, and ventilation duct/air compressor will be required to provide fresh air.

- *Cut drill stations:* Approximately 225 cubic meters of rock will be excavated to create a drill station outward from the raise. The back (roof) of the drill station will be supported with 1.5-meter friction bolts, plates, and chain-link fencing. Blasted rock will be hauled to the portal with a one cubic yard load-haul-dump and deposited on the existing waste rock dump adjacent to the portal.

- *Drilling:* Approximately 12 diamond drill holes, each about 35 meters long, will be drilled through the area adjacent to the top of the raise (Figure 28). As the drilling progresses, the core will be analyzed to determine the geologic structures in the vicinity of the raise. Based on data from the first few holes, the remaining drill holes will be positioned to most effectively grout the structure (Figure 28).

Figure 28

Figure 28 – back page

- *Grouting:* The geologic structures will be grouted to reduce or stop water inflows into the top of the raise. As grouting progresses, more holes may be required.

7.5.3.2 Effectiveness

The effectiveness of Alternative GA-3 will depend directly on the amount of time, drilling, and grouting invested. If successful, Alternative GA-3 will be a means of reducing or eliminating a considerable portion of the metals laden water load exiting the Glengarry Adit.

❖ *REMOVAL ACTION OBJECTIVES*

Implementation of Alternative GA-3 meets two of the RAOs for the project by preventing soluble contaminants from migrating into Fisher Creek, and preventing future releases of contaminants down the first raise.

❖ *OVERALL PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT*

This alternative, grouting-off the water source at the top of the first raise, provides a reasonable measure of control of exposure to contaminated water and reduces risk to the environment. It reduces the flow of metals-bearing water directly into the headwaters of Fisher Creek from one of the sources of inflow into the Glengarry Mine by constructing a physical barrier to water movement.

❖ *COMPLIANCE WITH ARARS*

Compliance with ARARs will not be fully achieved under Alternative GA-3. While, temporary water quality standards are currently being met in Fisher Creek under existing conditions, contaminant-specific standards associated with the Montana Water Quality Act, will not be achieved without other cleanup actions as discussed for Alternative GA-2.

Surface water quality at Station SW-3 will improve somewhat as a direct result of grouting the first raise in the Glengarry Mine. While improvements in water quality are limited by control of water chemistry at SW-3 by mineral precipitates and metals sorption, a considerable reduction in copper, zinc, and iron load will be realized with this alternative.

Groundwater quality will not likely be improved under this alternative, although, with the exception of iron and manganese concentrations, groundwater in Fisher Creek is in compliance with groundwater quality standards in both shallow alluvium and Precambrian granite water-bearing units, as shown by monitoring data collected in 2001 (Maxim 2002). Iron and manganese are ubiquitous in the District, and concentrations of these two metals are believed to be partially controlled by natural sources in bedrock. Contaminant-specific ARARs for ambient air will be met under this alternative, as air quality will not be impacted by construction operations.

Location-specific ARARs, particularly those associated with cultural and historic resources, will be met, as no cultural or historic features will be impacted if this alternative is implemented. Threatened and endangered species are present in or near the District will not be affected by this alternative as there will be no new disturbances, no permanent facilities, and implementation of the alternative will be completed in one season. No other location-specific ARARs apply.

Action-specific ARARs are expected to be met by this alternative. Substantive MPDES permit regulations will be met, as no facilities require a discharge of waste to the environment. The Montana Water Quality Act will not be fully complied with under this alternative as the Glengarry Adit will continue to discharge iron and other metals from other sources within the Glengarry Mine that exceeds standards. Other requirements for treating surface drainage, sediment control, construction and maintenance of sedimentation ponds, discharges from sedimentation ponds, and provisions for groundwater will be met by using BATs.

Action-specific State of Montana air quality regulations related to dust suppression and control during construction activities will be met using BMPs.

OSHA requirements will be met by requiring appropriate safety training for all on-site workers during construction phase. Site activities would be conducted under the guidance of a Health and Safety Plan for the site per OSHA 29 CFR 1910.120. Site personnel will have completed 40-hour hazardous waste operations and emergency response training and would be current with the 8-hour annual refresher training as required by OSHA 29 CFR 1910.120.

❖ *LONG-TERM EFFECTIVENESS AND PERMANENCE*

If the drilling program can successfully locate and grout-off the water source, Alternative GA-3 will be a very effective, long-term solution. The water-courses will be filled with grout, with the intention of diverting groundwater back to its original pre-mining flow paths.

❖ *REDUCTION OF TOXICITY, MOBILITY, OR VOLUME THROUGH TREATMENT*

If Alternative GA-3 is successful, the mobility of metals will be substantially reduced. The Glengarry Mine will no longer receive 25 to 68 liters per minute of metals laden water through the raise, transport the metals-laden water to the portal, and discharge the water directly into Fisher Creek. While there will be no reduction in toxicity or volume, the Glengarry Adit will be eliminated as a point-source discharge of water entering the short raise as this flow is returned to a pre-mining pathway.

❖ *SHORT-TERM EFFECTIVENESS*

No impacts to the community or the environment are expected with the implementation of this alternative. Only a limited amount of equipment and supplies will be required, all of which will travel on existing roads. Protection to workers will be afforded through standard work practices. Exposure to hazardous substances will be minimal, although direct contact with the water draining the raise will not be eliminated. All underground work will be conducted using standard work practices and protective devices.

The short-term effectiveness, if Alternative GA-3 is successful, will be immediate and measurable. Water flow into the raise will be reduced as the grouting takes place. Upon completion of the grouting program, success can be determined by measuring the difference in water flow in the Glengarry Mine on each side of the raise.

7.5.3.3 Implementability

The probability of Alternative GA-3 being successful at a reasonable cost is low. The water source and its controlling structure may be difficult to find, drilling may not be able to accurately target the source for grouting purposes if it is found, or grout when pumped could simply follow the structure and flow into the upper portion of the raise above the bulkheads undetected. If significant amounts of grout flow into the raise and accumulate on the top of the bulkheads, the bulkheads could become overloaded and collapse, causing significant hazards to workers and the environment.

7.5.3.4 Cost

TABLE 7-8
SUMMARY OF ALTERNATIVE GA-3 ESTIMATED COST

TASK	UNIT COST	UNITS	QUANTITY	COST
MOBILIZATION/DEMOBILIZATION				
Mobilization	$15,000	/ ls	1	$15,000
Demobilization	$15,000	/ ls	1	$15,000
TOTAL				$30,000
EQUIPMENT				
Mucker	$150	/ day	43	$6,450
Compressor	$50	/ day	43	$2,150
Generator	$50	/ day	89	$4,450
Core drill	$500	/ day	50	$25,000
Water truck	$250	/ day	50	$12,500
Grout plant	$250	/ day	50	$12,500
Pick-up trucks	$100	/ day	94	$9,400
Misc. plant (fan, pumps, jackleg drills, etc.)	$100	/ day	50	$5,000
TOTAL				$77,450
MATERIALS, SUPPLIES, and FUEL				
Fuel	$50	/ day	94	$4,700
5 cm Schd. 10 pipe, fittings, and hangers	$9.84	/ m	1,036	$10,200
Vent bag	$9.84	/ m	518	$5,100
Explosives	$17.67	/ m^3	226	$4,000
Ground support	$2,000	/ ls	1	$2,000
Electric cable	$16.40	/ m	518	$8,500
Bentonite based grout	$220	/ tonne	91	$20,000
Cement	$165	/ tonne	363	$60,000
Miscellaneous	$10,000	/ ls	1	$10,000
TOTAL				$124,500
LABOR				
5 man crew (drilling contractor)	$3,000	/ day	50	$150,000
3 man crew (mining contractor)	$1,800	/ day	43	$77,400
TOTAL				$227,400
ALTERNATIVE 3 SUBTOTAL				$459,350
Contingency (12%)				$55,122
TOTAL CONSTRUCTION ESTIMATE				$514,472
Engineering Evaluation and Design (8%)				$41,158
Construction Oversight (5%)				$25,724
Present Worth Post-Removal Site Control Estimate				$112,300
TOTAL ESTIMATED COST FOR ALTERNATIVE 3				**$693,653**
Assumptions:				
Site preparation: 39 days total (mining contractor)				
muck GG Tunnel: 8 days				
install utilities: 3 days				
support GG Tunnel: 12 days				
drill, blast, muck, support drill station: 16 days				
Drilling and grouting: 4 days total (mining contractor)				
help w/set-up and tear-down: 4 days				
Drilling and grouting: 50 days total (drilling contractor)				
set-up: 3 days				
drill and grout: 40 days				
moves: 4 days				
tear-down: 3 days				

7.5.4 Grout 1050 Roof Leak - Alternative GA-4

Approximately 320 meters in from the portal, water flows into the Glengarry drift at a rate of 10 to 50 liters per minute through a cross cutting geologic structure. The geologic structure is completely covered by timber sets, lagging, and ferricrete deposits up to 30 centimeters thick. Geologists entering the Glengarry Mine in 1973 reported the structure as a porphyry dike with an approximate N. 35 W. strike (Kennecott, 1973).

The purpose of Alternative GA-4 is to construct a grout curtain around the drift where it passes through the porphyry dike, in order to reduce the inflow of metals laden water. Alternative GA-4 includes excavating two diamond drill stations, one on each side of the porphyry dike (Figure 29). Core holes will be drilled from the stations to intersect the dike, determine its precise location, and measure pertinent characteristics (e.g., thickness, strike, dip, rock quality) of the dike and surrounding rock mass. Additional holes will be drilled then and grout will be pumped into fractures and voids in the dike and surrounding fractured rock mass to form an impermeable grout curtain around the Glengarry drift in the plane of the water bearing structure.

7.5.4.1 Alternative Task GA-4 Description

The following work is included in the implementation of Alternative GA-4:

- *Install utilities:* Prior to constructing the drill stations, 360 meters of 5 cm compressed air pipe and 360 meters of 5 cm drill water pipe will be installed from the portal in to the drill sites. After the drill stations are excavated, electric cable will be installed to provide power to the core drill. If Alternative GA-2 or portions of Alternative GA-5 or GA-6 have been completed, natural ventilation through the Glengarry drift and Como raise will be interrupted, and a ventilation duct will be required to provide fresh air.

- *Remove old timbers and ferricrete:* Two timber sets and lag-boards covering the porphyry dike will be removed. Ferricrete deposits and loose rock will be scaled down to present a clean surface for geologic assessment. The back (roof) will be supported with five-foot friction bolts, plates, and chain-link fencing. Debris will be hauled to the portal with a one cubic yard load-haul-dump. Timber will be set aside. Ferricrete and rock will be hauled to the waste repository.

- *Cut drill stations:* Approximately 450 cubic meters of rock will be excavated to create two diamond drill stations, one on each side of the roof leak. The back (roof) of the drill stations will be supported with 1.5-meter friction bolts, plates, and chain-link fencing. Blasted rock will be hauled to the portal with a one cubic yard load-haul-dump and deposited on the existing waste rock dump adjacent to the portal.

- *Drilling:* All assessment and grouting holes in Alternative GA-4 will be approximately BX size diamond drill holes. Data from the initial diamond drill holes will be used to characterize the nature and orientation of the water bearing structure and the country rock around it. This could require from two to eight, 15- to 25-meter long holes. The grout curtain is expected to require 20 primary and 20 secondary holes, each 15 to 25 meters long, for a total of approximately 800 meters of drilling.

Figure 29

Figure 29 – Back page

- *Grouting:* The appropriate type of grout will be determined after the assessment holes are analyzed. It is expected that Portland cement, micro-fine cement, a bentonite-based grout, or bentonite grout followed by a cement-based grout will be used. The primary holes will be grouted first. Secondary holes will be drilled between the primaries to determine the effectiveness of the grouting. The secondary holes also will be grouted. Tertiary holes may be required depending on the success of the primary and secondary holes. The amount of grout required is highly variable and extremely difficult to predict prior to drilling and grouting.

7.5.4.2 Effectiveness

The grouting project, if completely successful, will eliminate water inflow through the roof leak. If the grouting project is only partially successful, water flow into the Glengarry Mine through the 1050 roof leak will be substantially reduced. Either case will be a significant improvement over the existing condition.

The grout curtain can be viewed as an impermeable 15-meter diameter "donut" in a very large permeable plane (Figure 29). The Glengarry drift would be represented by the hole in the donut. Water flowing in the plane of the porphyry dike will flow around the donut and continue traveling downgradient (probably in the direction and volume of flow under pre-mining conditions). Thus, the 1050 grout curtain will not stop the flow of water along the porphyry dike or cause an increase in hydrostatic pressure around the drift; it will just keep the water from entering the drift.

❖ *REMOVAL ACTION OBJECTIVES*

Implementation of Alternative GA-4 meets two of the RAOs for the project by preventing soluble contaminants from migrating into Fisher Creek, and preventing future releases of contaminants into the drift at the 1050 roof leak.

❖ *OVERALL PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT*

This alternative, grouting the 1050 roof leak, provides a reasonable measure for controlling exposure to contaminated water and reduces risk to the environment. It reduces the volume of metals-bearing water flowing directly into the headwaters of Fisher Creek by constructing a physical barrier to water movement. The removal of the 10 to 50 liters per minute of water exiting the Glengarry Adit will lessen exposure of the environment to contaminated water.

❖ *COMPLIANCE WITH ARARS*

Compliance with ARARs will not be fully achieved under Alternative GA-4. While, temporary water quality standards are currently being met in Fisher Creek under existing conditions, contaminant-specific standards associated with the Montana Water Quality Act, will not be achieved without other cleanup actions as discussed for Alternative GA-2.

Surface water quality at Station SW-3 will improve as a direct result of grouting the 1050 roof leak in the Glengarry Mine. While improvements in water quality are limited by control of water chemistry at SW-3 by mineral precipitates and metals sorption, a considerable reduction in metals loading will be realized with this alternative.

Groundwater quality will not likely be improved under this alternative, although, with the exception of iron and manganese concentrations, groundwater in Fisher Creek is in compliance with groundwater quality standards in both shallow alluvium and Precambrian granite water-bearing units, as shown by monitoring data collected in 2001 (Maxim 2002). Iron and manganese are ubiquitous in the District, and concentrations of these two metals are believed to be partially controlled by natural sources in bedrock. Contaminant-specific ARARs for ambient air will be met under this alternative, as air quality will not be impacted by construction operations.

Location-specific ARARs, particularly those associated with cultural and historic resources, will be met, as no cultural or historic features will be impacted if this alternative is implemented. Threatened and endangered species are present in or near the District will not be affected by this alternative as there will be no new disturbances, no permanent facilities, and implementation of the alternative will be completed in one season. No other location-specific ARARs apply.

Action-specific ARARs are expected to be met by this alternative. Substantive MPDES permit regulations will be met, as no facilities require a discharge of waste to the environment. The Montana Water Quality Act will not be fully complied with under this alternative as the Glengarry Adit will continue to discharge iron and other metals from other sources within the Glengarry Mine that exceed standards. Other requirements for treating surface drainage, sediment control, construction and maintenance of sedimentation ponds, discharges from sedimentation ponds, and provisions for groundwater will be met by using BATs.

Action-specific State of Montana air quality regulations related to dust suppression and control during construction activities will be met using BMPs.

OSHA requirements will be met by requiring appropriate safety training for all on-site workers during construction phase. Site activities would be conducted under the guidance of a Health and Safety Plan for the site per OSHA 29 CFR 1910.120. Site personnel will have completed 40-hour hazardous waste operations and emergency response training and would be current with the 8-hour annual refresher training as required by OSHA 29 CFR 1910.120.

- *LONG-TERM EFFECTIVENESS AND PERMANENCE*

Grouting is a proven long-term method of constructing a nearly impermeable barrier in fractured rock. Upon completion of grouting, the water inflow at the 1050 roof leak will be reduced or nearly eliminated. Thus the long-term effect will be a smaller load of metals reporting to Fisher Creek via the Glengarry Adit discharge.

The long-term effectiveness of rock fracture grouting to prevent water flow can be lost due to ground movement and re-opening of fractures. The Fisher Mountain Porphyry around the 1050 roof leak is a fractured rock mass composed of blocks less than 0.25 meters in size. The drift is two meters wide. Thus, the back (roof) of the drift is composed of many small blocks keyed together and held in place by friction only. Inter-block movement over time is very likely to occur. The long-term effectiveness of Alternative GA-4 can best be guaranteed by tightly backfilling the Glengarry drift in the vicinity of the grout curtain to hold the roof blocks in place.

❖ *REDUCTION OF TOXICITY, MOBILITY, OR VOLUME THROUGH TREATMENT*

Alternative GA-4 will significantly reduce the mobility of metals. The Glengarry Mine will no longer receive 10 to 50 liters per minute of iron-bearing water through the 1050 roof leak. While there will be no reduction in toxicity or volume, the Glengarry Adit will be eliminated as a point-source discharge for the 1050 roof leak water.

❖ *SHORT-TERM EFFECTIVENESS*

No impacts to the community or the environment are expected with the implementation of this alternative. Only a limited amount of equipment and supplies will be required, all of which will travel on existing roads. Protection to workers will be afforded through standard work practices. Exposure to hazardous substances will be minimal, although direct contact with the water draining the mine will not be eliminated. All underground work will be conducted using standard work practices and protective devices.

The effectiveness of the grouting program will be immediate. Upon completion of grouting, the water inflow from the 1050 roof leak will be reduced or eliminated.

7.5.4.3 Implementability

Grouting of fractured bedrock to reduce permeability has been commonly used to stop groundwater in-flow in tunneling, dams, and construction sites for over a century (Houlsby, 1990). The proposed application in Alternative GA-4 is not significantly different. The success of the grouting program can be monitored as the grout is pumped. The success of the grouting can be further determined by measuring water flows along the sill of the drift upstream and downstream of the 1050 roof leak and calculating the difference in flow. Decisions concerning the need for additional (tertiary) holes can be made immediately.

7.5.4.4 Cost

TABLE 7-9
SUMMARY OF ALTERNATIVE GA-4 ALTERNATIVE COST

TASK	UNIT COST	UNITS	QUANTITY	COST
MOBILIZATION/DEMOBILIZATION				
Mobilization	$15,000	/ls	1	$15,000
Demobilization	$15,000	/ls	1	$15,000
TOTAL				$30,000
EQUIPMENT				
Mucker	$150	/day	23	$3,450
Compressor	$50	/day	23	$1,150
Generator	$125	/day	69	$8,625
Core drill	$500	/day	50	$25,000
Water truck	$250	/day	50	$12,500
Grout plant	$250	/day	50	$12,500
Pick-up trucks	$100	/day	69	$6,900
Misc. plant (fan, pumps, jackleg drills, etc.)	$100	/day	69	$6,900
TOTAL				$77,025
MATERIALS, SUPPLIES, and FUEL				
Fuel	$50	/day	69	$3,450
5 cm Schd. 10 pipe, fittings, and hangers	$9.84	/m	732	$7,200
Vent bag	$9.84	/m	366	$3,600
Explosives	$17.67	/m^3	226	$4,000
Ground support	$2,000	/ls	1	$2,000
Electric cable	$16.40	/m	366	$6,000
Bentonite based grout	$220	/tonne	91	$20,000
Cement	$165	/tonne	363	$60,000
Miscellaneous	$10,000	/ls	1	$10,000
TOTAL				$116,250
LABOR				
5 man crew (drilling contractor)	$3,000	/day	50	$150,000
2 man crew (mining contractor)	$1,200	/day	23	$27,600
TOTAL				$177,600
ALTERNATIVE 4 SUBTOTAL				$400,875
Contingency (12%)				$48,105
TOTAL CONSTRUCTION ESTIMATE				$448,980
Engineering Evaluation and Design (8%)				$35,918
Construction Oversight (5%)				$22,449
Present Worth Post-Removal Site Control Estimate				$112,300
TOTAL ESTIMATED COST FOR ALTERNATIVE 4				**$619,647**
Assumptions:				
Site preparation: 19 days total (mining contractor)				
muck GG Tunnel: 1 day				
install utilities: 2 days				
drill, blast, muck, support drill stations: 16 days				
Drilling and grouting: 4 days total (mining contractor)				
help w/set-up and tear-down: 4 days				
Drilling and grouting: 50 days total (drilling contractor)				
set-up: 3 days				
drill and grout: 40 days				
moves: 4 days				
tear-down: 3 days				

7.5.5 BACKFILL GLENGARRY DRIFT - ALTERNATIVE GA-5

This alternative includes filling the Glengarry drift with cemented rock and fines for long-term ground support and to reduce water movement through the drift. A plan schematic of the Glengarry drift is shown in Figure 30. There are three variations to this alternative:

- GA-5A - filling the drift in the Fisher Mountain Porphyry only (fill will begin at the portal plug location, if Alternative GA-6 is selected).

- GA-5B - filling the drift only in the Precambrian Granite section.

- GA-5C- filling the entire drift.

Mine backfilling is a means of returning the underground workings as near to the pre-mining conditions as possible. Waste rock present at the Glengarry Adit has been assessed for use as a cemented mine backfill material and found acceptable for use in this application based on quantity, strength, pumpability, and acid neutralizing potential (Bogert, 2001). Cemented backfill placed tightly to the back (roof) will eliminate future subsidence and the loosening of fractures within the rock mass adjacent to the underground opening. Backfill with a low hydraulic conductivity will limit movement of water into, within, or along backfilled mine workings.

7.5.5.1 Alternative Task Description

The following work is included in the implementation of Alternative GA-5. The locations where the following activities will be conducted are shown in Figure 30.

- *Engineering:* Backfill design tests to determine the appropriate cement content, water reducers, and retarders will be undertaken to ensure optimum strength and trouble-free pumping during backfill placement. Pumping and piping requirements will be calculated. Backfill placement procedures to ensure tight filling will be prepared.

- *Site preparation:* Debris including railroad ties, steel rails, ferricrete, and mud now covers the sill (floor) of the Glengarry drift. Debris will be pushed out to the portal. Timbers and rails will be separated and set aside. Water, ferricrete, and mud will flow into a settling pond, where it will be loaded and hauled to the SB-4B(B) repository.

- *Fill batching:* A portable screening plant will be setup adjacent to the Glengarry Dump. Material from the dump will be screened, and screened material passing the 2.5-centimeter fraction (undersize) will be used for backfill. Oversize material (exceeding 2.5-centimeter fraction) will be hauled to the repository. Undersize material will be batched with Portland cement and fresh water brought from off-site. The Glengarry Dump does not contain a sufficient volume of material passing 2.5 centimeters to complete either alternative GA-5B or GA-5C without crushing oversize rock. Therefore, a portable crushing and screening plant will be set-up adjacent to the Glengarry Dump for these two sub-alternatives and waste rock will be crushed on site.

- *Pumping:* A portable concrete pump will be set-up near the Glengarry Adit. A 15 cm pipe will extend from the pump to the area being filled. For Alternative GA-5, backfilling will begin at or near the contact between the Precambrian granite and the Fisher Mountain Porphyry (or first plug location, if Alternative GA-6 is selected) and work outward to a point near the portal (about 1,200 cubic meters of fill will be needed). For Alternative GA-5B, backfilling will begin at the farthest extent of each branch of the Glengarry drift and work outward to the "Y." When each branch of the drift has been filled, the drift will be filled outward to the Precambrian Granite/Fisher Mountain Porphyry contact (about 2,500 cubic meters of fill will be needed). For Alternative 5C, when each branch of the drift has been filled, the drift will be filled outward to a point near the portal (about 3,700 cubic meters of fill will be needed for this alternative).

- Cemented fill will be pumped at an anticipated rate of 10 to 20 cubic meters per hour. The drift will be filled in 15- to 30-meter segments. A portion of each segment will be filled tight to the back approximately every 15 to 30 meters, providing a barrier to water movement through the drift. Due to significantly longer pumping distances, Alternatives GA-5B and GA-5C will require a much higher pressure delivery system than Alternative GA-5A.

7.5.5.2 Effectiveness

Tightly backfilling underground excavations is a method of ensuring that no further ground movement will occur in the rock surrounding the opening. The relative impermeability of backfill significantly reduces movement of water through the filled opening. Thus, backfilling the Glengarry drift serves two purposes; it reduces water flow and provides long-term structural support and stability. This alternative must be used in concert with one of the grouting or plugging alternatives to be effective.

The first 420 meters of the Glengarry drift passes through the Fisher Mountain Porphyry, a highly fractured, pyritic rock mass. The remaining portion of the drift passes through Precambrian Granite (Figure 30). In the first 350 meters of the Glengarry drift, water enters the Glengarry drift through numerous fracture paths. Beyond 350 meters, the drift is essentially dry except for water entering from the raises. Therefore, backfill as a method of retarding or eliminating inflows to the Glengarry drift will be most effective in the first 350 meters of the drift.

❖ *REMOVAL ACTION OBJECTIVES*

Implementation of Alternative GA-5 meets two of the RAOs for the project by preventing soluble contaminants from migrating into Fisher Creek, and preventing future releases of contaminants into the drift.

❖ *OVERALL PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT*

This alternative, backfilling various portions of the Glengarry drift, when combined with other alternatives, provides a reasonable measure of control of exposure to contaminated water and reduces risk to the environment. It reduces the flow of metal-bearing water directly into the headwaters of Fisher Creek by constructing a physical barrier to water movement. Alternatives GA-5A and GA-5C are especially important as they provide support against future ground movement that could lessen the effectiveness of other alternatives.

Alternative GA-5A and GA-5C will significantly diminish water inflows from diffuse leaks in the first 320 meters of the Glengarry drift. The removal of up to 57 liters per minute flow of water exiting the Glengarry Adit will lessen exposure of the environment to contaminated water.

Figure 30

Figure 30 – back page

❖ *COMPLIANCE WITH ARARS*

Compliance with ARARs will not be fully achieved under Alternative GA-5. While, temporary water quality standards are currently being met in Fisher Creek under existing conditions, contaminant-specific standards associated with the Montana Water Quality Act, will not be achieved without other cleanup actions as discussed for Alternative GA-2.

Surface water quality at Station SW-3 will improve as a direct result of backfilling the Glengarry drift. While improvements in water quality also are limited by control of water chemistry at SW-3 by mineral precipitates and metals sorption, a considerable reduction in metals will be realized with this alternative.

Groundwater quality will not likely be improved under this alternative, although, with the exception of iron and manganese concentrations, groundwater in Fisher Creek is in compliance with groundwater quality standards in both shallow alluvium and Precambrian granite water-bearing units, as shown by monitoring data collected in 2001 (Maxim 2002). Iron and manganese are ubiquitous in the District, and concentrations of these two metals are believed to be partially controlled by natural sources in bedrock. Contaminant-specific ARARs for ambient air will be met under this alternative, as air quality will not be impacted by construction operations.

Location-specific ARARs, particularly those associated with cultural and historic resources, will be met, as no cultural or historic features will be impacted if this alternative is implemented. Threatened and endangered species are present in or near the District will not be affected by this alternative as there will be no new disturbances, no permanent facilities, and implementation of the alternative will be completed in one season. No other location-specific ARARs apply.

Action-specific ARARs are expected to be met by this alternative. Substantive MPDES permit regulations will be met, as no facilities require a discharge of waste to the environment. The Montana Water Quality Act will not be fully complied with under this alternative as the Glengarry Adit will continue to discharge metals from other sources within the Glengarry Mine that exceed standards. Other requirements for treating surface drainage, sediment control, construction and maintenance of sedimentation ponds, discharges from sedimentation ponds, and provisions for groundwater will be met by using BATs.

Action-specific State of Montana air quality regulations related to dust suppression and control during construction activities will be met using BMPs.

Occupational Safety and Health Administration requirements will be met by requiring appropriate safety training for all on-site workers during construction phase. Site activities would be conducted under the guidance of a Health and Safety Plan for the site per OSHA 29 CFR 1910.120. Site personnel will have completed 40-hour hazardous waste operations and emergency response training and would be current with the 8-hour annual refresher training as required by OSHA 29 CFR 1910.120.

❖ *LONG-TERM EFFECTIVENESS AND PERMANENCE*

Alternative GA-5A or Alternative GA-5C are crucial to guaranteeing the long-term effectiveness of Alternatives GA-4 and GA-6 by ensuring that grout curtains do not fail due to rock movement over time. Implementing Alternative GA-5A or GA-5C will permanently provide another barrier to water inflow into the Glengarry Mine from the Fisher Mountain Porphyry.

❖ *REDUCTION OF TOXICITY, MOBILITY, OR VOLUME THROUGH TREATMENT*

Mobility of metals will be significantly reduced by Alternative GA-5A, GA-5B, or GA-5C. The Glengarry Mine will no longer be a plumbing system for transporting metals-laden water directly from their source from underground locations to Fisher Creek. While there will be no reduction in toxicity or volume, the Glengarry Adit will be eliminated or substantially reduced as a point-source discharge for metals-bearing water. It is expected that water will flow along its pre-mining flow routes following completion of these activities.

❖ *SHORT-TERM EFFECTIVENESS*

No impacts to the community or the environment are expected with the implementation of this alternative. Only a limited amount of equipment and supplies will be required, all of which will travel on existing roads. Protection to workers will be afforded through standard work practices. Exposure to hazardous substances will be minimal, although direct contact with the water draining the mine will not be eliminated. All underground work will be conducted using standard work practices and protective devices.

The short-term effectiveness of Alternative GA-5A or alternative GA-5C will be immediate and measurable. Flow from the diffuse roof leaks in the first 320 meters of the Glengarry drift will be reduced or eliminated.

7.5.5.3 Implementability

Cemented backfill in mines has evolved into a very common practice in the last decade. It is used as a means of providing ground support by filling void spaces left in the ground by mining. Cemented backfill is commonly transported in underground mines over horizontal distances of a thousand meters or more through pipelines. Tests on waste rock present at the Glengarry Adit as a backfill source have demonstrated that a cemented backfill of adequate strength, pumpability, and acid neutralization potential can be produced and placed underground (Bogert, 2001).

The variations of Alternative GA-5 will require placing cemented backfill in the Glengarry drift, which currently discharges 35 to 215 liters per minute (9 to 57 gallons per minute). Cemented backfill cannot be effectively placed in flowing water without compromising strength and the ability to form an effective seal between the fill and the walls and back. If Alternative GA-5A is implemented after Alternatives GA-4 and GA-6 are successfully completed, flow from the raises and the 1050 roof leak will be greatly reduced, enabling the efficient placement of cemented backfill.

7.5.5.4 Cost

Alternative GA-5A and Alternative GA-5C backfill the adit through the Fisher Mountain Porphyry and provide stability at the critical plugs and grout curtains; however, GA-5C includes the added expense of filling the stable, dry Precambrian Granite portion of the drift. Summaries of estimated costs associated with each of the sub-alternative are provided in Tables 7-10, 7-11, and 7-12.

TABLE 7-10
SUMMARY OF ALTERNATIVE GA-5A ESTIMATED COST

TASK	UNIT COST	UNITS	QUANTITY	COST
MOBILIZATION/DEMOBILIZATION				
Mobilization	$25,000	/ls	1	$25,000
Site clean-up, restoration	$10,000	/ls	1	$10,000
Demobilization	$25,000	/ls	1	$25,000
TOTAL				$60,000
EQUIPMENT				
Mucker	$250	/day	35	$8,750
Generator	$125	/day	35	$4,375
Excavator	$700	/day	35	$24,500
Dump truck	$300	/day	35	$10,500
Front-end loader	$350	/day	35	$12,250
Screening plant	$400	/day	5	$2,000
Water truck	$200	/day	35	$7,000
Ready-mix truck (2 @ 25 days ea.)	$500	/day	50	$25,000
Concrete pump	$240	/day	25	$6,000
Pick-up trucks	$100	/day	35	$3,500
Misc. plant (hoppers, fan, water tank, etc.)	$100	/day	35	$3,500
TOTAL				$107,375
MATERIALS, SUPPLIES, and FUEL				
Fuel	$150	/day	35	$5,250
15 cm Schd. 40 pipe, fittings, and hangers	$66	/m	411	$27,000
Vent bag	$9.84	/m	381	$3,750
Cement	$132	/tonne	595	$78,720
Admixtures	$17	tonne of cemer	595	$9,840
Bentonite	$83	/tonne	680	$56,250
Miscellaneous	$10,000	/ls	1	$10,000
TOTAL				$190,810
LABOR				
4 man crew (surface)	$2,400	/day	35	$84,000
2 man crew (U/G)	$1,200	/day	35	$42,000
TOTAL				$126,000
ALTERNATIVE 5A SUBTOTAL				$484,185
Contingency (12%)				$58,102
TOTAL CONSTRUCTION ESTIMATE				$542,287
Engineering Evaluation and Design (8%)				$43,383
Construction Oversight (5%)				$27,114
Present Worth Post-Removal Site Control Estimate				$112,300
TOTAL ESTIMATED COST FOR ALTERNATIVE 5A				**$725,085**

Assumptions:

Surface work: 35 days total (surface contractor)
- haul away sediment pond: 2 days
- set up: 3 days
- screening: 5 days
- batch and pump: (1529 m^3 / (15.3 m^3 /hr x 4 hr/day) = 25 days @ ~15 m/day

U/G work: 35 days total (mining contractor)
- muck GG Tunnel: 5 days
- set-up, install backfill pipe: 5 days
- backfilling: 25 days

Volume of backfill = 365m x 1.83m x 2.29m = 1529 m^3

Cement = 365m x 1.83m x 2.29m / (0.4367 m^3 /tonne) x 0.17 = 595 tonnes

TABLE 7-11
SUMMARY OF ALTERNATIVE GA-5B ESTIMATED COST

TASK	UNIT COST	UNITS	QUANTITY	COST
MOBILIZATION/DEMOBILIZATION				
Mobilization	$25,000	/ls	1	$25,000
Site clean-up, restoration	$10,000	/ls	1	$10,000
Demobilization	$25,000	/ls	1	$25,000
TOTAL				$60,000
EQUIPMENT				
Mucker	$250	/day	83	$20,750
Generator	$125	/day	54	$6,750
Excavator	$700	/day	54	$37,800
Dump truck	$300	/day	54	$16,200
Front-end loader	$350	/day	54	$18,900
Screening plant	$400	/day	8	$3,200
Water truck	$200	/day	54	$10,800
Ready-mix truck (2 @ 38 days ea.)	$500	/day	76	$38,000
Concrete pump	$240	/day	38	$9,120
Pick-up trucks	$100	/day	54	$5,400
Misc. plant (hoppers, fan, water tank, etc.)	$100	/day	54	$5,400
TOTAL				$172,320
MATERIALS, SUPPLIES, and FUEL				
Fuel	$150	/day	83	$12,450
15 cm Schd. 40 pipe, fittings, and hangers	$66	/m	762	$50,000
Vent bag	$9.84	/m	762	$7,500
Cement	$132	/tonne	893	$118,080
Admixtures	$17	nne of ceme	893	$14,760
Bentonite	$83	/ton	1,021	$84,375
Miscellaneous	$15,000	/ls	1	$15,000
TOTAL				$302,165
LABOR				
4 man crew (surface)	$2,400	/day	54	$129,600
2 man crew (U/G)	$1,200	/day	83	$99,600
TOTAL				$229,200
ALTERNATIVE 5B SUBTOTAL				$763,685
Contingency (12%)				$91,642
TOTAL CONSTRUCTION ESTIMATE				$855,327
Engineering Evaluation and Design (8%)				$68,426
Construction Oversight (5%)				$42,766
Present Worth Post-Removal Site Control Estimate				$112,300
TOTAL ESTIMATED COST FOR ALTERNATIVE 5B				**$1,078,820**

Assumptions:

Surface work: 54 days total (surface contractor)
- haul away sediment pond: 5 days
- set up: 3 days
- screening: 8 days
- batch and pump: (2300 m˘ / (15.3 m˘ /hr x 4 hr/day) = 25 days @ ~15 m/day

U/G work: 83 days total (mining contractor)
- muck GG Tunnel: 424 m˘ / (12.2 m˘ /day) = 35 days
- set-up, install backfill pipe: 10 days
- backfilling: 38 days

Volume of waste = 152m x 1.83m x 1.52m = 424 m˘

Volume of backfill = 549m x 1.83m x 2.29m = 2300 m˘

Cement = 365m x 1.83m x 2.29m / (0.4367 m˘ /tonne) x 0.17 = 893 tonnes

TABLE 7-12
SUMMARY OF ALTERNATIVE 5-C ESTIMATED COST

TASK	UNIT COST	UNITS	QUANTITY	COST
MOBILIZATION/DEMOBILIZATION				
Mobilization	$25,000	/ls	1	$25,000
Site clean-up, restoration	$10,000	/ls	1	$10,000
Demobilization	$25,000	/ls	1	$25,000
TOTAL				$60,000
EQUIPMENT				
Mucker	$250	/day	115	$28,750
Generator	$125	/day	84	$10,500
Excavator	$700	/day	84	$58,800
Dump truck	$300	/day	84	$25,200
Front-end loader	$350	/day	84	$29,400
Screening plant	$400	/day	13	$5,200
Water truck	$200	/day	84	$16,800
Ready-mix truck (2 @ 63 days ea.)	$500	/day	126	$63,000
Concrete pump	$240	/day	63	$15,120
Pick-up trucks	$100	/day	84	$8,400
Misc. plant (hoppers, fan, water tank, etc.)	$100	/day	84	$8,400
TOTAL				$269,570
MATERIALS, SUPPLIES, and FUEL				
Fuel	$150	/day	115	$17,250
15 cm Schd. 40 pipe, fittings, and hangers	$66	/m	762	$50,000
Vent bag	$9.84	/m	762	$7,500
Cement	$132	/tonne	1,488	$196,800
Admixtures	$17	nne of ceme	1,488	$24,600
Bentonite	$83	/ton	1,701	$140,625
Miscellaneous	$15,000	/ls	1	$15,000
TOTAL				$451,775
LABOR				
4 man crew (surface)	$2,400	/day	84	$201,600
2 man crew (U/G)	$1,200	/day	115	$138,000
TOTAL				$339,600
ALTERNATIVE 5C SUBTOTAL				$1,120,945
Contingency (12%)				$134,513
TOTAL CONSTRUCTION ESTIMATE				$1,255,458
Engineering Evaluation and Design (8%)				$100,437
Construction Oversight (5%)				$62,773
Present Worth Post-Removal Site Control Estimate				$112,300
TOTAL ESTIMATED COST FOR ALTERNATIVE 5C				**$1,530,968**

Assumptions:

Surface work: 84 days total (surface contractor)
- haul away sediment pond: 5 days
- set up: 3 days
- screening: 13 days
- batch and pump: (3823 m˘ / (15.3 m˘ /hr x 4 hr/day) = 63 days @ ~15 m/day

U/G work: 115 days total (mining contractor)
- muck GG Tunnel: 424 m˘ / (12.2 m˘ /day) = 35 days
- set-up, install backfill pipe: 12 days
- backfilling: 63 days

Volume of waste = 152m x 1.83m x 1.52m = 424 m˘

Volume of backfill = 914m x 1.83m x 2.29m = 3815 m˘

Cement = 914m x 1.83m x 2.29m / (0.4367 m˘ /tonne) x 0.17 = 1488 tonnes

7.5.6 PLUG GLENGARRY DRIFT AT CRITICAL LOCATIONS - ALTERNATIVE GA-6

The Glengarry drift is collared in the Fisher Mountain Porphyry Formation. The drift passes through approximately 420 meters of Fisher Mountain Porphyry, and then passes into Precambrian Granite (Figure 30). Essentially all water entering the Glengarry drift comes through the raises or enters through fractures in the Fisher Mountain Porphyry. The Fisher Mountain Porphyry water is high in iron, aluminum, and zinc, whereas the Como raise water is very high in both iron and copper. The primary purpose of Alternative GA-6 is to isolate the raise water from the Fisher Mountain Porphyry water, and to prevent raise water from flowing through the Glengarry drift. Second, Alternative GA-6 stops Fisher Mountain Porphyry water from exiting the Glengarry Adit and discharging into Fisher Creek.

Alternative GA-6 includes three water-tight concrete grout plugs within the Glengarry drift (Figure 30). Two plugs will be constructed near the Precambrian Granite/Fisher Mountain Porphyry contact, one on the Granite side and one on the Fisher Mountain Porphyry side of the contact. Several highly altered porphyry dikes cross the Glengarry drift in the vicinity of the contact. It is possible that the dikes also cross the contact. The hydrostatic head resulting from water backed up behind plugs could force water along the dikes, by-passing a single plug. Therefore the drift will be plugged on each side of the contact, 30 or 40 meters away from the contact. A third plug, located near the portal, will block Fisher Mountain Porphyry water that drains into the drift between the portal and the contact.

7.5.6.1 <u>Alternative Task Description</u>

The following work is included in the implementation of Alternative GA-6:

- *Engineering:* Portal plugs will be designed assuming that the entire Glengarry Mine could fill with water to the top of the Como raise, exerting approximately 1.2 mega pascals (Mpa) pressure against each plug. A pump and piping system will be designed to transport concrete grout from the surface to the plug locations.

- *Excavation and plug-site preparation*: Plugs will be constructed beginning with the plug in the Precambrian Granite and working toward the portal. The same procedure will be followed for each plug. Prior to construction, 420 meters of 5 cm compressed air pipe and 420 meters of 5 cm drill water pipe will be installed from the portal to the plug site. Natural ventilation through the Glengarry Mine and Como raise will be interrupted, and ventilation duct will have to be installed to provide fresh air. The sill, back, and ribs at the plug location will be notched, scaled, and cleaned to allow a water-tight bond between the concrete and rock. A dam upstream of the plug will be constructed to prevent water from entering the plug excavation. A bypass pipe will be installed in the dam to pass water through the plug site and discharge the water downstream of the plug site. Wooden forms approximately four meters apart will be constructed at the front and back of the plug. To facilitate concrete pumping, steel pipe, either 10 cm or 15 cm in diameter, will be installed from the portal to the plug sites. Alternatively, a borehole will be drilled from each plug site up to the surface and concrete grout will be pumped from the surface, down through the boreholes to the plug site.

- *Plug construction:* The space between the back form and the front form will be pumped full of concrete grout. Air will discharge through a breather pipe at the highest point of the void between the forms. The forms will be abandoned in place. During construction and curing time, water in the mine will pass through the bypass pipe.

- *Grouting:* Upon completion of the plug, bedrock immediately surrounding the plug will be drilled and pressure grouted with Portland cement grout. When grouting is complete, the bypass pipe will be grouted shut.

7.5.6.2 Effectiveness

Concrete plugs to stop water flow are commonly used in dams and similar water retaining structures as well as in mines. In some mine reclamation applications, plugs have been inadequate because they have been installed too near the portal. Over time, hydrostatic head behind the plug has risen to a level sufficient to force water through fractures, by-passing the plug, and exiting the mine elsewhere.

Alternative GA-6 addresses the problem of high head behind the plugs by installing two plugs 400 meters back in the drift where the surrounding rock is tight and the hydrostatic head will not be large enough to force water to the surface through fractures. Water draining down the raises and entering the Glengarry drift will be stopped in the very dry and low permeability rock of the Precambrian Granite.

Groundwater from the Fisher Mountain Porphyry currently drains into the Glengarry drift and exits the portal. The plug near the portal will cause groundwater entering the Glengarry Mine from the Fisher Mountain Porphyry to remain within the Fisher Mountain Porphyry.

❖ *REMOVAL ACTION OBJECTIVES*

Implementation of Alternative GA-6 meets two of the RAOs for the project by preventing soluble contaminants from migrating into Fisher Creek, and preventing future releases of contaminants into the Glengarry drift at the 1050 roof leak.

❖ *OVERALL PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT*

Alternative GA-6 provides a reasonable measure of control to contaminated water and reduces risk to the environment. It reduces the flow of metal-laden water directly into Fisher Creek by constructing three barriers to water movement through the Glengarry drift.

The removal of up to 215 liters per minute of metal-bearing water exiting the Glengarry Adit will lessen exposure of the environment to contaminated water. While this alternative alone has the potential to significantly diminish or eliminate the flow of water from the Glengarry Adit, there is no redundancy in-place in the event of failure of the system in the future. The greatest degree of protection to the environment will be achieved by combining this alternative with other alternatives to ensure an effective, permanent reduction in exposure to contaminants.

❖ *COMPLIANCE WITH ARARS*

Compliance with ARARs will not be fully achieved under Alternative GA-6. While, temporary water quality standards are currently being met in Fisher Creek under existing conditions, contaminant-specific standards associated with the Montana Water Quality Act will not be achieved without other alternatives being combined with Alternative GA-2.

Surface water quality at Station SW-3 will improve as a direct result of setting plugs in the Glengarry Mine. While improvements in water quality are limited by control of water chemistry at SW-3 by mineral precipitates and metals sorption, a considerable reduction in metals will be realized with this alternative.

Groundwater quality will not likely be improved under this alternative, although, with the exception of iron and manganese concentrations, groundwater in Fisher Creek is in compliance with groundwater quality standards in both shallow alluvium and Precambrian granite water-bearing units, as shown by monitoring data collected in 2001 (Maxim, 2002). Iron and manganese are ubiquitous in the District, and concentrations of these two metals are believed to be partially controlled by natural sources in bedrock. Contaminant-specific ARARs for ambient air will be met under this alternative, as air quality will not be impacted by construction operations.

Location-specific ARARs, particularly those associated with cultural and historic resources, will be met, as no cultural or historic features will be impacted if this alternative is implemented. Threatened and endangered species are present in or near the District will not be affected by this alternative as there will be no new disturbances, no permanent facilities, and implementation of the alternative will be completed in one season. No other location-specific ARARs apply.

Action-specific ARARs are expected to be met by this alternative. Substantive MPDES permit regulations will be met, as no facilities require a discharge of waste to the environment. The Montana Water Quality Act will not be fully complied with under this alternative as the Glengarry Adit will continue to discharge iron and other metals from other sources within the Glengarry Mine that exceeds standards. Other requirements for treating surface drainage, sediment control, construction and maintenance of sedimentation ponds, discharges from sedimentation ponds, and provisions for groundwater will be met by using best BATs.

Action-specific State of Montana air quality regulations related to dust suppression and control during construction activities will be met using BMPs.

OSHA requirements will be met by requiring appropriate safety training for all on-site workers during construction phase. Site activities would be conducted under the guidance of a Health and Safety Plan for the site per OSHA 29 CFR 1910.120. Site personnel will have completed 40-hour hazardous waste operations and emergency response training and would be current with the 8-hour annual refresher training as required by OSHA 29 CFR 1910.120.

❖ *LONG-TERM EFFECTIVENESS AND PERMANENCE*

Alternative GA-6 should permanently eliminate the Glengarry Mine as a conduit transporting metal-laden groundwater from the Como Basin and Fisher Mountain Porphyry directly to Fisher Creek. Ground instability in the Fisher Mountain Porphyry has the potential to cause eventual failure of the plugs in the Fisher Mountain Porphyry, resulting in water leakage around the plugs. Combining alternative GA-5A or GA-5C with Alternative GA-6 would eliminate stability problems in the Fisher Mountain Porphyry.

Optimal long-term effectiveness and permanence would be achieved by combining Alternative GA-2 with Alternative GA-6. Implementation of these alternatives would prevent inflows from flooding the Glengarry Mine workings behind the plug(s) to the top of the Como raise and potentially cause failure of the plug(s) due to high hydrostatic pressure(s).

❖ *REDUCTION OF TOXICITY, MOBILITY, OR VOLUME THROUGH TREATMENT*

The mobility of metals will be substantially reduced or eliminated by Alternative GA-6. The Glengarry Mine will no longer be a conduit for transporting metals-laden water to Fisher Creek. Mobility will exist within each isolated segment of the mine, but the plugs will preclude mobility between segments of the Glengarry adits. There will be no reduction in toxicity or volume.

❖ *SHORT-TERM EFFECTIVENESS*

No impacts to the community or the environment are expected with the implementation of this alternative. Only a limited amount of equipment and supplies will be required, all of which will travel on existing roads. Protection to workers will be afforded through standard work practices. Exposure to hazardous substances will be minimal, although direct contact with the water draining the mine will not be eliminated. All underground work will be conducted using standard work practices and protective devices.

The effect of drift plugs will be immediate. Upon completion of the first plug and the surrounding grout curtain, the by-pass pipe will be grouted shut and water flow from the raises through the Glengarry mine to the portal will be substantially reduced or eliminated.

7.5.6.3 Implementability

Numerous portal and drift plugs have been previously installed in abandoned, underground mines. The greatest technical difficulty with Alternative GA-6 is pumping concrete to the plug sites. This will be accomplished either by pumping concrete from the portal site through a pipeline in the Glengarry drift or by drilling boreholes from the plug location up to the surface and pumping concrete through the borehole to the plug.

7.5.6.4 Cost

TABLE 7-13
SUMMARY OF ALTERNATIVE GA-6 ESTIMATED COST

TASK	UNIT COST	UNITS	QUANTITY	COST
MOBILIZATION/DEMOBILIZATION				
Mobilization	$40,000	/ ls	1	$40,000
Site clean-up, restoration	$10,000	/ ls	1	$10,000
Demobilization	$40,000	/ ls	1	$40,000
TOTAL				$90,000
EQUIPMENT				
Mucker	$250	/ day	79	$19,750
Generator	$125	/ day	79	$9,875
Excavator	$700	/ day	6	$4,200
Water truck	$200	/ day	74	$14,800
Ready-mix truck (2 @ 6 days ea.)	$500	/ day	12	$6,000
Concrete pump	$1,000	/ day	6	$6,000
Grout plant	$250	/ day	40	$10,000
Pick-up trucks	$100	/ day	79	$7,900
Misc. plant (fan, pumps, etc.)	$100	/ day	79	$7,900
TOTAL				$86,425
MATERIALS, SUPPLIES, and FUEL				
Fuel	$150	/ day	79	$11,850
15 cm Schd. 40 pipe, fittings, and hangers	$66	/ m	411	$27,000
Vent bag	$9.84	/ m	381	$3,750
Form materials	$5,000	/ ls	1	$5,000
Pre-mix	$196	/ m^3	115	$22,500
Cement	$165	/ tonne	227	$37,500
Bentonite based grout	$220	/ tonne	27	$6,000
Miscellaneous	$10,000	/ ls	1	$10,000
TOTAL				$123,600
LABOR				
5 man crew	$3,000	/ day	79	$237,000
TOTAL				$237,000
ALTERNATIVE 6 SUBTOTAL				$537,025
Contingency (12%)				$64,443
TOTAL CONSTRUCTION ESTIMATE				$601,468
Engineering Evaluation and Design (8%)				$48,117
Construction Oversight (5%)				$30,073
Present Worth Post-Removal Site Control Estimate				$112,300
TOTAL ESTIMATED COST FOR ALTERNATIVE 6				**$791,959**
Assumptions:				
U/G work: 79 days total (mining contractor)				
muck GG Tunnel: 5 days				
install utilities: 3 days				
excavate and clean site: 7 days/plug				
forms: 7 days/plug				
set-up, install slick-line: 5 days				
placing concrete: 1 day/plug				
grouting: 7 days/plug				
Volume of plug = 3.66 x 3.05 x 3.05 = 34 m^3				
Number of plugs: 3				

8.0 COMPARATIVE ANALYSIS OF ALTERNATIVES

This section compares the alternatives evaluated in detail in Section 7.0. The comparative analysis is performed for each of the three primary criteria -- effectiveness, implementability, and cost. Each of the three source areas (Como Basin, Fisher Creek, and Glengarry Adit) is considered separately. A discussion at the end of this section discusses the interrelationship between these three source areas. A preferred alternative is also identified at the end of the section.

8.1 COMO BASIN SOURCE AREA

The primary sources and pathways for contaminants in the Como Basin are soluble concentrations of metals present in metal-rich soils that overlie the massive sulfide Como deposit. Metals and acidity present in the soils become soluble in infiltrating precipitation, and are transported to the zone of contact between the unconsolidated soils and the Meagher Limestone, which is relatively impermeable. When fractures are encountered along the flow path of this recharge solution, or if man-caused penetrations in the Meagher are encountered such as the Como raise or improperly plugged boreholes, the contaminants enter the groundwater system and move toward discharge points in Fisher Creek.

8.1.1 EFFECTIVENESS

The alternatives evaluated for Como Basin present a range of effectiveness. In terms of reducing contaminant seepage and migration from metal-rich soils in the Como Basin, Alternatives CB-3B and CB-3C are the most effective of the alternatives evaluated. This is because the majority of metal-rich soils (Alternative CB-3B) and all metal-rich soils (Alternative CB-3C) are placed below a geomembrane liner and protected from infiltrating surface water. The cap placed over the waste in both alternatives provides a suitable medium to promote vegetation growth. Alternative CB-3A is much less effective because the soil cap, although providing a substrate for vegetation reestablishment, does not reduce the rate of infiltration and does not significantly diminish the risk for contaminant migration. Unamended soil will likely continue to release contaminants to the environment.

The overall effectiveness of Alternative CB-2C, which amends all soil materials in the source area, may be as effective as CB-3B in controlling contaminant migration. This is true, not because it eliminates seepage, but rather because the seepage should not contain high acidity or significant metal concentrations. The effectiveness of Alternative CB-2C may be somewhat affected by the ability to thoroughly mix the amendment with metal-rich soil. In addition, there is a very large amount of material in the Como Basin to be amended (190,174 cubic meters). Alternatives CB-2A and CB-2B are much less effective than the other alternatives for several reasons: 1) smaller volumes of metal-rich soil material are amended; 2) the seepage rate remains about the same as under existing conditions; and 3) non-amended metal-rich soil will likely still release contaminants to the environment. From this point of view, with the exception of the benefits of a soil cover, Alternative CB-3A will probably be little more effective than Alternative CB-2A.

Effectiveness of the composite cover system (Alternatives CB-3B and CB-3C), is superior to either shallow (30 cm) (CB-2A) or deep (100 cm) (CB-2B) *in-situ* treatment. The use of the geomembrane in the composite cover system reduces infiltration by a factor of 6 (from 23 to 3.7 l/min., or 6.1 to 0.97 gpm). Overall effectiveness of the No Action Alternative is poor compared to other alternatives.

Seepage through unamended disturbed and metal-rich soils that remain under the geomembrane liner should be reduced by an estimated 80% based on the HELP model infiltration results. In addition, surface water diversions will divert surface water run off from the rather small drainage areas that lie topographically above the Como Basin (Figure 7). These areas include the north flank of Fisher Mountain, which is an area only about half again as big as the Como Basin itself, and one that is comprised of steep predominantly bedrock slopes. These bedrock slopes shed snow cover rapidly in the early summer and most of the water that comes off of the sites can be captured in diversion ditches and routed around the Como Basin in channels. Diversion channels would be lined as an integral part of the geomembrane liner along the edges of the disturbed areas. There is a small recharge area above and to the west of the Como Basin along the Lulu Pass saddle (Figure 7) where surface water flows would also be captured in a runon diversion system.

The one remaining potential recharge pathway to the disturbed portions of the Como Basin following installation of a geomembrane is lateral or upwelling flow from bedrock into unamended disturbed soils beneath the liner. At the present time with the available data the magnitude of this component of flow cannot be evaluated. However, observations described above relating to the low permeability of the silicified Meagher Limestone that is the uppermost near surface bedrock unit and the 55 meter thick Wolsey Shale that immediately underlies the Meagher indicates this pathway of recharge may be minimal. In the nearby McLaren pit area these same bedrock lithologies have hydraulic conductivity coefficients of about 10^{-6}-cm/sec, which is about three orders of magnitude (1,000 times) less permeable than the disturbed soils of the Como Basin. In addition, observations of seepage into fractures in the upper level horizontal working off of the Glengarry raise into the Como basin show flow rates that range from 0.3 to 0.007 l/m (0.1 to 0.002 gpm) flow. All these data suggest that there will be minimal flow of groundwater up and into the disturbed soils underlying the geomembrane. During the summer of 2002 several shallow piezometers will be placed in the Como Basin soil material to quantify this potential pathway.

8.1.1.1 Removal Action Objectives

Alternatives CB-2C, CB-3B, and CB-3C achieve RAOs to a similar degree. By combining methods of either total amendment or capping, these alternatives prevent the migration of contaminated seepage out of metal-rich soil material. Alternative CB-3C, with all of the soil below the liner, may be perceived as less risky from a seepage point of view, but if the alternatives are implemented correctly, probably offers no distinct advantage over the others.

Alternatives CB-2A, CB-2B, and CB-3A do not meet RAOs, primarily because non-amended metal-rich soils remain at the Como Basin site and will be subject to infiltration that can produce acidic, metal-laden seepage. The No Action Alternative does not meet any RAOs except the RAO of preserving the existing, undeveloped character of the District and surrounding area.

8.1.1.2 Overall Protection of Human Health and the Environment

No unacceptable human health risks were identified in the Como Basin. The greatest risk to the environment comes from degraded surface and groundwater quality and its impact to aquatic life. Vegetated surfaces will reduce the potential for further erosion and migration of contaminants from source areas by stabilizing metal-rich soils, resulting in a reduction in sediment transport in Fisher Creek. Alternatives CB-2C, CB-3B, and CB-3C are about equally protective of the environment.

8.1.1.3 Compliance With ARARs

Temporary water quality standards are currently being met in Fisher Creek under existing conditions. However, none of the alternative actions proposed will achieve compliance with surface water quality standards, as load modeling studies suggest that the Como Basin metal-rich soils are not the only significant source of loading to Fisher Creek during either high or low flow.

Some improvement in surface water quality in the uppermost reaches of Fisher Creek is expected for alternatives that involve *in-situ* amendment or capping with a geomembrane because soluble concentrations of metals would be somewhat reduced. Under Alternatives CB-2C, CB-3B, and CB-3C, contaminant leaching may be eliminated from the metal-rich soils, with a consequent reduction in load to Fisher Creek. However, arsenic loading may increase from treated materials due to its greater mobility in neutral pH environments, leaving Alternative CB-2C with the greatest potential for increasing arsenic concentrations in Fisher Creek, which are currently at or below detection.

Surface water quality at Station SW-3 will slightly improve as a direct result of treating or capping metal-rich soils in the Como Basin, but water chemistry in the reaches below Station SW-3 appears to be controlled by mineral precipitates and sorption of metals, and by downgradient groundwater contributions rather than by upstream loading. In addition, under higher flow conditions, some load from the Como Basin area will be released due to saturation and seepage from unamended materials remaining under Alternatives CB-2A, CB-2B, and CB-3A.

Groundwater standards locally may or may not be met under the alternatives proposed (some are met locally already). Capping and *in-situ* treatment of unconsolidated metal-rich soils will likely have only a minor positive and very local effect on groundwater. It will likely have very little effect on groundwater for those times when the nonamended portions of wastes become saturated under Alternatives CB-2A, CB-2B, and CB-3A.

Failure to meet surface and groundwater standards is principally due to the fact that metal-rich soil is not the only source of contaminants in the Como Basin area (i.e. bedrock sources, groundwater migration sources, and transported sediment sources). Therefore, cleaning up or preventing seepage from wastes in the Como Basin does not address other sources in the Fisher Creek drainage. However, alternatives CB-3B and CB-3C will significantly decrease loading to Fisher Creek from the Como Basin source area and will have a positive effect on surface water quality, particularly during high flow when this source contributes approximately 20% of the total metal loading to Fisher Creek.

All the alternatives will have about the same impacts to threatened and endangered species. Alternatives CB-2C or CB-3C will have relatively greater impacts because these alternatives require more than one construction season to complete and considerably more construction traffic. Traffic impacts are greater to threatened and endangered species because of the greater amount of materials moved or required.

All alternatives will meet action-specific and location-specific ARARs equally. The No Action Alternative is the least compliant with ARARs of the alternatives considered.

8.1.1.4 Long-Term Effectiveness and Permanence

The No Action Alternative is neither effective in the long-term nor permanent. *In-situ* treatment may not be a permanent solution because metal-rich soils will not be fully amended under Alternatives CB-2A, CB-2B, and CB-3A. Monitoring and maintenance will be essential to maintaining the effectiveness of these alternatives in the long-term.

For Alternatives CB-2A, CB-2B, and CB-3A, there are some concerns that the long-term effectiveness could be compromised by capillary action bringing acidity and metals into the surface layer and negatively affecting vegetative success. This is probably less important for Alternative CB-3A with a soil cap. Long-term erosion is also a potential problem under Alternatives CB-2A, CB-2B, and CB-3A, as weathering could expose nonamended metal-rich soils. Alternatives CB-2C, CB-3B, and CB-3C, are expected to perform comparably over the long term and each should perform equally well.

Alternatives CB-2C (full amendment), and CB-3B, should provide long-term effectiveness by adding enough neutralizing amendment to fully eliminate future acid production that could result from reaction of sulfide minerals with infiltrating water. However, quality control during mixing operations will be needed to insure the metal-rich soils are mixed properly with the amendment.

The multi-layer caps in alternatives CB-3B and CB-3C could be impacted by environmental factors such as wetting/drying, freeze/thaw, and erosion. Long-term monitoring and maintenance will be a factor in the long-term effectiveness of these alternatives.

8.1.1.5 Reduction of Toxicity, Mobility, or Volume Through Treatment

None of the alternatives reduce the volume of contaminants. All of the alternatives, except the No Action Alternative, reduce mobility and loading of contaminants to Fisher Creek to some degree. Alternatives CB-2A, CB-2B, and CB-2C rely on treatment of metal-rich soils with a neutralizing amendment to reduce mobility. Alternatives CB-3B and CB-3C use a geomembrane liner as a part of a composite cover system to reduce mobility. Alternatives CB-2C, CB-3B, and CB-3C achieve the greatest reduction in mobility through treatment, since all the wastes are either amended above the liner or are capped below a liner. Alternative CB-3C is probably the most effective at reducing the risk of mobility. Reduction in plant toxicity through treatment or providing cover soil for vegetation establishment is achieved by all alternatives except the No Action Alternative.

8.1.1.6 Short-Term Effectiveness

Short-term effectiveness of alternatives CB-2A, CB-2B, and CB-3A, is similar in that construction will be completed in a period of no more than 90 days. Alternatives CB-2C, CB-3B, and CB-3C will likely require more than one construction season. Although there would be no construction-related impacts from the No Action Alternative, the impacts from contaminant source releases would continue in both the short- and long-term.

The types of short-term impacts associated with Alternatives CB-2C, CB-3B, and CB-3C are similar. These alternatives place more impacts on the local community and roads due to the greater number of truck trips required to haul materials to the Como Basin. Because of this, these alternatives pose the greatest risk to wildlife and the public from vehicle accidents. Much fewer materials are needed to implement Alternatives CB-2A, CB-2B, and CB-3A, so short-term impacts associated with these alternatives are considerably less than the other alternatives.

8.1.2 IMPLEMENTABILITY

All of the alternatives are technically and administratively feasible. Essential project components such as equipment, materials, and construction expertise, although distant from the site, are available. Alternatives CB-2C, CB-3B, and CB-3C require some specialized construction techniques, but these techniques are proven, available, and can be implemented at the site. Geomembrane liner installation for Alternatives CB-3B and CB-3C require specialized equipment and labor, including seam welders and seam test equipment. Quality Assurance/Quality Control for geomembrane liner installation is very strict, requiring experienced personnel and specialized equipment. Liners are available, but available specialized labor may be limited. Difficulties may be encountered with complete mixing of the lime amendment, especially for Alternative CB-2C. Specialized equipment such as a pug mill or other device may be required, and strict quality control measures will be needed to insure complete mixing.

Trucking requirements for Alternatives CB-2C and CB-3C are large, as are earth-moving requirements to implement Alternative CB-2C. These requirements should be able to be accommodated.

8.1.3 COST

Table 8-1 summarizes costs for the Como Basin Source Area alternatives. The least expensive of the action alternatives is Alternative CB-2A. Alternative CB-2B costs about 30% more than Alternative CB-2A. Alternative 2C is the most expensive of the alternatives considered. Alternative CB-3B is about 5% less expensive to implement than Alternative CB-3C, and is about 80% less expensive than Alternative CB-2C. Alternative CB-3A is the median cost of the alternatives considered.

TABLE 8-1
COMO BASIN SOURCE AREA ALTERNATIVES COST SUMMARY
New World Mining District Response and Restoration Project
Como Basin/Glengarry Adit/Fisher Creek Response Action

	Alternative	Cost
1	No Action	**$ 60,000**
2A	*In-Situ* Treatment Shallow Amendment	**$ 461,650**
2B	*In-Situ* Treatment Select Soil with Deep Amendment	**$ 595,700**
2C	*In-Situ* Treatment of All Metal-Rich Soils	**$3,637,000**
3A	*In-Situ* Treatment with Soil Cap	**$ 904,000**
3B	*In-Situ* Treatment with Geomembrane Cover and Amended Soil Cap	**$1,918,000**
3C	*In-Situ* Treatment with Geomembrane Cover and Soil Cap	**$2,000,000**

For Alternatives requiring lime amendments, it should be noted that a difference of 1% in the estimated pyrite content results in a 30 ton addition of lime required per kiloton of material treated and an increase in lime amendment costs ($62/m ton treated). It is essential that prior to actual amendment, accurate pyrite (pyritic sulfur) contents be determined.

8.2 FISHER CREEK SOURCE AREA

The primary sources and pathways for contaminants in the remaining dumps in Fisher Creek are soluble metals present in waste rock. Metals and acidity become soluble in infiltrating precipitation and surface water runon, and are transported to area surface water and groundwater. Most of the dumps are unvegetated, primarily due to the acidity of waste rock.

8.2.1 EFFECTIVENESS

Overall, *in-situ* treatment (Alternative FC-2) would be effective in providing suitable soil conditions for revegetation in the short-term, and a corresponding reduction in mobility of metal contaminants. However, because site conditions limit the depth of waste treatment, untreated wastes will remain at the sites. Under certain conditions, generally during moderate to extreme weather or periods of high runoff, untreated wastes could become saturated and release contaminants to the environment. There is also the potential for the treated surface of the waste to reacidify due to capillary rise of acid from underlying untreated wastes, resulting in a reduction in vegetation cover and vigor. Such a mechanism would likely cause the waste dump to revert to pre-treatment conditions.

Surface controls (Alternative FC-3) would be effective in reducing impacts that result from surface water runon encountering waste. Diversion of runon at dumps where this problem occurs is a simple, straight-forward approach to reducing mobility of contaminants. However, precipitation that falls directly on the dumps will continue to leach through the unvegetated dumps, creating the potential for contaminants to move off-site into surface water and groundwater.

Alternative FC-4, total removal is the most effective of the alternatives considered. The No Action Alternative does not address surface water impacts, nor does it provide any controls on contaminant migration.

8.2.1.1 <u>Removal Action Alternatives</u>

Alternative FC-4, total removal, meets most RAOs because wastes are removed and place in a controlled repository with leachate collection. Alternative FC-2, *in-situ* treatment, meets RAOs to some extent. Revegetating the waste dumps will greatly reduce the amount of soluble metals that can migrate from the dumps to surface water. Soluble metals will not be eliminated because some portion of the wastes in the dump will remain untreated and in contact with infiltrating precipitation.

Alternative FC-3, surface controls, meets only a few of the RAOs. The RAO of reducing or eliminating concentrated runoff and sediment discharges will be met through the rerouting of surface water at the sites. Soluble metals will not be eliminated because wastes in the dumps will remain untreated and in contact with infiltrating precipitation. No action meets one of the RAOs -- preserving the existing undeveloped character of the District and surrounding area.

8.2.1.2 <u>Overall Protection of Human Health and the Environment</u>

No unacceptable human health risks were identified at the remaining dumps in Fisher Creek. The greatest risk to the environment comes from degraded surface and groundwater quality and its impact to aquatic life. Vegetated surfaces will reduce the potential for further erosion and migration of contaminants from source areas by stabilizing metal-rich soils, resulting in a reduction in sediment transport in Fisher Creek. Alternatives FC-2 and FC-3 are about equally protective of the environment at most of the dump sites because most of the sites are located a good distance from surface water. Alternative FC-3 also provides some protection to the environment because the alternative addresses diversion of runon and runoff at sites that directly impact surface water.

8.2.1.3 Compliance with ARARs

Alternative FC-4 is the best of the alternatives when evaluating compliance with ARARs. However, temporary water quality standards are currently being met in Fisher Creek under existing conditions, and none of the alternative actions proposed will achieve compliance with surface water standards, as waste rock associated with the widely scattered Fisher Creek dumps are a relatively minor source of direct loading to Fisher Creek.

Some improvement in surface water quality in Fisher Creek is expected for each of the alternatives, with the greatest likely to occur if Alternative FC-4 is implemented. However, the Glengarry Dump is probably the greatest contributor to water quality degradation in Fisher Creek, and removal of this dump alone may do as much as removing all the dumps. The Glengarry Dump contains about 60% of the total waste rock present in the remaining Fisher Creek dumps. The Gold Dust waste rock dump contains an additional 26% of the total waste rock contained in Fisher Creek dumps. The impacts of this waste rock dump to water quality, however seems to be minimal (modest decrease in pH to about 5.5, and no significant metal loading). If both the Glengarry and Gold Dust dumps were removed approximately 85% of the remaining Fisher Creek dump material would be removed.

Alternative FC-3 will impact threatened and endangered species the least, with Alternative FC-4 having the greatest impact to these concerns. Traffic impacts are greater for Alternative FC-4 because of the greater amount of materials moved or required. Alternative FC-4 would require a considerable amount to road building and subsequent reclamation in order to provide access to these numerous sites for equipment to load and haul the material. Alternatives FC-2 and FC-4 are expected to meet action-specific and location-specific ARARs equally. The No Action Alternative is the least compliant with ARARs of the alternatives considered. Alternative FC-3 will not meet revegetation standards, because revegetation is not an element of the alternative.

8.2.1.4 Long-Term Effectiveness and Permanence

Most of the waste rock dumps included in Fisher Creek Source Area are very small. Because the entire package of waste materials at each dump site cannot be fully amended under Alternative FC-2, *in-situ* treatment may not be a permanent solution and acidity from unamended wastes lying below the amended zone has the potential to move upward to the surface, resulting in the return of the dump to an unvegetated condition. Alternative FC-3 is not considered to be a permanent solution because the wastes are generally left unaltered and unamended wastes would still be subject to erosion. Removing wastes under Alternative FC-4 should be a permanent solution requiring little maintenance and providing long-term effectiveness at the waste sites.

8.2.1.5 Reduction of Toxicity, Mobility, or Volume Through Treatment

None of the alternatives reduces the volume of contaminants. Alternatives FC-2, FC-3, and FC-4 reduce the mobility of contaminants to some degree, although only Alternative FC-2 reduces mobility through treatment with a neutralizing amendment. The greatest reduction in mobility is achieved by Alternative

FC-4 since all the wastes will be removed. Reduction in plant toxicity through treatment is achieved by Alternative FC-2.

8.2.1.6 Short-Term Effectiveness

Short-term effectiveness of all the alternatives considered for the Fisher Creek Source Area, except for no action, is similar in that construction will be completed in a period of no more than 90 days. Alternative FC-3 has the least impacts to the community because it can be constructed in 30 days less time and does not require upgrades to access the sites. Rather, equipment that can access the sites with a minimum of impact is one of the advantages of this alternative. There are no impacts in the short-term from the No Action Alternative.

Short-term impacts associated with Alternatives FC-2 and FC-4 are similar because road improvements will be required to access the dump sites. Alternative FC-4, total removal, requires the greatest amount of equipment, materials, and time to complete. Alternatives FC-4 places more impacts on the local community and roads due to the large number of truck trips that will be made hauling waste rock and construction materials to the repository site.

8.2.2 IMPLEMENTABILITY

All of the alternatives are technically and administratively feasible. Essential project components such as equipment, materials, and construction expertise, although distant from the site, are available. Alternative FC-3 is the most implementable because it requires only a few pieces of equipment to implement.

Alternative FC-4 requires some specialized construction techniques at the repository, but these techniques are proven and can be implemented at the site. Geomembrane liner installation requires specialized equipment and labor including seam welders and seam test equipment. Quality Assurance/Quality Control for geomembrane liner installation is very strict, requiring experienced personnel and specialized equipment. Liners are available in-state, but available specialized labor may be limited.

8.2.3 COST

Alternative FC-4, removal to an on-site repository, is by far the most expensive of the alternatives evaluated for the Fisher Creek Source Area. The total cost to implement this alternative is about $2,467,000. The No Action Alternative is the least expensive of the alternatives as there are no capital costs that will be expended for cleanup. However, there are external costs associated with no action, including the loss of certain ecological functions such as a healthy, viable fishery and aquatic community.

Alternative FC-3 is the least expensive ($283,000) of the alternatives where an action is taken, as no waste hauling or treatment is involved. The estimated cost for Alternative FC-2 is about $735,500.

8.3 GLENGARRY ADIT ALTERNATIVES

Issues associated with the Glengarry Adit Source Area are contaminated inflow into the underground mine workings from four specific sources. The principal impacts are contaminated outflow to both surface and groundwater in the Fisher Creek drainage. Therefore, all of the proposed engineering controls and alternatives for the Glengarry Adit Source Area involve controlling flow into and out of the mine.

8.3.1 EFFECTIVENESS

The No Action Alternative involves leaving the Glengarry Mine in its existing condition. Overall effectiveness of no action is poor. Under existing conditions, acidic water, dissolved metals, and sediment will continue to flow from the mine portal and into Fisher Creek.

From the point of view of contaminant concentration and loading, by far the principal source of metals and low pH water arises from flow (8 to 38 liters per minute) from the colluvial/bedrock contact in the Como Basin and down the second raise. Alternative GA-2 provides multiple barriers to contaminated water entering and flowing down the raise to the Glengarry Mine. A grout curtain encircling the raise collar will provide a barrier to keep shallow subsurface water flowing along the colluvial/bedrock contact in the Como Basin from flowing into the raise. Cement and bentonite plugs will provide a very tight seal within the raise and below the massive sulfide-bearing portion of the Meagher Limestone. Backfilling the raise will also act as a barrier to water movement, and will eliminate the chance of future spalling, loosening, and collapse of rock around the grout curtain and plug areas that could result in leakage past the plugs or failure of the grout curtain.

Other significant sources of inflow are the flow from the top of the first raise (38 to 64 liters per minute) and flow from the 1050 fracture system (10 to 50 liters per minute). These two inflow sources contribute two orders of magnitude less metals concentrations than the Como raise, but contribute a considerable iron and zinc load and exceed water quality standards for these two metals, among others. Water leakage from both these structures would be considerably reduced or eliminated if Alternatives GA-3 and GA-4 were implemented.

If grouting for Alternatives GA-3 and GA-4 are only partially successful, these two alternatives are still likely to be effective in substantially reducing flow into the mine. However, the effectiveness of Alternative GA-3 directly depends on the success of locating and sealing the fracture system above the first raise. If Alternatives GA-2 and GA-6 are selected, Alternative GA-3 becomes unnecessary.

Implementing Alternative GA-5 ensures no further ground movement will occur in the rock surrounding the Glengarry workings. This alternative provides structural stability and support to areas grouted and plugged under Alternatives GA-4 and GA-6. The relative impermeability of backfill will also significantly reduce the water flow through the filled portions of the workings.

Alternative GA-6 is the most effective of the alternatives in that it seals the underground workings with a series of plugs. Water draining down the raises and entering the Glengarry drift will be stopped in the very dry and low permeability rock of the Precambrian granite. A third plug located near the portal will block Fisher Mountain Porphyry water that drains into the drift between the portal and the contact. This alternative should be very effective in eliminating or minimizing outflow from the mine and into Fisher Creek.

A concern for the effectiveness of all Glengarry alternatives is that barriers (i.e. grouting and backfill) to underground flow are essentially diversions of flow into alternate pathways. For example, for GA-2, eliminating flow down the raise is a relatively straightforward solution and should be almost 100% effective. However, this flow will then be diverted into or retained in the Como Basin as potential outflow to FCT-11. Several points can be made concerning this outflow. Figure 31 illustrates annual flow volume distributions from the three main components of load to Fisher Creek below the Como Basin (FCT-11, FCT-12 and the Glengarry Mine). The impact of retaining 37 l/m (10 gpm) of flow that was already destined for the Como Basin, in a pre-Glengarry Mine scenario, is trivial by comparison with the total seasonal (ephemeral) outflow to FCT-11 from the basin (Figure 31). Flows in FCT-11 during high flow are as great as 5,520 l/m (1,458 gpm) and the range of flow values throughout the high flow period of the year (late May to late July on Figure 31) are from 1,140 to 5,520 l/m (300 to 1,458 gpm). During low flow period of the year, flow from the FCT-11 drainage ranges from 0 to 425 l/m (0 to 112 gpm). Because flow in FCT-11 is ephemeral, in most years there is no flow from approximately October through early to late May (zero flow has been recorded on two dates in May and two dates in late September of different years). So for alternative GA-2, once implemented, the problem is no longer one of flow from the mine, but has become a problem of flow from the Como Basin, which is discussed above. What can be said is that flow out of the Glengarry Mine has always been perennial, and the raise collar source was by far the most significant contributor to load from the mine (sometimes as much as 99%, 38 l/m (10 gpm) at 17 mg/l copper). By eliminating this flow, load from the Glengarry Mine to Fisher Creek will be significantly decreased during those periods when flow conditions in FCT-11 are at low or zero flow.

The other Glengarry Mine alternatives should also be quite effective in minimizing or eliminating flow from the Glengarry mine source. For the remainder of the alternatives, flow would be diverted from its present path through the workings and out the portal, presumably into premining fractures, where it would initially be retained as groundwater and eventually discharged to Fisher Creek through seeps, springs, and shallow groundwater recharge of the creek. For these alternatives, this diverted water and its respective load may report back to Fisher Creek. However, the next largest contaminant source in the Glengarry Mine is two orders of magnitude less concentrated than water coming down the raise from the Como Basin.

8.3.1.1 Removal Action Objectives

The six response action alternatives evaluated for the Glengarry Adit Source Area are about equal in achieving two of the project objectives, preventing soluble contaminants from migrating into Fisher Creek, and preventing future releases of contaminants from the workings. However, none of the alternatives meet all project objectives.

8.3.1.2 Overall Protection of Human Health and the Environment

Constructing a grout curtain around the collar of the Como raise and plugging and backfilling the raise itself, (Alternative GA-2), grouting-off the water source at the top of the first raise (Alternative GA-3), and grouting the 1050 roof leak (Alternative GA-4), all provide reasonable measures for controlling exposure to contaminated water and reduces risk to the environment. It reduces the volume of metal-bearing water and, therefore, the load of contaminants flowing directly from these sources, through the drift, and out the Glengarry Adit into the headwaters of Fisher Creek by constructing a physical barrier to water movement. The greatest degree of protection to the environment will be achieved by combining these alternatives with others to ensure an effective, permanent reduction in exposure to contaminants.

Backfilling various portions of the Glengarry workings (Alternative GA-5), when combined with other alternatives, provides a reasonable measure of control of exposure to contaminated water and reduces risk to the environment by reducing the flow of metal-bearing water directly into the headwaters of

Figure 31. Flow Data At Various Stations in the Fisher Creek Drainage (flow plotted according to month measured over 8 year period)

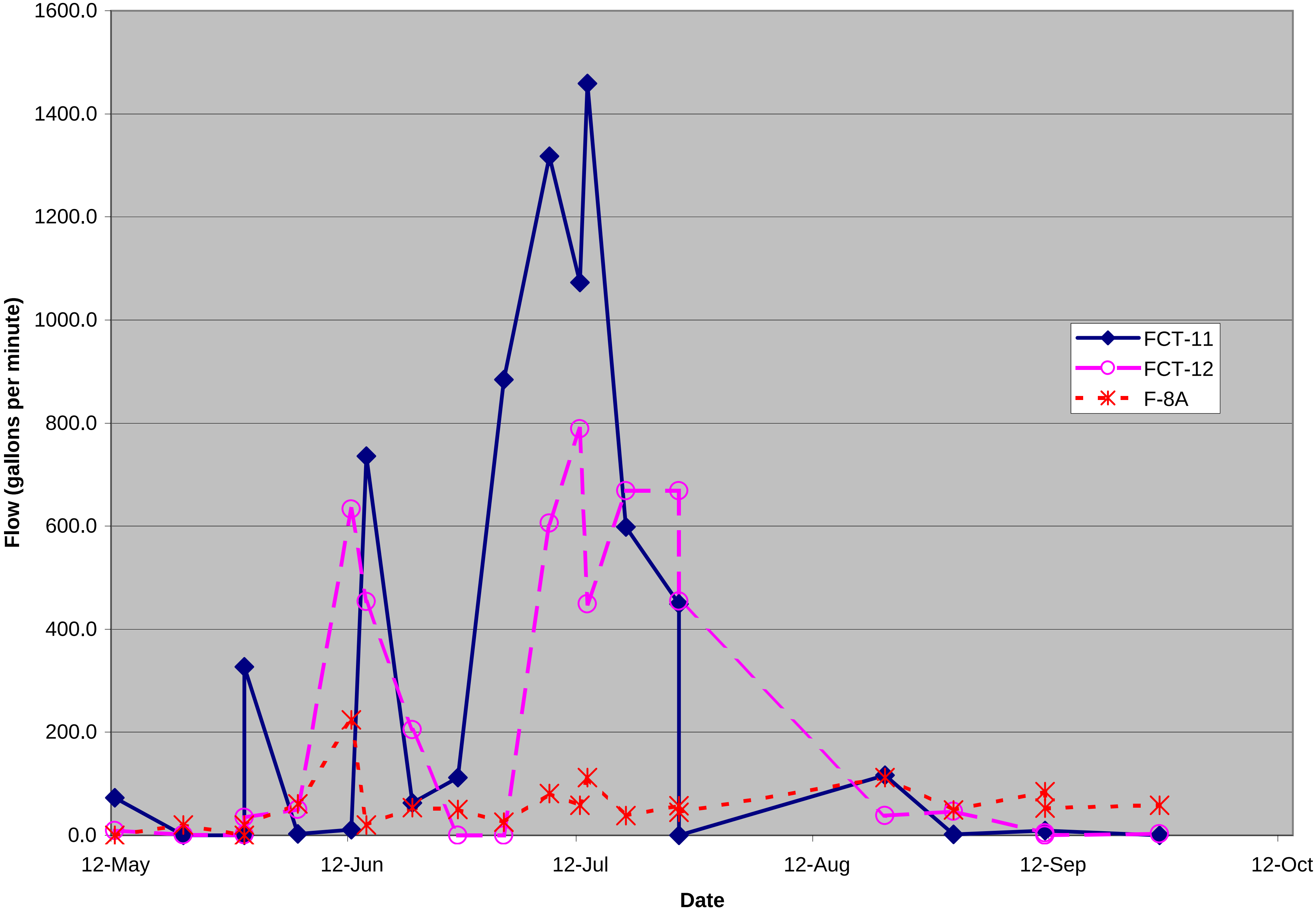

Figure 31- Back Page

Fisher Creek through construction of a physical barrier to water movement. Alternatives GA-5A and GA-5C are especially important as they provide support of grout curtains and plugs against future ground movement that could lessen the effectiveness of other alternatives. In addition, Alternative GA-5A and GA-5C diminish water in-flows from diffuse leaks in the first 320 meters of the Glengarry workings.

Alternative GA-6 provides a reasonable measure of control to contaminated water and reduces risk to the environment. It reduces the flow of metal-laden water directly into Fisher Creek by constructing three water-tight barriers to water movement through the Glengarry drift. While this alternative alone has the potential to significantly diminish or eliminate the flow of water from the Glengarry Adit, there is no redundancy in-place in the event of failure of a portion of the system in the future. The greatest degree of protection to the environment will be achieved when combining this alternative with others to ensure an effective, permanent reduction in exposure to contaminants.

8.3.1.3 Compliance with ARARs

Temporary water quality standards are currently being met in Fisher Creek under existing conditions. However, none of the alternative actions proposed will achieve compliance with surface water standards, as load modeling studies suggest that the Glengarry Adit discharge is not the only significant source of loading to Fisher Creek.

Some improvement in surface water quality in the uppermost reaches of Fisher Creek is expected for all the alternatives. Copper, iron, and zinc loading would be reduced considerably, although this varies somewhat depending on the combination of alternatives selected. No single alternative is as effective in improving water quality or achieving ARARs as a combination of Glengarry Adit Source Area alternatives.

Surface water quality at Station SW-3 will improve if the discharge from the Glengarry Adit is reduced or eliminated, but water chemistry in the reaches below Station SW-3 appears to be controlled by mineral precipitates and sorption of metals, and by downgradient groundwater contributions rather than by upstream loading. Groundwater standards locally may or may not be met under the alternatives proposed, but will likely improve locally.

The Glengarry Adit is not the only source of contaminants in the Fisher Creek headwaters. Therefore, reducing or eliminating the Glengarry Adit discharge does not address other sources. However, the loading from the Glengarry Mine is significant during both high and low flow conditions. During low flow conditions from early August through late May the adit contributes almost 90% of the metal loading to upper Fisher Creek. This is true because the tributaries to Fisher Creek are dry during this time of year so that the Glengarry Mine is almost the only source. During high flow conditions the Glengarry Mine contributes about 20% of the copper, 65% of the iron, 40% of the manganese, and 10% of the sulfate. Reduction of the flow from the Glengarry Mine (particularly from the first and second raises and the 1050 roof leak) would lead to a very significant reduction during low flow and a more modest but still significant reduction at high flow.

All alternatives will meet action-specific and location-specific ARARs equally. The No Action Alternative is the least compliant with ARARs of the alternatives considered.

❖ *LONG-TERM EFFECTIVENESS AND PERMANENCE*

For Alternative GA-2, backfilling the raise in conjunction with grouting will significantly reduce the chance of soil movement near the top of the raise, ensuring long-term stability. Alternatives GA-3 and GA-4 will be very effective in the long-term if drilling and grouting programs can successfully locate and grout-off flows from the raise and roof leak. Since long-term effectiveness of rock fracture grouting can be lost with ground movement, Alternatives GA-3 and GA-4 can best be guaranteed by tightly backfilling the Glengarry drift in the vicinity of the grout curtains. Therefore, either Alternatives GA-5A or GA-5C should be combined with this alternative to ensure long-term effectiveness and permanence.

Alternatives GA-5A or GA-5C are crucial to guaranteeing long-term effectiveness of Alternative GA-6. Implementing Alternative GA-5A or GA-5C will permanently provide another barrier to water inflow into the Glengarry workings from the Fisher Mountain Porphyry. Alternative GA-6 should permanently eliminate the Glengarry Mine as a conduit transporting metal-laden groundwater from the Como Basin and Fisher Mountain Porphyry directly to Fisher Creek. If Alternative GA-6 is implemented, combining Alternative GA-2 would eliminate any issues with mixing high copper concentrations from the Como raise with low copper concentrations present in the other three underground inflows.

8.3.1.4 Reduction of Toxicity, Mobility, or Volume through Treatment

The mobility of metals will be substantially reduced by all of the alternatives, and choosing to combine alternatives can further enhance this reduction of mobility. The Glengarry Adit will no longer be a well-connected plumbing system for transporting metals-laden water directly from the Como Basin to Fisher Creek. While there will be no reduction in toxicity or volume, the Glengarry Adit will be eliminated as a point-source discharge for the acidic, metal-laden water from the Como Basin deposit and there will be a significant reduction in metal-loading to Fisher Creek on a year around basis.

8.3.1.5 Short-term Effectiveness

Short-term effectiveness for all the alternatives is about equal. The short-term environmental effects of the alternatives will be immediate.

8.3.2 IMPLEMENTABILITY

Each of the alternatives proposed are readily implemented. Existing and established technologies are available and have been proven and previously tested. There are some additional factors, however, that should be considered.

Success of grouting (i.e. constructing water-tight grout curtains) can be monitored as grout is pumped and the grouting program adjusted as necessary. Success of the grouting can be further determined by measuring flows during and after grouting to determine if additional grouting is required.

Alternatives GA-2 and GA-4 have a very good chance of success. Alternative GA- 4 will be much easier to complete and probably more effective than Alternative GA-3 because the location and approximate orientation of the structure to be grouted is known. Alternative GA-3 has a high risk of failure due to unknowns about the structure to be grouted and the potential for the bulkheads to become overloaded and collapse, potentially causing the release of mud or grout to the environment and hazardous or fatal conditions to grout crews working in the drift below.

Cemented backfill in mines has evolved into a very common practice in the last decade. It is used as a means of providing ground support by filling void spaces left in the ground by mining. Portal and drift plugs have been previously installed in abandoned underground mines. The greatest technical difficulty with Alternative GA-6 is pumping concrete to the plug sites. This will be accomplished either by pumping concrete from the portal site through a pipeline in the workings or by drilling boreholes from the plug location up to the surface and pumping concrete through the borehole to the plug.

8.3.3 COST

Table 8-2 lists the costs of the Glengarry Source Area Alternatives

TABLE 8-2
GLENGARRY SOURCE AREA ALTERNATIVES COST SUMMARY
New World Mining District Response and Restoration Project
Como Basin/Glengarry Adit/Fisher Creek Response Action

Alternative		Cost
GA-1	No Action	**$ 60,000**
GA-2	Grout Curtain Around Como Raise, Backfill and Plug Como Raise	**$ 532,000**
GA-3	Grout First Raise	**$ 694,000**
GA-4	Grout 1050 Roof Leak	**$ 620,000**
GA-5A	Backfill the Fisher Mountain Porphyry only	**$ 725,000**
GA-5B	Backfill the Precambrian Granite only	**$ 1,079,000**
GA-5C	Backfilling the Entire Workings	**$ 1,531,000**
GA-6	Plug Glengarry Drift at Critical Locations	**$ 792,000**

8.4 INTERACTION BETWEEN SOURCE AREAS

Loading analysis suggests that metal loading from the Glengarry Adit is most significant (more than 90 % of the total load as measured immediately below the mine site) during low flow conditions from early August to late May. Metal loading from the Como Basin is most significant during high flow conditions, late May through late July. Loading for many constituents during low flow is about a factor of 10 lower than that during high flow. Therefore, it would seem appropriate to complete the most desirable Removal Action on both the Como Basin and Glengarry Source Areas in order to minimize contaminant migration on a year-round basis (high and low flow conditions) from both sources. The combination of both should significantly and positively impact loading and water quality in the upper reaches of Fisher Creek and will likely have some positive impacts on groundwater.

A response action targeting the smaller waste rock dumps that remain in the Fisher Creek Source area are probably second or even third order in terms of impact to water quality, and there are no residual risks to unacceptable human health at these sites. Only the Glengarry waste rock dump appears from metals loading analyses to have a significant impact on water quality in Fisher Creek. Water quality degradation from the Gold Dust waste dump has also been documented, however, primarily due to seepage of water from the adit through the waste with a subsequent decrease in pH but no significant metal loading impacts.

8.5 COMPARISON OF ALTERNATIVE BY LOADING ESTIMATES

A quantitative comparison of alternatives for the Como Basin and the Glengarry Adit is presented in this section by using estimated reductions in loading of copper and iron at several points in Fisher Creek. The Fisher Creek Source Area alternatives are not compared here because there is not sufficient data on loading impacts from the individual mine sites to make a quantitative assessment.

8.5.1 Como Basin Source Area

The decrease in loading estimated to result from the various alternatives under consideration for the Como Basin is summarized in Table 8-3. In this table, the No Action Alternative is compared with in-situ amendment alternatives (CB-2A, 2B, and 2C) and the infiltration control alternatives (CB-3A, 3B, and 3C). Amendment options involving in-situ treatment for the Como Basin would result in load reductions ranging from 4% to 100%, (Table 8-3). These amendments use varying amounts of lime to treat the disturbed sediments to varying depths. The amount of loading reduction estimated for each of these alternatives (CB-2A, 4%; CB-2B, 12%; and CB-2C, 100%) is, therefore, proportional to the amount of material amended (Table 8-3). Alternative CB-3A involves amending the upper 30 cm of disturbed and contaminated soils and covers them with an imported soil cap that aids in the establishment of revegetation and optimizes evapotranspiration. This alternative has the potential to reduce loads to Fisher Creek by the proportion of wastes amended and also by decreasing seepage through disturbed soil. Estimated reduction to loading by this alternative is about 9%. For Alternative CB-3B that combines a geomembrane over and amended contaminated soil cap, and Alternative CB-3C, which places an imported soil cover over the geomembrane, the estimated reductions are 84% and 80% respectively. The net estimated reduction in load from the Como Basin is calculated by summing the load reduction estimated for both lime amendment treatment and seepage reduction (Table 8-3).

The load reduction in Fisher Creek is further evaluated at three locations: FCT-11; surface water Station FC-2, which is below the Glengarry Dump; and, surface water monitoring Station SW-3. Load reduction is estimated for two constituents of concern, copper and iron, at each location, under high flow conditions only. This is because under base flow conditions (late October through early May) there is little or no surface water flow out of the Como Basin and into FCT-11, and therefore there is no significant contribution from the Como Basin to loading in Fisher Creek (Figure 31). Because each of the proposed alternatives directly affects loading at FCT-11, the percent reductions shown are equal to the net predicted for each alternative. However, the estimated reductions decrease significantly with distance from FCT-11, due to the added load contributed to Fisher Creek from other downstream sources (Glengarry adit, Glengarry waste rock dump seepage, FCT-12, and diffuse groundwater sources).

Table 8-3.
Estimated Decrease in Loading in Fisher Creek Resulting from Como Basin Alternatives
Como Basin/Glengarry Adit/Fisher Creek Response Action EE/CA

Alt #	Description Alternative	Load Change from Alternatives					Estimated % Load Reduction to Fisher Creek							Cost
		Volume Treated		Infiltration/Seepage Rate (from precipitation)			Net Reduction Como Basin %	FCT-11		Below Glengarry Dumps		SW-3		
		cu m	%	in/yr	gpm	Decrease %		High Flow Cu	High Flow Fe	High Flow Cu	High Flow Fe	High Flow Cu	High Flow Fe	
1	No action	0	0%	21.4	6.1	0	0%	0%	0%	0%	0%	0%	0%	$37,300
2A	Shallow Amend	6660	4%	21.4	6.1	0%	4%	4%	4%	2%	2%	1%	0%	$461,652
2B	Deep Amend	22300	12%	21.4	6.1	0%	12%	12%	12%	5%	5%	2%	1%	$595,685
2C	Full Amend	190174	100%	21.4	6.1	0%	100%	100%	100%	43%	39%	17%	12%	$3,636,893
3A	Shallow Amend w/ soil	7359	4%	20.5	5.8	5%	9%	9%	9%	4%	3%	1%	1%	$903,907
3B	Geomembrane w/ Shallow Amend	7359	4%	4.1	1.2	80%	84%	84%	84%	36%	33%	14%	10%	$1,917,835
3C	Geomembrane w/ Soil Cover	0	0%	4.1	1.2	80%	80%	80%	80%	34%	32%	14%	10%	$1,999,854
Portion of load contributed by FCT-11								1.00	1.00	0.43	0.39	0.17	0.12	
Existing Load in lbs/year								256	1065	1279	5326	2132	8876	
Existing Load in lbs/day								0.7	2.9	3.5	14.6	5.8	24.3	

NOTES:

1. 80-90% is the estimated decrease in run-on for Alternatives CB-2 and CB-3. The reduction is assumed to be the same based on effective lined diversion ditches and so does not change the calculated values.
2. Reduction in lateral flow originating in bedrock through wastes is unknown and is not accounted for in this comparison.
3. Base flow is November through April (6 months) during which there is no flow in FCT-11 and, therefore, no decrease in load
4. High flow is mid June to Late July (1.5 months)
5. Approximately 40% of the load reporting to Fisher Creek Station SW-3 is from diffuse groundwater sources located between the Glengarry Portal and SW-3.
6. Load reduction to Fisher Creek is calculated as: net reduction in Como Basin x contribution from FCT-11 eliminated under management scenarios at each station under high and low flow conditions.
7. Existing loads presented for comparison only.
8. Portion of load contributed by FCT-11 shown for illustrative purposes only.

Calculations shown in Table 8-3 indicate that under the preferred alternative (CB-3B), 84% of the copper and iron loading at FCT-11 could be removed under high flow conditions, but that this would only result in a net reduction of 10% iron and 14% of the copper load downstream at SW-3. It also shows that a very minor additional reduction of 3% at SW-3 could be accomplished at an additional cost of almost $2 million by implementing Alternative CB-2C (assuming a 100% load reduction from the Como Basin by this alternative). A visual comparison of the calculated percentage reductions with the existing total loads shown in the table gives a sense of the actual magnitude in contaminant loading reduction that might be expected.

8.5.2 Glengarry Mine Source Area

A similar estimation of load reduction has been made for the preferred alternative for the Glengarry Adit, as shown in Table 8-4. There is not sufficient detail in the analytical data to evaluate the load reduction for each alternative by itself; however, some generalizations on loading were made in Section 8.3.1. The closure plan for the adit will likely eliminate discharge from the portal itself, but may result in diversion of groundwater into fracture systems that may result in diffuse discharge into Fisher Creek below the adit. As there is no reliable estimate of the degree to which this may occur, Table 8-4 presents three different scenarios that represent reductions in load from the adit to Fisher Creek of 100%, 50%, and 20%. As shown in Table 8-4, if the adit closure were to work ideally in eliminating any contribution from groundwater in the vicinity of the underground workings, nearly all loading would be eliminated during low flow periods immediately below the Glengarry Dump for both copper and iron. Under high flow conditions, when groundwater and tributary FCT-11 also contribute significant loads to Fisher Creek, effectiveness of Glengarry Adit closure would drop to 25% for copper and 60% for iron. The data presented in Table 8-4 show that the reduction below the dump would decrease significantly if groundwater discharge increased due to the adit closure. At SW-3, even less reduction in load will be observed. Comparison of these predictions with the actual load at SW-3 suggests that although the copper load could be reduced by as much as 40% under low flow conditions, the reduction in loading under high flow conditions when most load is transported will be relatively small (1 to 5%) for copper regardless of the adit closure efficiency. Removal efficiency would be better for iron, ranging from 8 to 40% depending upon the efficiency of the adit closure.

8.6 PREFERRED ALTERNATIVE

The preferred alternative for the Como Basin/Glengarry Adit/Fisher Creek Response Action is a combination of the alternatives discussed for each of the separate source areas. Only by combining the alternatives discussed will any real and substantial improvements in water quality be realized in Fisher Creek. The preferred alternative for each of the three source areas is discussed below.

8.6.1 Como Basin Source Area

All the alternatives evaluated provide some measure of mitigation to man-caused mining impacts. Given what is known about the source of metals impacts in Fisher Creek, the fact that natural sources contribute a considerable metals load to the creek via groundwater and surface water pathways, eliminating all metals impacts from mining related activities will not be possible. However, Alternatives CB-3B and CB-3C would be the most effective at reducing mining-related metals impacts, and both would lead to a significant reduction in metal loading to Fisher Creek. Each of these sub-alternatives uses a geomembrane liner in a composite cover system to confine and reduce the mobility of contaminants present in soils in the basin. Alternative CB-3B should not present significantly more

Table 8-4
Estimated Decrease in Loading in Fisher Creek Resulting from the Preferred Glengarry Adit Alternative
Como Basin/Glengarry Adit/Fisher Creek Response Action EE/CA

Load Reduction from Preferred Glengarry Adit Alternative (GA-2, -4, -5A, and -6)	Estimated % Decrease in Load in Fisher Creek Sites							
	Fisher Creek Below Waste Rock Dump				SW-3[2]			
	High Flow Cu	Low Flow Cu	High Flow Fe	Low Flow Fe	High Flow Cu	Low Flow Cu	High Flow Fe	Low Flow Fe
Removing 100% 0f the load	25.1	99.3	59.8	99.7	5.1	39.7	39.0	39.8
Removing 50% of Load[1]	12.5	49.7	29.9	49.9	2.6	19.9	19.5	19.9
Removing 20% of Load[1]	5.0	19.9	12.0	19.9	1.0	7.9	7.8	8.0
Existing Total Load at SW-3 in lbs/year[3]					2132.0	149.4	8876.0	1255.1
Existing Total Load at SW-3 in lbs/day[3]					5.8	0.4	24.3	3.4

NOTES:

1. Assumes cut off of flow from Glengarry Mines is diverted to preexisting fracture flow and that a percentage of the load eventually reports to Fisher Creek
2. Approximately 40% of the load reporting to Fisher Creek SW-3 is from diffuse groundwater sources located between the Glengarry Portal and SW-3.
3. Existing total loads shown for comparison purposes only.
4. Percent of loading at low flow compared to high flow for Cu and Fe, is 7 and 14% respectively.

difficulty in the establishment of a vegetative cover as compared with Alternative CB-3C as long as procedures established by the USDA-FS are followed. Alternative CB-3C will require obtaining a local source of soil material, which involves disturbance and reclamation of a borrow site. For these reasons, Alternative CB-3B is the preferred alternative for the Como Basin Source Area. The total cost to implement this alternative is $1,925,000.

8.6.2 Fisher Creek Source Area

Except for the Glengarry Dump and the Gold Dust Dump, there appears to be little major impact from the 43 remaining waste rock dumps located in Fisher Creek. There are no identified human health risks, and environmental risks appear to be associated with waste rock that is in contact with surface water and/or groundwater. This is the case at the Glengarry Dump, where loading of contaminants was determined to make up nearly 15% of the load delivered to Fisher Creek during low flow conditions. Part of the reason for this is the location of the dump at the mouth of the Glengarry Adit, where flows discharging from the adit eventually infiltrate through part of the waste dump. Another reason is the location of the dump in the Fisher Creek floodplain, where it is prone to nearly constant contact with Fisher Creek and groundwater levels that are influenced or controlled by Fisher Creek. The Glengarry Dump accounts for about 59% of the remaining waste rock in Fisher Creek.

The Gold Dust site is somewhat similar to the Glengarry Dump in that the Gold Dust waste rock sits at the mouth of the adit, and discharge from the adit and a tributary stream to Fisher Creek flow through the dump before entering another tributary to Fisher Creek. Impacts to surface water from the Gold Dust waste rock appear to be only slightly decreased pH values (about 5.5). The dump is also one of the larger remaining dumps, constituting 26% of the waste rock left in the remaining dumps. Together, the Glengarry and Gold Dust dumps contain 85% of the waste rock in Fisher Creek.

Other waste rock dumps and their associated mine sites lie topographically well above the valley bottom, in dry locations and present little threat to surface or groundwater quality (except for brief periods during active precipitation or snowmelt). Some of the sites, in addition to being high and dry, are also considered to be cultural or historic resources (e.g. Glengarry Mine and Millsite, Gold Dust Adit), or prime sites for mineral collecting (e.g. Homestake mine dumps and Homestake Pit).
Because of the nominal nature of recognized impacts from remaining dumps in Fisher Creek, and because the Glengarry and Gold Dust waste dumps constitute 85% of the waste rock, the preferred alternative for the Fisher Creek Source Area is Alternative FC-3 for all waste dumps except the Glengarry and Gold Dust dumps. Alternative FC-4, total removal to the SB-4B(B) repository, is selected for the Glengarry and Gold Dust dumps. Alternative FC-3, surface controls, appear to be suitable for implementation at other waste rock dumps, where runon controls may be sufficient to reduce the majority of environmental impacts, especially with regard to surface water quality, that is associated with these remaining sites.

8.6.3 Glengarry Source Area

The most effective means of closure for the Glengarry Mine involves a combination of Alternatives that attempt to minimize mobility of contaminants as inflow and outflow from the mine. These alternatives are also selected for their implementability, that also offers the most in terms of long-term effectiveness and permanency, and provide for the maxim protection of human health and the environment. Although there is a need for “back-up” systems, for example, backfilling of intervals of the workings around grout curtains or plugs, the choices of alternatives have been selected to minimize redundancy.

For these reason the following alternatives have been selected:

- GA-2, a surface grout curtain around the raise collar with a concrete plug in the raise below the Meagher limestone and backfilling of the raise;

- GA-4 a grout curtain around the 1050 roof leak;

- GA-5A backfilling of the drift with cemented backfill in the Fisher Mountain Porphyry portion of the drift; and

- GA-6 the placement of two water-tight plugs and a portal plug in the Glengarry drift.

Alternative GA-3 has not been selected as it has the least chance for success, is the most dangerous, and the flow of water from the top of the first raise can easily be stopped at the plug set in the Precambrian granite (the most distant plug into the mine). This will backup and confine water from the first raise into a very dry portion of the mine, and will also keep water from the Precambrian Granite from mixing with that from the Fisher Mountain Intrusive.

Finally, it is recommended that the closure of the Glengarry mine be executed as a two-year program that allows for testing and monitoring the success of the first season of work. Alternatives GA-2, GA-4, and part of Alternative GA-6, which would involve setting the first plug in the Precambrian granite. Monitoring of the success of these alternatives during the winter and spring of the following year would allow for any adjustments to be made before the second season of work is done. Backfilling the drift (GA-5) and setting the remaining plugs (GA-6) would be completed the second season of work. Estimated cost of the preferred alternative for the Glengarry Source Area is $2,666,000

8.6.4 Combined Alternatives Impacts to Loading

Upper Fisher Creek is characterized by highly variable flow with rapidly increasing flow rates and short periods of sustained flow during snowmelt. As much as 90% of Fisher Creek's discharge volume occurs between mid May and early August. Discharge rates near the upper reaches of Fisher Creek range from less than 0.3 m^3/s (1 cfs) in late winter to over 1.4 m^3/s (150 cfs) during peak runoff.

Metals loading investigations by Amacher (1998) and Kimball and others (1999) indicate that a few distinct surface water sources in the upper 500 meters of Fisher Creek supply the majority of the contaminant load to the creek. Results of Amacher's investigation indicate that the major sources of metals loading into Fisher Creek are:

- Outflow from the Glengarry adit (F-8A)
- A tributary draining the northeastern flank of Fisher Mountain (FCT-12)
- A tributary draining the Como basin (FCT-11)
- Seepage from the Glengarry adit waste rock dump (FC-2)

In general, the loading studies agree about the major inflow sources that contribute metals to Fisher Creek. Roughly half of the sources contributing metal loading into the creek have been identified as surface sources, with estimates ranging from 40 to 60%. Subsurface flows will prove difficult to remediate, as these flows do not seem to be associated with any particular mining-related activity, and could very well represent natural acidic drainage.

Amacher (1998) and Kimball and others (1999) noted that the relative contribution of the four major sources varied considerably from spring runoff to base flow conditions. The majority of contaminant loading to Fisher Creek occurs under peak flow conditions. Comparison of loads indicates that while the Glengarry adit dominates water chemistry during low flow conditions, tributaries FCT-11 and FCT-12 contribute the majority of the annual load during high flow conditions.

In May, under base flow conditions, Glengarry Adit discharge (FC-2) accounts for most of the dissolved copper load to upper Fisher Creek. As snowmelt begins in June and proceeds into July, runoff from Fisher Mountain (FCT-12) and Como Basin (FCT-11) accounts for most of dissolved copper load. In the fall, the Glengarry Adit again accounts for the majority of copper load. Metals load contribution from groundwater is significant during spring runoff, but cannot be quantified with the available data.

Using copper and iron as examples, based on the combined predicted affect for the preferred alternative for each of three source areas (composite cover on Como Basin soils, closure of the Glengarry adit and removal of the Glengarry waste rock dump), copper loading to Fisher Creek could be reduced by as much as 90% during low flow at a point immediately below the present location of the Glengarry waste rock dump, and by a considerably smaller amount at SW-3. This is true because there is no or very little flow in the tributaries from Fisher Mountain or the Como Basin (or two other small tributaries) under base-flow conditions and approximately 90% of the load then comes from the Glengarry adit and seepage through the waste rock dump. The remaining load is from groundwater sources that report to surface water flow measured at SW-3. During these flow conditions, both Kimball and Amacher's studies indicate that groundwater inflow to Fisher Creek between the Glengarry Mine and SW-3 contributes at least 35 to 45% of the total load to SW-3.

The total estimated load reduction for the preferred alternative, using the three estimates of adit closure efficiency of 100, 50 and 20%, is summarized for copper and iron under high and low flow conditions in Table 8-5. The cost of the preferred alternative is also presented. These calculated estimates show that copper removal will likely range from 8 to 40%, depending upon the amount of load rerouted by the adit closure into preexisting fractures that in turn report to Fisher Creek. Using the total annual load data for copper (2,132 lbs/year under high flow conditions or 149.4 lbs/year under low flow conditions), and assuming annual flow of 3 months per year at high flow and 9 months per year at low flow, the preferred alternative could remove as few as 18 pounds (20% efficiency) or as much as 146 pounds (100% efficiency) of copper per year. Similarly for iron loading, the calculated estimates show that iron removal will likely range from 8 to 49%, depending upon adit closure efficiency. Using the total annual load data for iron (8,876 lbs/year under high flow conditions or 1,255 lbs/year under low flow conditions), and assuming annual flow at 3 months per year at high flow and 9 months per year at low flow, the preferred alternative could remove as few as 94 pounds (20% efficiency) or as much as 1,462 pounds (100% efficiency) of copper per year.

8.6.5 COMBINED ALTERNATIVE COST

Table 8-6 presents the combined alternative cost for the preferred alternative. For Alternative FC-3 Modified, the cost of the removal and disposal of the Glengarry Dump in the SB-4B(B) repository was estimated to be 70% of the total estimated cost for Alternative FC-4, and then added to the FC-3 total cost. This cost is conservative because alternative GA-5A will use approximately 25% of the Glengarry Dump for the backfill of the Glengarry drift.

Table 8-5
Estimated Load Reduction at Station SW-3 Resulting from the Preferred Alternative
Como Basin/Glengarry Adit/Fisher Creek Response Action EE/CA

		High Flow Cu Load %	Low Flow Cu Load %	High Flow Fe Load %	Low Flow Fe Load %	Cost
Como Basin CB-3B	Geomembrane w/ shallow amend	14.0	0.0	10.0	0.0	$1,917,835
Glengarry Adit GA-2, 4, 5A, 6	Removing 100% 0f the Glengarry load	5.1	39.7	39.0	39.8	$2,669,000
	Total	**19.1**	**39.7**	**49.0**	**39.8**	$4,586,835
Como Basin CB-3B	Geomembrane w/ shallow amend	14.0	0.0	10.0	0.0	
Glengarry Adit GA-2, 4, 5A, 6	Removing 50% of Glengarry Load	2.6	19.9	19.5	19.9	
	Total	**16.6**	**19.9**	**29.5**	**19.9**	
Como Basin CB-3B	Geomembrane w/ shallow amend	14.0	0.0	10.0	0.0	
Glengarry Adit GA-2, 4, 5A, 6	Removing 20% of Glengarry Load	1.0	7.9	7.8	8.0	
	Total	**15.0**	**7.9**	**17.8**	**8.0**	

TABLE 8-6
SUMMARY OF ESTIMATED COSTS FOR THE PREFERRED ALTERNATIVE
New World Mining District Response and Restoration Project
Como Basin/Glengarry Adit/Fisher Creek Response Action

Preferred Alternative	Cost
Como Basin Source Area – CB-3B	$ 1,918,000
Fisher Creek Source Area – FC-3 (Modified for removal of the Glengarry and Gold Dust Waste Rock Dumps)	$ 2,010,000
Glengarry Adit Source Area (Combination of GA-2, GA-4, GA-5A, and GA-6)	$ 2,666,000
TOTAL ESTIMATED RESPONSE ACTION COST	**$ 6,594,000**

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APPENDIX A

SOURCE AREA SITE FORMS

Como Basin/Glengarry Adit/Fisher Creek Response Action EE/CA
New World Mining District Response and Restoration Project

APPENDIX B

HELP MODELING RUN RESULTS

Como Basin/Glengarry Adit/Fisher Creek Response Action EE/CA
New World Mining District Response and Restoration Project

HYDROLOGIC EVALUATION OF
COMO BASIN SOIL MATERIAL

Prepared for:

United States Department of Agriculture
Forest Service
Northern Region

Prepared by:

Maxim Technologies, Inc.
303 Irene Street
P.O. Box 4699
Helena, Montana 59604

March 2002

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1.0 INTRODUCTION

The purpose of this investigation was to estimate the amount of seepage (infiltration) percolating through unconsolidated soil material in the Como Basin area. The Hydrologic Evaluation of Landfill Performance (HELP) model was used for this estimation. The HELP model is a quasi-two-dimensional hydrologic model developed by the U.S. Army Corps of Engineers for the EPA that models water movement across, into, through, and out of landfills. The HELP Users Guide (Schroeder et. al., 1994) states, "The primary purpose of the model is to assist in the comparison of design alternatives as judged by their water balances." The analysis presented in this section characterizes the current conditions in the Como Basin. In addition to infiltration analysis, another intent of this investigation was to use the values calculated for infiltration in conjunction with water quality data as a check of loading data to Fisher Creek measured in the surface tributary FCT-11 that flows out of the Como Basin.

In the Como Basin area, nearby bedrock wells demonstrate significant large-scale water level fluctuations of as much as 21 meters (68 feet). These wells include MW-1 (14.6 meters, 48 feet of fluctuation), EPA-11 (20.7 meters, 68 feet), and EPA-12 (16.5 meters, 54 feet). No monitor wells are completed in the Como Basin colluvial and soils materials proper. It is estimated that water levels unconsolidated soil material in the Como Basin fluctuate on the order of 0.6 to 1.0 meters (2 to 3 feet) in elevation as is observed in the similar geologic setting of the McLaren Pit less than 1.6 kilometers (1 mile) to the south. This fluctuation suggests that the sulfide-bearing soils of the Como Basin may be subject to periodic oxidation with subsequent flushing of infiltration waters through the material. As a result of oxidation and chemical reaction with the wastes, water that has percolated through the waste may contain considerable acidity and large metal concentrations, and is a known source of groundwater and surface water contamination.

By quantifying the source of water (i.e. infiltration or groundwater inflows) in the basin, the impact to Fisher Creek from the basin can be determined. Due to the limited quantity of detailed, long-term hydrogeologic and climatic data available, the U.S. EPA HELP3 (Hydrologic Evaluation of Landfill Performance) model was chosen as the most appropriate model for calculation of a water balance for the unconsolidated material in the Como Basin. No wells are completed in the Como Basin; thus, there was no data with which to calibrate the model. Without site specific data, the McLaren Pit HELP3 model layout and design (Reference Here) was followed for the purposes of the Como Basin model, but Como Basin site specific dimensions were used

2.0 APPROACH

The approach used for this evaluation was to use site-specific information to predict the potential rate of seepage (infiltration) and runoff through the unconsolidated soil material. The model used for this study was the U.S. EPA HELP3 (Hydrologic Evaluation of Landfill Performance) model. Although generally used for landfills, the HELP3 model has also been successfully used for a variety of mining-related projects. HELP3 is a quasi-two dimensional mass-balance model used to estimate the movement of water into and through a waste pile. Although HELP3 relies on analytical or semi-analytical approximations, experience has indicated that when properly applied and interpreted, HELP3 results are often similar to results obtained using more rigorous numerical techniques. Due to the limited quantity of data available, the HELP model was the most appropriate approach to calculate a water balance for the Como Basin.

3.0 INPUT PARAMETERS AND CALIBRATION TARGETS

Implementation of a HELP3 model requires the following input parameters or variables to be defined:

- Climatic information, including daily precipitation, daily solar radiation, and daily mean temperature
- Evapo-transpiration information, including maximum leaf area index (LAI), and starting and ending dates for growing season
- Design information, including layer types and thickness
- Soil material properties in each layer, including porosity, field capacity, wilting point, saturated hydraulic conductivity, initial water content and SCS curve number.

Values used for each of these input parameters are discussed below.

3.1 Climatic Information

The HELP model requires general climate data for computing potential evapotranspiration; daily climatologic data; soil characteristics; and design specifications to perform the analysis. The required general climate data include growing season, average annual wind speed, average quarterly relative humidity's, normal mean monthly temperatures, maximum leaf area index, evaporative zone depth and latitude.

3.1.1 Precipitation and Mean Daily Temperature

Daily precipitation and mean Daily temperature data for this model were taken from the HELP3 model for the McLaren Pit (Maxim, 2002: Mclaren EECA) in 2001. A SNOTEL site is maintained by the US Forest Service on Fisher Creek (Station FSHM8, station elevation = 9,100 feet) and is located 700 feet down Fisher Creek from the Como Basin. Although the Como Basin and the Fisher Creek SNOTEL site are in close proximity to each other, it was anticipated that a direct daily comparison of measured precipitation data could be problematic because of differences in elevation, prevailing wind directions and local topography. Precipitation and temperature data used for the McLaren Pit model were compared to measured precipitation and temperature values at five nearby SNOTEL sites including the Fisher Creek SNOTEL site. The Como Basin and McLaren Pit are close enough in proximity and at the same elevation to assume that the precipitation and temperature data would be similar enough for the purposes of this model.

3.1.2 Solar Radiation

Default solar radiation data from Billings Montana was used as an input term. Station latitude was set to the approximate site latitude of 45.08 degrees.

3.1.3 SCS Curve Number

An SCS curve number of 70 was used in this modeling effort.

3.1.4 Percent of area allowing runoff

Area allowing runoff used in this model was 50 percent. The McLaren Pit model was calibrated to water levels in wells completed in the waste rock. It was found during the calibration process that area-allowing runoff needed to be reduced from 100% to 50% for proper calibration of the model (Maxim, 2002; McLaren EECA, Appendix A).

3.1.5 Leaf Area Index

A value of 0.1 was used for the leaf area index to simulate the relative lack of vegetation in the Como Basin. This may be somewhat conservative given the fact that there is currently a limited amount of grass cover in the Como Basin.

3.1.6 Growing Season

A growing season should be expected to extend from Julian day 214 (July 1) to 278 (September 3). However, since the leaf area index is near 0, this likely has no impact on the model results.

3.2 Design Parameters

3.2.1 Soil Material Properties

Soil material properties for the unconsolidated soils of the Como Basin were taken from the Help Model for the McLaren Pit (Maxim, 2002; Mclaren EECA). Four samples of unconsolidated material from the McLaren Pit were collected and submitted for unsaturated hydraulic characteristics testing. In addition, a series of infiltration tests were also conducted at the McLaren Mine site.

3.2.2 Physical Domain Properties

A physical model domain was created using approximately 3.4 meters (11 feet (132) inches) of soil underlain by approximately 15 centimeters (6 inches) of a barrier soil layer. The actual backfill thickness varies from 0 to 10.7 meters (0 to 35 feet). However, an average overall depth of 3.4 meters (11 feet) was determined from various drill holes in the soil material. The barrier soil layer (relatively impermeable layer) was included to model the more limited flow potential from fracture controlled secondary permeability within the bedrock system underlying the Como Basin soils. Unsaturated hydraulic characteristics for the bedrock system were taken from literature values (Tindall, 1999). Model input parameters are summarized in Table 1.

TABLE 1
Summary of HELP3 Model Input Parameters Selected for Soil Material

Parameter	Waste rock	Barrier Soil Layer
Layer Type	Vertical Percolation	Barrier Soil
Layer Thickness (inches)	132 total	6
Porosity	0.4820	0.10
Field Capacity (vol/vol)	0.2950	0.0031
Wilting Point (vol/vol)	0.1770	0.0030
Saturated Hydraulic Conductivity (cm/sec)	1.8E-5	1E-7
Initial Water content (vol/vol)	0.377	0.1

4.0 RESULTS

Results of the modeling effort are presented in Table 2 with the model runs presented in Appendix A. Results show that seepage or drainage rate predicted through the disposal areas varies according to conditions of remediation. In the current state, seepage averages 6.1 gallons per minute (gpm). A 24-inch soil layer on top of the basin only drops the seepage rate to 5.8 gpm. In order to diminish the seepage rate considerably, a geomembrane layer in needed under the 24-inch soil layer. This drops the seepage rate to 0.97 gpm.

Table 2
Conditions for HELP Modeling of Infiltration Through Como Basin Soils

Condition	Annual Precipitation (inches)	Evapo-Transpiration (in/yr)	Run-off (in/yr)	Seepage (in/yr)	Seepage (gpm)
Existing Condition	54.07	15.8	16.8	21.4	6.1
24 Inch Soil Barrier Layer	54.07	15.8	16.8	20.5	5.8
Geomembrane Under 24 Inch Soil Layer	54.07	16.9	33.8	3.4	0.97

5.0 SENSITIVITY ANALYSIS

A qualitative sensitivity analysis was performed to identify which parameters have significant influence on the model results. The parameters included in the sensitivity analysis included thickness of the top soil layer (24 vs. 36 inches) on top of geomembrane, and soil texture of basin fill.

The model did not prove sensitive to either of these parameters tested. Increasing the soil layer thickness from 24 to 36 inches actually increased the amount of seepage from 0.97 gpm to 1.32 gpm. This can be accounted for because the thicker soil layer allows for more moisture to escape the processes of evapotranspiration. Increasing and decreasing the hydraulic conductivity in the model of the basin fill changed the seepage rate less than 0.1 gpm.

6.0 CONCLUSIONS

The HELP model described in this report was developed to help identify and evaluate the amount of seepage percolating through unconsolidated material in the Como Basin Results of the model show that the seepage or drainage rate predicted through the disposal will be decreased significantly by the installation of a geomembrane overlain by a soil layer. The sensitivity analysis indicates that the model adequately represents the model domain as we understand it and when various model input parameters are changed, the final results of the model are not greatly affected. Models are designed as interpretive tools, not as a means to a precise answer. Error associated with model predictions has not been quantified. Although the model could not be calibrated to known field conditions, as there is not a system of monitoring wells in the basin, the task of providing a good estimate of seepage rates over the next 50 years was met.

7.0 REFERENCES

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APPENDIX A

Help Output Files

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**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)                **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************


PRECIPITATION DATA FILE:    J:\NEWWORLD\COMO_E~1\HELP\COMO4.D4
TEMPERATURE DATA FILE:      J:\NEWWORLD\COMO_E~1\HELP\COMO7.D7
SOLAR RADIATION DATA FILE:  J:\NEWWORLD\COMO_E~1\HELP\COMO13.D13
EVAPOTRANSPIRATION DATA:    J:\NEWWORLD\COMO_E~1\HELP\COMO11.D11
SOIL AND DESIGN DATA FILE:  J:\NEWWORLD\COMO_E~1\HELP\COMOSL.D10
OUTPUT DATA FILE:           J:\NEWWORLD\COMO_E~1\HELP\comosl22.OUT


TIME:  10:46     DATE:   4/24/2002


******************************************************************************

     TITLE:  COMO PIT

******************************************************************************


     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
              COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                   LAYER  1
                                   --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER   6
           THICKNESS                 =    24.00   INCHES
           POROSITY                  =     0.4530 VOL/VOL
           FIELD CAPACITY            =     0.1900 VOL/VOL
           WILTING POINT             =     0.0850 VOL/VOL
           INITIAL SOIL WATER CONTENT  =     0.2134 VOL/VOL
           EFFECTIVE SAT. HYD. COND.   =  0.720000011000E-03 CM/SEC
         NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  1.06
                FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.
```

LAYER 2

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 0

THICKNESS	=	132.00 INCHES
POROSITY	=	0.4820 VOL/VOL
FIELD CAPACITY	=	0.2950 VOL/VOL
WILTING POINT	=	0.1770 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.2941 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.999999978000E-02 CM/SEC

LAYER 3

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 0

THICKNESS	=	6.00 INCHES
POROSITY	=	0.1000 VOL/VOL
FIELD CAPACITY	=	0.0031 VOL/VOL
WILTING POINT	=	0.0030 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.1000 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.180000006000E-04 CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS USER-SPECIFIED.

SCS RUNOFF CURVE NUMBER	=	70.00	
FRACTION OF AREA ALLOWING RUNOFF	=	50.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	5.500	ACRES
EVAPORATIVE ZONE DEPTH	=	26.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	5.596	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	11.836	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	2.394	INCHES
INITIAL SNOW WATER	=	3.970	INCHES
INITIAL WATER IN LAYER MATERIALS	=	44.546	INCHES
TOTAL INITIAL WATER	=	48.516	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
BILLINGS MONTANA

STATION LATITUDE	=	45.80 DEGREES
MAXIMUM LEAF AREA INDEX	=	0.10
START OF GROWING SEASON (JULIAN DATE)	=	130
END OF GROWING SEASON (JULIAN DATE)	=	278
EVAPORATIVE ZONE DEPTH	=	26.0 INCHES
AVERAGE ANNUAL WIND SPEED	=	11.30 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	59.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	54.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	47.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	58.00 %

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR BILLINGS MONTANA

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
5.50	2.90	7.00	10.50	4.70	2.60
2.20	1.70	2.90	2.70	5.70	6.60

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR BILLINGS MONTANA

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
12.40	15.00	20.90	25.90	35.00	44.30
49.30	49.90	42.20	33.30	22.40	15.60

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR BILLINGS MONTANA
AND STATION LATITUDE = 45.80 DEGREES

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 50

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	5.27	2.89	6.50	9.81	4.89	2.57

	2.57	1.77	2.68	2.81	6.00	6.30
STD. DEVIATIONS	2.62	1.59	3.32	4.80	2.28	0.97
	1.38	1.12	1.94	1.60	3.90	3.78

RUNOFF

TOTALS	0.000	0.022	1.403	5.820	6.581	2.698
	0.028	0.000	0.002	0.011	0.161	0.057
STD. DEVIATIONS	0.000	0.073	2.164	4.533	3.824	4.389
	0.196	0.000	0.008	0.030	0.297	0.216

EVAPOTRANSPIRATION

TOTALS	0.796	0.733	0.836	0.965	1.404	2.951
	2.468	1.781	1.820	1.352	0.760	0.800
STD. DEVIATIONS	0.122	0.131	0.127	0.303	0.763	0.880
	1.284	1.003	0.991	0.634	0.270	0.196

PERCOLATION/LEAKAGE THROUGH LAYER 3

TOTALS	0.0000	0.0000	0.2079	3.0855	7.1816	8.2479
	0.6089	0.1413	0.2412	0.5272	0.3065	0.0018
STD. DEVIATIONS	0.0000	0.0000	0.8262	3.5727	4.5487	6.2047
	1.9050	0.1241	0.5695	0.8929	0.7993	0.0124

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 3

AVERAGES	0.0000	0.0000	0.0086	0.2114	0.4711	0.8057
	0.0412	0.0026	0.0048	0.0100	0.0060	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0363	0.4559	0.5118	0.8167
	0.2455	0.0023	0.0113	0.0169	0.0157	0.0002

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 50

	INCHES	CU. FEET	PERCENT
PRECIPITATION	54.07 (9.731)	1079427.6	100.00
RUNOFF	16.783 (5.4592)	335064.84	31.041

EVAPOTRANSPIRATION	16.666 (2.7786)	332732.09	30.825
PERCOLATION/LEAKAGE THROUGH LAYER 3	20.54977 (5.25077)	410276.156	38.00868
AVERAGE HEAD ON TOP OF LAYER 3	0.130 (0.064)		
CHANGE IN WATER STORAGE	0.068 (9.6503)	1354.71	0.126

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 50

	(INCHES)	(CU. FT.)
PRECIPITATION	9.52	190066.812
RUNOFF	6.724	134251.0160
PERCOLATION/LEAKAGE THROUGH LAYER 3	3.426150	68403.07810
AVERAGE HEAD ON TOP OF LAYER 3	27.575	
SNOW WATER	46.81	934515.1250
MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.4552	
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.1233	

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FINAL WATER STORAGE AT END OF YEAR 50

LAYER	(INCHES)	(VOL/VOL)
1	5.6368	0.2349
2	38.8127	0.2940
3	0.6000	0.1000
SNOW WATER	6.859	

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**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)                **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**               FOR USEPA RISK REDUCTION ENGINEERING LABORATORY            **
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PRECIPITATION DATA FILE:    J:\NEWWORLD\COMO_E~1\HELP\COMO4.D4
TEMPERATURE DATA FILE:      J:\NEWWORLD\COMO_E~1\HELP\COMO7.D7
SOLAR RADIATION DATA FILE:  J:\NEWWORLD\COMO_E~1\HELP\COMO13.D13
EVAPOTRANSPIRATION DATA:    J:\NEWWORLD\COMO_E~1\HELP\COMO11.D11
SOIL AND DESIGN DATA FILE:  J:\NEWWORLD\COMO_E~1\HELP\C_2LAY2.D10
OUTPUT DATA FILE:           J:\NEWWORLD\COMO_E~1\HELP\c_2lay2.OUT


TIME:  10:26     DATE:   4/24/2002


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     TITLE:  COMO PIT

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     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
              COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                   LAYER  1
                                   --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER   0
           THICKNESS                   =    132.00   INCHES
           POROSITY                    =      0.4820 VOL/VOL
           FIELD CAPACITY              =      0.2950 VOL/VOL
           WILTING POINT               =      0.1770 VOL/VOL
           INITIAL SOIL WATER CONTENT  =      0.2894 VOL/VOL
           EFFECTIVE SAT. HYD. COND.   =  0.999999978000E-02 CM/SEC
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LAYER 2

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 0

THICKNESS	=	6.00	INCHES
POROSITY	=	0.1000	VOL/VOL
FIELD CAPACITY	=	0.0031	VOL/VOL
WILTING POINT	=	0.0030	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.1000	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.180000006000E-04	CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS USER-SPECIFIED.

SCS RUNOFF CURVE NUMBER	=	70.00	
FRACTION OF AREA ALLOWING RUNOFF	=	50.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	5.500	ACRES
EVAPORATIVE ZONE DEPTH	=	26.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	6.927	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	12.532	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	4.602	INCHES
INITIAL SNOW WATER	=	3.970	INCHES
INITIAL WATER IN LAYER MATERIALS	=	38.797	INCHES
TOTAL INITIAL WATER	=	42.767	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
BILLINGS MONTANA

STATION LATITUDE	=	45.80	DEGREES
MAXIMUM LEAF AREA INDEX	=	0.10	
START OF GROWING SEASON (JULIAN DATE)	=	130	
END OF GROWING SEASON (JULIAN DATE)	=	278	
EVAPORATIVE ZONE DEPTH	=	26.0	INCHES
AVERAGE ANNUAL WIND SPEED	=	11.30	MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	59.00	%
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	54.00	%
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	47.00	%
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	58.00	%

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING

COEFFICIENTS FOR   BILLINGS   MONTANA

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
5.50	2.90	7.00	10.50	4.70	2.60
2.20	1.70	2.90	2.70	5.70	6.60

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR   BILLINGS   MONTANA

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
12.40	15.00	20.90	25.90	35.00	44.30
49.30	49.90	42.20	33.30	22.40	15.60

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR   BILLINGS   MONTANA
AND STATION LATITUDE = 45.80 DEGREES

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS   1 THROUGH   50

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	5.27	2.89	6.50	9.81	4.89	2.57
	2.57	1.77	2.68	2.81	6.00	6.30
STD. DEVIATIONS	2.62	1.59	3.32	4.80	2.28	0.97
	1.38	1.12	1.94	1.60	3.90	3.78
RUNOFF						
TOTALS	0.000	0.021	1.393	5.830	6.576	2.698
	0.028	0.000	0.001	0.009	0.150	0.058
STD. DEVIATIONS	0.000	0.071	2.162	4.549	3.842	4.389
	0.196	0.000	0.003	0.024	0.287	0.221
EVAPOTRANSPIRATION						
TOTALS	0.796	0.733	0.835	0.924	1.263	2.322
	2.450	1.781	1.831	1.350	0.762	0.800

STD. DEVIATIONS	0.122	0.131	0.127	0.216	0.671	1.006
	1.300	1.085	1.034	0.648	0.270	0.196

PERCOLATION/LEAKAGE THROUGH LAYER 2

TOTALS	0.0000	0.0000	0.3216	3.5192	8.1722	8.0852
	0.2845	0.0142	0.1953	0.4255	0.3746	0.0000
STD. DEVIATIONS	0.0000	0.0000	1.1911	4.0256	4.9417	7.1224
	1.7541	0.0223	0.5323	0.8572	0.8162	0.0000

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 2

AVERAGES	0.0000	0.0000	0.0280	0.2996	0.8268	1.2010
	0.0469	0.0004	0.0044	0.0084	0.0075	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.1386	0.5955	0.8092	1.1322
	0.3252	0.0005	0.0119	0.0167	0.0160	0.0000

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 50

	INCHES	CU. FEET	PERCENT
PRECIPITATION	54.07 (9.731)	1079427.6	100.00
RUNOFF	16.763 (5.4534)	334680.50	31.005
EVAPOTRANSPIRATION	15.845 (2.8145)	316350.69	29.307
PERCOLATION/LEAKAGE THROUGH LAYER 2	21.39235 (5.26089)	427098.281	39.56711
AVERAGE HEAD ON TOP OF LAYER 2	0.202 (0.069)		
CHANGE IN WATER STORAGE	0.065 (9.6140)	1298.28	0.120

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 50

	(INCHES)	(CU. FT.)
PRECIPITATION	9.52	190066.812
RUNOFF	6.724	134251.0160
PERCOLATION/LEAKAGE THROUGH LAYER 2	3.920016	78263.12500
AVERAGE HEAD ON TOP OF LAYER 2	32.414	
SNOW WATER	46.81	934515.1250
MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.4820	
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.1857	

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FINAL WATER STORAGE AT END OF YEAR 50

LAYER	(INCHES)	(VOL/VOL)
1	38.5593	0.2921
2	0.6000	0.1000
SNOW WATER	6.859	

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**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)                **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**              FOR USEPA RISK REDUCTION ENGINEERING LABORATORY             **
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PRECIPITATION DATA FILE:    J:\NEWWORLD\COMO_E~1\HELP\COMO4.D4
TEMPERATURE DATA FILE:      J:\NEWWORLD\COMO_E~1\HELP\COMO7.D7
SOLAR RADIATION DATA FILE:  J:\NEWWORLD\COMO_E~1\HELP\COMO13.D13
EVAPOTRANSPIRATION DATA:    J:\NEWWORLD\COMO_E~1\HELP\COMO11.D11
SOIL AND DESIGN DATA FILE:  J:\NEWWORLD\COMO_E~1\HELP\COMOGEO.D10
OUTPUT DATA FILE:           J:\NEWWORLD\COMO_E~1\HELP\comogeo1.OUT


TIME:  10:22     DATE:   4/24/2002


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     TITLE:  COMO PIT

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     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
              COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                   LAYER  1
                                   --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER   6
           THICKNESS                  =     24.00   INCHES
           POROSITY                   =      0.4530 VOL/VOL
           FIELD CAPACITY             =      0.1900 VOL/VOL
           WILTING POINT              =      0.0850 VOL/VOL
           INITIAL SOIL WATER CONTENT =      0.4302 VOL/VOL
           EFFECTIVE SAT. HYD. COND.  =  0.720000011000E-03 CM/SEC
         NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  1.06
                FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.
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                         LAYER  2
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            TYPE 4 - FLEXIBLE MEMBRANE LINER
              MATERIAL TEXTURE NUMBER  35
THICKNESS                    =      0.06   INCHES
POROSITY                     =      0.0000 VOL/VOL
FIELD CAPACITY               =      0.0000 VOL/VOL
WILTING POINT                =      0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.199999996000E-12 CM/SEC
FML PINHOLE DENSITY          =      1.00   HOLES/ACRE
FML INSTALLATION DEFECTS     =      3.00   HOLES/ACRE
FML PLACEMENT QUALITY        =  3 - GOOD


                         LAYER  3
                         --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER   0
THICKNESS                    =    132.00   INCHES
POROSITY                     =      0.4820 VOL/VOL
FIELD CAPACITY               =      0.2950 VOL/VOL
WILTING POINT                =      0.1770 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.2950 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.999999978000E-02 CM/SEC


                         LAYER  4
                         --------

              TYPE 3 - BARRIER SOIL LINER
              MATERIAL TEXTURE NUMBER   0
THICKNESS                    =      6.00   INCHES
POROSITY                     =      0.1000 VOL/VOL
FIELD CAPACITY               =      0.0031 VOL/VOL
WILTING POINT                =      0.0030 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.1000 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.180000006000E-04 CM/SEC


        GENERAL DESIGN AND EVAPORATIVE ZONE DATA
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NOTE:  SCS RUNOFF CURVE NUMBER WAS USER-SPECIFIED.
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SCS RUNOFF CURVE NUMBER	=	70.00	
FRACTION OF AREA ALLOWING RUNOFF	=	50.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	5.500	ACRES
EVAPORATIVE ZONE DEPTH	=	24.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	10.325	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	10.872	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	2.040	INCHES
INITIAL SNOW WATER	=	3.970	INCHES
INITIAL WATER IN LAYER MATERIALS	=	49.865	INCHES
TOTAL INITIAL WATER	=	53.835	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
BILLINGS MONTANA

STATION LATITUDE	=	45.80	DEGREES
MAXIMUM LEAF AREA INDEX	=	0.10	
START OF GROWING SEASON (JULIAN DATE)	=	130	
END OF GROWING SEASON (JULIAN DATE)	=	278	
EVAPORATIVE ZONE DEPTH	=	24.0	INCHES
AVERAGE ANNUAL WIND SPEED	=	11.30	MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	59.00	%
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	54.00	%
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	47.00	%
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	58.00	%

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR BILLINGS MONTANA

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
5.50	2.90	7.00	10.50	4.70	2.60
2.20	1.70	2.90	2.70	5.70	6.60

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR BILLINGS MONTANA

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
12.40	15.00	20.90	25.90	35.00	44.30
49.30	49.90	42.20	33.30	22.40	15.60

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR BILLINGS MONTANA
AND STATION LATITUDE = 45.80 DEGREES

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 50

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	5.27	2.89	6.50	9.81	4.89	2.57
	2.57	1.77	2.68	2.81	6.00	6.30
STD. DEVIATIONS	2.62	1.59	3.32	4.80	2.28	0.97
	1.38	1.12	1.94	1.60	3.90	3.78
RUNOFF						
TOTALS	0.001	0.041	2.924	11.340	12.923	5.496
	0.112	0.002	0.125	0.178	0.490	0.134
STD. DEVIATIONS	0.005	0.114	4.299	8.786	7.426	8.779
	0.569	0.014	0.494	0.384	0.794	0.453
EVAPOTRANSPIRATION						
TOTALS	0.796	0.733	0.830	0.930	1.481	3.067
	2.473	1.812	1.804	1.353	0.770	0.801
STD. DEVIATIONS	0.122	0.131	0.137	0.339	0.774	0.872
	1.327	1.009	1.018	0.619	0.269	0.194
PERCOLATION/LEAKAGE THROUGH LAYER 2						
TOTALS	0.0928	0.0772	0.1398	0.2815	0.4149	0.4946
	0.4494	0.4041	0.3776	0.3738	0.2027	0.1070
STD. DEVIATIONS	0.0052	0.0046	0.0788	0.1213	0.1149	0.0552
	0.0357	0.0311	0.0484	0.1100	0.1266	0.0179
PERCOLATION/LEAKAGE THROUGH LAYER 4						
TOTALS	0.0928	0.0772	0.1398	0.2815	0.4149	0.4946
	0.4494	0.4041	0.3776	0.3738	0.2027	0.1070
STD. DEVIATIONS	0.0052	0.0046	0.0788	0.1213	0.1149	0.0552
	0.0357	0.0311	0.0484	0.1100	0.1266	0.0179

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 2

AVERAGES	3.1685	2.8463	4.8872	10.5348	15.1716	19.0746
	17.0041	15.3771	14.8416	14.0794	7.6310	3.7277
STD. DEVIATIONS	0.2080	0.1900	2.9427	4.6879	4.2791	2.0290
	1.2549	1.1215	1.7967	4.0982	4.9011	0.6756

DAILY AVERAGE HEAD ON TOP OF LAYER 4

AVERAGES	0.0020	0.0018	0.0030	0.0063	0.0089	0.0110
	0.0097	0.0087	0.0084	0.0081	0.0045	0.0023
STD. DEVIATIONS	0.0001	0.0001	0.0017	0.0027	0.0025	0.0012
	0.0008	0.0007	0.0011	0.0024	0.0028	0.0004

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 50

	INCHES	CU. FEET	PERCENT
PRECIPITATION	54.07 (9.731)	1079427.6	100.00
RUNOFF	33.766 (10.7412)	674141.44	62.454
EVAPOTRANSPIRATION	16.848 (2.8228)	336378.22	31.163
PERCOLATION/LEAKAGE THROUGH LAYER 2	3.41554 (0.31526)	68191.172	6.31735
AVERAGE HEAD ON TOP OF LAYER 2	10.695 (0.999)		
PERCOLATION/LEAKAGE THROUGH LAYER 4	3.41554 (0.31526)	68191.172	6.31735
AVERAGE HEAD ON TOP OF LAYER 4	0.006 (0.001)		
CHANGE IN WATER STORAGE	0.036 (9.5707)	717.06	0.066

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 50

	(INCHES)	(CU. FT.)
PRECIPITATION	9.52	190066.812
RUNOFF	10.467	208969.0160
PERCOLATION/LEAKAGE THROUGH LAYER 2	0.021115	421.56345
AVERAGE HEAD ON TOP OF LAYER 2	24.000	
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.021115	421.56345
AVERAGE HEAD ON TOP OF LAYER 4	0.014	
SNOW WATER	47.22	942756.6250
MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.4530	
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.2861	

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FINAL WATER STORAGE AT END OF YEAR 50

LAYER	(INCHES)	(VOL/VOL)
1	9.2315	0.3846
2	0.0000	0.0000
3	38.9400	0.2950
4	0.6000	0.1000
SNOW WATER	6.859	

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APPENDIX C

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARS)

Como Basin/Glengarry Adit/Fisher Creek Response Action EE/CA

New World Mining District Response and Restoration Project

Identification of Applicable or Relevant and Appropriate Requirements Como Basin/Glengarry Adit/Fisher Creek Response Action			
Standard, Requirement Criteria Or Limitation	**Citation**	**Description**	**ARAR Status**
FEDERAL CONTAMINANT-SPECIFIC			
Safe Drinking Water Act National Primary Drinking Water Regulation	40 USC § 300 40 CFR Part 141	Establishes health-based standards (MCLs) for public water systems.	Relevant and Appropriate
National Secondary Drinking Water Regulations	40 CFR Part 143	Establishes welfare-based standards (secondary MCLs) for public water systems.	Relevant and Appropriate
Clean Water Act Water Quality Standards	33 USC. §§ 1251-1387 40 CFR Part 131 Quality Criteria for Water 1976, 1980, 1986	Ch. 26- Water Pollution Prevention & Control Sets criteria for water quality based on toxicity to aquatic organisms and human health.	Relevant and Appropriate
FEDERAL LOCATION-SPECIFIC			
National Historic Preservation Act	16 USC § 470; 36 CFR Part 800; 40 CFR Part 6.310(b)	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 and to minimize harm to any National Historic Landmark adversely or directly affected by an undertaking.	Applicable
Archaeological and Historic Preservation Act	16 USC § 469; 40 CFR ' 6.301(c)	Establishes procedures to provide for preservation of historical and archaeological data which might be destroyed through alteration of terrain as a result of a Federal construction project or a Federally licensed activity or program.	Applicable
Historic Sites, Buildings and Antiquities Act	36 CFR § 62.6(d)	Requires Federal agencies to consider the existence and location of landmarks on the National Registry of Natural Landmarks to avoid undesirable impacts on such landmarks.	Applicable
Protection of Wetlands Order	40 CFR Part 6	Avoid adverse impacts to wetlands.	Applicable
Migratory Bird Treaty Act	16 USC § 703 et seq.	Establishes a federal responsibility for the protection of international migratory bird resource.	Applicable

Identification of Applicable or Relevant and Appropriate Requirements Como Basin/Glengarry Adit/Fisher Creek Response Action			
Standard, Requirement Criteria Or Limitation	**Citation**	**Description**	**ARAR Status**
FEDERAL LOCATION-SPECIFIC (continued)			
Fish and Wildlife Coordination Act	16 USC § 661 et seq.; 40 CFR Part 6.302(g)	Requires consultation when Federal department or agency proposes or authorizes any modification of any stream or other water body and adequate provision for protection of fish and wildlife resources.	Applicable
Floodplain Management Order	40 CFR Part 6	Requires Federal agencies to evaluate the potential effects of actions they may take in a floodplain to avoid the adverse impacts associated with direct and indirect development of a floodplain, to the extent possible.	Relevant and Appropriate
Bald Eagle Protection Act	16 USC §§ 668 et seq.	Establishes a federal responsibility for protection of bald and golden eagles. Requires consultation with the USFWS.	Applicable
Endangered Species Act	16 USC §§ 1531-1543; 40 CFR Part 6.302(h); 50 CFR Part 402	Requires action to conserve endangered species within critical habitat upon which species depend. Includes consultation with Dept. of Interior.	Applicable
FEDERAL ACTION-SPECIFIC			
Clean Water Act National Pollutant Discharge Elimination System	33 USC §§ 1251-1387 40 CFR Parts 121, 122, 125	Requires permits for the discharge of pollutants from any point source into waters of the United States.	Relevant and Appropriate
Clean Air Act National Primary and Secondary Ambient Air Quality Standards	42 USC § 7409;40 CFR Part 50.12	Air quality levels that protect public health.	Applicable
Surface Mining Control and Reclamation Act	30 CFR Parts 816, 784	Reclamation requirements for coal and certain non-coal mining.	Not Applicable
Resource Conservation and Recovery Act	42 USC § 6901	Defines those solid wastes that are subject to regulation as hazardous wastes under 40 CFR Parts 262-265 and Parts 124, 270 and 271.	Not Applicable
	40 CFR Part 257.3	Governs waste handling and disposal	Applicable
	40 CFR Part 264.228	Provisions regarding run-on and run-off controls	Applicable

Identification of Applicable or Relevant and Appropriate Requirements Como Basin/Glengarry Adit/Fisher Creek Response Action			
Standard, Requirement Criteria Or Limitation	**Citation**	**Description**	**ARAR Status**
FEDERAL ACTION-SPECIFIC (continued)			
Occupational Safety And Health Act Hazardous Waste Operations And Emergency Response	29 USC § 655 29 CFR 1910.120	Defines standards for employee protection during initial site characterization and analysis, monitoring activities, materials handling activities, training & ER.	Applicable
STATE CONTAMINANT-SPECIFIC			
Montana Water Quality Act	75-5-101 et seq., MCA	Establishes Montana's laws to prevent, abate and control the pollution of state waters.	Applicable
	ARM 17.30.601 et seq.	Provides the water use classification for various streams and imposes specific water quality standards per classification.	Applicable
Regulations Establishing Ambient Surface Water Quality Standards	ARM 17.30.637	Provides that surface waters must be free of substances attributable to industrial practices or other discharges that will: (a) settle to form objectionable sludge deposits or emulsions beneath the surface of the water or upon adjoining shorelines; (b) create floating debris, scum, a visible oil film or globules of grease or other floating materials; (c) produce odors, colors, or other conditions which create a nuisance or render undesirable tastes to fish or make fish in edible; (d) create concentrations or combinations of materials which are toxic or harmful to human, animal, plant or aquatic life; (e) create conditions which produce undesirable aquatic life.	Applicable
Montana Groundwater Pollution Control System Regulations	ARM 17.30.1011	Applies nondegradation requirements to any activity which could cause a new or increased source of pollution to state water	Not Applicable
	ARM 17.30.1006	Classifies groundwater into Classes I through IV based on the present and future most beneficial uses of the groundwater and states groundwater is to be classified to actual quality of actual use, whichever places the groundwater in a higher class.	Applicable

Identification of Applicable or Relevant and Appropriate Requirements Como Basin/Glengarry Adit/Fisher Creek Response Action			
Standard, Requirement Criteria Or Limitation	**Citation**	**Description**	**ARAR Status**
STATE CONTAMINANT-SPECIFIC (continued)			
Clean Air Act Of Montana	75-2-102, MCA	Montana's policy is to achieve and maintain such levels of air quality as will protect human health and safety and, to the greatest degree practicable, prevent injury to plant and animal life and property.	Applicacble
Air Quality Regulations	ARM 17.8.206	Establishes sampling, data collection, and analytical requirements to ensure compliance with ambient air quality standards.	Applicable
	ARM 17.8.222	No person shall cause or contribute to concentrations of lead in the ambient air which exceed the following 90-day average: 1.5 micrograms per cubic meter of air.	Applicable
	ARM 17.8.220	No person shall cause or contribute to concentrations of particulate matter in the ambient air such that the mass of settled particulate matter exceeds the following 30-day average: 10 grams per square meter.	Applicable
	ARM 17.8.223	No person may cause or contribute to concentrations of PM-10 in the ambient air which exceed the following standards: 1) 24-hr. avg. : 150 micrograms per cubic meter of air, with no more than one expected exceedance per year; 2) Annual avg.: 50 micrograms per cubic meter of air.	Applicable
Occupational Health Act of Montana	50-70-101, et. seq., MCA	The purpose of this act is to achieve and maintain such conditions of the work place as will protect human health and safety	Applicable
Occupational Air Contaminants Regulations	ARM 17.42.102	Establishes maximum threshold limit values for air contaminants believed that nearly all workers may be repeatedly exposed day after day without adverse health effects.	Applicable
Occupational Noise Regulations	ARM 17.42.101	Addresses occupational noise levels and provides that no worker should be exposed to noise levels in excess of the specified levels.	Applicable

Identification of Applicable or Relevant and Appropriate Requirements Como Basin/Glengarry Adit/Fisher Creek Response Action			
Standard, Requirement Criteria Or Limitation	**Citation**	**Description**	**ARAR Status**
STATE LOCATION-SPECIFIC			
Floodplain and Floodway Management Act	76-5-401, MCA	Lists the uses permissible in a floodway and generally prohibits permanent structures, fill, or permanent storage of materials or equipment.	Applicable
	76-5-402 MCA	Lists the permissible permanent structures that are allowed in the floodplain excluding the floodway, if they are permitted and meet certain minimum standards.	Applicable
	76-5-403, MCA	Lists certain uses which are prohibited in a designated floodway, including any change that will cause water to be diverted from the established floodway, cause erosion, obstruct the natural flow of water, or reduce the carrying capacity of the floodway, or the concentration or permanent storage of an object subject to flotation or movement during flood level periods.	Applicable
Floodplain Management Regulations	ARM 36.15.216	The factors to consider in determining whether a permit should be issued to establish or alter an artificial obstruction or nonconforming use in the floodplain or floodway are set forth in this section.	Applicable
	ARM 36.15.602	Specifies uses requiring permits for allowing obstructions in the floodway.	Applicable
	ARM 36.15.603	Proposed diversions or changes in place of diversions must be evaluated by the DNRC to determine whether they may significantly affect flood flows and, therefore, require a permit.	Applicable
	ARM 36.15.604	Prohibits new artificial obstructions or nonconforming uses that will increase the upstream elevation of the base flood 0.5 of a foot or significantly increase flood velocities.	Applicable

Identification of Applicable or Relevant and Appropriate Requirements Como Basin/Glengarry Adit/Fisher Creek Response Action			
Standard, Requirement Criteria Or Limitation	**Citation**	**Description**	**ARAR Status**
STATE LOCATION-SPECIFIC (continued)			
Floodplain Management Regulations (continued)	ARM 36.15.605	Identifies artificial obstructions and nonconforming uses that are prohibited within the designated floodway except as allowed by permit and includes "a structure or excavation that will cause water to be diverted from the established floodway, cause erosion, obstruct the natural flow of water, or reduce the carrying capacity of the floodway..." Solid waste disposal and storage of highly toxic, flammable, or explosive materials are also prohibited.	Applicable
	ARM 36.15.606	Identifies flood control works that are allowed with designated floodways pursuant to permit and certain conditions including: flood control levies and flood walls, rip rap, channelization projects, and dams.	Not Applicable
	ARM 36.15.701 and 703	Describes allowed uses in the flood fringe. Prohibited uses within the flood fringe (i.e., areas in the floodplain, but outside of the designated floodway) areas including solid waste disposal and storage of highly toxic, flammable or explosive material.	Applicable
	ARM 36.15.801	Allowed uses where floodway is not designated.	Applicable
Montana Solid Waste Management Act and Regulations	75-10-201, MCA ARM 17.50.505	Specifies the requirements that apply to the location of any solid waste management facility.	Applicable
Endangered Species	87-5-106, 107,111, MCA ARM 12.5.201	Fish and wildlife resources are to be protected and no construction project or hydraulic project shall adversely affect game or fish habitat.	Applicable

Identification of Applicable or Relevant and Appropriate Requirements
Como Basin/Glengarry Adit/Fisher Creek Response Action

Standard, Requirement Criteria Or Limitation	Citation	Description	ARAR Status
STATE LOCATION SPECIFIC (continued)			
Natural Streambed and Land Preservation Act	75-7-101, et seq., MCA	The adverse affects of any action shall minimize alteration or affects to a streambed or its banks	Applicable
Natural Streambed and Land Preservation Standards	ARM 36.2.404, 405, 406, and 410	Proposed projects are to be evaluated by the appropriate conservation district based on criteria including: 1) whether the project will pass anticipated sediment loads without creating harmful flooding or erosion problems upstream or downstream; 2) whether the project will minimize the amount of stream channel alteration; 3) whether the project will be as permanent a solution as possible and whether the method used will create a reasonably permanent and stable situation; 4) whether the project will minimize effects of fish and aquatic habitat: 5) whether the project will minimize turbidity or other water pollution problems; and, 6) whether the project will minimize adverse effects on the natural beauty of the area	Applicable
STATE ACTION SPECIFIC			
Montana Water Quality Act	75-5-605, MCA	Pursuant to this section, it is unlawful among other things, to cause pollution of any state waters, to place any wastes in a location where they are likely to cause pollution of any state waters, to violate any permit provision, to violate any provision of the Montana Water Quality Act, to construct, modify, or operate a system for disposing of waste (including sediment, solid waste and other substances that may pollute state waters) which discharge into any state waters without a permit or discharge waste into any state waters.	Applicable
MPDES Permit Requirements	ARM17.30.1342-1344	Sets forth the substantive requirements applicable to all MPDES and NPDES permits. Include the requirement to properly operate and maintain all facilities and systems of treatment and control.	Not Applicable
	ARM 17.30.1203 and 1344	Technology-based treatment for MPDES permits.	Not Applicable

Identification of Applicable or Relevant and Appropriate Requirements Como Basin/Glengarry Adit/Fisher Creek Response Action			
Standard, Requirement Criteria Or Limitation	**Citation**	**Description**	**ARAR Status**
STATE ACTION-SPECIFIC (continued)			
Nondegradation of Water Quality	75-5-303, MCA	States that existing uses of state waters and the level of water quality necessary to protect the uses must be maintained and protected. Provides exemption that allows changes of existing water quality resulting from emergency or remedial activity designed to protect the public health or the environment.	Not Applicable
	ARM 17.30.705	Provides that for any surface water, existing and anticipated uses and the water quality necessary to protect these uses must be maintained and protected unless degradation is allowed.	Not Applicable
	ARM 17.30.1011	Requires that any groundwater whose existing quality is higher than the standard for its classification must be maintained at that high quality in accordance with 75-5-303, MCA and ARM 17.30.701, et seq.	Not Applicable
Clean Air Act Of Montana	75-2-102, MCA	Montana's policy is to achieve and maintain such levels of air quality as will protect human health and safety and, to the greatest degree practicable, prevent injury to plant and animal life and property.	Applicable
Air Quality Requirements	ARM 17.8.308	No person shall cause or authorize the production, handling, transportation or storage of any material unless reasonable precautions to control emissions of airborne particulate matter are taken.	Applicable
	ARM 17.8.604	Lists certain wastes that may not be disposed of by open burning.	Applicable
	ARM 16.8.1401-1404	Sets forth emission standards for hazardous air pollutants	Applicable
Montana Solid Waste Management Act	75-10-201, et seq, MCA	Public policy is to control solid waste management systems to protect the public health and safety and to conserve natural resources whenever possible.	Relevant and Appropriate

Identification of Applicable or Relevant and Appropriate Requirements Como Basin/Glengarry Adit/Fisher Creek Response Action			
Standard, Requirement Criteria Or Limitation	**Citation**	**Description**	**ARAR Status**
STATE ACTION-SPECIFIC (continued)			
Solid Waste Management Regulations	ARM 17.50.505 and 508-509	The standards for solid waste disposal are set forth in this provision.	Not Applicable
	ARM 17.50.511	General operational and maintenance requirements for solid waste management systems are established pursuant to this section. This section requires that solid waste disposal be confined to areas within the disposal site that can be effectively maintained and operated.	Not Applicable
	ARM 17.50.523	Solid waste must be transported In such a manner as to prevent its discharge, dumping, spilling or leaking from the transport vehicle.	Relevant and Appropriate
Montana Hazardous Waste And Underground Storage Tank Act	75-10-401, et seq, MCA	State's policy to protect the public health and safety, the health of living organisms, and the environment from the effects of the improper, inadequate, or unsound management of hazardous wastes.	Not Applicable
Montana Hazardous Waste Regulations	ARM 17.54.701-703	By reference to federal regulatory requirements, these sections establish standards for all permitted hazardous waste management facilities.	Not Applicable
		1) 40 CFR 264.111 (referenced by ARM 17.54.720) establishes that hazardous waste facilities must be closed in such a manner as to minimize the need for further maintenance and control, minimize or eliminate, to the extent necessary to protect public health and the environment, post closure escape of hazardous wastes, hazardous constituents, leachate, contaminated runoff or hazardous waste decomposition products to the ground or surface waters or the atmosphere. Such closure must comply with the closure requirements of 40 CFR 264 Subpart G.	Not Applicable

Identification of Applicable or Relevant and Appropriate Requirements Como Basin/Glengarry Adit/Fisher Creek Response Action			
Standard, Requirement Criteria Or Limitation	**Citation**	**Description**	**ARAR Status**
STATE ACTION-SPECIFIC (continued)			
Montana Hazardous Waste Regulations (continued)	ARM 17.54.701-703 (continued)	2) 40 CFR 264.228(a)(2) (incorporated by reference by ARM 17.54.702) requires that at closure, free liquids must be removed or solidified, the wastes stabilized and the wastes management unit covered	Not Applicable
		3) 40 CFR 264.228(a)(2) and 310 (incorporated by reference in ARM 17.54.702) requires that surface impoundments and landfill caps must: (a) provide long-term minimization of migration of liquids through the unit; (b) function with minimum maintenance; (c) promote drainage and minimize erosion or abrasion of the final cover; (d) accommodate settling and subsidence; and (e) have a permeability less than or equal to the permeability of the natural subsoils present.	Not Applicable
		4) 40 CFR 264.228 and 310 (incorporated by reference in ARM 17.54.702) requires that a map be provided showing the dimensions of waste disposal units, together with the types and amounts of waste disposed of in each unit. Additionally, the owner must record a deed restriction, in accordance with state law, that will in perpetuity notify potential purchasers that the property has been used for waste disposal and that its use is restricted.	Not Applicable
	ARM 17.54.109-113	Establishes permit conditions, duration of permits, schedules.	Not Applicable
<u>Montana Strip and Underground Mine Reclamation Act</u>	82-4-231, MCA	Sets forth objectives that require the operator to prepare and carry out a method of operations plan to reclaim and revegetate the land affected by his operation	Relevant and Appropriate
	82-4-233, MCA	Requires that after the operation has been backfilled, graded, topsoiled and approved, the operator shall establish a vegetative cover on all impacted lands. Specifications for the vegetative cover and performance are provided.	Relevant and Appropriate

Identification of Applicable or Relevant and Appropriate Requirements Como Basin/Glengarry Adit/Fisher Creek Response Action			
Standard, Requirement Criteria Or Limitation	**Citation**	**Description**	**ARAR Status**
STATE ACTION-SPECIFIC (continued)			
Backfilling and Grading Requirements	ARM 17.24.501	Gives general backfilling and grading requirements.	Relevant and Appropriate
	ARM 17.24.504	Provides that permanent impoundments may be retained under certain circumstances.	Not Applicable
	ARM 17.24.514	Gives contouring requirements.	Relevant and Appropriate
	ARM 17.24.519	Operator may be required to monitor settling of regraded areas.	Not Applicable
	ARM 17.24.520	Spoil material may be disposed of on-site in accordance with requirements of this section. Contains specific requirements for siting, surface runoff, construction of underdrains and revegetation.	Not Applicable
Hydrology Requirements	ARM 17.24.631	Reclamation operations must be planned and conducted to minimize disturbance and prevent damage to the prevailing hydrologic balance.	Relevant and Appropriate
	ARM 17.24.633	Specifies that sediment controls must be maintained until the disturbed area has been restored and revegetated.	Relevant and Appropriate
	ARM 17.24.634	Drainage design shall emphasize premining channel and floodplain configurations that blend with the undisturbed drainage system above and below; will meander naturally; remain in dynamic equilibrium with the system; improve unstable premining conditions, provide for floods, provide for long term stability of the landscape; and establish a premining diversity of aquatic habitats and riparian vegetation.	Relevant and Appropriate
	ARM 17.24.635-637	Sets forth requirements for temporary and permanent diversions.	Relevant and Appropriate
	ARM 17.24.641	Sets methods for preventing drainage from acid-and toxic-forming wastes into ground and surface waters.	Relevant and Appropriate

Identification of Applicable or Relevant and Appropriate Requirements
Como Basin/Glengarry Adit/Fisher Creek Response Action

Standard, Requirement Criteria Or Limitation	Citation	Description	ARAR Status
STATE ACTION-SPECIFIC (continued)			
Hydrology Requirements (continued)	ARM 17.24.642	Prohibits permanent impoundments with certain exceptions, and sets standards for temporary and permanent impoundments.	Not Applicable
	ARM 17.24.643-646	Provides for groundwater and groundwater recharge protection, and surface and groundwater monitoring.	Not Applicable
	ARM 17.24.650	All permanent sedimentation ponds, diversions, impoundments, and treatment facilities must be renovated postmining and regraded to the approximate original contour.	Not Applicable
Top Soiling, Revegetation, and Protection of Wildlife and Air Resource Regulations	ARM 17.24.701-702	Requirements for stockpiling soil.	Not Applicable
	ARM 17.24.703	Materials other than, or along with, soil for final surfacing of spoils or other disturbances must be capable of supporting the approved vegetation and postmining land use.	Relevant and Appropriate
	ARM 17.24.711	The section requires “a diverse, effective, and permanent vegetative cover of the same seasonal utility native to the area of and to be affected and capable of meeting the criteria set forth in 82-4-233 shall be established on all areas of land affected except water areas and surface areas of roads.”	Not Applicable
	ARM 17.24.713	Specifies that seeding and planting of disturbed areas must be conducted during the first appropriate period for favorable planting after final seedbed preparation; but not longer than 90 days after top soil placement.	Relevant and Appropriate
	ARM 17.24.714	According to this section, as soon as practical, a mulch or cover crop must be used on all regraded and resoiled areas to control erosion, to promote germination of seeds, and to increase moisture retention of soil until permanent cover is established.	Relevant and Appropriate
	ARM 17.24.716	Establishes methods of revegetation	Relevant and Appropriate

Identification of Applicable or Relevant and Appropriate Requirements Como Basin/Glengarry Adit/Fisher Creek Response Action			
Standard, Requirement Criteria Or Limitation	**Citation**	**Description**	**ARAR Status**
STATE ACTION-SPECIFIC (continued)			
	ARM 17.24.717	Relates to the planting of trees and other woody species to establish a diverse, effective, and permanent vegetative cover.	Not Applicable
	ARM 17.24.718	Soil amendments must be used as necessary to aid in the establishment of permanent vegetation; irrigation, management, fencing, or other measures may also be used after review and approval by the dep't.	Relevant and Appropriate
	ARM 17.24.719	Livestock grazing on reclaimed land is prohibited until revegetation is established and can sustain managed grazing.	Not Applicable
	ARM 17.24.720	Sets annual department inspection requirements.	Not Applicable
	ARM 17.24.721	Section specifies that rills and gullies greater than 9 inches which form on the reclaimed area may need to be filled, graded or otherwise stabilized and the area reseeded or replanted.	Not Applicable
Top Soiling, Revegetation, and Protection of Wildlife and Air Resource Regulations (continued)	ARM 17.24.723	Monitoring of vegetation, soils and wildlife.	Not Applicable
	ARM 17.24.724	Success of revegetation shall be measured on the basis of unmined reference areas.	Not Applicable
	ARM 17.24.725	Sets periods of responsibility and evaluation.	Not Applicble
	ARM 17.24.726	Sets means of measuring productivity.	Not Applicable
	ARM 17.24.728	Sets requirements for composition of vegetation.	Not Applicable
	ARM 17.24.730-731	Revegetated area must furnish palatable forage in comparable quantity and quality during the same grazing period as the reference area.	Not Applicable

Identification of Applicable or Relevant and Appropriate Requirements Como Basin/Glengarry Adit/Fisher Creek Response Action			
Standard, Requirement Criteria Or Limitation	**Citation**	**Description**	**ARAR Status**
STATE ACTION-SPECIFIC (continued)			
	ARM 17.24.733	Sets requirements and measurement standards for trees, shrubs and half-shrubs.	Not Applicable
Top Soiling, Revegetation, and Protection of Wildlife and Air Resource Regulations (continued)	ARM 17.24.751	Required site activities must be conducted so as to avoid or minimize impacts to important fish and wildlife species, including critical habitat and any threatened or endangered species identified at the site.	Relevant and Appropriate
	ARM 17.24.761	Section requires fugitive dust control measures for site preparation and reclamation operations.	Relevant and Appropriate

APPENDIX D

DETAILED COST ESTIMATES

Como Basin/Glengarry Adit/Fisher Creek Response Action EE/CA
New World Mining District Response and Restoration Project

COMO BASIN
ENGINEER'S ESTIMATE - DESIGN ALTERNATIVES
New World Mining District Response and Restoration Project
Gallatin and Custer National Forest
Park County, Montana

ALTERNATIVE CB-1 - NO ACTION

	Unit	Unit Cost	Quantity	Cost	Explaination
Monitoring (PCRC Costs)	ls	$ 50,115.00	1.00	$50,115.00	Engineers Estimate
		Total Cost for Alternative:		$50,115.00	

ALTERNATIVE CB-2A - In-Situ Treatment with Shallow Amendment

	Unit	Unit Cost	Quantity	Cost	Explaination
Clearing and Grubbing	ha	$4,600.00	2.23	$10,258.00	A B & J Mine Rec. Contractor Bid
Upgrade Access Roads	km	$9,383.00	1.50	$14,074.50	Basin/Cataract Creek Eng. Est.
Spreading and Grading	m^3	$1.91	19,017.00	$36,322.47	McLaren Pit Eng. Estimate
Incorporate Lime in Upper 0.3 meters	ton	$62.00	633.00	$39,246.00	McLaren Pit Eng. Estimate
Drainage Channels	ls	$65,000.00	1.00	$65,000.00	Engineers Estimate
Erosion Control	ha	$3,420.00	2.79	$9,541.80	McLaren Pit Eng. Estimate x 2
Reclaim Roads	km	$6,850.00	6.00	$41,100.00	McLaren Pit Eng. Estimate
Revegetation	ha	$ 27,345.00	2.79	$76,292.55	McLaren Pit Eng. Estimate
		Subtotal		$291,835.32	
		Mobilization (10%)		$29,183.53	
		Contingency (12%)		$35,020.24	
		TOTAL CONSTRUCTION		$356,039.09	
		Eng. Eval. And Design (8%)		$28,483.13	
		Const. Oversight (5%)		$17,801.95	
		PRSC		$59,328.00	
		Total Cost for Alternative:		**$461,652.17**	

ALTERNATIVE CB-2B - In-Situ Treatment with 1 meter of Lime Amendment

	Unit	Unit Cost	Quantity	Cost	Explaination
Clearing and Grubbing	ha	$4,600.00	2.23	$10,258.00	A B & J Mine Rec. Contractor Bid
Upgrade Access Roads	km	$9,383.00	1.50	$14,074.50	Basin/Cataract Creek Eng. Est.
Spreading and Grading	m^3	$1.91	22,300.00	$42,593.00	McLaren Pit Eng. Estimate
Incorporate Lime in Upper 1 meter	ton	$62.00	2,100.00	$130,200.00	McLaren Pit Eng. Estimate
Drainage Channels	ls	$65,000.00	1.00	$65,000.00	Engineers Estimate
Erosion Control	ha	$3,420.00	2.79	$9,541.80	McLaren Pit Eng. Estimate x 2
Reclaim Roads	km	$6,850.00	6.00	$41,100.00	McLaren Pit Eng. Estimate
Revegetation	ha	$ 27,345.00	2.79	$76,292.55	McLaren Pit Eng. Estimate
		Subtotal		$389,059.85	
		Mobilization (10%)		$38,905.99	
		Contingency (12%)		$46,687.18	
		TOTAL CONSTRUCTION		$474,653.02	
		Eng. Eval. And Design (8%)		$37,972.24	
		Const. Oversight (5%)		$23,732.65	
		PRSC		$59,328.00	
		Total Cost for Alternative:		**$595,685.91**	

COMO BASIN
ENGINEER'S ESTIMATE - DESIGN ALTERNATIVES
New World Mining District Response and Restoration Project
Gallatin and Custer National Forest
Park County, Montana

ALTERNATIVE CB-2C - In-Situ Treatment with Complete Amendment

	Unit	Unit Cost	Quantity	Cost	Explaination
Clearing and Grubbing	ha	$4,600.00	3.35	$15,410.00	A B & J Mine Rec. Contractor Bid
Upgrade Access Roads	km	$9,383.00	1.50	$14,074.50	Basin/Cataract Creek Eng. Est.
Removal, Haul and Replacement After Lime Incorporation	m^3	$6.00	190,174.00	$1,141,044.00	Engineers Estimate
Incorporate Lime	ton	$62.00	17,990.00	$1,115,380.00	McLaren Pit Eng. Estimate
Misc. Construction	ls	$100,000.00	1.00	$100,000.00	Engineers Estimate
Drainage Channels	ls	$65,000.00	1.00	$65,000.00	Engineers Estimate
Erosion Control	ha	$3,420.00	3.35	$11,457.00	McLaren Pit Eng. Estimate x 2
Reclaim Roads	km	$6,850.00	6.00	$41,100.00	McLaren Pit Eng. Estimate
Revegetation	ha	$ 27,345.00	3.35	$91,605.75	McLaren Pit Eng. Estimate
		Subtotal		$2,595,071.25	
		Mobilization (10%)		$259,507.13	
		Contingency (12%)		$311,408.55	
		TOTAL CONSTRUCTION		$3,165,986.93	
		Eng. Eval. And Design (8%)		$253,278.95	
		Const. Oversight (5%)		$158,299.35	
		PRSC		$59,328.00	
		Total Cost for Alternative:		**$3,636,893.23**	

ALTERNATIVE CB-3A - In-Situ Treatment with Soil Cap

	Unit	Unit Cost	Quantity	Cost	Explaination
Clearing and Grubbing	ha	$4,600.00	2.23	$10,258.00	A B & J Mine Rec. Contractor Bid
Upgrade Access Roads	km	$9,383.00	1.50	$14,074.50	Basin/Cataract Creek Eng. Est.
Spreading and Grading	m^3	$1.91	19,017.00	$36,322.47	McLaren Pit Eng. Estimate
Incorporate Lime in Upper 0.3 meters	ton	$62.00	633.00	$39,246.00	McLaren Pit Eng. Estimate
60 cm of Cover Soil	m^3-km	$2.76	80,000.00	$220,800.00	Engineers Estimate
Drainage Channels	ls	$65,000.00	1.00	$65,000.00	Engineers Estimate
Misc. Construction	ls	$100,000.00	1.00	$100,000.00	Engineers Estimate
Erosion Control	ha	$3,420.00	2.79	$9,541.80	McLaren Pit Eng. Estimate x 2
Reclaim Roads	km	$6,850.00	6.00	$41,100.00	McLaren Pit Eng. Estimate
Revegetation	ha	$ 27,345.00	2.79	$76,292.55	McLaren Pit Eng. Estimate
		Subtotal		$612,635.32	
		Mobilization (10%)		$61,263.53	
		Contingency (12%)		$73,516.24	
		TOTAL CONSTRUCTION		$747,415.09	
		Eng. Eval. And Design (8%)		$59,793.21	
		Const. Oversight (5%)		$37,370.75	
		PRSC		$59,328.00	
		Total Cost for Alternative:		**$903,907.05**	

COMO BASIN
ENGINEER'S ESTIMATE - DESIGN ALTERNATIVES
New World Mining District Response and Restoration Project
Gallatin and Custer National Forest
Park County, Montana

ALTERNATIVE CB-3B - In-Situ Treatment with Geomembrane Cover and Amended Soil Cap

	Unit	Unit Cost	Quantity	Cost	Explaination
Clearing and Grubbing	ha	$4,600.00	2.23	$10,258.00	A B & J Mine Rec. Contractor Bid
Upgrade Access Roads	km	$9,383.00	1.50	$14,074.50	Basin/Cataract Creek Eng. Est.
Spreading and Grading	m^3	$1.91	19,017.00	$36,322.47	McLaren Pit Eng. Estimate
Removal, Haul and Replacement After Lime Incorporation	m^3	$6.00	22,300.00	$133,800.00	Engineers Estimate
Top Capping System	m^2	$24.76	22,300.00	$552,148.00	McLanen Pit Eng. Estimate
Drainage Gravel	m^3	$51.75	2,500.00	$129,375.00	2000 Sel. Source Eng. Estimate
Incorporate Lime in Upper 1 meters of Cover Soil	ton	$62.00	2,100.00	$130,200.00	McLaren Pit Eng. Estimate
Misc. Construction	ls	$150,000.00	1.00	$150,000.00	Engineers Estimate
Drainage Channels	ls	$65,000.00	1.00	$65,000.00	Engineers Estimate
Erosion Control	ha	$3,420.00	2.79	$9,541.80	McLaren Pit Eng. Estimate x 2
Reclaim Roads	km	$6,850.00	6.00	$41,100.00	McLaren Pit Eng. Estimate
Revegetation	ha	$ 27,345.00	2.79	$76,292.55	McLaren Pit Eng. Estimate
		Subtotal		$1,348,112.32	
		Mobilization (10%)		$134,811.23	
		Contingency (12%)		$161,773.48	
		TOTAL CONSTRUCTION		$1,644,697.03	
		Eng. Eval. And Design (8%)		$131,575.76	
		Const. Oversight (5%)		$82,234.85	
		PRSC		$59,328.00	
		Total Cost for Alternative:		**$1,917,835.64**	

ALTERNATIVE CB-3C - In-Situ Treatment with Geomembrane Cover and Imported Soil Cap

	Unit	Unit Cost	Quantity	Cost	Explaination
Clearing and Grubbing	ha	$4,600.00	2.23	$10,258.00	A B & J Mine Rec. Contractor Bid
Upgrade Access Roads	km	$9,383.00	1.50	$14,074.50	Basin/Cataract Creek Eng. Est.
Spreading and Grading	m^3	$1.91	19,017.00	$36,322.47	McLaren Pit Eng. Estimate
Top Capping System	m^2	$24.76	22,300.00	$552,148.00	McLaren Pit Eng. Estimate
Drainage Gravel	m^3	$51.75	2,500.00	$129,375.00	2000 Sel. Source Eng. Estimate
Cover Soil	m^3-km	$2.76	117,208.00	$323,494.08	Engineers Estimate
Misc. Construction	ls	$150,000.00	1.00	$150,000.00	Engineers Estimate
Drainage Channels	ls	$65,000.00	1.00	$65,000.00	Engineers Estimate
Erosion Control	ha	$3,420.00	2.79	$9,541.80	McLaren Pit Eng. Estimate x 2
Reclaim Roads	km	$6,850.00	6.00	$41,100.00	McLaren Pit Eng. Estimate
Revegetation	ha	$ 27,345.00	2.79	$76,292.55	McLaren Pit Eng. Estimate
		Subtotal		$1,407,606.40	
		Mobilization (10%)		$140,760.64	
		Contingency (12%)		$168,912.77	
		TOTAL CONSTRUCTION		$1,717,279.81	
		Eng. Eval. And Design (8%)		$137,382.38	
		Const. Oversight (5%)		$85,863.99	
		PRSC		$59,328.00	
		Total Cost for Alternative:		**$1,999,854.18**	

COMO BASIN RESPONSE ACTION POST REMOVAL SITE CONTROL NO ACTION ALTERNATIVE MAINTENANCE AND MONITORING COST						
Year	**Excavation and Dirt Work $/year**	**Fertilizer Reapplication $/year**	**Seed Reapplication $/year**	**Monitoring Wells**	**Monitoring (labor + analyses)**	**TOTAL COST $/year**
1	$2,000				$2,400	$4,400
2	$2,000				$2,400	$4,400
3	$1,500				$2,400	$3,900
4	$1,500				$2,400	$3,900
5	$1,500				$2,400	$3,900
6					$2,400	$2,400
7	$1,000				$2,400	$3,400
8					$2,400	$2,400
9	$1,000				$2,400	$3,400
10					$2,400	$2,400
11	$1,000				$2,400	$3,400
12					$2,400	$2,400
13	$1,000				$2,400	$3,400
14					$2,400	$2,400
15	$1,000				$2,400	$3,400
16					$2,400	$2,400
17	$1,000				$2,400	$3,400
18					$2,400	$2,400
19	$1,000				$2,400	$3,400
20					$2,400	$2,400
21	$1,000				$2,400	$3,400
22					$2,400	$2,400
23	$1,000				$2,400	$3,400
24					$2,400	$2,400
25	$1,000				$2,400	$3,400
26					$2,400	$2,400
27	$1,000				$2,400	$3,400
28					$2,400	$2,400
29	$1,000				$2,400	$3,400
30					$2,400	$2,400
Totals	$20,500	$0	$0	$0	$72,000	$92,500
		Net Present Value (Discount Rate = 4.9%)			($37,318)	($50,115)

Assuming minor maintainance will be required to disturbed areas in the years following the site work.
Assuming limited annual monitoring will be required.

COMO BASIN RESPONSE ACTION						
POST REMOVAL SITE CONTROL						
ALTERNATIVES 2A THROUGH 3C						
MAINTENANCE AND MONITORING COST						
Year	**Excavation and Dirt Work $/year**	**Fertilizer Reapplication $/year**	**Seed Reapplication $/year**	**Monitoring Wells**	**Monitoring (labor + analyses)**	**TOTAL COST $/year**
1	$3,500	$2,000	$7,600		$2,400	$15,500
2		$1,500	$2,500		$2,400	$6,400
3	$1,500				$2,400	$3,900
4		$1,000	$1,000		$2,400	$4,400
5	$1,000				$2,400	$3,400
6		$1,000			$2,400	$3,400
7	$1,000				$2,400	$3,400
8		$1,000			$2,400	$3,400
9					$2,400	$2,400
10					$2,400	$2,400
11					$2,400	$2,400
12					$2,400	$2,400
13					$2,400	$2,400
14					$2,400	$2,400
15					$2,400	$2,400
16					$2,400	$2,400
17					$2,400	$2,400
18					$2,400	$2,400
19					$2,400	$2,400
20					$2,400	$2,400
21					$2,400	$2,400
22					$2,400	$2,400
23					$2,400	$2,400
24					$2,400	$2,400
25					$2,400	$2,400
26					$2,400	$2,400
27					$2,400	$2,400
28					$2,400	$2,400
29					$2,400	$2,400
30					$2,400	$2,400
Totals	$7,000	$6,500	$11,100	$0	$72,000	$96,600
		Net Present Value (Discount Rate = 4.9%)			($37,318)	($59,328)
Assuming minor repairs will be required to reclamed areas in the 8 years following the site work.						
Assuming limited annual monitoring will be required.						

FISHER CREEK
ENGINEER'S ESTIMATE - DESIGN ALTERNATIVES
New World Mining District Response and Restoration Project
Gallatin and Custer National Forest
Park County, Montana

ALTERNATIVE FC-1 - NO ACTION

	Unit	Unit Cost	Quantity	Cost	Explaination
Monitoring	ls	$ 87,889.00	1	$87,889.00	Engineers Estimate
		Total Cost for Alternative:		$87,889.00	

ALTERNATIVE FC-2 - In-Situ Treatment with Shallow Amendment

	Unit	Unit Cost	Quantity	Cost	Explaination
Clearing and Grubbing	ha	$4,600.00	3.4	$15,640.00	A B & J Mine Rec. Contractor Bid
Upgrade Access Roads	km	$9,383.00	8.5	$79,755.50	Basin/Cataract Creek Eng. Est.
Waste Spreading and Grading	m^3	$3.82	16,840.0	$64,328.80	McLaren Pit Eng. Estimate *2
Incorporate Lime in Upper 0.3 meters	ton	$62.00	609.0	$37,758.00	McLaren Pit Eng. Estimate
Drainage Channels	ls	$43,000.00	1.0	$43,000.00	Engineers Estimate
Erosion Control	ha	$3,420.00	3.4	$11,628.00	McLaren Pit Eng. Estimate x 2
Reclaim Roads	km	$6,850.00	6.0	$41,100.00	McLaren Pit Eng. Estimate
Revegetation	ha	$ 42,517.00	3.4	$144,557.80	McLaren Pit Eng. Estimate x 1.5
		Subtotal		$437,768.10	
		Mobilization (10%)		$43,776.81	
		Contingency (12%)		$52,532.17	
		TOTAL CONSTRUCTION		$550,085.08	
		Eng. Eval. And Desgin (8%)		$44,006.81	
		Const. Oversight (5%)		$27,504.25	
		PRSC		$113,891.00	
	Total Cost for Alternative:			**$735,487.14**	

ALTERNATIVE FC-3 - Surface Controls

	Unit	Unit Cost	Quantity	Cost	Explaination
Clearing and Grubbing	ha	$4,600.00	1.7	$7,820.00	A B & J Mine Rec. Contractor Bid
Waste Spreading and Grading	m^3	$3.82	5,052.0	$19,298.64	McLaren Pit Eng. Estimate x 2
Drainage Channels	ls	$43,000.00	1.0	$43,000.00	Engineers Estimate
Erosion Control	ha	$3,420.00	3.4	$11,628.00	Engineers Estimate
Reclaim Roads	km	$6,850.00	6.0	$41,100.00	McLaren Pit Eng. Estimate
		Subtotal		$122,846.64	
		Mobilization (10%)		$12,284.66	
		Contingency (12%)		$14,741.60	
		TOTAL CONSTRUCTION		$149,872.90	
		Eng. Eval. And Desgin (8%)		$11,989.83	
		Const. Oversight (5%)		$7,493.65	
		PRSC		$113,891.00	
	Total Cost for Alternative:			**$283,247.38**	

FISHER CREEK

ENGINEER'S ESTIMATE - DESIGN ALTERNATIVES

New World Mining District Response and Restoration Project

Gallatin and Custer National Forest

Park County, Montana

ALTERNATIVE FC-4 - Total Removal of Waste and Transport to Repository SB-4B

	Unit	Unit Cost	Quantity	Cost	Explaination
Waste Removal, Haul, and Place					
Clearing and Grubbing	ha	$4,600.00	3.5	$16,008.00	A B & J Mine Rec. Contractor Bid
Upgrade Access Roads	km	$9,383.00	8.5	$79,755.50	Basin/Cataract Creek Eng. Est.
Excavate, Load and Haul Waste	m^3-km	$2.76	137,500	$379,500.00	Engineers Estimate
Regrade Removal Areas	ha	$2,965.25	3.4	$10,081.85	2000 Sel. Source Eng. Estimate
Revegetation of Removal Areas	ha	$ 42,517.00	3.4	$144,557.80	McLaren Pit Eng. Estimate x 1.5
Drainage Channels	ls	$43,000.00	1.0	$43,000.00	Engineers Estimate
Erosion Control	ha	$3,420.00	3.5	$11,901.60	McLaren Pit Eng. Estimate x 2
Reclaim Roads	km	$6,850.00	6.0	$41,100.00	McLaren Pit Eng. Estimate
Waste Spreading and Grading	m^3	$3.82	24,940.0	$95,270.80	McLaren Pit Eng. Estimate x 2
Repository Construction					
Clearing and Grubbing	ha	$4,774.00	1.3	$6,206.20	2000 Sel. Source Eng. Estimate
Topsoil Stockpile	m^3	$3.15	2,000.0	$6,300.00	2000 Sel. Source Eng. Estimate
Bottom Liner System	m^2	$27.10	6,500.0	$176,150.00	2000 Sel. Source Eng. Estimate
Top Capping System	m^2	$48.00	6,500.0	$312,000.00	2000 Sel. Source Eng. Estimate
Cover Soil	m^3	$7.08	9,100.0	$64,428.00	2000 Sel. Source Eng. Estimate
Cover Drains	ls	$25,000.00	1.0	$25,000.00	Engineers Estimate
Rock Toe	ls	$200,000.00	1.0	$200,000.00	Engineers Estimate
Sump, Temp Liner, Construction Cover, and Misc.	ls	$50,000.00	1.0	$50,000.00	Engineers Estimate
Erosion Control at Repository	ha	$6,500.00	1.3	$8,450.00	Engineers Estimate
Revegetation of Cover Soil	ha	$ 28,344.00	1.3	$36,847.20	McLaren Pit Eng. Estimate
		Subtotal		$1,706,556.95	
		Mobilization (10%)		$170,655.70	
		Contingency (12%)		$204,786.83	
		TOTAL CONSTRUCTION		$2,081,999.48	
		Eng. Eval. And Desgin (8%)		$166,559.96	
		Const. Oversight (5%)		$104,099.97	
		PRSC		$113,891.00	
		Total Cost for Alternative:		**$2,466,550.41**	

FISHER CREEK RESPONSE ACTION POST REMOVAL SITE CONTROL NO ACTION ALTERNATIVE MAINTENANCE AND MONITORING COST						
Year	**Excavation and Dirt Work $/year**	**Fertilizer Reapplication $/year**	**Seed Reapplication $/year**	**Monitoring Wells**	**Monitoring (labor + analyses)**	**TOTAL COST $/year**
1	$4,300				$4,300	$8,600
2					$4,300	$4,300
3	$4,300				$4,300	$8,600
4					$4,300	$4,300
5	$2,150				$4,300	$6,450
6					$4,300	$4,300
7	$2,150				$4,300	$6,450
8					$4,300	$4,300
9	$2,150				$4,300	$6,450
10					$4,300	$4,300
11	$2,150				$4,300	$6,450
12					$4,300	$4,300
13	$2,150				$4,300	$6,450
14					$4,300	$4,300
15	$2,150				$4,300	$6,450
16					$4,300	$4,300
17	$2,150				$4,300	$6,450
18					$4,300	$4,300
19	$2,150				$4,300	$6,450
20					$4,300	$4,300
21	$2,150				$4,300	$6,450
22					$4,300	$4,300
23	$2,150				$4,300	$6,450
24					$4,300	$4,300
25	$2,150				$4,300	$6,450
26					$4,300	$4,300
27	$2,150				$4,300	$6,450
28					$4,300	$4,300
29	$2,150				$4,300	$6,450
30					$4,300	$4,300
Totals	$36,550	$0	$0	$0	$129,000	$165,550
		Net Present Value (Discount Rate = 4.9%)			($66,862)	($87,889)

Assuming minor maintainance will be required to disturbed areas in the years following the site work.
Assuming limited annual monitoring will be required.

FISHER CREEK RESPONSE ACTION POST REMOVAL SITE CONTROL ALTERNATIVES FC-2 THROUGH FC-4 MAINTENANCE AND MONITORING COST						
Year	**Excavation and Dirt Work $/year**	**Fertilizer Reapplication $/year**	**Seed Reapplication $/year**	**Monitoring Wells**	**Monitoring (labor + analyses)**	**TOTAL COST $/year**
1	$8,600	$8,120	$8,120		$4,300	$29,140
2	$4,300	$4,000	$6,000		$4,300	$18,600
3	$2,150				$4,300	$6,450
4	$2,150	$1,255	$2,000		$4,300	$9,705
5	$2,150				$4,300	$6,450
6		$1,250			$4,300	$5,550
7	$1,000				$4,300	$5,300
8		$1,000			$4,300	$5,300
9					$4,300	$4,300
10					$4,300	$4,300
11					$4,300	$4,300
12					$4,300	$4,300
13					$4,300	$4,300
14					$4,300	$4,300
15					$4,300	$4,300
16					$4,300	$4,300
17					$4,300	$4,300
18					$4,300	$4,300
19					$4,300	$4,300
20					$4,300	$4,300
21					$4,300	$4,300
22					$4,300	$4,300
23					$4,300	$4,300
24					$4,300	$4,300
25					$4,300	$4,300
26					$4,300	$4,300
27					$4,300	$4,300
28					$4,300	$4,300
29					$4,300	$4,300
30					$4,300	$4,300
Totals	$20,350	$15,625	$16,120	$0	$129,000	$181,095
		Net Present Value (Discount Rate = 4.9%)			($66,862)	($113,891)

Assuming minor repairs will be required to reclamed areas in the 8 years following the site work.
Assuming limited annual monitoring will be required.