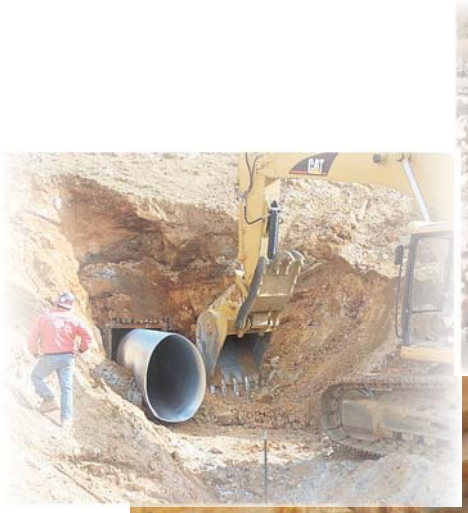
Final Adit Discharge Engineering Evaluation/Cost Analysis

New World Mining District Response and Restoration Project



TETRA TECH

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United States Department of Agriculture
Forest Service
Gallatin National Forest

Final

ADIT DISCHARGE
ENGINEERING EVALUATION/COST ANALYSIS
NEW WORLD MINING DISTRICT
RESPONSE AND RESTORATION PROJECT

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EXECUTIVE SUMMARY

Tetra Tech developed this Engineering Evaluation/Cost Analysis (EE/CA) for the United States Department of Agriculture Forest Service (USDA-FS). This EE/CA presents an engineering evaluation and cost analysis of alternatives that were developed to mitigate human health and environmental risks associated with mining-related discharges in the New World Mining District (District), which is generally located north of Cooke City, Montana. These discharges result from historic gold, silver, copper, and lead mining activity that was active during the period from the 1864 to the early 1950's. Seepage from mining-related discharges is characterized by elevated metal concentrations and sometimes acidic pH values that contribute to degradation of receiving surface water streams and groundwater resources.

The purpose of this EE/CA is to develop, screen, and evaluate potential response alternatives that would reduce or eliminate impacts associated with adit discharge from historic mines and other mining-related discharges located in the District. 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). A draft of this adit discharge EE/CA was released in December of 2006 for agency and public review. A number of comments were received from the following agencies or organizations and were used to modify the draft EE/CA: Montana Department of Environmental Quality (DEQ); US Environmental Protection Agency (EPA) Region 8; National Park Service; US Geological Survey (USGS); Beartooth Alliance; Center for Science in Public Participation (CSP); and the Greater Yellowstone Coalition (GYC). The resulting Final Adit Discharge EE/CA (this document) is considerably revised from the early draft version, and the USDA-FS will select a response alternative to be implemented in an Action Memorandum.

Of the more than 150 historic mine sites located in the District, 27 adit openings with discharges were originally inventoried and monitored. Of these sites, only ten are perennial discharges with water quality that exceeds Montana's standards. In addition, three subsurface drains located at the reclaimed McLaren Pit site convey poor quality water from the reclaimed area to Daisy Creek; as such, these drains are included in the evaluation of mining-related discharges. The characterization of the nature and extent of the discharges indicates that some contribute significant loads to tributary streams while others have very minor impacts. Of the 11 discharges (ten adits and the McLaren Pit subsurface drains) that exceed aquatic water quality criteria, two are located on non-District property, which, according to the Consent Decree (the legal basis for response and restoration work), no work can be conducted at these sites until other criteria are met.

Final reclamation work was conducted at four additional adits, the Black Warrior Adit, Glengarry Mill-Site Adit, and the Lower Tredennic Adit in 2008/2009 and the McLaren Adit in 2010 after the draft version of this EE/CA was prepared (Tetra Tech, 2006). Therefore, only five remaining discharges were carried through the screening and evaluation of potential response action alternatives in this EE/CA. A list of the discharges evaluated is presented in **Table ES-1**.

The Consent Decree states that a Notice of District Property Work Completion will not be issued until work is conducted to address (i) releases or threats of release of hazardous substances, pollutants or contaminants that are related to the District Property; (ii) 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 related to the District Property; and (iii) conditions affecting water quality and natural resources in Miller, Fisher, and Daisy Creeks and their tributaries, from the headwaters of each creek to the confluence of each with, respectively, Soda Butte Creek, Lady of the Lake Creek, and the Stillwater River.

The Natural Resources Working Group reached the consensus understanding that the principal goal of activities associated with the New World Response and Restoration Project is to achieve the best water quality practicable (Natural Resources Working Group, 2002). The Group also agreed that sediment loading from the road network was the primary source of impacts contributing to natural resource damages although physical habitat to support fisheries is lacking in headwaters areas of the District. For these reasons, actions to rehabilitate District roads are expected to contribute more significantly to the rehabilitation of natural resource damages compared to adit closure work.

A streamlined risk evaluation was completed to determine if human health and environmental risks are present at the five remaining discharge sites. This streamlined evaluation demonstrated that there is no human health risk associated with any of the discharges at the site and that ecological risks are clearly associated with only one of the discharges: the McLaren Pit subsurface drains. Ecological risks associated with these discharges appear in surface water tributaries that receive the discharges. Contaminants of concern -- aluminum, cadmium, copper, iron, lead, and zinc -- present ecological risks to aquatic life from ingestion and direct contact. In addition, wildlife species may be at risk from these discharges, although it is not possible to determine a site-specific assessment of exposure and risk due to the lack of site-specific knowledge of both species characteristics and exposure conditions.

Aquatic water quality standards are exceeded in all adit discharges evaluated except the Gold Dust Adit for one or more parameter. However, impacts to receiving waters immediately downstream of the adit discharges (using water quality aquatic standards) are not measured for the Little Daisy Adit or the Gold Dust Adit (Mn only), which means that these sites pose little to no risk to the aquatic environment. Impacts from the Henderson Mountain Dump 7 adit in Fisher Creek and the Henderson Mountain Adit (M-25) in Daisy Creek (Table 4-2) are less clear. Even though the standards for aquatic risks are exceeded in these latter adit discharges, because the flow from these adits is relatively low compared to in-stream flows and the adits do not directly discharge to surface water, and because the adits are a considerable distance from receiving waters the impact to downstream receiving waters is questionable or unclear.

For the discharges where ecological risks are low, aquatic risk is mitigated because either there were no exceedances of aquatic water quality standards at the discharge point, or the discharge did not directly enter a receiving stream, or, if the discharge did enter a receiving water, no impact to the stream could be measured directly down-gradient of the discharge. However, because water quality criteria were exceeded in these discharges either historically or currently, the sites were brought forward into the detailed analysis of alternatives so that a determination could be made on whether a response action could be implemented to meet applicable standards.

TABLE ES-1
DISCHARGE SITES REQUIRING RESPONSE ACTION EVALUATION

Site Name	Site No.	AIMSS Rank*	Discharge Flow Range (gpm)	Site Status**
Little Daisy Adit and Dump	M-1	20	0.5-220	Collapsed/Reclaimed 2005
Gold Dust Adit	F-28	24	1.3-247	Closed/Reclaimed 2005
Henderson Mountain Dump 7	AE-17	51	0.0-5	Collapsed/Reclaimed 2004
Henderson Mountain Adit	M-25	No rank	<0.04-25	Collapsed
McLaren Pit Subsurface Drains	DCSW-101, -102, -103	No rank	2.5-52	Three drains under cap

Notes: * AIMSS - Abandoned and Inactive Mines Scoring System
** Reclaimed status indicates previous response action conducted at the site to remove waste rock and/or close the opening
gpm gallons per minute

General response technologies and process options that are potentially capable of achieving established goals and objectives related to the treatment or reduction of mining-related discharges were screened, and the most promising technologies were then used to develop a reasonable set of alternatives that would be evaluated in detail. Response technologies considered included no action, institutional controls, engineering controls, and water treatment controls.

In response to agency and public comment on the 2006 Draft EE/CA (Tetra Tech 2006) additional studies were undertaken with respect to flow and water quality from the McLaren subsurface drains. Continuous data recorders were installed in in the subsurface drains in August 2008 to monitor year-round flow and routine water quality sampling of the discharges continued to be monitored. Data acquired from the recorders in 2009 and 2010 showed that flow ceases or decreases to a minimal amount between about mid-October to mid-November and the drains remain dry through late May when they begin to flow again coinciding with snowmelt.

Other agency and public comments led to a review of the bioreactor water treatment technologies for possible changes in design components of the treatment systems and likely cost reductions based on these changes and the identification of seasonal flows from the McLaren under drains. New considerations from both of these studies resulted in changes to analysis of alternatives in the Final EE/CA.

After screening of the response technologies, it was evident that the most promising were related to either emplacing engineering controls to reduce or eliminate flows from the adit discharges, or water treatment technologies to reduce or eliminate contaminants present in the discharges. Alternatives were then developed from the two types of technologies.

These alternatives are listed in **Table ES-2**. Source control alternatives specifically focused on the McLaren Pit subsurface drains were identified in the screening process but were not further considered for alternative development and detailed evaluation due to effectiveness, implementability, and cost concerns.

In addition to analyzed alternatives, the implementation of the Revised Final Site-Wide, Long-Term Operations and Maintenance Plan is considered an essential action that is Common to all Alternatives, including the NA-1 No Action Alternative. The Final Site-Wide, Long-Term Operations and

Maintenance Plan was issued in 1999 (Tetra Tech 2009) and was informally revised in 2010 and 2011. The Revised Final plan will be issued late in December of 2011.

Primary objectives for work covered in the Long-Term Operations and Maintenance Plan are to document and monitor the effectiveness of reclamation response and restoration actions; to provide for maintenance actions as required to ensure long-term stability of erosion controls and reclamation covers; to monitor surface and groundwater quality and to satisfy the requirements of the rule allowing adoption of temporary water quality standards. The Plan provides descriptions of annual monitoring tasks that will be completed to determine whether additional maintenance of reclaimed sites is needed, how maintenance work will be done, and estimated costs of site-wide monitoring and maintenance. This long-term operations and maintenance plan for the project begins after reclamation actions are completed in 2011 and covers activities that will occur for the following 20 years. The operations and maintenance period will therefore begin in 2012 and end in 2032. This Plan also provides an outline of specific tasks that form the basis for estimating costs for long-term operations, monitoring and maintenance tasks. This plan is not static and may be modified as needs arise due to changing site conditions or decisions made after the initial release of this report.

Because multiple sites are being considered in this EE/CA, and because many of the sites share similar characteristics, it was evident that the detailed analysis of alternatives could be streamlined by grouping the sites according to similar characteristics and then evaluating the alternatives for each group of sites rather than for each site. To this end, the sites were placed into groups. One set of groupings was based on the physical characteristics of the discharges, and these groups were evaluated against potential engineering source control alternatives. Another set of groupings was based on the chemical characteristics of the discharges and these groups were evaluated against potential water treatment alternatives. Alternatives for both of these technologies were developed along parallel paths by dividing the mines into groups for both engineering and water treatment alternative analysis. The concept of dividing mine related discharges into groups was useful for determining the effectiveness and applicability of various engineering closure and water treatment technologies, and was particularly useful when a large number of adit discharges were initially analyzed in the Draft Adit EE/CA (Tetra Tech 2006). However, with the reduction in the number of discharges to the under-drains and five (5) remaining adits (**Table ES-1**) the utility of dividing the discharges into groups is no longer as important, with several previously defined larger groups containing only one adit discharge. The group concept is retained in this Final- EE/CA in order to allow a review of the greater number of adits initially evaluated in the 2006 Draft EE/CA.

For engineering source control alternatives, there were two groups of sites: sites with open or recently closed adits and sites with collapsed adits. The engineering source control response technology retained from the screening evaluation was plugging, and the alternative evaluated for both types of sites (open and collapsed) consisted of placing two plugs within the underground workings. These two alternatives, EC-1 and EC-2, are further described in **Table ES-2**. A No Action alternative was also evaluated. For water treatment control alternatives, the sites fell into five groups. For each group, six water treatment alternatives were evaluated, including both passive treatment technologies and active treatment technologies. These alternatives are described in **Table ES-2**.

Engineering source controls were only considered for adit discharges that are amenable to this type of closure; these include one accessible mine (Gold Dust adit) and one inaccessible mine (Little Daisy adit). The remaining sites have underground workings that are too short to be considered for engineering source control measures. The two engineering source control alternatives evaluated (EC-1 and EC-2) use high strength, acid-resistant, watertight, cement plugs that block the flow of water and greatly reduce or eliminate a discharge. Watertight plugs have been shown to be effective in greatly reducing or eliminating water flow from mine sites. The effect of placing plugs will be immediate and permanent,

and the mobility of metals will be permanently reduced or eliminated. The cost to implement the alternatives ranges from $792,027 to $1,459,530 at each site.

Infiltration of adit portal discharges (Alternative WT-1) was considered for all adit sites. Under this alternative, water is diverted from a surface discharge at the portal into an subsurface infiltration basin, where it is allowed to mix with groundwater in a mixing zone. Water quality is improved by a combination of dilution and natural attenuation or adsorption onto unconsolidated colluvial materials. In order to use infiltration as a treatment method, non-degradation requirements issued by the Montana DEQ must be met.

The Little Daisy adit and the Henderson Mountain Dump 7 adit both had infiltration basins constructed to treat adit discharges in 2004 and 2005 respectively under actions defined by the Miller Creek Action Memorandum (USDA Forest Service, 2004). Reclamation activities were also conducted at the Glengarry Mill-Site, Lower Tredennic, and Black Warrior adits, in 2008 and 2009 under a USFS Action Memorandum issued in 2008 (USDA Forest Service, 2008). A description of these activities is included below in the sections for each respective adit, and each included portal closures and infiltration basins. Because no further work is planned for these adits, other discussions related to and data collected for these adits and reported in the 2006 draft Adit EE/CA were removed from this final version of the EE/CA. A portal and infiltration basin closure was also constructed at the McLaren adit in 2010 following a non-degradation analysis. Activities at this site are also discussed in this Final EE/CA.
In addition it was determined that an infiltration basin may not be desirable or necessary at the Gold Dust adit based on manganese being the only exceedance (human health Secondary Maximum Contaminant Level guidelines) for the adit discharge and the natural attenuation of this constituent over a long flow-path prior to reaching the main-stem of Fisher Creek where manganese in the Gold Dust tributary is well below the guideline. Infiltration is also not deemed necessary or desirable for the Henderson Mountain adit as the discharge flows immediately to groundwater below the portal and does not come to surface over the 1800 feet (500 M) distance between the portal and Daisy Creek where only minor exceedances of the copper aquatic life standards are measured that are likely attributed to other nearby sources.

TABLE ES-2
RESPONSE ACTION ALTERNATIVES FOR MINING-RELATED DISCHARGES

Alternative	Process Option Description
NA-1 No Action	None, but includes implementation of the Final Site-Wide, Long-Term Operations and Maintenance Plan
EC-1 Plug an Accessible Adit	Applicable for the Gold Dust Adit. Place high strength, acid-resistant, cement plugs to block and seal workings at a location about 76 meters (250 feet) into the mine and another plug near the portal to reduce or eliminate adit discharge. Cement or conventional backfill placed around the plug for ground support and to further restrict water flow. Portal closure and site reclamation.
EC-2 Reopen and Plug an Inaccessible Adit	Applicable for the Little Daisy Adit. Reopen inaccessible adits by excavation of portals, water discharge through a sediment pond, and mucking workings to 76 meters (250 feet). Place high strength, acid-resistant, cement plugs to block and seal workings at a location about 76 meters (250 feet) into the mine and another plug near the portal to reduce or eliminate adit discharge. Cement or conventional backfill will be placed around the plug for ground support and to further restrict water flow. Portal closure and site reclamation.
WT-1 Infiltration and Natural Attenuation	Discharge directed to subsurface drain field. As discharge infiltrates ground, aeration, dispersion, precipitation, and other chemical and biological attenuation processes act to reduce contaminants of concern (COC) concentrations.
WT-2 Anaerobic Bioreactor (SSBR or LSBR) with limestone matrix incorporation (and sodium hydroxide addition for LSBR), and Open Limestone Channel	Designs rely on metabolic activity of microorganisms to attenuate COCs primarily through precipitation as metal sulfide mineral phases in either a solid substrate (SSBR) or liquid substrate (LSBR) anaerobic reactant media. In the case of the SSBR, limestone is incorporated into the solid matrix to precipitate metals and increase pH. An LSBR additionally uses sodium hydroxide additions to increase pH and precipitate metals. The Open Limestone Channel is located after the bioreactor to provide additional pH buffering and metal precipitation.
WT-3 Anaerobic Bioreactor (SSBR or LRBR), and Open Limestone Channel	Designs rely on metabolic activity of microorganisms to attenuate COCs primarily through precipitation as metal sulfide mineral phases in either a solid substrate (SSBR) or liquid substrate (LRBR) anaerobic reactant media. Used in series with open limestone channels that add alkalinity to the waste stream thereby facilitating precipitation of metal hydroxides.
WT-4 Manganese Removal Cell	Manganese removal cells are modifications of limestone drains that allow sufficient residence time for precipitation of manganese oxides.
WT-5 Chemical Addition, Precipitation, Micro-filtration	Chemical agents added to waste water stream to increase or decrease pH; facilitates precipitation of insoluble mineral phases. Residual suspended solids removed by micro-filtration.
WT-6 Ion Exchange	Inorganic zeolites or synthetic organic resins provide a solid immobile substrate to capture charged particles.

Passive, semi-passive, and conventional active treatment response alternatives were evaluated for each source under review. With many of the innovative or passive treatment approaches, it is unclear given available current literature if the technology can meet the stringent aquatic standards applied to the New World sites. This is due in part because, in many of the studies reported in the literature, the recorded detection limits are above the aquatic criteria set for Montana B-1 standards. It is therefore difficult to predict removal efficiencies by biological and/or other passive treatment technologies, and treatability testing with actual discharge waters would be necessary to define achievable removal efficiencies for each discharge. The cost to implement passive water treatment alternatives ranges from $55,688 to $2.5 million.

In contrast, conventional, active treatment technologies such as chemical addition-precipitation followed by micro- or nano-filtration, or reverse osmosis, typically have the best chance of consistently meeting effluent discharge standards from a proven technology standpoint. However, the remoteness of the location, limited access, and the severe winter climate in the District would make operation and maintenance of active technologies very difficult and expensive, and may also render these more proven technologies less efficient than would be expected with close monitoring in a very controlled environment. Typically, implementation of an active treatment technology could only be accomplished at a significant increase in cost over a passive treatment system. The cost to implement active water treatment alternatives ranges from $3.6 million to $5.5 million.

Following review of the detailed and comparative analysis of alternatives, and based on the results of the evaluation at each site for the three primary criteria, effectiveness, implementability, and cost, the USDA-FS selected a preferred alternative for each of the four adit discharges and for the McLaren Pit subsurface drains. Preferred Alternatives are presented in **Table ES-3** and are described by discharge below.

TABLE ES-3
PREFERRED ALTERNATIVE FOR MINING-RELATED DISCHARGES

Site Name	Preferred Alternative
Group 1	
McLaren Pit Subsurface Drains	No Action (NA-1)
Group 2	
Little Daisy Adit	No Action (NA-1) (small infiltration basin, constructed in 2004)
Group 3	
Gold Dust Adit	No Action (NA-1)
Group 4	
Henderson Mountain Adit	No Action (NA-1)
Group 5	
Henderson Mountain Dump 7	No Action (NA-1) (infiltration basin, constructed in 2005)

McLaren Pit Subsurface Drains

The McLaren Pit subsurface drain discharges exceed standards for all COCs and are a major source of loading at station DC-2. However, the majority of the load at DC-2 results from non-specific, unidentified (non-point) sources other than the McLaren Adit or McLaren subsurface drains.

Only water treatment alternatives are applicable to the subsurface drains (relevant source containment options are screened out in Section 6.0 due to high cost and difficult implementability). Alternative WT-2 (Anaerobic Bioreactor with Limestone Matrix Incorporation/Sodium Hydroxide Additions, and Open Limestone Channel) and Alternative WT-5 (Chemical Addition, Precipitation, and Micro-filtration) were both determined to be effective in treating water discharging from the drains, but are expensive (as much as $5,513,922), and have serious construction and operation problems associated with them. The problems associated with trying to operate an active water treatment system (Alternative WT-5), considering the access required, are many and difficult, and such a treatment system would seriously impact recreational use of the Daisy Pass Road by winter recreationists.

The chances of successful installation and effective operation of a water treatment system when weighed against the total cost leaves the No Action Alternative as the most desirable alternative, particularly while the results of longer term monitoring of the effectiveness of the McLaren Pit Cap are evaluated over the next few years. The seasonally large flow volumes and high contaminant loads would not permit the development of an effective infiltration basin for the subsurface drain discharges and preliminary calculations suggest the discharge to groundwater would not meet non-degradation requirements. No Action is also preferred because the large loading contribution from non-specific and unidentified (non-point) sources other than the McLaren Adit or subsurface drains will prevent water quality standards at station DC-2 from being met even if a water treatment technology was employed for the subsurface discharges.

Little Daisy Adit

The Little Daisy discharge, which exceeds aquatic standards for a number of COCs, does not discharge to surface water; it instead percolates into colluvial material a short distance below the infiltration basin constructed near the collapsed portal, and does not surface again down-gradient of the mine. Therefore, if this discharge ultimately reaches Miller Creek, it does so as a dilute and dissipated groundwater source some 1,067 meters (3,500 feet) down-gradient of the mine site in Miller Creek. Load from the Little Daisy discharge could not be detected in Miller Creek during a synoptic study of metals loading to the Creek by the USGS.

The Little Daisy Adit is amenable to closure by Engineering Source Control Alternative EC-2, Plugging an Inaccessible Adit. This high cost ($1.45 million) method may result in an effective closure, depending on underground conditions in the workings, with water flow from the adit reduced or eliminated. However, because underground conditions are unknown, implementability of this alternative may be extremely difficult, costly and successful reentry of the Little Daisy may not be possible.

As the Little Daisy discharge exceeds aquatic standards, the moderate flow of about 30 Lpm (8 gpm) suggests that an anaerobic bioreactor system could function for an extended time, although the cost of this form of passive treatment is about $800,000. Active treatment (Alternative WT-5) is plagued by many difficulties with respect to year-round operations, site access, and power and supply requirements. The projected cost of over $3.5 million makes the passive system more attractive, particularity considering its potential long-term effectiveness.

Loading data presented indicate the only metal in the Little Daisy discharge that exceeds 1% of the load in Miller Creek at station SW-2 is manganese (5.0% of the total in-stream load of manganese in Miller

Creek). There is no direct traceable connection from this discharge to Miller Creek, and groundwater data from monitoring wells in Miller Creek below the Little Daisy (MW-5P and MW-5A) do not appear to be impacted from the signature of the Little Daisy discharge. In addition, recent water quality results (2006) for Miller Creek stations SW-2 and SW-5, showed that only copper exceeds applicable standards, with suspended sediment the cause of a portion of these exceedances in the total recoverable fraction. The area of elevated soil copper levels on the west flank of Henderson Mountain is one source of copper in the suspended fraction.

Based on the flow path for the Little Daisy Adit discharge and the lack of measurable impact to receiving groundwater, it appears that infiltration into surrounding soils and colluvial materials provide conditions where natural attenuation and/or dilution of contaminants is occurring under existing conditions. Because there does not appear to be any measurable impact from the Little Daisy discharge and because the costs associated with treating or eliminating the discharge are at least $800,000, the preferred alternative for this site is No Action. Long-term monitoring of water quality in Miller Creek that will be done as part of the overall project plan will allow the USDA-FS to regularly evaluate whether this alternative continues to be appropriate for the site.

Gold Dust Adit

After completing work involved with grouting boreholes in the Gold Dust Adit, discharge from the adit has been reduced to about 16.6 Lpm (4.4 gpm). Water flowing from the portal flows through about 305 meters (1,000 feet) of open grassy meadows and willow covered wetlands prior to entering Fisher Creek. At the portal, the Gold Dust discharge meets all chronic aquatic life standards, and only exceeds the human health guideline for manganese (0.05 mg/L). Manganese loading from the Gold Dust Adit discharge could contributes as much as 3.9% of the total manganese load at station SW-4 in Fisher Creek.

The Gold Dust Adit is suitable for closure using Engineering Source Control Alternative EC-1, Plugging an Accessible Adit. Use of a plugging system for closure is considered to be a highly effective method to reduce or eliminate flows from the Gold Dust Adit. Implementing this alternative is technically and administratively feasible. The cost of closure is estimated to be about $792,027.

Constructing a manganese removal cell under Alternative WT-4 would be a passive treatment technology that has been shown to be effective at removing manganese at other mining sites, although it is difficult to predict final effluent water quality at this time because site-specific performance data is needed before this assessment can be made. While the cost of passive manganese removal treatment is about $185,270 and much less than active water treatment at $3.6 million, final effluent water quality from an active treatment system would assure the manganese standard is met. However, while it is effective, active treatment (Alternative WT-5) is plagued by difficulties related to surface infrastructure requirements, power requirements, and the ability to operate on a year-round basis under the extreme climate and access conditions present at the site. Due to these supply requirements, winter recreation along the Lulu Pass Road would be significantly impacted under active treatment.

It is probable that Alternative NA-1, No Action, could achieve the level of manganese reduction required, given sufficient distance between the discharge source and the receptor stream. Manganese is oxidized by numerous bacteria found in nature, and, therefore, it is likely that in the oxidizing, organic-rich, uppermost soil horizon, manganese would be sequestered and removed from solution. This is in fact what happens downstream of the Gold Dust Adit under existing conditions; that is, a long, open, low gradient stretch of stream that flows through grassland and willow covered wetlands before entering Fisher Creek.

Based on the reduction in flow achieved by grouting boreholes in 2005, the effective adit closure, the relatively high cost to either plug or treat the existing discharge, and the fact that there is no aquatic risk associated with manganese, the preferred alternative for the Gold Dust Adit is No Action.

Henderson Mountain Adit

This adit is inaccessible except by foot up a steep hillside above the Daisy Pass Road. Because the small dump at the site indicates that the underground workings are very short (probably less than three to five meters [10 to 15 feet] based on the size of the waste rock dump), this discharge is likely a natural spring. As the bedrock source in the area is known to contain elevated metals, water from the Henderson Mountain Adit exceeds standards for aluminum, copper, and lead, with only copper seasonally exceeding aquatic standards at station SW-2 in Miller Creek.

The Henderson Mountain Adit is not amenable to Engineering Source Control alternatives as it is too short and too close to the surface. Due to difficult access and the small physical size of the site, implementation of either passive or active water treatment would be difficult if not impossible, and would likely not allow optimizing these technologies to assure final effluent water quality. Therefore, No Action is the preferred alternative for this discharge.

Henderson Mountain Dump 7

Henderson Mountain Dump 7 is characterized by relatively low flows and relatively low metal concentrations. Henderson Mountain Dump #7 historically discharged at an average rate of 5.3 Lpm (1.4 gpm) onto a topographic swale on the southeast flank of Henderson Mountain. The discharge is located approximately 760 meters (2,500 feet) from Fisher Creek. Historically, the water has infiltrated into surrounding soils and could not be traced as either a seep or spring down-gradient of the site, however, during mine reclamation activities in 2005 flow from the adit was redirected into a small infiltration basin located at the portal (Alternative WT-1 Infiltration).

Because the Henderson Mountain Dump #7 is too short and too shallow for an engineering flow control closure, the No Action Alternative is most applicable. The fact that the Henderson Mountain Dump 7 discharges through an infiltration basin to colluvial materials some 760 meters (2,500 feet) distant from Fisher Creek, support the preferred alternative selection of No Action.

Preferred Alternative Costs

For all four adits (Little Daisy, Gold Dust, Henderson Mountain and Henderson Mountain Dump 7 adits) and the McLaren subsurface drains evaluated for closure in this EE/CA, the Preferred Alternative was the No Action Alternative (NA-1). Therefore, the estimated cost of implementing the Adit Discharge Response Action for the New World Response and Restoration Project are for long term monitoring, operations and maintenance of the site presented as an Action Common to All Alternatives. The estimated cost for implementing the Revised Long-Term Operations and Maintenance Plan are variable depending on the year (2012 through 2032) and range in cost from about $100,000 to $150,000. Extended costs for the entire 20 years period are estimated at total cost of $1,845,289. Detailed costs from the engineers estimate for the alternatives not selected for this EE/CA are also provided in **Appendix D**.

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LIST OF ACRONYMS AND ABBREVIATIONS

AIMSS	Abandoned and Inactive Mines Scoring System
ARARs	Applicable or Relevant and Appropriate Requirements
ALD	anoxic limestone drain
ARD	acid rock drainage
ATSDR	Agency for Toxic Substances and Disease Registry
BAT	best available technology
BMP	best management practice
CaCO3	calcium carbonate
CBMI	Crown Butte Mines, Inc.
CERCLA	Comprehensive Environmental Response, Compensation, & Liability Act
COC	contaminant of concern
CFR	Code of Federal Regulations
cfs	cubic feet per second
District	New World Mining District
DNRC	Montana Department of Natural Resources and Conservation
EE/CA	Engineering Evaluation/Cost Analysis
EPA	U.S. Environmental Protection Agency
gpm	gallons per minute
HEAST	Health Effects Assessment Summary Tables
HHS	Human Health Standard
HI	Hazard Index
HQ	Hazard Quotient
IRIS	EPA's Integrated Risk Information System
kg/month	kilograms per month
Lpm	liters per minute
LSBR	liquid reactant bioreactor
MCL	maximum contaminant level
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
mmhos/cm	millimhos per centimeter
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NDP	non-District Property
NFS	National Forest System
OLC	open limestone channel
ppm	parts per million
PRSC	post-removal site control
RAOs	removal action objectives
RCRA	Resource Conservation and Recovery Act
SSBR	solid substrate bioreactor
s.u.	standard units
TDS	total dissolved solids
UOS	URS Operating Services
USDA-FS	United States Department of Agriculture Forest Service

1.0 INTRODUCTION

Tetra Tech developed this Engineering Evaluation/Cost Analysis (EE/CA) for the United States Department of Agriculture Forest Service (USDA-FS). This EE/CA presents an engineering evaluation and cost analysis of alternatives for response and restoration work proposed for mining-related discharges in the New World Mining District (District). The District is located generally north of Cooke City, Montana (Figure 1). The discharges are related to historic gold, silver, copper, and lead mining activity.

Seepage from mining-related discharges is characterized by elevated metal concentrations and sometimes acidic pH values that contribute to degradation of receiving surface water streams and nearby groundwater resources. In this report, identified impacts related to these discharges are described and characterized, response alternatives are proposed, and the cost of implementing proposed alternatives are estimated. The geographic area included for study in this EE/CA includes all mining adit-related discharges in the Daisy Creek, Fisher Creek, Miller Creek, and a portion of the Soda Butte Creek watersheds (Figure 1).

1.1 PURPOSE AND APPROACH

The purpose of this Final Adit Discharge EE/CA is to develop, screen, and evaluate potential response alternatives that would reduce or eliminate impacts associated with adit discharges from historic mines and other mining-related discharges located in the District. 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 clean-up 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).

1.2 PROJECT BACKGROUND

On August 12, 1996, the United States signed a Settlement Agreement (Agreement) with Crown Butte Mines, 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 cleanup 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 (Figure 1). District Property is defined in the Consent Decree as all property or interests in property that CBMI relinquished to the U.S. Government. If funds are available after District Property is cleaned up to the satisfaction of the United States, the clean-up of other mining disturbances in the District may be undertaken.

Terms of the Consent Decree stipulate that work will be conducted to address (i) releases or threats of release of hazardous substances, pollutants or contaminants that are related to the District Property; (ii) *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 related to the District Property; and (iii) conditions affecting water quality and natural resources in Miller, Fisher, and Daisy Creeks and their

tributaries, from the headwaters of each creek to the confluence of each with, respectively, Soda Butte Creek, Lady of the Lake Creek, and the Stillwater River.

The Natural Resources Working Group reached the consensus understanding that the principal goal of activities associated with the New World Response and Restoration Project is to achieve the best water quality practicable (Natural Resources Working Group, 2002). The Group also agreed that sediment loading from the road network was the primary source of impacts contributing to natural resource damages although physical habitat to support fisheries is lacking in headwaters areas of the District. For these reasons, actions to rehabilitate District roads are expected to contribute more significantly to the rehabilitation of natural resource damages compared to adit closure work. Work is currently underway (August 2011) under a separate contract to rehabilitate certain road segments including replacement of culverts and cut and fill slope regrading and revegetaion. In other areas select road segments will be closed. Therefore, natural resource damages are not discussed further in this EE/CA.

In 1995, the Environmental Protection Agency (EPA) began a site investigation that 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 including baseline data collected by CBMI from 1989 through 1995; an evaluation of the new data collected during the 1996, 1997, and 1998 field seasons; and an overall evaluation of the complete data set with respect to adequacy for the purposes of restoration and reclamation of historically mined sites.

The USDA-FS assisted CBMI in October 1998 in completing and submitting a Support Document and Implementation Plan to support CBMI's petition for temporary modification of water quality standards, which was approved on June 4, 1999. The petition for temporary standards was necessary to temporarily modify surface water quality standards for Daisy Creek including a headwater portion of the Stillwater River, and Fisher Creeks so that improvements to water quality might be achieved during 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). Initial construction activities associated with this response action were completed in 2002, and involved removing approximately 25,000 cubic meters (32,000 cubic yards) of mine waste and mill tailings from nine mine waste areas, disposing of these wastes in an engineered repository, and re-vegetating about 1.9 hectares (4.6 acres) of the former waste areas.

The second response action implemented by the USDA-FS in the District was the McLaren Pit Response Action (Maxim, 2001b). Construction activities were initiated in 2002 and were completed in October 2003. These activities included consolidation of waste rock dumps from the Daisy Creek headwaters area into the McLaren Pit, capping the consolidated wastes with a composite soil/geomembrane impermeable cap, and re-vegetating 4.5 hectares (11 acres). Minor closure activities were taken on the discharging McLaren Adit (Winter Tunnel) site at the north end of the McLaren Pit in 2003 with the plugging of an exploration drill hole from surface that intercepted the adit and contributed significant portion of the adit discharge. This is described in greater detail in section 2.6.1 below.

The third response action implemented by the USDA-FS was the Como Basin/Glengarry Adit/Fisher Creek Response Action (Maxim, 2002a). 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 were similar in that they both contain contaminated soils and/or mine waste rock deposits as a principal source of sulfide-bearing material that is oxidized to form an acid-rich, metal-laden leachate, which was in turn mobilized and impacted the

quality of surface water and groundwater. These two areas differ in scale in that the Como Basin Source Area was a large area (2.23 hectares; 5.5 acres) underlain at shallow depths by a massive sulfide ore deposit, whereas the Fisher Creek Source Area contained a number of small scattered waste rock piles in the upper Fisher Creek drainage and other small, but locally severe erosional problems. The implemented response action for the Como Basin Source Area used a composite cover system (geomembrane liner overlain by amended soil cover) to confine and reduce the mobility of contaminants present in soils in the basin. Work was begun on this project in 2005 and completed in 2006. The response action for the Fisher Creek Source Area used surface controls (regrading, drainage control, shallow soil lime amendment, and revegetation) for select waste rock dumps and the removal of other waste rock dumps to the Selective Source repository. Several waste rock dumps either reclaimed or removed were associated with discharging adits and often the adit discharge was directed into a subsurface infiltration basin located at or near the portal during reclamation. These sites are described in detail individually in sections 2.6.4 and 2.6.5. The response action for the Fisher Creek source area was implemented between 2004 and 2005.

Reclamation and closure of the Glengarry Adit Source Area, where contaminated inflows into underground workings flowed through the workings before discharging contaminated water into Fisher Creek, involved grouting contaminated inflows and plugging outflows from the mine with water-tight hydraulic adit plugs, and essentially eliminated discharge from the mine workings. This project was initiated in 2003 and was completed in September 2005.

The fourth response action implemented by the USDA-FS was the Miller Creek Response Action (Maxim, 2002a). The response action for the Miller Creek Source Area used surface controls (regrading, drainage control, shallow soil lime amendment, and revegetation) for the reclamation of three select waste rock dumps and the removal of two other waste rock dumps (2) to the Selective Source Repository. The two waste rock dumps removed were at the Little Daisy and Black Warrior Adit sites and were associated with discharging adits. The adit discharges from both were directed into a subsurface infiltration basins located at or near the portals during reclamation. These latter two sites are described in detail individually in sections 2.6.8 and 2.6.9. The response action for the Miller Creek source area was implemented between 2004 and 2005. The Miller Creek Response Action also called for the reclamation of several major road related erosional sediment source problems which are being addressed by a construction contract to be implemented during the summer of 2010.

The fifth response action implemented by the USDA-Forest Service was directed at stemming the flow of water from the Glengarry Mill Site Adit thereby eliminating or reducing uncontrolled releases of metals from this mining-related source into Fisher Creek. The Glengarry Adit discharges an average of 15 liters per minute (4 gallons per minute) of low pH water and metals contaminated water that flows for a short distance on ferricretes surficial deposits and then infiltrates into colluvial materials, where the metals-tainted water is transported as groundwater to into Fisher Creek. Minor remedial actions were also proposed for the Tredennic and Black Warrior adit portal areas as follow-ups to past Response Actions that removed mine waste rock dumps, recontoured and revegetated these historic mine sites in 2002 and 2004 respectively. The Glengarry Mill-site Adit wad closed with an underground grout curtain, infiltration basin and a portal plug that reduced flow from the adit by as much as 60% and eliminated the surface discharge. Remediation at the Lower Tredennic and Black Warrior mines involved minor work on adit drainage to insure that the drainage was captured by previously installed infiltration basins and additional revegetation work.

A sixth response action was implemented by the Forest Service for the McLaren Adit during the summer of 2010. This work included backfilling the adit portal with coarse rock and installing a drain-pipe inward of the rock plug to capture and redirect adit discharge into an infiltration basin located outside and down gradient of the adit. Non-degradation calculations were completed prior to

construction of the infiltration gallery (basin) (Tetra Tech 2009c). The non-degradation calculations showed that only the trigger value for zinc would be exceeded in groundwater beneath the infiltration gallery, but no applicable DEQ-7 ground or surface water quality standards for zinc would be exceeded. Some portion of the zinc load in McLaren adit seepage likely originated from zinc plated galvanized steel culverts and grates previously installed in the adit and beneath the roadway. These culverts were replaced with a corrugated HDPE culvert during construction in 2010.

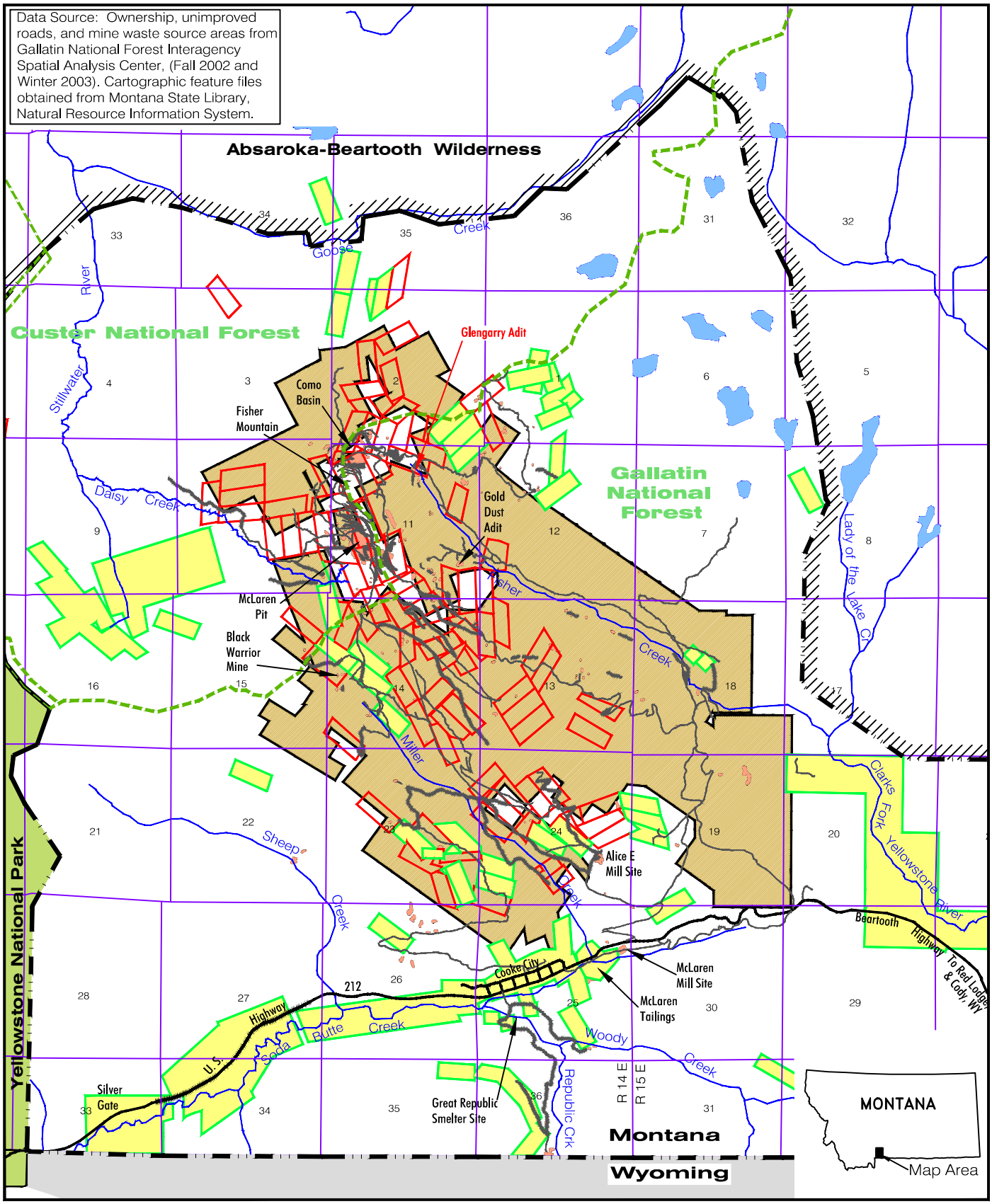
A major goal of this reclamation work was to achieve compliance with State of Montana water quality standards at the completion of the project. A key consideration in the interpretation and implementation of Montana's water quality standards is that natural conditions do not violate Montana's standards (75-5-306 MCA):

> *1, It is not necessary that wastes be treated to a purer condition than the natural condition of the receiving stream as long as the minimum treatment requirements established under this chapter are met.*
>
> *2. "Natural" refers to conditions or material present from runoff or percolation over which man has no control or from developed land where all reasonable land, soil, and water conservation practices have been applied.*

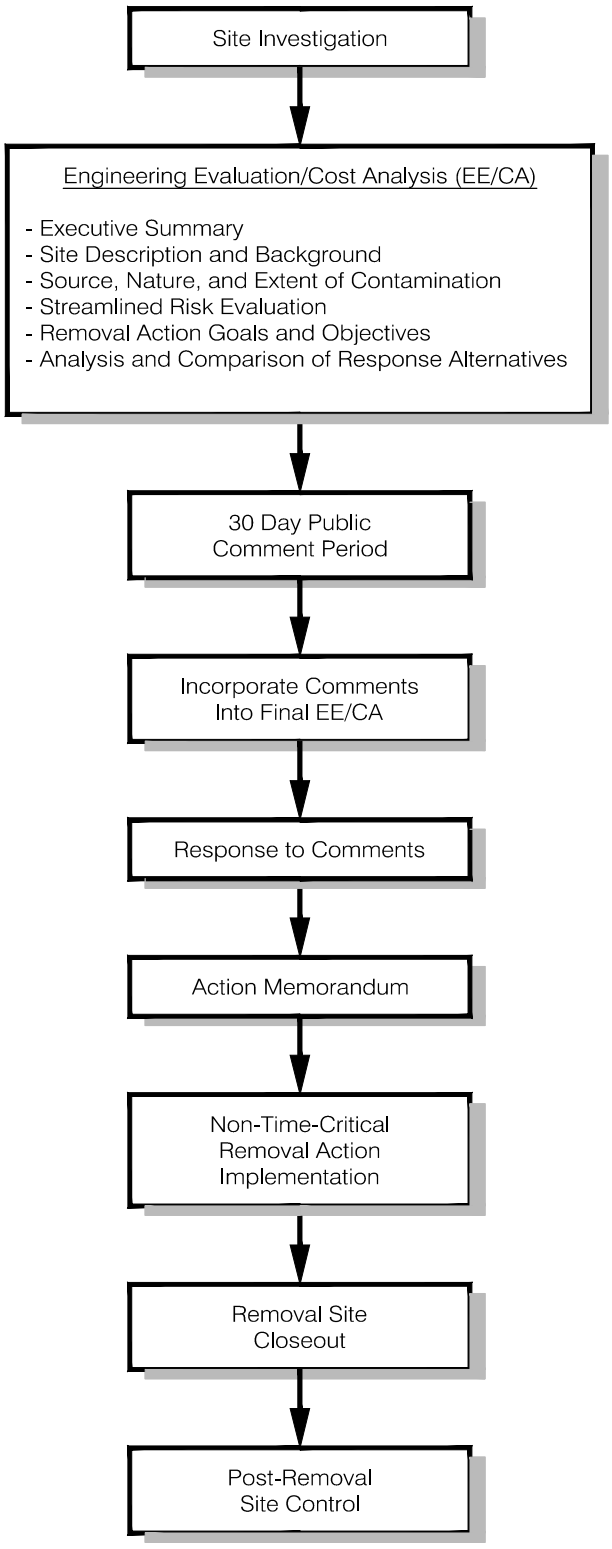
Montana's definition of natural allows for water quality standard exceedances to be considered "natural" if all reasonable land, soil and water conservation practices have been applied (MDEQ, 2009). Multiple methods used to calculate pre-mining (i.e. "natural") water quality of receiving streams in the New World District indicated that the natural pre-mining conditions of headwaters in the District were characterized by low pH and/or elevated metal concentrations (Tetra Tech, 2009a). Tetra Tech (2010a) described all reclamation activities conducted in the District and compared the resultant water quality with calculated pre-mining conditions. This study concluded the following;

- current conditions in Daisy Creek reflect natural conditions,
    - drainage from the McLaren Adit is of better quality than the pre-mining condition of the receiving stream,
    - there is evidence that the McLaren Pit subsurface drains exist in a condition that is the same as that of pre-mining receiving water,
- water quality in the headwaters of Fisher Creek is the same as pre-mining conditions except that lower pH conditions existed prior to completion of the Como Raise in the 1930s,
    - water quality in lower Fisher Creek is unchanged compared to pre-mining conditions,
    - the Gold Dust Adit discharge is of quality that is as pure as the natural condition of the receiving stream, and
- the relatively good water quality currently monitored in Miller Creek likely existed prior to mining and the adits in this drainage do not discharge directly to surface water.

In summary, Tetra Tech (2010a) concluded that water quality in receiving streams and in adit/drain discharges that are in direct communication with surface water are of equal or better quality compared to pre-mining conditions in receiving surface water and therefore are in compliance with Montana water quality standards under the provisions of 75-5-306 MCA.



Project Vicinity Map
New World Mining District
Response and Restoration Project
Cooke City Area, Montana
FIGURE 1



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Non-Time-Critical Removal Action Process
New World Mining District
Response and Restoration Project
Cooke City Area, Montana
FIGURE 2

1.3 REPORT HISTORY AND ORGANIZATION

A draft of this adit discharge EE/CA was released in December of 2006 for agency and public review. A number of comments were received from the following agencies or organizations and were used to modify the draft EE/CA: Montana Department of Environmental Quality (DEQ); US Environmental Protection Agency (EPA) Region 8; National Park Service; US Geological Survey (USGS); Beartooth Alliance; Center for Science in Public Participation (CSP); and the Greater Yellowstone Coalition (GYC). The resulting Final Adit Discharge EE/CA (this document) is considerably revised from that early draft version. In 2008 and 2009, reclamation activities were conducted at the Glengarry Mill-Site, Lower Tredennic, and Black Warrior adits, under a USFS Action Memorandum issued in 2008 (USDA Forest Service, 2008). In addition, a portal and infiltration basin closure was also constructed at the McLaren adit in 2010 following a non-degradation analysis. Activities undertaken at these sites are discussed in this Final EE/CA. The USDA-FS will select a response alternative to implement on the four remaining adits and the McLaren subsurface drains based on this EE/CA document in a subsequent Action Memorandum.

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 data pertinent to characterizing adit discharge sources within the Daisy, Fisher, and Miller Creek drainage basins. In particular, adit seepage chemistry and flow data are reviewed and compared to data from surface water monitoring stations to determine the relative contribution of each adit to the total metal load in receiving surface water. Section 4.0 summarizes human health and ecologic risks associated with discharges and recreational use of the sites. Section 5.0 outlines the response action scope, removal action objectives (RAOs), and reclamation goals for the site. The RAOs were developed by the USDA-FS, and goals were identified based on both applicable or relevant and appropriate requirements (ARARs) and representative cleanup guidelines for mine waste sites. 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 presents a comparative analysis of the alternatives where a preferred alternative is selected.

Figures and tables are incorporated into the text of this report. References cited in the document are listed at the end of the text. Appended information includes water quality and flow data for adits and surface water monitoring stations, risk evaluation calculations, a list of ARARs, and detailed cost estimates for the alternatives discussed in Sections 7.0 and 8.0.

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2.0 SITE DESCRIPTION

The District includes both National Forest System (NFS) land and private land in a historic metal mining area located north of Cooke City, Montana (Figure 1). This historic mining district contains both mining-related and natural conditions that impact surface and groundwater resources and affect 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; adit discharges from both mine wastes and abandoned mine workings; and natural acid rock drainage. Human health and environmental risk 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 SITE LOCATION

The District falls within the boundaries of the Gallatin and Custer National Forests and lies adjacent to Yellowstone National Park's northeastern-most corner (Figure 1). 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 NFS 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 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, Wyoming and Cooke City, Montana. 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). 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 vicinity of Fisher Mountain, around which many of 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. Headwaters tributaries that feed these three branches of the Yellowstone are named, respectively, Fisher Creek, Daisy Creek, and Miller Creek (Figure 1).

2.2 CLIMATE

The New World District has a continental climate modified by its 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 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 -16.5°C (2.4°F)

and an average maximum temperature of –4.8°C (23.3°F). Temperatures are warmest in July with an average minimum temperature of 3.3°C (37.9°F) and an average maximum temperature of 22.8°C (73.1°F).

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 having the highest average monthly precipitation (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, about 41 feet) (USDA, 1975).

A meteorological station was maintained in upper Fisher Creek and 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).

2.3 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 Daisy Creek drainage basin collects water from the north side of Daisy Pass, the north flank of Crown Butte, the west flank of Fisher Mountain and Lulu Pass, the north flank of Bull of the Woods Pass and the east flanks of Wolverine Pass and Mount Abundance (Figure 1**)** Daisy Creek flows northward from its origin below Daisy Pass approximately three kilometers (two miles) to its confluence with the Stillwater River, which continues generally northward through the Absaroka-Beartooth Wilderness Area.

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, the east flank of Henderson Mountain and from the Como Basin (Figure 1). Fisher Creek flows southeastward from its origin below Lulu Pass and is joined by a few small unnamed tributaries in the reach between the Glengarry Adit and the southern end 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 eastward through northwestern Wyoming and then turns north and joins the Yellowstone River near Laurel, Montana.

The Miller Creek drainage basin collects water from the south side of Daisy and Bull-of-the-Woods passes, the southwest flank of Henderson Mountain, and the east flank of Miller Mountain (Figure 1). Just east of Cooke City, Miller Creek flows into Soda Butte Creek, which flows westward into Yellowstone National Park where it joins the Lamar River.

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 three drainages, only a

few winter and spring flow measurements have been made. Peak flows occur between mid May and early August and most commonly in late June or early July.

Groundwater occurs in two hydro-stratigraphic units in the three drainage basins: 1) surficial unconsolidated alluvial and colluvial deposits localized along drainages, and 2) fractured bedrock. Unconsolidated deposits that host groundwater consist primarily of narrow strips of alluvial/colluvial material deposited parallel to tributary channels and the main stems of Daisy, Fisher, and Miller creeks. Groundwater within unconsolidated sediments is recharged by direct infiltration of surface runoff and in some areas by discharge from bedrock seeps, springs, and fractures. Groundwater flow within unconsolidated material is generally parallel to topographic slope.

The primary porosity of bedrock units throughout the District is very limited. Most porosity and permeability is secondary, and results from fractures and faults in bedrock. Recharge to bedrock occurs primarily as direct infiltration of snowmelt and runoff, particularly where fractures daylight.

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. Significant preferential groundwater flow along the Crown Butte Fault, which controls the location of the Miller Creek valley, has been demonstrated by pump testing.

2.4 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. 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. A portable smelter was reported to have been in operation in the Miller Creek drainage in the late 1880's. 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 1920's. The Glengarry Mining Company operated a flotation mill in the upper Fisher Creek drainage in the 1920's to process copper-gold ores from the Spalding Tunnels. The Spalding Tunnels were developed in a north-south fault structure (Crown Butte Fault) on the south side of Scotch Bonnet Mountain (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 Spalding 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 massive sulfide mineralization of the Como stratabound replacement deposit near Lulu Pass.

The Tredennic Mines were operated by the Tredennic Development Company on claims located on the southeast flank of Scotch Bonnet Mountain. 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 was recorded from any of the Tredennic workings (Lovering, 1929).

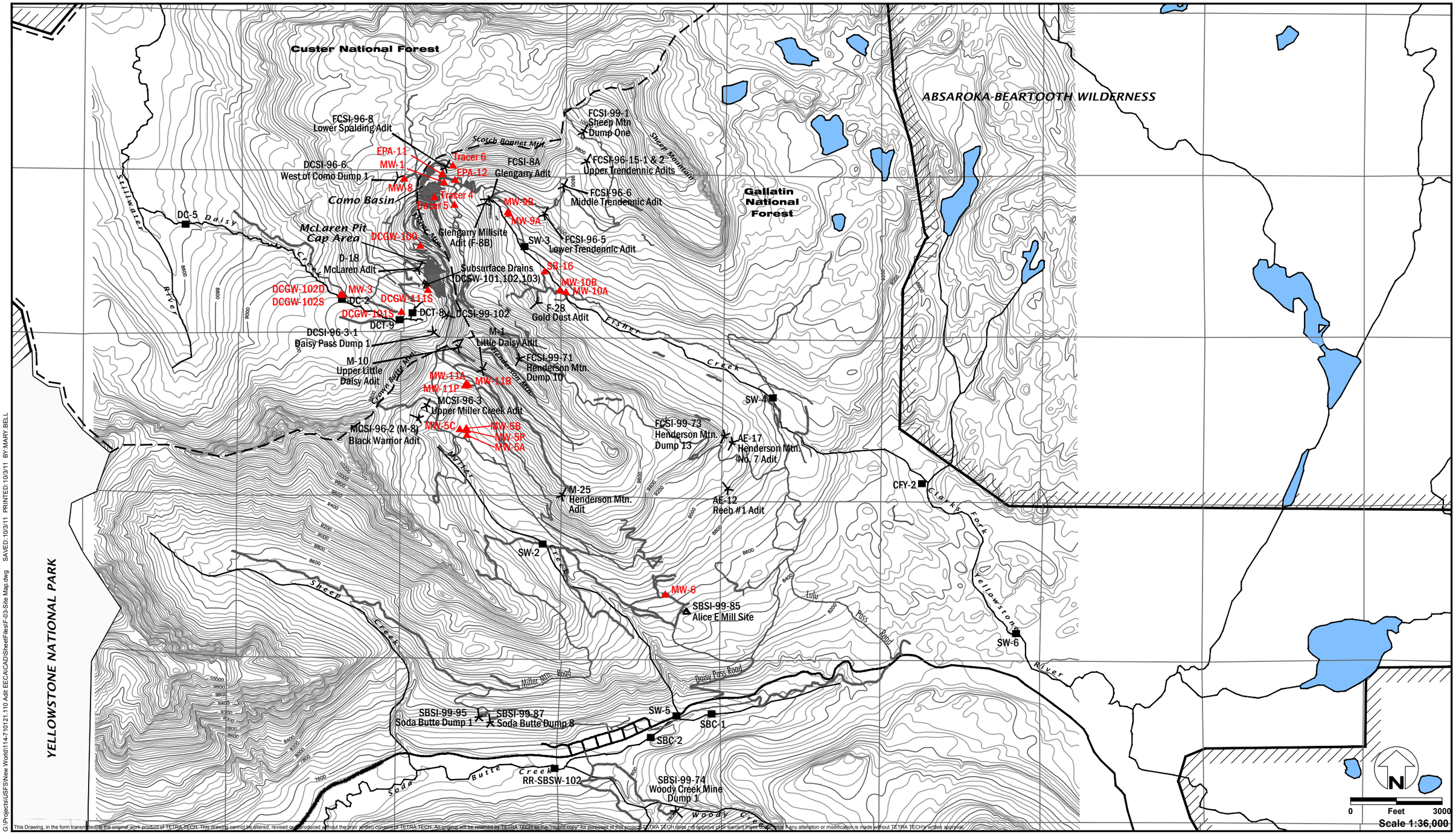
The Gold Dust Adit is located on the southwest side of the Fisher Creek Valley, near the break in slope forming the flank of Henderson Mountain (Figure 3). The adit was driven by Western Smelting and Power Company between 1920 and 1925 and drifts to the southwest for about 700 meters (2,300 feet). No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

Three mines were important in the early mining history of the Miller Creek area: the Little Daisy Mine (also known as the Daisy Mine), the Black Warrior Mine, and the Alice E Mine. In addition to these three mines, several small underground mines were operated on the west side of Miller Creek, on the mid- to lower-slopes of Miller Mountain (Figure 3). The Little Daisy Mine is located on the northwestern slope of Henderson Mountain immediately southeast of Daisy Pass. Western Smelting and Power operated the mine intermittently from 1888 to about 1918. The Little Daisy Mine has approximately 2,385 feet of workings (Lovering, 1929) with portals on both the southwest (Little Daisy Adit) and northeast flanks (Homestake Adit) of Henderson Mountain (Figure 3). The Little Daisy Mine produced gold and copper ore from sulfide and oxide replacement mineralization in blocks of Pilgrim Limestone caught up in the Homestake Stock and the upper portion of the Homestake Breccia Pipe.

The Black Warrior Mine (Figure 3) lies southeast of Bull-of-the-Woods Pass, near the headwaters of Miller Creek. It consists of an underground adit about 130 meters (425 feet) in length and a 24-meter high (80-foot) raise to surface. The adit was driven to the north-northeast along fracture-controlled lead-zinc-silver mineralization in the Pilgrim Limestone along what may be a splay of the Crown Butte Fault zone.

The Alice E Mine (Figure 3) is located on the southwestern flank of Henderson Mountain. The mine was operated in the mid-1890's as an open-pit operation that mined oxidized gold from fracture-controlled mineralization in the brittle Flathead Formation (sandstone/quartzite). Some gold-bearing pyritic ore is exposed in these workings and contained in the waste rock; however, because the Alice E Mine recovered gold using cyanide it was not effective in treating sulfide-rich ores. The Alice E Mine proper is located on private property, although the mill site that contains both tailings and waste rock is located on NFS land (non-District Property).

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.



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G:\Projects\USFS\New World\114-710121.110 Adit EECA\CAD\SheetFiles\F-03-Site Map.dwg SAVED: 10/3/11 PRINTED: 10/3/11 BY: MARY BELL

Source: Topographic data from USGS 7.5 Cooke City Quad
Contour Interval = 40'

- District Boundary
- Forest Boundary
- Roads
- SW-2 ■ Surface Water Station
- Collapsed Adit Discharge Site
- Open Adit Discharge Site
- Other Discharge Site
- MW-3 ▲ Monitoring Well

Site Map
New World Mining District
Response and Restoration Project
Cooke City Area, Montana
FIGURE 3

Extensive exploration of the area by a number of major mining companies for sediment-hosted, massive sulfide and porphyry copper and molybdenum deposits continued from 1974 until 1996, with CBMI as the last major company to hold an interest in the District. CBMI executed exploratory drilling programs for stratabound replacement and breccia pipe deposits containing gold, copper, and silver mineralization in the District from 1987 to 1993. This exploration work produced new subsurface deposit discoveries and led to extensive drilling in the Miller Creek and Homestake deposit areas located under the north end of Henderson Mountain in the upper Miller Creek drainage. In addition, the Homestake deposit was drilled from underground drill stations in the Gold Dust Adit in 1993.

2.5 DISTRICT GEOLOGY

The geology and mineral deposits of the District were mapped and described by Lovering (1929) and Elliott mapped the geology of the Cooke City Quadrangle in 1979 (Elliot 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 Eyrich (1969), Johnson (1991), Johnson and Meinert (1994), 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 lower Fisher Creek and scattered outcrops on the southern flank of Henderson Mountain (Figure 4). Paleozoic sedimentary rocks consisting of sandstone, siltstone, shale, limestone, and dolomite unconformably overlie these basement rocks and occur on the north and west flanks of Fisher Mountain, on the southwest flank of Sheep Mountain, and outcrop extensively in the Miller Creek area along the flanks of Henderson Mountain, Miller Mountain, and Crown Butte. These sedimentary rocks generally dip gently to the southwest and are intruded by Tertiary (Eocene) felsic calc-alkaline stocks, laccoliths, sills, and dikes. There are four principle plutons in the District. From north to south these are: Scotch Bonnet Diorite, Fisher Mountain Intrusive Complex, Homestake Stock, and the Henderson Mountain Stock. The Fisher Mountain and Homestake Intrusive complexes (Figure 4) exhibit concentrically zoned, porphyry-style alteration characterized by quartz-sericite-pyrite-chalcopyrite alteration assemblages. Both of these intrusive complexes were explored in the 1960s-1980s for porphyry copper and porphyry molybdenum deposits.

The Miller Creek drainage occurs along the southwest flank of Henderson Mountain, which is cored by the Homestake and Henderson Mountain Stocks. The location of the valley is controlled by Pleistocene (glacial) and recent erosion along the Crown Butte Fault that crosses Crown Butte and Daisy Pass and extends southward along the Miller Creek valley axis (Figure 4).

The gold-copper-silver deposits in the 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., Little Daisy Mine, Spalding and Tredennic 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). Late stage vein and replacement deposits of lead, zinc, and silver that occur more peripheral to the District, some of which occur in Miller Creek (Black Warrior Mine and some Miller Mountain deposits) are also genetically related to these two stocks.

Mineralization in the Daisy, Fisher, and Miller Creek areas is spatially, temporally, and genetically related to the emplacement and alteration of the Fisher Mountain Intrusive Complex and the Homestake and Henderson Mountain stocks. In addition, recent (1980's) exploration activities identified large areas of mineralization and alteration containing anomalous metal enrichment in intrusive rock and overlying soils

on the southwest flank of Henderson Mountain. Detailed descriptions of mineralization in the District are presented in the Como Basin/Glengarry Adit/Fisher Creek Response Action EE/CA (Maxim, 2002a) and the Miller Creek Response Action EE/CA (Maxim, 2003a) and are not repeated here.

2.6 DESCRIPTION AND MINERALIZATION OF MINES IN THE DISTRICT

This section presents a description of the major mines in the District. With a few exceptions, most mines are underground and are entered through adit openings that have collapsed at all but two sites. Most of the major mines described below have adit discharges. Figure 3 shows the location of all the discharging adits in the District.

Three adits, the Glengarry Mill-Site, Lower Tredennic, and Black Warrior adits, were discussed and evaluated in the 2006 draft version of this EE/CA (Tetra Tech, 2006). Reclamation activities have been conducted at the Glengarry Mill-Site, Lower Tredennic, and Black Warrior adits, in 2008 and 2009 under a USFS Action Memorandum (2008). A description of these activities is included below in the sections for each respective adit. Because no further work is planned for these adits, other discussions related to and data collected for these adits and reported in the 2006 draft Adit EE/CA were removed from this final version of the EE/CA. Construction reports for the reclamation and/or closure of these three adits can be found in construction or other report cited below for each of the adits.

It should be noted that these adits were grouped together with other adits for evaluation of engineering controls and water treatment technologies in the 2006 Draft EE/CA (Tetra Tech, 2006). Although these three adits are no longer considered for action in this EE/CA, the remaining adits are still referred to by Group number in order to maintain consistency with the 2006 draft even though in some cases a Group may only comprise a single adit in this report.

2.6.1 McLaren Adit and Subsurface Drains

In 1933, The McLaren gold-copper-silver mining operation was developed on the west side of Fisher Mountain (Figure 3). Initial mining and exploration was conducted from a series of eight east-northeast trending adits of varying length (Figure 5). The geometry of the ore exposed in the exploration adits indicated that the ore deposit in the McLaren Mine area was aerially extensive, tabular and dipped gently to the southwest. It was determined that the McLaren gold-copper deposits could be most efficiently mined by open pit methods. In the subsequent open pit mining operations, waste rock was stripped from the underlying massive sulfide ore, and stockpiled to the north side of the pit. The massive sulfide ore was stripped down to its lower contact with an inter-formational dacitic intrusive sill. Presumably, these first eight adits were mined out during open pit mining operations, although this cannot be confirmed as portions of these former adit levels may be buried by waste rock pit-backfill.

Ore present beneath an inter-formational, Tertiary-age, dacitic intrusive sill occurring in the upper third of the Meagher Limestone at the McLaren Mine was not mined, and significant additional reserves were discovered by CBMI to lie beneath this intrusive sill. In addition, by recent and current economic standards, most waste rock placed as backfill into the open-pit is of ore-grade. CBMI drilled in the McLaren Mine area proper from 1987 through 1990 to evaluate the ore remaining in the lower portion of the Meagher Limestone and in mine backfill materials within the McLaren Pit (CBMI, 1990).

In addition to the eight adits likely obliterated by mining in the McLaren Pit, a ninth adit, called the McLaren Adit (or the Winter Tunnel), appeared on maps in 1952, one year prior to the cessation of open pit mining. The McLaren Adit was driven to the northeast from the northwest corner of the McLaren Pit. Due to a mill fire that ended mine operations, the McLaren Adit was not disturbed by historic open-pit mining activities and remains at the north end of the pit. It collars at about 2,938

meters (9,640 feet) in elevation near the junction of the main county road with the Lake Abundance road (Figure 3). Based on the size of a waste rock dump (3,100 cu yds) located near the portal and the dimensions of the adit, it is estimated that the length of workings could be as much as 540 meters (1,770) feet , but part of this waste rock volume likely includes material from crosscuts and drifts, and/or stopes developed in the mine.

The USDA-FS reopened the McLaren Adit in September of 2001 using a track-mounted excavator to explore the workings and look for sources of the water inflow that generates the discharge from the mine portal. Figure 6 is a geologic map of the accessible portion of the workings and Figure 7 shows the reconditioned adit portal. Altered and mineralized sedimentary rocks of the Meagher Limestone (pyrite, chalcopyrite, and abundant iron-oxides) are complexly intruded by the Fisher Mountain porphyry over the accessible and visible portions of the mine. No water sources other than an occasional drip were observed in the first 107 meters (350 feet), but water was flowing over a meter (3.5 foot) high dam at a caved-in section of the mine at 130 meters (423 feet), and flowing down an exploration borehole drilled from the surface that had intersected the adit at about 112 meters (366 feet). Because the mine flows year-round, it was assumed that a significant inflow must occur at some point further into the mine. In a successful effort to reduce flow into the adit, the drill hole that penetrated the adit from the surface was plugged in September 2003, reducing the flow from the borehole to zero and reducing the flow discharged at the portal to less than 12 liters per minute (3.2 gpm)(Maxim, 2004a). This flow discharged by way of a tributary to Daisy Creek. In the last sample analyzed for metals from the McLaren Adit in September 2008, copper, iron, and manganese concentrations in the discharge exceeded Circular DEQ-7 aquatic standards that would be applicable to surface water in Daisy Creek. Aluminum, cadmium, lead, and zinc are typically present at relatively low concentrations. Circum-neutral pH values have been measured during most sampling events. The percent contribution of average metal loads from the McLaren Adit to base flow loads at DC-2 in Daisy Creek is less than 1.0% except for iron, lead, and manganese. The McLaren Adit theoretically could contribute as much as 14.9% of the total iron load, 1.8% of the total lead load, and 3.4% of the total manganese load measured at DC-2. The adit was permanently closed in 2010 when the portal was plugged with coarse rock and a piping system was installed to capture and direct adit discharge through a drop inlet and into an infiltration basin located outside and down gradient of the adit. Non-degradation calculations were completed for the infiltration basin for the McLaren adit discharge. Plugging the portal was also used to restrict access to the McLaren Adit, thereby preventing any access to underground workings that might result in personal injury. No further response actions are planned for the McLaren Adit.

GEOLOGY LEGEND

Quaternary Deposits

- d — MINE DUMPS AND MILL TAILINGS
- ALLUVIUM
- Qu — UNDIFFERENTIATED SURFICIAL DEPOSTIS
- Ql — LANDSLIDE DEPOSITS
- Qg — GLACIAL DEPOSITS

Intrusive Rocks

- PORPHYRITIC ANDESITE AND ANDESITE PORPHYRY
- Trp — RHYODACITE PORPHYRY
- LATITE PORPHYRY
- Trl — RHYODACITE PORPHYRY OF LULU PASS
- RHYODACITE PORPHYRY OF HENDERSON MOUNTAIN
- Tl — LATITE AND PORPHYRITIC LATITE
- Trpq — QUARTZ "EYE" RHYODACITE PORPHYRY
- COMPLEX OF FISHER MOUNTAIN AREA
- Tbx — BRECCIA OF ALICE E. MINE AREA
- BRECCIA OF HOMESTAKE MINE AREA
- DIORITE OF SCOTCH BONNET MOUNTAIN
- TRACHYANDESITE PORPHYRY

Precambrian Basement and Sedimentary

- WAPITI FORMATION
- Tlc — LAMAR RIVER AND CATHEDRAL CLIFFS FORMATION
- Mm — MADISON LIMESTONE
- Dt — THREE FORKS FORMATION
- Dj — JEFFERSON FORMATION
- BIGHORN DOLOMITE
- Cs — SNOWY RANGE FORMATION
- Cpi — PILGRIM LIMESTONE
- Cp — PARK SHALE
- Cm — MEAGHER LIMESTONE
- Cw — WOLSEY SHALE
- Cf — FLATHEAD SANDSTONE
- Wgd — QUARTZ DOLERITE
- Wm — METADOLERITE
- Wom — OLIVINE METAGABBRO
- METADOLERITE PORPHYRY
- Wg — GRANITIC ROCKS

Stillwater River
Daisy Creek
Scotch Bonnet Mtn.
Glengary Adit
Crown Butte Mtn.
Henderson Mtn.
Timber Creek
Creek
Absaroka-Beartooth Wilderness
Custer National Forest
Gallatin National Forest
Cooke City
212
Highway
Silver Gate

- FAULT, CONCEALED
- TRACE OF SURFACE OF TECTONIC DENUDATION OF HEART MOUNTAIN DETACHMENT
- HEART MOUNTAIN DETACHMENT FAULT
- FAULT, INFERRED
- FAULT, INTRUDED BY DIKE
- PORPHYRITIC BASALT AND BASALT PORPHYRY
- REVEALED
- RHYOLITE
- ADIT
- COLLAPSED ADIT

N

0 Feet 3000

Scale 1:36,000

Source: Topographic data from USGS 7.5 Cooke City Quad Contour Interval = 40'

Geology from USGS Miscellaneous Investigation Series Map I-1084, Geologic Map of the Southwest Part of the Cooke City Quadrangle, Montana and Wyoming, James E. Elliott, 1979.

Geologic Map of the New World Mining District
New World Mining District
Response and Restoration Project
Cooke City Area, Montana
FIGURE 4

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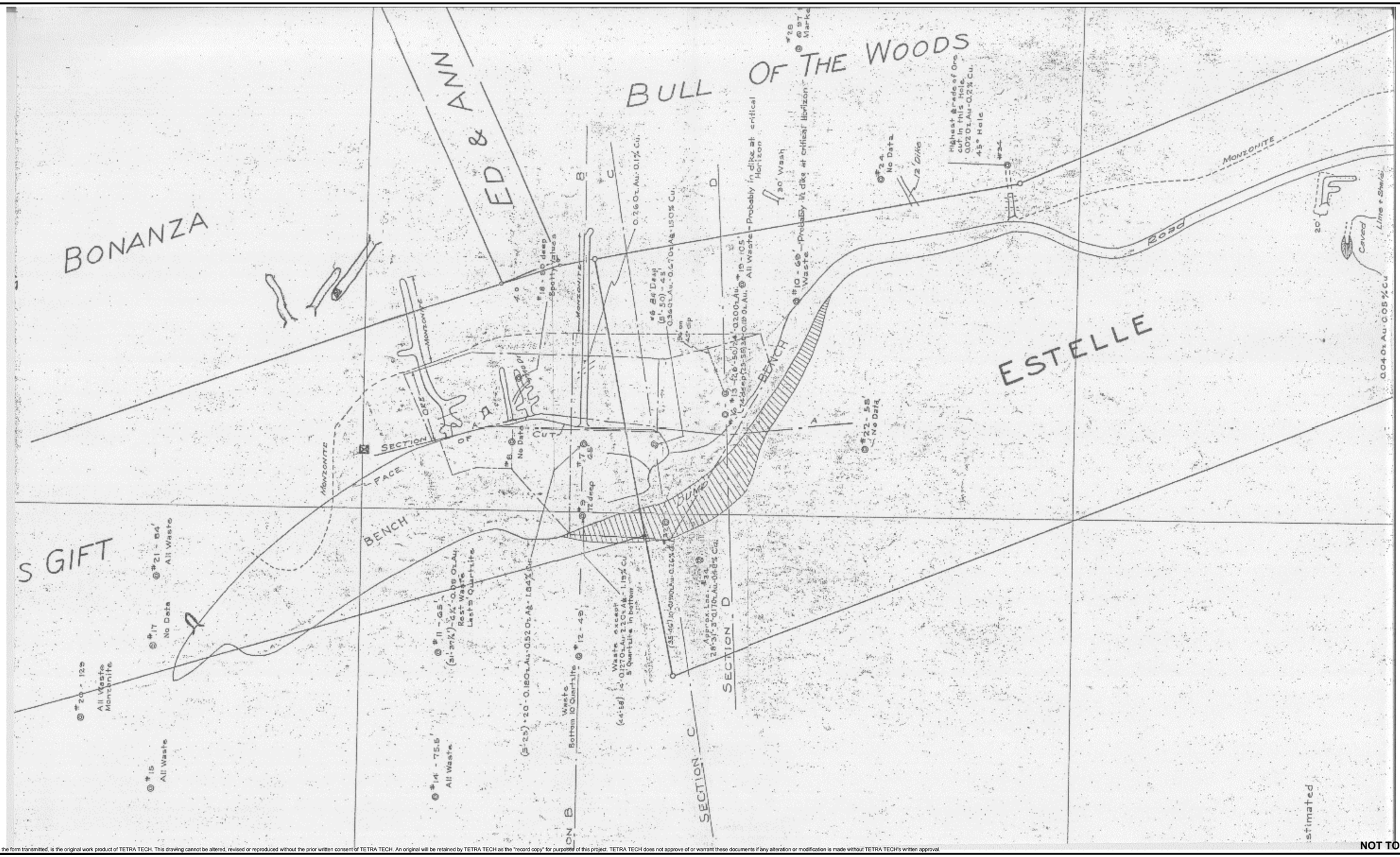
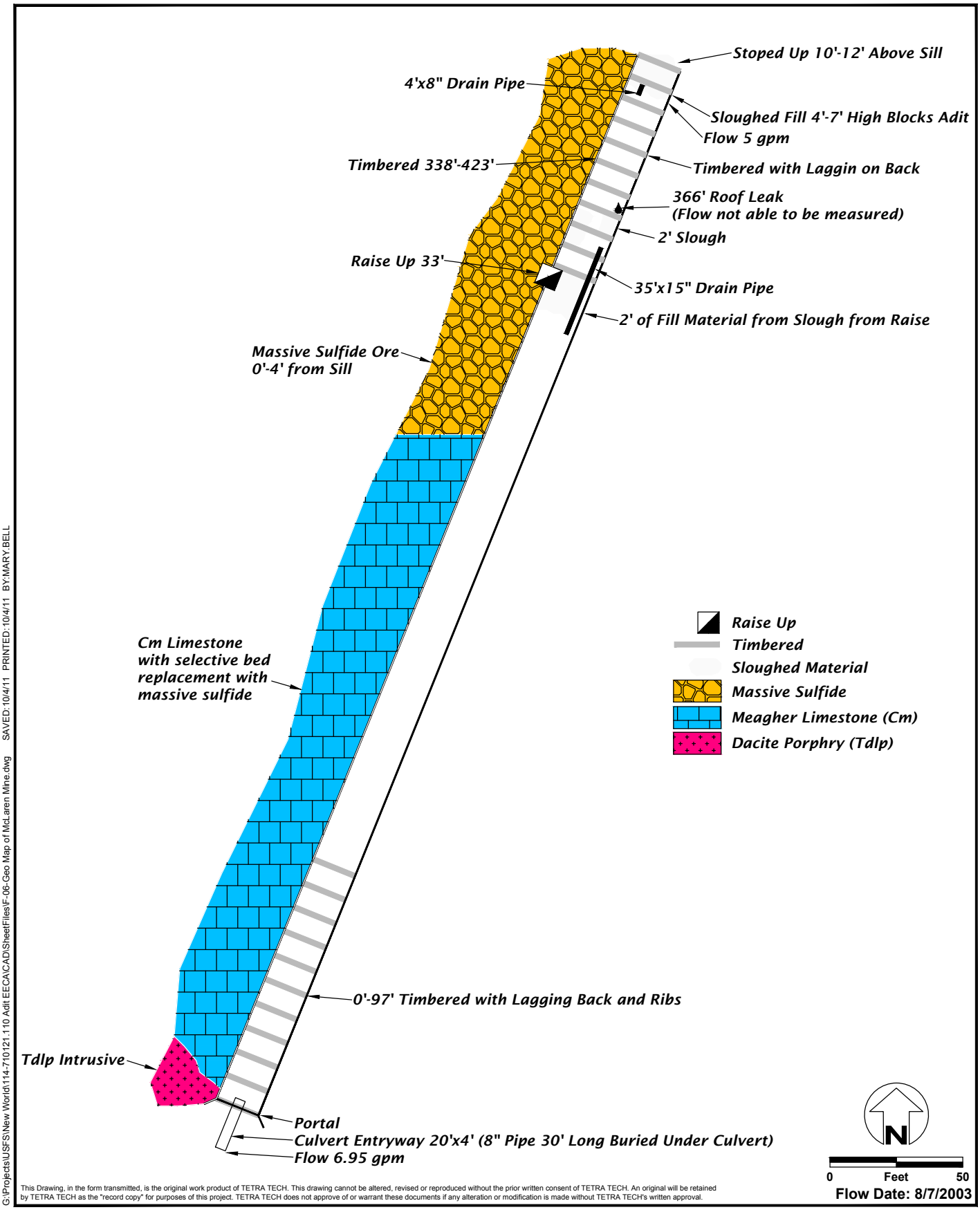

BONANZA
ED & ANN
BULL OF THE WOODS
ESTELLE
S GIFT
BENCH
BENCH
SECTION A
SECTION B
SECTION C
SECTION D
Road
Manzonite
Manzonite
Manzonite



G:\Projects\USFS\New World\114-710121.110 Adit EECA\CAD\SheetFiles\F-06-Geo Map of McLaren Mine.dwg SAVED:10/4/11 PRINTED:10/4/11 BY:MARY.BELL

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(Width Exagerated)

gpm = gallons per minute

Map of the McLaren Adit
New World Mining District
Response and Restoration Project
Cooke City, Montana
FIGURE 6

Figure 7. Photograph of reopening of the McLaren Mine Adit (or Winter Tunnel)

The Final McLaren Pit Response Action EE/CA was prepared and released in December of 2001, the Action Memorandum was issued in January of 2002, construction took place in 2002 and 2003, and the final construction report was released in July of 2006. The McLaren open pit was regraded, capped with an impermeable liner, and covered with a drainage system and soil cover between July 2002 and October 2003 during the McLaren Pit Response Action. During waste rock regrading operations, several wet areas were encountered. One of these was a series of seeps originating from bedrock at the toe of the pit high-wall. The others were point sources in bedrock that were found in the lower portion of the pit (Civil Consulting Services, 2006). These wet areas were excavated and filled with coarse drain rock, and a drain pipe was inserted in the rock to facilitate draining water from the wet areas so that regrading could proceed. There were four drains constructed, and the ends of these drains were terminated in a runoff channel down-gradient of the pit. One of the drain pipes was covered in the channel with rock, but the terminal ends of three drain pipes are accessible. These sites are shown on Figure 3 as sample sites DCSW-101, DCSW-102, and DCSW-103. Water from these drains exhibited very acidic pH values, ranging between 2.2 and 4.4 s.u., with generally poor water quality (copper and iron concentrations in the mg/L range). Subsurface drain water quality is discussed further in Section 3.3.2 and presented in Table 3-5. The combined flow from the three drains ranges from 9.4 Lpm to 196.6 Lpm (2.5 gpm to 52 gpm) and averaged about 79 Lpm (21 gpm) during times when flow was measured. Continuous data recorders were installed in August 2008 to monitor year-round flow from the subsurface drains. Data acquired from the recorders in 2009 and 2010 showed that flow ceases between mid-October and mid-November and the drains remain dry through late May when they begin to flow again coinciding with snowmelt. No further response actions are proposed for the McLaren subsurface drains.

2.6.2 *Glengarry Adit and Glengarry Mill-Site Adit*

The Glengarry Adit (F8-A), located at an elevation of approximately 2,840 meters (9,320 feet) at the base of the eastern flank of Fisher Mountain, was actively being driven in 1925 (Lovering, 1929) (Figure 3). The adit was driven 701 meters (2,300 feet) towards Lulu Pass in an attempt to intercept mineralization beneath the Spalding Tunnels located on the south-facing flank of Scotch Bonnet Mountain. No mineralization was encountered at the level of the Glengarry Adit (Lovering, 1929). In the early 1930s, two nearly vertical raises were constructed from an extended heading driven to the

southwest from a "Y" intersection underground in the Glengarry adit. 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 Meagher Limestone formation, and a massive sulfide deposit hosted in the Meagher.

A grout/plugging project to limit the inflow to and discharge from the Glengarry Adit was completed in 2005 as part of the Como Basin/Glengarry Adit/Fisher Creek Response Action EE/CA (Maxim, 2002a). The Action Memorandum was released in December of 2002. The Como Basin raise collar and a major fault system that was making water underground in the mine were grouted in 2003. In 2004, a watertight raise plug and two adit plugs were constructed and portions of the raise and adit were backfilled for ground support around the plugs. Two additional plugs and another cement backfilled portion of the adit were constructed in 2005. The simple (non-watertight) portal closure plug was constructed in October of 2005. These actions have resulted in a decrease of flow from as much as 144 liters per minute (Lpm) (38 gallons per minute [gpm]) prior to grouting and plugging to 7.9 Lpm (2.1 gpm) measured on October 27, 2005, 2.05 Lpm (0.54 gpm) measured on June 28, 2006, and 6 Lpm (1.6 gpm) measured on August 28, 2006. Flow has recently decreased to an immeasurable seep during the June, 2008 monitoring event. A final construction report was prepared for the Glengarry Mine Closure (Tetra Tech 2007) and is available on the Gallatin National Forest New World Project website. In 2009, maintenance was conducted on the portal plug at the Glengarry Mine site (Tetra Tech, 2009b). Overall flow from the Glengarry adit (and adit discharge loading to Fisher Creek) has been reduced by as much as 98%. As a result of the closure of the Como Raise and successful stemming of the flow from the Glengarry Adit, no further response actions are contemplated for the remaining Glengarry discharge in this EE/CA.

The Glengarry Mill-Site Adit (F8-B), located immediately south of the main Glengarry Adit, consisted of a single horizontal adit extending approximately 40 feet from its portal. A small building, clearly designed for storage, sat at the portal of the adit (Figure 8). This adit appeared to have been driven to serve as an extended storage area, possibly for explosives. The adit itself was in good condition and had a gate constructed of steel bars, which was buried by about 0.6 meters (2 feet) of ferri-hydroxide mud. The ferri-hydroxide mud extended to the back of the workings and was mixed with debris along the sill (floor). There was seepage from the Glengarry Mill-Site Adit with very low discharge rates, ranging from 3.0 to 19 Lpm (0.8 to 5.0 gpm) (average 15 Lpm [4 gpm]). However, a maximum flow of 102 Lpm (26.9 gpm) was measured in September 1989. Water from the adit flowed over an extensive ferricrete bench outside of the portal, down across the mill site, and infiltrated into colluvial materials below the mill site approximately 46 meters (150 feet) from Fisher Creek. This shallow groundwater likely resurfaced as base-flow in Fisher Creek.

Figure 8. Glengarry Mill-Site Adit

The presence of significant depths of ferri-hydroxide mud in the Glengarry Mill Site adit and the extensive bench of ferricrete at the portal suggested that the seepage may have originated from bedrock fractures carrying reduced iron in solution. Once the reduced iron in solution contacted the atmosphere, rapid deposition of iron hydroxides occurred. Iron deposition occurs because the solubility of reduced iron is about three times greater than oxidized iron, so contact of reduced, iron-bearing groundwater with atmospheric oxygen lowers the solubility, causing precipitation of ferri-hydroxide mud. Where this material precipitates within colluvial materials, it cements the material into a well-indurated rock called ferricrete. The main Glengarry Adit also contained as much as one meter or more of ferri-hydroxide mud along the sill when it was rehabilitated. The fact that such an extensive bench of ferricrete existed in outcrop near the Glengarry Mill-Site Adit portal suggested that the process of ferricrete deposition had been ongoing on for a long time. This conclusion is supported by Furniss and Hinman (1998) who performed radiocarbon dating of ferricrete deposits located approximately 100 meters (110 yards) from the portal. They determined that these deposits range from about 6,000 to 8,800 years old. It further suggested that stemming the flow of this shallow adit might only divert water to other naturally occurring fractures along the exposed ferricrete bench.

An Action Memorandum was prepared for the Glengarry Mill Site, Lower Tredennic and Black Warrior Adits In July of 2008 (USDA-FS, 2008) and was based on analysis presented in the draft Adit Discharge EE/CA (Tetra Tech 2006). The Glengarry Mill Site adit was reclaimed later in summer of 2008. Reclamation consisted of reopening the adit and removing mud, rock fall debris, and ferricrete deposits from the adit sill. The fracture controlled source(s) of water entering the tunnel were located and three grout rings (on ten-foot centers) were installed from within the tunnel to stem flow from fractures. A portal plug with an infiltration basin was constructed and the portal area was regraded and revegetated (**Figure 9**). Flow from the adit was reduced from 8.1 gallons per minute immediately prior the construction period to 2.3 gallons per minute at the end of the one month construction period. This represents a 72% reduction in flow and load to groundwater and ultimately to the receiving surface waters of Fisher Creek. A final construction report was prepared for the Glengarry Mill-Site Adit (Tetra Tech 2008) and is available on the Gallatin National Forest New World Project website. No further response actions are planned for the Glengarry Mill-Site adit.

Figure 9. Reclaimed Glengarry Mill-Site Area

2.6.3 Tredennic Mines

The Tredennic Mines were operated by the Tredennic 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. Figures 10, 11, and 12 are photographs of the three sites and Figure 13 shows the historic underground workings of the Lower and Middle Tredennic mines. 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 upper adit lies to the northeast of the lower two adits and was collared at about 9,800 feet in elevation. The middle adit (420 feet long), which is collared at about 2,926 meters (9,600 feet), 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 Tredennic Dump # 1 Adit (FCSI-96-5) collared at 2,889 meters (9,480 feet) with more extensive workings (247 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. A number of short adits lying at higher elevations on Scotch Bonnet Mountain were also affiliated with the Tredennic Mines. No significant production has occurred from any of the Tredennic workings.

Adit seeps have been observed or measured at all of the three Tredennic adit portals, although consistent discharge has only been measured at the Lower Tredennic Dump # 1 Adit, while the other adits are often dry or, when flowing, produce only very small volumes of seepage. Discharge from the Middle Tredennic Mine flows into Polar Star Creek, a tributary to Fisher Creek. Discharge from the Upper and Lower Tredennic mines infiltrates into the ground before reaching Polar Star Creek. Waste rock dumps were removed and the surface disturbances recontoured and revegetated in 2001. A mine drainage control system was constructed in front of the collapsed adits on the regraded former dump surfaces at each of these sites to allow capture and controlled discharge of the seasonal (less than 19 Lpm [5 gpm]) outflows from the Upper and Middle Tredennic adits, and the perennial discharge from the Lower Tredennic Adit (about 2.3 to 19 Lpm [0.6 to 5 gpm]). These systems consists of a small fabric/soil covered gravel infiltration basin placed at near the mouth of the collapsed adit and a gravel-lined drainage channel designed to allow capture and controlled discharge of the flow from the adits. Additional earth work at the Lower Tredennic adit portal (i.e. placement of rock in and along the portal

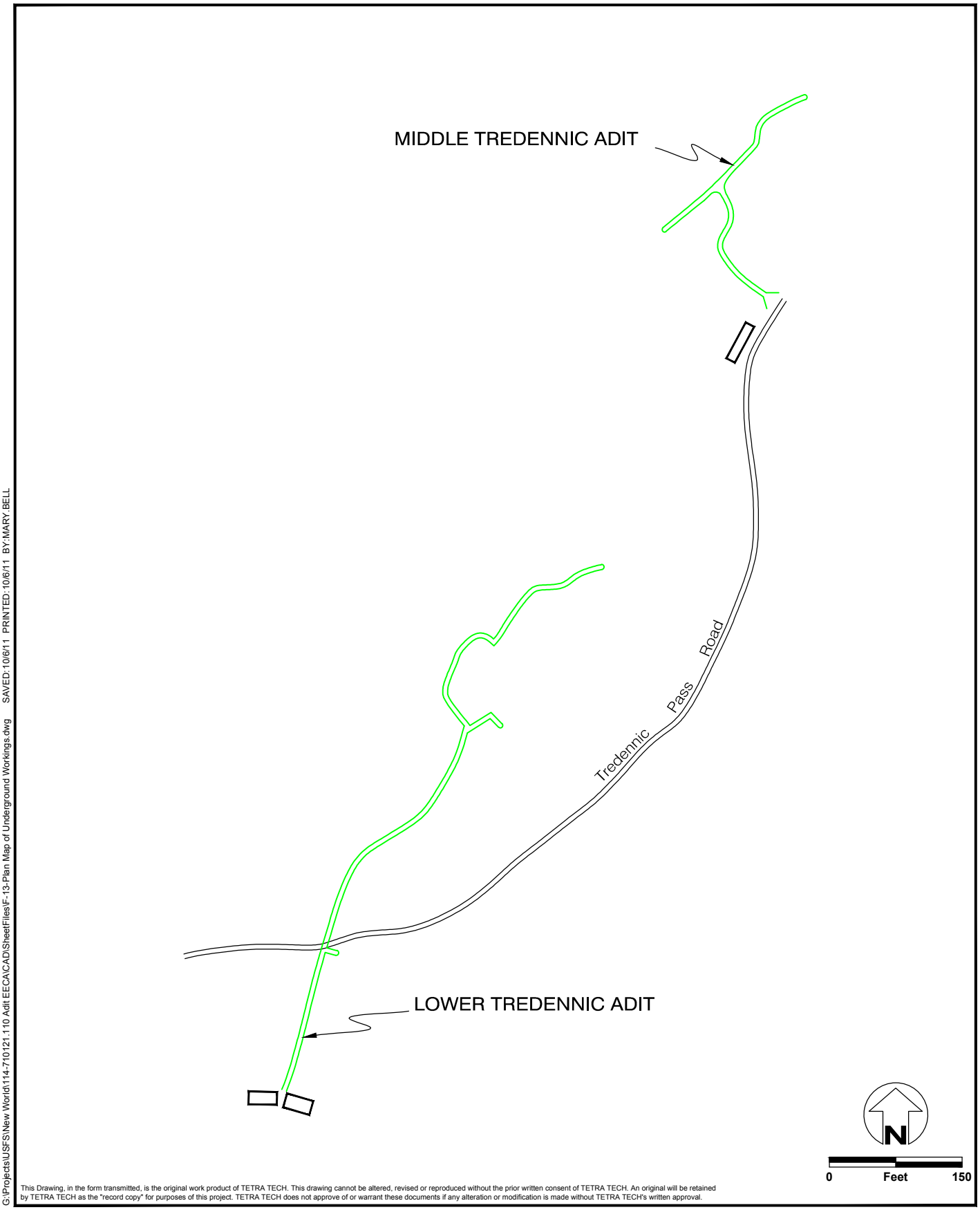
drainage channel) was completed in summer 2009 to ensure that water discharging from the portal is completely directed to the infiltration basin at the site. No additional response actions are planned for the Tredennic adits.

Figure 10. Reclaimed Upper Tredennic Dumps 1 & 2

Figure 11. Reclaimed Middle Tredennic Dump

Figure 12. Photographs of Reclaimed Lower Tredennic Dump #1 Adit.

Collapsed Lower Tredennic Dump #1 Adit (above) and the mine drainage control system, gravel basin, and armored channel. Photos taken in August 2004, three years following reclamation



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G:\Projects\USFS\New World\114-710121.110 Adit EECA\CAD\SheetFiles\F-13-Plan Map of Underground Workings.dwg SAVED:10/6/11 PRINTED:10/6/11 BY:MARY.BELL

(after Lovering, 1929)

Plan Map Showing the Underground Workings of the Middle and Lower Tredennic Mines
New World Mining District
Response and Restoration Project
FIGURE 13

2.6.4 Gold Dust Adit

The Gold Dust Adit (F-28) is located on the southwest side of the Fisher Creek Valley, near the break in slope forming the flank of Henderson Mountain (elevation 2,810 meters [9,220 feet]) (Figure 3). Facilities associated with this mine include the Chicago (White) smelter, and aerial tram that connected the portal with the smelter (762 meters [2,500 feet] long), blacksmiths shop, boarding house, electric compressor (still in building), and several cabins. The aerial tram was subsequently extended up the side of Henderson Mountain to the Homestake Adit. The Gold Dust Adit was driven between 1920 and 1925 and drifts to the southwest for about 701 meters (2,300 feet)(**Figure 14**). No production is recorded from the adit. The majority of the waste rock dump, which contained about 4,360 cubic meters (5,700 cubic yards) of material, was removed from the portal of the Gold Dust Adit in 2005 as part of the Fisher Creek Removal Action. A small portion of the waste was left for historic interpretation purposes. Figure 15 shows the condition of the portal prior to waste removal.

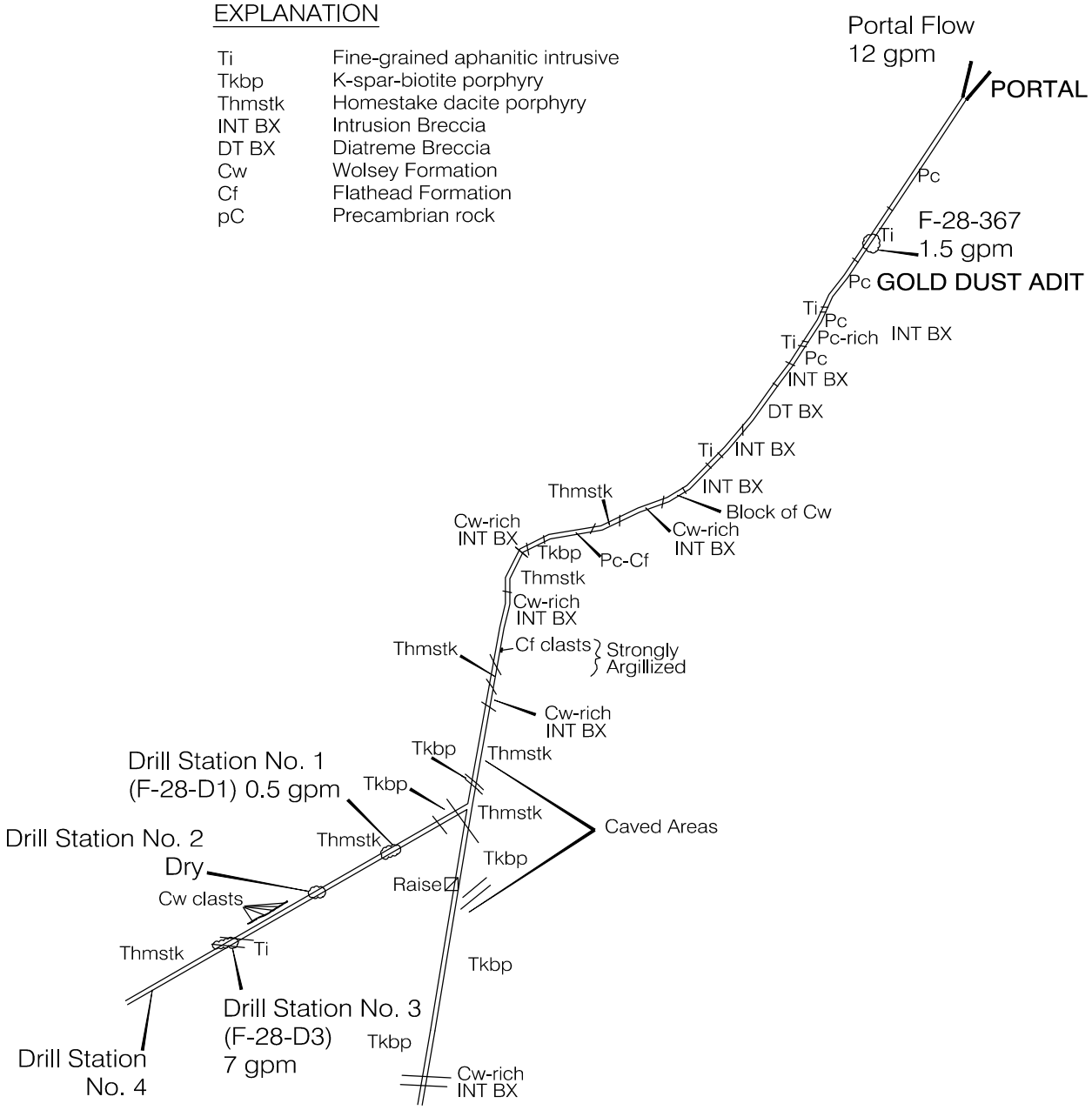
The adit is driven in Precambrian granite for the first 900 feet, and then crosses into monzonite porphyry intrusion breccia of the Homestake stock (**Figure 14**). The intrusion breccia contains varying amounts of sub-angular clasts of sedimentary rocks of predominantly Wolsey shale that range in size from a few centimeters to house size blocks. Inclusion free zones of monzonite porphyry also exist. Relatively fresh biotite-bearing monzonite gives way to strongly sericitized monzonite porphyry further into the mine. Mineralized specimens observed from the mine contained specular hematite, pyrite, ankerite, epidote, and quartz (Lovering, 1929).

After discovery of the Homestake Breccia Pipe in 1990 by surface drilling, CBMI executed an underground drilling program from the Gold Dust Adit to delineate mineralization in the middle and lower portion of the breccia pipe by drilling angle holes from four drill stations. The mine portal and underground workings were rehabilitated to gain access and to cut the four new drill stations. Approximately 7,111 meters (23,331 feet) of core 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 timber sets, a locking steel gate, and a wooden air-door. The mine discharged water prior to being rehabilitated by CBMI, with an average discharge of about 49 Lpm (13 gpm). Since the time of drilling, at least two of the packers had failed and these holes were producing a combined flow of about 30 Lpm (8 gpm) when measured in 2004 (Maxim, 2005c). Two or three other holes were also making small amounts of water (combined about 11 Lpm [3 gpm]).

During August and September of 2005, the USDA-FS contracted with Denver Grouting (who had recently completed work in the Glengarry Adit) to re-enter the Gold Dust Adit, remove packers from drill holes, and grout and plug all drill holes producing water. After successful completion of this work, flow from the Gold Dust Adit portal was reduced to an average flow of 34 Lpm (9.1 gpm) measured between October 2005 and September 2008. This decrease in flow represents a 41% reduction from the average flow prior to closure and a commensurate reduction in loading from the discharge to tributaries of Fisher Creek.

In 2005, the Forest Service completed surface reclamation and restoration of the Gold Dust portal area (**Figure 16**). The restoration work was undertaken to preserve various aspects of the site for cultural resource purposes and as such the site was developed as an interpretative site. Activities at the portal included: backfilling of the portal with coarse rock for about 15-20 feet, removal of approximately 7,000 cubic yards of the portal pad waste rock dump to the selective source repository, construction of portal timber façade, and construction of a rock armored diversion ditch for adit discharge to the south of the remaining waste rock pile at the portal.

After completing work involving grouting boreholes and portal area reclamation, discharge from the Gold Dust Adit has been reduced to about 16.6 Lpm (4.4 gpm). At the portal, the Gold Dust discharge meets all chronic aquatic life standards, and only exceeds the human health guideline for manganese (0.05 mg/L). Manganese loading from the Gold Dust Adit discharge could contribute as much as 3.9% of the total manganese load at station SW-4 in Fisher Creek. However, water flowing from the portal flows through about 305 meters (1,000 feet) of open grassy meadows and willow covered wetlands prior to entering Fisher Creek. Under similar conditions manganese is often oxidized by numerous bacteria found in nature, and, therefore, it is likely that in the oxidizing, organic-rich, uppermost soil horizon, manganese would be sequestered and removed from solution. This is in fact what is occurring under existing conditions and manganese concentrations meet the human health standards in the down gradient tributary of the Gold Dust adit prior to entering Fisher Creek. No additional response actions are planned for the Gold Dust adit.



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(after Crown Butte Mines, 1993)

Flow Data: 8/14/2003

Flow in gallons per minute (gpm)

Geologic Map of the Gold Dust Adit
New World Mining District
Response and Restoration Project
FIGURE 14

Figure 15. Gold Dust Adit Portal

Figure 16. Reclaimed Gold Dust Adit waste rock dump area

2.6.5 ***Henderson Mountain Dump # 7 Adit***

Two adits are located at the southeast terminus of Henderson Mountain at an elevation of approximately 2,780 meters (9,120 feet). Both of these adits were developed in stockwork fracture zones in the Cambrian Flathead Sandstone and lie in close proximity to one another. The only obvious sulfide mineral present is pyrite, although abundant iron-oxide occurs on fractured rock surfaces. Based on the size of the waste rock dumps, neither adit extended more than about 18 meters (60 feet) (and perhaps considerably less) into the side of Henderson Mountain. Numerous other similar small prospect pits occur throughout the immediate area (Figure 17).

One of the adits was dry but the second adit, Henderson Mountain Dump # 7 (AE-17) (Figure 3), discharged less than 3 Lpm (1 gpm) of seepage. The adit discharge exceeded aquatic life stands for aluminum, copper, iron, and human health Secondary Maximum Contaminant Level guidelines for manganese (Tetra Tech, 2006c). This adit is characterized by low flows and relatively low metal concentrations, and has historically discharged at an average rate of 5.3 Lpm (1.4 gpm) onto a topographic swale on the southeast flank of Henderson Mountain. The discharge is located approximately 760 meters (2,500 feet) from Fisher Creek. Historically, the water has infiltrated into groundwater in surrounding soils before reaching any surface water tributary to Fisher Creek, and could not be traced as either a seep or spring down-gradient of the site. Both of these collapsed adits were closed in August 2004 as part of the Fisher Creek Surface Controls Response Action EE/CA (Tetra Tech, 2002) and the Forest Service's Action Memorandum (USFS, 2002) (Figure 17) . A mine drainage control system consisting of a small gravel basin was constructed at the mouth of Henderson Mountain Dump # 7 adit portal as part of the response action. There is no evidence to suggest that metal loading from the Henderson Mountain Dump 7 is affecting water quality in Fisher Creek. No additional response actions are planned for the Henderson Mountain Dump # 7 adit.

Figure 17. Photographs of Henderson Mountain Dump #7 Adit before and after reclamation

2.6.6 ***Sheep Mountain # 1 Adit***

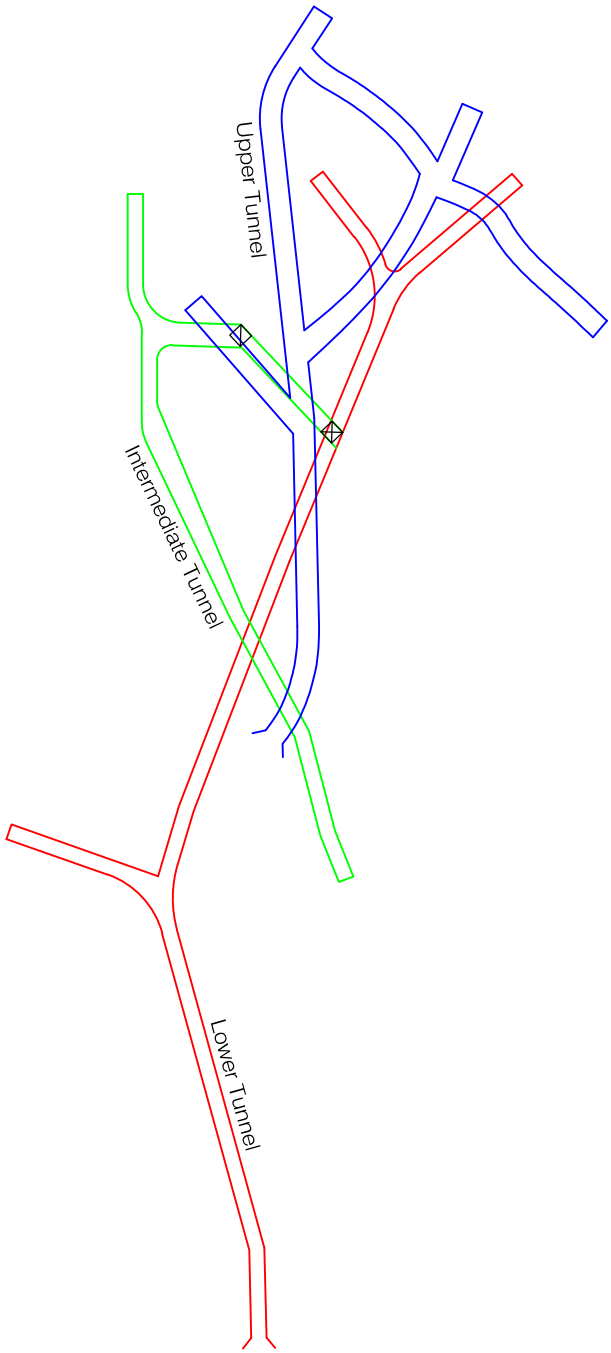
The Sheep Mountain # 1 Adit (FCSI-99-1 [Figure 3]) is located on the northwest flank of Sheep Mountain southeast of the saddle between Sheep and Scotch Bonnet Mountains and to the north and upgradient from the Upper Tredennic Mine area. The Sheep Mountain #1 site consists of a small waste rock dump (about 185 cubic yards) and an almost completely caved portal. Based on the size of the waste rock dump, the adit probably was driven somewhat less than 30 meters (100 feet) into Sheep Mountain. The adit itself seems to be driven in a porphyritic intrusive rock that is in contact with the Flathead Sandstone. The intrusive is highly sericitized and altered. Pyrite is the only obvious sulfide present although there is abundant iron-oxide on fracture surfaces in the dump material. Although the adit seepage when observed has usually been low (<4 gpm, average 2 gpm) there is some evidence that higher flows occur as can be seen by iron-stained seepage channels at the toe of the waste rock dump. The Sheep Mountain #1 adit is located on non-District Property**,** and therefore no response actions are planned for the Sheep Mountain #1 adit at this time.

Figure 18. Sheep Mountain Adit

2.6.7 ***Spalding Tunnels***

The Glengarry Mining Company initially had operations on the south-facing flank of Scotch Bonnet Mountain immediately northeast of Lulu Pass (2,957 meters [9,700 feet] in elevation) (Figure 3). On old historic mine maps these workings are called the Spalding Tunnels. The Spalding Tunnels consist of three short adits (60 to 96 meters long; 200 to 315 feet long) at different elevations, the lower two of which are connected by a winze (Figure 19). Prior to 2001, the upper and lower adit portals were closed with backfilled mine waste materials. The middle adit was accessible for about the first 50 feet, where a cave had blocked the workings.

Waste rock at the Upper, Middle, and Lower Spalding adits was removed during August 2001 for the Selective Source Response Action. Reopening of the lower Spalding Adit portal was attempted with a tracked-excavator in the summer of 2001 following waste rock removal. Before reclaiming the site, a low flow of adit seepage (0.38 to 7.6 Lpm; 0.1-2 gallons per minute) was present in the spring and early summer. Despite considerable effort using both a tracked excavator and a rubber-tired backhoe digging exploratory trenches in 2001, the portal could not be relocated for reopening. Figure 20 shows the reclaimed dump in August 2004, three years after the dump was removed.



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(after Lovering, 1929)

Raise or Winze
between Lower and
Intermediate Tunnels

☒ Top

☒ Bottom

Map Showing the Location of Underground Workings in the Spalding Tunnels Area
New World Mining District
Response and Restoration Project
FIGURE 19

Figure 19. Back page.

Figure 20. Reclaimed Lower Spalding Dump (August 2004). Pole indicates former location of adit.

Reclamation of the upper and lower waste rock dump sites and their respective portal areas was accomplished by regrading of the slope following the removal of waste rock, lime amendment of surficial materials, and mixing topsoil with the lime-amended surface (Figure 20). The middle tunnel portal was backfilled with rock. A mine drainage control system consisting of a gravel basin and a gravel-lined drainage channel was constructed at the former location of the lower adit. No seepage from the Spalding reclaimed area has been observed since 2001. No additional response actions are planned for the Spaulding Tunnel adits.

2.6.8 Little Daisy Adit

The Little Daisy Mine (surface water station M-1) is located on the northwestern slope of Henderson Mountain southeast of Daisy Pass at an elevation of about 3,000 meters (9,840 feet) (Figure 3). The ruins of a stamp mill (only the foundation remains; the stamp mill was moved to Cooke City), boarding house, stable, and two cabins are located at the mine site just below the portal between the adit and the Daisy Pass road. A photograph of the Little Daisy dump and mill site is shown in Figure 21.

The Little Daisy Mine has approximately 726 meters (2,385 feet) of workings (Lovering, 1929) with portals on both the southwest and northeast facing flanks of Henderson Mountain (Figure 23). The longer of the two adits, the Little Daisy Adit, is collared just above the old stamp mill site. Its trend is east-northeast and the workings are approximately 427 meters (1,400 feet) in length. Only about 366 meters (1,200 feet) of these workings were accessible in the early 1920's (Lovering, 1929). This adit is connected by a raise of about 60 meters (200 feet) in height that connects with a shorter adit (Homestake Adit) that collars on the northeast flank of Henderson Mountain (elevation 3,036 meters; 9,960 feet). This adit was driven to the west-southwest, parallel to and slightly northwest of the main Daisy Adit; it is about 152 meters (500 feet) in length. The top of the raise is about 122 meters (400 feet) in from the portal of this adit.

Figure 21. Little Daisy Mine Dump and Mill Site Dump
Little Daisy Mine Dump (gray waste) and Mill Site Dump (brown waste at center of photograph). Collapsed adit is located in road cut at top of gray dump.

Mineralization consists of blocks of Park Shale and Pilgrim Limestone caught up in an intrusive matrix (quartz monzonite of the Homestake Stock) to form an intrusion breccia. The sedimentary blocks have been skarn-altered and replaced by assemblages of garnet, epidote, magnetite, pyrite, and chalcopyrite. Although gold was recovered in the stamp mill at the Daisy Mill Site, Lovering (1929) suggests that most of the ore's value must have been in copper. Drilling by CBMI between 1990 and 1993 identified ore grade mineralization in the Homestake Breccia Pipe (a phreatic explosion vent to the surface). The Daisy Adit penetrates Henderson Mountain about 18 meters (60 feet) above the elevation of ore-grade mineralization of the Homestake Breccia Pipe.

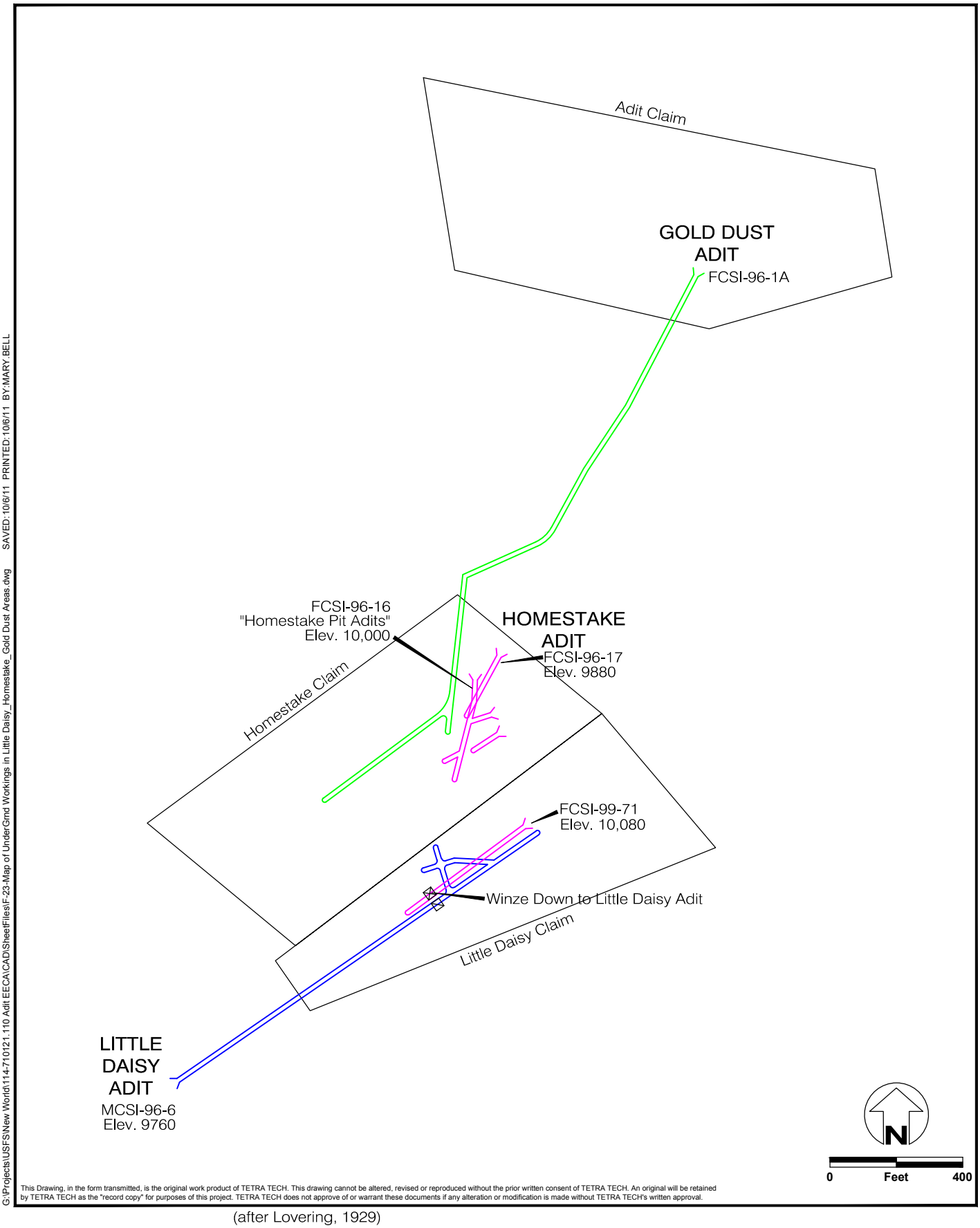
The Little Daisy Adit portal was partially backfilled and access blocked with mine wastes, although seepage discharged from the adit through the backfill. In the early 1990's the portal was partially open, and CBMI pumped water from behind the portal berm for core drilling. This information suggests that there may be a considerable amount of water backed-up into the workings behind the portal backfill. Water from the adit discharged across the Henderson Mountain road and historically infiltrated into mine waste and talus below the road prior to 2005.

The waste rock dump for the Little Daisy Adit contained about 680 cubic meters (890 cubic yards) of material that was spread out over a talus slope and tailed downhill toward the mill site (Figure 21) Waste rock was removed from the site by the USDA-FS in 2005. The dump area was reclaimed (Figure 22) and a mine drainage control system, which consists of a small gravel basin, was constructed at the break in slope below the **collapsed** adit, on the west side of and below the access road along Henderson Mountain. The Little Daisy adit discharge, has a moderate flow of 30 Lpm (8 gpm) and exceeds aquatic standards exceeds aquatic standards for cadmium, iron, and zinc and has a near-neutral pH. The adit discharge also exceeds the human health Secondary Maximum Contaminant Level guideline for manganese of 0.05 mg/L (Tetra Tech, 2006c). However, it does not discharge to surface water; it instead percolates into colluvial material a short distance below the infiltration basin constructed near the collapsed portal, and does not surface again down-gradient of the mine. Therefore, if this discharge ultimately reaches Miller Creek, it does so as a dilute and dissipated

groundwater source some 1,067 meters (3,500 feet) down-gradient of the mine site in Miller Creek. Load from the Little Daisy discharge could not be detected in Miller Creek during a synoptic study of metals loading to the Creek by the USGS.

At the point of infiltration, the discharge is some 600 meters (2,000 feet) from the nearest surface water in Miller Creek, and there are no measurable impact to surface water from the infiltrated water along this reach of the creek. The mill site dump and mill site features are considered historic features and were not removed or revegetated. No additional response actions are planned for the Little Daisy adit.

Figure 22. Little Daisy Adit and waste rock dump following reclamation



G:\Projects\USFS\New World\114-710121.110 Adit EECA\CAD\SheetFiles\F-23-Map of UnderGrnd Workings in Little Daisy_Homestake_Gold Dust Areas.dwg SAVED:10/6/11 PRINTED:10/6/11 BY:MARY.BELL

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(after Lovering, 1929)

Raise or Winze
☒ Bottom
☒ Top

Map of Underground Workings in the Little Daisy Adit
Homestake Adit and Gold Dust Adit Mine Areas
New World Mining District
Response and Restoration Project
FIGURE 23

Henderson Mountain Adit

The Henderson Mountain Adit (M-25) (Figure 3) is an isolated adit located on the steep southwestern flank of Henderson Mountain well above the Daisy Pass Road with no road access. This adit occurs in an area of anomalously high metal concentrations in soil and intrusive rock associated with the Henderson Mountain Stock. Soils in this area contain copper values as high as 500 parts per million.

The adit has a very small waste rock dump (less than a few cubic meters [10 to 20 cubic yards]) and a caved portal (Figure 24). It sits some distance from a small tributary of Miller Creek. It is possible that this feature is actually the site of spring water development rather than an adit. Water discharging from the adit flows across mine waste and into the tributary. Late in the summer and early fall, the tributary stream above the adit is dry but flow becomes perennial below the adit. Discharge at this adit site ranges from 0.15 to 94.6 Lpm (0.04 to 25 gpm). Cleasby and Nimick (2002) suggest that three anomalous copper concentrations collected in small tributaries to Miller Creek located downhill of this adit might be attributable in part to flow from the adit. No additional response actions are planned for the Henderson Mountain adit.

Figure 24. Henderson Mountain Adit (M-25).

2.6.9 Upper Miller Creek Dump Adit

The Upper Miller Creek Dump Adit (MCSI-96-3) (Figure 3) is located near the headwaters of Miller Creek about 200 meters (656 feet) to the northeast of the Black Warrior Adit. This is a very small caved adit with a small waste rock dump containing less than 60 cubic meters (80 cubic yards) of material. Based on the size of the dump, the adit is no more than 15 meters (50 feet) in length. The caved adit has a small seep that has always been less than 7.6 Lpm (2 gpm). Flow from the adit travels for a short distance across colluvial soils and infiltrates into the colluvium in a generally marshy area east of the Black Warrior Mine. This adit is located on private land and is a non-District Property and because of this no response actions are planned for the Upper Miller Creek Dump adit at this time.

2.6.10 Black Warrior Adit

The Black Warrior Mine lies near the headwaters of Miller Creek. It consists of an underground adit (surface water station M-8) about 130 meters (425 feet) in length and a 25 meter (80 feet) long raise to surface. The collar of the raise to surface occurs at an elevation of about 2,893 meters (9,490 feet) and lies just to the southeast of Bull-of–the-Woods Pass (Figure 3). The raise was closed by CBMI for safety reasons by backfilling with ripped dolomitic bedrock from adjacent outcrops. A soil cover was placed over the disturbed portion of the raise site and the site was seeded and fertilized. The adit was driven to the north-northeast along a high angle fracture or fault that is likely a splay of the Crown Butte Fault zone. Both vein and replacement type deposits of lead-zinc-silver mineralization occur in the Pilgrim Limestone host.

The area disturbed at the Black Warrior portal area is about 0.07 hectares (0.17 acres) and includes a small ore load-out structure. There is a small dump (610 cubic meters [800 cubic yards]) at the collapsed mine portal, which had been historically closed with backfilled mine wastes. Figure 25 shows the Black Warrior site prior to reclamation. Typically small rates of water flow, ranging from about 0.34 Lpm (0.09 gallons per minute) to 22.3 Lpm (5.9 gpm) have been measured at the adit portal. Flows up to 37.8 Lpm (10 gpm) have occasionally been measured. The Black Warrior discharge historically exceeded standards for several COCs at the collapsed adit portal. Water from the adit seep flowed around the east side of the waste rock dump and from there flowed on the surface for about 30.5 meters (100 feet) before joining a small tributary of Miller Creek. In a synoptic sampling run conducted by Cleasby and Nimick (2002), there was no measurable impact to surface water in Miller Creek in a sample collected immediately downstream of the confluence of the Black Warrior tributary with Miller Creek. Waste rock was removed from the site in 2005 by the USDA-FS as part of the Miller Creek Removal Action (USDA-FS 2004), and a mine drainage control system, consisting of a gravel basin placed at the mouth of the collapsed adit was constructed in 2005 (
Figure 26). In 2008, a small rock/soil collection apron was constructed at the portal site to direct remaining adit discharge to the previously constructed infiltration basin. Willow cuttings were also planted along the old adit discharge and buried infiltration basin channels during the 2008 field season. No additional response actions are planned for the Black Warrior adit area.

Figure 25. Photograph of the Black Warrior waste rock dump prior to waste removal

Figure 26. Black Warrior mine recontoured

2.6.11 Other Mines

There are many other small mines and prospects in the District for which little is known of the history of development or extent of underground workings. Most of these have very small waste rock dumps at the adit openings, indicating the workings are likely very limited as well. While little is known of these other mines, those with discharges have been inventoried and sampled and are included in the Site Characterization section of this EE/CA.

3.0 SOURCE, NATURE, AND EXTENT OF CONTAMINATION

This section presents data that characterize the nature and extent of contamination associated with mining-related discharges in the District. A considerable amount of surface water flow and chemistry data, along with groundwater quality data from monitoring wells, have been collected in the Daisy Creek, Fisher Creek, and Miller Creek drainages. These data were collected from 1989 through fall 2008. Adit seepages were not sampled in 2009.

3.1 SITE RANKING AND LIST OF ADIT DISCHARGES

At the beginning of the New World Mining District Response and Restoration Project in 1999, all sites in the District were prioritized using the Abandoned and Inactive Mines Scoring System (AIMSS). This modified hazard ranking system (HRS) was developed for the MDEQ Mine Waste Cleanup Bureau (Pioneer, 1995; 1996) to prioritize abandoned mine sites in Montana. AIMSS scoring was completed on 132 source areas using data collected in 1999. AIMSS ranks waste sources relative to each other using site-specific data and the HRS scoring algorithm. In AIMSS, four exposure pathways are 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, higher contaminant concentrations, large contaminant quantities, and/or large areas of disturbance.

Table 3-1 lists the adit sites with discharges or historic discharges in the District in order of AIMSS rank. These sites are shown on **Figure 3**. It is important to note that waste dumps present at the sites contribute to the ranking score, and, for many of these sites, mine waste that was once present has been removed as part of a previous response action. At some of these reclaimed sites water discharging for the adits was redirected into infiltration basins at the site. Of the 27 adits in the District with discharges or historic discharges, six are on non-District Property; non-District Property includes both private lands that were not included in the Settlement Agreement or are located on National Forest System lands that lie outside the District Property boundary (**Figure 1**).

Table 3-2 presents a list of the 25 adit discharges in three categories: 1) Discharges with water quality exceedances; 2) Discharges without water quality exceedances, and 3) Discharges with seasonal flows. This third category includes a number of discharges that either have been dry for several years or have become recently dry (last few sampling events). **Table A-1** in **Appendix A** lists the number of samples collected at each discharging adit, the last date sampled, and pH and flow characteristics for the 25 discharges.

The sites shown in the first group of discharges in **Table 3-2** are all perennial flows except for the Henderson Mountain Dump 7 discharge. Flows from group 1 discharges range from very low (less than 3.8 Lpm [1.0 gpm]) to more than several hundred Lpm. Exceedances of water quality criteria, as annotated in the table, are different for each site, ranging from exceedance of only the manganese human health guideline at the Gold Dust and Lower Tredennic sites, to exceedances of aluminum, copper, iron, and manganese at the Glengarry Adit Mill Site seep.

Sites included in the second grouping shown in **Table 3-2** are perennial adit discharges with no water quality exceedances. As these sites currently meet human health and aquatic water quality criteria, a response action is not necessary; these sites will not be further discussed or evaluated in this EE/CA nor

will the Glengarry Mill Site Adit, Lower Tredennic, Black Warrior Adit, or the McLaren Adit which saw final reclamation work in 2008, 2009, or 2010 as discussed in Section 2.6.

TABLE 3-1
AIMSS RANKING AND STATUS OF ADIT DISCHARGE SITES

Site Name	Site No.	AIMSS Rank[1]	Discharge Flow Range (gpm)	Site Status
Black Warrior	MCSI-96-2 (M-8)	2	0.1-10	Collapsed/Reclaimed 2005 and 2008
Soda Butte Dump 1	SBSI-99-95	4	0.0-0.1	NDP
Woody Creek Mine Dump 1[2]	SBSI-99-74	5	3.1-10	NDP
Alice E Mill Site	SBSI-99-85	12	0.0-10.0	NDP
Soda Butte Dump 8	SBSI-99-87	13	3.0-100	NDP
Glengarry Mill Site (includes middle adit)	F-8B	15	3.0-26.9	Closed/Reclaimed 2008
McLaren Adit	D-18	17	1.8-29.6	Reclaimed 2010
Little Daisy Adit and Dump	M-1	20	0.5-220	Collapsed/ Reclaimed 2004
Sheep Mountain No. 1	FCSI-99-1	21	0.0003-10	NDP
Lower Spalding Dump	FCSI-96-8	23	0-0.9	Backfilled/Reclaimed 2001
Gold Dust Adit	F-28	24	1.3-250	Closed/Reclaimed 2005
Lower Tredennic Dump 1	FCSI-96-5	26	0.6-5	Collapsed/Reclaimed 2001and 2009
Daisy Pass Dump 1	DCSI-96-3-1	30	<0.1-2	Collapsed
Henderson Mountain Dump 10	FCSI-99-71	32	0-12	Backfilled/Reclaimed 2004
Upper Tredennic Dump 2	FCSI-96-15-2	36	0-0.5	Reclaimed 2001
Upper Miller Creek Dump‡	MCSI-96-3	43	0.5-2	NDP
Middle Tredennic Dump 1	FCSI-96-6	45	0-10	Reclaimed 2001
Henderson Mountain Dump 7	AE-17	51	0.0-5	Collapsed/Reclaimed 2004
Henderson Mountain Dump 13	FCSI-99-73	66	5-15	Collapsed
Near McLaren Pit	DCSI-99-102	69	0	Dry
Upper Tredennic Dump 1	FCSI-96-15-1	70	0-1	Collapsed/Reclaimed 2001
West of Como Dump 1	DCSI-96-6	86	0	Dry Reclaimed 2005 and 2006
Henderson Mountain Adit	M-25	NR	1.8-25	Collapsed
Upper Little Daisy Adit	M-10	NR	0-5.8	Dry
Reeb No. 1 Adit	AE-12	NR	0	Dry

Notes: [1] AIMSS - Abandoned and Inactive Mines Scoring System
[2] Originally ranked with private property sites; rank shown for scoring with public sites.
NDP – non-District Property; NR – not ranked; gpm – gallons per minute

TABLE 3-2
ADIT DISCHARGES IN THE NEW WORLD MINING DISTRICT

Adit Station #	Site Name	Drainage	Status	Flow Type[1]	Flow (gpm)		Last pH (s.u.)	Water Quality[2]
					Range	Recent		
F-8B	Glengarry Mill Site Adit	Fisher	Reclaimed 2008 Infiltration Basin	Perenn	1.1-26.9	3.1[3]	3.4	Al Cu Fe Mn*
F-28	Gold Dust Adit	Fisher	Reclaimed 2005 Flowing	Perenn	1.3-250	4.4	6.9	Mn*
FCSI-96-5	Lower Tredennic Dump 1	Fisher	Reclaimed 2009 Infiltration Basin	Perenn	0.6-5	1.4	5.9	Mn*
FCSI-99-1	Sheep Mountain #1 (NDP)	Fisher	Flowing	Perenn	0.002-10	0.002	7.3	Pb
D-18	McLaren Adit	Daisy	Reclaimed 2010 Infiltration Basin	Perenn	1.8-29.6	5.9	5.9	Cu Fe Mn*
M-8	Black Warrior Adit	Miller	Reclaimed 2008 Infiltration Basin	Perenn	0.1-10	0.269	7.1	Cd
MCSI-96-3	Upper Miller Creek Dump (NDP)	Miller	Flowing	Perenn	0.2-2	0.269	5.9	Cd
M-1	Little Daisy Adit	Miller	Surface Reclaimed 2004; Infiltration Basin, Flowing	Perenn	0.5-220	8.9	6.8	Cd Fe Mn* Zn
M-25	Henderson Mt Adit	Miller	Flowing	Perenn	0-25	0.045	7.0	Al Cu Pb
AE-17	Henderson Mountain Dump 7	Fisher	Reclaimed 2004 Infiltration Basin	Season	0-5	Dry	6.9	Al Cu Fe Mn*
FCSI-99-73	Henderson Mountain Dump 13	Fisher	Flowing	Perenn	5-15	15	6.6	None
DCSI-96-3-1	Daisy Pass Dump 1	Daisy	Flowing	Perenn	<0.1-2	1.0	6.8	None
SBSI-99-74	Woody Ck. Mine Dump 1 (NDP)	Woody	Flowing	Perenn	3.1-10	4.0	6.9	None
SBSI-99-85	Alice E. Mill Site seep (NDP)	Soda Butte	Flowing	Perenn	0-10.0	4.0	5.4	None
SBSI-99-87	Soda Butte Dump 8 (NDP)	Soda Butte	Flowing	Perenn	3-100	3	6.9	None
FCSI-96-15-1	Upper Tredennic Dump 1	Fisher	Dry; reclaim 2001 Infiltration Basin	Season	0-1.0	Dry	3.3	--
FCSI-96-15-2	Upper Tredennic Dump 2	Fisher	Dry; reclaim 2001 Infiltration Basin	Season	0-0.5	Dry	2.9	--
FCSI-96-6	Middle Tredennic Dump 1	Fisher	Reclaim 2001	Season	0-10	Dry	4.8	--
F-2	Lower Spalding Dump	Fisher	Dry; reclaim 2001 Infiltration Basin	Season	0-0.9	Dry	2.6	--
FCSI-96-7	Middle Spalding	Fisher	Dry; reclaim 2001	Season	--	Dry	--	--
FCSI-99-71	Henderson Mountain Dump 10	Fisher	Dry; reclaim 2004	Season	0-12	Dry	7.5	--
F-8	Glengarry Middle Adit	Fisher	Dry	Season	0-1.4	Dry	3.5	--
DCSI-99-102	Near McLaren Pit	Daisy	Dry	Season	0	Dry	--	--
DCSI-96-6	West of Como Dump 1	Daisy	Dry	Season	0	Dry	--	--
M-10	Upper Little Daisy Adit	Miller	Dry	Season	0-5.8	--	7.84	--
AE-12	Reeb #1	Soda Butte	Dry	Season	0	Dry	3.3	--
SBSI-99-95	Soda Butte Dump 1 (NDP)	Soda Butte	Dry	Season	0-0.1	Dry	7.4	--

Notes:
1 Perenn = perennial flow; Season = seasonal flow
2 Exceeded chronic standard in most recent sampling event (hardness = 100 milligrams/liter where applicable); Al-aluminum; Cd-cadmium; Cu-copper; Fe-iron; Mn-manganese; Pb-lead; Zn-zinc; * indicates exceeds human health guideline for Mn (manganese has no aquatic standard)
3 Data shown for Glengarry Mill Site Adit are from August 2008, prior to adit closure.
NDP = non District Property; gpm = gallons per minute; s.u. = standard units

The seasonal discharges listed among the third grouping of sites shown in **Table 3-2** generally only flow for a month or so during the snowmelt period. In 2001, six of the sites in the third group were reclaimed by removing waste rock dumps, regrading removal areas, and re-vegetating the former dump sites. Flows from all these sites reclaimed in 2001 have diminished over the years, and have completely dried up at the Lower Spalding Mine. The remaining six sites in the third grouping were also dry when last visited (see Table A-1 in Appendix A). Due to the seasonal nature and very low flows measured at the group three sites, a response action is unwarranted; these discharges will not be further evaluated in this EE/CA.

For the reasons stated above, only the discharges that are district properties in the first grouping will be further characterized and evaluated in this EE/CA (Table 3-3). This excludes the reclaimed and recently closed McLaren Adit, Glengarry Mill Site Adit, and the Lower Tredennic Adit (Lower Tredennic Dump 1) and Black Warrior Adit that had minor closure actions in 2009. In addition, the collected discharge from the McLaren Pit subsurface drains (see Section 2.6.1) will be considered as discharges that could be mitigated by a potential response action because the drains constitute a significant source of loading to Daisy Creek. All of the water sources collected by the subsurface drains are from bedrock springs; two drains collect groundwater directly from bedrock fractures and the remaining water sources are strongly suspected to originate in bedrock fractures. Flow measurements taken between 2004 and 2008 show an average combined flow rate of 72 Lpm (19 gpm) for the three drains. Water quality for the subsurface drains is discussed in section 3.3.2 and presented in Table 3-5.

TABLE 3-3
ADIT DISCHARGES SELECTED FOR FURTHER EVALUATION IN THIS EE/CA

Adit Station #	Site Name	Drainage	Status	Flow Type[1]	Flow (gpm)		Last pH (s.u.)	Water Quality[2]
					Range	Rec-ent		
F-28	Gold Dust Adit	Fisher	Reclaimed 2005, Flowing	Perenn	1.3-247	4.4	6.9	Mn*
M-1	Little Daisy Adit	Miller	Surface Reclaimed 2004; Infiltration Basin, Flowing	Perenn	0.5-220	8.9	6.8	Cd Fe Mn* Zn
M-25	Henderson Mt Adit	Miller	Flowing	Perenn	0-25	0.045	7.0	Al Cu Pb
AE-17	Henderson Mountain Dump 7	Fisher	Reclaimed 2004 Infiltration Basin	Season	0-5	Dry	6.9	Al Cu Fe Mn*

Notes:
1 Perenn = perennial flow; Season = seasonal flow
2 Exceeded chronic standard in most recent sampling event (hardness = 100 milligrams/liter where applicable); Al-aluminum; Cd-cadmium; Cu-copper; Fe-iron; Mn-manganese; Pb-lead; Zn-zinc; * indicates exceeds human health guideline for Mn (manganese has no aquatic standard)
NDP = non District Property; gpm = gallons per minute; s.u. = standard units

3.2 SURFACE WATER QUALITY DATA EVALUATION APPROACH

A considerable amount of surface water flow and chemistry data has been collected for Daisy Creek, Fisher Creek, and Miller Creek. In conjunction with their application for a hard rock mining permit, CBMI began comprehensive surface and groundwater quality monitoring and discharge measurements in 1989 that continued through 1996. More recent work by the USGS (Cleasby and Nimick, 2001; Kimball *et al.* 1999; Nimick and Cleasby, 2000), EPA (1989), and the USDA Forest Service (1999 to present)

continued to build on the database and understanding of surface water characteristics in the District. Water quality and flow data are available on the Internet from the New World project database at http://www.fs.fed.us/rl/gallatin. Additionally, **Appendix A** compiles data for selected parameters in samples collected from surface water and adit monitoring locations on all sample dates through September 2010, while summary statistics for surface water and adit discharge data are presented respectively in **Tables 3-4** and **3-5** and have been differentiated into all data, "high flow" data (samples collected in late May, June, and July during high flow), and "low flow" data (samples collected the other nine to ten months of the year). These tables were not updated with 2009 water quality data because the adits were not sampled in 2009. Because of this it was decided that comparison of adit data collected in 2008 and earlier should be compared with 2008 and earlier water quality data. These data are discussed by drainage in subsequent sections.

Drainage specific temporary standards have been developed for both Daisy Creek and Fisher Creek (Maxim, 2005a). **Table 3-4** and the following discussion refer to Circular DEQ-7 water quality standards as a point of reference for all water quality monitoring stations (MDEQ, 2008).

Figures 31 through 33, and Figures 35 and 36 show copper, iron, and zinc concentrations as a function of flow relative to Circular DEQ-7 standards as well as the temporary standard for applicable monitoring stations. Companion graphs shown on these figures exhibit concentration data plotted chronologically.

Circular DEQ-7 surface water standards are based on total recoverable metal concentrations with the exception of aluminum (standard based on dissolved concentration) (MDEQ, 2008). Most discussion in this EE/CA is thus based on total recoverable concentrations. However, it should be noted that total recoverable concentrations could be influenced by suspended sediment in water, thereby overestimating the concentration of metals actually dissolved in solution and biologically available. Dissolved metal concentrations in surface water samples collected from District monitoring sites are often much lower compared to total recoverable concentrations when the pH of the water is in the neutral to alkaline range. For instance, Cleasby and Nimick (2002) reported total recoverable metal concentrations for Miller Creek that in many cases were 1.5 to 2 times greater than corresponding dissolved concentrations. This effect is especially pronounced for total recoverable iron concentrations that tended to be much greater (by as much as 200 times) compared to dissolved concentrations.

TABLE 3-4
SUMMARY OF SURFACE WATER FLOW AND QUALITY IN DAISY, FISHER, AND MILLER CREEKS

Station	Summary Statistic[1]	Flow (gpm) or %[2]	Concentration (total recoverable in milligrams per liter) or Percent						
			Aluminum	Cadmium	Copper	Iron	Lead	Manganese	Zinc
Daisy Creek									
DC-2	Average of all data before Oct. 2003	1508	11.74	0.0037	2.94	12.75	0.006	1.72	0.45
	Average of all data after Oct. 2003	1180	8.14	0.0026	1.85	9.81	0.005	1.42	0.39
	% Change	**-22**	**-31**	**-30**	**-37**	**-23**	**-17**	**-17**	**-13**
	Average of high flow data before Oct. 2003	2842	6.97	0.0022	1.93	9.86	0.006	0.83	0.27
	Average of high flow data after Oct. 2003	3261	3.82	0.001	0.74	4.98	0.004	0.41	0.13
	% Change	**15**	**-45**	**-55**	**-62**	**-49**	**-33**	**-51**	**-52**
	Average low flow data before Oct. 2003	244	11.78	0.0038	3.08	12.38	0.005	1.91	0.50
	Avg low flow data after Oct. 2003	73	10.44	0.0036	2.44	12.39	0.004	1.95	0.53
	% Change	**-70**	**-11**	**-5**	**-21**	**0**	**-20**	**2**	**6**
DC-5	Average of all data before Oct. 2003	3308	3.36	0.0013	1.07	3.18	0.003	0.48	0.17
	Average of all data after Oct. 2003	2956	2.18	0.0008	0.54	1.92	0.001	0.37	0.13
	% Change	**-11**	**-35**	**-38**	**-50**	**-40**	**-67**	**-23**	**-24**
	Average of high flow data before Oct. 2003	7686	1.93	0.0005	0.58	2.86	0.002	0.21	0.08
	Average of high flow data after Oct. 2003	9762	0.94	0.0002	0.15	1.18	0.002	0.10	0.04
	% Change	**27**	**-51**	**-60**	**-74**	**-59**	**0**	**-52**	**-50**
	Average low flow data before Oct. 2003	277	4	0.0018	1.38	2.69	0.002	0.63	0.22
	Avg low flow data after Oct. 2003	234	2.68	0.0010	0.70	2.22	0.001	0.48	0.16
	% Change	**-16**	**-33**	**-44**	**-49**	**-17**	**-50**	**-24**	**-27**
SW-7	Average of all data before Oct. 2003	22237	0.24	<0.0001	0.064	0.49	0.002	0.039	0.022
	Average of all data after Oct. 2003	12980	0.09	<0.0001	0.014	0.26	0.001	0.027	0.010
	% Change	**-42**	**-63**	**0**	**-78**	**-47**	**-50**	**-31**	**-55**
	Average of high flow data before Oct. 2003	35965	0.38	0.0002	0.109	0.70	0.003	0.039	0.024
	Average of high flow data after Oct. 2003	36888	0.19	<0.0001	0.033	0.28	0.001	0.019	0.005
	% Change	**3**	**-50**	**-50**	**-70**	**-60**	**-67**	**-51**	**-79**
	Average low flow data before Oct. 2003	1241	0.08	<0.0001	0.015	0.25	0.001	0.039	0.021
	Avg low flow data after Oct. 2003	1026	0.05	<0.0001	0.006	0.25	0.001	0.030	0.013
	% Change	**-17**	**-38**	**0**	**-60**	**0**	**0**	**-23**	**-38**
Chronic Aquatic Life Standard (Hardness = 50 mg/l)			**0.087[3]**	**0.00016**	**0.005**	**1**	**0.001**	**0.05[3]**	**0.07**
Chronic Aquatic Life Standard (Hardness = 100 mg/l)			**0.087**	**0.00027**	**0.009**	**1**	**0.003**	**0.05**	**0.12**

Notes: 1 Data collected between 1989 and 2010; high flow calculated using June and July sampling events; low flow calculated using all other data
2 gpm = gallons per minute; % change indicates increase (positive) or decrease (negative) in flow and concentration for applicable stations.
3 Aluminum standard applies to dissolved concentrations in water with pH 6.6-9.0 s.u.; manganese standard is secondary MCL based on aesthetic qualities.

TABLE 3-4 (continued)
SUMMARY OF SURFACE WATER FLOW AND QUALITY IN DAISY, FISHER, AND MILLER CREEKS

Station	Summary Statistic[1]	Flow (gpm) or %[2]	Concentration (total recoverable in milligrams per liter) or Percent						
			Aluminum	Cadmium	Copper	Iron	Lead	Manganese	Zinc
Fisher Creek									
SW-3	Average of all data before Oct. 2004	1632	2.56	0.0008	0.69	5.29	0.005	0.81	0.12
	Average of all data after Oct. 2004	1007	1.93	0.0006	0.66	1.31	0.002	0.42	0.10
	% Change	**-38**	**-25**	**-25**	**-4**	**-75**	**-60**	**-48**	**-17**
	Average of high flow data before Oct. 2004	3075	1.96	0.0005	0.57	3.63	0.004	0.29	0.06
	Average of high flow data after Oct. 2004	3420	1.23	0.0001	0.30	1.24	0.002	0.13	0.02
	% Change	**11**	**-37**	**-80**	**-47**	**-66**	**-50**	**-55**	**-67**
	Average low flow data before Oct. 2004	268	2.95	0.0010	0.80	6.53	0.006	1.10	0.17
	Avg low flow data after Oct. 2004	79	2.20	0.0008	0.80	1.34	0.002	0.52	0.13
	% Change	**-71**	**-25**	**-20**	**0**	**-79**	**-67**	**-53**	**-24**
SW-4	Average of all data before Oct. 2004	11654	0.29	0.0003	0.091	0.48	0.0018	0.058	0.08
	Average of all data after Oct. 2004	6455	0.09	0.0002	0.045	0.09	0.0004	0.019	0.04
	% Change	**-45**	**-69**	**-33**	**-51**	**-81**	**-78**	**-67**	**-50**
	Average of high flow data before Oct. 2004	18692	0.42	0.0003	0.101	0.79	0.002	0.056	0.11
	Average of high flow data after Oct. 2004	20649	0.16	0.0001	0.052	0.16	0.0004	0.020	0.02
	% Change	**10**	**-62**	**-67**	**-49**	**-80**	**-80**	**-64**	**-82**
	Average low flow data before Oct. 2004	3329	0.19	0.0003	0.082	0.21	0.0016	0.058	0.05
	Avg low flow data after Oct. 2004	2226	0.06	0.0002	0.042	0.06	0.0004	0.018	0.04
	% Change	**-33**	**-68**	**-33**	**-49**	**-71**	**-75**	**-69**	**-20**
CFY-2	Average of all data before Oct. 2004	4676	0.11	0.0001	0.031	0.132	0.0009	0.018	0.018
	Average of all data after Oct. 2004	7369	0.07	0.0001	0.016	0.05	0.0004	0.006	0.013
	% Change	**58**	**-36**	**0**	**-48**	**-62**	**-56**	**-67**	**-28**
	Average of high flow data before Oct. 2004	11000	0.21	0.0001	0.060	0.307	0.0010	0.029	0.018
	Average of high flow data after Oct. 2004	24042	0.14	0.0001	0.040	0.15	0.0006	0.018	0.009
	% Change	**119**	**-33**	**0**	**-33**	**-51**	**-40**	**-38**	**-50**
	Average low flow data before Oct. 2004	462	0.05	0.0001	0.016	0.039	0.0009	0.013	0.018
	Avg low flow data after Oct. 2004	419	0.02	0.0001	0.007	0.01	0.0004	0.002	0.014
	% Change	**-9**	**-60**	**0**	**-56**	**-74**	**-56**	**-85**	**-22**
Chronic Aquatic Life Standard (Hardness = 50 mg/l)			**0.087[3]**	**0.00016**	**0.005**	**1**	**0.001**	**0.05[3]**	**0.07**
Chronic Aquatic Life Standard (Hardness = 100 mg/l)			**0.087**	**0.00027**	**0.009**	**1**	**0.003**	**0.05**	**0.12**

Notes: 1 Data collected between 1989 and 2010; high flow calculated using June and July sampling events; low flow calculated using all other data
2 gpm = gallons per minute; % change indicates increase (positive) or decrease (negative) in flow and concentration for applicable stations.
3 Aluminum standard applies to dissolved concentrations in water with pH 6.6-9.0 s.u.; manganese standard is secondary MCL based on aesthetic qualities.

TABLE 3-4 (continued)
SUMMARY OF SURFACE WATER FLOW AND QUALITY IN DAISY, FISHER, AND MILLER CREEKS

Station	Summary Statistic[1]	Flow (gpm) or %[2]	Concentration (total recoverable in milligrams per liter) or Percent						
			Aluminum	Cadmium	Copper	Iron	Lead	Manganese	Zinc
Miller Creek									
SW-2	Average All Data	4668	0.14	0.0001	0.018	0.27	0.002	0.012	0.02
	Average All High Flow Data	9066	0.26	0.0001	0.032	0.53	0.004	0.023	0.02
	Average all Low Flow Data	656	0.04	0.0001	0.008	0.07	0.001	0.006	0.02
SW-5	Average All Data	6283	0.17	0.0001	0.017	0.32	0.002	0.013	0.03
	Average All High Flow Data	11170	0.27	0.0001	0.027	0.54	0.002	0.020	0.02
	Average all Low Flow Data	1195	0.06	0.0001	0.006	0.08	0.001	0.007	0.04
Chronic Aquatic Life Standard (Hardness = 50 mg/l)			**0.087[3]**	**0.00016**	**0.005**	**1**	**0.001**	**0.05[3]**	**0.07**
Chronic Aquatic Life Standard (Hardness = 100 mg/l)			**0.087**	**0.00027**	**0.009**	**1**	**0.003**	**0.05**	**0.12**

Notes: 1 Data collected between 1989 and 2010; high flow calculated using June and July sampling events; low flow calculated using all other data
2 gpm = gallons per minute; % change indicates increase (positive) or decrease (negative) in flow and concentration for applicable stations.
3 Aluminum standard applies to dissolved concentrations in water with pH 6.6-9.0 s.u.; manganese standard is secondary MCL based on aesthetic qualities.

TABLE 3-5
SUMMARY OF ADIT DISCHARGE FLOW AND WATER QUALITY DATA IN DAISY, FISHER, AND MILLER CREEK DRAINAGES

Adit Station Number and Name	Number of Samples[1]	Statistic	Flow (gpm)	Field pH (s.u.)	Field SC (umhos/cm)	Hardness (mg/L as CaCO3)	Concentration (total recoverable in milligrams per liter)[2]							
							Sulfate	Aluminum	Cadmium	Copper	Iron	Lead	Manganese	Zinc
Daisy Creek Drainage														
All data through September 2010														
D-18 McLaren	31	Min	1.8	3.4	90	230	149	0.08	<0.0001	<0.001	3.6	<0.001	0.1	<0.01
		Mean	10.4	6.2	677	361	305	0.5	0.0008	0.028	18.9	0.003	0.9	0.04
		Max	29.6	7.1	1035	449	421	5.0	0.0049	0.14	38	0.010	1.24	0.09
DCSW-101 McLaren Sub-Drain	14	Min	2.2	2.3	1021	104	450	22.5	0.0061	9.4	89	0.005	2.10	1.20
		Mean	12.1	2.9	1335	139	619	27.2	0.009	12.9	129	0.009	3.03	1.68
		Max	26.0	4.4	2870	185	797	34.3	0.016	20.7	199	0.016	5.1	2.82
DCSW-102 McLaren Sub-Drain	15	Min	0.0	2.4	1444	155	595	22.2	0.01	13.0	90	0.001	3.47	1.74
		Mean	7.1	2.7	1671	210	824	28.9	0.02	16.3	134	0.0026	4.53	2.54
		Max	23.3	4.2	1900	275	1160	42.2	0.029	27.7	265	0.009	6.31	4.29
DCSW-103 McLaren Sub-Drain	14	Min	0.3	2.2	2674	445	1740	62.2	0.017	23	254	0.002	8.7	3.2
		Mean	1.1	2.6	3045	621	2174	84.3	0.023	33	386	0.002	12.2	4.2
		Max	2.4	4.1	3700	750	3050	122	0.032	47.3	678	0.004	16.7	5.25
Data collected after plugging adit inflow (September 2003-September 2008)														
D-18 McLaren	9	Min	3.6	5.8	750	404	363	0.1	<0.0001	0.018	19.1	<0.001	1.0	0.01
		Mean	5.5	6.4	848	429	389	0.3	<0.0001	0.027	26.5	0.002	1.1	0.06
		Max	7.6	6.8	1035	449	421	0.7	<0.0001	0.04	34	0.004	1.24	0.09
Fisher Creek Drainage														
F-8B Glengarry Mill-Site	9	Min	0.8	3.1	176	23	54	0.19	<0.0001	0.07	6.46	<0.001	0.66	0.05
		Mean	5.3	3.4	322	47	90	0.29	0.0007	0.11	15.9	0.002	1.0	0.11
		Max	26.9	3.85	728	84	118	0.34	<0.0026	0.24	41	0.002	1.1	0.13
FCSI-96-5 Lower Tredennic Dump 1	8	Min	0.3	5.91	180	95	45	< 0.05	0.0001	0.002	0.12	0.001	0.074	0.02
		Mean	2.0	6.5	199	99	49	0.12	0.0002	0.004	0.28	0.002	0.15	0.04
		Max	5.0	7.1	238	102	58	0.29	0.0003	0.008	0.62	0.003	0.27	0.06
FSCI-99-1 Sheep Mt. # 1	7	Min	0.003	5.46	66	24	16	<0.05	<0.0001	0.005	0.06	0.004	<0.003	<0.01
		Mean	2.4	6.8	141	88	40	0.4	0.0006	0.055	1.8	0.067	0.08	0.08
		Max	10.0	8.29	322	187	82	1.36	0.0014	0.21	7.15	0.3	0.29	0.22

Notes: 1 Number of samples varies for each parameter; number shown is maximum number of samples for any one parameter.
2 A "<" value reported for the mean indicates parameter was below detection for all sampled dates, value shown is the greatest detection limit used.
gpm = gallons per minute; s.u. = standard units; mg/l = milligrams per liter; umhos/cm = micromhos per centimeter; SC = specific conductance

TABLE 3-5 (continued)
SUMMARY OF ADIT DISCHARGE FLOW AND WATER QUALITY DATA IN DAISY, FISHER, AND MILLER CREEK DRAINAGES

Adit Station Number and Name	Number of Samples[1]	Statistic	Flow (gpm)	Field pH (s.u.)	Field SC (umhos/cm)	Hardness (mg/L as CaCO3)	Concentration (total recoverable in milligrams per liter) [2]							
							Sulfate	Aluminum	Cadmium	Copper	Iron	Lead	Manganese	Zinc
Fisher Creek Drainage (continued)														
AE-17 Henderson Mt. Dump # 7	7	Min	0	6.2	130	68	29	<0.1	0.0001	0.01	0.7	<0.001	0.08	0.0366
		Mean	1.2	6.7	162	79	42	0.07	0.0007	0.02	1.2	0.003	0.1	0.06
		Max	5.0	7.3	194	94	72	0.11	<0.0026	0.023	1.6	0.01	0.12	0.11
F-28 Gold Dust	16*	Min	4.9	6.3	423	376	163	<0.05	<0.0001	<0.001	0.09	<0.001	0.004	<0.01
		Mean	32.0	7.1	953	574	380	0.06	0.0003	0.004	0.46	0.001	0.063	0.02
		Max	246.9	7.6	1260	759	591	0.21	<0.005	0.012	2.23	0.015	0.152	0.05
	Samples collected after plugging boreholes in adit (August 2005)													
	9	Min	3.4	6.12	303	64	142	0.05	<0.0001	<0.001	0.01	<0.001	0.03	<0.01
		Mean	7.9	6.97	645	317	251	0.10	<0.0001	0.003	0.68	0.002	0.11	0.02
		Max	24.2	7.7	884	423	323	0.35	<0.0001	0.010	2.64	0.005	0.25	0.04
Miller Creek Drainage														
M-1 Little Daisy	24	Min	0.5	5.85	107	215	7	<0.1	<0.0001	<0.001	0.58	<0.01	0.18	<0.01
		Mean	16.4	6.82	963	510	321	0.1	0.0005	0.016	7.1	0.03	1.49	0.12
		Max	179.5	7.35	1763	633	541	0.33	<0.001	0.051	33.7	0.15	3.05	0.33
M-25 Henderson Mountain	9	Min	0.04	4.51	50	8	18	0.15	<0.0001	0.29	<0.03	<0.01	<0.02	<0.01
		Mean	10.0	6.0	296	25	26	0.31	0.0008	0.44	0.14	0.024	0.02	0.09
		Max	25.0	7.05	1065	54	39	0.59	0.0013	0.56	0.34	0.051	0.024	0.17
M-8 Black Warrior	19	Min	0.1	7.0	167	106	23	<0.05	0.001	<0.001	0.02	0.001	<0.003	0.1
		Mean	3.5	7.5	351	149	39	14.9	0.004	0.04	17.5	0.29	0.45	0.89
		Max	10.0	8.22	624	201	66	57.9	0.011	0.16	83.5	1.36	2.06	2.96
MCSI-96-3 Upper Miller Creek Dump	7	Min	0.04	5.93	110	61	12	<0.05	0.0004	<0.001	0.02	<0.003	<0.02	0.11
		Mean	1.0	6.62	174	83	25	6.7	0.0048	0.02	11.8	0.32	1.5	0.85
		Max	2.0	7.57	301	99	33	10.4	0.0093	0.03	19.1	0.61	3.64	1.48

Notes: 1 Number of samples varies for each parameter; number shown is maximum number of samples for any one parameter.
2 A "<" value reported for the mean indicates parameter was below detection for all sampled dates, value shown is the greatest detection limit used.
* Gold Dust data are averages of sample measurements or concentrations from 1994 through 2004; during prior years, Crown Butte Mines, Inc. was conducting exploration activities underground, which resulted in elevated suspended sediment content measured in total recoverable fraction.
gpm = gallons per minute; s.u. = standard units; mg/l = milligrams per liter; umhos/cm = micromhos per centimeter; SC = specific conductance; NA = not analyzed

3.3 DAISY CREEK DRAINAGE BASIN

3.3.1 Daisy Creek Surface Water Quality and Flow

Water quality and flow data collected from 1989 through 2010 at three locations (DC-2, DC-5, and SW-7) in the Daisy Creek drainage provide a basis for assessing impacts to Daisy Creek. Surface water monitoring station DC-2 is located approximately 810 meters (2,660 feet) downstream of the headwaters of Daisy Creek and is the furthest upstream station influenced by discharge from the McLaren Adit. Station DC-5 is located approximately 3,025 meters (9,925 feet) downstream, and station SW-7 is located approximately 6 kilometers (3.7 miles) downstream from the headwaters of Daisy Creek.

At sampling station DC-2, aluminum, cadmium, copper, iron, lead, manganese and zinc exceeded water quality standards both before and after the McLaren Pit was capped in October 2003 even though concentrations have decreased considerably since the cap was constructed (Table 3-4). During the September 2008 sampling event, aluminum, cadmium, copper, iron, lead, and zinc concentrations were above aquatic life standards. The mean copper concentration measured after capping was 1.86 milligrams per liter (mg/L) (Table 3-4), a 37% reduction from concentrations measured prior to capping. Comparing copper concentrations measured during high flows before and after capping, a 60% reduction in concentration is evident (Table 3-4). This same result is seen for the other metals shown in Table 3.3, with the greatest reduction in concentrations measured during the high flow sampling period between late May and mid-July. Copper and zinc concentrations tend to increase during low flow periods, but are usually below the respective narrative standards for this station.

The pH of water in the stream at station DC-2, even after capping, is strongly acidic during low flows (**Table A-2, Appendix A**), although the pH has increased considerably during high flows since the cap was constructed. The most recent pH value measured after capping was 4.0 standard units (s.u.) in September 2008, although during high flow in July 2008 the pH was 6.8 s.u.

Flow versus concentration graphs of copper, iron, and zinc at station DC-2 (Figure 27) indicate that concentrations measured after capping during the high flow snowmelt period were either the lowest or among the lowest measured since 1990. These positive changes in water quality at station DC-2 are attributed to the emplacement of the McLaren Pit cap, which allows the melting snow to move off the cap without passing through the waste lying under the cap.

At sampling station DC-5, aluminum, cadmium, copper, iron, lead, manganese, and zinc concentrations were above Circular DEQ-7 standards prior to capping the McLaren Pit (**Table A-2; Appendix A and Figure 28)**. Subsequent to capping, lead and zinc concentrations at DC-5 have dropped to near or below the aquatic life standard (**Table A-2; Appendix A and Figure 28**). The historic average copper concentration prior to capping at this station was 1.07 mg/L (Table 3-4); the average copper concentration after capping is less than half this value. When the data are separated into high and low flow regimes, the after capping mean copper concentrations are 75% and 50% lower, respectively, than the mean concentrations measured before capping. Neutral pH values were measured at DC-5 during all sample events occurring after capping the McLaren Pit (Table A-2). Similar reductions were seen in concentrations of the outer metals at this station as well.

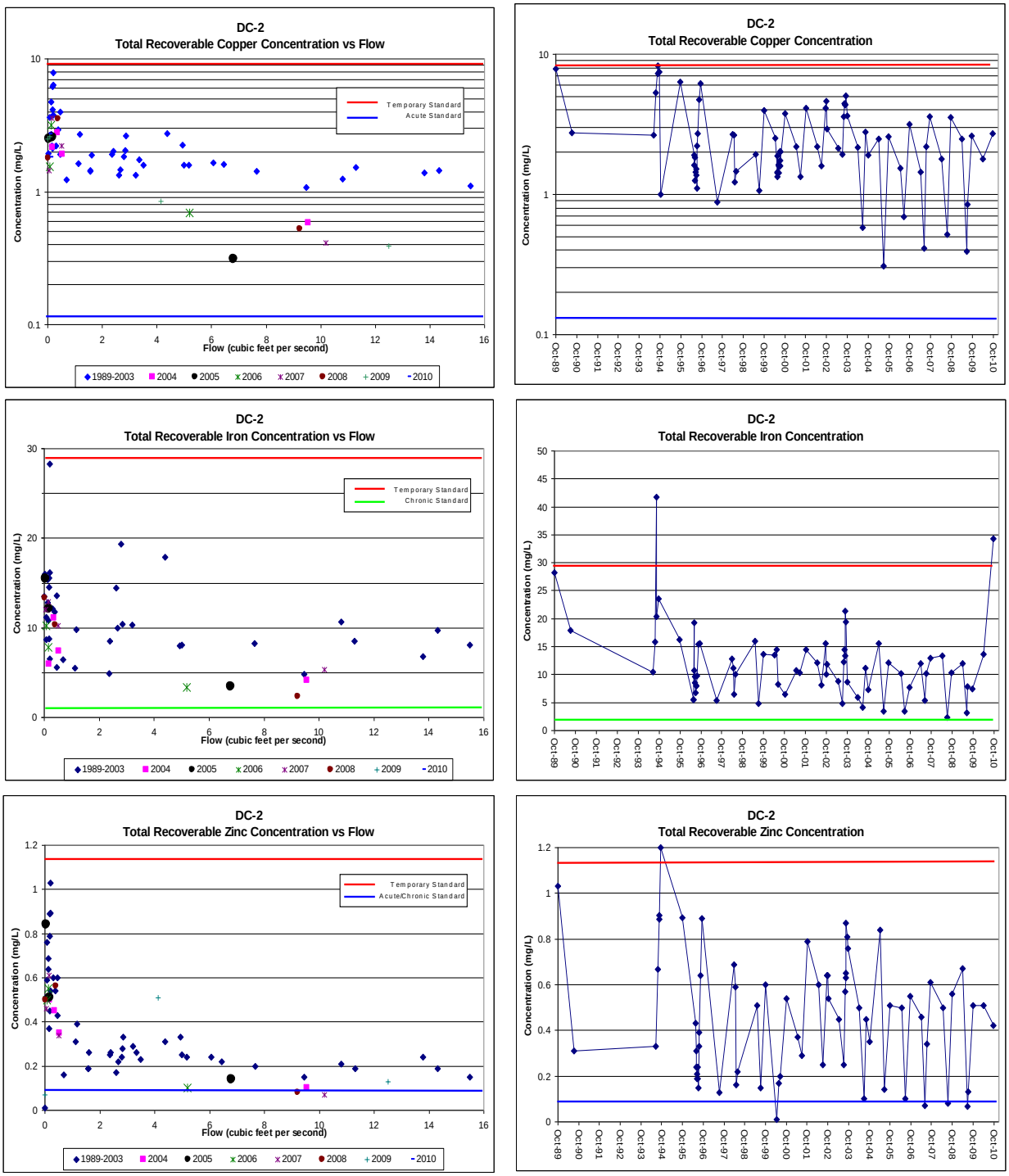


Figure 27. Concentration and Concentration vs. Flow at Station DC-2 for Copper, Iron, and Zinc

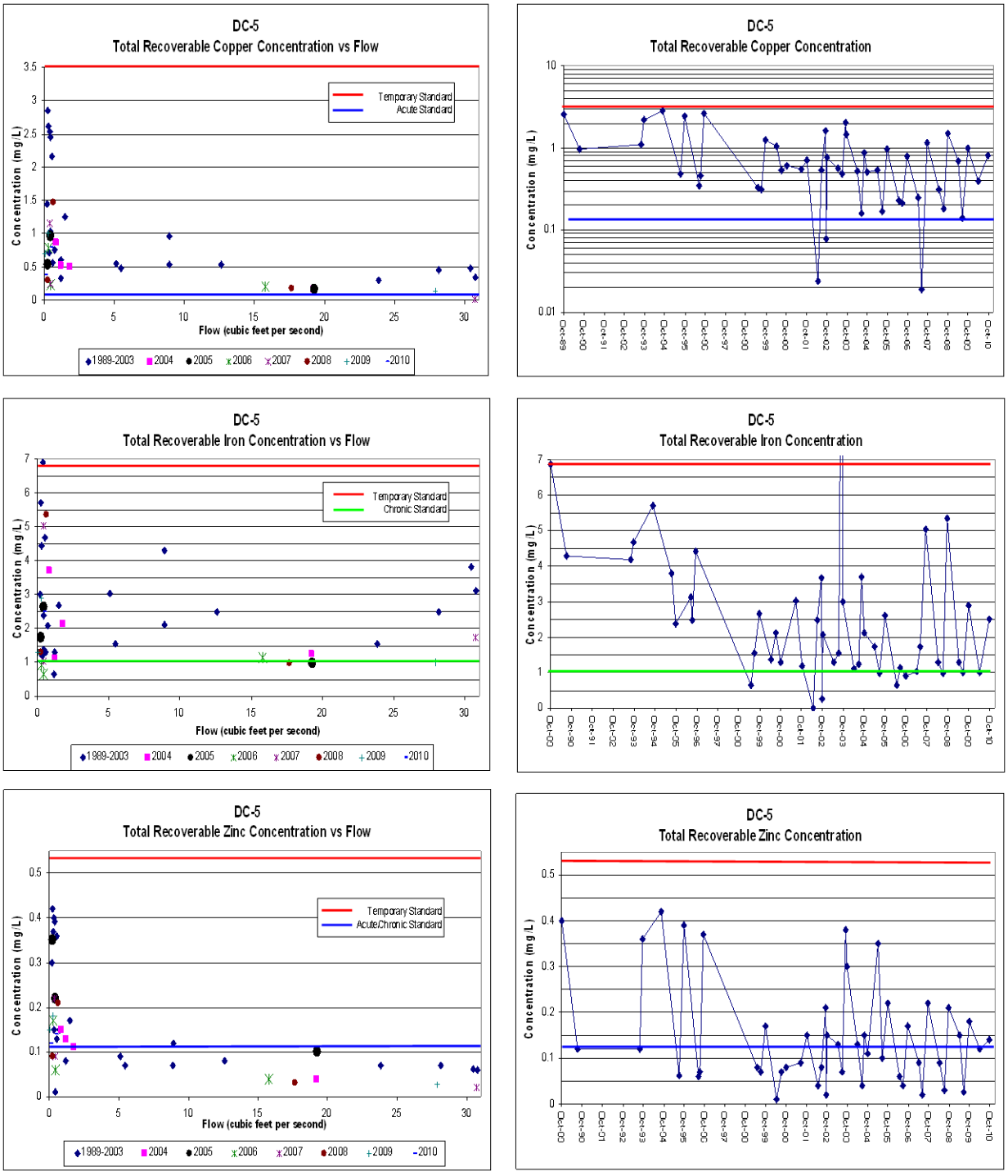


Figure 28. Concentration and Concentration vs. Flow at Station DC-5 for Copper, Iron, and Zinc.

Average metal concentrations at sampling station SW-7 were considerably less than at sampling stations located above the confluence of Daisy Creek and the Stillwater River (**Table 3-4**). With the exception of aluminum and copper, metal concentrations generally met Circular DEQ-7 water quality standards or occasionally exceeded the standards only slightly (**Figure 27**). Copper concentrations have decreased since capping the McLaren Pit, but exceeded the acute and chronic water quality standards in more than half of the sampling events conducted since the pit was capped (**Table 3-4**). As at stations DC-2 and DC-5, average metal concentrations were considerably lower at station SW-7 after capping compared to before capping the McLaren Pit (**Figure 29)**. Reductions measured after capping during high flow ranged from 2 to 69% and 4 to 56% during low flow (**Table 3-4**). The average iron concentration was the only metal to show an increase (4%) in concentration in the post-capping period (**Table 3-4**).

While water quality in Daisy Creek currently exceeds chronic and/or acute aquatic life standards for some constituents, it is likely that elevated metal concentrations and acidic pH conditions existed prior to mining activity in the Daisy Creek drainage basin. Multiple lines of evidence including stream-specific estimation equations, qualitative observations (i.e. historically deposited metal rich sediments and the existence of copper bogs), and examination of water quality in areas of the District not affected by mining were used to estimate pre-mining water quality in the specific areas of the District (Tetra Tech, 2009a). These estimations indicate that pH in the upper 481 meters of Daisy Creek was likely about 3.8 and copper concentrations averaged 8.5 mg/L (ranging from 4.1 to 14 mg/L) prior to mining. Further downstream, at DC-2 pre-mining estimates of pH and copper concentrations were similar to values and concentrations currently measured at this station.

3.3.2 McLaren Pit Subsurface Drains

Surface water monitoring station DC-2 is located approximately 810 meters (2,660 feet) downstream of the headwaters of Daisy Creek and is the furthest upstream station influenced by discharge from the McLaren subsurface drains. Station DC-5 is located approximately 3,025 meters (9,925 feet) downstream, and station SW-7 is located approximately 6 kilometers (3.7 miles) downstream from the headwaters of Daisy Creek. **Table 3-5** shows data collected from the McLaren Pit subsurface drains. Water from these drains exhibited very acidic pH values, ranging between 2.1 and 4.4 s.u., with generally poor water quality (copper and iron concentrations in the 10 to 600 mg/L range). The combined flow from the three drains ranges from 10.2 Lpm to 171 Lpm (2.7 gpm to 45 gpm) and averaged about 72 Lpm (19 gpm) during times when flow was measured. Continuous data recorders were installed in August 2008 to monitor year-round flow from the subsurface drains. Interpretation of data from the recorders is complicated due to the effect of ice formation and sediment migration that prevents accurate pressure (i.e. depth) readings during certain parts of the year. Data acquired from the recorders in 2009 and 2010 showed that flow ceases or decreases to a minimal amount between about mid-October to mid-November and the drains remain dry through late May when they begin to flow again coinciding with snowmelt.

3.3.3 Daisy Creek Loading Analysis

Mean metal concentration and flow data were used to calculate metal loads to determine the relative contribution of metals from the McLaren Pit subsurface drains to Daisy Creek (**Table 3-6,** and **Figure 27**) as measured at DC-2 during the time following McLaren Pit capping. The load calculation at DC-2 was performed using the average base flow load measured between October 2003 and September 2010, which includes loads measured in April, August, September, and October each year.

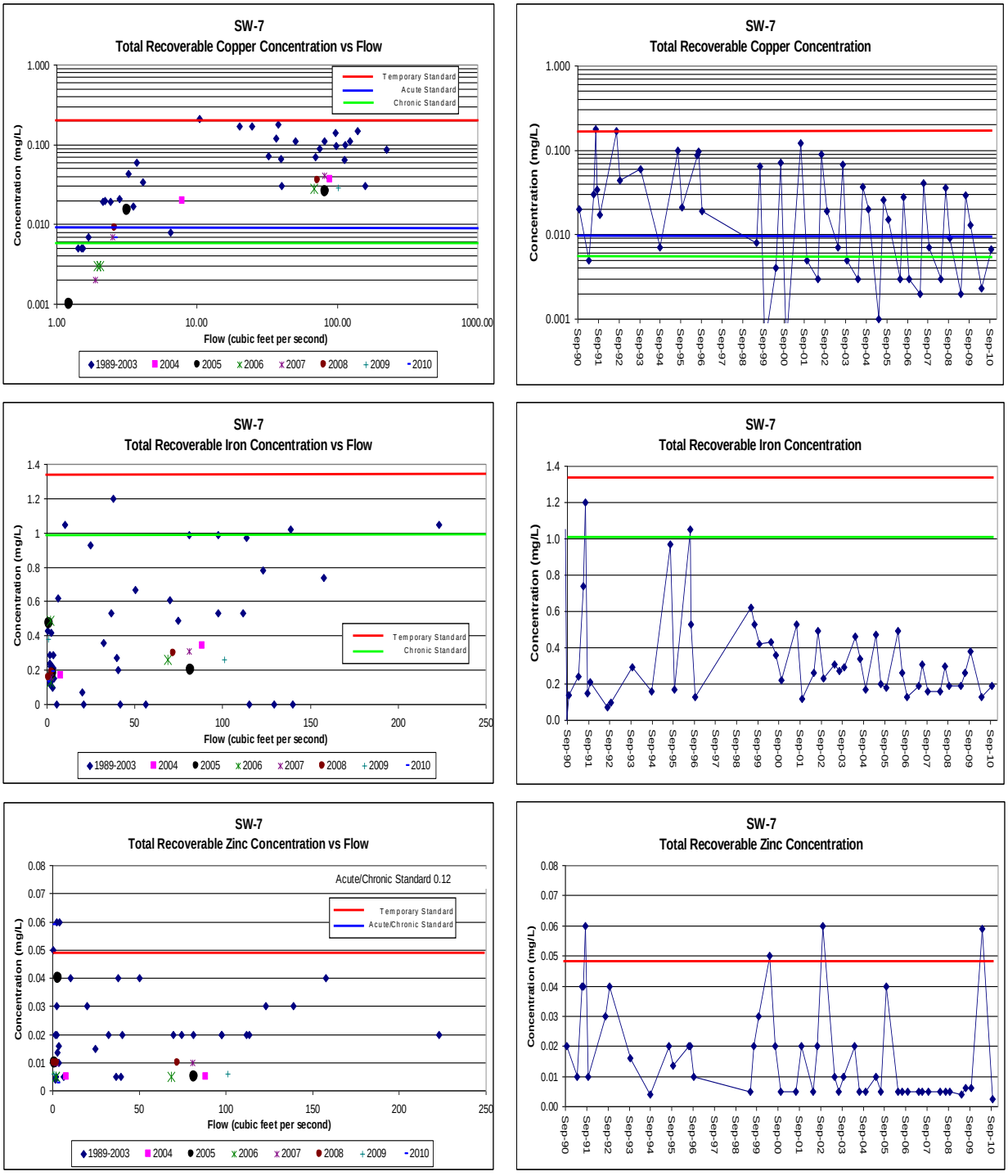


Figure 29. Concentration and Concentration vs. Flow at Station SW-7 for Copper, Iron, and Zinc

TABLE 3-6
PERCENT CONTRIBUTION OF METALS LOADING FROM MCLAREN PIT SUBSURFACE DRAINS AT DAISY CREEK STATION DC-2 AFTER CAPPING THE MCLAREN PIT

Data Low Flow Conditions

Station Number	Aluminum		Cadmium		Copper		Iron	
	Load[1] kg/month	Post-Capping % Contribution at DC-2	Load kg/month	Post-Capping % Contribution at DC-2	Load kg/month	Post-Capping % Contribution at DC-2	Load kg/month	Post-Capping % Contribution at DC-2
DCSW-101	24.1	19.5	0.009	22.4	12.0	39.2	118	94.4
DCSW-102	3.0	2.5	0.001	3.6	1.83	6.0	12.6	10.0
DCSW-103	10.3	8.3	0.003	7.1	3.96	12.9	43.4	34.7
Total Contribution[2]	37.4	30.3	0.0	33.1	17.8	58.1	174.4	139
DC-2 Post-Capping[3]	123	40.6	0.040	53.0	30.6	33.7	125.4	30.8
DC-2 Pre-Capping Low Flow	304		0.076		91.0		406.7	
	Lead		Manganese		Zinc		Flow (gallons per minute)	
	Load kg/month	Post-Capping % Contribution at DC-2	Load kg/month	Post-Capping % Contribution at DC-2	Load Kg/month	Post-Capping % Contribution at DC-2		
DCSW-101	0.0067	11.8	2.9	13.9	1.6	27.4	5.4	
DCSW-102	0.0001	0.25	0.46	2.2	0.25	4.4	0.78	
DCSW-103	0.0003	0.53	1.6	7.6	0.52	9.0	0.76	
Total Contribution[2]	0.007	12.60	4.9	23.7	2.3	40.9	6.9	
DC-2 Post-Capping[3]	0.056	31.2	20.9	51.8	5.7	41.1	72.6	
DC-2 Pre-Capping Low Flow	0.181		40.3		14.0		284	

Notes: 1 DC-2 post-capping and subsurface drain loads are average low flow after capping McLaren Pit (October 2003 through Sept. 2010); DC-2 pre-capping loads are average low flow loads measured prior to October 2003 (n varies).
2 Total Contribution is the total combined load from DSCW-101, 102, and 103.
3 Post Capping % for Station DC-2 is percent of Pre-Capping average low flow load.
kg/month = kilograms per month

TABLE 3-6 (continued)
PERCENT CONTRIBUTION OF METALS LOADING FROM MCLAREN PIT SUBSURFACE DRAINS AT DAISY CREEK STATION DC-2 AFTER CAPPING THE MCLAREN PIT

Data for High Flow Conditions

Station Number	Aluminum		Cadmium		Copper		Iron	
	Load[1] kg/month	Post-Capping % Contribution at DC-2	Load kg/month	Post-Capping % Contribution at DC-2	Load kg/month	Post-Capping % Contribution at DC-2	Load kg/month	Post-Capping % Contribution at DC-2
DCSW-101	92.9	5.9	0.029	9.5	43.3	15.9	372	17.4
DCSW-102	77.4	4.9	0.045	14.7	36.00	13.2	334.5	15.6
DCSW-103	25.0	1.6	0.007	2.2	9.94	3.7	128.3	6.0
Total Contribution[2]	195.2	12.3	0.1	26.4	89.2	32.8	835.3	39
DC-2 Post-Capping[3]	1587	65.7	0.304	43.0	272.3	38.1	2144.7	47.0
DC-2 Pre-Capping High Flow	2415		0.706		715.6		4564.8	

Station Number	Lead		Manganese		Zinc		Flow (gallons per minute)
	Load kg/month	Post-Capping % Contribution at DC-2	Load kg/month	Post-Capping % Contribution at DC-2	Load kg/month	Post-Capping % Contribution at DC-2	
DCSW-101	0.0431	1.8	8.8	5.7	5.1	10.2	21.0
DCSW-102	0.0074	0.3	11.61	7.5	7.44	14.9	14.2
DCSW-103	0.0007	0.0	3.2	2.1	1.14	2.3	1.6
Total Contribution[2]	0.051	2.2	23.7	15.3	13.7	27.4	36.9
DC-2 Post-Capping[3]	2.355	95.5	155.0	63.3	49.9	48.7	3261
DC-2 Pre-Capping High Flow	2.466		244.7		102.5		2842

Notes: 1 DC-2 post-capping and subsurface drain loads are June and July data after capping McLaren Pit (October 2010) DC-2 pre-capping loads are average high flow loads measured prior to October 2003 (n varies).
2 Total Contribution is the total combined load from DSCW-101, 102, and 103.
3 Post Capping % for Station DC-2 is percent of Pre-Capping average high flow load.
kg/month = kilograms per month

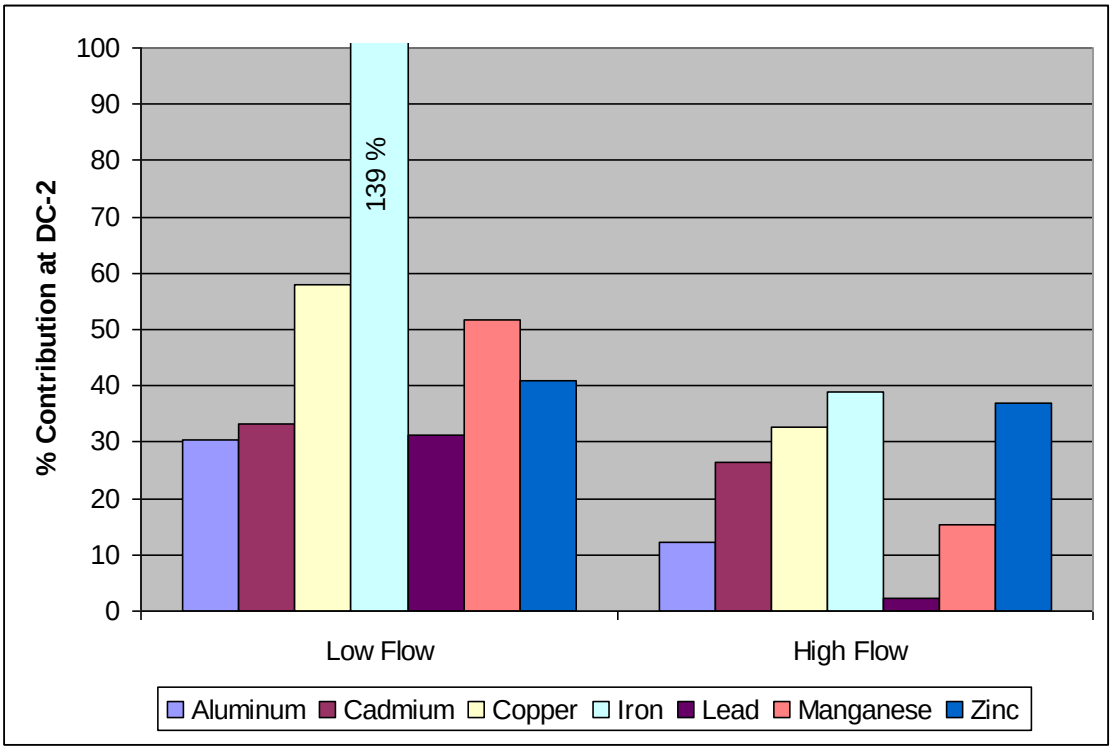


Figure 30. Metal Loads Calculated For McLaren Pit Subsurface Drains at Station DC-2

Significant contributions to the upper reaches of Daisy Creek come from the McLaren Pit subsurface drains (DCSW-101, -102, and -103) as well as from other unidentified non-point sources. The subsurface drains were installed during the McLaren Pit Response Action to provide outlets for springs discharging from bedrock in the area of the high-wall. On average, the combined load from the three drains accounted for as much as 139% of the iron load and considerable contributions of aluminum (30.3%), cadmium (33.1%), copper (58.1%), manganese (23.7%), and zinc (40.9%) when compared to the loads measured at DC-2 when the subsurface drains are discharging during low flow conditions (Figure 30). The low flow iron load (139% of the load measured at station DC-2) indicates that iron is not conserved and that considerable iron precipitation occurs in the stream channel between the drain outlet and the DC-2 monitoring location.

Most of the combined load from the three subsurface drains is contributed by DCSW-101. The relative contribution from the drains increased for each of the metals analyzed except for cadmium, during low flow conditions compared to the high flow percentage contribution (**Figure 30**). However, it is worth noting that the drains do not appear to flow for a period of about 6 months between November and May. During this time, the drains do not contribute any metal loading in Daisy Creek.

Table 3-6 also shows average metal loads at DC-2 for the period prior to capping the McLaren Pit. Post-capping metal loads calculated for the average low flow periods sampled after October 2003 range from 30% to 53% of those calculated for low flow sample events occurring before capping. A similar relationship occurred during post-capping high flow events with post-capping loads between 38% and 95% of the pre-capping high flow loads. These data indicate that capping the McLaren Pit was effective in reducing loads in Daisy Creek, although metal concentrations in Daisy Creek do not yet approach water quality standards.

Data plotted in Figures 27 through 29 show metal concentrations for samples collected in 2004 through 2010 are in the lower range of values measured in samples collected previously at similar flow rates.

3.4 FISHER CREEK DRAINAGE

3.4.1 Fisher Creek Surface Water Quality and Flow

Surface water quality in Fisher Creek was historically impacted by runoff from the Como Basin, discharges from adits (Sheep Mountain #1, Tredennic, Glengarry, Gold Dust, and Henderson Mountain #7), seeps, springs, and groundwater that carry high metal loads (Maxim 2002), and other sources such as natural soils. As a result, metal concentrations measured at Fisher Creek monitoring stations SW-3 and SW-4 (Figure 3) often exceed Circular DEQ-7 water quality standards for aluminum, cadmium, copper, iron, lead, manganese, and zinc (**Table 3-4**). Water at station SW-3 is typically acidic, ranging from 3.1 to 7.0 s.u. since October 2004 (**Table A-2, Appendix A**); pH increases to between 5.6 and 7.2 s.u. at station SW-4 for the same period.

Data presented in **Table 3-4** and Figures 31 and 32 indicate that metal concentrations are generally lower during periods of high flow than during low flow events at upstream station SW-3. At station SW-4, the opposite is generally true. These observations are consistent with those described by Maxim (2002) and suggest that dilution occurs near the headwaters of Fisher Creek during periods of high flow. **Table 3-4** also shows that concentrations of metals at both these stations have decreased considerably since the Glengarry Adit was closed in October 2004. When all data are averaged, iron concentrations decreased the most since the adit was closed with a reduction of 75% at SW-3 and 81% at SW-4. Average iron concentrations at SW-3 still exceed aquatic standards even with this reduction.

As discussed above in section 3.3.1, estimates of pre-mining water quality have been made for the District, including Fisher Creek (Tetra Tech, 2009a). These estimates indicate that surface water quality at SW-3 was acidic (pH around 4.8) and copper-rich (0.26 mg/L) prior to mining. Naturally occurring acidic and metal-rich inflows that contribute metals to Fisher Creek below SW-3 are present and not affected physically or hydrologically by mining (Kimball et al., 1999). These inflows were most likely present prior to mining.

Water collected at monitoring station CFY-2, located downstream from SW-3 and SW-4 at the confluence of Fisher Creek and the Clarks Fork of the Yellowstone River (Figure 3), is of better quality yet generally exceeds aquatic standards for copper during certain flow periods each year (**Table A-2, Appendix A**. Metal concentrations at CFY-2 tend to increase during high flow conditions (**Figure 33**). An increase in metal loading at station CFY-2 during high flow is likely due to suspended fine-grained sediment present in the water.

3.4.2 Fisher Creek Adit Discharge Water Quality and Flow

Numerous adit discharge locations in the Fisher Creek drainage have been monitored. Flow from the Glengarry Adit (station F-8A, Figure 3) was measured most recently on June 26, 2006. Prior to plugging the adit, average flow from the portal was 210 Lpm (56 gpm) and ranged from 50 to 850 Lpm (15 to 224 gpm) (Maxim, 2002a). Flow was very low at about 2.0 Lpm (0.5 gpm) on June 26, although the discharge still exceeded aquatic water quality criteria for copper (0.038 mg/L) and iron (2.52 mg/L). While flow could not be measured during a subsequent event on June 12, 2007 at F-8A, water quality analysis showed that water quality from the seeping adit continued to exceed water quality criteria for copper (0.39 mg/L) and iron (23.6 mg/L). It is possible data from the recent sample event were influenced by sediment contained in the small volume of adit seepage that was available for sampling. Water quality at

monitoring stations FSCI-99-1 (Sheep Mountain # 1 Adit), AE-17 (Henderson Mountain Dump # 7), and F-28 (Gold Dust Adit) is somewhat better than the Glengarry Mill-Site Adit station with pH ranging from 5.5 to 8.3 s.u. and metal concentrations that are not as greatly elevated. However, each of these adits discharges water that would exceed applicable aquatic standards for one or more of the following elements: cadmium, copper, iron, lead, and manganese (**Table 3-4**). It should be noted that data collected prior to 1994 for the Gold Dust Adit were not included in this analysis. This is because these data are believed to have been influenced by drilling and other exploration activities that took place in the adit during this time.

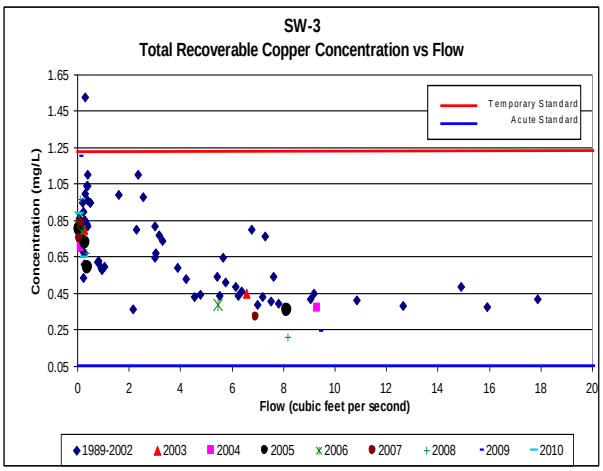
3.4.3 Fisher Creek Loading Analysis

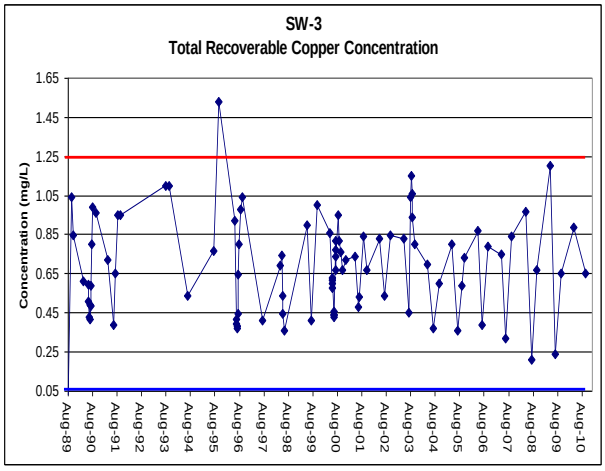
Previous studies have suggested that the Glengarry Adit contributed up to 65.3% of the load of certain metals to Fisher Creek at station SW-3 prior to the USDA's Glengarry Adit closure project (Amacher 1998; Kimball *et. al*. 1999). With closure of the adit complete in October 2004, discharge from the Glengarry Adit had decreased to about 2.0 Lpm (0.5 gpm) by June 2006, with concurrent decreases in metals concentrations. Metal loads from what remained of the adit discharge were less than 0.5% of the average low flow load measured at station SW-3 except for iron (1.1%) (**Table 3-7**).

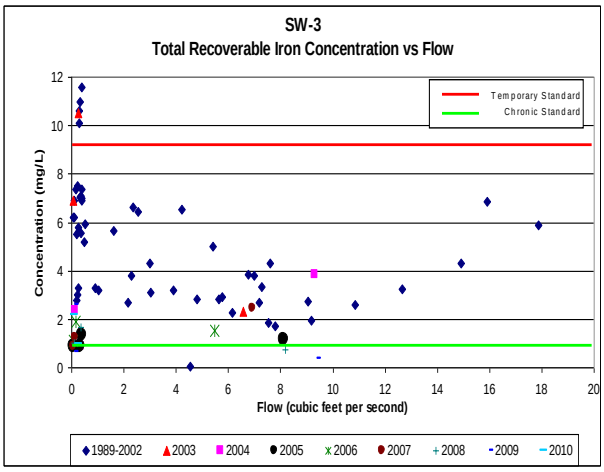
With the dramatic reduction in loading from the Glengarry Adit closure, the loading analysis presented in **Table 3-7** was completed by comparing the mean flows and concentrations for the Fisher Creek adits (except for the Gold Dust) with the average low flow loads measures at the Fisher Creek monitoring stations between October 2004 and September 2008 (i.e. post-closure water quality). For the Gold Dust adit, data from September 2006 through September 2008 are used in the loading calculation because previous water quality data may have been influenced by reclamation construction work conducted at the site in 2004, 2005, and 2006.

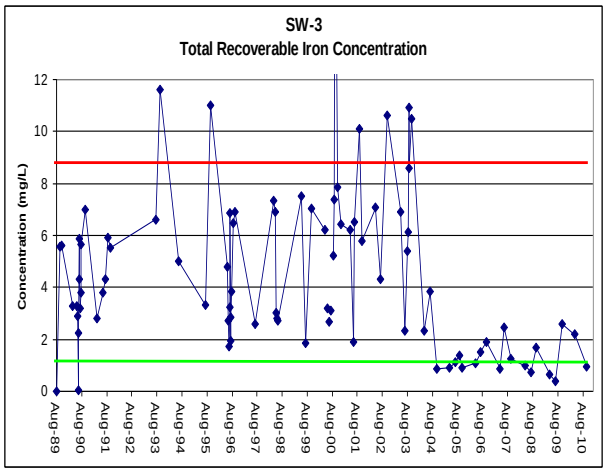
Aluminum, copper, iron, and manganese loads calculated for the three Fisher Creek main-stem stations (SW-3, SW-4, and CFY-2) decrease with distance downstream during the October 2004 to September 2008 low flow sampling events (**Table 3-7** and Figure 34). This indicates that attenuation mechanisms such as dilution, adsorption, and/or precipitation occur as metals travel downstream. Precipitation of dissolved metals is likely to occur as pH reaches circum-neutral values downstream of station SW-4 (**Table A-2, Appendix A**). On the other hand, cadmium, lead, and zinc loads increased between stations SW-3 and SW-4 (**Table 3-7**), suggesting that cumulative loading of these elements occurs from sources located below station SW-3.

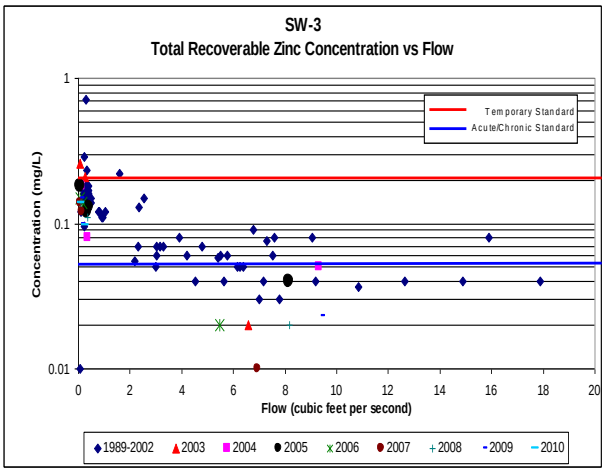
As shown in **Table 3-7**, the mean discharge from the Sheep Mountain #1 Adit (station FSCI-99-1) contributed 4.2% of the lead load at SW-3 (**Table 3-7**). This adit site contributed less than 1% of the total load for each of the remaining metals measured at station SW-3.











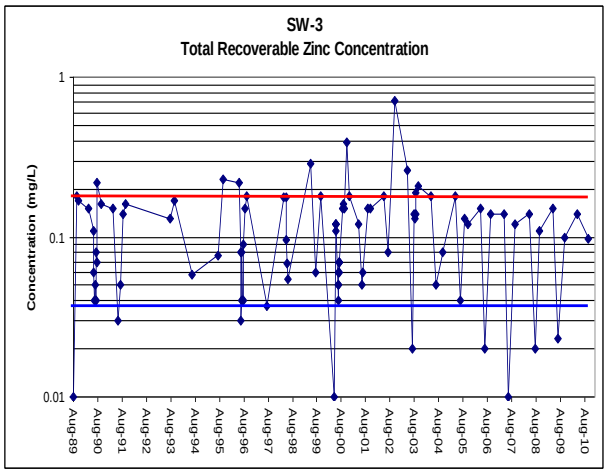
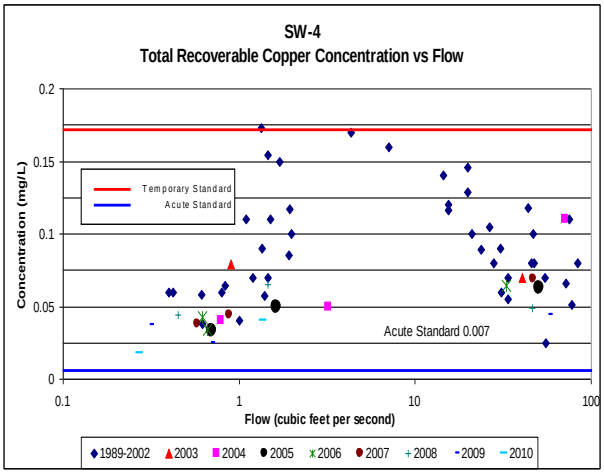
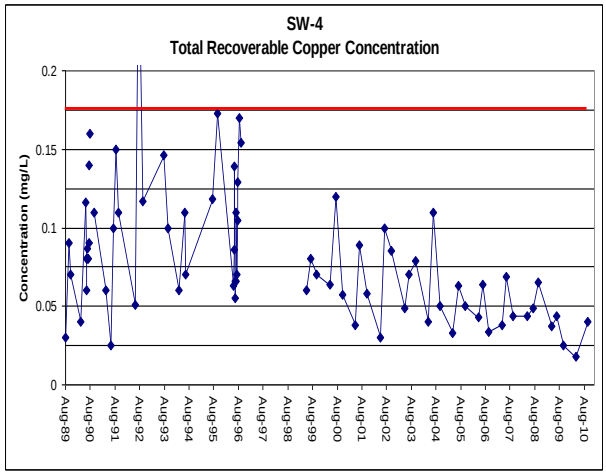
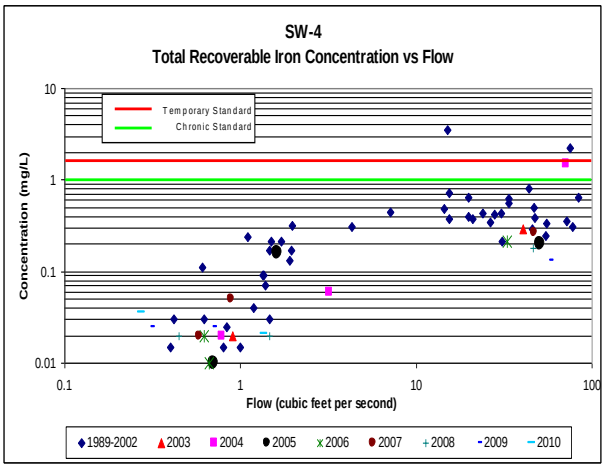
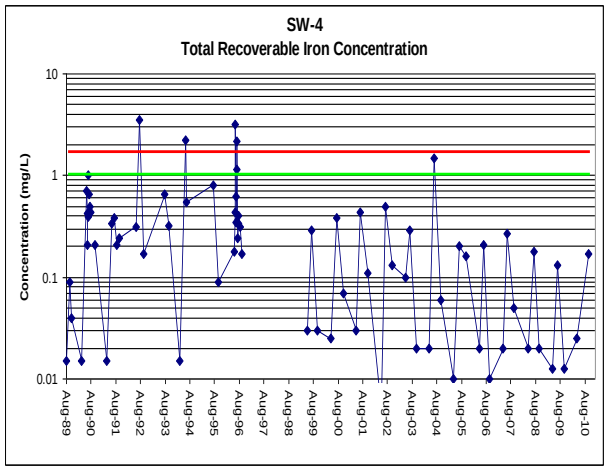


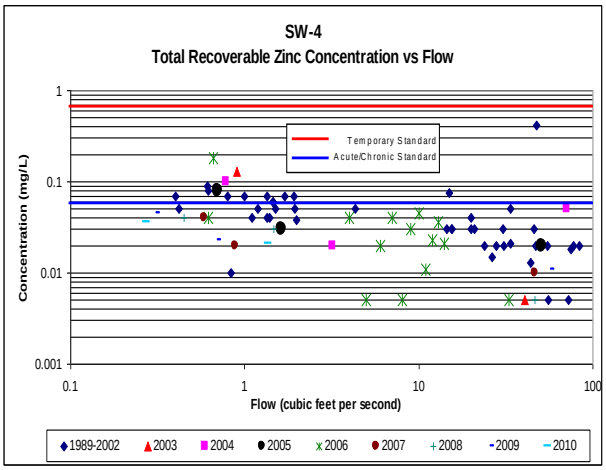
Figure 31. Concentration and Concentration vs. Flow at Station SW-3











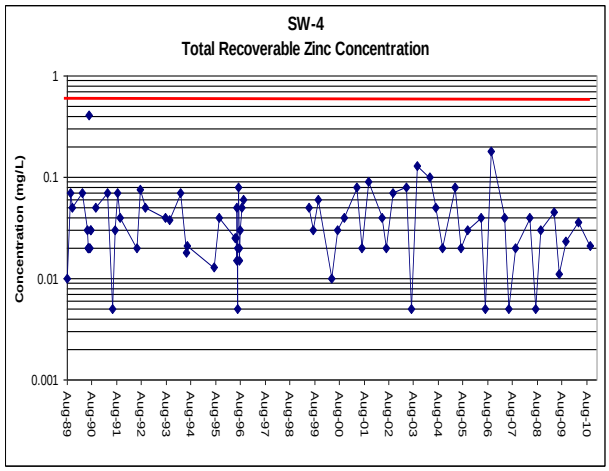


Figure 32. Concentration and Concentration vs. Flow at StationSW-4

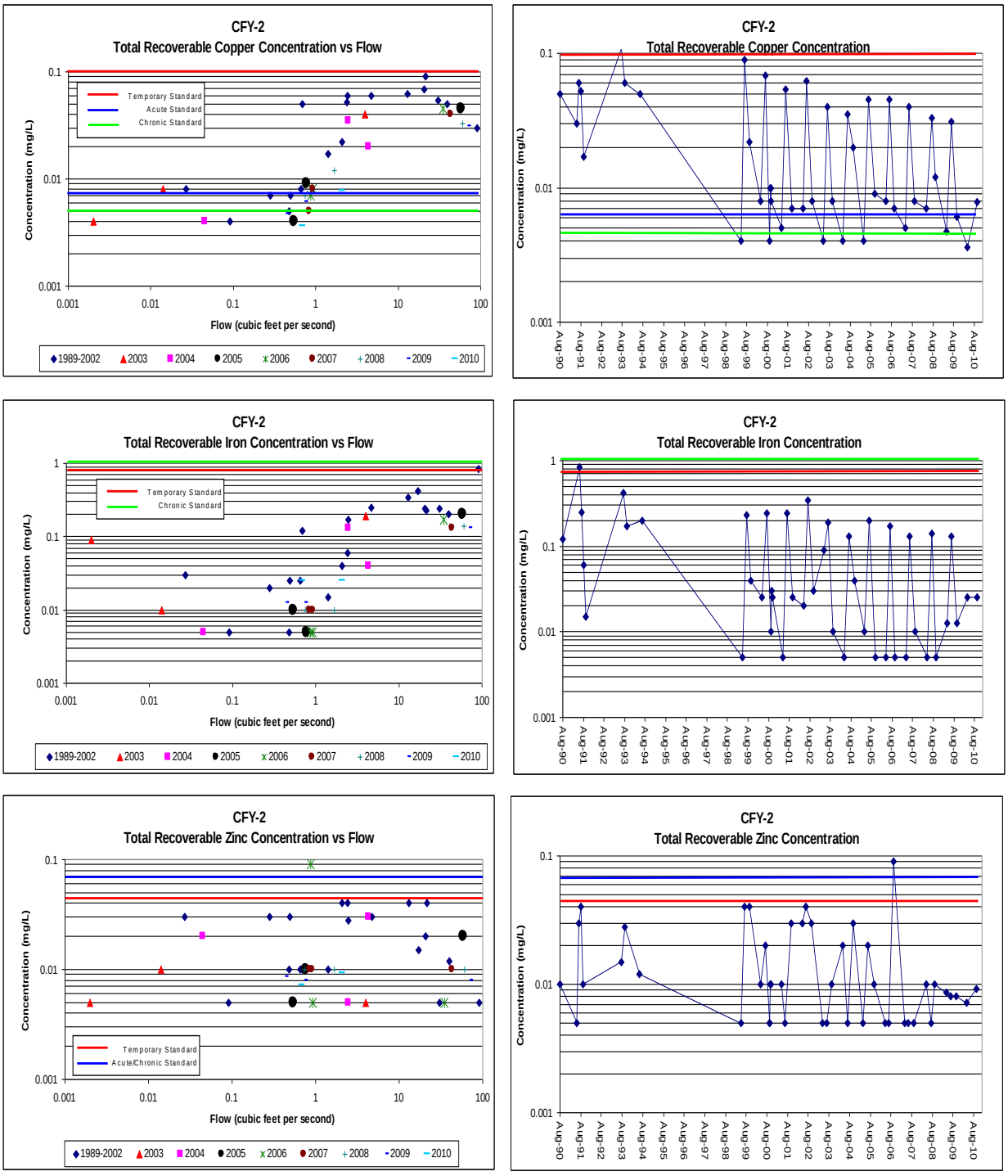


Figure 33. Concentration and Concentration vs. Flow at Station CFY-2

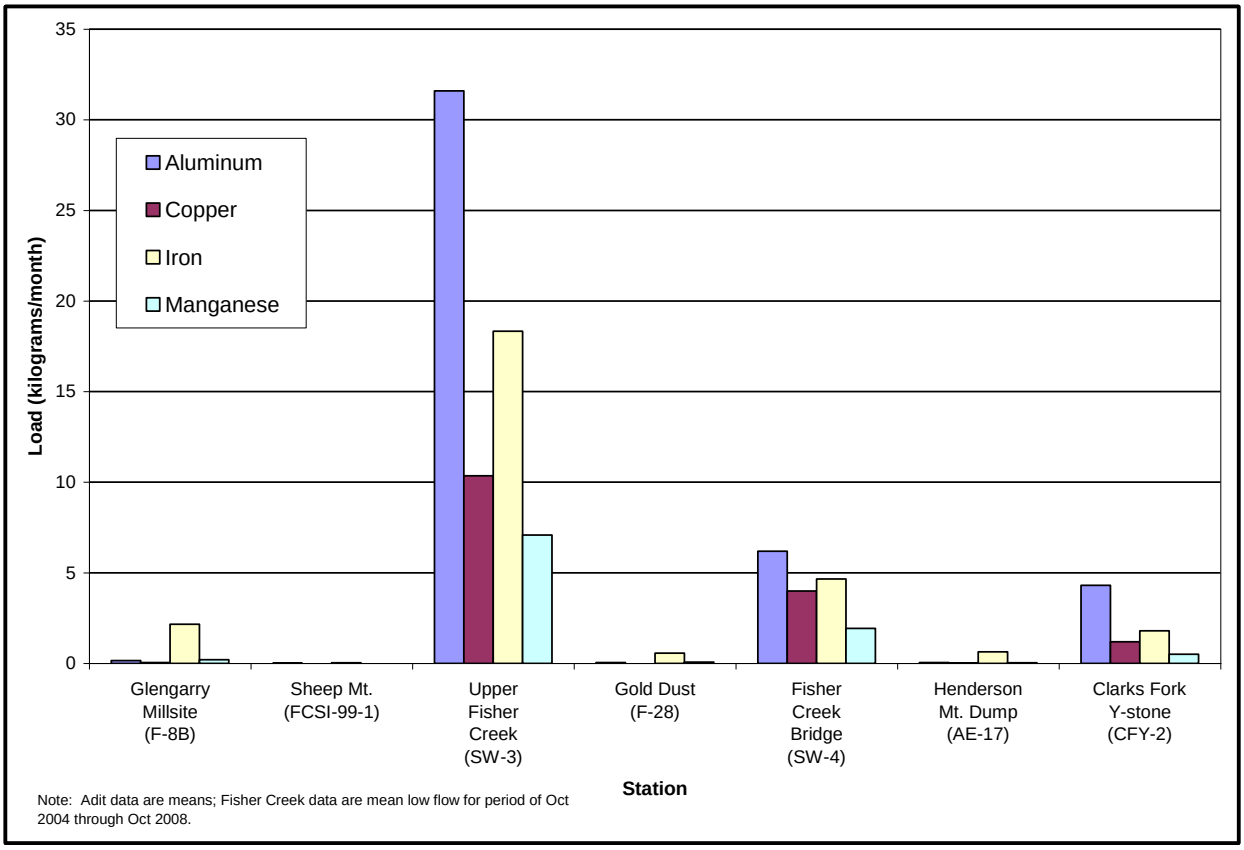


Figure 34. Metal Loads in Fisher Creek and Fisher Creek Adit Discharges

Based on average concentration and flow data measured at the Gold Dust Adit after October 2006, this adit, which discharges to Fisher Creek between stations SW-3 and SW-4, contributes less than 0.5% of the cadmium, copper, and zinc loads measured at station SW-4 and about 0.79%, 12.3%, 2.1%, and 3.9% of the aluminum, iron, lead, and manganese load, respectively (**Table 3-7**). Discharge from the Henderson Mountain Dump 7 (station AE-17), which enters Fisher Creek between SW-4 and CFY-2 contributes 35.6% of the iron load and 6.7% of the manganese load measured at station CFY-2. Other metal loads from this adit were 1.1% or less of the load at station CFY-2 (**Table 3-7**).

3.5 MILLER CREEK DRAINAGE

3.5.1 Miller Creek Surface Water Quality and Flow

No temporary standards are in place for Miller Creek, as water quality in Miller Creek is generally of high quality with circum-neutral pH and metals concentrations that tend to be low (Maxim 2003a; Cleasby and Nimick 2002). Water quality data for Miller Creek monitoring stations SW-2 and SW-5 show cadmium, copper, iron, manganese, lead, and zinc have occasionally exceeded water quality standards, particularly under high flow conditions in June and July (**Table 3-4** and Figures 35 and 37). These exceedances likely result from the influence of suspended sediments on total recoverable metals analyses. It should be noted that cadmium and lead concentrations were usually below detection at both stations, and that the calculated mean values are biased by anomalously high concentrations recorded during a June 1990 high-flow sampling event (**Table A-2, Appendix A**). Flow at SW-2 and SW-5 ranges from about 240 to 151,000 Lpm (63 to 40,000 gpm).

TABLE 3-7
PERCENT CONTRIBUTION OF ADIT METALS LOADING TO FISHER CREEK

Station	Aluminum				Cadmium				Copper			
	Load kg/month	% Contribution at SW-3	% Contribution at SW-4	% Contribution at CFY-2	Load kg/month	% Contribution at SW-3	% Contribution at SW-4	% Contribution at CFY-2	Load kg/month	% Contribution at SW-3	% Contribution at SW-4	% Contribution at CFY-2
Glengarry (F-8A)	0.006	0.02			0.000004	0.04			0.003	0.03		
Sheep Mtn. #1 (FCSI-99-1)	0.010	0.03			0.00002	0.22			0.001	0.01		
SW-3	32	100			0.01	100			10.4	100		
Gold Dust (F-28)	0.05		0.79		0.00007		0.40		0.0026		0.066	
SW-4	6.2		100		0.02		100		4.0		100	
Henderson Mtn. (AE-17)	0.05			1.06	0.00005			0.76	0.009			0.77
CFY-2	4.3			100	0.006			100	1.2			100

	Iron				Lead				Manganese			
	Load kg/month	% Contribution at SW-3	% Contribution at SW-4	% Contribution at CFY-2	Load kg/month	% Contribution at SW-3	% Contribution at SW-4	% Contribution at CFY-2	Load kg/month	% Contribution at SW-3	% Contribution at SW-4	% Contribution at CFY-2
Glengarry (F-8A)	0.2	1.1			0.00004	0.16			0.03	0.36		
Sheep Mtn. #1 (FCSI-99-1)	0.04	0.21			0.001	4.2			0.002	0.03		
SW-3	18	100			0.03	100			7.1	100		
Gold Dust (F-28)	0.57		12.3		0.0010		2.1		0.08		3.9	
SW-4	4.7		100		0.05		100		1.9		100	
Henderson Mtn. (AE-17)	0.6			35.6	0.001			1.147	0.03			6.7
CFY-2	1.8			100	0.05			100	0.5			100

	Zinc			
	Load kg/month	% Contribution at SW-3	% Contribution at SW-4	% Contribution at CFY-2
Glengarry (F-8A)	0.003	0.15		
Sheep Mtn. #1 (FCSI-99-1)	0.003	0.14		
SW-3	2	100		
Gold Dust (F-28)	0.02		0.45	
SW-4	3.4		100	
Henderson Mtn. (AE-17)	0.02			1.03
CFY-2	2.1			100

Notes: 1 Data for Fisher Creek monitoring stations SW-3, SW-4, and CFY-2 are the average low flow measured from Oct 04 through Sept 08, the same period that adit data are available for.

2 Glengarry loads calculated using data collected in Sept 06; Gold Dust loads calculated using data collected from Sept 06 through Sept 08; remaining adit data is average for period of record.

kg = kilograms

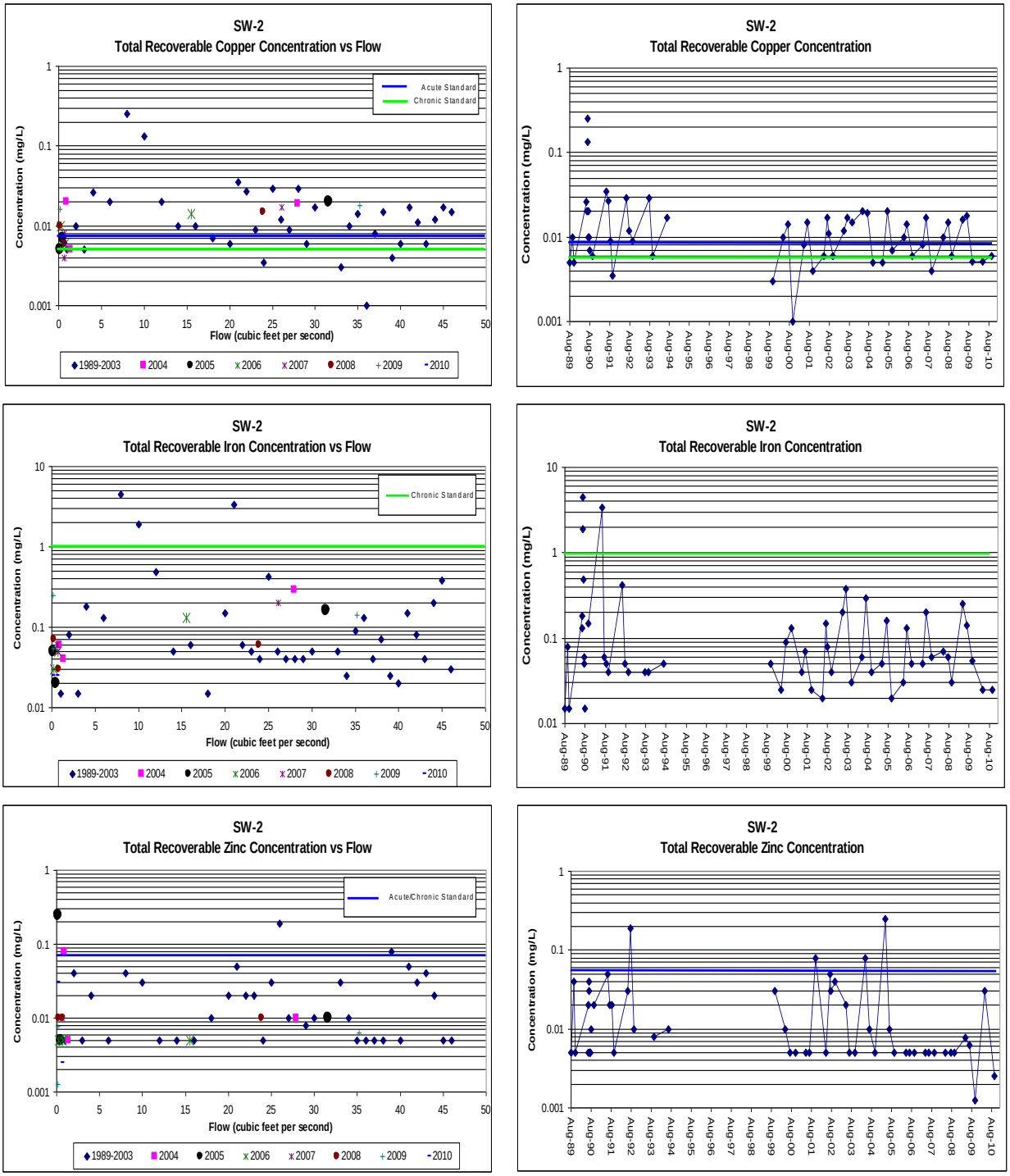


Figure 35. Concentration and Concentration vs. Flow Graphs at Station SW-2

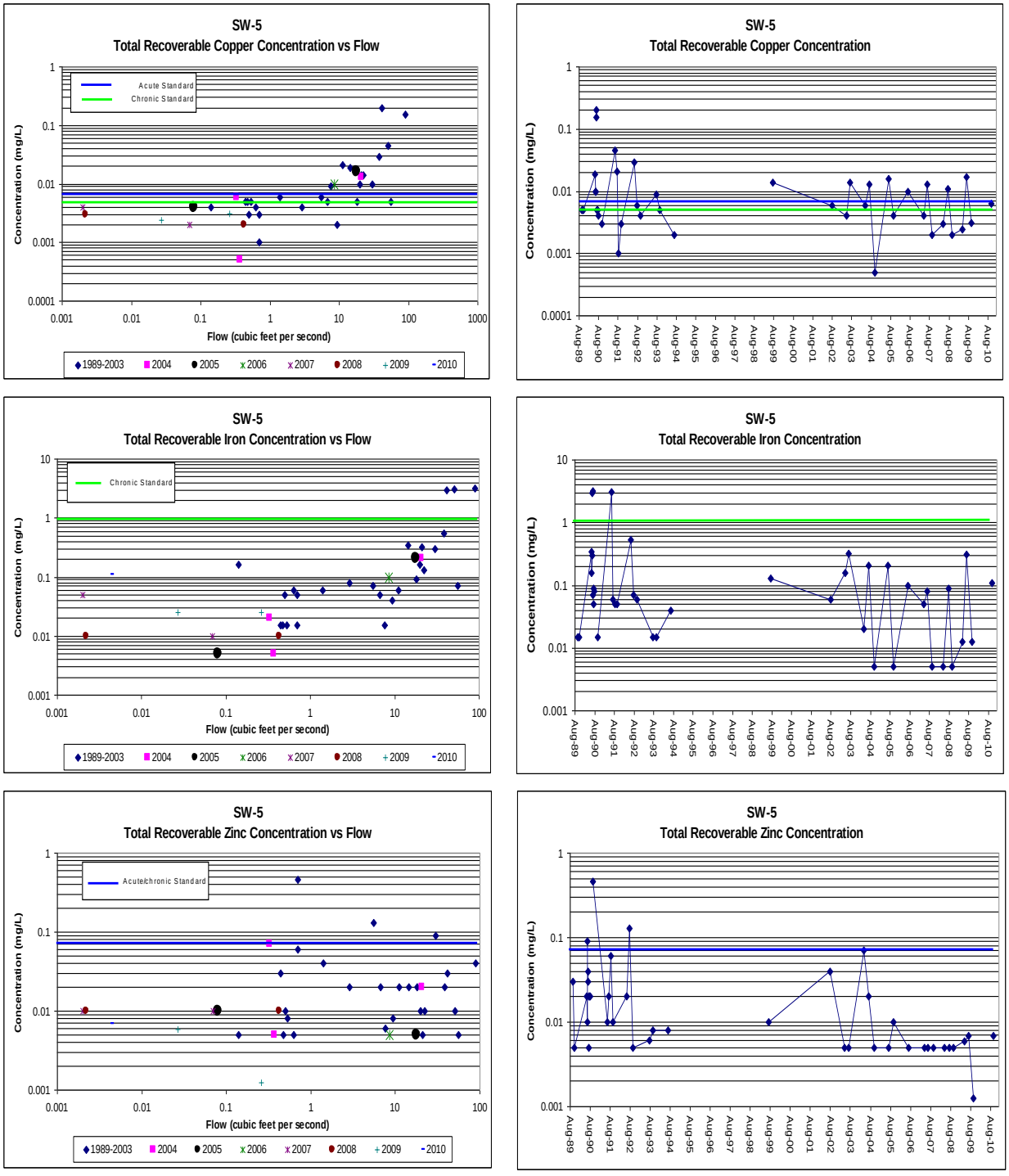


Figure 36. Concentration and Concentration vs. Flow Graphs at Station SW-5

3.5.2 Miller Creek Adit Discharge Water Quality and Flow

There are several adit discharges in the Miller Creek drainage. The Little Daisy Adit (station M-1) has been sampled for flow and metal concentrations on 11 dates between 1989 and 2008 (**Table A-5, Appendix A**). The Henderson Mountain Adit (station M-25) and the Upper Miller Creek Dump (station MCSI-96-3) have been sampled for flow and metal concentrations on three occasions, with the most recent event occurring in August 2007.

Adit discharge water quality tends to be poor compared to that of Miller Creek. Values of pH range from 4.5 to 8.2 s.u. and elevated metal concentrations have been recorded at most of the discharging adits in the drainage (**Table 3-5**). Most of the adit discharges display elevated concentrations of cadmium, copper, and lead, while a limited number also display elevated concentrations of iron, manganese, or zinc. Aluminum in adit discharges from M-10 and M-25 may exceed aquatic standards, although the standard is based on dissolved concentrations while only total recoverable aluminum data are available for these two sites. Total recoverable aluminum was below the detection limit (0.1 mg/l) in most samples from the Little Daisy Adit with the exceedences of the aquatic standard occurring in two of the six samples collected since 2001.

Adits discharging to Miller Creek tend to have low flows, with average flows calculated for high flow periods that range from seven to 40 Lpm (2.0 to 10.7 gpm). The greatest flow rates occur at the Little Daisy Adit (M-1) and the Henderson Mountain Adit (M-25) with average flow around 40 Lpm (10 gpm) (**Table 3-5**). A mean flow of 62 Lpm (16.4 gpm) for the Little Daisy Adit is biased by an anomalously high flow rate of 680 Lpm (179.5 gpm) reported for September 1989 (**Table A-5, Appendix A**).

3.5.3 Miller Creek Loading Analysis

A loading analysis was performed to assess the relative contribution of metals from the discharging adits present in the Miller Creek watershed. As discussed in Section 3.2, differences in collection times for available data required multiple comparisons to be made in order to gain an understanding of the effect of loading from the adits. The loading analysis for Miller Creek examines adit discharge contributions based on the following four data sets:

1. Mean loads calculated for all available sampling events.
2. Mean loads calculated for available high flow sampling events (i.e., those occurring in June and July).
3. Most recent date(s) on which high flow samples were collected at stations SW-2 and SW-5 (July 2008) and at the adit discharge sites (July 2003).
4. Most recent date(s) on which low flow samples were collected at stations SW-2, SW-5 and the adit discharge sites (September 2008).

All the adits of interest described in this evaluation are located upstream of Station SW-2 (Figure 3). When averaged across all available sampling events or all available high flow events, load data show that adit contributions account for a minor amount of the total metal load to Miller Creek at station SW-2 (**Table 3-8**). The average load in any adit discharge is most often less than 0.1% of the load in Miller Creek at this station and in no case is greater than 1%. As the metal load at SW-2 is less than the load at the downstream monitoring station SW-5 when using the average of all available data or all high flow data, sources of metal loading other than the identified adits contributes to metal loading in Miller Creek. As discussed by Cleasby and Nimick (2000) and Maxim (2003a), a possible source of metal

loading is diffuse drainage across calcium poor rock and/or drainage originating in the metal-enriched soils derived from mineralization along the southwest flank of the Henderson Mountain stock.

Comparison of the most recent comparable high flow sampling events (i.e., mid-July 2008 for SW-2 and SW-5; mid-July 2003 for adit discharges) shows that relative contributions from adit discharges were higher compared to average contributions calculated for high flow events measured during the entire period of record (**Table 3-8;** Figure 37). In some cases the most recent high and low flow metal loads calculated for adit discharges were greater than Miller Creek in-stream loads.

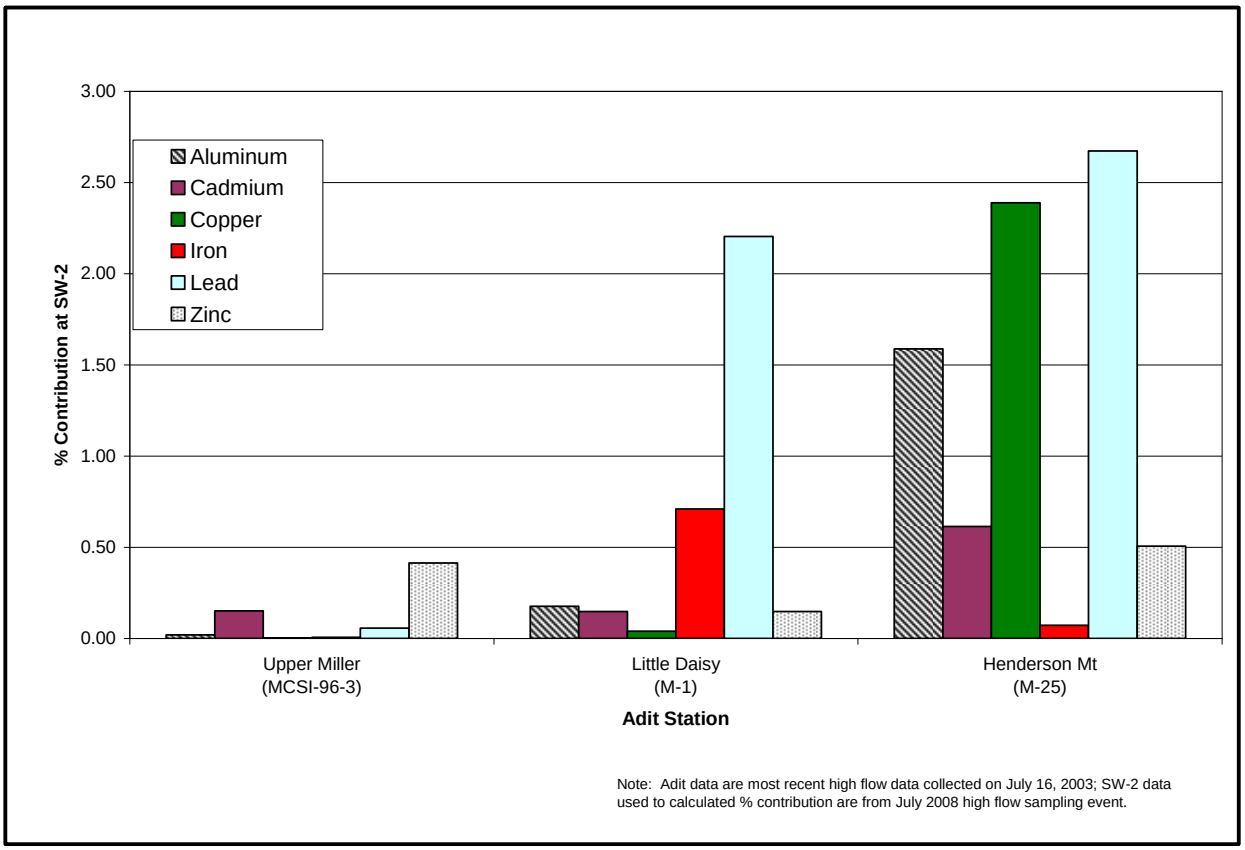


Figure 37. Percent Contribution of Metal Loads at Station SW-2

The most recent sampling events from which loads in Miller Creek can be compared with the Little Daisy adit discharge load occurred during low flow conditions in the fall (i.e., SW-2, and the Little Daisy Adit in September 2008). The other two adits (Henderson Mountain and Upper Miller Creek) have only been sampled during high flow conditions. This comparison assumes that low flow discharges from the Little Daisy adit remains relatively constant from year to year. During these recent low flow sampling events, loads in Miller Creek at SW-2 were one to two orders of magnitude lower compared to mean loads calculated for other periods due to lower concentrations and reduced flows in 2008. While the adit discharge loads were lower, the relative contribution to loading from these two discharges was much greater in September 2008 compared to the high flow events. Loading calculations indicate that the Little Daisy Adit (station M-1) contributed 1,184% of iron, 1,950% of manganese, and 78% of zinc loads measured at SW-2 in September 2008. As the Little Daisy Adit discharges to talus below the adit with no direct connection to Miller Creek, this comparison of recent low flow data is only hypothetical.

TABLE 3-8
PERCENT CONTRIBUTION OF ADIT METALS LOADING TO MILLER CREEK

Station ID	Aluminum		Cadmium		Copper		Iron		Lead		Manganese		Zinc	
	Load kg/mon	% At SW-2	Load kg/mon	% at SW-2	Load kg/mon	% at SW-2	Load kg/mon	% at SW-2	Load kg/mon	% at SW-2	Load kg/mon	% at SW-2	Load kg/mon	% at SW-2
Average of All Data														
MCSI-96-3	0.168	0.054	0.0002	0.3	0.0006	0.0017	0.290	0.045	0.0069	0.16	0.057	0.23	0.04	0.3
M-1	0.06	0.02	0.0002	0.4	0.008	0.03	6.5	1.0	0.02	0.5	1.2	5.0	0.08	0.6
M-25	0.67	0.2	0.0007	1.1	0.8	2.4	0.08	0.01	0.02	0.5	0.04	0.2	0.08	0.6
SW-2	308	100	0.06	100	33	100	647	100	4.4	100	24	100	14	100
SW-5	715		0.19		66		1496		6.9		55		22	
Average of All High Flow Data														
MCSI-96-3	0.008	0.001	0.0001	0.09	0.00017	0.0002	0.007	0.0005	0.0005	0.005	0.003	0.006	0.04	0.1
M-1	0.03	0.005	0.00003	0.02	0.004	0.01	0.5	0.04	0.007	0.1	0.1	0.2	0.01	0.04
M-25	0.7	0.1	0.0005	0.4	0.6	0.9	0.08	0.01	0.02	0.2	0.04	0.1	0.04	0.2
SW-2	640	100	0.14	100	68	100	1345	100	10.3	100	57	100	28.0	100
SW-5	1107		0.3		102		2318		12.3		99		37.5	
Recent High Flow Sampling Event*														
MCSI-96-3	0.008	0.019	0.0001	0.2	0.0002	0.0006	0.007	0.006	0.0005	0.056	0.003	0.13	0.04	0.4
M-1	0.08	0.18	0.0001	0.1	0.01	0.04	0.75	0.7	0.02	2.2	0.5	20.6	0.01	0.1
M-25	0.7	1.6	0.0005	0.6	0.6	2.4	0.08	0.07	0.02	2.7	0.04	1.4	0.04	0.5
SW-2	44	100	0.09	100	26.3	100	105	100	0.9	100	2.6	100	8.8	100
SW-5	16		0.03		6.3		63		0.3		3.1		6.3	
Most Recent Low Flow Sampling Event**														
M-1	0.04	2.6	0.0004	3	0.0007	0.2	19.9	1184	0.0015	2.6	3.3	1950	0.22	78
SW-2	1.4	100	0.017	100	0.3	100	1.7	100	0.06	100	0.2	100	0.3	100

Notes: * Loads for recent high flow sampling event calculated using July 2008 data for SW-2 and SW-5; July 16, 2003 data used for adit discharges.
** Loads for most recent low flow sampling event calculated using September 2008 data.
kg/mon = kilograms per month

In contrast to mean data for the entire period of record showing greater metal loads at SW-5 (**Table 3-8**), loads at SW-2 were much higher (139 to 417%) than those at SW-5 except for manganese (84%) during the most recent high flow sampling event. As the stream reach between SW-2 and SW-5 is a loosing reach under all but very high flow conditions, interpretation of loading data can be complicated. It is important to note that, despite high relative contributions from the Little Daisy adit discharges shown in **Table 3-7** for the most recent sampling event, only copper exceeded aquatic standards at SW-2 or SW-5 in 2008.

3.6 LOADING ANALYSIS SUMMARY

Five adit discharges have been identified in the District (Sheep Mountain #1 Adit and the Upper Miller Creek Dump are on non-District property) for which one or more COC is present at a concentration that exceeds the Circular DEQ-7 aquatic standards and therefore may need either water treatment or some physical engineering means of source control to meet standards. In addition, three drains that convey water from upgradient of the McLaren Pit cap are also being evaluated for potential mitigation. Water quality data are summarized for these discharges in **Table 3-9** (median values); constituents that exceed the standards are in bold font.

There is significant variability in flow and water quality associated with the discharges listed in **Table 3-9** as illustrated in Figure 38 and 40. However, similarities in water quality between the sources allow for grouping the discharges based on similar water chemistries and/or other characteristics such as metals concentrations, flow rates, or COC mass loadings. To facilitate further evaluation of the discharges, five groups are identified in **Table 3-9** and shown in Figure 38.

Loading calculations show that contributions of metals from the McLaren Adit to Daisy Creek are minor except for iron (14.9%) and manganese (3.5%) at surface water monitoring station DC-2. These data indicate that there are other sources of metal loading contributing to Daisy Creek. One such source is the McLaren Pit drains (DCSW-101, -102, and - 103). On average, the combined load from these drains contributes as much as 129% of the iron load and between 22 and 46% of the aluminum, cadmium, copper, manganese, and zinc loads at DC-2 when the subsurface drains are flowing. However, recently acquired data shows that the flow from the drains ceases between mid-October and mid-November and the drains remain dry through late May. During this time (about 6 months) loading from the drains to Daisy creek does not occur.

Comparison of water quality before and after initiation of Glengarry Adit closure and load contributions from adit drainage discharging into Fisher Creek indicate that water quality is improving in response to the grout/plugging project. Flow that discharged from the Glengarry Adit in September 2006 (2.0 Lpm; 0.5 gpm) still contributed 1% of the iron load measured at station SW-3, but all other metal loads were less than 0.5%. In September 2008, discharge from the former Glengarry Adit portal was low enough that reliable estimation of flow rate was not possible. These data suggest that the closure project will be successful in reducing loads from the former adit.

Following grouting of boreholes in the Gold Dust Adit, metal loads discharging from the adit in after September 2006 were less than 0.5% as measured at station SW-4 except for aluminum, iron, lead, and manganese (0.79%, 12.3%, 2.1%, and 3.9%, respectively). Relative contributions of metal loads from other adits discharging into Fisher Creek are minor.

Comparison of metal loads at adit discharge and Miller Creek monitoring stations indicates that the metal loading from adits is generally responsible for only very minor amounts of the total metal load at the nearest downstream monitoring station, SW-2. Despite metal contributions from adit discharges, only copper exceeded an aquatic standard at stations SW-2 or SW-5 in 2006.

TABLE 3-9
WATER QUALITY (MEDIAN VALUES), CONTAMINANTS OF CONCERN, AND WATER TREATMENT GOALS

Site Name by Adit Discharge Source Groupings	Flow (gpm)[1]	pH (s.u.)[2]	Acidity (mg/L as CaCO3)[3]	Concentration (milligrams per liter)									
				DO	SO_4^{2-}	HCO_3^-	Al	Cd	Cu	Fe	Pb	Mn	Zn
Group 1													
McLaren Pit Cap Sub-surface Drains	23	**2.6**	588	6.6	828	<1	**33.7**	**0.0170**	**18.5**	**163**	**0.003**	**4.9**	**2.82**
Group 2													
Little Daisy Adit	8	7.0	<2	5	**332**	210	**0.1**	**0.0004**	**0.0160**	**4.0**	**0.02**	**1.51**	**0.11**
Group 3													
Gold Dust Adit [4]	4	6.9	<2	10.46	**289**	155	0.05	<0.0001	0.002	0.42	0.001	**0.09**	0.02
Group 4													
Henderson Mt Adit	5	5.9	5	6	20	4	**0.20**	0.0010	**0.46**	<0.05	**0.011**	<0.02	**0.10**
Group 5													
Henderson Mountain Dump 7	1	6.7	<2	7	34	56	**0.105**	**0.0006**	**0.018**	**1.205**	**0.003**	**0.091**	0.045
Sheep Mountain #1 (NDP)	0.5	6.9	<2	8	21	16	**0.110**	**0.0002**	**0.013**	0.43	**0.009**	0.026	0.050
Upper Miller Creek Dump (NDP)	1	6.5	<2		30	59	**9.5**	**0.0046**	**0.030**	**16.4**	**0.360**	**0.880**	**0.960**
DEQ-7 Chronic Aquatic Life Standard (Calculated for Hardness = 50 mg/l)							**0.087**[5]	**0.00016**	**0.005**	**1**	**0.001**	**0.05**[6]	**0.07**
DEQ-7 Chronic Aquatic Life Standard (Calculated for Hardness = 100 mg/l)							**0.087**	**0.00027**	**0.009**	**1**	**0.003**	**0.05**	**0.12**

Notes
1 gpm = gallons per minute
2 s.u. = standard units
3 mg/L - milligrams per liter
4 Gold Dust data from September 2006 to September 2008 – post-borehole plugging.
5 Aluminum standard is based on dissolved concentrations and is applicable to water with pH between 6.6 to 9.0.
6 Manganese standard is a secondary MCL based on aesthetic qualities.
Bold indicates value exceeding DEQ-7 chronic aquatic life standards at hardness adjusted 50 mg/L; actual hardness of receiving water varies.

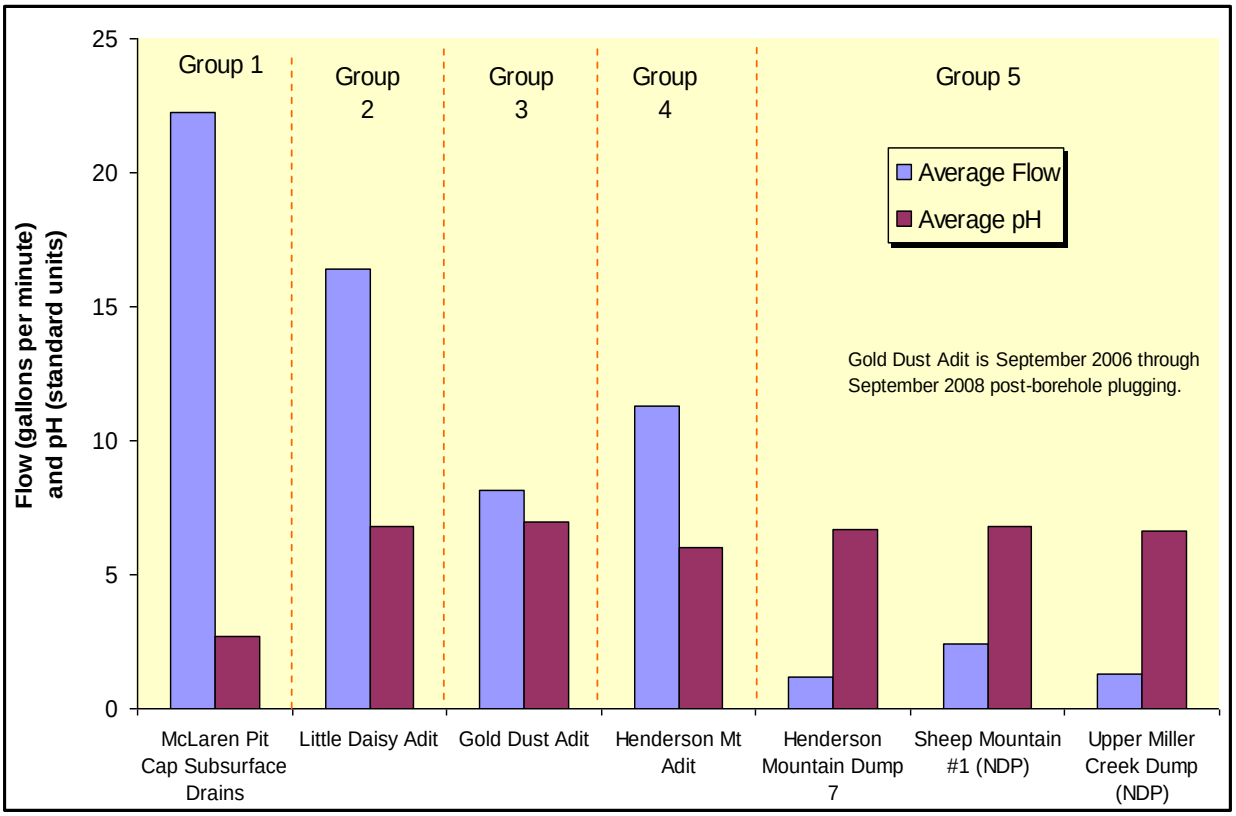


Figure 38. Comparison of average flow and pH from New World District adits being evaluated for water treatment

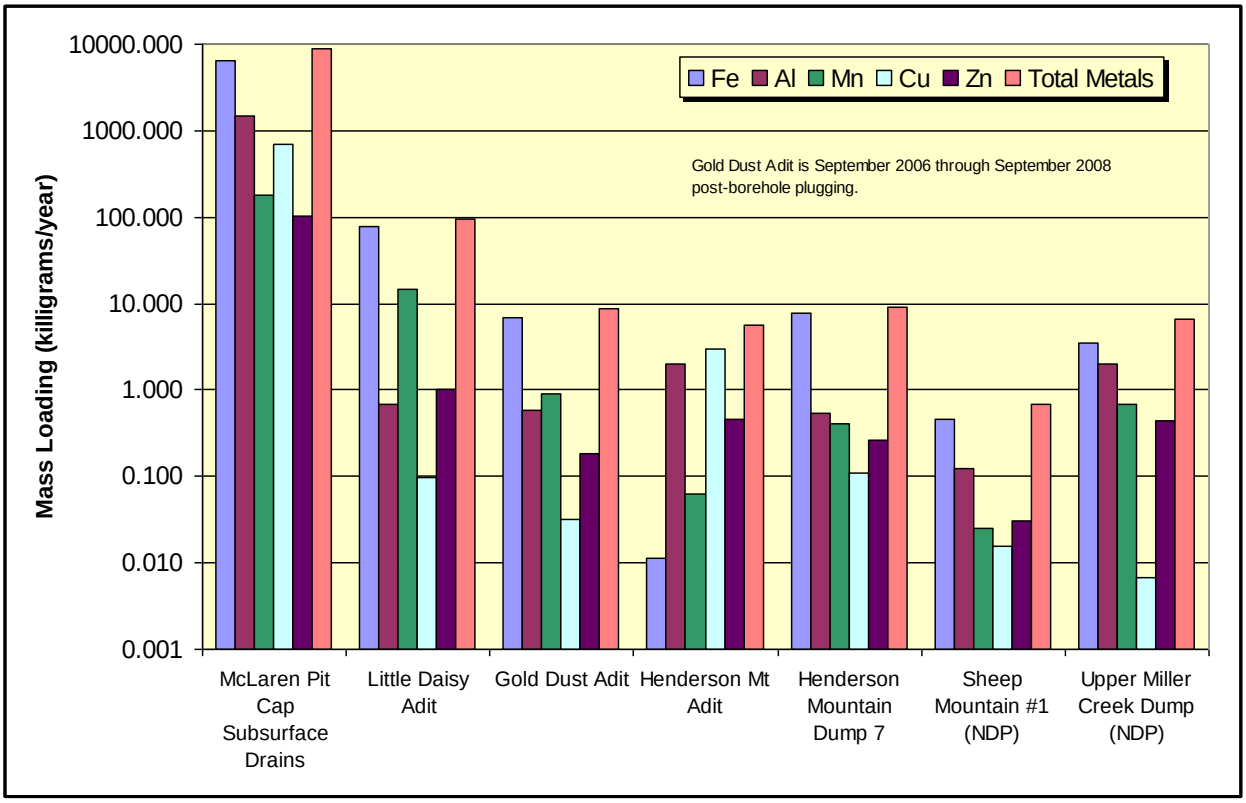


Figure 39. Comparison of annual metals loading from New World adits

Recent analyses performed on samples collected during low flow conditions in fall 2008 indicate that the M-1 (Little Daisy) adit discharges contribute a considerable amount of the total iron, manganese, and zinc loads measured at SW-2. Despite the high relative contribution from this adit, concentrations of cadmium, iron, manganese, and zinc measured at SW-2 were well below applicable Circular DEQ-7 surface water standards.

3.7 GROUNDWATER

Groundwater chemistry and flow characteristics vary widely in the District, predominantly influenced by geology. A summary of the extensive information present in project documents is presented here. Additional detail on groundwater flow and quality is presented in numerous reports available in the project library, a few of which are referenced in this report (Maxim, 2006b; 2005b; 2004a; 2003b; 2001b; URS, 1998; 1997).

Groundwater occurs within two general hydrostratigraphic units in the area: unconsolidated sediments and consolidated bedrock. Unconsolidated sediments are thin relative to bedrock units and are primarily composed of colluvium, alluvium, and glacial deposits. Groundwater flow through unconsolidated material is diffuse, and the rate and direction of flow is usually more predictable than groundwater flow through bedrock units. The permeability and storage capacity of unconsolidated sediments are relatively very high compared to bedrock units.

Groundwater flow in bedrock is primarily controlled by secondary permeability developed along fractures and joints. As a result, primary porosity and permeability within bedrock in the area is very

low (with a few exceptions) as evidenced by low sustained base flow from adits and springs, and low yields to wells and borings drilled in the District. Throughout the area, groundwater typically flows from mountain ridges to valley bottoms, but flow can be locally controlled by fracture orientation, geologic structures (faults), and mine workings.

Water levels fluctuate widely in response to snowmelt and precipitation, with the greatest changes in water levels occurring in late June/early July in the headwaters areas of the District. Water level changes are greatest in bedrock, in some cases as much as 20 meters (65 feet) or more over the hydrograph year (Maxim, 2000). These water level changes may lag behind snowmelt and maximum surface water flows by as little as two to three weeks. Water levels typically fall as the summer progresses into autumn, but levels in shallow aquifers can rise in response to heavy rain or snow events.

Springs and seeps occur where groundwater intersects the topographic surface, and these features are often localized near the surface expression of fractures and/or geologic structures. As with surface flows, discharge rates from seeps and springs are variable and exhibit large seasonal variations.

A discussion of groundwater characteristics is presented in the following sections. The discussion is separated into the major geographic areas of the District, and includes a discussion of the potential impacts that adit discharges may have on groundwater quality.

3.7.1 McLaren Pit Area

Groundwater information for the McLaren Pit area has been assembled from data collected since 1989 when the first monitoring wells were installed by CBMI. The EPA conducted very detailed studies in the pit by drilling a number of waste rock, bedrock, and dye tracer injection wells in 1996 and 1997. The USDA-FS conducted further studies in the area below the pit between 2000 and 2009 with the drilling and sampling of additional monitoring wells.

Groundwater levels fluctuate widely in the McLaren Pit area as described in the previous section. Highest water levels are associated with the annual spring snowmelt period, with water levels in the waste rock beginning to rise in mid to late May as snowmelt percolates into the subsurface. Water levels in the waste rock peaked in early July in 1997 (URS, 1998) and in early to mid-June in 2005 and 2006 (Maxim, 2006b). Water levels in bedrock wells trail those in the shallower waste rock wells by a week or two, but all wells reach peak water level elevation in June or July and then slowly decline until the following May (URS, 1998).

Groundwater flow in shallow bedrock units underlying the McLaren Pit is generally south to southeast (URS, 1998), and primarily moves through faults and fractures, as mentioned above. While this flow is complicated by fracture orientation, fracture density, and the geologic unit where fractures are present, it is evident from potentiometric surface elevations that groundwater in shallow bedrock beneath the pit has a vertical component of flow both downward and upward. Water level data collected from October 1996 through October 1997 show that vertical gradients are downward when water levels in the shallow waste rock are lowest to dry (October through May) and switch from downward to upward during the peak snowmelt period in late June and early July. This phenomenon is illustrated by higher water elevations measured in a shallow well completed in the Meagher Limestone (EPA-10) and a nearby companion well completed in waste rock in the pit (EPA-4) (URS, 1998). Other shallow bedrock wells in the McLaren Pit that are completed in the Meagher Limestone and Wolsey Shale exhibited water levels that rise above the elevation of the base of the pit.

Due to the complex geology, it is difficult to determine the degree of upward or downward movement of groundwater pit and therefore there is some uncertainty on whether groundwater in the waste rock in the pit is largely influenced by groundwater flow from bedrock. The EPA attempted to answer this question using groundwater tracing studies. Two tracing studies were completed by URS in 1997 and 1998 in the pit area, which involved injecting several different fluorescent dyes in tracer wells and then sampling nearby monitoring wells to determine the tracer flow path. Dye was injected during low water levels in August 1997. Two different dyes were used, and dye was injected into two wells located up-gradient of the pit and completed in the Fisher Mountain Intrusive (Tracer 1 and 2). Dye from Tracer 1 was detected in a well located in Miller Creek and another well located in Fisher Creek, but this dye was not detected in any of the wells completed in the McLaren Pit. About six months following dye injection, dye injected in Tracer 2 was first detected in McLaren Pit wells completed in the Meagher Limestone and Wolsey Shale, and in a well in Miller Creek.

In May 1998, when water levels were considerably higher than during dye injection the previous year, two dyes were injected in Tracer 2 and monitoring well EPA-5, which is also completed in the Fisher Mountain Intrusive. Dye from these wells was detected shortly after injection in several of the bedrock wells completed in rock formations beneath the pit, in one of the waste rock wells in the pit, in several surface water tributaries draining the pit, in several locations in Fisher Creek, and in Miller Creek. The conclusion reached following the results of the two dye investigations completed in the McLaren Pit (URS, 1998) was that there was clear evidence to support a model where flow is beneath the McLaren Pit in bedrock and probably not via a pathway through the waste rock. This conclusion was based on the limited permeability of the waste rock and the higher permeability of the fractured bedrock system.

While the two dye studies focused on the interaction of groundwater in bedrock beneath the pit, the USDA-FS focused its investigation on the flow and quality of water in shallow colluvium and shallow bedrock in the area down-gradient of the pit to the headwaters of Daisy Creek. Groundwater flow in the shallow groundwater system in this area is generally perpendicular to slope and toward Daisy Creek. Vertical hydraulic gradients are both downward and upward depending on where along the slope the wells are placed, and groundwater flow is likely influenced to some extent by the Crown Butte Fault (Figure 4). URS (1998) noted the importance of the Crown Butte Fault in the transmission of dye into the Miller Creek drainage.

Groundwater quality in the McLaren Pit area is distinctly different depending on location relative to the pit, the Crown Butte Fault, and the geologic formation associated with the water. Background water quality varies considerably depending on the geologic formation, as shown in **Table 3-10,** where metals concentrations in well DCGW-100, which is completed in the Meagher Limestone at a depth of 235 feet up-gradient of the McLaren Pit, are relatively low compared to metals concentrations in well Tracer 2, which is completed in the Fisher Mountain Intrusive up-gradient of the McLaren Pit at a depth of 135 feet. Water in Tracer 2 is acidic and contains substantially higher concentrations of aluminum, cadmium, copper, and iron concentrations than the more neutral water intercepted by well DCGW-100.

TABLE 3-10
CONCENTRATIONS OF SELECTED PARAMETERS IN GROUNDWATER IN MCLAREN PIT AREA

Well Designation	pH (standard units)	Dissolved Metals (milligrams per liter) (1)						
		Al	Cd	Cu	Fe	Mn	Pb	Zn
Colluvial Wells								
DCGW-111S	4.41	5.4	0.02	8.5	1.7	6.4	0.015	3.5
DCGW-133	2.65	16.6	0.0068	6.9	7.8	2.1	0.0063	0.83
DCGW-101S	3.38	1.5	0.00053	0.11	0.073	0.15	0.0017	0.064
DCGW-102S(2)	7.5	0.22	0.0002	0.005	0.81	0.4	0.01	<0.01
Bedrock Wells								
DCGW-101D(3)	6.22	0.014	0.00007	0.0005	<0.025	0.4	0.00007	0.0053
DCGW-102D(2)	7.7	0.1	<0.0001	<0.001	0.1	0.3	<0.001	<0.01
MW-3(3)	7.63	0.011	<0.00005	<0.00025	<0.025	0.34	<0.00005	0.0032
Background Wells								
Tracer 2(3)	3.56	75.2	0.0011	4	92.4	0.5	0.00034	0.17
DCGW-100(3)	6.72	0.013	<0.00005	0.00072	2.4	1.3	<0.00005	0.013
Standard(4)	--	--	0.005	1.3	0.3	0.05	0.015	2.1

Notes: (1) Data from September 2010 sampling event unless otherwise noted (Tetra Tech, 2011)
(2) Data from July 2003 sampling event (Maxim, 2004b)
(3) Metals data from July 2009 sampling event (Tetra Tech 2010b)
(4) Montana DEQ human health standard, Circular DEQ-7 (MDEQ, 2010); shading indicates exceedance of standard
-- Indicates not measured or not applicable

Downhill and down-gradient of the former McLaren Pit, a zone of shallow groundwater exhibiting relatively low pH and high conductivity, sulfate, and metals concentrations extends toward the Crown Butte fault (wells DCGW-111S and -133; **Figures 3 and 4; Table 3-10**)(Maxim, 2006b; 2004a; 2005b; Tetra Tech, 2009b; 2010b; 2011). This zone then parallels the fault and continues to Daisy Creek. The McLaren Pit is the source of acidic and metals laden groundwater in this zone that is caused by oxidation of pyrite and other sulfide minerals (Maxim, 2001b). Further downstream of where the fault intersects Daisy Creek, pH rises in groundwater as more carbonate rocks become dominant (wells DCGW-102S and MW-3; Figure 3), and metal concentrations fall below human health standards, except for iron and manganese concentrations (**Table 3-10**). Iron and manganese concentrations are ubiquitous in the District, as reflected in concentrations of these parameters measured in background wells (**Table 3-10**).

Work completed in 2002 and 2003 led to the conclusion that significant contaminant loading to Daisy Creek comes from contaminated surface water tributaries originating in the McLaren Pit area, and discrete zones of preferential flow of contaminated groundwater through shallow colluvial material. Tributary DCT-8 and a zone of more transmissive colluvium and fractured shallow bedrock associated with the Crown Butte Fault appear to be the primary conduits controlling transport of metals from the McLaren Pit to groundwater and ultimately to the manganese bog and Daisy Creek. Impacted shallow groundwater flowing down-gradient in colluvium is believed to be redirected along the Crown Butte Fault, which seems to serve as a preferential pathway transporting contaminants to Daisy Creek. Tributary DCT-8 drains impacted water from the capped McLaren Pit area, including the McLaren subsurface drains (DCSW-101, -102, and -103).

3.7.2 Fisher Creek

Comparison of groundwater chemistry for wells completed in various bedrock units in Fisher Creek (**Table 3-11**) suggest several types of water quality depending on the host aquifer. Figure 3 shows the locations of these wells. 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**).

Groundwater quality and water level data collected in the Como Basin indicate groundwater flow is controlled primarily by near vertical fractures, joints, and faults (Maxim, 2002a). Interconnectedness between fractures and joints appears moderate to minimal. Dissolved metals concentrations in groundwater appear to be highest in Como Basin wells during July, when groundwater levels are at their seasonal peak. However, in the Como Basin area, water quality trends with respect to well depth and formation completion are not evident (Maxim, 2002a). The poorest water quality is intercepted by wells located near the Glengarry adit underground workings (wells MW-1, EPA-11, and EPA-12). Except for iron and manganese, wells in Fisher Creek that are downstream of the Glengarry Mill-Site (MW-9A and -9B) and the Gold Dust (MW-10A and -10B), groundwater quality is in compliance with groundwater standards. Groundwater in lower Fisher Creek (MW-11) meets human health standards.

3.7.3 Miller Creek

There are several groups of wells in the Miller Creek drainage. Two groups of wells were installed to determine hydraulic characteristics of specific formations; MW-5P, a pumping well, and MW-5A, MW-5B, and MW-5C (observation wells) are located along and near the Crown Butte Fault zone in upper Miller Creek (Figure 3); MW-11A and -11P are located along the Daisy Pass Road near the Little Daisy Mine. The last well, MW-6, is located on non-District Property on the southwest flank of Henderson Mountain near the Alice E Mine. These wells have been monitored intermittently since 1989.

There is no water quality data for well MW-11P, as this well was only used for pump testing. For the MW-5 nest of wells in upper Miller Creek, groundwater is nearly neutral in pH and there are no exceedances of MDEQ's Circular DEQ-7 human health standards (**Table 3-12**). These wells are the nearest wells down gradient of the Little Daisy Adit. Groundwater in well MW-6, located down-gradient of the Alice E Mine, is acidic, and human health standards are exceeded for iron, manganese, and lead. There is no adit discharge from the Alice E. Mine, but down gradient of the mine and well MW-6 is the Alice E. Mill-Site seep. (This seep is a non-District Property). Water from the seep does not exceed surface water standards (see **Table 3-2**).

TABLE 3-11
CONCENTRATIONS OF SELECTED PARAMETERS IN GROUNDWATER IN FISHER CREEK

Well Designation	pH[1] (standard units)	Dissolved Metals (milligrams per liter) [1]						
		Al	Cd	Cu	Fe	Mn	Pb	Zn
Como Basin and Upper Fisher Creek								
EPA-11[3]	5.37	0.33	0.00094	<0.00025	161	6.6	0.0097	0.44
Tracer-4[2, 3]	4.42	1.79	0.0006	0.31	99.3	9.06	0.019	1.7
Tracer-5[4]	3.4	36.6	0.0026	0.62	76.6	1.36	0.006	0.35
MW-1[4, 5]	5.36	0.15	0.00012	0.001	78.8	4.6	0.00086	0.13
EPA-12[6]	6.04	0.014	<0.00005	<0.00025	40.3	2.1	<0.00005	0.068
Glengarry Mill Site Area Wells								
MW-9A[4, 7]	4.34	0.027	0.0001	0.0001	0.063	0.0051	<0.00005	0.013
MW-9B[4, 8]	5.15	0.014	<0.00005	0.0012	1	0.093	<0.00005	0.018
Gold Dust Area Wells								
SB-16[4, 8]	7.26	0.012	<0.00005	<0.00025	0.45	0.21	<0.00005	0.003
MW-10A[4, 7]	4.64	0.034	0.00011	0.023	0.025	0.094	<0.00005	0.0094
MW-10B[4, 8]	6.75	0.034	0.000078	0.023	<0.025	0.091	<0.00005	0.0093
Lower Fisher Creek								
MW-11[4, 8]	4.67	0.042	<0.00005	0.0036	0.054	0.0016	0.00093	0.0043
Background Wells								
Tracer-6[6, 9]	6.2	0.11	0.0004	0.07	32.4	4.16	<0.001	0.13
MW-8[2, 10]	6.69	<0.05	<0.0001	0.001	0.02	<0.003	<0.001	<0.01
Standard[11]	--	--	0.005	1.3	0.3	0.05	0.015	2.1

Notes:
(1) Data from Sept 2010 sampling event unless noted otherwise
(2) Data from July 2003 (most recent data for this station)
(3) Well completed in Fisher Mountain Intrusive
(4) Data from July 2009 (most recent data for this station)
(5) Well completed in Wolsey Shale
(6) Well completed in Scotch Bonnet Diorite
(7) Well completed in alluvium
(8) Well completed in Precambrian granite
(9) Data from July 2004 (most recent data for this station)
(10) Well completed in Lulu Pass Rhyodacite
(11) MT DEQ-7 (MDEQ, 2010; shaded cells exceed standard
-- Indicates not measured or not applicable

TABLE 3-12
CONCENTRATIONS OF SELECTED PARAMETERS IN GROUNDWATER IN MILLER CREEK

Well Designation	pH (standard units)	Dissolved Metals (milligrams per liter) [1]						
		Al	Cd	Cu	Fe	Mn	Pb	Zn
MW-5A	6.59	<0.05	<0.0001	<0.001	<0.01	<0.003	0.001	0.03
MW-5P	6.22	<0.05	<0.0001	<0.001	<0.01	<0.003	<0.001	0.02
MW-6	4.2	5.49	0.0007	0.1	18.9	0.37	0.072	0.15
Standard[2]	--	--	0.005	1.3	0.3	0.05	0.015	2.1

Notes:
(1) Data from July 2005 sampling event for MW-5A and MW-5P. and July 2004 for MW-6 (Maxim, 2005c)
(2) Montana DEQ human health standard, Circular DEQ-7 (MDEQ, 2010); shading indicates exceedance of standard
-- indicates not applicable

Spring data is often used as an indicator of groundwater quality and flow. More than 60 springs have been located, characterized, and sparingly sampled in the Miller Creek drainage since 1989. Analysis of spring data by Hydrometrics (1990) showed Miller Creek water belonged to one type of water (Type III), with water chemistry dominated by calcium, bicarbonate, and sulfate ions. This groundwater type contained low metal concentrations with a near neutral pH. Durst (1999) performed another study of springs in Miller Creek. Springs were divided into groups based on association with geologic formations, lineaments (e.g., faults), and those of unknown origin. Springs associated with geologic formations tended to have higher SC values than the other groups of springs. Four springs included in his analysis were from adits; thirteen springs produced iron staining on substrate below the spring discharge.

3.8 CONCEPTUAL MODEL

The majority of underground mines in the District were developed using adit entries. Adits were driven into mineralized and non-mineralized bedrock, including massive sulfide deposits. As an adit advances into mineralized rock, oxygen in the atmosphere reacts with certain minerals in the surrounding rock, accelerating acid-generating, oxidation reactions in the mine workings. These reactions produce acid, and, due to the resulting low pH associated with acid production, cause metals such as aluminum, copper, and iron to become soluble. As rain and snowmelt enter the mine workings through fractures, faults, and abandoned exploration borings, water becomes acidified and transports dissolved metals from the adit to surface water and groundwater.

Many adit discharges are greatly influenced by annual recharge from the melting snowpack. This is reflected by large variations in flow during the spring, and the tendency for these flows to diminish through the summer, to the point that several adits dry up in late August and September.

3.9 ADIT DISCHARGES REQUIRING RESPONSE ACTION EVALUATION

The characterization of the nature and extent of mining impacts related to adit discharges in the District indicates that some of the discharges present in the District contribute significant loads to tributary streams, while others have very minor impacts. Of the discharges that exceed aquatic water quality criteria, two are located on non-District property. Regardless of the relative impacts of the Sheep Mountain No. 1 and Upper Miller Creek Dump discharges, no work can be conducted at these sites until a Certificate of Completion is received from the U.S. Government for District Property sites. Therefore, these two sites will be dropped from further evaluation in this EE/CA. **Table 3-13** lists the five discharges that will be carried through the screening and evaluation of potential response action alternatives.

TABLE 3-13
DISCHARGE SITES REQUIRING RESPONSE ACTION EVALUATION

Site Name	Site No.	AIMSS Rank*	Discharge Flow Range (gpm)	Site Status**
Little Daisy Adit and Dump	M-1	20	0.5-220	Collapsed/Dump Reclaimed with Infiltration Gallery 2005
Gold Dust Adit	F-28	24	1.3-250	Closed/Dump Reclaimed 2005
Henderson Mountain Dump 7	AE-17	51	0.0-5	Collapsed/Dump Reclaimed with Infiltration Gallery 2004
Henderson Mountain Adit	M-25	No rank	1.8-25	Collapsed
McLaren Pit Subsurface Drains	DCSW-101	No rank	6.8-32	Three drains under cap

Notes: * AIMSS - Abandoned and Inactive Mines Scoring System
** Reclaimed status indicates previous response action conducted at the site to remove waste rock or close the opening
gpm gallons per minute

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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 discharges in the District that were described in previous sections of this EE/CA. Risks are evaluated using site-specific chemical concentration data to provide an estimate of how and to what extent people, flora, and fauna might be exposed to the contaminants of concern using reasonable exposure scenarios. This streamlined risk evaluation examines risks under existing site conditions, assuming no cleanup activities are performed at the site. This streamlined risk evaluation was completed in accordance with EPA guidance for non-time-critical removal actions (EPA. 1993).

4.1 STREAMLINED HUMAN HEALTH RISK EVALUATION

The streamlined human health risk evaluation involves identifying contaminants of concern (COCs), determining the nature of exposures to COCs, and determining the toxicity of COCs. The evaluation is accomplished by evaluating available site data, identifying applicable human populations and exposure routes, reviewing toxicity data, and characterizing overall risk by comparing COC concentrations in water to previously derived risk-based cleanup guidelines. Human health risk-based cleanup guidelines were developed for abandoned mine sites by Montana's Mine Waste Cleanup Bureau (MWCB) using site data that was combined from over 200 abandoned mine sites in Montana (Tetra Tech, 1996).

4.1.1 Contaminants of Concern

COCs are contaminants that pose significant potential risks to human health. Standard EPA criteria that must be collectively satisfied to establish a COC are the following: (1) the contaminant 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. The data used to determine if the discharges meet these criteria is presented in **Appendix A**.

For all the sites, trace metals that satisfy the first criteria include aluminum, arsenic, cadmium, chromium, copper, iron, lead, mercury, manganese, nickel, silver, and zinc. Collectively, except for arsenic, chromium, mercury, nickel, and silver, these metals have been detected in more than 20% of the samples analyzed. The second criterion is more difficult to apply, since background levels in surface water range widely across the site, primarily as a function of surface water flow conditions and geology. Background conditions may not be as meaningful, then, in determining whether specific trace metals are associated with background conditions or historic mining disturbances.

Therefore, for the purposes of the human health risk assessment, those metals detected in more than 20% of the samples collected, cadmium, copper, lead, manganese, and zinc, are considered potential COCs. Aluminum in surface water is not considered a risk to human health, as there are no human health standards for aluminum in MDEQ's list of numeric water quality standards (MDEQ Circular DEQ-7, 2004). Iron is generally considered nontoxic as well, and human health guidelines for iron are based on aesthetic properties such as taste, odor, and staining. Therefore, iron is not considered a COC for the adit discharge sites, as these sites are not used as a source of drinking water.

4.1.2 Exposure Assessment

An exposure assessment identifies potentially exposed human populations, exposure pathways, and typical exposure durations. Analytical results for adit discharge water samples are then used to estimate COC concentrations at exposure points and the potential intake of contaminants.

There is no residential use of District Property in or around any of the discharges considered in this EE/CA. Current human exposure to site-related contaminants in adit discharge water is via seasonal recreational activities that occur during the snow-free period in the District, which generally falls between the months of June and October. From late fall through the spring, access to the discharge sites is exclusively over snow, and during this period the adit discharge sites are covered with snow and do not pose a risk to humans.

Exposure pathways are limited to direct contact (dermal exposure) with discharge water and ingestion of water. Instances of direct contact might occur from wading through or in discharges, washing in discharge water, or using discharge water for other recreational pursuits such as gold panning. Ingestion would likely occur from incidental ingestion rather than purposeful drinking of water, since most of the discharges are non-palatable due to unpleasant odor and taste attributes that are mainly associated with iron and manganese staining and coloring. Both of the exposure pathways are likely to be minor, as relatively few people are exposed to the adit discharges during their recreational pursuits and because the majority of people recreating in the District are generally in the area for only a few days to a couple of weeks. Exposures on any one day are believed to be of very short duration, on the order of minutes.

Because there are no site specific data on exposure, the risk evaluation completed by MDEQ for abandoned mine sites (Tetra Tech, 1996) is used as a benchmark for human exposure to contaminated water. The MDEQ 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. For a risk evaluation that would be pertinent to the adit discharge sites, only the exposure scenario for the gold panner/rock-hounds would be similar to the potential exposure of humans to COCs in the District.

Exposure pathways for Gold panners/rock-hounds in the Tetra Tech analysis included dermal exposure to adit discharge water and consumption of adit discharge water. Exposure to contaminants involved an estimation of contaminant intake, contaminant concentration, contact rate with water, exposure frequency, exposure duration, body weight, and average time for pathway-specific exposures. For the water ingestion rate, the gold panner/rock hound was assumed to be more than 18 years of age and would consume 1 liter of water per day for 50 days per year. For dermal exposure, hands and forearms were considered to be the surfaces exposed for an exposure time that lasted 6 hours per day. A body weight of 70 kilograms (154 pounds) was assumed for an adult gold panner/rock hound and 15 kilograms (33 pounds) for a child gold panner. The exposure duration period was 30 years. The exposure point concentrations used in the calculations were the median values measured for each media.

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.

Toxicity is generally broken into two classes, carcinogenic and non-carcinogenic. For carcinogens, specific toxicity values are obtained from cancer slope factors; for non-carcinogens, chronic reference doses are used. For the District adit discharges, the only potential carcinogen of the COCs is cadmium. Cadmium is considered carcinogenic when it is inhaled in sufficient quantities to cause tumors in the trachea and lungs. Since cadmium present in water is not inhaled, it is not considered a carcinogen for this risk evaluation.

Chronic reference doses were determined in the Tetra Tech study for each of the COCs present at the adit discharge sites. These chronic reference doses represent the dose above that which would be expected to adversely affect human health. Chronic reference doses are measured in milligrams per kilogram per day.

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 a gold panner/rock hound for the ingestion and dermal exposure routes (Tetra Tech, 1996). Risks were determined for individual routes of exposure and additive effects. The results of risk characterization provide a basis for decisions about the necessity to mitigate contaminant exposures at the site. For non-carcinogens, a critical chemical dose must be exceeded before a health effect is observed. The likelihood of an adverse health effect is represented by the ratio of a chemical exposure level and the chronic reference dose. This ratio is referred to as a hazard quotient (HQ), with any value greater than one indicating an adverse health effect may occur due to a chemical exposure. Hazard quotient values are summed across exposure pathways and for all chemical exposures to develop Hazard Index (HI) values.

Using the methodology and formulas developed in the Tetra Tech document, hazard indexes were calculated for each of the 8 adit discharges and McLaren Pit subsurface drains considered in this EE/CA. The exposure point concentration used in the calculation was the mean value measured at each site. A summary of the results is presented in **Table 4-1.** Supporting data is presented in **Appendix B,** with pertinent formulas and values used in this risk evaluation referenced from the following pages in the Tetra Tech document: page 34, Figure 4-2, Pathway Specific Formulas Used for Chemical Exposure Calculations; page 48, Table 4-6, Dermal Permeability Constants; Appendix A, page A-82, Estimated Noncarcinogenic HI for Gold Panner/Rock Hound (Adult Only – Ingestion – T/Weighted-Dermal) Exposures to Adit Discharges at Montana Abandoned Mines.

As shown in the table, only one site has a Hazard Index value greater than 1.0, the McLaren Pit subsurface drains. The HI's for the rest of the adit sites are less than one, indicating that these adit discharges do not pose a risk to human health. For the McLaren Pit subsurface drains, 98% of the HI score is due to ingestion of this water. The assumptions used for ingestion (Section 4.1.2) for the gold panner/rock hound include drinking one liter of water per day, 50 days per year, for 30 years. Since such a scenario is highly unlikely, the HI score for the McLaren Pit subsurface drains was recalculated for 0.25 liters of water (incidental ingestion) for 10 days per year for 30 years. The recalculation of the HI using this scenario is 0.20 (**Appendix B**). Because the exposure scenario under the second set of assumptions is also conservative, in that it is highly unlikely that a person would drink the water coming from the drains more than incidentally, water discharging from the McLaren Pit subsurface drains is not considered to present any risk to human health.

Table 4-1
HAZARD INDEX CALCULATIONS FOR ADIT DISCHARGES

Adit Name	Flow (gpm)	pH field (s.u.)	Total Recoverable Mean Concentration (milligrams per liter)					Hazard Quotient [1]		Hazard Index [2]
			Cadmium	Copper	Lead	Manganese	Zinc	Ingestion	Dermal	
McLaren Pit Drains	23.0	2.6	0.0170	18.5	0.003	4.9	2.82	2.7991	0.06152	2.86059
AE-17 Henderson Mt. Dump # 7	1.2	6.7	0.0007	0.02	0.003	0.1	0.06	0.0568	0.00094	0.05777
F-28[4] Gold Dust	7.9	6.9	<0.0001	0.003	0.002	0.11	0.02	0.0559	0.00115	0.05706
M-1 Little Daisy	16.4	6.8	0.0005	0.016	0.03	1.49	0.12	0.6301	0.01149	0.64160
M-25 Henderson Mountain	10.0	6.0	0.0008	0.44	0.024	<0.02 [3]	0.09	0.0646	0.00062	0.06525

Notes:
[1] Hazard Quotient (HQ) calculated by dividing site-specific dose for each chemical by a reference dose; formulas and calculations shown in Appendix B.
[2] Hazard Index (HI) equal to the sum of the ingestion and dermal hazard quotients; a sum greater than 1 indicates a potential health hazard.
[3] "<" value reported for the mean indicates parameter was below detection for all sampled dates, value shown is the greatest detection limit used.
[4] Gold Dust data are September 2006 fall low flow sampling event post-borehole closure.
NDP = non-District Property; gpm = gallons per minute; s.u. = standard units.

4.2 STREAMLINED ECOLOGICAL RISK EVALUATION

The streamlined ecological risk evaluation was completed to assess the potential risk that adit discharges pose to wildlife and aquatic ecosystems. The evaluation was performed by comparing concentrations of COCs in the discharges 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 streamlined ecological risk evaluation is only intended to be qualitative.

The streamlined 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

Using the same EPA criteria as discussed in Section 4.1.1, COCs that present a potential risk to wildlife and aquatic systems at the site are aluminum, cadmium, copper, iron, lead, manganese, and zinc. These elements are detected in more than 20% of the adit discharge samples and are associated with mining disturbances. As with the human health risk assessment, background levels in surface water range widely across the site, primarily as a function of surface water flow conditions and geology. Background conditions may not be as meaningful, then, in determining whether specific trace metals are associated with background conditions or historic mining disturbances. Therefore, for the purposes of this streamlined ecological risk assessment, aluminum, cadmium, copper, iron, lead, manganese, and zinc are considered potential COCs.

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 residing in streams downstream of where discharges enter a surface water course. This population may be affected by concentrations of COCs that directly enter the receiving stream. The second group of receptors is wildlife that may use the adit discharge water for consumption.

Potentially adverse exposures of elevated metals to aquatic life and wildlife can be quasi-quantitatively assessed by comparing site-specific water quality criteria to toxicity-based criteria and standards. Exposure pathways for aquatic life include: 1) direct exposure of aquatic organisms to metals in surface water that exceed toxicity thresholds; and 2) ingestion of aquatic species (e.g., insects) that have accumulated contaminants by predators to the extent that they are toxic to predators (e.g., fish). Exposure pathways for wildlife include direct contact (dermal exposure) with discharge water and ingestion of discharge water. Instances of direct contact might occur from wading or swimming through discharges. Ingestion would likely occur from incidental ingestion rather than purposeful drinking, since most of the discharges would likely be avoided in preference to other easily obtainable sources of water, as the odor and taste attributes of adit discharges are likely less desirable.

Exposure pathways for aquatic species apply only for those adit discharges that reach a surface water body where aquatic species reside. The Henderson Mountain No.7 (AE-17), Henderson Mountain Adit (M-25), and Little Daisy percolate into the ground after leaving the closed adits and do not flow to surface water. The Gold Dust adit flows into a tributary to Fisher Creek. The McLaren Pit subsurface drains flow into tributaries to Daisy Creek.

Exposure pathways for wildlife are likely to be minor as the adit discharges constitute only a small portion of the water available in the District, and, based on cursory observations of the sites, wildlife are not known to favor any discharge over other sources of water. Exposure to discharge waters on any day is thought to likely be of very short duration. The exposure period for wildlife, as with humans, would be limited to the snow-free period between the months of June and October. From late fall through the spring, the adit discharge sites are covered with snow.

4.2.3 Ecological Effects Assessment

The COCs are known to have toxic effects on aquatic species, which have led to the adoption of acute and chronic water quality criteria promulgated by the State of Montana (MDEQ, 2008). Criteria for cadmium, copper, lead, and zinc are calculated as a function of water hardness while aluminum and iron criteria are fixed numerical standards. An average hardness of 100 mg/L was used to calculate applicable hardness based standards for these elements. Manganese is not considered a risk to aquatic life according to MDEQ Circular DEQ-7 standards.

There are many different wildlife species that could be exposed to COCs. These include birds, many species of mammals (including rodents, ungulates, shrews, rabbits, pikas, mountain lion, and bears), reptiles, and amphibians. For wildlife, many factors would influence the toxicity of COCs. These include body weight, growth rate, metabolic rate, ingestion rate, surface area of exposed skin, habitat characteristics, and population dynamics (e.g., habitat range, population density, and mating season). Unlike the human health toxicity assessment, toxicity of contaminants will range widely by species; for instance, toxicity to a meadow vole would be different than toxicity to elk, deer, or bear. Additional complications with assessing ecological effects include a lack of toxicity information on many species, especially species that inhabit the subalpine ecosystem that dominates the New World District. Because there are potentially a large number of wildlife species that could be exposed to the COCs, and because there are no site-specific exposure data available to make a generalized effects assessment, the effects assessment will focus on aquatic species rather than wildlife.

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. This was accomplished by comparing mean concentrations of adit discharge water quality to acute and chronic aquatic standards. This comparison is somewhat 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 the District. In addition, toxicity to the most sensitive species may not in itself be a limiting factor for the maintenance of a healthy, aquatic ecosystem. **Table 4-2** lists the adit discharge sites' water quality compared to aquatic standards.

Table 4-2
AQUATIC ECOSYSTEM RISK CHARACTERIZATION SUMMARY

Adit Name	Flow (gpm)	pH field (s.u.)	Total Recoverable Mean Concentration (milligrams per liter)						Direct Discharge?[1]	Impact Measured In Stream?[2]	Potential Risk Present?[3]
			Aluminum	Cadmium	Copper	Iron	Lead	Zinc			
McLaren Pit Drains	20.8	2.6	**33.7**	**0.0170**	**18.5**	**163**	**0.003**	**2.82**	Yes	Yes	**Yes**
Henderson Mt. Dump # 7	1.2	6.7	0.07	**0.0007**	**0.02**	**1.2**	0.003	0.06	No	Yes (?)	No
Gold Dust (F-28)*	3.6	6.8	0.10	<0.0001	0.003	0.68	0.002	0.02	Yes	Yes (?)	No
Little Daisy (M-1)	18.1	6.8	0.10	**0.0005**	**0.016**	**7.1**	**0.03**	**0.12**	No	No	No
Henderson Mt. Adit (M-25)	11.3	5.8	**0.31**	**0.0008**	**0.44**	<0.14[4]	**0.024**	0.09	No	Yes (?)	No
Acute Criteria			0.75	0.00213	0.014	NA	0.082	0.1198			
Chronic Criteria			0.087	0.00027	0.0093	1	0.0032	0.1198			

Notes:
1 A yes indicates discharge directly enters tributary or stream; a no indicates discharge infiltrates into ground and does not discharge to a stream.
2 A yes indicates surface water sampling downstream of discharge exceeds aquatic criteria (see Section 3.0); no indicates no impact measured in downstream sample; a yes (?) indicates impacts are measured downstream but may not be related to adit discharge (explained in detail above section 2.6).
3 Risk assumed to be present if 1 and 2 are both yes.
4 "<" value reported for the mean indicates parameter was below detection for all sampled dates, value shown is the greatest detection limit used.
* Gold Dust data are September 2006 low flow sampling event post-borehole closure.
NDP = non-District Property; gpm = gallons per minute; s.u. = standard units.
Bold font indicates that parameter exceeds DEQ-7 acute and/or chronic aquatic life standard.

Aquatic water quality standards are exceeded in all discharges listed in Table 4-2 except the Gold Dust Adit for one or more parameter. However, impacts to receiving waters immediately downstream of the adit discharges (as measured by aquatic standards) are not measured for the Little Daisy Adit or the Gold Dust Adit (Mn only) (Table 4-2), which means that these sites pose little to no risk to the aquatic environment. Impacts to receiving waters are clearly evident as a result of discharges from the McLaren Pit drains. Impacts from the Henderson Mountain Dump 7 adit in Fisher Creek and the Henderson Mountain Adit (M-25) in Daisy Creek (Table 4-2) are less clear. Even though the standards for aquatic risks are exceeded in these latter adit discharges, because the flow from these adits are relatively low compared to in-stream flows and the adits do not directly discharge to surface water, and because the adits are a considerable distance from receiving waters the impact to downstream receiving waters is questionable or unclear.

5.0 RESPONSE ACTION SCOPE, GOALS, AND OBJECTIVES

The risk evaluation demonstrated that there is no human health risk associated with any of the discharges at the site and that ecological risks are likely associated only with the McLaren Pit subsurface drains. Environmental risks associated with these discharges appear in down gradient surface water tributaries that receive the discharges. Contaminants (aluminum, cadmium, copper, iron, lead, and zinc) present ecological risks to aquatic life from ingestion and direct contact. In addition, wildlife species may be at risk from these discharges, although a meaningful exposure assessment and risk characterization is difficult due to the lack of site-specific knowledge of both species characteristics and exposure conditions.

Twenty-five discharges were inventoried in the District and identified in Section 3.0. Of these, 12 discharges were dry or only flowed for a brief period in 2004, and five discharges did not exceed water quality criteria for identified COCs. Of the remaining discharges, only one (McLaren Pit subsurface drains) constitute a risk to the environment, as discussed above. The Gold Dust discharge does not pose any risk to human health or the environment, but the discharge still exceeds the Circular DEQ-7 water quality guideline for manganese.

This section of the EE/CA presents the scope of the Adit Discharge Response Action and Response Action Objectives (RAOs) to meet project goals and applicable or relevant and appropriate requirements (ARARs).

5.1 SCOPE AND OBJECTIVES

The scope of this response action is directed at eliminating or reducing uncontrolled releases of metals from mining-related discharges. Reducing or eliminating contaminated discharges or treatment of acidic and/or metal-laden waters from the identified discharges will lead to a direct improvement in surface water quality in receiving streams. 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.

As outlined in the Overall Project Work Plan (Maxim, 1999b), 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. To meet these goals within the scope of the Adit Discharge Response Action, project-specific RAOs are:

- Prevent potential exposure through the food chain to metal contaminants from acid discharges to the extent practicable.
- Prevent or limit future releases of hazardous substances, pollutants, or contaminants.
- Comply with applicable or relevant and appropriate requirements (ARARs) to the extent practicable, considering the exigencies of the circumstances.

5.2 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. A list of ARARs is presented in **Appendix C**.

5.2.1 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**. Enforcement of cleanup goals may be executed at specific water quality stations, in which case the cleanup goal for hardness dependent contaminants should be calculated based on the hardness at a specific stream station. The hardness-dependent goals shown in the table are based on a hardness of 100 mg/L.

TABLE 5-1
ARAR-BASED RECLAMATION GOALS FOR SURFACE WATER

	Total Recoverable Metals (micrograms/liter)(1)						
	Aluminum	**Cadmium**	**Copper**	**Iron**	**Lead**	**Manganese**	**Zinc**
Goal	87	0.27	9.3	300	3.2	50	119.8

Notes: (1) Standards are in terms of total recoverable concentrations. Hardness based criteria are calculated for hardness = 100 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. The Board approved a rule allowing temporary standards on specific reaches of Fisher Creek, Daisy Creek, and the headwaters of the Stillwater River on June 4, 1999. No temporary standards have been established for Miller Creek.

5.2.2 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**.

TABLE 5-2
ARAR-BASED RECLAMATION GOALS FOR GROUNDWATER

Chemical	Type [1]	Concentration (μg/L)
Arsenic	HHS (MCL)	20 (50)
Cadmium	HHS/MCL	5
Copper	HHS/MCL	1,300
Iron	MCL	300[2]
Lead	HHS/MCL	15
Manganese	MCL	50[2]
Zinc	HHS (MCL)	2,000 (5,000)

Notes: (1) HHS = Human Health Standard (MDEQ, 2008); MCL = Maximum Contaminant Level (EPA, 1996)
(2) Human health guideline for taste, odor, color.
μg/L = micrograms per liter

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6.0 IDENTIFICATION AND SCREENING RESPONSE TECHNOLOGIES

The description of the source, nature, and extent of contamination (Section 3.0) and the RAOs developed for mining-related discharges in the District (Section 5.0) provide the basis for development and screening of response alternatives for the Adit Discharge EE/CA. 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 defining response alternatives. The EPA guidance suggests that only the most qualified technologies that apply to the source of contamination be evaluated in detail in the EE/CA. Using this guidance, removal action activities were grouped into general response technologies that are considered reasonable approaches to mitigating identified risks and that are implementable.

Based on the EPA guidance, technologies that were deemed ineffective after preliminary consideration are not evaluated in the EE/CA. Specifically, actions such as infiltration, surface dispersion, and plugging were considered for the McLaren Pit under drains but were eliminated from detailed evaluation in the EE/CA. Reasons for eliminating these technologies are summarized below in Section 8.4.1.

This section of the report presents the potential response technologies, screens the technologies, and then develops alternatives. The alternatives are then evaluated in detail against three principal 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 response actions and process options are specifically applied to either treatment of contaminated discharges or reducing or eliminating the flow of contaminants from mining-related discharges to surface water in the Daisy, Miller, and Fisher Creek drainages.

General response actions potentially capable of achieving RAOs and goals related to the treatment or reduction of mining-related discharges are screened for applicability in **Table 6-1**. Response actions include no action, institutional controls, engineering controls, and water treatment controls. The general response actions, technology types, and process options are also discussed in the following text. Screening comments are found in **Table 6-1**, and the logic and reasons for removing technologies or process options by screening are discussed in the text. Technologies and options retained for alternative development are shaded in **Table 6-1** and highlighted in the text.

6.1.1 No Action

No action means that there is no active response action implemented at a site. No action does include monitoring water quality and assessing site conditions on a regular annual basis. No action is generally used as a baseline against which other response options are compared; therefore, ***the no action alternative is retained*** for consideration in the detailed analysis of alternatives.

6.1.2 Institutional Controls

Institutional controls are used to restrict or control access to or use of a site (**Table 6-1**). 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. These options are ***retained*** to complement clean up and safety actions and would likely be combined with other process options.

TABLE 6-1
RESPONSE TECHNOLOGY SCREENING SUMMARY

General Response Action	Response Technology	Treatment or Process Technology	Description	Screening Comment
NO ACTION	None	Not Applicable	Includes water quality monitoring to assess site conditions on an annual basis.	Retained for comparison to other options. Allows on-going evaluation of site conditions.
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 barred 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 surface water infiltration into near-surface fractures and workings, or may minimize seepage of water from workings into adjacent fractures. Effective in isolating near surface workings from surface water infiltration; readily implementable; best when used in conjunction with backfill of workings for optimum 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. Readily implementable; best when used in conjunction with backfill of workings for optimum structural support.
		Cemented Backfill of Workings	Placing an aggregate based cemented backfill along sections of raise or tunnel for structural support and strength, and to restrict flow along the workings.	Effective in support of working to prevent collapse and protection of grout curtains; significantly restricts flow when installed tight to back; readily implementable.

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

TABLE 6-1 (continued)
RESPONSE TECHNOLOGY SCREENING SUMMARY

General Response Action	Response Technology	Treatment or Process Technology	Description	Screening Comment
ENGINEERING CONTROLS (continued)	Underground Flow Control (continued)	Acid Resistant Cement Tunnel Plugs	Placing a high strength, acid-resistant cement plug to block and seal workings in raises or tunnels 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);.
	Containment (McLaren Subsurface Drains)	Cut-off Trench	Excavation of a trench upgradient of mine waste to intercept groundwater flow. Intercepted water is routed around the waste in an open channel.	Appropriate for interception of near-surface groundwater (generally less than 5 to 20 m) using conventional construction equipment. Effective in porous media but use in fractured bedrock makes uncertainty level high; not effective where upward vertical flow present. Generally implementable in unconsolidated materials; very difficult to construct in bedrock, especially at depths greater than 5 m. Trench stability would be a priority consideration. Cost expected to be high due to difficulty excavating to desired depth.
		Slurry Wall	Excavation of a trench upgradient of mine waste and emplacement of low permeable material in the trench that forces groundwater to move laterally around the waste.	Similar to cut-off trench except clay or cement used to provide a physical barrier to flow; uses conventional construction equipment. Effective in porous media but used in fractured bedrock makes uncertainty level high; not effective where upward vertical flow present. Generally implementable in unconsolidated materials; very difficult to construct in bedrock. Cost expected to be high
		Grout Curtain (linear emplacement)	Involves drilling closely spaced boreholes upgradient of mine waste into unconsolidated surface material and bedrock, and injecting cement or bentonite grout under high or low pressure to prevent lateral movement of groundwater.	Pressure grouting reduces permeability in materials near borehole; overlapping boreholes create grout curtain that provides a physical barrier to groundwater flow; uncertainty lies in knowledge of groundwater flow paths and how flows will adjust after grouting. Implementable with conventional drilling and grouting equipment. Cost expected to be very high.

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

TABLE 6-1 (continued)
RESPONSE TECHNOLOGY SCREENING SUMMARY

General Response Action	Response Technology	Treatment or Process Technology	Description	Screening Comment
WATER TREATMENT CONTROLS	Passive Treatment Technologies	Infiltration/Natural Attenuation	Discharges directed to sub-surface drain field. As discharge infiltrates into the ground, aeration, dispersion, precipitation, and other chemical and biological attenuation processes act to reduce COC concentrations.	Appropriate only for sites that have low potential for contaminant impacts, such as sites with very low flows and/or very low metal loads.
		Aerobic and/or Anaerobic Bioreactors	Various designs rely on metabolic activity of microorganisms to attenuate COCs primarily through precipitation as metal sulfide mineral phases.	Not all metals are amenable to formation of sulfide minerals (e.g., aluminum and manganese). In such cases, it may be necessary to couple a bioreactor with other treatment technologies.
		Constructed Wetlands	Reduce COC concentrations through biological attenuation/reduction.	Unlikely to function for more than a few months per year due to long, harsh winters in the New World District.
		Passive Chemical Adsorption/Ion Exchange	Synthetic and/or natural aluminum and iron oxyhydroxides and synthetic zeolites adsorb metal cations from water through ion exchange reactions.	Treatment is most applicable to low flows and low concentrations of dissolved metals or as a polishing step following other treatments. Adsorbing substrate would need to be removed and replaced periodically when retention capacity is exceeded.
		Limestone Drains and Manganese Removal Cells	Limestone drains add alkalinity to waste streams thereby facilitating precipitation of metal hydroxide mineral phases. Manganese removal cells are modifications of limestone drains that allow sufficient residence time for precipitation of manganese oxides.	Open limestone channels and sequential alkalinity producing systems would be applicable for some discharges but anoxic limestone drains would not be applicable as a stand-alone technology. Limestone drains would need to be cleaned periodically.

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

TABLE 6-1 (continued)
RESPONSE TECHNOLOGY SCREENING SUMMARY

General Response Action	Response Technology	Treatment or Process Technology	Description	Screening Comment
WATER TREATMENT CONTROLS (continued)	Active Treatment Technologies	Ion Exchange	Inorganic zeolites or synthetic organic resins provide a solid immobile substrate to capture charged particles.	Typically involves use of multiple treatment vessels to ensure continuous treatment. Susceptible to interference by calcium, sodium, chloride, and sulfate. Easily clogged by suspended solids.
		Reverse Osmosis	Pumps used to force water through a semi-permeable membrane / filter.	Requires reliable power supply, heated facility, and regularly scheduled maintenance.
		Chemical Addition, Precipitation, and Micro-filtration	Chemical agents added to waste water stream to increase and/or decrease pH facilitating precipitation of insoluble mineral phases. Residual suspended solids removed by micro-filtration.	Packaged, skid-mounted systems are commercially available. Year-round access required for routine monitoring and maintenance.
		Coagulation/Flocculation	Metal salts added to waste water dissolve and form precipitates to which oppositely charged COC particles and molecules adsorb. The adsorbed compounds are then removed by sedimentation and/or filtration.	Because of the excess of iron and/or aluminum compared to other trace metals in many adit discharges it is unlikely that addition of extra metal salts would be required for treatment.
		Thermal Evaporation	Contaminated water is evaporated, which generates solid wastes that require disposal at an appropriate facility.	Significant energy is required and evaporation removes water from the watershed.

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

6.1.3 Engineering Source Controls

Engineering source controls are used to reduce the mobility of contaminants by reducing or eliminating the flow of a contaminated adit discharge. In an underground mine application, engineering controls are used to stem water inflow or outflow from the mine or to provide structural support or strength to materials or mine workings. Underground engineering controls may include grout curtains, cemented backfill, or watertight cement plugs (**Table 6-1**). Engineering controls generally do not reduce the volume or toxicity of hazardous materials.

6.1.3.1 UNDERGROUND FLOW CONTROL

Underground flow control technologies are used as contaminant source and migration control measures. They are used to eliminate, minimize, or divert contaminated water flows from either entering or leaving underground mine workings. By doing so, these controls minimize the impacts of discharging contaminated water to surface water. 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 constructed.

Methods such as near-surface grout curtains in unconsolidated materials or fractured bedrock around shallow near-surface workings are often accomplished by drilling these materials and filling fractures and porous voids using high- or low-pressure cement or bentonite grouting techniques to prevent infiltration or seepage into the mine. Near-surface grouting is typically used around portals or raise or shaft collars and is typically used in conjunction with plugs or backfill. These techniques can also be used to structurally stabilize near-surface workings. The objective of grouting is to reduce surface water infiltration into near-surface fractures and workings, or to minimize seepage of water from workings into adjacent bedrock fractures. Grouting often works best when used in conjunction with backfilling of adjacent workings for optimum ground support and or with a portal plug. For these reasons, a near-surface grout curtain is generally not used as a "stand-alone" technique to stem water inflows or outflows from mines, but rather is typically used in conjunction with ground stabilization around a portal plug or portal backfill.

Grout curtains placed into fracture systems that act as pathways for water flowing into mine workings are usually constructed by drilling fractured rock or fault zones and filling fractures using high-pressure cement or bentonite grouting techniques. These grout curtains are very effective at stemming or diverting water flow into the mine workings. Water is typically diverted into pre-mining flow path fractures. As with shallow grout curtains, flowing fracture grout curtains function best when used in conjunction with adjacent backfill in the workings to provide long-term structural support of the grouted fracture system and the surrounding ground.

Cemented backfills are constructed by placing aggregate-based, cemented backfill along sections of raises or tunnels for structural support and strength, and to restrict water flow along the workings. Cemented backfills are often used to support workings to prevent collapse, thereby providing protection of grout curtains or adit plugs. Cemented backfills significantly restrict water flow when installed tight to the back of the workings. When used in this manner, these fills effectively become elongated "watertight" plugs.

Cement plugs that act as watertight barriers or seals to groundwater flow are appropriate technologies when underground flows need to be controlled, diverted, or eliminated. Cemented plugs are constructed by placing a high strength, sometimes acid-resistant, cement plug to block and seal workings in raises or tunnels, thus acting as a seal or barrier to groundwater flow. Cement plugs are also

effective as a barrier or seal to water flow along workings or isolating select areas of underground workings in order to prevent mixing of groundwater. Cement plugs are most effective when used with a backfill for ground support to prevent damage to the plug should that portion of the mine collapse; however, this is not always required. Cement plugs are also more effective when used in pairs; one plug is placed outboard of the inflow to stop the flow of water toward the portal and hold back most of the hydrostatic head; a second plug is placed closer to the portal to act as a backup to block any water that bypasses the first plug.

One of the most important underlying characteristics in understanding water movement through rock in the New World District is that all of the bedrock flow is the result of secondary porosity and permeability, or flow in fractures or along faults. There are no true porous media bedrock aquifers in the District. The degree of interconnection of fractures appears to be fair to poor with overall hydraulic conductivities ranging from 10^{-4} to 10^{-5} centimeters per second (cm/sec). Hydraulic conductivities in fault zones can be much higher. Cement plugs and fracture fill grout curtains can be designed to yield hydraulic conductivities in the range of 10^{-6} to 10^{-8} cm/sec. Therefore, once a cement plug or grout curtain is used to effectively seal the adit or fracture system, flow will preferentially occur in the higher transmissivity rock adjacent to the plug. This likely diverts water into flow paths along pre-mining fractures.

Each of these alternatives uses common underground mining practices, with equipment that is readily available, and site- or application-specific designs. Shallow, surface grout curtains are typically only used in combination with watertight cement plugs installed in adit portals and shaft or raise collar areas where the plugs are used to shut off flow to underground workings. Likewise, cement backfills are most typically used as ground support around underground grouted fracture systems or surrounding tunnel plugs. For these reasons, ***underground flow control techniques are retained*** as a possible response action.

6.1.3.2 CONTAINMENT

The containment options listed in **Table 6-1** focus on solving the unique problems associated with the McLaren Pit subsurface drains. Containment technologies, other than those discussed in the previous section, are not appropriate for the other adit discharges. As described in Section 2.6.1, the subsurface drains were constructed underneath the McLaren Pit cap to drain off water seeping from bedrock near the McLaren Pit high wall. While there is some evidence that the source of water in the drains is from deeper bedrock sources (see Groundwater discussion in Section 3.7.1), some component of flow may be moving laterally into the waste rock through fractures intercepted by open pit. In an attempt to prevent groundwater from moving laterally through the capped waste rock, containment would try to isolate the wastes from up-gradient sources of groundwater by constructing a physical barrier to groundwater flow. Containment of wastes at contaminated sites is a fairly common and effective technique that has been employed for decades in the United States, United Kingdom, and Europe, as well as other countries. While the term containment usually means contaminants are isolated on a site, the containment options discussed here for the McLaren Pit would intercept or block lateral migration of groundwater through the capped waste rock. These options would not affect the component of flow that is vertically upward into the mine waste pit backfill. The physical containment barriers considered for the McLaren Pit include a cut-off trench, slurry wall, and grout curtain.

A cut-off trench is a shallow trench that would be excavated up-gradient of the McLaren Pit cover. The depth of excavation would be determined by the elevation of the base of the waste rock in the pit so that the trench intercepts any groundwater that could move laterally between the cover and the base of the waste rock. Excavation would be done with conventional excavators that have the capacity to reach

design depths. At the McLaren Pit site a cut-off trench would likely be constructed one to two meters wide, and about 430 meters (1410 feet) long up-gradient of the McLaren Pit. Excavated materials would be side-cast along the trench margin. The trench has to have self-supporting walls; if not, another option such as a slurry wall would have to be considered, Groundwater that collects in the trench would be routed to a point at either end of the trench and discharged to the surface.

The effectiveness of a cut-off trench in intercepting groundwater would be considered poor to fair, as the trench is unlined and cannot prevent water from flowing through the bottom or down gradient side of the trench. Constructing a trench (implementability) up-gradient of the McLaren Pit to a sufficient depth (estimated to be as much as 35 meters) would be extremely difficult and would be expected to become more difficult with depth due to the nature of excavating fractured bedrock. In addition, the site of the excavation in the area of the high wall will have very limited space for both equipment and the side-cast spoils. Costs are expected to be moderate to high due to the depth of excavation required and would depend on the difficulty of excavating bedrock.

A slurry wall is constructed in the same manner as a cut-off trench except that a structural liquid containing bentonite clay, cement-bentonite mixture, or cement earth mixture would be used to backfill the trench. The slurry hydraulically shores the trench to prevent collapse and forms a filter cake to reduce ground water flow. Slurry walls have been effectively constructed at hundreds of sites in the United States, typically to depths of up to 30 meters. Excavating to depths greater than 30 m would be accomplished with a clam shell bucket and crane, but this technology is only practical in unconsolidated materials. The most effective design for a slurry wall is to key the wall into a low permeability layer at the bottom of the trench so that groundwater cannot flow under the wall.

Slurry walls are more effective in preventing lateral flow of groundwater than cut-off trenches because the trench is sealed, especially where it can be keyed into an impermeable layer at depth. As the trench walls are supported, the ability to excavate to greater depths is improved. The same constructability issue described above for a cut-off trench applies. Costs for this technology are expected to be high with much of the added expense over a cut-off trench associated with procuring, delivering, and mixing slurry materials.

Grout curtains provide a similar barrier to groundwater flow as slurry walls except that, rather than excavating a trench, grout is injected into the subsurface through drilled boreholes. Injection is achieved using a variety of equipment and methods, but all systems use pressure to force grout into rock fractures and openings. Conventional drilling equipment is used to drill boreholes. Borehole spacing is dependent on fracture density and orientation and is done in phases such that primary holes are bracketed by secondary holes, and secondary holes are bracketed by tertiary holes until the desired permeability is reached. For the McLaren Pit, a curtain more than 430 meters (1,400 feet) long would be required, resulting in hundreds of holes and thousands to tens of thousands of meters of hole drilled. The most common grouts used in this application are bentonite and cement mixtures, similar to those used to plug the Glengarry Adit, Como Raise, and boreholes in the McLaren and Gold Dust adits. Grout would be selected to have long-term performance under acidic conditions.

A grout curtain would be more effective than a slurry wall or cut-off trench because the maximum depth of the curtain (35 meters) could be attained. There would be some uncertainty and unpredictability in how groundwater flow paths would adjust to the grout curtain. The technology is implementable, although it would require several hundred boreholes and considerable quantities of grout to produce an effective curtain. However, the cost to install a grout curtain is expected to be very high, as drilling closely spaced holes is expensive and material transport costs would be high.

One overriding consideration for containment options at the McLaren Pit is the uncertainty of the portion of flow that moves laterally through the capped pit area and the portion of flow that moves vertically into the capped waste from bedrock below. Dye tracer results and potentiometric heads in bedrock monitoring wells in the pit indicate that some portion of flow is upward from bedrock. As containment options described above do not affect this portion of flow, the overall effectiveness of each of the three options will be negatively impacted. For this reason, as well as for effectiveness and implementability issues associated with cut-off trenches and slurry walls, and the very high costs associated with grout curtains ***containment technologies are not retained*** for the McLaren Pit subsurface drains.

6.1.3.3 Adit Groups by Site and Engineering Characteristics

There are a number of physical characteristics that the adit sites and associated underground workings share that allow the sites to be divided into groups based on the kinds of engineering underground flow controls that might be applicable. **Table 6-2** shows the five adits under consideration for stemming water flow using an engineering response action grouped by site and engineering characteristics.

Before implementing underground flow controls, underground workings need to be reconditioned such that safe access can be gained. With safe access to the underground workings established, an assessment of the condition and suitability of the workings can be made relative to the application of Engineering Source Controls. Source controls would be used to stem inflows to underground workings or to reduce or eliminate mine outflows. Currently, only one of the four mine adits being examined in this EE/CA are accessible (**Table 6-2**). (The Gold Dust Adit was blocked with an earthen closure to exclude access to the workings in 2005, but the workings are still considered accessible for this evaluation as the earthen plug can easily be removed).

The goal of stemming or eliminating flow from adits requires sufficient length to the workings to be able to construct an engineering barrier. In addition, it is important that the source of water inflow to the mine be a sufficient distance in the mine to allow constructing a barrier outboard of the inflow and not too close to the surface or adit opening. Plugs placed too close to the surface or portal redirect flow into shallow, open fractures in adjacent rock, which in turn will likely discharge to the surface. This may eliminate a point source discharge, but does little to remedy the underlying problem of contaminated water discharge. Watertight plugs are also known to work better in pairs, so it is best if there is enough length in the adit to construct two plugs. Therefore, short or shallow adits are generally not suitable for closure by engineering source control methods. Adits listed in Group C in **Table 6-2** are deemed too short to effectively stem outflows with any of the Engineering Source Control technologies identified in **Table 6-1**. These adits include Henderson Mountain Dump 7 (closed by blasting) and Henderson Mountain Adit.

Flowing fracture grout curtains are not needed in the Gold Dust Adit, the only mine that is accessible and was previously assessed for a potential engineering closure (**Table 6-2**). This mine has underground workings that are suitable for constructing a two plug closure system. This site may also require the use of cemented backfill in the workings to provide ground support for the plugs. This mine is assigned to Group A (**Table 6-2**). The only other mine with workings of sufficient length for flowing fracture grout curtains or tunnel and portal plugs is assigned to Group B and includes only the Little Daisy mine (**Table 6-2**). However, as this mine is inaccessible, the workings would require reopening and assessment before the appropriateness of using and Engineering Source Control alternatives to reduce or eliminate the discharge could be fully evaluated.

TABLE 6-2
ADIT GROUPS BY SITE AND ENGINEERING CHARACTERISTICS

Adit Groups	Workings Accessible	Likelihood of Inaccessible Workings Being Open	Length of Workings Mined (feet)	Fracture Grout Curtain	Suitable for Tunnel Plug	Amenable to Flow Control Technology
Group A						
Gold Dust Adit	✓	✓	2,300	None Needed	✓	Yes
Group B						
Little Daisy Adit		Fair to Poor	2,385	Unknown	Possible Unknown	Unknown Need to Reopen
Group C						
Henderson Mtn. Dump 7		Poor (closed by blasting)	25-60	Short Adit	Short Adit	No
Henderson Mountain Adit		Poor	20-40?	Short Adit	Short Adit	No

6.1.3.4 REOPENING INACCESSIBLE MINES

Reopening inaccessible mines is generally costly, is entered into with no guarantee of success, and is potentially rife with uncertainty. Rock quality and the age of a mine are two attributes that can be used to provide some estimate of reopening success, however. For example, the Glengarry Mine, although old (1920s-1934), was driven in fractured but fairly solid intrusive rock, and was known to have been reopened by the Montana Department of Natural Resources and Conservation (DNRC) in 1974. It was likely, then, that it could be successfully reopened again, as it was in 2001. A different example is the Little Daisy Adit, which was probably last mined in about 1918. In the late 1920's, Lovering, a geologist with the US Geological Survey, could only access the first 427 meters (1,400 feet) of the 701 meters (2,300 feet) of workings (Lovering 1929). Presumably, the workings behind the backfilled portal would be much less likely to have remained open without caving since that time.

Table 6-2 identifies only the Little Daisy Adit (Group B) that, if reopened, might be amenable to stemming flow using one or more of the response action technologies identified in **Table 6-1.** The Little Daisy Adit has workings known to extend for 701 meters (2,300 feet)(**Table 6-2**). **Table 6-2** also qualitatively assesses the likelihood of inaccessible workings being open based on age and estimates of rock quality. The likelihood of inaccessible workings being open in the Little Daisy Mine is rated as "fair to poor" for the reasons discussed in the paragraph above.

6.1.4 Water Treatment Controls

Water treatment control technologies use either active or passive treatment technologies (**Table 6-1**) to treat contaminated discharge once it has left the adit portal. Numerous water treatment technologies are presently available for removing contaminating compounds from aqueous media. Treatment technologies considered here are not an exhaustive listing of all potentially applicable water treatment processes, but rather represent a range of processes that are potentially suitable for the water type and the goals for treated effluent quality. Water treatment technologies evaluated include a range of conventional, innovative, and industry-specific methods that span the expected range of process effectiveness, implementability, complexity, and cost.

Median water quality data for discharges, initially discussed in Section 3.0, are presented again in **Table 6-3**. **Table 6-3** groups the discharges by discharge chemistry type and lists the Circular DEQ-7 aquatic water quality standards that are the goals for treated water. Highlighted cells in **Table 6-3** indicate constituents whose median concentration values exceed Circular DEQ-7 standards. The constituents of concern (COCs) identified at the discharge sites are divalent (Cd^{2+}, Cu^{2+}, Fe^{2+}, Pb^{2+}, Mn^{2+}, and Zn^{2+}) and/or trivalent (Al^{3+}, and Fe^{3+}) metal ions. Therefore, only treatment technologies that are applicable to metals removal are included in the preliminary technology screening.

TABLE 6-3
WATER QUALITY (MEDIAN VALUES), CONTAMINANTS OF CONCERN, AND WATER TREATMENT GOALS

Site Name by Adit Discharge Source Groupings	Flow (gpm)[1]	pH (s.u.)[2]	Acidity (mg/L as CaCO3)[3]	Concentration (milligrams per liter)									
				DO	SO_4^{2-}	HCO_3^-	Al	Cd	Cu	Fe	Pb	Mn	Zn
Group 1													
McLaren Pit Cap Subsurface Drains	23	**2.6**	588	6.6	828	<1	**33.7**	**0.0170**	**18.5**	**163**	**0.003**	**4.9**	**2.82**
Group 2													
Little Daisy Adit	8	7.0	<2	5	**332**	210	**0.1**	**0.0004**	**0.0160**	**4.0**	**0.02**	**1.51**	**0.11**
Group 3													
Gold Dust Adit [4]	4	6.9	<2	10.46	**289**	155	0.05	<0.0001	0.002	0.42	0.001	**0.09**	0.02
Group 4													
Henderson Mt Adit	5	5.9	5	6	20	4	**0.20**	0.0010	**0.46**	<0.05	**0.011**	<0.02	**0.10**
Group 5													
Henderson Mountain Dump 7	1	6.7	<2	7	34	56	**0.105**	**0.0006**	**0.018**	**1.205**	**0.003**	**0.091**	0.045
Sheep Mountain #1 (NDP)[7]	0.5	6.9	<2	8	21	16	**0.110**	**0.0002**	**0.013**	0.43	**0.009**	0.026	0.050
Upper Miller Creek Dump (NDP)[7]	1	6.5	<2		30	59	**9.5**	**0.0046**	**0.030**	**16.4**	**0.360**	**0.880**	**0.960**
DEQ-7 Chronic Aquatic Life Standard (Calculated for Hardness = 50 mg/l)							**0.087**[5]	**0.00016**	**0.005**	**1**	**0.001**	**0.05**[6]	**0.07**
DEQ-7 Chronic Aquatic Life Standard (Calculated for Hardness = 100 mg/l)							**0.087**	**0.00027**	**0.009**	**1**	**0.003**	**0.05**	**0.12**

Notes
1 gpm = gallons per minute
2 s.u. = standard units
3 mg/L - milligrams per liter
4 Gold Dust data from October 2005 through September 2008 – post-borehole plugging.
5 Aluminum standard is based on dissolved concentrations and is applicable to water with pH between 6.6 to 9.0.
6 Manganese standard is a secondary MCL based on aesthetic qualities.
7 NDP = Non-District Property, not considered further in this analysis.
Bold indicates value exceeding DEQ-7 chronic aquatic life standards at hardness adjusted 50 mg/L; actual hardness of receiving water varies

A brief description of each water treatment control technology is presented below, along with general operational information and comments regarding applicability for implementation within the New World District. A preliminary analysis of each identified treatment technology is also provided to facilitate screening. Those technologies that meet identified goals and objectives and are potentially applicable to District discharges are retained for detailed analysis (shaded rows in **Table 6-1**). Technologies deemed infeasible and/or ineffective based on preliminary evaluation are dropped from further consideration.

6.1.4.1 EVALUATION AND SCREENING APPROACH

Evaluation and selection of the appropriate water treatment technologies for contaminated water sources is often a complex process. There are numerous technologies available and many are only effective against a small subset of potential constituents. Selection of a water treatment technology for application in the New World District is additionally complicated by several factors including:

- Numerous sources that have varied flow rates and contaminant concentrations
- Inability to combine water sources for treatment due to geographical constraints
- Very low treatment goals (Circular DEQ-7) and target levels for several constituents
- The remoteness and limited physical and seasonal accessibility of the sites
- The lack of a power source to the identified discharges
- The extremely high elevations and harsh climate of the sites
- The pristine nature of areas surrounding the District

In general terms, water treatment processes can be divided into two groups based on infrastructure requirements and the level of activity required to operate the systems. Passive and/or semi-passive technologies require limited infrastructure and, once installed, require no or very limited human involvement to maintain and operate. These technologies offer significant advantages over conventional active treatment approaches at remote sites like those in the New World District. The use of chemical addition and energy consuming treatment processes are virtually eliminated with passive treatment systems. In addition, the requirement for constant site access for process monitoring and equipment maintenance is removed. However, for many of these technologies, it is unclear if the technology can treat the discharge water to the stringent aquatic water quality standards required and/or how long a particular technology will function before needing replacement.

In contrast, active treatment requires a supporting infrastructure, some form of power, and periodic routine maintenance. While active technologies can potentially be very effective at removing metals to the low aquatic standards imposed in the New World District, the remoteness of the sites and inaccessibility to the sites for much of the year suggests that the successful implementation of these technologies could be difficult and expensive. Thus, implementation of active treatment technologies with the greatest likelihood of meeting all water quality standards would require major road improvements, a reliable source of power provided by construction of new electrical power lines and/or on-site diesel generators, construction of numerous structures to house equipment, and increased vehicular traffic necessary to move personnel and supplies. These types of infrastructure improvements would have long-term affects on the local environment and would likely impact the pristine nature of the surrounding area. During the evaluation process, these factors were carefully considered such that a retained technology would have a high likelihood of meeting water quality standards while having a minimal impact on the natural qualities of the area.

Applicable response technologies and process options summarized in **Table 6-1** are further described and screened in the following sections. Water treatment technologies have been divided into two groups: active and passive or semi-passive. The treatment technologies evaluated in this EE/CA include:

- Passive Systems
  - Infiltration
  - Anaerobic bioreactors
  - Constructed wetlands
  - Passive chemical adsorption or ion exchange
  - Limestone drains

- Active Systems:
  - Ion exchange
  - Reverse osmosis
  - Chemical addition, precipitation, and micro-filtration
  - Coagulation/Flocculation
  - Evaporation

6.1.4.2 PASSIVE TREATMENT TECHNOLOGIES

❖ *INFILTRATION-NATURAL ATTENUATION*

Infiltration would convert discharges from surface flows to subsurface flows where natural attenuation process (e.g., adsorption, precipitation, and dilution) would be more likely to occur. Discharges would be collected and directed to a subsurface drain field from which it would infiltrate the ground. The Montana DEQ requires a non-degradation analysis be conducted prior to directing surface flows (including adit discharges) into underground infiltration basins. The infiltration system would rely on gravity flows; there would be no power or ongoing maintenance requirements. The infiltration system would aerate the discharge resulting in the precipitation of iron and co-precipitation of other metals. Infiltration would also tend to enhance dispersion and dilution of the discharges.

The term "natural attenuation" describes a set of processes that include a variety of physical, chemical, or biological processes that, under favorable conditions, act without human intervention to reduce the mass, toxicity, mobility, volume, or concentration of contaminants in soil or groundwater. These in-situ processes include biodegradation; dispersion; dilution; sorption; volatilization; radioactive decay; and chemical or biological stabilization, transformation, or destruction of contaminants.

Natural attenuation processes are typically occurring at all sites, but to varying degrees of effectiveness depending on the types and concentrations of contaminants present and the physical, chemical, and biological characteristics of the soil and groundwater. Natural attenuation processes may reduce the potential risk posed by site contaminants in three ways:

1. Transformation of contaminant(s) to a less toxic form through destructive processes such as biodegradation or abiotic transformations;
2. Reduction of contaminant concentrations whereby potential exposure levels may be reduced; and
3. Reduction of contaminant mobility and bioavailability through sorption onto the soil or rock matrix.

Generally, infiltration-natural attenuation would only be appropriate for sites that have a low potential for contaminant migration, such as when flows and/or contaminant loads are low and/or when the attenuation capacity of the soil matrix is very high. In addition, non-degradation analysis must be conducted to document that the changes to groundwater quality would not be significant. All adit

discharges in the New World district might be considered for infiltration however, those that are most amenable to treatment by infiltration include those which have low flow rates (less than 11 Lpm [3 gpm]) and low metals concentrations (on average approximately 1 x 10^{-5} moles/L). ***Infiltration-Natural Attenuation processes are retained*** for future consideration.

- *BIOREACTORS (AEROBIC AND/OR ANAEROBIC)*

Bioreactors rely on the metabolic activity of microorganisms to transform contaminants to less toxic and/or immobile species. Microorganisms can accelerate metal oxidation reactions and thereby promote the precipitation of metal oxyhydroxides. Conversely, many bacterial species can facilitate metal and sulfate reduction and promote the removal of metals from the aqueous phase by the precipitation of metal sulfide solids.

Various design configurations are employed for bioremediation including horizontal flow aerobic wetlands, horizontal flow anaerobic wetlands, vertical flow wetlands, and anaerobic bioreactors (also known as sulfate-reducing bacteria bioreactors).

Subsurface bioreactors have been employed successfully for metal removal at numerous sites including those at high elevations with a climate similar to that of the New World District (Christensen, Laake et al., 1996; Gusek, 1998; Skousen, Rose et al., 1998; URS, 2003). Due to the reactions that occur within the bioreactors, soluble organics, nitrogen compounds, and residual sulfides that are produced need to be removed from the effluent prior to release. This is typically accomplished by placing an aerobic polishing cell downstream from the anaerobic bioreactor.

Anaerobic bioreactors can be constructed with either a solid reactant (solid substrate bioreactors, such as composted cow manure, sawdust or alfalfa hay (Drury, 1999), or a liquid reactant (liquid-reactant bioreactors), such as, methanol, ethanol or ethylene glycol (Tsukamoto, Miller et al., 1999; Greben, Maree et al., 2000). Liquid reactant bioreactors can overcome three deficiencies associated with solid-reactant systems: decreases in permeability with time, decreasing substrate reactivity, and freezing in cold climates (URS, 2003).

Often, an anaerobic bioreactor is coupled with other treatment technologies to maintain the effectiveness of the system and ensure that all the metals are removed. Sulfate reducing bacteria are generally most active in the pH range of 5 to 8, and therefore when influent waters are very acidic (i.e., pH < 4) anoxic limestone drains (see below) can be placed upstream of the bioreactor to add alkalinity and ensure that conditions are optimal for sulfate reduction (Hammack, et al., 1994). The primary mechanism of metals removal is through precipitation as metal sulfide mineral phases. Not all metals are amenable to formation of sulfide minerals (e.g., aluminum and manganese) and therefore are not effectively removed within the bioreactor. However, aluminum and manganese can be removed downstream of the bioreactor in an aerobic polishing pond or by passing the bioreactor effluent through an oxic limestone channel (see below).

Anaerobic bioreactors can be designed to handle a wide range of flows and metals concentrations. These systems alone, or in combination with other technologies, as discussed above, would be appropriate for discharges with acidic to alkaline pH, and that have sulfate concentrations in excess of total metals concentrations, which includes discharges in Groups 1 through 4.

These systems are passive or semi-passive, could be operated with minimal maintenance, and have been successfully used at other mine sites for metal treatment. ***Aerobic and anaerobic bioreactor processes are retained*** for future consideration.

❖ *CONSTRUCTED WETLANDS*

Constructed treatment wetlands have been used at numerous ARD sites for water treatment to remove heavy metals. Because of long, harsh winters that are characteristic of the District, it is unlikely that constructed wetlands could function for more than a few months out of the year. ***Constructed wetlands are not retained*** for future consideration.

❖ *PASSIVE CHEMICAL ADSORPTION/ION EXCHANGE*

Passive chemical adsorption and/or ion exchange reactions remove metal contaminants from water by absorbing cations or exchanging inherent cations for other aqueous phase cations on a basis of ion selectivity. Synthetic and natural iron and aluminum oxyhydroxides strongly adsorb numerous metal cations and natural and synthetic zeolites have been shown to be very effective for removing metal ions from waste water through ion exchange reactions (Cornell, et al. 1996; Langmuir 1997).

This treatment approach would be most applicable to low flows and low concentrations of dissolved metals or as a polishing step following other treatments. There is a finite adsorption/exchange capacity with any material, and, because of the passive nature of the systems, when retention capacity is exceeded, the material would need to be replaced and disposed off site. The systems could be sized, however, to last for numerous years before needing replacement. Adit discharges in Group 5 would be most amenable to treatment with this passive technology. ***Passive chemical Adsorption/ion exchange processes are retained*** for future consideration.

❖ *LIMESTONE DRAINS AND MANGANESE REMOVAL CELLS*

Limestone drains add alkalinity to mine wastewater streams and thereby facilitate the precipitation of metal (hydr)oxide mineral phases, removing precipitating species from the aqueous phase and promoting sorption of other trace metals.

Limestone ($CaCO_3$) is used extensively for treatment of ARD to increase the pH of waste water and promote metal removal by enhancing precipitation reactions (Ziemkiewicz, et al., 1997; Cravotta and Trahan, 1999). Treatment with limestone is generally passive or semi-passive and is used in various system configurations such as open limestone channels, anoxic limestone drains (ALD), and vertical flow reactors or sequential alkalinity producing systems. The adit discharges considered for treatment in the District are oxic with measured DO levels greater than 4 mg/L. While open limestone channels and sequential alkalinity producing systems would be applicable for treatment of some of the discharges, anoxic limestone drains would not be applicable as a stand-alone technology.

As discussed previously, anoxic limestone drains coupled to anaerobic bioreactors could help to add alkalinity and maintain the reactors at a pH that supports optimum sulfate reducing biotic activity. Anoxic limestone drains would therefore be appropriate in treatment trains for treating acidic water from Group 1 discharges. Several of the flows contain aluminum and/or manganese that exceed water quality standards; these contaminants may not be removed effectively in an anaerobic bioreactor. For these flows in Groups 1 through 4, positioning an open limestone channel downstream from the bioreactor would enhance aluminum and manganese removal. In addition, manganese is the only COC that exceeds the applicable water quality standard in flows from the Gold Dust adit which is oxic and has a pH above 6.5. For these flows, an open limestone channel could effectively remove manganese as a stand-alone treatment technology. A modification of the open limestone channel is the manganese removal bed, which is a lined pond filled with limestone that provides a residence time sufficiently long

to allow manganese oxides to precipitate. Manganese removal beds would also be applicable for those systems that have manganese as the primary COC, such as the Gold Dust Adit. ***Limestone drains and manganese removal cells are retained*** for future consideration.

6.1.4.3 ACTIVE TREATMENT TECHNOLOGIES

- *ION EXCHANGE*

Ion exchange is a reversible reaction wherein an ion (an atom or molecule with an electrical charge) in solution is exchanged for a similarly charged ion attached to an immobile solid particle. The solid ion exchange particles are either naturally occurring inorganic zeolites or synthetically produced organic resins. The synthetic organic resins are most commonly used today because their characteristics can be tailored to specific applications. This alternative can achieve high quality effluent, and is most applicable when used as a polishing step for production of high purity water.

The ion exchange treatment process typically involves emplacement of multiple pressure treatment vessels to ensure continuous treatment. System redundancy is required so that one reaction vessel can be operated while others are on standby or in the regeneration mode. Ion exchange reactions are susceptible to interference by competing ions such as calcium, sodium, chloride, and sulfate, and the systems are easily clogged by suspended solids. Therefore, extensive pretreatment to remove suspended solids and competing ions may be required to achieve effluent goals at some of the discharge sites. In addition, ion exchange resins are susceptible to poisoning through the non-reversible incorporation of certain ions on exchange sites. Resins must be regenerated using acid and/or caustic solutions, which generate waste brine that must then be treated on site or disposed off site. Depending on influent water quality, waste brine might be classified a hazardous waste, which would significantly increase disposal costs. The ability of the treatment process to consistently achieve water quality goals and maintain reactivity without extensive water pretreatment for discharges with high total dissolved solids (TDS) is uncertain. Because manganese concentrations in discharge from the Henderson Mountain Dump 7 are elevated above what could be reliably treated by ion exchange ***active treatment using ion exchange processes are not retained*** for future consideration.

- *REVERSE OSMOSIS*

Reverse osmosis uses a membrane that is semi-permeable, allowing the fluid being purified to pass through, while rejecting contaminants that remain. Reverse osmosis, also known as hyper-filtration, will remove particles as small as ions from a solution. Reverse osmosis is used to purify water and remove salts and other impurities in order to improve the color, taste, or other properties of the fluid. It is used to produce water that meets the most demanding specifications that are currently in place.

Most reverse osmosis technology uses a process known as cross flow to allow the membrane to continually clean itself. As some of the fluid passes through the membrane, the rest continues downstream, sweeping the rejected species away from the membrane. The reject water (called *retentate* or *waste brine*) requires further treatment and/or disposal. The process of reverse osmosis requires a driving force to push the fluid through the membrane, and the most common force is pressure from a pump. The separation of ions with reverse osmosis is aided by charged particles and is therefore very effective for removing divalent and trivalent metal ions.

Reverse osmosis membranes are susceptible to fouling and therefore must be inspected often and periodically cleaned using specialized cleaning solutions. Often pretreatment of feed water is required

for optimized treatment efficiency. Pretreatment can consist of pressure filtration, softening, treatment with anti-scalants, and/or water heating.

Reverse osmosis has been used effectively for treatment of various mine wastewater streams. However, reverse osmosis requires a reliable power supply, significant infrastructure including a heated facility to house the equipment, disposal of waste brine, and regularly scheduled routine maintenance. These factors suggest that reverse osmosis may have limited applicability for water treatment at sites in remote locations with limited access. However, this proven technology has a high probability of treating the mine discharges to the aquatic standards required for the discharge sites.

In the New World District, reverse osmosis may be applicable as a polishing step in a treatment train for discharges in Groups 1 through 4 if other technologies are unable to treat discharges to acceptable levels. However, due to the infrastructure, power, and the high maintenance requirements, ***reverse osmosis is not retained*** for future consideration.

- *CHEMICAL ADDITION, PRECIPITATION AND MICRO-FILTRATION*

Water treatment using this technology involves addition of chemical agents to the wastewater stream to change the chemistry (e.g., increase and/or decrease pH) and facilitate precipitation of insoluble mineral phases. Treatment of acidic water that contains elevated concentrations of metals through pH adjustment is a demonstrated technology capable of treating large volumes and can, under some conditions, remove metals to acceptable levels (Skousen, et al., 1998; Smith, 2000). Low pH water can be neutralized or made alkaline by the addition of readily available additives such as sodium hydroxide (NaOH), calcium hydroxide (hydrated lime, $Ca(OH)_2$), or calcium oxide (lime, CaO). The mechanism for removal of constituents is primarily through precipitation, co-precipitation, and/or sorption reactions. As acidic waters increase in pH, many metals become supersaturated with respect to various mineral phases and these species are precipitated from solution. Other COCs can co-precipitate and/or sorb to surfaces of the precipitating minerals (Stumm and Morgan, 1981). In addition, kinetic limitations on redox reactions and the formation of certain mineral phases are overcome at more alkaline pH levels (Cornell and Schwertmann, 1996). Following metal precipitation, which removes the bulk of the metals, residual fine suspended particles are removed by micro-filtration, which is used as a polishing step. Depending on the water quality of the waste stream, residual waste solids may be considered a hazardous waste.

Packaged, skid-mounted systems consisting of membrane modules, recirculation pumps, in-place cleaning loop, backpulse mechanism, instrumentation, and controls are commercially available and require a minimal footprint. The systems would require routine monitoring and maintenance and year-round access. This technology would be most applicable for treating Groups 1 through 4 discharges containing elevated iron and aluminum, which would form the bulk of the precipitate and provide adsorption sites for other trace elements and nucleation mass for flocculation formation. ***Chemical addition, Precipitation, and Micro-filtration processes are retained*** for future consideration.

- *COAGULATION/FLOCCULATION*

The process of coagulation involves the addition of metal salts that dissolve, undergo hydrolysis, and form precipitates in the treatment system. The amorphous precipitates that form during coagulation provide adsorption sites for oppositely charged particles and/or molecules. These charged compounds can then be removed from solution by attachment to the precipitates, a mechanism referred to as surface complexation, facilitating physical removal by sedimentation and/or filtration. This technology

has been used effectively to remove metals from mine wastewater streams and domestic drinking water supplies.

The process of metal removal with this technology is approximately equivalent to that discussed above for chemical addition/precipitation. The discharge waters of concern in the New World district, in general, contain a molar excess of iron and/or aluminum when compared to other trace metals (e.g., cadmium, copper, lead, manganese, and zinc). It is therefore unlikely that the addition of extra metal salts to remove the trace heavy metals would be required for treatment of discharges from Groups 1 through 4. Such a process is more applicable to discharges in Group 5 but other technologies are available that would require much less infrastructure, maintenance, and would be equally effective for metals removal. ***Coagulation and Flocculation processes are not retained*** for future consideration.

- *THERMAL EVAPORATION*

Thermal evaporation uses energy to evaporate contaminated water and generates solid wastes that contain the contaminants. Solids that are generated can then be disposed off site in an appropriate disposal facility.

Thermal evaporation is generally applicable to low flows and requires significant energy resources. The generated solids can contain relatively high levels of contaminants and therefore require disposal as a hazardous waste, which increases disposal costs. In addition, evaporation would remove water from the watershed. Implementation of this technology would require emplacement of infrastructure to house and protect the units and delivery of power to each location where used. ***Thermal Evaporation processes are not retained*** for future consideration.

6.1.4.4 SUMMARY OF WATER TREATMENT TECHNOLOGIES

In this section, several technologies have been discussed and evaluated for potential applicability in treating metals-contaminated discharges in the District. Results of the initial technology screening are shown in **Table 6-4**. Five of the ten technologies discussed in Section 6.1 will be retained for further evaluation.

The treatment technologies listed in **Table 6-4** are thought to be the most applicable for treating the varied water quality present in the six District Property discharges. As there is considerable variability in flow rates and water quality associated with the discharges listed in **Table 6.2** and illustrated in Figure 38 and **39**. However, as discussed in Section 3.4, similarities in water quality between the discharges allow for consolidation based on similar water chemistries and/or other characteristics such as metals concentrations, flow rates, or COC mass loadings. Therefore, rather than evaluate each of the potential treatment technologies against each discharge, the discharges have been grouped and technologies have been evaluated according to the likely effectiveness in relation to discharge characteristics. These groups are the following:

TABLE 6-4
RESULTS OF WATER TREATMENT TECHNOLOGY SCREENING

Treatment Technology	Retained	Rejected
Infiltration/Natural Attenuation	✓	
Anaerobic bioreactors	✓	
Constructed wetlands		✓
Passive chemical adsorption/ion exchange		✓
Limestone drains	✓	
Ion exchange	✓	
Reverse osmosis		✓
Chemical addition-precipitation-micro filtration	✓	
Coagulation/Flocculation		✓
Thermal evaporation		✓

1. Group 1 discharges can be described as acid rock drainage (ARD). Water quality from this group is of the poorest quality, with acidic pH, relatively high metals concentrations, and elevated sulfate (Figure 38 and **39**). Total mass loadings of metals from these sources equal about 110,000 kg/yr (242,500 lbs/yr). Water quality from the McLaren Adit is near neutral (pH = 6.5) and is more similar to that of the Little Daisy Adit, but because this discharge is adjacent to the McLaren Pit subsurface drains, combining these flows into a single source for treatment was deemed appropriate. Therefore sources in this group include the McLaren Pit subsurface drains (DCSW-101, -102, and 103):
2. Water from the Little Daisy Adit (M-1), the only remaining source from the 2006 draft EE/CA (Tetra Tech, 2006) in Group 2, is of circum-neutral pH, and flows with a median rate of 30 Lpm (8.0 gpm). The total mass loading of metals from this discharge is about 700 kg/yr (1550 lbs/yr) (Figure 39).
3. The Gold Dust Adit (F-28) discharge, the only remaining source from the 2006 draft EE/CA (Tetra Tech, 2006) in Group 3, is also being evaluated as a separate group. This source is circum-neutral (pH = 6.9) with a post-borehole plugging flow of 15.0 Lpm (4.0 gpm). Manganese is the only COC for this discharge and exceeds the human health guideline.
4. Henderson Mt Adit (M-25) is the lone remaining member of Group 4. This adit discharge of 19 Lpm (5 gpm), is slightly acidic (pH = 5.9), contains very little iron, and has elevated concentrations of aluminum, copper, and lead.
5. The fifth group is characterized by low water flows (less than 11 Lpm [3 gpm]), near neutral pH, and relatively low concentrations of metals. Excluding Non-District Properties (Sheep Mountain #1 and Upper Miller Creek Dump), the only source remaining in this group is the Henderson Mountain Dump 7 (AE-17)

6.2 RESPONSE ALTERNATIVE DEVELOPMENT

The most promising technologies and process options identified and retained through the screening process are shown as shaded rows in **Table 6-1**. These options appear to be effective and readily implementable over a range of costs, and will be used as the basis for developing response action alternatives for further consideration in Section 7.0.

One approach to developing alternatives is to combine a variety of process options from different response technologies into alternatives. Each alternative, then, can consist of different options that offer either a distinct benefit over options in other alternatives or that provide a different approach to meeting RAOs and goals. This method of alternative development is best used when the alternatives will be used to respond to multiple and different types of contamination issues on one site. This approach works well for Engineering Source Control response alternatives, where a number of process options could be applied in different combinations to stem the flow from adit discharges.

Combining process options into alternatives does not lend itself as well to Water Treatment Control process options. So, for application in this EE/CA, a number of different process options using water treatment control technologies will be considered to address a single issue: treatment of contaminated water at multiple sites with different characteristics. It is this unique set of attributes that lead us to define the actual process options as the response action alternatives for the Water Treatment Control response alternatives.

The Engineering Source Control and Water Treatment Control response action alternatives that will be evaluated further are presented in **Table 6-5**. To facilitate this analysis, the discharge sites were grouped by physical characteristics for engineering source control technologies and by water quality and flow characteristics for water treatment options (**Table 6-3**). In addition to covering a range of effectiveness and implementability, these alternatives also cover a reasonable range of costs. Each of these attributes, effectiveness, implementability, and cost, are important factors that will be considered in some detail in Section 7.0.

The institutional controls brought forward though the screening process are access restrictions that include fencing and gates, land use controls, and portal closures (**Table 6-6**). These controls are designed principally to provide for public safety with respect to limiting access to the underground workings. Rather than carrying these forward as response action alternatives, each site will need to be evaluated individually for how best to provide for public safety and closure. The sites currently range from completely collapsed and stable adit portals, to open adits with no provisions for limiting access.

TABLE 6-5
RESPONSE ACTION ALTERNATIVES FOR MINING-RELATED DISCHARGES

Alternative	Process Option Description
NA-1 No Action	Water quality monitoring and assessment of site conditions.
EC-1 Plug an Accessible Adit	Applicable for the Gold Dust Adit. Place high strength, acid-resistant, cement plugs to block and seal workings at a location about 76 meters (250 feet) into the mine and another plug near the portal to reduce or eliminate adit discharge. Cement or conventional backfill placed around the plug for ground support and to further restrict water flow. Portal closure and site reclamation.
EC-2 Reopen and Plug an Inaccessible Adit	Applicable for the Little Daisy Adit. Reopen inaccessible adits by excavation of portals, water discharge through a sediment pond, and mucking workings to 76 meters (250 feet). Place high strength, acid-resistant, cement plugs to block and seal workings at a location about 76 meters (250 feet) into the mine and another plug near the portal to reduce or eliminate adit discharge. Cement or conventional backfill will be placed around the plug for ground support and to further restrict water flow. Portal closure and site reclamation.
WT-1 Infiltration and Natural Attenuation	Applicable to all 4 adits to be evaluated, infiltration basins have already been constructed at the Little Daisy, Henderson Mountain Dump #7, McLaren, Black Warrior, Lower Tredennic Dump 1, and Glengary Millsite adit locations. Discharge directed to subsurface drain field. As discharge infiltrates ground, aeration, dispersion, precipitation, and other chemical and biological attenuation processes act to reduce contaminants of concern (COC) concentrations.
WT-2 Anaerobic Bioreactor (SSBR or LSBR) with limestone matrix incorporation (and sodium hydroxide addition for LSBR), and Open Limestone Channel	Designs rely on metabolic activity of microorganisms to attenuate COCs primarily through precipitation as metal sulfide mineral phases in either a solid substrate (SSBR) or liquid substrate (LSBR) anaerobic reactant media. In the case of the SSBR, limestone is incorporated into the solid matrix to precipitate metals and increase pH. An LSBR additionally uses sodium hydroxide additions to increase pH and precipitate metals. The Open Limestone Channel is located after the bioreactor to provide additional pH buffering and metal precipitation.
WT-3 Anaerobic Bioreactor (SSBR or LRBR), and Open Limestone Channel	Designs rely on metabolic activity of microorganisms to attenuate COCs primarily through precipitation as metal sulfide mineral phases in either a solid substrate (SSBR) or liquid substrate (LRBR) anaerobic reactant media. Used in series with open limestone channels that add alkalinity to the waste stream thereby facilitating precipitation of metal hydroxides.
WT-4 Manganese Removal Cell	Manganese removal cells are modifications of limestone drains that allow sufficient residence time for precipitation of manganese oxides.
WT-5 Chemical Addition, Precipitation, Micro-filtration	Chemical agents added to waste water stream to increase or decrease pH; facilitates precipitation of insoluble mineral phases. Residual suspended solids removed by micro-filtration.
WT-6 Ion Exchange	Inorganic zeolites or synthetic organic resins provide a solid immobile substrate to capture charged particles.

TABLE 6-6
INSTITUTIONAL CONTROLS OPTIONS

Alternative	Process Option Description
Fencing/Signage	Install fences around contaminated areas to limit access. Gating of access roads or mine portals
Land Use Controls	Legal restrictions to control current and future land use
Portal Closures	Close mine portals with backfill, plugging, or installation of locking bared gates. Also necessary for public safety.

6.3 ACTION COMMON TO ALL ALTERNATIVES

Implementation of the Revised Final Site-Wide, Long-Term Operations and Maintenance Plan is considered an essential action common to all alternatives including the NA-1 No Action Alternative. The Final Site-Wide, Long-Term Operations and Maintenance Plan was issued in 1999 (Tetra Tech 2009) and was informally revised in 2010 and 2011. The Revised Final plan will be issued late in December of 2011.

The Plan provides descriptions of annual monitoring tasks that will be completed to determine whether additional maintenance of reclaimed sites and the repository is needed, how maintenance work will be done, and estimated costs of site-wide monitoring and maintenance. This long-term operations and maintenance plan for the project begins after reclamation actions are completed in 2011 and covers activities that will occur for the following 20 years. The operations and maintenance period will therefore begin in 2012 and end in 2032. This Plan is intended to modify the Overall Work Plan (Maxim, 1999a), and the Repository Monitoring Plan (Maxim, 2006c) during the years of its implementation.

Primary objectives for work covered in the Long-Term Operations and Maintenance Plan are to document and monitor the effectiveness of reclamation response and restoration actions; to provide for maintenance actions as required to ensure long-term stability of erosion controls and reclamation covers; to monitor surface and groundwater quality and to satisfy the requirements of the rule allowing adoption of temporary water quality standards. This Plan also provides an outline of specific tasks that form the basis for estimating costs for long-term operations, monitoring and maintenance tasks. This plan is not static and may be modified as needs arise due to changing site conditions or decisions made after the initial release of this report.

To meet the objectives for the Revised Site-Wide, Long-Term Operations and Maintenance Plan, the following specific activities will be performed:

- Maintain community relations. Public meetings will no longer necessarily be held annually in both Bozeman and Cooke City. It is anticipated that as many as two meetings may be held annually.
- Maintain the project database.
- Continue monitoring surface water and groundwater quality in the District as required by the BER for verification that temporary water quality standards are being met.

- Continue monitoring surface water and groundwater quality in the District, including monitoring surface water and groundwater conditions downstream of the Como Basin capped reclamation area, downstream of the closed Glengarry Adit, and downstream and within the capped McLaren Pit.
- Continue to monitor the New World Waste Repository at select groundwater locations. Solution accumulating within the Repository will be pumped as necessary and is estimated to occur once a year.
- Monitor erosion and vegetation at all reclamation sites every 5 years.
- Prepare abbreviated annual reports that summarize the work that was completed, present data gathered, and delineate the work that will be performed the following year.

Costs for long-term operations and maintenance activities are estimated based on a number of assumptions including average annual inflation rate, discount rate, and frequency of certain operations and maintenance activities such as soil sampling during reclamation monitoring, reseeding, and replacement of culverts. The estimated cost for implementing the Revised Long-Term Operations and Maintenance Plan are variable depending on the year (2012 through 2032) and range from about $100,000 to $150,000. Extended costs for the entire 20 years period are estimated at total cost of $1,845,289.

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7.0 DETAILED ANALYSIS OF RESPONSE ALTERNATIVES

Response alternatives that were developed and that passed the initial screening process in Section 6 (**Table 6-1**) have been carried forward for analysis here in Section 7.0. These alternatives represent a range of potential actions or process options that can meet, to some degree, RAOs for this portion of the project, and achieve distinct levels of protectiveness to the environment for a reasonable range of costs. The detailed evaluation includes a description of each alternative and an evaluation based on effectiveness, implementability, and cost. The adits considered for further evaluation in this EE/CA are those listed in Table 3-3 and include the Gold Dust, Little Daisy, Henderson Mountain and Henderson Mountain Dump #7 adits. In addition, the McLaren subsurface drains are considered for water treatment alternatives.

7.1 ORGANIZATION

The detailed analysis presented in this section has been organized into two separate discussions: one for Engineering Response Technology Control alternatives and the other for Water Treatment Response Technology Control alternatives. The alternatives are evaluated as stand-alone alternatives; that is, a detailed analysis of a combination of alternatives from the two types of resource technology groups is not done. However, combined alternatives are considered in the comparative analysis discussion presented in Section 8.

Similarities between the adit sites and discharge sources allow for consolidation into groups based on similar engineering/site characteristics or water quality/chemistry characteristics. The four adit discharges were subdivided into 3 groups (A, B, and C) based on accessibility and length of the adits (**Table 6-2**) for the Engineering Source Control alternatives. For Water Treatment Control alternatives, 5 groups (1 to 5) were designated based on water chemistry, range of flow, and location of the discharge (**Table 6-3**). An appropriate range of treatment alternatives was then identified for each of the source groups (**Table 6-4**). The grouping allowed a more expedient analysis where, in some cases, the appropriate alternative was evaluated against a group rather than an individual adit or discharge source.

7.2 EVALUATION CRITERIA

Three criteria will be used to evaluate response action alternatives: effectiveness, implementability, and cost. A general description of each criterion is presented below.

7.2.1 Effectiveness

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. For the adit discharge response alternatives, effectiveness was gauged primarily by the ability of an alternative to either reduce or eliminate the discharge (loading) in the case of the Engineering Response Action Alternatives, or in the case of Water Treatment Response Alternatives, to remove COCs such that treatment effluent meets chronic aquatic water quality standards (**Table 3-3**).

As some of the response alternatives evaluated may not achieve the appropriate standards, the effectiveness evaluation also considered an alternative's ability to reduce total outflow from adits or to remove a portion of COCs from the waters to be treated. Also considered was the ability of the alternative to provide long-term effectiveness based on the alternative's reliability.

7.2.2 *Implementability*

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 contaminant source, availability of the required equipment and expertise to implement the alternative, and overall reliability of the alternative. In particular, alternative evaluation with respect to implementability included:

- Construction considerations including schedule and the availability of manpower, equipment, and materials required for implementation
- Infrastructure requirements (power supply)
- Reliability and simplicity or complexity of operation and the required maintenance
- Remoteness of location, accessibility, and climatic conditions

Implementability also considers the appropriateness of combinations of alternatives based on site-specific conditions. Administrative feasibility evaluates logistical and scheduling constraints.

7.2.3 *Cost*

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 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 water treatment alternatives. These PRSC costs were estimated using reasonable assumptions for likely and potential maintenance and monitoring requirements. PRSC are estimated for a 20-year period. The present worth for PRSC is calculated using a discount rate factor of 4.0% (OSWER, 1993). It is not anticipated that there would be any PRSC costs associated with the engineering response alternatives in that they are designed to be a "walk-away" solution to adit discharge. There would also be no PRSC casts associated with the No Action Alternative (NA-1) because the only likely charge, ongoing monitoring, would be covered by Overall Project Work Plan (Maxim, 1999) as modified through 2011, and the Site-Wide Long Term Operations and Maintenance Plan (Tetra Tech 2009d) would be implemented beginning in 2012.

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. Summary cost tables are

presented in the cost discussion for each alternative with the supporting unit cost spreadsheets presented in **Appendix D**.

7.3 ALTERNATIVE NA-1, NO ACTION

The no action alternative involves leaving the various mine adits and sub-surface drains in their existing condition. No further underground flow control or water treatment measures would be attempted at the sites. There would be no attempt to control or treat contaminant migration from the mines, or to reduce its toxicity or volume. It should be noted that previous response actions have been completed at the majority of the adit discharges sites, as presented in the detailed mine description section 2.6 above (e.g. waste rock dumps were removed from the McLaren, Little Daisy, and partially removed from the Gold Dust adit areas; the portal was closed at the Henderson Mountain Dump 7 site; infiltration basins were constructed at the McLaren, Glengarry Millsite, Lower Tredennic Dump 1, Black Warrior, Little Daisy and Henderson Mountain Dump 7 sites; and revegetation of waste removal areas was completed at the Little Daisy, Gold Dust, Glengarry Millsite, Lower Tredennic Dump 1, Black Warrior and Henderson Mountain Dump 7 sites).

Seepage from the adits/discharges would continue under this alternative. Natural attenuation may reduce COC concentrations and loading over time. However, the degree of natural attenuation, particularly at Group 1 Water Treatment sites (McLaren Pit subsurface drains), is likely minimal and any noticeable degree of natural attenuation would take place only over a very long period of time. The No Action alternative is most applicable to discharges in Group 5 (Henderson Mountain Dump 7), which have low flows and metal concentrations. More permanent closures have been installed at the Gold Dust, McLaren, and Henderson Mountain Dump #7 sites to prevent public access and to provide for public safety. Water quality monitoring would be performed each year in following with the rule for temporary standards and the objectives outlined in the project Overall Project Work Plan (Maxim, 1999) as modified through 2011, and the Site-Wide Long Term Operations and Maintenance Plan (Tetra Tech 2009d) would be implemented beginning in 2012. Assessment of site conditions would be performed annually to evaluate whether changes in water quality warrant any additional actions at a site(s).

7.3.1 Effectiveness (NA-1)

Overall effectiveness of no action is poor. Under existing conditions, acidic water, dissolved metals, and/or sediment will continue to flow from adit portals and percolate into nearby soils or migrate to surface water or groundwater. Discharges would not be altered from present conditions and would not meet water quality standards for the contaminants that exceed standards. The No Action Alternative does not address surface water and/or groundwater impacts, nor does it provide any controls on direct contact or ingestion by humans or wildlife. Toxicity, mobility, and volume of contaminants would not be reduced under the No Action Alternative, although contaminant sources may be expected to diminish over time as oxidation of sulfides depletes the contaminant source.

For discharges that are a significant distance from a receiving surface water body, natural attenuation reactions, such as infiltration, evaporative precipitation, adsorption, and dilution occurring between the source and the receiving stream could significantly reduce metals loadings and ecological risk. Adits that fall into this category include the Gold Dust, Little Daisy, Henderson Mountain #7, and the Henderson Mountain Adit.

The No Action alternative is currently in compliance with narrative and numeric temporary water quality standards at the principal downstream stations monitored in each of the drainages (Daisy Creek,

DC2, DC-5 and SW-7; and Fisher Creek; SW-3, SW4 and CFY-2). However, as these standards expire in 2014, No Action is not expected to move water quality appreciably toward compliance with the B-1 standards for these streams.

7.3.2 Implementability (NA-1)

This alternative is both technically and administratively feasible.

7.3.3 Cost (NA-1)

No capital or annual maintenance costs would be incurred under the No Action alternative. As annual monitoring costs associated with this alternative are carried under the Overall Project Work Plan (as modified) (Maxim, 1999: Appendix D) through 2011 and then the Site Wide Long-Term Operations and Maintenance Plan (Tetra Tech, 2009d) for the project beginning in 2012: there are no costs specifically identified with this alternative for this evaluation.

7.4 ANALYSIS OF ENGINEERING SOURCE CONTROL ALTERNATIVES

This section presents the detailed analysis of underground Engineering Source Control alternatives listed in **Table 6-1**. The Gold Dust adit is evaluated under Alternative EC-1 as an assessable adit that is suitable for plugging, and the Little Daisy Adit is evaluated under Alternative EC-2 as a inaccessible adit that may be suitable for plugging. The remaining adits Henderson Mountain and Henderson Mountain Dump 7 adits are to short in length to be considered for closures using hydraulic adit plugs. Because these two Engineering Source Control alternatives are similar, the level of analysis under effectiveness for Alternative EC-2 is abbreviated rather than reiterating the same evaluation presented for Alternative EC-1. A summary of common elements is provided in the analysis for Alternative EC-2, along with specific distinctions between the two source control alternatives.

7.4.1 Alternative EC-1, Plugging an Accessible Adit

This alternative involves closing the Gold Dust adit to reduce or eliminate the discharge. (The adit was secured in 2005 to prevent physical access to the workings, and this closure would be removed to implement this alternative). Water quality assessments have been completed. Two watertight plugs would be utilized for plugging the workings.

The Gold Dust Adit was driven between 1920 and 1925, and drifts to the southwest for about 701 meters (2,300 feet). A major portion of the waste rock dump, which contained approximately 4,358 cubic meters (5,700 cubic yards), was removed from below the portal of the Gold Dust Adit in 2005. The adit is driven in Precambrian granite for the first 274 meters (900 feet) and then crosses into monzonite porphyry intrusion breccia of the Homestake stock.

Crown Butte Mines opened the mine in 1992 and executed an underground drilling program from the Gold Dust Adit, drilling 23 angle holes from four drill stations near the back of the mine. Drill holes that were making water when drilled were closed with mechanical packers. The mine discharged water at an average rate of about 49 Lpm (13 gpm), about 42 Lpm (11 gpm) of which comes from water discharging from underground boreholes. A borehole grouting project was completed at the drill stations in September 2005 and involved reentering the Gold Dust Adit, removing packers from drill holes, and grouting and plugging with cement all drill holes in the adit that were making water. Successful plugging of these drill holes reduced the flow from the portal by 68% in the first month following plugging. Flow

measured in September 2008 at the site (4 gpm or 15 Lpm) indicated that the reduction in flow was maintained through the first three years after plugging.

In 2005, the Forest Service completed surface reclamation and restoration of the Gold Dust portal area (Figure 16). The restoration work was undertaken to preserve various aspects of the site for cultural resource purposes and as such the site was developed as an interpretative site. Activities at the portal included: backfilling of the portal with coarse rock for about 15-20 feet, removal of approximately 7,000 cubic yards of the portal pad waste rock dump to the selective source repository, construction of portal timber façade, and construction of a rock armored diversion ditch for adit discharge to the south of the remaining waste rock pile at the portal.

Alternative EC-1 will further stem the already reduced flow of water from the adit. Two high-strength, watertight, cement plugs would be placed in the adit (Figure 40). The innermost plug would be constructed about 76 meters (250 feet) in from the portal, outboard of any significant inflows into either of the mines. This plug would be designed as a high pressure plug and placed in competent, relatively unfractured rock. It is envisioned that this plug would stem most of the mine outflow and hold back the largest portion of the hydrostatic head behind the plug. The outermost plug would be designed as a low pressure plug and be placed about 18 meters (60 feet) in from the portal. Both plugs are designed to redirect water that now leaves the adit back into fractures that carried water along pre-mining flow paths. Both plugs would have either a cemented or a conventional backfill placed on either side of the plug to provide ground support for the section of the workings containing the plugs. The watertight plugs are expected to appreciably reduce or eliminate adit discharge. The portal would be closed with conventional backfill methods and disturbances in the portal area would be reclaimed and revegetated. Site drainage would be established that would minimize or eliminate long-term maintenance requirements.

7.4.1.1 TASK DESCRIPTION (EC-1)

The following work is included in the implementation of Alternative EC-1:

- *Engineering:* Prior to commencing work, a general scoping of the portal site would be completed to determine the stability and safety requirements for routine work access and activities. A plan would be devised to dispose of water on-site during the construction phases of work. A suitable sediment retention pond would be designed. Portal plugs would be designed based on the rock mass quality, the potential hydrostatic head, the burden of rock above the plug, and other considerations. A system of two plugs is anticipated. The inner plug would be a high pressure plug situated in competent rock with enough burden overhead to prevent hydraulic jacking of the fractures in the rock mass. The inner plug would contain most of the water flow. The outer plug would be a low pressure plug designed to disperse the water that enters the drift outward of the high pressure plug.

- *Excavation and Plug Site Preparation*: If necessary, topsoil would be stripped from the site and stockpiled. A lay-down area would be leveled and prepared for equipment set-up. A muck storage pad would be constructed adjacent to the portal site. A sediment retention pond sufficient to contain surges of sediment-laden water during plug construction would be excavated and bermed using fill material from the excavation. Water from the portal and muck storage pad would be ditched or piped to the sediment retention pond. The portal would be stabilized for safe access and working conditions and portal integrity would be maintained with bolts, mesh, or timbers as necessary. Plugs would be constructed beginning with the high pressure plug and working outward (Figure 40). The same procedure would be followed for each plug. Prior to construction,

compressed air, drill water, and ventilation utilities would be installed to the plug sites. The sill and ribs at the plug location would be notched, scaled, and cleaned to allow a watertight bond between the cement and rock. The back would be domed to permit a tight seal at the top of the plug. A dam upstream of the plug would be constructed to prevent tunnel water from entering the plug excavation. A bypass pipe would be installed in the dam to pass tunnel water through the plug site and discharge the water downstream of the plug site during construction. I-beam framed, wooden forms approximately four meters apart would be constructed at the front and back of the plug. To facilitate cement pumping, steel pipe either 10 cm or 15 cm in diameter would be installed from the portal to the plug sites. If suitable, rock removed from the drift would be saved on-site for future use as backfill in the closure process.

- *Plug Construction:* The space between the back form and the front form would be pumped full of cement. Air would discharge through a breather pipe at the highest point of the dome in the back. The forms would be abandoned in place. If necessary, during the pouring and curing time, the tunnel water would pass through the bypass pipe.

- *Grouting:* Upon completion of the cement pour, the small void left in the dome would be pressure grouted with Portland cement or bentonite based grout. If the bypass pipe was left in place during pouring and grouting, it would be grouted shut once the plug pour is complete.

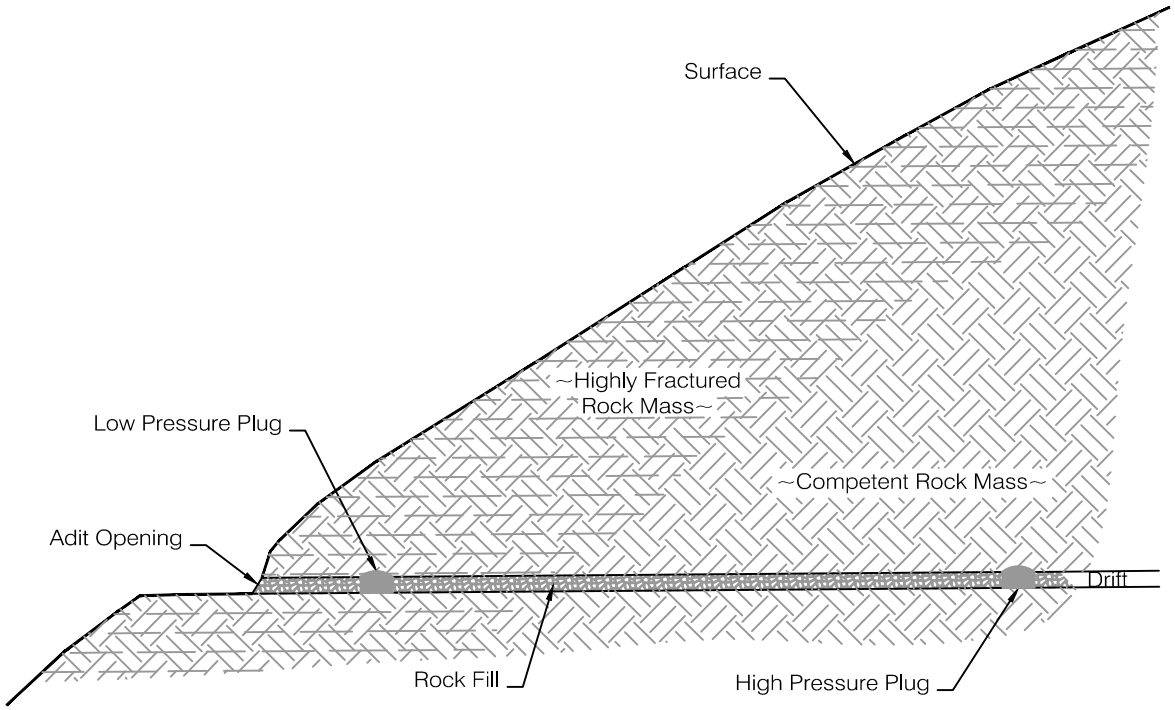
- *Backfill for Stability:* Rock would be gobbed behind, between, and in front of the plugs to help ensure drift stability adjacent to the plugs (Figure 40). The gob would also help prevent potential catastrophic failure of the plugs. Rock from the waste rock dump or rock removed from the portal area or drift would be used as backfill. A small contingency has been added if rock needs to be hauled in for use as backfill material.

- *Site Clean-up and Restoration:* Upon completion of the plug work, the portal would be backfilled. The sediment retention pond may be mucked out and then backfilled. The site would be graded so that surface water drains naturally into nearby channels and reclaimed. Excess waste rock or mine muck may need to be hauled off-site to a designated repository. The site would be revegetated.

7.4.1.2 EFFECTIVENESS (EC-1)

Cement 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, the hydrostatic head behind the plug rose to a level sufficient to force water through fractures, bypassing the plug, and exiting the mine portal or elsewhere. Alternative EC-1 addresses the problem of high head behind the inboard plug by placing it 76 meters (250 feet) into the Gold Dust adit in low permeability Precambrian Granite rock. The Gold Dust Adit has the potential to develop very large hydrostatic heads behind plugs due to the difference in elevation between the innermost plug, estimated at 2,804 meters (9,200 feet) in elevation, and the top of Henderson Mountain at 3,139 meters (10,300 feet). The plugs will have to be high-strength to account for this condition, and it may be desirable to place a third plug in the adit.

G:\Projects\USFS\New World\114-710121.110 Adit EECA\CAD\SheetFiles\F-40-Schematic of Two Plug System.dwg SAVED:10/6/11 PRINTED:10/6/11 BY:MARY.BELL



NOT TO SCALE

April 2005

Schematic of Two Plug System
New World Mining District
Response and Restoration Project
Cooke City, Montana
FIGURE 40

Both mines will have a second plug placed about 18 meters (60 feet) in from the portal as a backup to the first plug. This plug would allow water to be redirected into adjacent fractures at a lower pressure than those generated behind the inboard plug. It is anticipated that water will seek pre-mining routes as a preferred flow pattern rather than exiting the portal.

- *REMOVAL ACTION OBJECTIVES*

Implementation of Alternative EC-1 meets one of the RAOs for the project by minimizing or preventing contaminants dissolved in water from entering surface water in Fisher Creek from the Gold Dust Adit.

- *OVERALL PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT*

Alternative EC-1 provides considerable control to the migration of contaminated water and reduces risk to human health and the environment. It reduces the flow of metal-laden water directly into Fisher Creek from the Gold Dust Adit by constructing two barriers to water movement through the adits.

The removal of metal-bearing water-flow exiting the Gold Dust portal (15 Lpm [4 gpm]) will lessen exposure of the environment to contaminated water. This alternative has the potential to significantly diminish or eliminate the flow of water from the either of the mine portals. The use of two plugs provides a measure of redundancy should one plug fail in the future. In addition, the use of a cement or conventional backfill on either side of the plug provides long-term ground stability in the vicinity of the plug, thereby protecting the plugs in the event nearby sections of the mine collapse in future years.

- *COMPLIANCE WITH ARARS*

A list of ARARs is presented in **Appendix C**. Compliance with surface water quality ARARs can be fully achieved under Alternative EC-1 if the discharge is eliminated. Complete removal of the relatively small contaminant loads associated with the discharge, however, will likely not affect current conditions in Fisher Creek where surface water aquatic standards are not being met. Contaminant concentrations in the headwaters of the stream are several orders of magnitude higher than the applicable Circular DEQ-7 aquatic life standards, and complete removal of the relatively small contaminant loads associated with the discharge is not great enough to meet water quality ARARs. However, surface water quality at station SW-4 (Fisher Creek) may improve as a direct result of setting plugs in the Gold Dust Adit where a reduction in iron (12.3%), lead (2.1%), and manganese (3.9%) loading might be expected. Although, the geochemical conditions in Fisher Creek are complex and this simple analysis of load reduction does not take into account geochemical equilibrium conditions that control metals concentrations in the two streams.

Groundwater quality will not likely improve by implementation of this alternative, although, with the exception of iron and manganese, groundwater in Fisher Creek complies with groundwater standards both in shallow alluvial and bedrock aquifers. Iron and manganese are ubiquitous throughout the district and their concentrations are believed to be partially controlled by natural bedrock sources. Contaminant-specific ARARs for ambient air will be met under this alternative, as air quality would not be affected by construction operations.

Location-specific ARARs, particularly those associated with cultural and historic resources will be met, as no cultural or historic resources will be impacted by the implementation of this alternative. Threatened and endangered species present in or near the District may be affected by the activities associated with implementing this alternative in the short-term but it is not likely that these species will

be adversely affected, as there will be no new disturbances, no permanent facilities, and implementation of the alternatives 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 wastewater to the environment. Requirements for treating surface drainage, sediment control, construction and maintenance of sediment ponds, discharges from sediment ponds, and provisions for groundwater protection will be met by Best Available Technologies (BATs).

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

OSHA requirements will be met by requiring appropriate safety training for all on-site workers during the construction phase. Site activities would be conducted under the guidance of a Health and Safety Plan for the site as 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 EC-1 should permanently eliminate the Gold Dust Mine as a conduit for transporting metal-laden groundwater from the adit directly into Fisher Creek. Potential ground instability conditions in the mine that might lead to mechanical failure of the plugs would be mitigated by the placement of cemented or conventional backfill around the plugs. The use of two plugs in the adit provides redundancy and helps to minimize the development of high hydrostatic pressures behind the outboard plug.

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

The mobility and volume of metals will be greatly reduced by Alternative EC-1. The Gold Dust adit will no longer be a conduit for transporting metals-laden water to Fisher Creek. Mobility will exist within isolated segments of the mine, but the plugs will preclude mobility between segments. There will be no reduction in toxicity or volume through treatment, but a large reduction in the discharge volume will be attained under this alternative.

- *SHORT TERM EFFECTIVENESS*

The effect of placing tunnel and portal plugs will be immediate. Upon completion of the first plug and the placement of adjacent cemented backfill, water inflow into the adits will be terminated. After both tunnel plugs are in place the flow from the Gold Dust portal will be very significantly reduced or eliminated. The number of construction workers, equipment, and supplies needed to construct the alternative is relatively small; construction of the alternative is not expected to have a noticeable effect on local services or roads in the surrounding area.

7.4.1.3 IMPLEMENTABILITY (EC-1)

Numerous portal and drift plugs have been previously installed in abandoned underground mines, including the Glengarry Mine in the New World District. The greatest technical difficulty with Alternative EC-1 is pumping cement to the plug sites. This will be accomplished by pumping cement from the portal site through a pipeline installed in the adit workings. Pumping cement over these

distances is not too difficult as long as the piping system is capable of withstanding the pressures generated by pumping the cement. Cement has been pumped over distances of as much as 152 meters (500 feet) in the Glengarry Adit. Bulkheads capable of holding back the cement in the plug stations are routinely constructed of timbers and steel I-beams.

7.4.1.4 COST (EC-1)

The Gold Dust adit is currently accessible and the adit are long enough to effectively install a two plug closure system. The cost estimate for construction of two plugs, with cement backfill and site reclamation for the adit is provided in **Table 7-1**. A detailed cost breakdown is provided in **Appendix D**. The cost to plug the adit would be about $792,027.

TABLE 7-1
COST ESTIMATE SUMMARY
PLUGGING AN ACCESSIBLE ADIT (ALTERNATIVE EC-1)

Gold Dust Adit	
Mobilization/Demobilization	$ 80,000
Reclamation	$20,000
Equipment	$ 135,777
Materials, Supplies, Fuel	$ 103,213
Labor	$298,200
Contingency (10%)	$ 63,719
Subtotal	**$700,709**
Engineering Evaluation and Design (5%)	$ 35045
Construction Oversight (8%)	$ 56,073
TOTAL	**$792,027**

7.4.2 Alternative EC-2, Reopen and Plug an Inaccessible Adit

One historical mine with a caved or backfilled adit portal is considered for closure under alternative EC-2. The Little Daisy mine has workings that are 701 meters (2,300 feet) in length. Physical descriptions of the mine is presented in Section 2.0. As shown in **Table 6-2**, the Henderson Mountain Dump #7, and Henderson Mountain Adit are too short (less than 18 meters [60 feet]) for placing underground flow controls.

Rock quality and the age of the mine are two attributes that can be used to provide some estimate of likely success of reopening. The Little Daisy mine was operated in the early 1900's, and has varying degrees of estimated rock quality (**Table 6-2**). The Little Daisy adit was driven in a silicified but brecciated zone developed along the contact of the Homestake stock and the Pilgrim Limestone. Only the first 366 meters (1,200 feet) of the adit were assessable in the mid 1920's when Lovering entered the mine (Lovering, 1929). The Little Daisy adit is rated as "fair to poor" with respect to the likelihood of inaccessible workings being easily reopened.

Alternative EC-2 involves reopening mines with caved or backfilled portals. Reopening the adit would be accomplished by excavating the portal, discharging mine water into a sediment pond, and mucking sediment from the first 76 to 91 meters (250 to 300 feet) of workings. Another option to reopening the adits would be to drill a boring into the underground workings from the surface and then pump cement to the plug sites. With reasonable access, this option could potentially be less expensive than reopening the mine, although locating the subsurface workings by drilling may be difficult. This method of plug placement is not developed further in this evaluation, as the reopening method is more conservative in terms of cost.

Once the adit is open and safely accessible, the two plug system, consisting of high-strength, acid-resistant, watertight, cement plugs described for Alternative EC-1, would be installed to seal the workings. The first plug would be placed at a location about 76 meters (250 feet) into the mine and the second plug near the portal, about 18 meters (60 feet) into the mine. Cement or conventional backfill would be placed around the plug for ground support and to further restrict water flow.

For purposes of evaluation and cost analysis, two scenarios for access are considered. One assumes that once the portal is opened, there would be relatively easy access through the first 76 meters (250 feet) of workings to the point where the innermost plug would be set. The second scenario assumes that once a portal was opened, the mine workings will be in poor condition with a considerable amount of sloughed or caved material that needs to be removed in order to gain access to the first 76 meters (250 feet) of workings. Costs have been developed for both the easy and difficult access scenarios. The Little Daisy is likely to be difficult to access.

7.4.2.1 TASK DESCRIPTION (EC-2)

Two scenarios for reopening the Little Daisy Adit are presented below, one assuming an easy access to the interior plug station location, and one assuming the access is difficult. Once access to the interior plug site is gained, tasks required for site preparation, plug construction, grouting, backfilling, and site clean-up and reclamation are identical to those described for Alternative EC-1 and are not repeated here.

❖ *EASY ACCESS SCENARIO*

- *Engineering:* Prior to commencing work, a general scoping of the portal site will be completed to determine the most effective means of reopening the portal, maintaining portal stability, and disposing of water during the reopening and construction phases of work. An assessment of the portal site will be made to establish the original sill and back locations prior to disturbing the site. A suitable sediment retention pond will be designed. After the portal is reopened, the best method of clearing debris from the drift and supporting the drift will be selected.

- *Site preparation:* If necessary, topsoil would be stripped from the site and stockpiled. A lay-down area will be leveled and prepared for equipment set-up. A muck storage pad will be constructed adjacent to the portal site. A sediment retention pond sufficient to contain sediment generated by surges of water produced during the portal and drift reopening will be excavated and bermed using fill material from the excavation. Water from the portal and muck storage pad will be ditched or piped to the sediment retention pond. Once cleared of sediment, water from the retention pond would be discharged to natural drainage channels.

- *Portal Reopening:* Using a hydraulic excavator, the portal will be gently excavated to the original sill elevation. The portal integrity will be maintained with bolts, mesh, or timbers as necessary. If water is dammed-up behind the portal, the dam will be excavated in stages to minimize water surges or alternatively water may be pumped from behind the dam. The excavator is expected to be able to clear the portal and few feet inside the portal.

- *Drift mucking and ground support:* Using a small mucker or a slusher, all debris will be removed from the sill of the drift and placed on the muck storage pile. Steel and wood will be separated from the rock and mud. Ground stability will be maintained by a combination of scaling, bolting, screening, or timbering. Underground utilities will consist of compressed air and water hoses for drilling, and a vent bag for ventilation.

❖ *DIFFICULT ACCESS SCENARIO*

The tasks required under the difficult access scenario for Alternative EC-2 are the same as those described above for the easy access scenario, with the exception of the Drift Mucking and Ground Support Task described below.

- *Drift mucking and ground support:* Using a small mucker or a slusher, all debris will be removed from the sill of the drift and placed on the muck storage pile. Steel and wood will be separated from the rock and mud. Ground stability will be maintained by a combination of scaling, bolting, screening, or timbering. Underground utilities will consist of compressed air and water hoses for drilling and vent bag. This access scenario anticipates more extensive mucking and ground support requirements than the easy access scenario. The drift may have considerable sloughed and caved sections that needs to cleared over substantial distances and the drift may need to be cleared significantly beyond 250 feet to permit the high pressure plug to be located in competent rock.

7.4.2.2 EFFECTIVENESS (EC-2)

The Little Daisy mine is currently inaccessible, but the workings are long enough to effectively close the mine with a two plug system if it can be reopened. Cement plugs to stop water flow are commonly used in a variety of water retaining structures including dams and mines. The Glengarry Mine has had cement plugs installed along its workings that have effectively reduced and seasonally eliminated water

flow from the portal. Historically, plugs that have been installed too near the portal have failed over time as the hydrostatic head behind the plug has risen to a level sufficient to force water through fractures, bypassing the plug, and forcing water to exit the mine at the portal or elsewhere. The use of two plugs located at distances of 18 and 76 meters (60 and 250 feet) from the portal provides redundancy and sets the plugs far enough back into the mine to overcome these problems. In addition, the use of two plugs allows the inboard plug to hold most of the hydrostatic head behind it, thereby minimizing the hydrostatic head on the near-surface, or outer, plug.

Alternative EC-2 addresses the problem of high head behind the inboard plug in the adit by installing a plug 76 meters (250 feet) back in the tunnel in a zone of relatively higher competency rock than near-surface rock. It is envisioned that plugs would be set in intrusive breccia in the Little Daisy Mine which is likely to be fairly competent at this depth, where the surrounding rock is tight and the hydrostatic head will not be large enough to force water to the surface through fractures. The mine is not likely to generate very large hydrostatic heads behind the innermost plug. The difference in elevation between the portal of the Little Daisy Mine and the top of Henderson Mountain is about 122-152 meters (400-500 feet).

A second plug will be placed about 18 meters (60 feet) in from the portal as a backup to the first plug and would allow water to be redirected into adjacent fractures at a lower pressure than those generated behind the inboard plug. Water will seek pre-mining routes as a preferred flow pattern rather than having water exiting the portal.

Many of the detailed items concerning effectiveness discussed under Alternative EC-1 apply directly to this Alternative EC-2. Alternative EC-2 meets the RAOs for minimizing or preventing contaminants dissolved in water from the mine from entering surface water in the vicinity of Miller Creek by constructing two barriers to water movement through the adit, which in turn reduces risk to human health and the environment. The use of a cement or conventional backfill on either side of the plug provides long-term ground stability in the vicinity of the plug, thereby protecting the plugs in the event nearby sections of the mine collapse in future years.

One primary difference between the two alternatives is the analysis of compliance with ARARs, as the adits closed under this Alternative EC-2 have different loading characteristics than the two adits addressed by Alternative EC-1. Compliance with surface water quality ARARs can be largely achieved under Alternative EC-2 if the discharge is eliminated. In Miller Creek, the receiving water for the Little Daisy discharge, surface water aquatic standards are currently being met at the nearest downstream monitoring station except for copper. Exceedances of the copper standards in Miller Creek are partially associated with the suspended sediment load from sources that include the Daisy Pass road and the west flank of Henderson Mountain in addition to any concentrations associated with the Little Daisy discharge.

Groundwater quality will not likely be improved by implementation of this alternative, although, with the exception of iron and manganese, groundwater in the Miller Creek drainage in the vicinity of the adit complies with groundwater standards.

7.4.2.3 IMPLEMENTABILITY (EC-2)

Reopening inaccessible closed mines may or may not be successful, and is rife with uncertainty. Because underground conditions are unknown, implementability of this alternative may be extremely difficult, and successful reentry of the mines may not be accomplished. Extensive caving behind the collapsed portal may be present, requiring intensive ground support measures before the workings are stabilized.

If the collapsed workings can be made accessible to the plug sites, implementability of the alternative would be similar as that described for Alternative EC-1. Numerous abandoned underground mines have been reopened, and portal and drift plugs have been previously installed to stem the flow of water from adits in underground mines, including the Glengarry Mine. As with Alternative EC-1, the greatest technical difficulty with Alternative EC-2 is pumping cement to the plug sites. This will be accomplished by pumping cement from the portal site through a pipeline installed in the adit workings. Pumping cement over these distances is not too difficult as long as the piping system is capable of withstanding the pressures generated by pumping the cement. Cement has been pumped over distances of as much as 152 meters (500 feet) in the Glengarry Adit. Bulkheads capable of holding back the cement in the plug stations are routinely constructed of timbers and steel I-beams. Alternative EC-2 is both implementable and technically feasible.

7.4.2.4 COST (EC-2)

A cost estimate for closure with a two plug system as described in Alternative EC-2 with an easy access scenario is summarized in **Table 7-2**; the cost for a difficult access scenario is summarized in **Table 7-3**. A detailed cost breakdown is provided in **Appendix D**. The cost to plug any one of the three adits is a function of the difficulty in opening the adit for access to the plug sites.

TABLE 7-2
COST ESTIMATE SUMMARY
PLUGGING AN INACCESSIBLE ADIT (ALTERNATIVE EC-2) WITH EASY ACCESS

Mobilization/Demobilization	$ 80,000
Reclamation	$ 20,000
Equipment	$ 197,307
Materials, Supplies, Fuel	$ 118,213
Labor	$508,200
Contingency (15%)	$ 92,372
Subtotal	**$1,016,092**
Engineering Evaluation and Design (5%)	$ 50,805
Construction Oversight (8%)	$ 81,287
TOTAL	**$1,148,184**

TABLE 7-3 COST ESTIMATE SUMMARY PLUGGING AN INACCESSIBLE ADIT (ALT. EC-2) WITH DIFFICULT ACCESS	
Mobilization/Demobilization	$ 80,000
Reclamation	$30,000
Equipment	$ 256,787
Materials, Supplies, Fuel	$ 131,213
Labor	$ 676,200
Contingency (15%)	$ 117,420
Subtotal	**$1,291,620**
Engineering Evaluation and Design (5%)	$ 64,581
Construction Oversight (8%)	$ 103,330
TOTAL	**$1,459,531**

7.5 ANALYSIS OF WATER TREATMENT CONTROL ALTERNATIVES

This section presents the detailed analysis of water treatment control alternatives listed in **Table 6-1**. The various water sources typically contain several metal species, not all of which are amenable to treatment by the same technology. For example, anaerobic bioreactors can be very effective for removing cadmium, copper, iron, lead, nickel, and zinc from solution via the formation of metal sulfides. In contrast, manganese is not removed as effectively because manganese is mobile under reducing conditions (as Mn^{2+}) and does not readily react with sulfide to form a solid phase species. Therefore, in this section, treatment trains incorporating more than one of the technologies described in Section 6.0 are evaluated as complete systems that are capable of treating the entire suite of metals in a particular discharge. The source groups and the range of alternatives appropriate to each of the discharges are summarized in **Table 7-4**.

As discussed in Section 6.1.4, the treatment technologies evaluated can be divided into two groups based on whether they require ongoing active operation and maintenance or are passive or semi-passive systems. When multiple treatment technologies have been assembled into treatment trains to remove multiple metals, technologies from within one of the broadly defined groups (i.e., active or passive) have been combined. Conventional water treatment technologies could likely be assembled to treat all discharges to the imposed standards, but only at a significant cost, including both capital and long-term operation and maintenance. Passive treatment systems may not be able to meet all the aquatic standards for all metals but would require substantially less capital and long-term operation and maintenance costs.

The water treatment technologies require a brief discussion of cost analysis that clarifies the items considered and not considered in generating the cost analysis. The following cost items were considered:

- Direct Capital Costs - construction costs (materials, labor, profit)
- Indirect Capital Costs – a percentage of the direct capital costs that includes the following: treatment testing (10%); engineering and design (10%); contingency (25%); and mobilization/demobilization (10%).

- Operation and maintenance – The 20-year present worth of operation and maintenance was calculated assuming an annual discount rate of four percent. Operation and maintenance included labor, reagents, heat/power, residual disposal, and road maintenance, and in some cases, replacement of the system.

Several items that may have an effect on the actual implementation cost of the alternatives were not included in the cost estimates. **Typically, omission of these cost items would not affect the comparative analysis of the alternatives but would affect the actual implementation cost**. The assumptions used in defining the alternative for cost estimating purposes are listed below.

- Treatment systems were designed for average or median flows. Flows from most sources are known to vary seasonally, but the amount of flow data available is limited. Actual remedy implementation would require consideration of peak flows through capacity over-design, flow equalization ponds or tanks, or peak flow diversions. Cost estimates did not consider any of these features.

TABLE 7-4
WATER TREATMENT ALTERNATIVES EVALUATED FOR NEW WORLD DISTRICT DISCHARGES

Treatment Process	McLaren Pit cap drains	Little Daisy Adit	Gold Dust Adit [1]	Henderson Mt Adit	Henderson Mountain Dump 7
Group	**1**	**2**	**3**	**4**	**5**
Median Flow (gpm)	23	8.5	3.6	8.5	1.4
pH	2.6	6.9	6.8	5.8	6.7
Alternative WT-1: Infiltration	✓	✓	✓	✓	✓
Alternative WT-2: Anaerobic Bioreactor (SSBR or LSBR), Limestone Matrix Incorporation/Sodium Hydroxide Additions, and open limestone channel (OLD)	✓				
Alternative WT-3: Anaerobic Bioreactor (SSBR or LSBR), and open limestone channel		✓		✓	✓
Alternative WT-4: Manganese Removal Cell			✓		
Alternative WT-5: Chemical Addition, Precipitation & Micro-filtration	✓	✓	✓	✓	
Alternative WT-6: Ion Exchange					✓

Note 1 Gold Dust flow and pH data are the most recent post-borehole plugging data from September 2008

- Specific location and topography were not considered. It is understood that the sources are in remote, mountainous locations, which would make implementation and operation of a selected remedy more expensive. However, these factors would apply to all alternatives evaluated for a particular source, and therefore would not significantly affect the comparative analysis.
- Road construction/access improvements were not included. Some level of access improvement would be required for the implementation and operation of selected remedies regardless of which alternative(s) is selected. Road maintenance and snow plowing was included for alternatives requiring year-round access.
- Duplication of treatment components was not included. Implementation of a selected treatment system may require a "dual-train" system, where two side-by-side systems would be installed. This would allow continued operation during breakdown or maintenance, and adjustments or further testing in the case of some of the technologies that are not fully developed.
- Monitoring was not included. Some level of monitoring would likely be required as a part of the operation and maintenance for the implemented remedies. Assuming that the level of monitoring would be similar between the various alternatives, this omission would not affect the comparative analysis.

7.5.1 Alternative WT-1: Infiltration

Infiltration is considered by itself or in conjunction with other alternatives for closure of all adit discharges (not subsurface drains) in Groups 1 through Group 5. Flow sources would simply be rerouted from surface to subsurface, enhancing the potential for dilution and natural biogeochemical, chemical, and physical reactions to attenuate the migration of COCs. Non-degradation analyses would need to be prepared prior to construction for any site where Alternative WT-1 is selected.

A subsurface drain field would be constructed using gravel-bedded perforated pipe. If selected for implementation, the drain field would be sized to fit the flow volume and contaminant level concentrations such that non-degradation requirements would be met through use of a mixing zone. The drain fields would be covered with a 0.6-meter (two-foot) thick soil layer to protect from freezing. It has been assumed that the system would require replacement every 20 years due to plugging with metal precipitates.

7.5.1.1 Effectiveness (WT-1)

Implementation of Alternative WT-1 meets one of the RAOs for the project by minimizing or preventing contaminants dissolved in water from directly entering surface water in either Miller Creek or Fisher Creek, and protects human health and wildlife from direct contact and ingestion risks. Dilution and natural attenuation processes occurring in the subsurface are likely to be effective at reducing the already low metals concentrations from Group 5 discharges and variably effective for other group sources**.**

❖ *Long-Term Effectiveness and Permanence, and Short-Term Effectiveness*

Because the inherent buffering capacity of the soils is unknown, long-term effectiveness may be limited and will be dependent to some extent on the distance between the discharge and the receiving surface water body. Given sufficient distance for natural attenuation reactions to occur, and mass of organic and inorganic material to interact with, it is likely that this option could provide long-term treatment for

these low flow discharges. Replacement of the gravel infiltration basin may be required in the future if minerals deposit in interstitial spaces and constrict water flow through the gravel.

The number of construction workers, equipment, and supplies needed to construct the alternative is small; construction of the alternative can be completed in a matter of days or weeks and is not expected to have a noticeable effect on local services or roads in the surrounding area.

- *COMPLIANCE WITH ARARS*

A list of ARARs is presented in **Appendix C**. Compliance with surface water quality ARARs may not be achieved under Alternative WT-1. While surface discharges will be eliminated during most of the year, some discharge to surface water may occur before attenuation of contaminants is complete. Complete removal of the relatively small contaminant loads associated with the Group 2, 3, 4, and 5 discharges will likely not be measurable in Miller Creek and Fisher Creek nor would complete removal of Group 1 discharges improve water quality in Daisy Creek to meet DEQ-7 standards. The Little Daisy and Henderson Mountain adits currently do not directly discharge to Miller Creek and the Henderson Mountain Dump #7 adit does not currently directly discharge to Fisher Creek. Fisher Creek surface water aquatic standards are not being met currently due to other sources of metals.

Groundwater quality will not likely improve under this alternative, although, with the exception of iron and manganese, groundwater in Fisher and Miller Creeks comply with groundwater standards both in shallow alluvial and bedrock aquifers. Iron and manganese are ubiquitous throughout the district and their concentrations are believed to be partially controlled by natural bedrock sources. Contaminant-specific ARARs for ambient air will be met under this alternative, as air quality would not be affected by construction operations.

Location-specific ARARs, particularly those associated with cultural and historic resources will be met, as no cultural or historic resources will be impacted by the implementation of this alternative. Threatened and endangered species present in or near the District may be affected by the activities associated with implementing this alternative in the short-term, but it is not likely that these species will be adversely affected, as there will be no new disturbances, no permanent facilities, and implementation of the alternatives 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 demonstrating compliance with non-degradation requirements will be met including submittal of non-degradation analyses for any site where Alternative WT-1 is selected. Requirements for groundwater protection will be met by Best Available Technologies (BATs). Action-specific State of Montana air quality regulations related to dust suppression and control during construction activities will be met by using Best Management Practices (BMPs).

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

Contaminant mobility will be reduced by Alternative WT-1, and toxicity may be reduced through natural attenuation processes. There will be no reduction in discharge volume through treatment.

7.5.1.2 IMPLEMENTABILITY (WT-1)

This alternative is implementable and feasible given that adequate area with a sufficient depth of soil above the water table or bedrock is available. If soil depths are insufficient, imported soil can be used.

Construction is straight-forward using readily available materials and equipment. Operation and maintenance is minimal, excepting periodic replacement. A two-foot burial depth should provide sufficient frost protection given the deep snow pack in the area. Additional testing of infiltration rate and buffering capacity would provide for design optimization.

7.5.1.3 COST (WT-1)

A cost estimate to implement the infiltration alternative (WT-1) at a single site is provided in **Table 7-5**; detailed costs are provided in **Appendix D**.

TABLE 7-5
CAPITAL AND OPERATIONAL COST ESTIMATE SUMMARY FOR ALTERNATIVE WT-1

Infiltration	
Direct Capital Costs	$9,201
Indirect Capital Costs	$7,361
O+M Costs (Present Worth)	$4,536
TOTAL	**$21,097**

7.5.2 Alternative WT-2: Anaerobic Bioreactor with Limestone Matrix Incorporation/Sodium Hydroxide Additions,, and Open Limestone Channel

Alternative WT-2 primarily relies on metal removal as sulfides in a liquid- or solid-reactant sulfate-reducing bioreactor (LSBR or SSBR followed by an open limestone channel (OLD). Previous versions of this EE/CA (Tetra Tech, 2006) described a treatment system that utilized an aerobic limestone drain (ALD) to pre-treat discharge upstream of the bioreactor. Upon further review in response to comments, it was decided that the ALD would not be effective at some sites and an alternative design was suggested (Tetra Tech, 2008).

In lieu of the ALD, limestone would be added to the solid- or liquid-reactant matrix to generate alkalinity and raise the pH. This allows for pH adjustment and metal precipitation yet avoids armoring by aluminum and iron hydroxides that typically reduce the effectiveness of aerobic limestone drains because the area for precipitation is distributed throughout the reactor rather than allowing precipitation to occur primarily at the location of the inlet pipe. In the case of a LSBR, additional pH control is afforded by the injection of sodium hydroxide to into the influent water upstream of the bioreactor and the resulting iron and aluminum precipitates formed are allowed to settle out of suspension in a settling pond prior to flowing through the bioreactor. The effluent from either type of bioreactor is also sent to an oxic limestone channel/aeration cell for removal of residual manganese, aluminum, soluble organics, nitrogen compounds, and sulfides.

This alternative is applicable for treatment of Group 1 discharges (the McLaren Pit Cap subsurface drains), which are acidic to circum-neutral in pH and contain multiple metals that exceed standards.

Figure 41 illustrates one possible configuration of the two component system using the solid-reactant sulfate reducing bioreactor. A treatment train employing the liquid-reactant sulfate reducing bioreactor would be designed very much the same, although the entire bed would be filled with a mixture of gravel and limestone and the liquid organic substrate would be added to the influent mine water. A sodium

hydroxide injection station would be built upstream of and separated from the bioreactor by a settling pond where iron and aluminum precipitates would settle out of solution before the influent entered the bioreactor.

For design parameters, the following general assumptions are made for either type of substrate bioreactor (SSBR or LSBR):

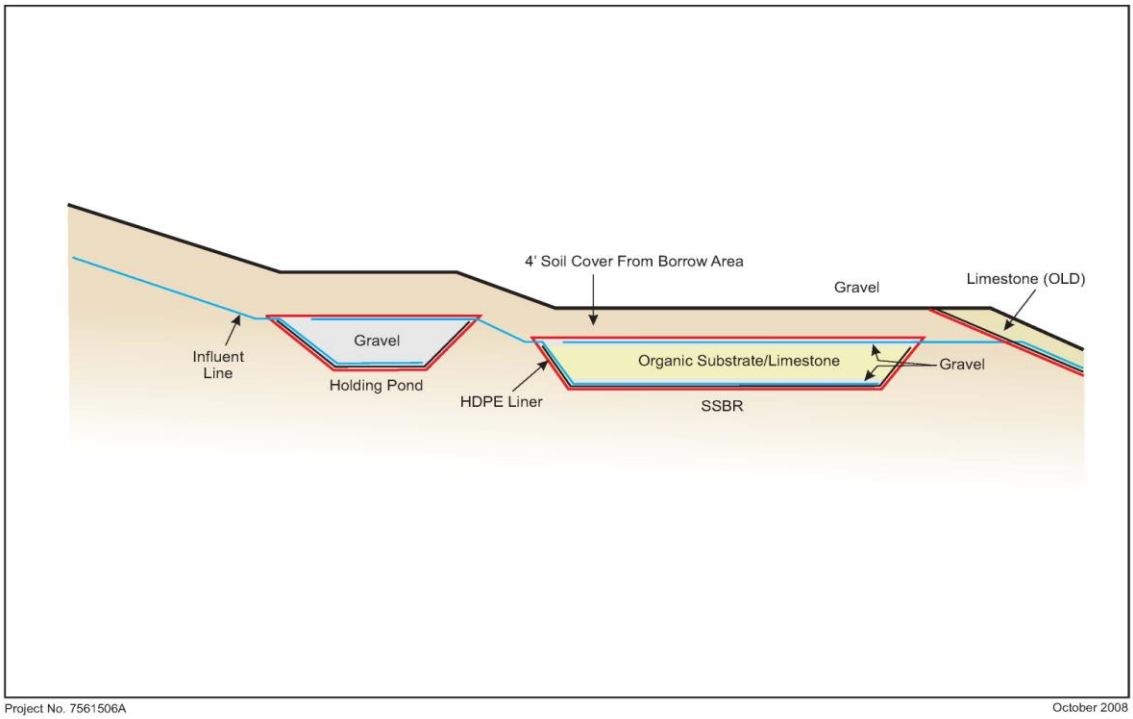
- All bulk fill materials are delivered directly to the site,
- Subsurface drain flows are combined at the existing discharge locations and piped downhill to the holding pond for the SBR,
- System flow rate is 22 gpm based on combined mean flow data,
- A geotextile will cover the holding pond and SBR to minimize infiltration of runoff, precipitation and snowmelt and to minimize oxygen infiltration,
- The holding pond, SBR and oxic limestone drain are lined with geotextile to minimize water loss,
- The holding pond hydraulic retention time is 24 hours at design flow,
- The holding pond will be filled with geochemically inert gravel so that pond can be buried,
- The holding pond and SBR will be buried and covered with 4 feet of soil to minimize freezing,
- Soil cover for the holding pond and SBR will be obtained locally, perhaps from the borrow area,
- The system would not require maintenance and sampling would be unnecessary during the winter weather months,
- Conservation of mass upon mixing of the drains is assumed.

In addition the assumptions listed above, it is also assumed that bench and pilot scale testing of the selected bioreactor system would be conducted prior to full-scale build-out.

The liquid-reactant bioreactor is considered a semi-passive treatment system requiring the addition of alcohol or other nutrient to fuel bacterial respiration; therefore, this system would require some level of maintenance. The alcohol would be stored in a heated shelter and metered directly into the influent line just upstream of the liquid-reactant sulfate reducing bioreactor. In contrast, a solid-reactant sulfate reducing bioreactor would require no ongoing operations and maintenance, but recent literature has suggested that solid-substrate bioreactors have not been effective for ARD treatment for more than about 3 to 5 years and therefore may need to be replaced more often (URS, 2003). For this evaluation, we have assumed a treatment life of 5 years for the SSBR and 15 years for the LSBR.

7.5.2.1 EFFECTIVENESS (WT-2)

Solid-reactant sulfate reducing bioreactors and LSBRs are able to treat metals-contaminated water to low concentrations (Tsukamoto, Miller et al. 1999; URS, 2003). However, full-scale liquid-reactant treatment systems have only been implemented at a few sites (e.g. the Leviathan Mine in California [URS, 2003] and the Hollister Mine in Nevada); therefore, a significant amount of testing would be required before a full-scale design could be completed. If testing proves the system successful, RAOs and overall protectiveness of human health and the environment would be met by this alternative at the sites.



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October 2008

Figure 41

Solid Substrate Bioreactor (SSBR) Schematic
Holding Pond-Oxic Limestone Drain (OLD)

Long-Term Effectiveness and Permanence

Long-term reliability of this system is unknown. However, given the high concentrations of aluminum (Al^{3+}), iron ($Fe^{3+/2+}$), and sulfate (SO_4^{-2}) in the combined McLaren under drain flows, Alternative WT-2 would likely have short- to medium-term effectiveness.

Open limestone channels can be subject to decreasing effectiveness due to limestone armoring with iron and/or aluminum oxy-hydroxides. However, recent experiments have demonstrated that coated limestone continues to dissolve at a significant rate, and that armored limestone was 50 to 90% as effective as unarmored limestone in neutralizing acid (Ziemkiewicz, Skousen et al., 1997). The length of the channel and the gradient, which affects turbulence and build up of coatings, are design factors that can be varied to optimize performance. Optimum performance appears to be attained with slopes greater than 20% where flow velocities keep precipitates in suspension and clean solids from limestone surfaces. A secondary concern for open limestone channels is the very cold temperatures in the District and presence of a considerable amount of snowpack -- typically in the range of 4.5 to 7.5 meters (15 to 25 feet). It is assumed that the open limestone channel would need to be over-designed to allow for some amount of freezing at the surface while providing protection for subsurface flow.

The liquid-reactant sulfate reducing bioreactors have several advantages over the solid-reactant sulfate reducing bioreactors, with better control of the reaction rate and constant permeability. A disadvantage of the solid/liquid sulfate reducing bioreactor system is that it is semi-passive and requires critically applied operation and maintenance activities. This includes a building that would be heated year-round using a generator fueled by diesel or gasoline, and delivery of reagents year-round to the site which would require plowing the Daisy Pass and Lulu Pass roads or making deliveries of fuels and reagents in the winter with a snow cat or other large, over-the-snow equipment.

- *SHORT-TERM EFFECTIVENESS AND REDUCTION IN MOBILITY, TOXICITY, AND VOLUME THROUGH TREATMENT*

Short-term impacts resulting from construction are not expected to impact local services or roads in the surrounding area, as the number of construction workers, equipment, and supplies needed to construct the system would only be a minor addition to the current level of use. Construction of the alternative could be completed in one construction season, although weather conditions may require more than one season to complete all work for the system. Shipments of reagents will occur several times per year, and every few years increased activity will be required to fully replace reactants in the bioreactor. Periodic maintenance will also be required.

Alternative WT-2 will substantially reduce contaminant volume, mobility, and toxicity through treatment.

- *COMPLIANCE WITH ARARS*

Compliance with surface water quality ARARs (**Appendix C**) can be fully achieved under Alternative WT-2. Treatment of the discharges will result in effluent that meets aquatic standards. Complete removal of the McLaren Unit contaminant load should result in a substantial change in water quality at station DC-2 in Daisy Creek, as the McLaren Pit subsurface drains contribute as much as 93% of the iron load and a substantial amount (as much as 32%) of the remaining contaminants during low flow conditions. However, surface water quality in Daisy Creek will not meet B-1 standards, as other sources are present that would cause water quality exceedances to persist. Iron and manganese are ubiquitous throughout the district and their concentrations are believed to be partially controlled by

natural bedrock sources. Contaminant-specific ARARs for ambient air will be met under this alternative, as air quality would not be affected by construction operations.

Location-specific ARARs, particularly those associated with cultural and historic resources will be met, as no cultural or historic resources will be impacted by implementation of the alternative. Threatened and endangered species present in or near the District may be affected by the activities associated with implementing this alternative. The alternative requires a facility at each site and year-round operations that could disturb threatened and endangered species movements and distribution, particularly during the winter months. Regular operations and maintenance through the winter will also substantially change winter access on the Daisy Pass and Lulu Pass roads because the roads may require plowing unless large, over-the-snow equipment is used. While the level of traffic involved with operation and maintenance activities is expected to be within the level of traffic currently associated with recreational use of the area, plowing these roads may change migration patterns for area wildlife, with potential impacts to the grey wolf. 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 treated water will meet surface water aquatic criteria. Action-specific State of Montana air quality regulations related to dust suppression and control during construction activities will be met by using Best Management Practices (BMPs).

7.5.2.2 IMPLEMENTABILITY (WT-2)

Construction of the anoxic limestone drain, SSBR/LSBR, and open limestone channel components are implementable and the treatment process is feasible. Construction is straight-forward using readily available materials and equipment. However, the construction season is short, and this may cause difficulties in completing the system in one season. The systems require a fairly large area to construct (about 0.41 hectares or one acre) for the combined flows of McLaren under drains. Access to the site for delivery of reagents would be difficult during the winter due to deep snow.

7.5.2.3 COST (WT-2)

The cost estimate presented in **Appendix D** presents the estimated construction cost for an Alternative WT-2 treatment system. Line item costs include reagent storage and delivery system (liquid-reactant sulfate reducing bioreactor only), and an open limestone channel. Operations and maintenance costs include operating labor, reagents, snow plowing, road maintenance, and complete replacement of the solid-reactant sulfate reducing bioreactor every five years and replacement of the liquid-reactant sulfate reducing bioreactor every 15 years (**Table 7-6**). Year-round access and labor have been included in the liquid-reactant sulfate reducing bioreactor cost estimate, only. As shown in **Table 7-6**, estimated costs for the liquid-reactant sulfate reducing bioreactor are similar to the solid-reactant sulfate reducing bioreactor for the combined McLaren under drains. These costs do not include expenses for bench or pilot-scale testing of either system. Costs for this alternative in the final EE/CA (this document) were revised based on agency and public comments to the draft EE/CA (Tetra Tech 2006).

TABLE 7-6
CAPITAL AND OPERATIONAL COST ESTIMATE SUMMARY FOR ALTERNATIVE WT-2

Anoxic Limestone Drain/Sulfate Reducing Bioreactor/ Open Limestone Channel - McLaren Under Drains		
	Solid Reactant	**Liquid Reactant**
Direct Capital Costs	$546,202	$1,197,660
Indirect Capital Costs	$274,533	$500,009
O+M Costs (Present Worth)	$1,634,567	$613,504
TOTAL	**$2,455,301**	**$2,311,173**

7.5.3 Alternative WT-3: Anaerobic Bioreactor (solid-reactant sulfate reducing bioreactor or liquid-reactant sulfate reducing bioreactor)-open limestone channel

Alternative WT-3 is equivalent to that described for Alternative WT-2 with the exception that no additions of limestone or sodium hydroxide are made. This configuration is applicable for treating water in discharges from the Little Daisy Adit, Henderson Mt Adit, and the Henderson Mountain Dump 7. These flows have a pH that is near-neutral, metals amenable to sulfide precipitation, and contain aluminum and/or manganese above the aquatic standards or human health guidelines.

7.5.3.1 EFFECTIVENESS (WT-3)

Solid-reactant sulfate reducing bioreactors and liquid-reactant sulfate reducing bioreactors are able to treat metals-contaminated water to low concentrations (URS, 2003; Tsukamoto and Miller, undated; MFG, Inc, undocumented project experience). Because Alternative WT-2 and WT-3 are very similar, the discussion of short and long-term effectiveness contained in the previous section for Alternative WT-2 is applicable to Alternative WT-3.

7.5.3.2 IMPLEMENTABILITY (WT-3)

The solid-reactant sulfate reducing bioreactor/liquid-reactant sulfate reducing bioreactor-open limestone channel system components are implementable and the treatment process is feasible. Construction is straight-forward using readily available materials and equipment. However, the construction season is short. Access, including delivery of reagents, would be difficult during winter weather due to the deep snow. The liquid-reactant sulfate reducing bioreactors have several advantages over the solid-reactant sulfate reducing bioreactors, including control of the reaction rate and constant permeability. A disadvantage of the liquid reactant is that it requires more operation and maintenance costs.

7.5.3.3 COST (WT-3)

Cost estimates were prepared assuming a SSBR with a 32 Lpm (8.5 gpm) capacity is needed for the Little Daisy and Henderson Mountain adits, and a solid-reactant sulfate reducing bioreactor with a 5 Lpm (1.4 gpm) capacity is needed for the Henderson Mountain Dump #7 Adit. The cost estimate includes construction cost of the treatment systems with line items for the solid-reactant sulfate reducing bioreactor and open limestone channel. Operations and maintenance costs include complete solid-reactant sulfate reducing bioreactor replacement every five years except at the Henderson Mtn.

Dump 7 site where replacement every 10 years has been assumed to be sufficient. **Table 7-7** summarizes costs associated with this alternative; a detailed breakdown of cost is provided in **Appendix D**. Costs for this alternative in the final EE/CA (this document) were revised based on agency and public comments to the draft EE/CA (Tetra Tech 2006).

TABLE 7-7
CAPITAL AND OPERATIONAL COST ESTIMATE SUMMARY FOR ALTERNATIVE WT-3

Anaerobic Bioreactor (Solid-Reactant Sulfate Reducing Bioreactor) and Open Limestone Channel		
	Little Daisy and Henderson Mtn. Adits (8.5 gallons per minute)	**Henderson Mountain Dump #7 Adit (1.4 gallons per minute)**
Direct Capital Costs	$164,716	$35,176
Indirect Capital Costs	$90,594	$19,347
O+M Costs (Present Worth)	$544,276	$58,963
TOTAL	**$799,585**	**$113,486**

7.5.4 Alternative WT-4: Manganese Removal Cell

Manganese removal cells can add alkalinity and provide suitable residence time and substrate contact to allow manganese to precipitate prior to discharging to a receiving stream. This technology is appropriate for the Gold Dust adit. This discharge is circum-neutral in pH with only manganese concentrations that exceed a water quality standard, the human health guideline of 0.050 mg/L.

7.5.4.1 Effectiveness (WT-4)

Manganese removal cells have been shown to be effective for manganese removal, especially for low flows and where iron and aluminum concentrations are relatively low and limestone armoring is minimal (URS, 2003). Typically, manganese removal cells are configured as a limestone-filled pond, which presents limitations in an area with a harsh winter climate such as that in the New World District. Thus, the manganese removal cell envisioned for this site would be constructed in the shallow subsurface similar to the solid-reactant sulfate reducing bioreactor (Figure 41) except it would be filled with limestone only.

- *Long-Term Effectiveness, Permanence, Short-Term Effectiveness, and Reduction in Toxicity, Mobility, and Volume Through Treatment*

Because the manganese loads contained in the Gold Dust Adit are very low as compared to many ARD streams, there is a reasonable expectation that the system would remain effective over the long-term. A trench would be sized to allow for sufficient residence time for manganese removal via precipitation as manganese oxide ($MnO_{2)}$. The trench would be constructed below grade and covered with sufficient soil to protect from freezing, thus allowing the system to operate year round.

Alternative WT-4 will substantially reduce contaminant volume, mobility, and toxicity through treatment.

Short-term impacts resulting from construction will be minimal, as the number of construction workers, equipment, and supplies needed to construct the system are minor. Construction of the alternative can be completed in a matter of days or weeks and is not expected to have a noticeable effect on local services or roads in the surrounding area.

- *COMPLIANCE WITH ARARS*

Compliance with surface water quality ARARs should be achieved at the site where this alternative could be applied. Groundwater quality will improve only locally, in the immediate vicinity of the adit, as iron and manganese are the only contaminants that exceed groundwater guidelines in Fisher Creek. Contaminant-specific ARARs for ambient air will be met under this alternative.

Location-specific ARARs, particularly those associated with cultural and historic resources will be met, as no cultural or historic resources will be impacted by implementation of the alternative. Threatened and endangered species present in or near the District will not be affected by this alternative, as there will be only a small disturbance to install the system, the permanent facility will be buried, and construction 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 treated water will meet surface water aquatic criteria. Action-specific State of Montana air quality regulations related to dust suppression and control during construction activities will be met by using Best Management Practices (BMPs).

7.5.4.2 IMPLEMENTABILITY (WT-4)

Manganese removal cells are easily implemented and would require little to no maintenance.

7.5.4.3 COST (WT-4)

Costs for manganese removal cells, shown in **Table 7-8**, were estimated for a flow of about 49 Lpm (13 gpm) at the Gold Dust Adit (to account for higher flows associated with the snowmelt period). O & M costs are associated with replacement and disposal of the removal cell limestone about every 10 years.

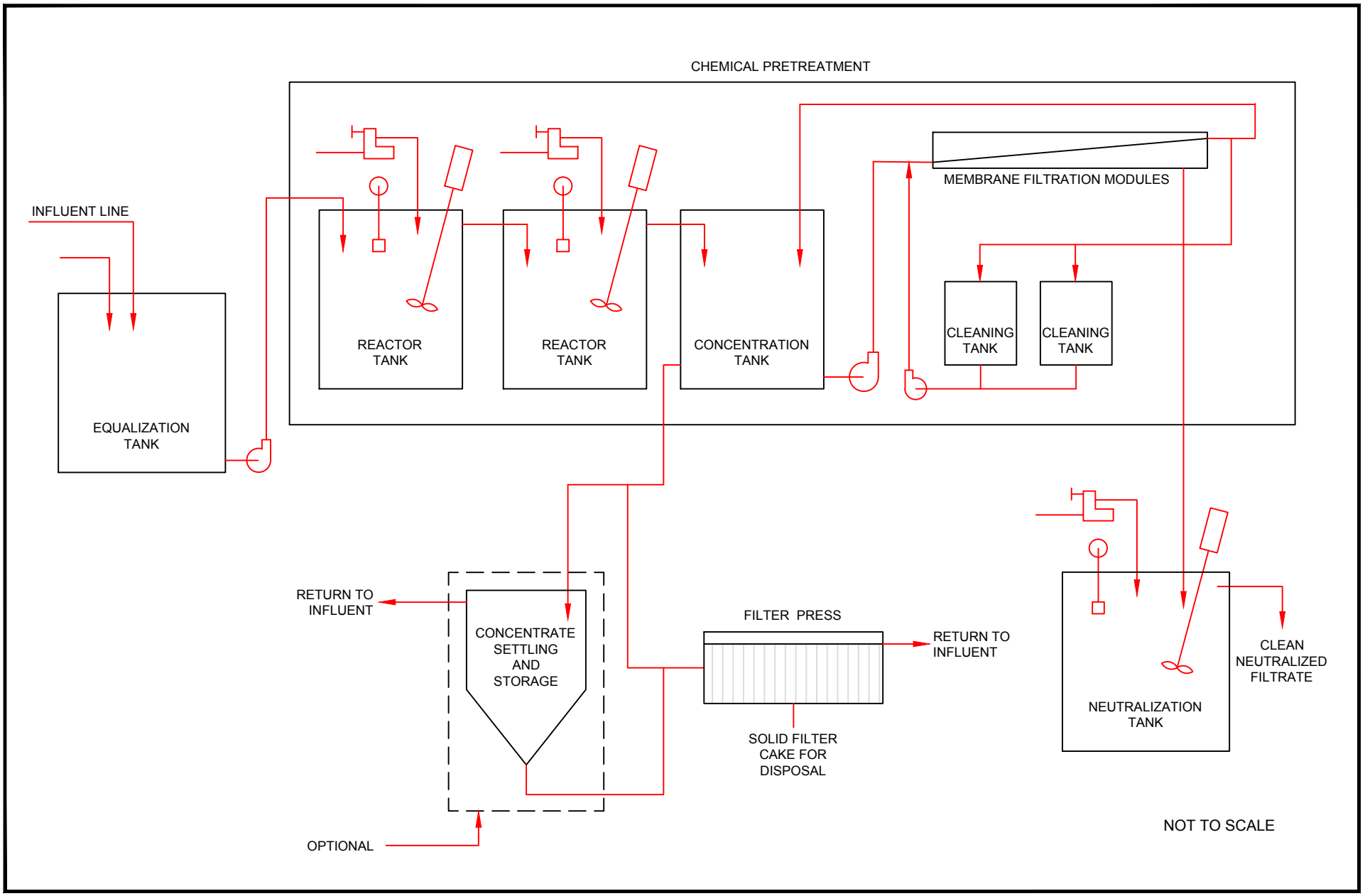
TABLE 7-8
CAPITAL AND OPERATIONAL COST ESTIMATE SUMMARY FOR ALTERNATIVE WT-4

Manganese Removal Cell	
	Gold Dust Adit (13 gallons per minute)
Direct Capital Costs	$56,250
Indirect Capital Costs	$30,937
O+M Costs (Present Worth)	$98,083
TOTAL	**$185,270**

7.5.5 Alternative WT-5: Chemical Addition, Precipitation & Micro-filtration

Active treatment for sources in Groups 1 through 4 would utilize a packaged, skid-mounted treatment system with a capacity of between 19 to 95 Lpm (5 to 25 gpm) or 95 to 188 Lpm (25 to 50 gpm), dependent on source requirements. The system would consist of pretreatment, filtration, and neutralization Figure 42). Pretreatment consists of pH adjustment to 8.5 to 9.5 s.u. that causes metal hydroxides to precipitate to a filterable size. Filtration would utilize a proprietary advanced membrane filtration system that discharges very low metal concentration filtrates. The pH would be adjusted to neutral prior to discharge. Additional studies would be required to test pretreatment and filtration scenarios to optimize operation and effluent water quality.

The system would include reagent storage and feed equipment, and sludge handling including filter press and sludge storage. The system would be powered by a diesel generator located on site. The complete treatment system would be housed in heated buildings with adequate space for reagent, fuel, sludge, and equipment storage, offices, and break and changing rooms. Assumptions for operation of the system include storage capacity for at least a one-month supply of reagents, fuel, and any consumables as well as adequate space to store one month's sludge production. The road to the site would require improvement and snow removal year-round. This would mean both the Daisy Pass and Lulu Pass roads would require plowing.



MFG, Inc.
consulting scientists and engineers

FIGURE 42
CHEMICAL ADDITION, PRECIPITATION, AND MICRO-FILTRATION SCHEMATIC

Date:	APRIL 2005
Project:	181159X
File:	MFG-SCHEM-01.dwg

Figure 42 – back page

7.5.5.1 EFFECTIVENESS (WT-5)

Treatment systems using pH adjustment and filtration are able to treat metals-contaminated water to very low concentrations at similar sites (McKenzie, 1980; Skousen, Rose et al., 1998). Further testing will be required to determine actual achievable effluent quality. Further processing by reverse osmosis may be required to meet standards for all metals, although this contingency has not been included in the cost estimate for the system. Implementing this alternative would meet RAOs and overall protectiveness of human health and the environment.

- *LONG-TERM EFFECTIVENESS AND PERMANENCE*

There will be considerable demand for short and long-term operation and maintenance to keep these systems running efficiently. Fiber optic cable, which would allow for remote system monitoring, could be installed to reduce operation and maintenance costs. This would involve installing cable from a station located in Cooke City to the site. The cost to install such a system has not been included in this analysis. Excluding this type of infrastructure investment, it is probable that routine site visits (possibly daily) will be required to ensure effective system operation. It is also assumed that monthly deliveries of fuel (diesel for the electrical generator and propane for the heating system) will be required along with monthly trips to deliver chemicals and remove sludge. It would be possible to extend the time between deliveries, but this would involve increasing storage capacity and the size of associated infrastructure.

The very cold temperatures and deep snow pack characteristic of the District may impact overall system effectiveness and assumptions for long-term operations and maintenance. Any disruption of power and/or heat generation could cause significant damage to the system and require additional expenditures for system maintenance beyond what has been assumed for this analysis. Long-term effectiveness critically depends on continual monitoring and maintenance of the system and the system will have to be operated in perpetuity.

- *SHORT-TERM EFFECTIVENESS AND REDUCTION IN MOBILITY, TOXICITY, AND VOLUME THROUGH TREATMENT*

Short-term impacts resulting from construction are not expected to have a major impact on local services or roads in the surrounding area, as the number of construction workers, equipment, and supplies needed to construct the system would be a nominal addition to the current level of use. Construction of the alternative could be completed in one construction season, although weather conditions may require more than one season to complete all work for the systems. Shipments of fuel and reagents will occur monthly, and this requirement will severely affect the recreational snowmobile use of the Daisy Pass and Lulu Pass roads.

Alternative WT-5 will substantially reduce contaminant volume, mobility, and toxicity through treatment.

- *COMPLIANCE WITH ARARS*

Compliance with surface water quality ARARs (**Appendix C**) can be fully achieved under Alternative WT-5 for the applicable adit discharges. Treatment of the discharges will result in effluent that meets aquatic standards. Complete removal of the McLaren under drain contaminant load should result in a substantial change in water quality at station DC-2 in Daisy Creek, as the drains contribute a substantial portion of the metals load during both low and high flow conditions. An improvement in water quality in Fisher Creek could also be expected with the treatment of the Gold Dust discharge, especially with regard to iron and manganese. However, surface water quality in Daisy Creek and Fisher Creek will

likely not meet B-1 standards, as other sources are present in these headwater drainages that would allow water quality exceedances to persist.

Groundwater quality may locally improve substantially in Daisy Creek with the treatment of the McLaren subsurface drain flows. In conjunction with reduction in loading as a result of the McLaren Pit cap, contaminant loads to groundwater would be much lower than under current conditions. In Fisher Creek, reducing the load from the Gold Dust discharge may locally have a positive impact on iron and manganese concentrations in groundwater, although these two contaminants may still exceed human health guidelines for these metals. Iron and manganese are ubiquitous throughout the district and their concentrations are believed to be partially controlled by natural bedrock sources. Contaminant-specific ARARs for ambient air will be met under this alternative, as air quality would not be affected by construction operations, although exhaust from diesel generators may locally affect air quality.

Location-specific ARARs, particularly those associated with cultural and historic resources will be met, as no cultural or historic resources will be impacted by implementation of the alternative. Threatened and endangered species present in or near the District may be affected by the activities associated with implementing this alternative. The alternative requires a facility at each site and year-round operations that could disturb threatened and endangered species movements and distribution, particularly during the winter months. Regular operations and maintenance will be required through the winter, which will substantially change winter access on the Daisy Pass and Lulu Pass roads because the roads will require plowing. While the level of traffic involved with operation and maintenance activities is expected to be within the level of traffic currently associated with recreational use of the area, plowing these roads may change migration patterns for area wildlife, with potential impacts to the grey wolf. 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 treated water will meet surface water aquatic criteria. Action-specific State of Montana air quality regulations related to dust suppression and control during construction activities will be met by using Best Management Practices (BMPs).

7.5.5.2 IMPLEMENTABILITY (WT-5)

The active treatment system alternative is implementable and feasible. The treatment processes are well understood and commonly used. Packaged treatment systems are readily available. Construction is straight-forward using readily available materials and equipment. However, the construction season is short and this may require a two-season period to complete installation of the system. Access including delivery of reagents and sludge disposal would be difficult during winter weather due to the deep snow.

7.5.5.3 COST (WT-5)

The cost estimate summarized in **Table 7-9** includes construction cost of the treatment system, shelter, and support equipment. Operations and maintenance costs include operating labor, electrical power, reagents, sludge disposal, snow plowing, and road maintenance. Cost estimates are provided for a 95-189 Lpm (25-50 gpm) system and a 19-95 Lpm (5-25 gpm) system. A detailed cost breakdown is provided in **Appendix D**.

TABLE 7-9
CAPITAL AND OPERATIONAL COST ESTIMATE SUMMARY FOR ALTERNATIVE WT-5

Chemical Addition, Precipitation, and Micro-filtration		
	McLaren Pit Cap Drains (25 to 50 gallons per minute)	**Group 2, 3, and 4 Discharges Little Daisy, Gold Dust and Henderson Mt. Adits (5 to 25 gallons per minute)**
Direct Capital Costs	$665,781	$525,781
Indirect Capital Costs	$366,180	$341,757
O+M Costs (Present Worth)	$4,481,962	$2,711,782
TOTAL	**$5,513,922**	**$3,579,320**

7.5.6 Alternative WT-6: Ion Exchange

The ion exchange process as evaluated for Group 5 (Henderson Mountain Dump 7) would be a semi-active system. Such a system would typically be housed in a permanent heated structure and require nearly continuous maintenance. The system as proposed here would be placed in underground vaults for freeze protection and be gravity fed (Figure 43). Because the source water is of reasonably good water quality, the system would consist of pre-filtration (0.2 to 0.3 μm diameter pore size) and a single ion exchange vessel sized to provide at least one-year capacity.

7.5.6.1 EFFECTIVENESS (WT-6)

This alternative is capable of achieving high quality effluent meeting Circular DEQ-7 standards in the effluent stream. Bench-scale testing would be needed to determine which commercial ion exchange resins would provide the best results and to allow estimation of system capacity.

- *LONG-TERM EFFECTIVENESS, PERMANENCE, SHORT-TERM EFFECTIVENESS, AND REDUCTION IN TOXICITY, MOBILITY, AND VOLUME THROUGH TREATMENT*

Long-term effectiveness of this treatment process is expected to be good. The effectiveness of the system should be easy to monitor to determine if treatment levels are being met, and barrels could be replaced or added as needed. Long-term effectiveness critically depends on continual monitoring and maintenance of the system and the system will have to be operated in perpetuity.

Short and long-term effectiveness could be adversely affected by the very harsh climate in the area, which could potentially lead to system upset due to freezing and/or inundation during the snowmelt period. Short-term impacts resulting from construction will be minimal, as the number of construction workers, equipment, and supplies needed to construct the system are minor. Construction of the alternative can be completed in a matter of days or weeks and is not expected to have a noticeable effect on local services or roads in the surrounding area.

❖ *COMPLIANCE WITH ARARS*

Compliance with surface water quality ARARs should be achieved under Alternative WT-6. Groundwater quality will improve in the immediate vicinity of the discharge. Contaminant-specific ARARs for ambient air will be met under this alternative.

Location-specific ARARs, particularly those associated with cultural and historic resources will be met, as no cultural or historic resources will be impacted by implementation of the alternative. Threatened and endangered species present in or near the District may be affected by the activities associated with implementing this alternative in the short-term. However, it is not likely that these species will be adversely affected, as there will be only a small disturbance to install the system, the permanent facility will be buried, and construction will be completed in one season. Regular operations and maintenance will be required, but the level of traffic involved with these activities is expected to be within the level of traffic currently associated with recreational use of the area. 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 treated water will meet surface water aquatic criteria. Action-specific State of Montana air quality regulations related to dust suppression and control during construction activities will be met by using Best Management Practices (BMPs).

7.5.6.2 IMPLEMENTABILITY (WT-6)

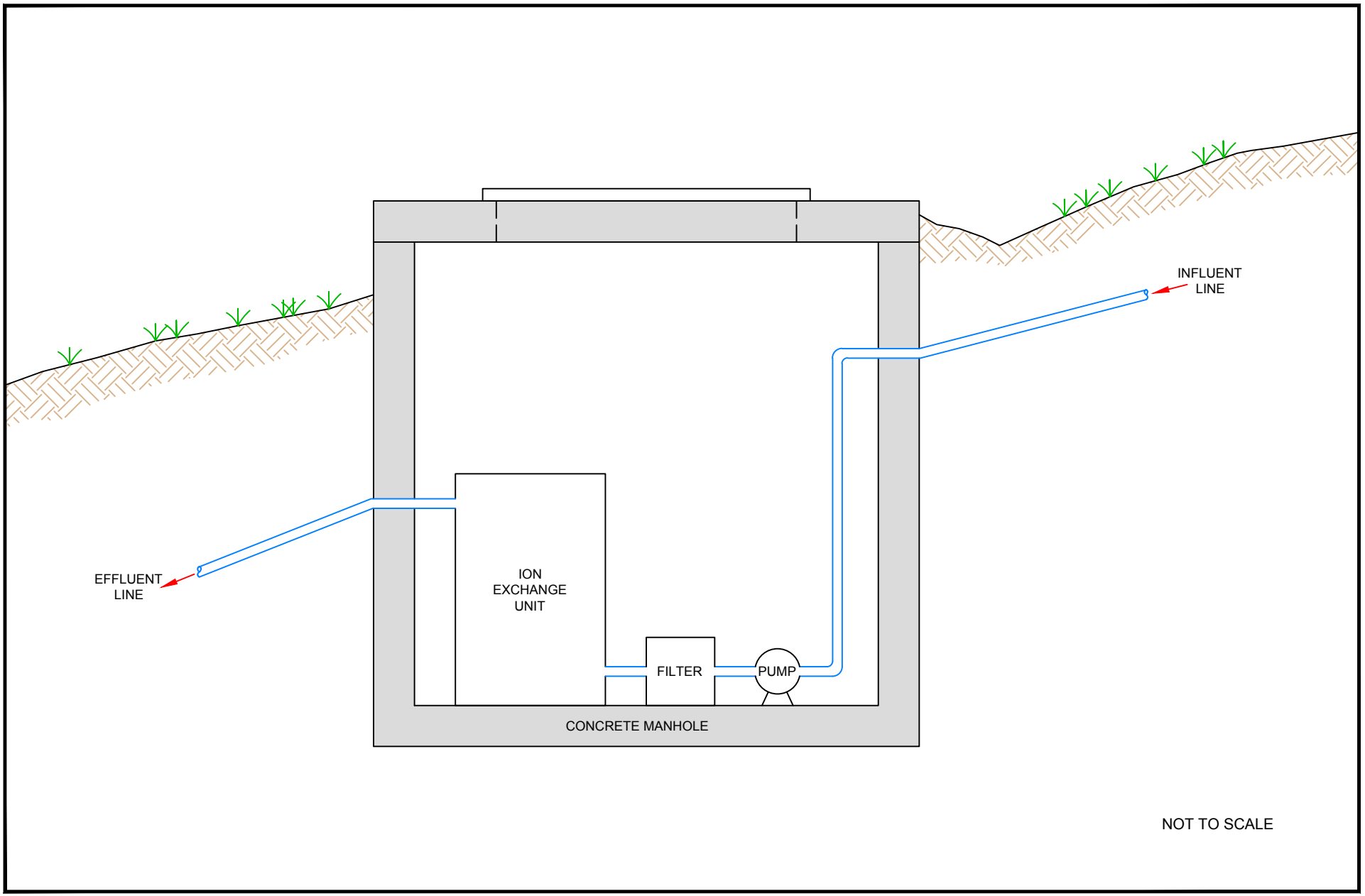
The ion exchange treatment system alternative is implementable and feasible. Packaged treatment systems are readily available and a simple system as described here could easily be constructed on site. Construction is straight-forward using readily available materials and equipment. Access would be difficult during winter weather due to the deep snow. However, if properly sized, the resin would only need to be replaced annually and could be done when weather permitted.

7.5.6.3 COST (WT-6)

The cost estimate includes flow collection system, manhole installation, and ion exchange system installation. Operations and maintenance costs include annual system replacement. Cost estimates are provided for a 9.5 Lpm (2.5 gpm) system appropriate for Group 5 sources (**Table 7-10**). A cost breakdown is provided in **Appendix D**.

TABLE 7-10
CAPITAL AND OPERATIONAL COST ESTIMATE SUMMARY FOR ALTERNATIVE WT-6

Ion Exchange	
Direct Capital Costs	$16,044
Indirect Capital Costs	$8,824
O+M Costs (Present Worth)	$24,868
TOTAL	**$55,688**



MFG, Inc.
consulting scientists and engineers

FIGURE 43
ION EXCHANGE
INSTALLATION SCHEMATIC

Date:	APRIL 2005
Project:	181159X
File:	MFG-SCHEM-01.dwg

Figure 43 – back page

8.0 COMPARATIVE ANALYSIS OF ALTERNATIVES

This section compares the alternatives developed in Section 6.2 (**Table 6-5**) and evaluated in detail in Section 7.0. Response alternatives were developed to reduce, minimize, or eliminate environmental impacts associated with contaminated discharges to receiving surface water and groundwater resources. There is no human health risk associated with the adit discharges.

Two very different types of response technologies were used to develop the response alternatives: Engineering Source Control and Water Treatment Control technologies. Alternatives for both of these technologies were developed along parallel paths by dividing the mines into groups for both engineering and water treatment alternative analysis (**Tables 6-2 and 6-3**, respectively). The concept of dividing mine related discharges into groups was useful for determining the effectiveness and applicability of various engineering closure and water treatment technologies in Chapter 6 (**Tables 6-2 and 6-3**, respectively) and in Chapter 7 (**Table 7-4**), and was particularly useful when a large number of adit discharges were initially analyzed in the Draft Adit EE/CA (Tetra Tech 2006). However, with the reduction in the number of discharges to the under-drains and four (4) remaining adits (**Tables 7-4 and 8-1**) the utility of dividing the discharges into groups is no longer as important, with several previously defined larger groups containing only one adit discharge.

The comparative analysis developed in this section is performed for each of the three primary criteria -- effectiveness, implementability, and cost. As described in Section 7.1, costs are estimated for comparative purposes only, as many design details that would affect costs are preliminary. Actual costs are expected to range from 50% higher to 30% lower than comparative costs estimated for this EE/CA. For the water treatment alternatives, operations and maintenance costs are included at present worth value for a 20-year period and include replacement of reactive media on either a one, five, or ten-year schedule, depending on the treatment technology requirements. The engineering control alternatives do not have any associated operation and maintenance costs.

The following sections first summarize the evaluation of alternatives as applied to the three types of response actions (No Action, Engineering Closure, and Water Treatment) and then compares the relevant and potentially applicable alternatives (**Table 7-4**) on an individual adit discharge basis. The only exception to this is combining of the McLaren adit discharge with the McLaren subsurface drains for water treatment alternative analysis purposes, principally because of their proximity to one another. A preferred alternative is identified at the end of the section.

8.1 SUMMARY OF THE NO ACTION ALTERNATIVE (NA-1)

No Action does not alter the existing condition of mining related discharges. Underground flow controls or water treatment measures would not be implemented at the sites. There would be no attempt to control or treat contaminant migration from the mines to nearby surface water, or to reduce its toxicity or volume.

Water captured in drains below the McLaren Pit cap would continue to discharge via the subsurface drains into Daisy Creek tributaries. The Gold Dust discharge would continue to discharge contaminated water into or within short distances of active streams. The Henderson Mountain Dump 7, Henderson Mountain Adit, and Little Daisy adit discharges would continue to infiltrates into nearby soils and presumably to groundwater.

Natural attenuation would reduce contaminant concentrations and loading over time. However, the degree of natural attenuation, particularly at the McLaren subsurface drain sites, is likely minimal and any noticeable degree of natural attenuation would take place over a very long period of time. The No Action alternative is most applicable to discharge from Henderson Mountain Dump 7, which has low flows and relatively low metal concentrations. From an engineering point of view, the No Action alternative is also most applicable to Henderson Mountain Dump 7 and Henderson Mountain Adit (**Table 6-2**) because the adits are too short to construct an effective physical closure.

No Action appears to be more applicable to those discharges that have relatively small contributions to the total metals loads measured at the nearest downstream surface water monitoring site (**Table 8-1**). For example, the Little Daisy Adit and Henderson Mountain Adit discharges each contribute than 5.0 % or less of the total load of individual COCs at the nearest downstream surface water sampling site.

TABLE 8-1
SUMMARY OF ADIT AND SUBSURFACE DRAINS LOADING ANALYSIS

Source Name	Al	Cd	Cu	Fe	Pb	Mn	Zn
Percent of Load as Measured at DC-2 Daisy Creek							
McLaren Subsurface Drains	**24.9**	**26.5**	**46.3**	**129.3**	16.7	**19.3**	33.1
McLaren Adit*	**0.22**	**0.16**	**0.05**	**14.9**	1.8	**3.5**	0.74
Unaccounted or Non-specific Load Source at DC-2	74.9	73.3	53.6	--	81.5	77.2	66.2
Percent of Load as Measured at SW-4 Fisher Creek							
Gold Dust Adit	0.79	0.40	0.066	12.3	2.1	**3.9**	0.45
Percent of Load as Measured at CFY-2 Clarks Fork of the Yellowstone Below Confluence with Fisher Creek							
Henderson Mtn. Dump #7	**1.06**	**0.76**	**0.77**	**35.6**	**1.1**	**6.7**	1.0
Percent of Load as Measured at SW-2 Miller Creek							
Little Daisy Adit	**0.02**	**0.4**	**0.03**	**1.0**	**0.5**	**5.0**	**0.6**
Henderson Mtn. Adit	**0.2**	1.1	**2.4**	0.01	**0.5**	0.2	0.6

Notes: Shading indicates loads that are greater than 1% of total load at the next downstream surface water station; McLaren Pit subsurface drain loads at DC-2 are September average low flow data between October 2003 and Sept. 2008.
Bold numbers highlight constituents that exceed the applicable surface water standard.
* The McLaren Adit was permanently reclaimed in 2010 and is not considered for additional treatment. The contribution of load from this source is reported in this table because infiltrated discharge may still deliver metal loads to Daisy Creek.

8.2 SUMMARY OF ENGINEERING SOURCE FLOW CONTROL ALTERNATIVES

Engineering source controls were only considered for adit discharges that are amenable to this type of closure. These include the currently accessible Gold Dust adit, and the currently inaccessible Little Daisy adit. Other adits evaluated in this EE/CA are considered to have underground workings that are too short to be considered for engineering source control measures. This is because adit water sources are too near the surface, and diverted water from a physical closure would likely easily bypass the closure and discharge to the surface through other nearby shallow, near-surface fractures.

The two engineering source control alternatives evaluated (EC-1 and EC-2) both use a high strength, acid-resistant, watertight cement plug placed approximately 76 meters (250 feet) into the mine workings with a second plug placed near the portal. Plugs block the flow of water and greatly reduce or eliminate a discharge. Backfill is used for ground support for plugs as well as increasing the restriction to flow.

Watertight plugs have been shown at a number of sites, including the Glengarry Adit, to greatly reduce or eliminate mine discharges. The effect of placing tunnel and portal plugs will be immediate and permanent, and the mobility of metals will be permanently reduced or eliminated. The two alternatives differ in that one addresses mine that is currently accessible (EC-1, Gold Dust adit) and the other addresses mines that are not accessible and need to be reopened prior to plugging (EC-2 Little Daisy Adit). These is more uncertainty associated with the effectiveness, implementability, and cost of Alternative EC-2 because little is known of the conditions of the underground workings that would make this alternative successful.

8.3 SUMMARY OF WATER TREATMENT ALTERNATIVES

While all of the COCs identified at the discharge sites are heavy metals, differences in metal characteristics and reactivity complicates water treatment response action alternative selection. For discharges with several metals above the applicable aquatic standards, scenarios were developed that combine water treatment response alternatives to successfully remove the entire set of target COCs from the discharge stream.

Passive, semi-passive, and conventional active treatment response alternatives were evaluated for each source under review. **With many of the innovative or passive treatment approaches, it is unclear given available current literature if the technology can meet the stringent aquatic standards applied to the New World sites.** This is due in part because, in many of the studies reported in the literature, the recorded detection limits are above the aquatic criteria set for Montana B-1 standards. It is therefore difficult to predict removal efficiencies by biological and/or other passive treatment technologies, and treatability testing with actual adit discharge waters will be necessary to define achievable removal efficiencies for each discharge. Furthermore, as discussed in Section 3.3.1, it is likely that naturally occurring water quality conditions that existed prior to mining also did not meet aquatic standards (Tetra Tech, 2009a).

In contrast, conventional, active treatment technologies such as chemical addition-precipitation followed by micro- or nano-filtration, or reverse osmosis typically have the best chance of consistently meeting effluent discharge standards from a proven technology standpoint. However, the remoteness of the location, limited access, and the severe winter climate in the District would make operation and maintenance of the active technologies very difficult and expensive, and may render these more proven technologies less efficient than would be expected with close monitoring in a very controlled environment. Typically, implementation of an active treatment technology could only be accomplished at a significant increase in cost over a passive treatment system. In addition, the construction of power lines though the area to provide the power likely required by conventional water treatment systems, would not meet one of the primary goals of the Consent Decree, which calls for maintaining the undeveloped character of the project area.

8.4 COMPARISON OF ALTERNATIVES BY MINE GROUP

8.4.1 Group 1 Alternatives - McLaren Subsurface Drains

Comparison of the Group 1 discharge alternatives is summarized in **Table 8-2**. Group 1 discharges include the McLaren subsurface drain discharges (DCSW-101, -102, and -103). Load contributions from the subsurface drains include 129% of the iron, 46% of the copper, and 33% of the zinc, among others (**Table 8-1**). This leaves an unaccounted, or non-specific (non-point) source, load in Daisy Creek at station DC-2 ranging from 81% of the lead to 53% of the copper (**Table 8-1**).

Technologies considered for treatment of the subsurface drains included infiltration (WT-1) and/or construction of dispersion aprons to eliminate the point sources. Plugging the subsurface drains was also considered. All of these actions were determined to be ineffective or infeasible during preliminary review and therefore are not evaluated in this EE/CA. Infiltration and dispersion are considered infeasible due to the presence of thick ferricrete deposits below the drain discharges. This impermeable ferricrete would prevent infiltration or dispersion of drain discharge. Plugging the subsurface drains would allow water to accumulate in the backfilled pit and would potentially cause geotechnical instability that would compromise the McLaren Pit cap.

Engineering Source Flow Controls are not suitable for closing the McLaren subsurface drains as the drains discharge at such a high volume and contain a significant contaminant loads at relatively high metal concentrations. Plugging the drains could also cause water to back-up and flow into the waste backfilled McLaren Pit. This would increase saturation of the backfilled waste potentially causing stability issues for the geotextile covered pit.

Alternative WT-2 (Anaerobic Bioreactor with Limestone Matrix Incorporation/Sodium Hydroxide Additions & Open Limestone Channel) and Alternative WT-5 (Chemical Addition, Precipitation & Micro-filtration) were evaluated for treatment of water from the combined Group 1 McLaren subsurface drains (**Table 8-2**). The combined chemical mass loading from the McLaren Pit subsurface drains (~140,000 kg/yr or 154 tons based on high flow data) and associated high flow rates creates a difficult treatment situation. Alternative WT-5 has a high probability of meeting water quality standards and could be supplemented with a reverse osmosis unit, if necessary. Alternative WT-2, although it would be effective in reducing COCs, may have a difficult time meeting water quality standards. In addition, Alternative WT-5 would likely be very effective over the long term, whereas the long-term effectiveness of Alternative WT-2 is unknown and the organic substrate in the passive anaerobic bioreactor would need to be replaced frequently to account for the high metal loads treated.

Both alternatives are implementable using conventional equipment and materials, although Alternative WT-2 would likely require a very large area to install the passive system and the innovative technologies would require on-site testing to complete a design for the site. The passive technology of Alternative WT-2 simplifies operations and requires no infrastructure or routine operations. The problems associated with trying to operate an active water treatment system for Alternative WT-5, considering access required for the materials that routinely need to be delivered or stored at the site, the waste that needs to be routinely removed, and the daily access required for operation would seem to be truly formidable. This is particularly true given the severe weather, remoteness of the site, difficult site access, lack of power, and high level of winter recreational use at the site.

Both systems are quite expensive; the passive Alternative WT-2 ranges in price from $2,311,173 for a liquid substrate bioreactor to $2,455,301 for a solid substrate bioreactor. A liquid substrate bioreactor

is the most likely choice between these two types of bioreactors because of the requirement that the system operate year-round with temperatures below freezing for at least six months of the year. The cost for the active WT-5 system is $5,513,922 (**Table 8-2**).

8.4.2 Group 2 Alternatives - Little Daisy Adit

The comparative evaluation of alternatives for the Group 2 site, the Little Daisy Adit, is summarized in **Table 8-3**. The Little Daisy Adit is amenable to closure using engineering source controls for an inaccessible adit, Alternative EC-2. Use of a plugging system for closure is considered to be a highly effective method for the Little Daisy Adit. Implementation of this alternative would greatly reduce or eliminate flow from the adit. It is also technically and administratively feasible and implementable. The cost of implementing Alternative EC-2 is about $1,495,530. The potential difficulty of reopening the Little Daisy Adit for assessment cannot be effectively evaluated. A small infiltration basin (WT-1) was installed near the portal of the Little Daisy adit during reclamation of the mine site and removal of the waste rock dump in 2004. It is only partially effective due to the steep slope located immediately below the adit portal that allows the infiltrated water to come back to surface over a short distance down the slope, before disappearing into unconsolidated talus and colluvial materials further down the slope, some 600 meters (2,000 feet) from Miller Creek. The other water treatment alternatives deemed most applicable for the Little Daisy Adit are Alternative WT-3 (Anaerobic Bioreactor and OLC) and Alternative WT-5 (Chemical Addition, Precipitation & Micro-filtration). The Little Daisy discharge has several metals above aquatic standards and a near-neutral pH; however, total metals loading is relatively low (less than 1% except for manganese). These factors, combined with a moderate flow of about 30 Lpm (8 gpm), suggests that an Anaerobic Bioreactor system could function for an extended time period, possibly 10 to 20 years depending on the type of bioreactor installed (i.e., SSBR or LSBR). In this case, the anaerobic bioreactor would benefit from the addition of an Open Limestone Channel down gradient of the bioreactor to add alkalinity to the water and enhance the precipitation of metals. Alternative WT-5, active treatment, is plagued by the same difficulties with respect to year-round operations, site access, power, and supply requirements as those described for the Group 1 sites. In addition, the projected cost differential of almost $2.8 million dollars between the passive bioreactor ($799,585) and the active treatment system ($3,579,320) makes the passive system more attractive, particularity considering the potentially long-term effectiveness.

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Table 8-2
Comparison of Selected Water Treatment Alternatives for the McLaren Pit Subsurface Drains and McLaren Adit
New World Mining District Response and Restoration Project
Adit Discharge EE/CA

Alternative	Description of Technology	Effectiveness	Implementability	Infrastructure & Operational Needs	Total Estimated Cost [(1)]
No Action Alternative **Alternative NA-1**	No technology involved.	Overall effectiveness is poor. Leaves the McLaren Adit and subsurface drain discharges in existing condition. Acidic water, dissolved metals, and sediment will continue to flow to Daisy Creek. No reduction in toxicity or volume. Not effective in reducing concentrations of metals at the source. Natural attenuation reactions may effectively reduce some metal loading and ecological risk in McLaren Adit discharge through time; not expected for subsurface drains. Does not meet ARARs.	Technically and administratively feasible. Implementable as no action is required.	None	No Cost
Engineering Alternative **Alternative EC-1** **Plug an Accessible Adit** (McLaren Adit Only)	Underground engineering flow control treatment using high strength, acid-resistant, water-tight cement plugs installed about 76 meters (250 feet) into mine and plug near the portal to block flow. Backfill would be used for ground support for plugs and increased restriction of flow.	Water-tight plugs will greatly reduce or eliminate water flow from the McLaren Adit to Daisy Creek. The mobility of metals will be permanently reduced. The effect of placing tunnel and portal plugs will be immediate and permanent. However, the load of metals from McLaren Adit to Daisy Creek is less than 13% of total load at DC-2; therefore this closure method will not significantly affect instream water quality in Daisy Creek. Meets ARARs.	Implementable using readily available equipment and technologies. Numerous portal and drift plugs have been previously installed in abandoned in underground mines, including the Glengarry Mine in the New World District.	Requires installation of subsurface piping grid. One permanent surface pipe clean-out structure required. Requires conventional construction and underground mining equipment and materials. Requires trained personnel that are readily available in the Western US. No operation or maintenance required once project is completed.	$ 792,027
Water Treatment Alternative **Alternative WT-1: Infiltration** (McLaren Adit only)	Flow sources rerouted from surface to subsurface, subsurface drain field sized to fit the flow volume and contaminant level concentrations, constructed using gravel-bedded perforated pipe, covered with a 0.6-meter (two-foot) thick soil layer to protect from freezing, McLaren adit requires dewatering, portal excavation and reentering to install the adit drainage system. Shallow soils and groundwater with poor drainage below the portal require extending piping system several hundred feet in a lined and graveled ditch to the infiltration basin. Lager infiltration basin required because of the higher flow volume and contaminant level. Area requiring reclamation during closure is large and may require hauling additional fill material to regrade the portal area.	Subsurface drain field sized to fit flow volume and contaminant level concentrations such that non-degradation requirements are met through use of a mixing zone. Meets RAOs by minimizing or preventing contaminants dissolved in water from directly entering surface water and protects human health and wildlife from direct contact and ingestion risks. Dilution and natural attenuation processes occurring in the subsurface are likely to be effective at reducing the low metals concentrations from discharges and variably effective for higher metal concentrations.	Implementable and feasible if adequate area with a sufficient depth of soil above the water table or bedrock is available. If soil depths are insufficient, imported soil can be used. Construction is straight-forward using readily available materials and equipment. Operation and maintenance is minimal, excepting periodic replacement due to plugging with metals.	No permanent infrastructure required. Requires only conventional construction equipment and materials. May require replacement of drain field substrate every 20 years due to plugging with metal precipitates..	$ 82,595

Table 8-2
Comparison of Selected Water Treatment Alternatives for the McLaren Pit Subsurface Drains and McLaren Adit
New World Mining District Response and Restoration Project
Adit Discharge EE/CA

Alternative	Description of Technology	Effectiveness	Implementability	Infrastructure & Operational Needs	Total Estimated Cost [1]
Water Treatment Alternative **Alternative WT-2: Anaerobic Bioreactor (SSBR or LSBR) with Limestone Matrix Incorporation/Sodium Hydroxide Addition, and Open Limestone Channel** **Combined McLaren Unit**	Passive treatment technology that relies on water neutralization with limestone (and sodium hydroxide addition for LSBR), biological sulfate reduction to precipitate metal sulfides, and an aeration/neutralization cell for removal of residual aluminum and manganese.	Effective at reducing COC concentrations but may have difficulty in meeting standards. Difficult to predict final effluent water quality due to site-specific conditions. Long-term effectiveness is unknown. High likelihood that effectiveness could decrease due to high metals loading.	Implementable using conventional equipment and materials although a fairly large area is required. Innovative technologies would require testing to complete design. Passive technology simplifies operation.	Passive system with no infrastructure or routine operational needs. Requires replacement of organic substrate every 5 to 10 years.	SSBR: $ 2,455,301 LSBR: $ 2,311,173
Water Treatment Alternative **Alternative WT-5: Chemical Addition, Precipitation & Micro-filtration.** **Combined McLaren Unit**	Active treatment system utilizing the addition of chemicals (NaOH or other base to raise pH and possibly ferric iron salt to add sorptive capacity), precipitation tank to remove large flocs, and a membrane filtration unit to remove suspended solids.	High probability of achieving target aquatic standards. RO unit could be added to further reduce COC concentrations. Good long-term effectiveness. Meets ARARs. Does not meet project objectives for minimizing changes to historic character of the District.	Packaged systems make installation of this technology feasible. Remote location and harsh weather would make operation difficult. Common technologies would require some testing for optimization. Would severely impact recreational winter use on Daisy Pass Road.	Requires significant infrastructure to hold equipment, bulk chemicals, and solid filter cake. Continuous supply of electrical power and heat source for buildings is required. Monthly deliveries of reagents and fuel are assumed along with monthly trips for waste disposal. Daily access for system operation and maintenance may be required.	$ 5,513,922

Notes: 1 Capital and 20-years O+M (includes scheduled reactant replacement costs for water treatment alternatives)

Table 8-3
Comparison of Selected Water Treatment Alternatives for the Little Daisy Adit
New World Mining District Response and Restoration Project
Adit Discharge EE/CA

Alternative	Description of Technology	Effectiveness	Implementability	Infrastructure & Operational Needs	Total Estimated Cost (1)
No Action Alternative **Alternative NA-1**	No technology involved.	Not effective for reducing concentrations of metals at the source. Natural attenuation reactions may effectively reduce metals loading and ecological risk. Does not meet ARARs.	Implementable as no action is required.	None	No Cost
Engineering Alternative **Alternative EC-2** **Reopen and Plug Inaccessible Adit** **Difficult Access**	Reopen inaccessible Little Daisy adit involves excavation of the portal, water discharge through a sediment pond, and mucking workings to 76 meters. High strength, acid-resistant, water-tight cement plugs would be placed at 76 meters (250 feet) from portal and near the portal to block flow. Backfill would be used for ground support for plugs and increased restriction of flow.	Water-tight plugs will greatly reduce or eliminate water flow from the Little Daisy Adit to upper Miller Creek drainage Basin. There is no direct discharge to Daisy Creek. The mobility of metals will be permanently reduced. Effective as a barrier or seal to water flow along workings or isolating select areas of underground workings in order to prevent groundwater mixing. The effect of placing tunnel and portal plugs will be immediate and permanent. Meets ARARs	Implementable using available equipment and technologies. Installing portal and drift plugs has been shown to be successful. However, regaining access to the Little Daisy workings to set plugs is unpredictable, and may be somewhat difficult. Because underground conditions are unknown, implementability of this alternative may be extremely difficult, and reentry of the mine may not be successful.	No permanent infrastructure required. Requires conventional construction and underground mining equipment and materials. Requires trained personnel that are readily available in the Western US. No operation or maintenance required once project is completed.	$ 1,459,531
Water Treatment Alternative **Alternative WT-1: Infiltration**	Flow sources rerouted from surface to subsurface, subsurface drain field sized to fit the flow volume and contaminant level concentrations, constructed using gravel-bedded perforated pipe, covered with a 0.6-meter (two-foot) thick soil layer to protect from freezing, system may require replacement every 20 years	Subsurface drain field sized to fit flow volume and contaminant level concentrations such that non-degradation requirements are met through use of a mixing zone. Meets RAOs by minimizing or preventing contaminants dissolved in water from directly entering surface water and protects human health and wildlife from direct contact and ingestion risks. Dilution and natural attenuation processes occurring in the subsurface are likely to be effective at reducing the low metals concentrations from discharges and variably effective for higher metal concentrations**.**	Implementable and feasible if adequate area with a sufficient depth of soil above the water table or bedrock is available. If soil depths are insufficient, imported soil can be used. Construction is straight-forward using readily available materials and equipment. Operation and maintenance is minimal, excepting periodic replacement due to plugging with metals.	Requires installation of subsurface piping grid. No permanent surface infrastructure required. Requires only conventional construction equipment and materials. May require replacement of drain field substrate every 20 years due to plugging with metal precipitates..	$21,097
Water Treatment Alternative **Alternative WT-3: Anaerobic Bioreactor (SSBR or LRBR) and OLC**	Passive treatment technology that relies on biological sulfate reduction to precipitate metal sulfides and an aeration/ neutralization cell for removal of residual aluminum and manganese.	Effective at reducing concentration of all COCs. Difficult to predict final effluent water quality. Long term effectiveness may be affected if system becomes plugged with precipitates.	Implementable using conventional equipment and materials. Testing required to complete design. Passive technology simplifies operation.	Passive system with no infrastructure or routine operational needs. Requires replacement of organic substrate every 10 to 20 years.	$799,585
Water Treatment Alternative **Alternative WT-5: Chemical Addition, Precipitation & Micro-filtration.**	Active treatment system utilizing the addition of chemicals (NaOH or other base to raise pH and possibly ferric iron salt to add sorptive capacity), precipitation tank to remove large flocs, and a membrane filtration unit to remove suspended solids.	High probability of achieving target aquatic standards. RO unit could be added to further reduce COC concentrations. Good long-term effectiveness. Meets ARARs. Does not meet project objectives for minimizing changes to historic character of the District.	Packaged systems make installation of this technology feasible. Remote location and harsh weather would make O+M difficult. Common technologies would require some testing for optimization. Would severely impact recreational winter use on Daisy Pass Road.	Requires significant infrastructure to hold equipment, bulk chemicals, and solid filter cake. Continuous supply of electrical power and heat source for buildings is required. Monthly deliveries of reagents and fuel are assumed along with monthly trips for waste disposal. Daily access for system operation and maintenance would be required.	$3,579,320

Notes: 1 Capital and 20-years O+M (includes scheduled reactant replacement costs for water treatment alternatives)

8.4.3 Group 3 Alternatives - Gold Dust Adit

The comparative evaluation of alternatives for the Gold Dust Adit is summarized in **Table 8-4**. The Gold Dust Adit is suitable for closure using Alternative EC-1, Plugging an Accessible Adit. Use of a plugging system for closure is considered to be a highly effective method for flow reduction from the Gold Dust Adit. Implementation of this alternative would reduce or eliminate flow from the adit that, following grouting of boreholes in the drill stations in October 2005, has been reduced to 16.6 Lpm (4.4 gpm). This alternative is technically and administratively feasible and implementable, with an estimated cost of about $792,027.

The water treatment alternatives considered somewhat effective for treating the Gold Dust Adit discharge are Alternative WT-4 (Manganese Removal Cell) and Alternative WT-5 (Chemical Addition, Precipitation & Micro-filtration). Currently, the only contaminant in the Gold Dust discharge is manganese, which exceeds the human health Secondary Maximum Contaminant Level guideline of 0.05 mg/L. Alternative WT-4 is a passive treatment technology, which consists of a large subsurface limestone filled chamber to add alkalinity and provide adequate residence time for manganese precipitation. This technology has been shown to be effective at removing manganese at other mining sites. However, it is difficult to predict final effluent water quality because of the uniqueness of site conditions. Active water treatment, Alternative WT-5, although effective at removing low levels of metals, is very expensive and plagued by the same difficulties discussed above related to surface infrastructure requirements, power requirements, sludge disposal, and the ability to operate on a year-round basis under the extreme climate and access conditions present at the site. The cost of a passive manganese removal cell is estimated to be about $185,270, and the cost of active water treatment is about $3,579,320.

It is probable that No Action could achieve the level of manganese reduction required given sufficient distance between the discharge source and Fisher Creek. Manganese is oxidized by numerous bacteria found in nature, and it is likely that in the oxidizing, organic-rich uppermost soil horizon, manganese would be sequestered and removed from solution. This situation exists downstream of the Gold Dust Adit under current conditions where there is a long, open, low gradient stretch of stream that flows through grassland and willow covered wetlands before entering Fisher Creek. In the synoptic study completed on Fisher Creek by Amacher et. al. (1998), manganese concentrations measured at the mouth of the Gold Dust tributary were well below the manganese guideline. The effectiveness of this natural system suggests that the construction of an infiltration basin (WT-1) is unnecessary and unwarranted.

8.4.4 Group 4 Alternatives - Henderson Mountain Adit

The Henderson Mountain Adit (M-25) is the only adit discharge included in Group 4. **Table 8-5** summarizes the comparative analysis of alternatives appropriate for this adit. This adit is situated on the southwest flank of Henderson Mountain in an area of known metal anomalies in both soils and bedrock (e.g., copper concentrations in soils in excess of 500 parts per million). The adit is inaccessible except by foot up a steep hillside above the Daisy Pass road; the adit is too short and too close to the surface to close using engineering source control Alternative EC-2. The adit does not discharge directly to surface water but rather infiltrates to groundwater some 550 meters (1800 feet) from Miller Creek.

Water treatment alternatives deemed most applicable to the treatment of this discharge include Alternative WT-3 (Anaerobic Bioreactor and OLC) and Alternative WT-5 (Chemical Addition, Precipitation & Micro-filtration). The moderate flow rates averaging 19 Lpm (5 gpm) and low total

metals loading (~215 kg/yr or 0.24 tons) suggest that Alternative WT-3 would provide effective treatment. Alternative WT-3 is a passive treatment technology that relies on biological sulfate reduction to precipitate metal sulfides and an aeration/neutralization cell for removal of residual aluminum and manganese. Alternative WT-3 should be effective in reducing metals for a number of years before its effectiveness begins to be reduced; however, final water quality is not predictable. The alternative is implementable using conventional equipment and materials, although access to the site will be difficult and the limited area at the site coupled with its location on a steeply sloping hillside may preclude optimizing a design for this passive system. The cost to implement Alternative WT-3 is about $799,585, although this cost does not include the cost for building a road to the site, which would be considerable.

Active chemical treatment has been discussed in association with several mine groups listed above. In this application, although it is very effective at removal of COCs, the cost to implement Alternative WT-5, $3,579,320, coupled with the limited space and difficult topography of the site make implementing this alternative prohibitive.

The presence of multiple metals above the aquatic standards and the slightly acidic pH of this discharge make it difficult to predict the effectiveness of the No Action Alternative (NA-1). Only copper is measured at station SW-2 in Miller Creek above the aquatic standard and the Henderson Mountain Adit is not the only source of copper above SW-2 (samples collected by Cleasby and Nimick (2002) in three nearby tributaries that flow off the southwest flank of Henderson Mountain contained elevated copper levels). The construction of an infiltration basin (WT-1) seems unwarranted as the discharge from the Henderson Mountain source currently infiltrates to colluvial materials some 550 meters (1800 feet) feet from Miller Creek.

8.4.5 Group 5 Alternatives – Henderson Mountain Dump 7 Adit

Group 5 includes only the Henderson Mountain Dump 7 adit characterized by low flow volumes (less than 3 Lpm [1 gpm]), and relatively low metal concentrations. Drainage from this adit historically infiltrated to groundwater before reaching any surface water tributary to Fisher Creek. A mine drainage control system consisting of a small gravel basin (Alternative WT-1) was constructed at the mouth of Henderson Mountain Dump # 7 adit portal as part of the 2005 response action.

The characteristics of the Henderson Mountain Dump described above suggest that no action alternative (Alternative NA-1) may be a reasonable alternative for closure. The Henderson Mountain Dump #7 is too short and too shallow for an Engineering Source Control closure.

Several Water Treatment Alternatives are suitable for treatment of water that historically discharged from the Henderson Mountain Dump 7 adit. These alternatives are compared in **Table 8-6** and discussed briefly below. Costs associated with water treatment alternatives for Group 5 adit discharges are also shown in **Table 8-6**.

- Alternative WT-3 – Anaerobic Bioreactor and OLC: This alternative would be applicable to Henderson Mountain Dump 7 that exceeds standards for aluminum, copper, iron, and manganese. Cost estimate: $113,486
- Alternative WT-6 – Ion Exchange: This alternative is applicable to Henderson Mountain Dump 7, as commercially available resins can be designed to remove all COCs. However, relatively high inflow pressures (approximately 10 feet of head) are required to drive this system and this may not be achievable at the site. Cost estimate: $55,688

The No Action alternative (NA-1) is the most cost-effective response action presented for the Henderson Mountain Dump 7 given that a small infiltration basin was constructed at the portal in 2005. The No Action may not meet RAOs due to site geology, however the current adit discharge to groundwater is located at a considerable distance from the receiving surface water of Fisher Creek.

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Table 8-4
Comparison of Selected Water Treatment Alternatives for the Gold Dust Adit
New World Mining District Response and Restoration Project
Adit Discharge EE/CA

Alternative	Description of Technology	Effectiveness	Implementability	Infrastructure & Operational Needs	Total Estimated Cost [1]
No Action Alternative **Alternative NA-1**	No technology involved.	Not effective for reducing concentrations of metals at the source. Natural attenuation reactions may achieve the level of manganese reduction required given sufficient distance between the discharge source and the receptor stream. Does not meet ARARs.	Implementable as no action is required.	None	No Cost
Engineering Alternative **Alternative EC-1** **Plug an Accessible Adit** (Gold Dust Adit)	Underground engineering flow control treatment using high strength, acid-resistant, water-tight cement plugs installed about 76 meters (250 feet) into mine and plug near the portal to block flow. Backfill would be used for ground support for plugs and increased restriction of flow.	Water-tight plugs will greatly reduce or eliminate water flow from the Gold Dust Adit to Fisher Creek. Mobility of metals will be permanently reduced. Effective as a barrier or seal to water flow along workings or isolating select areas of underground workings in order to prevent mixing of groundwater. The effect of placing tunnel and portal plugs will be immediate and permanent. Meets ARARs.	Implementable using readily available equipment and technologies. Numerous portal and drift plugs have been previously installed in abandoned underground mines, including the Glengarry Mine in the New World District.	No permanent infrastructure required. Requires conventional construction and underground mining equipment and materials. Requires trained personnel that are readily available in the Western US. No operations or maintenance required once project is completed.	$ 792,027
Water Treatment Alternative **Alternative WT-1: Infiltration**	Flow sources rerouted from surface to subsurface, subsurface drain field sized to fit the flow volume and contaminant level concentrations, constructed using gravel-bedded perforated pipe, covered with a 0.6-meter (two-foot) thick soil layer to protect from freezing, system may require replacement every 20 years	Subsurface drain field sized to fit flow volume and contaminant level concentrations such that non-degradation requirements are met through use of a mixing zone. Meets RAOs by minimizing or preventing contaminants dissolved in water from directly entering surface water and protects human health and wildlife from direct contact and ingestion risks. Dilution and natural attenuation processes occurring in the subsurface are likely to be effective at reducing the low metals concentrations from discharges and variably effective for higher metal concentrations**.**	Implementable and feasible if adequate area with a sufficient depth of soil above the water table or bedrock is available. If soil depths are insufficient, imported soil can be used. Construction is straight-forward using readily available materials and equipment. Operation and maintenance is minimal, excepting periodic replacement due to plugging with metals.	Requires installation of subsurface piping grid. No permanent surface infrastructure required. Requires only conventional construction equipment and materials. May require replacement of drain field substrate every 20 years due to plugging with metal precipitates..	$21,097
Water Treatment Alternative **Alternative WT-4: Manganese Removal Cell**	Passive treatment technology, which would consist of a large subsurface limestone filled chamber to add alkalinity and provide residence time to allow manganese precipitation.	This technology has been shown to be effective at removing manganese at other mining sites. Difficult to predict final effluent water quality due to site-specific conditions.	Implementable using conventional equipment and materials. Testing required for design. Passive technology simplifies operation.	Requires construction of a subsurface impoundment. No above ground infrastructure required and no routine operational requirements.	$185,270
Water Treatment Alternative **Alternative WT-5: Chemical Addition, Precipitation & Micro-filtration**	Active treatment system utilizing the addition of chemicals (NaOH or other base to raise pH and possibly ferric iron salt to add sorptive capacity), precipitation tank to remove large flocs, and a membrane filtration unit to remove suspended solids.	High probability of achieving target aquatic standards. RO unit could be added to further reduce COC concentrations. Good long-term effectiveness. Meets ARARs. Does not meet project objectives for minimizing changes to historic character of the District.	Packaged systems make installation of this technology feasible. Remote location and harsh weather would make operation difficult. Common technologies would require some testing for optimization. Would severely impact recreational winter use on Lulu Pass Road.	Requires significant infrastructure to hold equipment, bulk chemicals, and solid filter cake. Continuous supply of electrical power and heat source for buildings is required. Monthly deliveries of reagents and fuel are assumed along with monthly trips for waste disposal. Access for system operation and maintenance will be required.	$3,579,320

Notes: 1 Capital and 20-years O+M (includes scheduled reactant replacement costs for water treatment alternatives)

Table 8-5
Comparison of Selected Water Treatment Alternatives for the Henderson Mt Adit
New World Mining District Response and Restoration Project
Adit Discharge EE/CA

Alternative	Description of Technology	Effectiveness	Implementability	Infrastructure & Operational Needs	Total Estimated Cost [1]
No Action Alternative **Alternative NA-1**	No technology involved.	Not effective in reducing concentrations of metals at the source. Natural attenuation reactions may effectively reduce metals loading and ecological risk. Only copper exceeds aquatic standards at station SW-2 in Miller Creek, and this adit is not the only source of copper. Does not meet ARARs.	Implementable as no action is required.	None	No Cost
Water Treatment Alternative **Alternative WT-1: Infiltration**	Flow sources rerouted from surface to subsurface, subsurface drain field sized to fit the flow volume and contaminant level concentrations, constructed using gravel-bedded perforated pipe, covered with a 0.6-meter (two-foot) thick soil layer to protect from freezing, system may require replacement every 20 years. Requires new road to access site, site preparation and additional reclamation at $25,000.	Subsurface drain field sized to fit flow volume and contaminant level concentrations such that non-degradation requirements are met through use of a mixing zone. Meets RAOs by minimizing or preventing contaminants dissolved in water from directly entering surface water and protects human health and wildlife from direct contact and ingestion risks. Dilution and natural attenuation processes occurring in the subsurface are likely to be effective at reducing the low metals concentrations from discharges and variably effective for higher metal concentrations.	Implementable and feasible if adequate area with a sufficient depth of soil above the water table or bedrock is available. If soil depths are insufficient, imported soil can be used. Construction is straight-forward using readily available materials and equipment. Operation and maintenance is minimal, excepting periodic replacement due to plugging with metals.	Requires installation of subsurface piping grid. No permanent surface infrastructure required. Requires only conventional construction equipment and materials. May require replacement of drain field substrate every 20 years due to plugging with metal precipitates..	$46,097
Water Treatment Alternative **Alternative WT-3: Anaerobic Bioreactor (SSBR or LRBR), and OLC**	Passive treatment technology that relies on biological sulfate reduction to precipitate metal sulfides and an aeration/ neutralization cell for removal of residual aluminum and manganese.	Effective at reducing COC concentrations. Difficult to predict final effluent water quality. Long-term effectiveness is unknown. Effectiveness could decrease due to high metals loading to the system from discharge water.	Implementable using conventional equipment and materials. Innovative technologies would require testing to complete design. Requires new road construction to access site along difficult terrain. Limited area at the site coupled with location on a steeply sloping hillside may preclude optimizing a design for this passive system.	Passive system with no infrastructure or routine operational needs. Organic substrate will require replacement as often as every 5 years	$799,585
Water Treatment Alternative **Alternative WT-5: Chemical Addition, Precipitation & Micro-filtration**	Active treatment system utilizing the addition of chemicals (NaOH or other base to raise pH and possibly ferric iron salt to add sorptive capacity), precipitation tank to remove large flocs, and a membrane filtration unit to remove suspended solids.	High probability of achieving target aquatic standards. RO unit could be added to further reduce COC concentrations. Good long-term effectiveness. Meets ARARs. Does not meet project objectives for minimizing changes to historic character of the District.	Packaged systems make installation of this technology feasible. Requires new road construction to access site along difficult terrain. Remote location and harsh weather would make operation difficult. Common technologies would require some testing for optimization. Would severely impact recreational winter use on Daisy Pass Road.	Requires significant infrastructure to hold equipment, bulk chemicals, and solid filter cake. Continuous supply of electrical power and heat source for buildings is required. Monthly deliveries of reagents and fuel are assumed along with monthly trips for waste disposal. Access for system operation and maintenance would be required.	$3,579,320

Notes: 1 Capital and 20-years O+M (includes scheduled reactant replacement costs for water treatment alternatives)

Table 8-6
Comparison of Selected Water Treatment Alternatives for Henderson Mountain Dump 7 Adit Discharge
New World Mining District Response and Restoration Project
Adit Discharge EE/CA

Alternative (applicable sources)	Description of Technology	Effectiveness	Implementability	Infrastructure & Operational Needs	Total Estimated Cost [(1)]
No Action Alternative **Alternative NA-1**	No technology involved.	Not effective for reducing concentrations of metals at the source. Natural attenuation reactions may effectively reduce metals loading and ecological risk. Does not meet ARARs for all Group 5 sites.	Implementable as no action is required.	None	No Cost
Water Treatment Alternative **Alternative WT-1: Infiltration** (Henderson Mountain Dump 7)	Flow sources rerouted from surface to subsurface, subsurface drain field sized to fit the flow volume and contaminant level concentrations, constructed using gravel-bedded perforated pipe, covered with a 0.6-meter (two-foot) thick soil layer to protect from freezing, system may require replacement every 20 years. Requires new road to access site, site preparation and additional reclamation at $25,000.	Subsurface drain field sized to fit flow volume and contaminant level concentrations such that non-degradation requirements are met through use of a mixing zone. Meets RAOs by minimizing or preventing contaminants dissolved in water from directly entering surface water and protects human health and wildlife from direct contact and ingestion risks. Dilution and natural attenuation processes occurring in the subsurface are likely to be effective at reducing the low metals concentrations from discharges and variably effective for higher metal concentrations**.**	Implementable and feasible if adequate area with a sufficient depth of soil above the water table or bedrock is available. If soil depths are insufficient, imported soil can be used. Construction is straight-forward using readily available materials and equipment. Operation and maintenance is minimal, excepting periodic replacement due to plugging with metals.	Requires installation of subsurface piping grid. No permanent surface infrastructure required. Requires only conventional construction equipment and materials. May require replacement of drain field substrate every 20 years due to plugging with metal precipitates..	$21,097
Water Treatment Alternative **Alternative WT-3: Anaerobic Bioreactor& OLC** (Henderson Mountain Dump 7)	Passive treatment technology that relies on biological sulfate reduction to precipitate metal sulfides and an aeration/neutralization cell for removal of residual aluminum and manganese.	Effective at reducing COC concentrations. Difficult to predict final effluent water quality due to site conditions. Long-term effectiveness is unknown.	Easily constructed and implemented. Innovative technologies would require testing to optimize design.	Passive system with no infrastructure or routine operational needs. Requires replacement of organic substrate every 5 years.	$113,486
Water Treatment Alternative **Alternative WT-6: Ion Exchange** (Henderson Mountain Dump 7)	Semi-passive system consisting of a pump, filtration unit, and ion exchange vessels. Relies on ion exchange reactions onto natural and/or synthetic resins for contaminant removal.	Capable of achieving high quality effluent meeting stringent standards. Good long term effectiveness. Meets ARARs.	Easily constructed and implemented. Testing required to optimize design. Higher inflow pressures (approximately 10 feet of head) required to drive system may not be achievable at some sites.	Requires construction of a subsurface impoundment to hold reaction vessels. Pump(s) will require a reliable source of electricity. Operational requirements consist of inspection of pumps, filters, and replacement of ion exchange resin on an annual basis.	$55,688

Notes: 1 Capital and 20-years O+M (includes scheduled reactant replacement costs for water treatment alternatives)

8.5 PREFERRED ALTERNATIVE

This section presents the preferred alternative for each of the discharge sites. This discussion is summarized in **Table 8-7**.

8.5.1 Action Common to all Alternatives

Implementation of the Revised Final Site-Wide, Long-Term Operations and Maintenance Plan is considered an essential action common to all alternatives including the NA-1 No Action Alternative. The Final Site-Wide, Long-Term Operations and Maintenance Plan was issued in 1999 (Tetra Tech 2009) and was informally revised in 2010 and 2011. The Revised Final plan will be issued late in December of 2011.

The Plan provides descriptions of annual monitoring tasks that will be completed to determine whether additional maintenance of reclaimed sites and the repository is needed, how maintenance work will be done, and estimated costs of site-wide monitoring and maintenance. This long-term operations and maintenance plan for the project begins after reclamation actions are completed in 2011 and covers activities that will occur for the following 20 years. The operations and maintenance period will therefore begin in 2012 and end in 2032. This Plan is intended to modify the Overall Work Plan (Maxim, 1999a), and the Repository Monitoring Plan (Maxim, 2006c) during the years of its implementation.

Primary objectives for work covered in the Long-Term Operations and Maintenance Plan are to document and monitor the effectiveness of reclamation response and restoration actions; to provide for maintenance actions as required to ensure long-term stability of erosion controls and reclamation covers; to monitor surface and groundwater quality and to satisfy the requirements of the rule allowing adoption of temporary water quality standards. This Plan also provides an outline of specific tasks that form the basis for estimating costs for long-term operations, monitoring and maintenance tasks. This plan is not static and may be modified as needs arise due to changing site conditions or decisions made after the initial release of this report.

8.5.2 McLaren Pit Subsurface Drains

Table 8-1 shows that the McLaren Pit subsurface drain discharges exceed standards for all COCs and are a major source of loading at station DC-2. However, the majority of the load at DC-2 results from non-specific, unidentified (non-point) sources other than the McLaren subsurface drains (**Table 8-1**). The possible exception to this may be iron during low flow periods, however, iron is not typically conserved in solution, but is rather precipitated out along flow paths as ferricrete deposits.

TABLE 8-7
PREFERRED ALTERNATIVE FOR MINING-RELATED DISCHARGES *

Site Name	Preferred Alternative
Group 1	
McLaren Pit Subsurface Drains	No Action (NA-1)
Group 2	
Little Daisy Adit	No Action (NA-1) (small infiltration basin, constructed in 2004)
Group 3	
Gold Dust Adit	No Action (NA-1)
Group 4	
Henderson Mountain Adit	No Action (NA-1)
Group 5	
Henderson Mountain Dump 7	No Action (NA-1) (infiltration basin, constructed in 2005)

- Implementation of the Revised Final Long-Term Operations and Maintenance Plan is considered and Action Common to All Alternatives.

Only water treatment alternatives are applicable to the subsurface drains (relevant source containment options were screened out in Section 6.0 due to high cost and difficult implementability). Alternative WT-1 (Infiltration) would not be effective due to inadequate depth of soil and the presence of impermeable ferricrete deposits below the drains. Alternative WT-2 (Anoxic Limestone Drain, Anaerobic Bioreactor & Open Limestone Channel) and Alternative WT-5 (Chemical Addition, Precipitation, and Micro-filtration) were both determined to be effective in treating water discharging from the drains, but are expensive (as much as $5,513,922), and have serious construction and operation problems associated with them. The problems associated with trying to operate an active water treatment system (Alternative WT-5), considering the access required, are many and difficult, and such a treatment system would seriously impact recreational use of the Daisy Pass Road by winter recreationists.

The chances of successful installation and effective operation of a water treatment system when weighed against the total cost leaves the No Action Alternative as the most desirable alternative, particularly while the results of longer term monitoring of the effectiveness of the McLaren Pit Cap are evaluated over the next few years. The seasonally large flow volumes and high contaminant loads would not permit the development of an effective infiltration basin for the subsurface drain discharges and preliminary calculations suggest the discharge to groundwater would not meet non-degradation requirements. No Action is also preferred because the large loading contribution from non-specific and unidentified (non-point) sources other than the McLaren Adit or subsurface drains will prevent water quality standards at station DC-2 from being met even if a water treatment technology was employed for the subsurface discharges.

8.5.3 Little Daisy Adit

The Little Daisy discharge, which exceeds aquatic standards for a number of COCs, does not discharge to surface water; it instead percolates into colluvial material a short distance below the infiltration basin constructed near the collapsed portal, and does not surface again down-gradient of the mine. Therefore, if this discharge ultimately reaches Miller Creek, it does so as a dilute and dissipated source some 1,067 meters (3,500 feet) down-gradient of the mine site in Miller Creek. Load from the Little Daisy discharge could not be detected in Miller Creek during a synoptic study of metals loading to the Creek by the USGS.

The Little Daisy Adit is amenable to closure by Engineering Source Control Alternative EC-2, Plugging an Inaccessible Adit. This method may be an effective closure, depending on underground conditions in the workings, with water flow from the adit reduced or eliminated. However, because underground conditions are unknown, implementability of this alternative may be extremely difficult, and successful reentry of the Little Daisy may not be possible.

As the Little Daisy discharge exceeds aquatic standards, the moderate flow of about 30 Lpm (8 gpm) suggests that an anaerobic bioreactor system could function for an extended time, although the cost of passive treatment is about twice that of the Engineering Source Control alternative. Active treatment (Alternative WT-5) is plagued by many difficulties with respect to year-round operations, site access, and power and supply requirements. The projected cost of over $3 million makes the passive system more attractive, particularity considering its potential long-term effectiveness.

Loading data presented in **Table 8-1** indicate the only metal in the Little Daisy discharge that exceeds 1% of the load in Miller Creek at station SW-2 is manganese (5.0% of the total in-stream load of manganese in Miller Creek). There is no direct traceable connection from this discharge to Miller Creek, and groundwater data from monitoring wells in Miller Creek below the Little Daisy (MW-5P and MW-5A) do not appear to be impacted from the signature of the Little Daisy discharge. In addition, recent water quality results (2006) for Miller Creek stations SW-2 and SW-5, showed that only copper exceeds applicable standards, with suspended sediment the cause of a portion of these exceedances in the total recoverable fraction. The area of elevated soil copper levels on the west flank of Henderson Mountain is one source of copper in the suspended fraction.

Based on the flow path for the Little Daisy Adit discharge and the lack of measurable impact to receiving surface or groundwater, it appears that infiltration into surrounding soils and colluvial materials provide conditions where natural attenuation and/or dilution of contaminants is occurring under existingconditions. Because there does not appear to be any measurable impact from the Little Daisy discharge and because the costs associated with treating or eliminating the discharge are several hundred thousand dollars, the preferred alternative for this site is No Action. Long-term monitoring of water quality in Miller Creek that will be done as part of the overall project plan will allow the USDA-FS to regularly evaluate whether this alternative continues to be appropriate for the site.

8.5.4 Gold Dust Adit

After completing work involved with grouting boreholes in the Gold Dust Adit, discharge from the adit has been reduced to about 16.6 Lpm (4.4 gpm). Water flowing from the portal flows through about 305 meters (1,000 feet) of open grassy meadows and willow covered wetlands prior to entering Fisher Creek. This existing situation is essentially the same as would be constructed under Alternative WT-1 (Infiltration) and therefore this Alternative was not selected for implementation. At the portal, the Gold Dust discharge meets all chronic aquatic life standards, and only exceeds the human health guideline for manganese (0.05 mg/L). Manganese loading from the Gold Dust Adit discharge could contributes as much as 3.9% of the total manganese load at station SW-4 in Fisher Creek.

The Gold Dust Adit is suitable for closure using Engineering Source Control Alternative EC-1, Plugging an Accessible Adit. Use of a plugging system for closure is considered to be a highly effective method to reduce or eliminate flows from the Gold Dust Adit. Implementing this alternative is technically and administratively feasible. The cost of closure is estimated to be about $792,027.

Constructing a manganese removal cell under Alternative WT-4 would be a passive treatment technology that has been shown to be effective at removing manganese at other mining sites, although it is difficult to predict final effluent water quality at this time because site-specific performance data is needed before this assessment can be made. While the cost of passive treatment is one-twentieth that of active water treatment, final effluent water quality from an active treatment system would assure the manganese standard is met. However, while it is effective, active treatment (Alternative WT-5) is plagued by difficulties related to surface infrastructure requirements, power requirements, and the ability to operate on a year-round basis under the extreme climate and access conditions present at the site. Due to these supply requirements, winter recreation along the Lulu Pass Road would be significantly impacted under active treatment.

It is probable that Alternative NA-1, No Action, could achieve the level of manganese reduction required given sufficient distance between the discharge source and the receptor stream. Manganese is oxidized by numerous bacteria found in nature, and, therefore, it is likely that in the oxidizing, organic-rich, uppermost soil horizon, manganese would be sequestered and removed from solution. This is in fact what happens downstream of the Gold Dust Adit under existing conditions; that is, a long, open, low gradient stretch of stream that flows through grassland and willow covered wetlands before entering Fisher Creek.

Based on the reduction in flow achieved by grouting boreholes in 2005, the effective adit closure, the relatively high cost to either plug or treat the existing discharge, and the fact that there is no aquatic risk associated with manganese, the preferred alternative for the Gold Dust Adit is No Action.

8.5.5 Henderson Mountain Adit

This adit is inaccessible except by foot up a steep hillside above the Daisy Pass Road. Because the small dump at the site indicates that the underground workings are very short (probably less than three to five meters [10 to 15 feet] based on the size of the waste rock dump), this discharge is likely a natural spring. As the bedrock source in the area is known to contain elevated metals, water from the Henderson Mountain Adit exceeds standards for aluminum, copper, and lead, with only copper seasonally exceeding aquatic standards at station SW-2 in Miller Creek.

The Henderson Mountain Adit is not amenable to Engineering Source Control alternatives as it is too short and too close to the surface. Due to difficult access and the small physical size of the site, implementation of either passive or active water treatment would be difficult if not impossible, and would likely not allow optimizing these technologies to assure final effluent water quality. Therefore, No Action is the preferred alternative for this discharge.

8.5.6 Henderson Mountain Dump 7

Henderson Mountain Dump 7 is currently the only site included in Group 5. This site is characterized by relatively low flows and relatively low metal concentrations.

Henderson Mountain Dump #7 historically discharged at an average rate of 5.3 Lpm (1.4 gpm) onto a topographic swale on the southeast flank of Henderson Mountain. The discharge is located

approximately 760 meters (2,500 feet) from Fisher Creek. Historically, the water has infiltrated into surrounding soils and could not be traced as either a seep or spring down-gradient of the site, however, during mine reclamation activities in 2005 flow from the adit was redirected into a small infiltration basin located at the portal (Alternative WT-1 Infiltration).

Because the Henderson Mountain Dump #7 is too short and too shallow for an engineering flow control closure, the No Action Alternative is most applicable. The fact that the Henderson Mountain Dump 7 discharges through an infiltration basin to colluvial materials some 760 meters (2,500 feet) distant from Fisher Creek, support the preferred alternative selection of No Action.

8.5.7 Preferred Alternative Costs

For all four adits (Little Daisy, Gold Dust, Henderson Mountain and Henderson Mountain Dump 7 adits) and the McLaren subsurface drains evaluated for closure in this EE/CA, the Preferred Alternative was the No Action Alternative (NA-1). Therefore, the estimated cost of implementing the Adit Discharge Response Action for the New World Response and Restoration Project are for long term monitoring, operations and maintenance of the site presented as an Action Common to All Alternatives. The estimated cost for implementing the Revised Long-Term Operations and Maintenance Plan are variable depending on the year (2012 through 2032) and range in cost from about $100,000 to $150,000. Extended costs for the entire 20 years period are estimated at total cost of $1,845,289. Detailed costs from the engineers estimate for the alternatives not selected for this EE/CA are also provided in **Appendix D**.

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APPENDIX A

SELECTED SURFACE AND ADIT WATER QUALITY AND FLOW DATA

Adit Discharge Response Action EE/CA
New World Mining District Response and Restoration Project

TABLE A-1
ADIT DISCHARGE SAMPLING SUMMARY
New World Mining District Adit Discharge Engineering Evaluation/Cost Analysis

Adit Station #	Site Name	Other Station Identifier	Location	Last pH (su)	Flow (gpm)		No. of Samples	Last Sampled
					Range	Last		
FISHER CREEK DRAINAGE								
F-28	Gold Dust Adit	FCSI-96-1 FCSI-96-1A	Middle Fisher Creek Valley; portal	6.9	1.3-247	4.4	43	9/22/2008
F-28-367	Gold Dust underground sample	F-28-367 FCSI-96-1A-367	367 feet from portal	7.9	1.5	1.5	1	8/14/2003
F-28-111	Gold Dust underground sample	GDPT 111	730 feet from portal	7.7	--	--	1	3/29/1992
F-28-112	Gold Dust underground sample	GDPT 112	730 feet from portal	7.7	--	--	1	3/29/1992
F-28-800	Gold Dust underground sample	RR-GD-800	800 feet from portal	6.9	38.6	38.6	1	9/16/2004
F-28-D1	Gold Dust underground sample	FCSI-96-1A-D1	Drill station D1; 1850 feet from portal	7.7	0.5	0.5	1	8/14/2003
F-28-D2	Gold Dust underground sample	GDDS 2	Drill station D2; about 2000 feet from portal	8.2	--	--	2	3/28/1992
F-28-D3	Gold Dust underground sample	FCSI-96-1A-D3	Drill station D3; about 2150 feet from portal	7.7	7	7	1	8/14/2003
F-8A	Glengarry Adit	FCSI-96-2A	Glengarry Mine at base of Lulu Pass switchbacks in Fisher Creek	6.9	0.45-219	0.45	80	6/12/2007
F-8B	Glengarry Millsite Adit	FCSI-96-4	Glengarry Millsite adit	3.4	0.8-26.9	3.1	9	8/15/2008
F-8	Glengarry Middle Adit	--	Middle adit between main adit and millsite	3.5	0-1.4	Dry	7	8/26/2004
FCSI-99-1	Sheep Mountain #1 (NDP)	--	Upper Tredennic basin, flank of Sheep Mountain	7.26	0.003-10	0.003	7	9/17/2007
FCSI-96-15-1	Upper Tredennic Dump 1	FCSI-96-15	Upper Tredennic basin	3.3	0-1.0	Dry	4	7/28/2004
FCSI-96-15-2	Upper Tredennic Dump 2	--	Upper Tredennic basin	2.9	0-0.5	Dry	3	7/16/2003
FCSI-96-6	Middle Tredennic Dump 1	--	Lower Tredennic basin	4.8	0-10	Dry	6	7/28/2004
FCSI-96-5	Lower Tredennic Dump 1	--	Lower Tredennic Basin	5.9	0.27-5	1.5	8	9/22/2008
F-2	Lower Spaulding Dump	FCSI-96-8 Lulu-1	South side of Lulu Pass	2.6	0-0.9	Dry	6	7/13/2001

TABLE A-1
ADIT DISCHARGE SAMPLING SUMMARY
New World Mining District Adit Discharge Engineering Evaluation/Cost Analysis

Adit Station #	Site Name	Other Station Identifier	Location	Last pH (su)	Flow (gpm)		No. of Samples	Last Sampled
					Range	Last		
FCSI-96-7	Middle Spaulding	--	South side of Lulu Pass	--	--	Dry	3	8/27/2004
FCSI-99-71	Henderson Mountain Dump 10	--	Above upper road to Homestake Mine	7.5	0-12	Dry	3	7/27/2004
FCSI-99-73	Henderson Mountain Dump 13	--	SE Henderson Mt, off Henderson Mt Rd	6.6	5-15	15	3	7/27/2004
AE-17	Henderson Mountain Dump 7	FCSI-99-68	SE Henderson Mt, off Henderson Mt Rd.	6.2	0-5	2.0	7	7/27/2004
DAISY CREEK DRAINAGE								
D-18	McLaren Adit	DCSI-96-1	W flank of Fisher Mountain; portal	5.9	1.8-29.6	6.0	31	9/23/2008
D-18-366	McLaren Mine underground	--	Borehole 366 feet in from portal	7.1	0-5.5	Dry	2	8/7/2003
D-18-423	McLaren Mine underground	--	Caved area 423 feet in from portal	7.1	1.5-4.7	4.7	2	8/7/2003
DCSI-99-102	Near McLaren Pit	--	Headwall below county road east of McLaren Pit	--	0	Dry	2	7/29/2004
DCSI-96-3-1	Daisy Pass Dump 1	--	Below Daisy Pass	6.8	<0.1-2	1.0	3	7/29/2004
DCSI-96-6	West of Como Dump 1	--	West side of Lulu pass, Goose Creek	--	0	Dry	2	7/29/2004
MILLER CREEK DRAINAGE								
M-8	Black Warrior Adit	MCSI-96-2; M-4; PA# 34-079	SE Bull of the Woods Pass	7.1	0.1-10	0.2	19	9/18/2007
MCSI-96-3	Upper Miller Creek Dump	--	Near Black Warrior, private land	5.9	0.04-2	0.27	7	9/18/2007
M-1	Little Daisy Adit	MCSI-96-6	SE Daisy Pass	6.8	0.5-220	8.9	24	9/23/2008
M-10	Upper Little Daisy Adit	--	Shaft above Little Daisy Adit	7.84	0-5.8	--	5	9/26/1991
M-25	Henderson Mt Adit	--	SW side Henderson Mountain; above Daisy Pass road	7.0	<0.04-25	<0.04	9	8/20/2007

TABLE A-1
ADIT DISCHARGE SAMPLING SUMMARY
New World Mining District Adit Discharge Engineering Evaluation/Cost Analysis

Adit Station #	Site Name	Other Station Identifier	Location	Last pH (su)	Flow (gpm)		No. of Samples	Last Sampled
					Range	Last		
SODA BUTTE CREEK DRAINAGE								
SBSI-99-74	Woody Ck. Mine Dump 1 (NDP)	--	Woody Creek, Mohawk claim	6.9	3.1-10	4.0	3	7/29/2004
AE-12	Reeb #1	--	SE flank of Henderson Mountain	3.3	0	Dry	2	7/7/2001
SBSI-99-85	Alice E. Millsite seep (NDP)	AE-6	S Henderson Mountain	5.4	0-10.0	4.0	4	7/29/2004
SBSI-99-87	Soda Butte Dump 8 (NDP)	--	Off Miller Mt Road, near Cooke City	6.9	3-100	3	4	7/29/2004
SBSI-99-95	Soda Butte Dump 1 (NDP)	--	Off Miller Mt Road, near Cooke City	7.4	0-0.1	Dry	3	7/29/2004

Notes: NDP = Non-District Property

TABLE A-2 - STATISTICAL SUMMARY OF WATER QUALITY DATA 1989-2010

New World Mining District Response and Restoration Project

Sample Station	Sample Date	Data Source	Flow (cfs)	Flow Flag	Field pH (su)	Aluminum Total Rec. (mg/l)	Al(calc)	Al Flag	Arsenic Total Rec. (mg/l)	As(calc)	As Flag	Cadmium Total Rec. (mg/l)	Cd(calc)	Cd Flag	Chromium Total Rec. (mg/l)	Cr(calc)	Cr Flag	Copper Total Rec. (mg/l)	Cu(calc)	Cu Flag	Iron Total Rec. (mg/l)	Fe(calc)	Fe Flag	Lead Total Rec. (mg/l)	Pb(calc)	Pb Flag	Manganese Total Rec. (mg/l)	Mn(calc)	Mn Flag	Zinc Total Rec. (mg/l)	Zn(calc)	Zn Flag
Chronic Standard (for Hardness = 50 mg/l)						0.087			0.15			0.00016			0.049			0.0052			1			0.0013			NA			0.067		
Acute Standard (for Hardness = 50 mg/l)						0.75			0.34			0.001			1.02			0.0073			NA			0.034			NA			0.067		
Chronic Standard (for Hardness = 100 mg/l)						0.087			0.15			0.0027			0.086			0.0093			1			0.0032			NA			0.12		
Acute Standard (for Hardness = 100 mg/l)						0.75			0.34			0.0021			1.8			0.0140			NA			0.082			NA			0.12		
CFY-2	9-Aug-90	Hydrometrics	0.69		6.78	0.1	0.1		0.0050	0.0025	<	0.00100	0.0005	<	0.0200	0.01	<	0.05	0.05		0.12	0.12		0.01	0.005	<	0.04	0.04		0.02	0.01	<
CFY-2	5-Jun-91	Hydrometrics	91.6		7.05	0.5	0.5		0.0010	0.0005	<	0.00010	0.00005	<	0.0200	0.01	<	0.06	0.03	<	0.83	0.83		0.002	0.002		0.03	0.03		0.01	0.005	<
CFY-2	9-Jul-91	Hydrometrics	4.7		8.62	0.1	0.05	<	0.0050	0.0025	<	0.00020	0.0002		0.0200	0.01	<	0.06	0.06		0.25	0.25				J	0.03	0.03		0.03	0.03	
CFY-2	13-Aug-91	Hydrometrics	2.4		8.6	0.1	0.1		0.0050	0.0025	<	0.00020	0.0002		0.0200	0.01	<	0.052	0.052		0.06	0.06		0.002	0.001	<	0.04	0.04		0.04	0.04	
CFY-2	24-Sep-91	Hydrometrics	1.4		9.22	0.1	0.05	<	0.0050	0.0025	<	0.00010	0.00005	<	0.0200	0.01	<	0.017	0.017		0.03	0.015	<	0.002	0.001	<	0.02	0.01	<	0.01	0.01	
CFY-2	23-Jul-93	Hydrometrics	17.03		7.44	0.3	0.3		0.0010	0.0005	<	0.00010	0.0001		0.0010	0.0005	<	0.11	0.11		0.42	0.42		0.002	0.001	<	0.05	0.05		0.03	0.015	<
CFY-2	21-Sep-93	Hydrometrics	2.46		7.3	0.1	0.1		0.0010	0.0005	<	0.00020	0.0002		0.0010	0.0005	<	0.06	0.06		0.17	0.17		0.002	0.001	<	0.09	0.09		0.028	0.028	
CFY-2	15-Jun-94	Hydrometrics	39.63		6.23	0.2	0.2		0.0010	0.0005	<	0.00010	0.00005	<	0.0010	0.0005	<	0.05	0.05	J	0.2	0.2		0.002	0.001	<	0.03	0.03		0.012	0.012	J
CFY-2	6-May-99	Maxim	0.091		7.35	0.1	0.05	<				0.00010	0.00005	<				0.004	0.004		0.01	0.005	<	0.001	0.0005	<	0.005	0.0025	<	0.01	0.005	<
CFY-2	9-Jul-99	Maxim	21.46		7.24	0.2	0.2					0.00010	0.0001					0.09	0.09		0.23	0.23		0.001	0.0005	<	0.019	0.019		0.04	0.04	
CFY-2	29-Sep-99	Maxim	2.071		7.33	0.1	0.05	<				0.00020	0.0002					0.022	0.022		0.04	0.04		0.001	0.0005	<	0.017	0.017		0.04	0.04	J
CFY-2	13-Apr-00	Maxim	0.658		8.02	0.05	0.025	<				0.00010	0.00005	<				0.008	0.008		0.05	0.025	<	0.001	0.0005	<	0.005	0.0025	<	0.02	0.01	<
CFY-2	8-Jul-00	Maxim	20.55		6.19	0.2	0.2	J				0.00010	0.00005	<				0.068	0.068	J	0.24	0.24	J	0.001	0.0005	<	0.035	0.035	J	0.02	0.02	J
CFY-2	22-Sep-00	Maxim			7.09	0.1	0.05	<				0.00010	0.00005	<				0.004	0.004		0.01	0.01		0.001	0.0005	<	0.003	0.0015	<	0.01	0.005	<
CFY-2	28-Sep-00	Maxim			7.1	0.1	0.05	<				0.00010	0.00005	<				0.01	0.01		0.03	0.03		0.001	0.0005	<	0.004	0.004		0.01	0.005	<
CFY-2	10-Oct-00	Maxim				0.1	0.05	<				0.00010	0.00005	<				0.01	0.01		0.05	0.025	<	0.003	0.0015	<	0.005	0.0025	<	0.02	0.01	<
CFY-2	19-Oct-00	Maxim			6.19	0.1	0.05	<				0.00010	0.00005	<				0.008	0.008		0.05	0.025	<	0.001	0.0005	<	0.004	0.004		0.01	0.01	
CFY-2	21-Apr-01	Maxim	0.48		7.47	0.1	0.05	<				0.00010	0.00005	<				0.005	0.005		0.01	0.005	<	0.001	0.0005	<	0.003	0.0015	<	0.01	0.01	
CFY-2	26-Jun-01	Maxim	30.66		6.95	0.1	0.05	<				0.00010	0.0001					0.054	0.054		0.24	0.24		0.002	0.002	J	0.024	0.024		0.01	0.005	<
CFY-2	11-Oct-01	Maxim	0.49		6.42	0.1	0.05	<	0.0030	0.0015	<	0.00010	0.00005	<				0.007	0.007		0.05	0.025	<	0.001	0.0005	<	0.003	0.0015	<	0.03	0.03	J
CFY-2	26-Apr-02	Maxim	0.28		6.5	0.1	0.05	<				0.0001	0.00005	<				0.007	0.007		0.02	0.02		0.001	0.0005	<	0.005	0.005		0.03	0.03	
CFY-2	1-Jul-02	Maxim	13		7.51	0.3	0.3	J				0.0001	0.00005	<				0.062	0.062		0.34	0.34		0.001	0.001		0.03	0.03		0.04	0.04	J
CFY-2	8-Oct-02	Maxim	0.027		7.92	0.1	0.05	<				0.0002	0.0002					0.008	0.008		0.03	0.03		0.001	0.0005	<	0.003	0.0015	<	0.03	0.03	J
CFY-2	22-Apr-03	Maxim	0.002		6.47	0.05	0.025	<				0.0001	0.00005	<				0.004	0.004		0.09	0.09		0.001	0.0005	<	0.003	0.0015	<	0.01	0.005	<
CFY-2	1-Jul-03	Maxim	4		6.35	0.17	0.17					0.0001	0.00005	<				0.04	0.04		0.19	0.19		0.001	0.0005	<	0.024	0.024		0.01	0.005	<
CFY-2	30-Sep-03	Maxim	0.014		5.67	0.05	0.025	<				0.0001	0.00005	<				0.008	0.008		0.01	0.01		0.001	0.0005	<	0.003	0.0015	<	0.01	0.01	
CFY-2	6-Apr-04	Maxim	0.045		7.38	0.05	0.025	<				0.0001	0.00005	<				0.004	0.004		0.01	0.005	<	0.001	0.0005	<	0.005	0.0025	<	0.02	0.02	JF%
CFY-2	28-Jun-04	Maxim	2.48		7.8	0.09	0.09					0.0001	0.00005	<				0.035	0.035		0.13	0.13		0.001	0.0005	<	0.013	0.013		0.01	0.005	<
CFY-2	5-Oct-04	Maxim	4.33		7.25	0.08	0.08					0.0001	0.0001					0.02	0.02		0.04	0.04		0.001	0.0005	<	0.01	0.01		0.03	0.03	
CFY-2	5-Apr-05	Maxim	0.54		7.57	0.05	0.025	<				0.0001	0.00005	<				0.004	0.004		0.01	0.01		0.001	0.0005	<	0.003	0.0015	<	0.01	0.005	<
CFY-2	6/28/2005	Maxim	58.17		6.3	0.2	0.2				--	0.0001	0.00005	<			--	0.045	0.045		0.2	0.2		0.001	0.001		0.021	0.021		0.02	0.02	
CFY-2	10/11/2005	Maxim	0.77		6.86	0.05	0.025	<			--	0.0001	0.00005	<			--	0.009	0.009		0.01	0.005	<	0.001	0.0005	<	0.003	0.0015	<	0.01	0.01	
CFY-2	26-Apr-06	Maxim	0.92		6.9	0.05	0.025	<				0.0001	0.00005	<				0.008	0.008		0.01	0.005	<	0.001	0.0005	<	0.003	0.0015	<	0.01	0.005	<
CFY-2	28-Jun-06	Maxim	34.94		7.3	0.16	0.16					0.0001	0.00005	<				0.045	0.045		0.17	0.17		0.001	0.0005	<	0.025	0.025		0.01	0.005	<
CFY-2	26-Sep-06	Maxim	0.87		7.2	0.05	0.025	<				0.0001	0.00005	<				0.007	0.007		0.01	0.005	<	0.001	0.0005	<	0.003	0.0015	<	0.09	0.09	
CFY-2	11-Apr-07	Tt	0.837		6.57	0.05	0.025	<			--	0.0001	0.00005	<			--	0.005	0.005		0.01	0.005	<	0.001	0.0005	<	0.003	0.0015	<	0.01	0.005	<
CFY-2	12-Jun-07	Tt	43.4		6.3	0.14	0.14				--	0.0001	0.00005	<			--	0.04	0.04		0.13	0.13		0.001	0.0005	<	0.01	0.01		0.01	0.005	<
CFY-2	17-Sep-07	Tt	0.915		6.87	0.05	0.025	<			--	0.0001	0.00005	<			--	0.008	0.008		0.01	0.01		0.001	0.0005	<	0.003	0.0015	<	0.01	0.005	<
CFY-2	17-Apr-08	Tt	0.74		5.16	0.05	0.025	<				0.0001	0.00005	<				0.007	0.007		0.01	0.005	<	0.001	0.0005	<	0.003	0.0015	<	0.01	0.01	
CFY-2	22-Sep-08	Tt	1.675		6.7	0.05	0.025	<				0.0001	0.00005	<				0.012	0.012		0.01	0.005	<	0.001	0.001	JF%	0.006	0.006		0.01	0.01	
CFY-2	14-Jul-08	Tt	60.47		7.19	0.06	0.06					0.0001	0.00005	<				0.033	0.033		0.14	0.14		0.001	0.0005	<	0.016	0.016		0.01	0.005	<
CFY-2	09-Apr-09	Tt	0.44		6.52	0.0055	0.0055					0.000045	4.5E-05	J				0.0047	0.0047		0.025	0.0125	<	0.00005	2.5E-05	<	0.0009	0.0009		0.0086	0.0086	
CFY-2	23-Jun-09	Tt	70.9		7.48	0.13	0.13					0.000051	5.1E-05	J				0.031	0.031		0.13	0.13		0.00037	0.00037		0.016	0.016		0.008	0.008	
CFY-2	29-Sep-09	Tt	0.748		5.65	0.053	0.053					0.000056	5.6E-05	J				0.0061	0.0061		0.025	0.0125	<	0.00005	2.5E-05	<	0.001	0.001		0.008	0.008	
CFY-2	06-Apr-10	Tt	0.687		6.18	0.0096	0.0096	JF%				0.00008	0.00004	<				0.0036	0.0036		0.05	0.025	<	0.0001	0.00005	<	0.00071	0.00071		0.0072	0.0072	
CFY-2	27-Sep-10	Tt	2.07		6.91	0.021	0.021					0.00008	0.00004	<				0.0078	0.0078		0.05	0.025	<	0.0001	0.00005	<	0.0029	0.0029		0.0092	0.0092	

Notes: mg/l = milligrams/liter; su = standard units
n = number of samples

< = less than detection
J = estimated value

NA - not applicable

TABLE A-2 - STATISTICAL SUMMARY OF WATER QUALITY DATA 1989-2010

New World Mining District Response and Restoration Project

Sample Station	Sample Date	Data Source	Flow (cfs)	Flow Flag	Field pH (su)	Aluminum Total Rec. (mg/l)	Al(calc)	Al Flag	Arsenic Total Rec. (mg/l)	As(calc)	As Flag	Cadmium Total Rec. (mg/l)	Cd(calc)	Cd Flag	Chromium Total Rec. (mg/l)	Cr(calc)	Cr Flag	Copper Total Rec. (mg/l)	Cu(calc)	Cu Flag	Iron Total Rec. (mg/l)	Fe(calc)	Fe Flag	Lead Total Rec. (mg/l)	Pb(calc)	Pb Flag	Manganese Total Rec. (mg/l)	Mn(calc)	Mn Flag	Zinc Total Rec. (mg/l)	Zn(calc)	Zn Flag
Chronic Standard (for Hardness = 50 mg/l)						0.087			0.15			0.00016			0.049			0.0052			1			0.0013			NA			0.067		
Acute Standard (for Hardness = 50 mg/l)						0.75			0.34			0.001			1.02			0.0073			NA			0.034			NA			0.067		
Chronic Standard (for Hardness = 100 mg/l)						0.087			0.15			0.0027			0.086			0.0093			1			0.0032			NA			0.12		
Acute Standard (for Hardness = 100 mg/l)						0.75			0.34			0.0021			1.8			0.0140			NA			0.082			NA			0.12		
Station CFY-2: 1989 to 2004 Low Flow (n)			15		18	19			5			19			4			19			19			19			19			19		
Minimum			0.002		5.670	0.025			0.001			0.0001			0.001			0.004			0.005			0.0005			0.002			0.005		
Maximum			4.330		9.220	0.100			0.003			0.0005			0.010			0.060			0.170			0.0050			0.090			0.040		
Mean			1.029		7.226	0.054			0.002			0.0001			0.008			0.016			0.039			0.0009			0.013			0.018		
Standard Deviation (SD)			1.265		0.860	0.024			0.001			0.0001			0.005			0.018			0.043			0.0010			0.022			0.012		
Mean + (2 x SD); for pH: Mean - (2 x SD)			3.558		5.506	0.103			0.004			0.0003			0.017			0.052			0.126			0.0029			0.057			0.043		
Station CFY-2: 1989-2004 High Flow (n)			10		10	10			4			10			4			10			10			9			10			10		
Minimum			2.480		6.190	0.050			0.001			0.0001			0.001			0.030			0.130			0.0005			0.013			0.005		
Maximum			91.600		8.620	0.500			0.003			0.0002			0.010			0.110			0.830			0.0020			0.050			0.040		
Mean			24.511		7.138	0.206			0.001			0.0001			0.005			0.060			0.307			0.0010			0.029			0.018		
Standard Deviation (SD)			26.414		0.765	0.136			0.001			0.0000			0.005			0.025			0.201			0.0006			0.010			0.014		
Mean + (2 x SD); for pH: Mean - (2 x SD)			77.339		5.609	0.479			0.003			0.0002			0.016			0.109			0.708			0.0022			0.048			0.046		
Station CFY-2: 1998 to 2004 All (n)			25		28	29			9			29			8			29			29			28			29			29		
Minimum			0.002		5.670	0.025			0.001			0.0001			0.001			0.004			0.005			0.0005			0.002			0.005		
Maximum			91.600		9.220	0.500			0.003			0.0005			0.010			0.110			0.830			0.0050			0.090			0.040		
Mean			10.422		7.194	0.107			0.002			0.0001			0.006			0.031			0.132			0.0009			0.018			0.018		
Standard Deviation (SD)			20.011		0.814	0.108			0.001			0.0001			0.005			0.029			0.176			0.0009			0.020			0.013		
Mean + (2 x SD); for pH: Mean - (2 x SD)			50.443		5.567	0.323			0.004			0.0003			0.016			0.089			0.483			0.0027			0.058			0.043		
Station CFY-2: 2005 to 2010 Low Flow (n)			12		12	12			0			12			0			12			12			12			12			12		
Minimum			0.440		5.160	0.006						0.0000						0.004			0.005			0.0000			0.001			0.005		
Maximum			2.070		7.570	0.053						0.0001						0.012			0.025			0.0010			0.006			0.090		
Mean			0.934		6.591	0.024						0.00005						0.007			0.010			0.0004			0.002			0.014		
Standard Deviation (SD)			0.468		0.660	0.011						0.00000						0.002			0.007			0.0003			0.001			0.024		
Mean + (2 x SD); for pH: Mean - (2 x SD)			1.871		5.270	0.047						0.0001						0.012			0.025			0.0010			0.005			0.062		
Station CFY-2: 2005-2010 High Flow (n)			5		5	5			0			5			0			5			5			5			5			5		
Minimum			34.940		6.300	0.060						0.0001						0.031			0.130			0.0004			0.010			0.005		
Maximum			70.900		7.480	0.200						0.0001						0.045			0.200			0.0010			0.025			0.020		
Mean			53.576		6.914	0.138						0.0001						0.039			0.154			0.0006			0.018			0.009		
Standard Deviation (SD)			14.314		0.570	0.051						0.0000						0.007			0.030			0.0002			0.006			0.007		
Mean + (2 x SD); for pH: Mean - (2 x SD)			82.205		5.774	0.240						0.0001						0.052			0.215			0.0011			0.029			0.022		
Station CFY-2: 2005-2010 All (n)			17		17	17			0			17			0			17			17			17			17			17		
Minimum			0.440		5.160	0.006						0.0000						0.004			0.005			0.0000			0.001			0.005		
Maximum			70.900		7.570	0.200						0.0001						0.045			0.200			0.0010			0.025			0.090		
Mean			16.417		6.686	0.058						0.0000						0.016			0.053			0.0004			0.006			0.013		
Standard Deviation (SD)			25.742		0.636	0.060						0.0000						0.015			0.069			0.0003			0.008			0.020		
Mean + (2 x SD); for pH: Mean - (2 x SD)			67.901		5.415	0.178						0.0001						0.047			0.191			0.0010			0.023			0.053		
Temporary Standard - CFY-2					5.7	0.47			NA			NA			NA			0.11			0.75			0.002			0.082			0.044		
SW-3	2-Aug-89	Hydrometrics				0.1	0.05	<	0.0050	0.0025	<	0.00100	0.0005	<				0.03	0.03		0.03	0.015	<	0.01	0.005	<	0.11	0.11		0.01	0.01	
SW-3	15-Sep-89	Hydrometrics	0.36			3.7	3.7		0.0050	0.0025	<	0.00100	0.0005	<				1.04	1.04		5.58	5.58		0.01	0.005	<	1.24	1.24		0.18	0.18	
SW-3	20-Oct-89	Hydrometrics	0.26		3.43	3.7	3.7		0.0050	0.0025	<	0.00100	0.0005	<				0.85	0.85		5.59	5.59		0.01	0.005	<	1.23	1.23		0.17	0.17	
SW-3	17-Mar-90	Hydrometrics	0.25		3.44	2.2	2.2		0.0050	0.0025	<	0.00100	0.0005	<				0.61	0.61		3.27	3.27		0.01	0.005	<	1	1		0.15	0.15	
SW-3	28-May-90	Hydrometrics	0.9		3.35	3	3		0.0050	0.0025	<	0.00040	0.0004		0.0200	0.01	<	0.593	0.593		3.3	3.3		0.003	0.003		0.49	0.49		0.11	0.11	
SW-3	5-Jun-90	Hydrometrics	5.75		5.49	2.1	2.1											0.51	0.51		2.9	2.9								0.06	0.06	
SW-3	13-Jun-90	Hydrometrics	4.54		3.33	1.8	1.8											0.43	0.43		0.04	0.04								0.04	0.04	
SW-3	20-Jun-90	Hydrometrics	6.15		6.56	1.8	1.8					0.00200	0.002		0.0200	0.01	<	0.49	0.49		2.26	2.26		0.01	0.005	<	0.23	0.23		0.05	0.05	
SW-3	27-Jun-90	Hydrometrics	17.89		4.76	1.7	1.7		0.0050	0.0025	<	0.00010	0.0001		0.0200	0.01	<	0.419	0.419		5.89	5.89		0.004	0.004		0.16	0.16		0.04	0.04	
SW-3	3-Jul-90	Hydrometrics	14.9		4.66	1.6	1.6					0.00100	0.0005	<	0.0200	0.01	<	0.486	0.486		4.3	4.3		0.01	0.005	<	0.19	0.19		0.04	0.04	
SW-3	10-Jul-90	Hydrometrics	3.9			1.7	1.7					0.00100	0.0005	<	0.0200	0.01	<	0.59	0.59		3.18	3.18		0.01	0.005	<	0.27	0.27		0.08	0.08	
SW-3	17-Jul-90	Hydrometrics	2.3		3.67	2	2											0.8	0.8		3.79	3.79								0.07	0.07	
SW-3	26-Jul-90	Hydrometrics	1.6		3.6	2.6	2.6		0.0050	0.0025	<	0.00040	0.0004		0.0200	0.01	<	0.99	0.99		5.66	5.66		0.003	0.003		0.56	0.56		0.22	0.22	
SW-3	25-Sep-90	Hydrometrics	0.4		4.5	3.3	3.3		0.0050	0.0025	<	0.00090	0.0009		0.0200	0.01	<	0.96	0.96		6.98	6.98		0.007	0.007		1.29	1.29		0.16	0.16	
SW-3	15-Mar-91	Hydrometrics	0.2		2.79	2.7	2.7		0.0050	0.0025	<	0.00100	0.0005	<	0.0200	0.01	<	0.72	0.72		2.79	2.79		0.01	0.005	<	0.89	0.89		0.15	0.15	
SW-3	5-Jun-91	Hydrometrics	7		3.46	1.1	1.1		0.0010	0.0005	<	0.00010	0.0001		0.0200	0.01	<	0.39	0.39		3.78	3.78		0.002	0.002		0.16	0.16		0.03	0.03	
SW-3	9-Jul-91	Hydrometrics	3		2.91	1.46	1.46		0.0050	0.0025	<	0.00180	0.0018	J	0.0200	0.01	<	0.65	0.65		4.32	4.32		0.002	0.002	J	0.29	0.29		0.05	0.05	
SW-3	14-Aug-91	Hydrometrics	0.5		3.24	2.9	2.9		0.0050	0.0025	<	0.00070	0.0007		0.0200	0.02		0.95	0.95		5.93	5.93		0.004	0.004		0.93	0.93		0.14	0.14	
SW-3	24-Sep-91	Hydrometrics	0.2		3.29	4.3	4.3		0.0050	0.0025	<	0.00220	0.0022		0.0200	0.01	<	0.95	0.95		5.51	5.51		0.006	0.006		1.26	1.26		0.16	0.16	
SW-3	23-Jul-93	Hydrometrics	2.36		3.37	3.3	3.3		0.0010	0.001		0.00040	0.0004		0.0030	0.003		1.1	1.1		6.62	6.62		0.002	0.001	<	0.56	0.56		0.13	0.13	
SW-3	21-Sep-93	Hydrometrics	0.38		3.46	3.8	3.8		0.0010	0.0005	<	0.00100	0.001		0.0010	0.0005	<	1.1	1.1		11.6	11.6		0.009	0.009		1.67	1.67		0.17	0.17	
SW-3	14-Jun-94	Hydrometrics	5.42		3.79	2.6	2.6		0.0010	0.0005	<	0.00030	0.0003		0.0010	0.0005	<	0.54	0.54	J	5	5		0.007	0.007		0.29	0.29		0.058	0.058	J

Notes: mg/l = milligrams/liter; su = standard units
n = number of samples

< = less than detection
J = estimated value

NA - not applicable

TABLE A-2 - STATISTICAL SUMMARY OF WATER QUALITY DATA 1989-2010

New World Mining District Response and Restoration Project

Sample Station	Sample Date	Data Source	Flow (cfs)	Flow Flag	Field pH (su)	Aluminum Total Rec. (mg/l)	Al(calc)	Al Flag	Arsenic Total Rec. (mg/l)	As(calc)	As Flag	Cadmium Total Rec. (mg/l)	Cd(calc)	Cd Flag	Chromium Total Rec. (mg/l)	Cr(calc)	Cr Flag	Copper Total Rec. (mg/l)	Cu(calc)	Cu Flag	Iron Total Rec. (mg/l)	Fe(calc)	Fe Flag	Lead Total Rec. (mg/l)	Pb(calc)	Pb Flag	Manganese Total Rec. (mg/l)	Mn(calc)	Mn Flag	Zinc Total Rec. (mg/l)	Zn(calc)	Zn Flag
Chronic Standard (for Hardness = 50 mg/l)						0.087			0.15			0.00016			0.049			0.0052			1			0.0013			NA			0.067		
Acute Standard (for Hardness = 50 mg/l)						0.75			0.34			0.001			1.02			0.0073			NA			0.034			NA			0.067		
Chronic Standard (for Hardness = 100 mg/l)						0.087			0.15			0.0027			0.086			0.0093			1			0.0032			NA			0.12		
Acute Standard (for Hardness = 100 mg/l)						0.75			0.34			0.0021			1.8			0.0140			NA			0.082			NA			0.12		
SW-3	14-Jul-95	Hydrometrics	7.29		3.29	2.5	2.5		0.0020	0.002		0.00040	0.0004		0.0010	0.001		0.766	0.766	J	3.32	3.32	J	0.008	0.008		0.41	0.41		0.076	0.076	
SW-3	27-Sep-95	Hydrometrics	0.31		3.6	4.8	4.8		0.0010	0.0005	<	0.00090	0.0009		0.0010	0.001		1.53	1.53		11	11		0.008	0.008		1.66	1.66		0.231	0.231	
SW-3	21-May-96	Hydrometrics			3.22	4.3	4.3					0.00100	0.001					0.92	0.92		4.8	4.8		0.006	0.006		0.891	0.891		0.22	0.22	
SW-3	12-Jun-96	Hydrometrics	9.04		3.1													0.417	0.417		2.73	2.73	J							0.08	0.08	J
SW-3	20-Jun-96	Hydrometrics	7.795		3.4	1.6	1.6					0.00020	0.0002					0.395	0.395		1.72	1.72		0.003	0.0015	<	0.167	0.167		0.03	0.03	
SW-3	26-Jun-96	Hydrometrics	12.65		4.16													0.381	0.381		3.25	3.25								0.04	0.04	
SW-3	2-Jul-96	Hydrometrics	15.9		3.67													0.374	0.374		6.88	6.88								0.08	0.08	J
SW-3	11-Jul-96	Hydrometrics	9.18		4.09	1.3	1.3	J				0.00010	0.0001					0.448	0.448		1.93	1.93		0.003	0.0015	<	0.163	0.163		0.04	0.04	
SW-3	18-Jul-96	Hydrometrics	5.644		3.76													0.646	0.646		2.84	2.84								0.08	0.04	<
SW-3	25-Jul-96	Hydrometrics	6.767		3.59													0.803	0.803		3.83	3.83								0.09	0.09	
SW-3	21-Aug-96	Hydrometrics	2.552		3.94													0.98	0.98		6.46	6.46								0.15	0.15	
SW-3	11-Sep-96	Hydrometrics	0.38		3.58	3.5	3.5					0.00090	0.0009	J				1.04	1.04		6.91	6.91		0.008	0.008		1.32	1.32		0.18	0.18	
SW-3	8-Jul-97	UOS Data	10.843			1.81	1.81		0.0100	0.005	<	0.00500	0.0025	<	0.0100	0.005	<	0.411	0.411		2.6	2.6					0.165	0.165		0.0368	0.0368	
SW-3	27-Mar-98	UOS Data	0.17		2.5	3.15	3.15											0.691	0.691		7.35	7.35					1.31	1.31		0.177	0.177	
SW-3	23-Apr-98	UOS Data	0.112		3.5	3.08	3.08											0.745	0.745		6.92	6.92					1.26	1.26		0.177	0.177	
SW-3	5-May-98	UOS Data	0.217		5.44	2.51	2.51											0.535	0.535		3.03	3.03					0.502	0.502		0.0965	0.0965	
SW-3	13-May-98	UOS Data	4.783		6.3	2.26	2.26											0.443	0.443		2.82	2.82					0.348	0.348		0.0689	0.0689	
SW-3	29-May-98	UOS Data	2.172		3.63	1.77	1.77											0.361	0.361		2.71	2.71					0.231	0.231		0.0547	0.0547	
SW-3	6-May-99	Maxim	0.2244		3.45	3.9	3.9					0.00110	0.0011					0.9	0.9		7.49	7.49		0.007	0.007		1.35	1.35		0.29	0.29	
SW-3	9-Jul-99	Maxim	7.53		4.12	1.5	1.5					0.00020	0.0002					0.41	0.41		1.85	1.85		0.002	0.002		0.162	0.162		0.06	0.06	
SW-3	30-Sep-99	Maxim	0.306		3.43	3.1	3.1					0.00050	0.0005					1	1		7.03	7.03		0.002	0.002		1.3	1.3		0.18	0.18	J
SW-3	13-Apr-00	Maxim	0.055		3.25	3.2	3.2					0.00140	0.0014					0.86	0.86		6.2	6.2		0.008	0.008		1.32	1.32		0.02	0.01	<
SW-3	18-May-00	Maxim	0.935		4.1													0.58	0.58											0.11	0.11	
SW-3	18-May-00	Maxim	0.797		4													0.62	0.62											0.12	0.12	
SW-3	18-May-00	Maxim	1.04		4.1	2.5	2.5					0.00040	0.0004					0.6	0.6		3.19	3.19		0.003	0.003		0.56	0.56		0.12	0.12	
SW-3	18-May-00	Maxim	0.809		4													0.63	0.63											0.12	0.12	
SW-3	18-Jun-00	Maxim	7.18		3.91	1.8	1.8					0.00020	0.0002					0.43	0.43		2.67	2.67		0.003	0.003		0.18	0.18		0.04	0.04	
SW-3	18-Jun-00	Maxim	6.37		3.79													0.46	0.46											0.05	0.05	
SW-3	18-Jun-00	Maxim	6.24		3.81													0.44	0.44											0.05	0.05	
SW-3	18-Jun-00	Maxim	5.52		3.78													0.44	0.44											0.06	0.06	
SW-3	8-Jul-00	Maxim	3.02		3.54													0.82	0.82	J										0.07	0.07	J
SW-3	8-Jul-00	Maxim	3.03		3.44	2	2	J				0.00010	0.00005	<				0.67	0.67	J	3.11	3.11	J	0.002	0.002		0.37	0.37	J	0.06	0.06	J
SW-3	8-Jul-00	Maxim	3.16		3.5													0.77	0.77	J										0.07	0.07	J
SW-3	8-Jul-00	Maxim	3.3		3.71													0.74	0.74	J										0.07	0.07	J
SW-3	16-Aug-00	Maxim	0.49		2.6	2.8	2.8					0.00110	0.0011					0.95	0.95		5.21	5.21		0.007	0.007		1.06	1.06		0.15	0.15	
SW-3	1-Sep-00	Maxim	0.381		3.6	2.8	2.8					0.00060	0.0006					0.82	0.82		7.38	7.38		0.005	0.005		1.11	1.11		0.16	0.16	
SW-3	17-Sep-00	Maxim	0.218		3.4	3.1	3.1											0.76	0.76		22	22		0.003	0.003		1.5	1.5		0.15	0.15	
SW-3	19-Oct-00	Maxim			3	2.9	2.9					0.00010	0.00005	<				0.67	0.67		7.84	7.84	J	0.007	0.007		1.29	1.29		0.39	0.39	
SW-3	6-Dec-00	Maxim			3.28	3	3					0.00100	0.001					0.72	0.72		6.44	6.44		0.007	0.007		1.25	1.25		0.18	0.18	
SW-3	21-Apr-01	Maxim	0.103		3.74	2.6	2.6					0.00100	0.001					0.74	0.74		6.21	6.21		0.006	0.006		1.12	1.12		0.12	0.12	
SW-3	11-Jun-01	Maxim			3.05	1.7	1.7		0.0030	0.0015	<	0.00010	0.00005	<				0.48	0.48		1.92	1.92		0.003	0.0015	<	0.2	0.2		0.05	0.05	J
SW-3	26-Jun-01	Maxim	4.208		3.79	2.5	2.5					0.00030	0.0003					0.53	0.53		6.53	6.53		0.007	0.007	J	0.31	0.31		0.06	0.06	
SW-3	31-Aug-01	Maxim	0.29		3.57	2.7	2.7					0.00560	0.0056					0.84	0.84		10.1	10.1		0.012	0.012		1.17	1.17		0.15	0.15	
SW-3	11-Oct-01	Maxim	0.27		3.29	2.4	2.4		0.0030	0.0015	<	0.00110	0.0011					0.67	0.67		5.79	5.79		0.004	0.004		0.87	0.87		0.15	0.15	
SW-3	26-Apr-02	Maxim	0.37		2.76	3.1	3.1					0.001	0.001					0.83	0.83		7.1	7.1		0.006	0.006		1.28	1.28		0.18	0.18	
SW-3	1-Jul-02	Maxim	7.6		3.92	1.7	1.7	J				0.0003	0.0003					0.54	0.54		4.31	4.31		0.003	0.003		0.3	0.3		0.08	0.08	J
SW-3	8-Oct-02	Maxim	0.29		3.55	3.6	3.6					0.001	0.001					0.85	0.85		10.6	10.6		0.009	0.009		1.48	1.48		0.71	0.71	J
SW-3	23-Apr-03	Maxim	0.05		3.31	2.51	2.51					0.0012	0.0012					0.83	0.83		6.92	6.92		0.008	0.008		1.3	1.3		0.26	0.26	
SW-3	1-Jul-03	Maxim	6.57		3.41	1.62	1.62					0.0002	0.0002					0.45	0.45		2.32	2.32		0.002	0.002		0.29	0.29		0.02	0.02	
SW-3	31-Jul-03	Maxim			4.1	2.83	2.83		0.001	0.0005	<	0.0005	0.0005					1.04	1.04		5.38	5.38		0.005	0.005		0.78	0.78		0.14	0.14	JF%
SW-3	14-Aug-03	Maxim			3.6	3.1	3.1		0.001	0.0005	<	0.0005	0.0005					1.15	1.15		6.13	6.13		0.01	0.01		1.31	1.31		0.13	0.13	
SW-3	21-Aug-03	Maxim				3	3					0.0009	0.0009					1.06	1.06		10.9	10.9		0.009	0.009		1.5	1.5		0.14	0.14	
SW-3	22-Aug-03	Maxim				3.1	3.1					0.0009	0.0009					0.94	0.94		8.58	8.58		0.013	0.013		1.48	1.48		0.19	0.19	
SW-3	30-Sep-03	Maxim	0.258		3.3	2.86	2.86					0.0008	0.0008					0.8	0.8		10.5	10.5		0.009	0.009		1.74	1.74		0.21	0.21	
SW-3	5-Apr-04	Maxim	0.136		3.4	2.2	2.2					0.0008	0.0008					0.7	0.7		2.34	2.34		0.004	0.004		0.9	0.9		0.18	0.18	JF%
SW-3	28-Jun-04	Maxim	9.32		4.5	2.27	2.27					0.0002	0.0002					0.37	0.37		3.84	3.84		0.005	0.005		0.18	0.18		0.05	0.05	
SW-3	5-Oct-04	Maxim	0.35		3.85	1.52	1.52					0.0005	0.0005					0.6	0.6		0.87	0.87		0.002	0.002		0.29	0.29		0.08	0.08	
SW-3	5-Apr-05	Maxim	0.08		3.84	1.75	1.75					0.0009	0.0009					0.8	0.8		0.9	0.9		0.002	0.002		0.49	0.49		0.18	0.18	
SW-3	28-Jun-05	Maxim	8.13		4	1.49	1.49				--	0.0001	0.0001				--	0.36	0.36		1.14	1.14		0.002	0.002		0.14	0.14		0.04	0.04	
SW-3	29-Aug-05	Maxim	0.38		3.8	1.36	1.36				--	0.0006	0.0006				--	0.59	0.59		1.36	1.36		0.002	0.002		0.42	0.42		0.13	0.13	(1)
SW-3	11-Oct-05	Maxim	0.31		4.53	2.31	2.31				--	0.0007	0.0007				--	0.73	0.73		0.9	0.9		0.002	0.002		0.52	0.52		0.12	0.12	
SW-3	26-Apr-06	Maxim	0.07		3.8	2.61	2.61					0.0009	0.0009					0.87	0.87		1.1	1.1		0.001	0.001		0.54	0.54		0.15	0.15	
SW-3	28-Jun-06	Maxim	5.46		5	1.74	1.74					0.0001	0.0001					0.39	0.39		1.52	1.52		0.002	0.002		0.18	0.18		0.02	0.02	

Notes: mg/l = milligrams/liter; su = standard units
n = number of samples

< = less than detection
J = estimated value

NA - not applicable

TABLE A-2 - STATISTICAL SUMMARY OF WATER QUALITY DATA 1989-2010

New World Mining District Response and Restoration Project

Sample Station	Sample Date	Data Source	Flow (cfs)	Flow Flag	Field pH (su)	Aluminum Total Rec. (mg/l)	Al(calc)	Al Flag	Arsenic Total Rec. (mg/l)	As(calc)	As Flag	Cadmium Total Rec. (mg/l)	Cd(calc)	Cd Flag	Chromium Total Rec. (mg/l)	Cr(calc)	Cr Flag	Copper Total Rec. (mg/l)	Cu(calc)	Cu Flag	Iron Total Rec. (mg/l)	Fe(calc)	Fe Flag	Lead Total Rec. (mg/l)	Pb(calc)	Pb Flag	Manganese Total Rec. (mg/l)	Mn(calc)	Mn Flag	Zinc Total Rec. (mg/l)	Zn(calc)	Zn Flag
Chronic Standard (for Hardness = 50 mg/l)						0.087			0.15			0.00016			0.049			0.0052			1			0.0013			NA			0.067		
Acute Standard (for Hardness = 50 mg/l)						0.75			0.34			0.001			1.02			0.0073			NA			0.034			NA			0.067		
Chronic Standard (for Hardness = 100 mg/l)						0.087			0.15			0.0027			0.086			0.0093			1			0.0032			NA			0.12		
Acute Standard (for Hardness = 100 mg/l)						0.75			0.34			0.0021			1.8			0.0140			NA			0.082			NA			0.12		
SW-3	26-Sep-06	Maxim	0.16		3.62	2.81	2.81					0.0008	0.0008					0.79	0.79		1.89	1.89		0.002	0.002		0.59	0.59		0.14	0.14	
SW-3	11-Apr-07	Tt	0.065		5	2.14	2.14				--	0.001	0.001				--	0.75	0.75		0.87	0.87		0.001	0.001		0.45	0.45		0.14	0.14	
SW-3	12-Jun-07	Tt	6.94		7	1.72	1.72				--	0.0002	0.0002				--	0.32	0.32		2.46	2.46		0.002	0.002		0.13	0.13		0.01	0.01	
SW-3	17-Sep-07	Tt	0.142		3.85	2.51	2.51				--	0.0008	0.0008				--	0.84	0.84		1.26	1.26		0.002	0.002		0.57	0.57		0.12	0.12	
SW-3	17-Apr-08	Tt	0.0852		3.64	2.13	2.13					0.0011	0.0011					0.97	0.97		1.01	1.01		0.001	0.001		0.54	0.54		0.14	0.14	
SW-3	14-Jul-08	Tt	8.17		5.38	0.74	0.74					0.0001	0.0001					0.21	0.21		0.72	0.72		0.001	0.001		0.1	0.1		0.02	0.02	
SW-3	22-Sep-08	Tt	0.37		3.78	2.95	2.95					0.0007	0.0007					0.67	0.67		1.69	1.69		0.002	0.002	JF%	0.58	0.58		0.11	0.11	
SW-3	08-Apr-09	Tt	0.113		3.79	2.1	2.1					0.0011	0.0011					1.2	1.2		0.65	0.65		0.001	0.001		0.61	0.61		0.15	0.15	
SW-3	23-Jun-09	Tt	9.4		4.86	0.47	0.47					0.00013	0.00013					0.24	0.24		0.38	0.38		0.00039	0.00039		0.098	0.098		0.023	0.023	
SW-3	29-Sep-09	Tt	0.144		3.11	2.1	2.1					0.00066	0.00066					0.65	0.65		2.6	2.6		0.0019	0.0019		0.53	0.53		0.099	0.099	
SW-3	06-Apr-10	Tt	0.103		3.55	1.8	1.8	JF%				0.0011	0.0011					0.89	0.89		2.2	2.2		0.00067	0.00067		0.49	0.49		0.14	0.14	
SW-3	27-Sep-10	Tt	0.267		3.8	2	2					0.00065	0.00065					0.65	0.65		0.97	0.97		0.001	0.001		0.5	0.5		0.098	0.098	
Station SW-3: 1989 to 2004 Low Flow (n)			36		39	39			13			33			7			43			40			34			39			43		
Minimum			0.050		2.500	0.050			0.001			0.0001			0.001			0.030			0.015			0.002			0.110			0.010		
Maximum			4.783		6.300	4.800			0.003			0.0056			0.020			1.530			22.000			0.013			1.740			0.710		
Mean			0.598		3.584	2.949			0.002			0.0010			0.009			0.795			6.535			0.006			1.098			0.168		
Standard Deviation (SD)			0.890		0.680	0.820			0.001			0.0009			0.007			0.243			3.743			0.003			0.411			0.107		
Mean + (2 x SD); for pH: Mean - (2 x SD)			2.377		2.224	4.589			0.004			0.0028			0.022			1.280			14.020			0.012			1.919			0.383		
Station SW-3: 1989-2004 High Flow (n)			34		34	25			10			22			11			36			30			21			22			36		
Minimum			1.600		2.910	1.100			0.001			0.0001			0.001			0.370			0.040			0.0010			0.160			0.020		
Maximum			17.890		6.560	3.300			0.005			0.0025			0.010			1.100			6.880			0.0080			0.780			0.220		
Mean			6.852		3.854	1.956			0.002			0.0005			0.007			0.573			3.626			0.0036			0.290			0.064		
Standard Deviation (SD)			3.909		0.703	0.519			0.001			0.0007			0.004			0.200			1.633			0.0021			0.162			0.037		
Mean + (2 x SD); for pH: Mean - (2 x SD)			14.669		2.448	2.993			0.005			0.0019			0.015			0.972			6.893			0.0077			0.614			0.137		
Station SW-3: 1998 to 2004 All (n)			70		73	64			23			55			18			79			70			55			61			79		
Minimum			0.050		2.500	0.050			0.001			0.0001			0.001			0.030			0.015			0.0010			0.110			0.010		
Maximum			17.890		6.560	4.800			0.005			0.0056			0.020			1.530			22.000			0.0130			1.740			0.710		
Mean			3.636		3.710	2.561			0.002			0.0008			0.008			0.694			5.288			0.0053			0.807			0.121		
Standard Deviation (SD)			4.198		0.699	0.864			0.001			0.0008			0.005			0.249			3.338			0.0028			0.518			0.098		
Mean + (2 x SD); for pH: Mean - (2 x SD)			12.031		2.311	4.289			0.004			0.0025			0.018			1.192			11.964			0.0109			1.843			0.316		
Station SW-3: 2005 to 2010 Low Flow (n)			13		13	13			0			13			0			13			13			13			13			13		
Minimum			0.065		3.110	1.360						0.0006						0.590			0.650			0.0007			0.420			0.098		
Maximum			0.380		5.000	2.950						0.0011						1.200			2.600			0.0020			0.610			0.180		
Mean			0.176		3.855	2.198						0.0008						0.800			1.338			0.0015			0.525			0.132		
Standard Deviation (SD)			0.115		0.460	0.442						0.0002						0.163			0.588			0.0005			0.055			0.023		
Mean + (2 x SD); for pH: Mean - (2 x SD)			0.406		2.935	3.082						0.0012						1.125			2.514			0.0026			0.636			0.178		
Station SW-3: 2005-2010 High Flow (n)			5		5	5			0			5			0			5			5			5			5			5		
Minimum			5.460		4.000	0.470						0.0001						0.210			0.380			0.0004			0.098			0.010		
Maximum			9.400		7.000	1.740						0.0002						0.390			2.460			0.0020			0.180			0.040		
Mean			7.620		5.248	1.232						0.0001						0.304			1.244			0.0015			0.130			0.023		
Standard Deviation (SD)			1.488		1.102	0.589						0.0000						0.077			0.804			0.0007			0.034			0.011		
Mean + (2 x SD); for pH: Mean - (2 x SD)			10.596		3.044	2.409						0.0002						0.458			2.852			0.0030			0.197			0.044		
Station SW-3: 2005-2010 All (n)			18		18	18			0			18			0			18			18			18			18			18		
Minimum			0.065		3.110	0.470						0.0001						0.210			0.380			0.0004			0.098			0.010		
Maximum			9.400		7.000	2.950						0.0011						1.200			2.600			0.0020			0.610			0.180		
Mean			2.244		4.242	1.929						0.0006						0.662			1.312			0.0015			0.415			0.102		
Standard Deviation (SD)			3.507		0.920	0.646						0.0004						0.269			0.631			0.0006			0.189			0.054		
Mean + (2 x SD); for pH: Mean - (2 x SD)			9.258		2.401	3.222						0.0014						1.200			2.574			0.0027			0.793			0.210		
Narrative Standard - SW-3					2.1	4.54			NA			0.002			NA			1.256			9.259			0.01			1.718			0.225		
SW-4	2-Aug-89	Hydrometrics				0.1	0.05	<	0.005	0.0025	<	0.001	0.0005	<				0.03	0.03		0.03	0.015	<	0.01	0.005	<	0.11	0.11		0.01	0.01	
SW-4	15-Sep-89	Hydrometrics	1.35			0.2	0.2		0.005	0.0025	<	0.001	0.0005	<				0.09	0.09		0.09	0.09		0.01	0.005	<	0.07	0.07		0.07	0.07	
SW-4	20-Oct-89	Hydrometrics	1.19		5.75	0.1	0.1		0.005	0.0025	<	0.001	0.0005	<				0.07	0.07		0.04	0.04		0.01	0.005	<	0.06	0.06		0.05	0.05	
SW-4	17-Mar-90	Hydrometrics	1		5.55	0.1	0.05	<	0.005	0.0025	<	0.001	0.0005	<				0.04	0.04		0.03	0.015	<	0.01	0.005	<	0.02	0.01	<	0.07	0.07	
SW-4	29-May-90	Hydrometrics	15.4		7.22	0.8	0.8		0.005	0.0025	<	0.0001	0.00005	<	0.02	0.01	<	0.116	0.116		0.71	0.71		0.002	0.001	<	0.05	0.05		0.03	0.03	
SW-4	5-Jun-90	Hydrometrics	27.84		6.7	0.3	0.3											0.08	0.08		0.42	0.42								0.02	0.02	
SW-4	13-Jun-90	Hydrometrics	30.73		5.52	0.2	0.2											0.06	0.06		0.21	0.21								0.02	0.02	
SW-4	15-Jun-90	Hydrometrics	21.9																													
SW-4	20-Jun-90	Hydrometrics	47.46		6.45	0.3	0.3					0.001	0.0005	<	0.02	0.01	<	0.08	0.08		0.39	0.39		0.01	0.005	<	0.04	0.04		0.41	0.41	
SW-4	22-Jun-90	Hydrometrics	88.8																													

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NA - not applicable

TABLE A-2 - STATISTICAL SUMMARY OF WATER QUALITY DATA 1989-2010

New World Mining District Response and Restoration Project

Sample Station	Sample Date	Data Source	Flow (cfs)	Flow Flag	Field pH (su)	Aluminum Total Rec. (mg/l)	Al(calc)	Al Flag	Arsenic Total Rec. (mg/l)	As(calc)	As Flag	Cadmium Total Rec. (mg/l)	Cd(calc)	Cd Flag	Chromium Total Rec. (mg/l)	Cr(calc)	Cr Flag	Copper Total Rec. (mg/l)	Cu(calc)	Cu Flag	Iron Total Rec. (mg/l)	Fe(calc)	Fe Flag	Lead Total Rec. (mg/l)	Pb(calc)	Pb Flag	Manganese Total Rec. (mg/l)	Mn(calc)	Mn Flag	Zinc Total Rec. (mg/l)	Zn(calc)	Zn Flag
Chronic Standard (for Hardness = 50 mg/l)						0.087			0.15			0.00016			0.049			0.0052			1			0.0013			NA			0.067		
Acute Standard (for Hardness = 50 mg/l)						0.75			0.34			0.001			1.02			0.0073			NA			0.034			NA			0.067		
Chronic Standard (for Hardness = 100 mg/l)						0.087			0.15			0.0027			0.086			0.0093			1			0.0032			NA			0.12		
Acute Standard (for Hardness = 100 mg/l)						0.75			0.34			0.0021			1.8			0.0140			NA			0.082			NA			0.12		
SW-4	26-Jun-90	Hydrometrics	112.4		7.11	0.5	0.5		0.005	0.0025	<	0.0002	0.0002		0.02	0.01	<	0.087	0.087		1.02	1.02		0.002	0.001	<	0.05	0.05		0.02	0.02	
SW-4	28-Jun-90	Hydrometrics	100.37																												
SW-4	3-Jul-90	Hydrometrics	83.9		9.07	0.4	0.4					0.002	0.002		0.02	0.01	<	0.08	0.08		0.65	0.65		0.01	0.01		0.04	0.04		0.02	0.02	
SW-4	5-Jul-90	Hydrometrics	49.4																												
SW-4	6-Jul-90	Hydrometrics																													
SW-4	7-Jul-90	Hydrometrics																													
SW-4	8-Jul-90	Hydrometrics																													
SW-4	10-Jul-90	Hydrometrics	30.6			0.3	0.3					0.001	0.0005	<	0.02	0.01	<	0.09	0.09		0.43	0.43		0.01	0.005	<	0.05	0.05		0.03	0.03	
SW-4	11-Jul-90	Hydrometrics																													
SW-4	12-Jul-90	Hydrometrics	25																												
SW-4	13-Jul-90	Hydrometrics																													
SW-4	14-Jul-90	Hydrometrics																													
SW-4	15-Jul-90	Hydrometrics																													
SW-4	16-Jul-90	Hydrometrics																													
SW-4	17-Jul-90	Hydrometrics	14.4		6.6	0.4	0.4											0.14	0.14		0.49	0.49								0.03	0.03	
SW-4	18-Jul-90	Hydrometrics																													
SW-4	19-Jul-90	Hydrometrics	11.7																												
SW-4	20-Jul-90	Hydrometrics																													
SW-4	21-Jul-90	Hydrometrics																													
SW-4	22-Jul-90	Hydrometrics																													
SW-4	23-Jul-90	Hydrometrics																													
SW-4	24-Jul-90	Hydrometrics																													
SW-4	25-Jul-90	Hydrometrics																													
SW-4	26-Jul-90	Hydrometrics																													
SW-4	27-Jul-90	Hydrometrics	7.1		6.87	0.3	0.3		0.005	0.0025	<	0.0004	0.0004		0.02	0.01	<	0.16	0.16		0.44	0.44		0.002	0.001	<	0.1	0.1		1.95	1.95	J
SW-4	23-Aug-90	Hydrometrics	3.2		7.05																										
SW-4	25-Sep-90	Hydrometrics	1.5		5	0.3	0.3		0.005	0.0025	<	0.0003	0.0003		0.02	0.01	<	0.11	0.11		0.21	0.21		0.002	0.001	<	0.13	0.13		0.05	0.05	
SW-4	15-Mar-91	Hydrometrics	0.8		6.79	0.1	0.05	<	0.005	0.0025	<	0.001	0.001		0.02	0.01	<	0.06	0.06		0.03	0.015	<	0.01	0.005	<	0.02	0.01	<	0.07	0.07	
SW-4	5-Jun-91	Hydrometrics	55.3		7.07	0.2	0.1	<	0.001	0.0005	<	0.0001	0.00005	<	0.02	0.01	<	0.05	0.025	<	0.67	0.335	<	0.002	0.001	<	0.03	0.015	<	0.01	0.005	<
SW-4	9-Jul-91	Hydrometrics	21		6.72	0.1	0.05	<	0.005	0.0025	<	0.0002	0.0002		0.02	0.02		0.1	0.1		0.38	0.38		0	0	J	0.05	0.05		0.03	0.03	
SW-4	14-Aug-91	Hydrometrics	1.7		6.25	0.4	0.4		0.005	0.0025	<	0.0002	0.0002		0.02	0.01	<	0.15	0.15		0.21	0.21		0.002	0.001	<	0.12	0.12		0.07	0.07	

Notes: mg/l = milligrams/liter; su = standard units
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NA - not applicable

TABLE A-2 - STATISTICAL SUMMARY OF WATER QUALITY DATA 1989-2010

New World Mining District Response and Restoration Project

Sample Station	Sample Date	Data Source	Flow (cfs)	Flow Flag	Field pH (su)	Aluminum Total Rec. (mg/l)	Al(calc)	Al Flag	Arsenic Total Rec. (mg/l)	As(calc)	As Flag	Cadmium Total Rec. (mg/l)	Cd(calc)	Cd Flag	Chromium Total Rec. (mg/l)	Cr(calc)	Cr Flag	Copper Total Rec. (mg/l)	Cu(calc)	Cu Flag	Iron Total Rec. (mg/l)	Fe(calc)	Fe Flag	Lead Total Rec. (mg/l)	Pb(calc)	Pb Flag	Manganese Total Rec. (mg/l)	Mn(calc)	Mn Flag	Zinc Total Rec. (mg/l)	Zn(calc)	Zn Flag
Chronic Standard (for Hardness = 50 mg/l)						0.087			0.15			0.00016			0.049			0.0052			1			0.0013			NA			0.067		
Acute Standard (for Hardness = 50 mg/l)						0.75			0.34			0.001			1.02			0.0073			NA			0.034			NA			0.067		
Chronic Standard (for Hardness = 100 mg/l)						0.087			0.15			0.0027			0.086			0.0093			1			0.0032			NA			0.12		
Acute Standard (for Hardness = 100 mg/l)						0.75			0.34			0.0021			1.8			0.0140			NA			0.082			NA			0.12		
SW-4	24-Sep-91	Hydrometrics	1.1		6.66	0.3	0.3		0.005	0.0025	<	0.0006	0.0006		0.02	0.01	<	0.11	0.11		0.24	0.24		0.002	0.001	<	0.08	0.08		0.04	0.04	
SW-4	27-May-92	Hydrometrics	77.78		7.72	0.2	0.2		0.005	0.0025	<	0.0001	0.00005	<	0.01	0.005	<	0.051	0.051		0.31	0.31		0.002	0.001	<	0.03	0.03		0.02	0.02	
SW-4	19-Jul-92	Hydrometrics	15		6.87	3.4	1.7	<	0.005	0.0025	<	0.0002	0.0002		0.01	0.005	<	0.29	0.29		7.1	3.55	<	0.002	0.001	<	0.16	0.16		0.15	0.075	<
SW-4	23-Sep-92	Hydrometrics	1.95		7.04	0.3	0.3		0.005	0.0025	<	0.0004	0.0004		0.01	0.005	<	0.117	0.117		0.17	0.17		0.002	0.001	<	0.13	0.13		0.05	0.05	
SW-4	21-Jul-93	Hydrometrics	19.92		7.47	0.3	0.3		0.001	0.0005	<	0.0001	0.0001		0.001	0.0005	<	0.146	0.146		0.65	0.65		0.002	0.001	<	0.09	0.09		0.04	0.04	J
SW-4	21-Sep-93	Hydrometrics	1.98		6.95	0.2	0.2		0.001	0.0005	<	0.0002	0.0002		0.001	0.0005	<	0.1	0.1		0.32	0.32		0.002	0.001	<	0.16	0.16		0.038	0.038	
SW-4	2-Mar-94	Hydrometrics	0.4		7.7	0.1	0.05	<	0.001	0.0005	<	0.0005	0.0005		0.001	0.0005	<	0.06	0.06		0.03	0.015	<	0.002	0.001	<	0.01	0.005	<	0.07	0.07	
SW-4	26-May-94	Hydrometrics	75.23		8.45	0.8	0.8		0.001	0.001		0.0001	0.0001		0.001	0.0005	<	0.11	0.11		2.25	2.25		0.003	0.003		0.06	0.06		0.018	0.018	
SW-4	15-Jun-94	Hydrometrics	33.79		7.01	0.5	0.5		0.001	0.0005	<	0.0001	0.0001		0.001	0.0005	<	0.07	0.07	J	0.55	0.55		0.002	0.001	<	0.05	0.05		0.021	0.021	J
SW-4	14-Jul-95	Hydrometrics	43.74		6.64	0.5	0.5		0.001	0.0005	<	0.0001	0.0001		0.002	0.002		0.118	0.118	J	0.8	0.8	J	0.002	0.001	<	0.07	0.07		0.026	0.013	<
SW-4	27-Sep-95	Hydrometrics	1.34		6.7	0.2	0.2		0.001	0.0005	<	0.0003	0.0003		0.001	0.0005	<	0.173	0.173		0.09	0.09		0.002	0.001	<	0.12	0.12		0.08	0.04	<
SW-4	21-May-96	Hydrometrics			6.15	0.2	0.2					0.0001	0.0001					0.063	0.063		0.18	0.18		0.003	0.0015	<	0.03	0.03		0.05	0.025	<
SW-4	29-May-96	Hydrometrics			7.84	0.4	0.4					0.0001	0.00005	<				0.086	0.086		0.44	0.44		0.003	0.0015	<	0.05	0.05		0.05	0.025	<
SW-4	5-Jun-96	Hydrometrics			6.27	1.1	1.1					0.0001	0.0001					0.139	0.139		3.17	3.17		0.005	0.005		0.067	0.067		0.03	0.015	<
SW-4	12-Jun-96	Hydrometrics	33.7		6.23													0.055	0.055		0.62	0.62	J							0.05	0.05	J
SW-4	19-Jun-96	Hydrometrics	72.157		7.82	0.2	0.2					0.0001	0.0001					0.066	0.066		0.35	0.35		0.003	0.0015	<	0.031	0.031		0.01	0.005	<
SW-4	26-Jun-96	Hydrometrics			6.41													0.066	0.066		1.14	1.14								0.02	0.02	
SW-4	2-Jul-96	Hydrometrics			6.58													0.11	0.11		2.17	2.17								0.08	0.08	J
SW-4	11-Jul-96	Hydrometrics	54.84		5.96	0.2	0.2	J				0.0001	0.00005	<				0.07	0.07		0.49	0.245	<	0.003	0.0015	<	0.033	0.033		0.02	0.02	
SW-4	18-Jul-96	Hydrometrics	26.42		6.81													0.105	0.105		0.34	0.34								0.03	0.015	<
SW-4	25-Jul-96	Hydrometrics	19.92		6.64													0.129	0.129		0.4	0.4								0.03	0.03	
SW-4	21-Aug-96	Hydrometrics	4.315		6.91													0.17	0.17		0.31	0.31								0.05	0.05	
SW-4	11-Sep-96	Hydrometrics	1.46		6.4	0.4	0.4					0.0003	0.0003	J				0.154	0.154		0.17	0.17		0.003	0.0015	<	0.15	0.15		0.06	0.06	
SW-4	27-Mar-98	UOS Data	0.69		6.95																										
SW-4	22-Apr-98	UOS Data	0.578		7.08																										
SW-4	5-May-98	UOS Data			6.41																										
SW-4	13-May-98	UOS Data	4.783		6.05																										
SW-4	6-May-99	Maxim	0.42		7.38	0.1	0.05	<				0.0004	0.0004					0.06	0.06		0.03	0.03		0.001	0.0005	<	0.021	0.021		0.05	0.05	
SW-4	9-Jul-99	Maxim	45.706		7.21	0.3	0.3					0.0001	0.0001					0.08	0.08		0.29	0.29		0.001	0.0005	<	0.027	0.027		0.03	0.03	
SW-4	30-Sep-99	Maxim	1.46		5.28	0.1	0.05	<				0.0003	0.0003					0.07	0.07		0.03	0.03		0.001	0.0005	<	0.072	0.072		0.06	0.06	J
SW-4	13-Apr-00	Maxim	0.837		8.21	0.05	0.025	<				0.0004	0.0004					0.064	0.064		0.05	0.025	<	0.001	0.0005	<	0.014	0.014		0.02	0.01	<
SW-4	8-Jul-00	Maxim	15.48		6	0.3	0.3	J				0.0001	0.00005	<				0.12	0.12	J	0.38	0.38	J	0.001	0.0005	<	0.064	0.064	J	0.03	0.03	J
SW-4	19-Oct-00	Maxim	1.39		5.25	0.1	0.05	<				0.0001	0.00005	<				0.057	0.057		0.07	0.07	J	0.001	0.0005	<	0.058	0.058		0.04	0.04	
SW-4	21-Apr-01	Maxim	0.62		7.17	0.1	0.05	<				0.0003	0.0003					0.038	0.038		0.03	0.03		0.001	0.0005	<	0.008	0.008		0.08	0.08	
SW-4	26-Jun-01	Maxim	23.84		7.01	0.3	0.3					0.0002	0.0002					0.089	0.089		0.43	0.43		0.001	0.001	J	0.048	0.048		0.02	0.02	
SW-4	11-Oct-01	Maxim	0.61		6.79	0.2	0.2		0.003	0.0015	<	0.0003	0.0003					0.058	0.058		0.11	0.11		0.001	0.0005	<	0.009	0.009		0.09	0.09	
SW-4	26-Apr-02	Maxim			6.28	0.1	0.05	<				0.0003	0.0003					0.03	0.03		0.01	0.005	<	0.001	0.0005	<	0.006	0.006		0.04	0.04	
SW-4	1-Jul-02	Maxim	47		7.5	0.3	0.3	J				0.0001	0.00005	<				0.1	0.1		0.5	0.5		0.001	0.0005	<	0.051	0.051		0.02	0.02	J
SW-4	8-Oct-02	Maxim	1.91		7.58	0.1	0.1					0.0004	0.0004					0.085	0.085		0.13	0.13		0.001	0.0005	<	0.088	0.088		0.07	0.07	J
SW-4	23-Apr-03	Maxim			6.25	0.05	0.025	<				0.0003	0.0003					0.049	0.049		0.1	0.1		0.001	0.0005	<	0.013	0.013		0.08	0.08	
SW-4	1-Jul-03	Maxim	40.8		6.21	0.25	0.25					0.0001	0.00005	<				0.07	0.07		0.29	0.29		0.001	0.0005	<	0.044	0.044		0.01	0.005	<
SW-4	30-Sep-03	Maxim	0.903		5.72	0.05	0.025	<				0.0002	0.0002					0.079	0.079		0.02	0.02		0.001	0.0005	<	0.055	0.055		0.13	0.13	
SW-4	5-Apr-04	Maxim	0.784		5.57	0.05	0.025	<				0.0002	0.0002					0.04	0.04		0.02	0.02		0.001	0.0005	<	0.005	0.005		0.1	0.1	JF%
SW-4	28-Jun-04	Maxim	70.91		7.9	0.8	0.8					0.0001	0.00005	<				0.11	0.11		1.48	1.48		0.003	0.003		0.045	0.045		0.05	0.05	
SW-4	5-Oct-04	Maxim	3.21		6.2	0.12	0.12					0.0002	0.0002					0.05	0.05		0.06	0.06		0.001	0.0005	<	0.029	0.029		0.02	0.02	
SW-4	4/5/2005	Maxim	0.7		7.19	0.05	0.025	<			--	0.0002	0.0002				--	0.033	0.033		0.01	0.01		0.001	0.0005	<	0.008	0.008		0.08	0.08	)
SW-4	6/28/2005	Maxim	50.84		6.6	0.25	0.25				--	0.0001	0.00005	<			--	0.063	0.063		0.2	0.2		0.001	0.0005	<	0.028	0.028		0.02	0.02	
SW-4	10/11/2005	Maxim	1.62		6.3	0.05	0.025	<			--	0.0002	0.0002				--	0.05	0.05		0.16	0.16		0.001	0.0005	<	0.005	0.005		0.03	0.03	
SW-4	26-Apr-06	Maxim	0.62		7.18	0.05	0.025	<				0.0002	0.0002					0.043	0.043		0.02	0.02		0.001	0.0005	<	0.005	0.005		0.04	0.04	
SW-4	28-Jun-06	Maxim	33.1		6.26	0.19	0.19					0.0001	0.00005	<				0.064	0.064		0.21	0.21		0.001	0.0005	<	0.034	0.034		0.01	0.005	<
SW-4	26-Sep-06	Maxim	0.66		5.56	0.08	0.08					0.0002	0.0002					0.034	0.034		0.01	0.01		0.001	0.0005	<	0.026	0.026		0.18	0.18	
SW-4	11-Apr-07	Tt	0.582		6.58	0.05	0.025	<			--	0.0002	0.0002				--	0.038	0.038		0.02	0.02		0.001	0.0005	<	0.014	0.014		0.04	0.04	
SW-4	12-Jun-07	Tt	46.7		6.9	0.3	0.3				--	0.0001	0.00005	<			--	0.069	0.069		0.27	0.27		0.001	0.0005	<	0.02	0.02		0.01	0.005	<
SW-4	17-Sep-07	Tt	0.88		6.91	0.07	0.07				--	0.0002	0.0002				--	0.044	0.044		0.05	0.05		0.001	0.0005	<	0.033	0.033		0.02	0.02	
SW-4	17-Apr-08	Tt	0.448		5.88	0.05	0.025	<				0.0002	0.0002					0.044	0.044		0.02	0.02		0.001	0.0005	<	0.011	0.011		0.04	0.04	
SW-4	14-Jul-08	Tt	46.54		6.88	0.13	0.13					0.0001	0.00005	<				0.049	0.049		0.18	0.18		0.001	0.0005	<	0.022	0.022		0.01	0.005	<
SW-4	22-Sep-08	Tt	1.462		6.01	0.11	0.11					0.0002	0.0002					0.065	0.065		0.02	0.02		0.001	0.001	JF%	0.046	0.046		0.03	0.03	
SW-4	08-Apr-09	Tt	0.312		6.33	0.011	0.011					0.00025	0.00025					0.037	0.037		0.025	0.0125	<	0.00005	2.5E-05	<	0.0075	0.0075		0.045	0.045	
SW-4	23-Jun-09	Tt	57.7		6.45	0.15	0.15					0.000061	6.1E-05	J				0.044	0.044		0.13	0.13		0.00021	0.00021		0.018	0.018		0.011	0.011	
SW-4	29-Sep-09	Tt	0.699		5.89	0.051	0.051					0.00014	0.00014					0.025	0.025		0.025	0.0125	<	0.00005	2.5E-05	<	0.0077	0.0077		0.023	0.023	
SW-4	06-Apr-10	Tt	0.272		6.17	0.018	0.018	JF%				0.00016	0.00016					0.018	0.018		0.05	0.025	<	0.0001	0.00005	<	0.0016	0.0016		0.036	0.036	
SW-4	27-Sep-10	Tt	1.36		6.8	0.065	0.065					0.00015	0.00015					0.04	0.04		0.17	0.17		0.0001	0.00005	<	0.031	0.031		0.021	0.021	

Notes: mg/l = milligrams/liter; su = standard units
n = number of samples

< = less than detection
J = estimated value

NA - not applicable

TABLE A-2 - STATISTICAL SUMMARY OF WATER QUALITY DATA 1989-2010

New World Mining District Response and Restoration Project

Sample Station	Sample Date	Data Source	Flow (cfs)	Flow Flag	Field pH (su)	Aluminum Total Rec. (mg/l)	Al(calc)	Al Flag	Arsenic Total Rec. (mg/l)	As(calc)	As Flag	Cadmium Total Rec. (mg/l)	Cd(calc)	Cd Flag	Chromium Total Rec. (mg/l)	Cr(calc)	Cr Flag	Copper Total Rec. (mg/l)	Cu(calc)	Cu Flag	Iron Total Rec. (mg/l)	Fe(calc)	Fe Flag	Lead Total Rec. (mg/l)	Pb(calc)	Pb Flag	Manganese Total Rec. (mg/l)	Mn(calc)	Mn Flag	Zinc Total Rec. (mg/l)	Zn(calc)	Zn Flag
Chronic Standard (for Hardness = 50 mg/l)						0.087			0.15			0.00016			0.049			0.0052			1			0.0013			NA			0.067		
Acute Standard (for Hardness = 50 mg/l)						0.75			0.34			0.001			1.02			0.0073			NA			0.034			NA			0.067		
Chronic Standard (for Hardness = 100 mg/l)						0.087			0.15			0.0027			0.086			0.0093			1			0.0032			NA			0.12		
Acute Standard (for Hardness = 100 mg/l)						0.75			0.34			0.0021			1.8			0.0140			NA			0.082			NA			0.12		
Station SW-4: 1989 to 2004 Low Flow (n)			30		34	30			16			30			11			31			31			30			30			31		
Minimum			0.400		5.000	0.025			0.001			0.0001			0.001			0.030			0.005			0.0005			0.005			0.010		
Maximum			77.780		8.450	0.800			0.003			0.0010			0.010			0.173			2.250			0.0050			0.160			0.130		
Mean			7.413		6.679	0.192			0.002			0.0003			0.006			0.082			0.207			0.0016			0.058			0.052		
Standard Deviation (SD)			18.918		0.853	0.205			0.001			0.0002			0.004			0.040			0.409			0.0016			0.048			0.028		
Mean + (2 x SD); for pH: Mean - (2 x SD)			45.248		4.972	0.602			0.004			0.0007			0.015			0.162			1.026			0.0049			0.155			0.108		
Station SW-4: 1989-2004 High Flow (n)			31		27	23			8			20			11			28			28			20			20			28		
Minimum			7.100		5.520	0.050			0.001			0.0001			0.001			0.025			0.210			0.0000			0.015			0.005		
Maximum			112.400		9.070	1.700			0.003			0.0020			0.020			0.290			3.550			0.0100			0.160			1.950		
Mean			41.649		6.839	0.417			0.002			0.0003			0.008			0.101			0.790			0.0021			0.056			0.110		
Standard Deviation (SD)			27.157		0.710	0.357			0.001			0.0004			0.006			0.048			0.840			0.0024			0.032			0.368		
Mean + (2 x SD); for pH: Mean - (2 x SD)			95.964		5.419	1.132			0.004			0.0011			0.019			0.198			2.470			0.0069			0.119			0.846		
Station SW-4: 1998 to 2004 All (n)			61		61	53			24			50			22			59			59			50			50			59		
Minimum			0.400		5.000	0.025			0.001			0.0001			0.001			0.025			0.005			0.0000			0.005			0.005		
Maximum			112.400		9.070	1.700			0.003			0.0020			0.020			0.290			3.550			0.0100			0.160			1.950		
Mean			25.968		6.767	0.290			0.002			0.0003			0.007			0.091			0.484			0.0018			0.058			0.080		
Standard Deviation (SD)			29.897		0.791	0.300			0.001			0.0003			0.005			0.045			0.708			0.0020			0.042			0.254		
Mean + (2 x SD); for pH: Mean - (2 x SD)			85.763		5.185	0.890			0.004			0.0009			0.017			0.181			1.900			0.0057			0.141			0.587		
Station SW-4: 2005 to 2010 Low Flow (n)			12		12	12			0			12			0			12			12			12			12			12		
Minimum			0.272		5.560	0.011						0.0001						0.018			0.010			0.0000			0.002			0.020		
Maximum			50.840		7.180	0.250						0.0003						0.065			0.200			0.0010			0.046			0.180		
Mean			4.980		6.351	0.063						0.0002						0.042			0.060			0.0004			0.018			0.044		
Standard Deviation (SD)			14.449		0.479	0.066						0.0000						0.014			0.072			0.0003			0.014			0.044		
Mean + (2 x SD); for pH: Mean - (2 x SD)			33.878		5.392	0.195						0.0003						0.069			0.203			0.0010			0.046			0.131		
Station SW-4: 2005-2010 High Flow (n)			4		5	5			0			5			0			5			5			5			5			5		
Minimum			33.100		6.260	0.025						0.0001						0.033			0.010			0.0002			0.008			0.005		
Maximum			57.700		7.190	0.300						0.0002						0.069			0.270			0.0005			0.034			0.080		
Mean			46.010		6.736	0.159						0.0001						0.052			0.160			0.0004			0.020			0.021		
Standard Deviation (SD)			10.068		0.375	0.100						0.0001						0.015			0.098			0.0001			0.009			0.033		
Mean + (2 x SD); for pH: Mean - (2 x SD)			66.146		5.986	0.358						0.0002						0.081			0.356			0.0007			0.039			0.087		
Station SW-4: 2005-2010 All (n)			17		17	17			0			17			0			17			17			17			17			17		
Minimum			0.272		5.560	0.011						0.0001						0.018			0.010			0.0000			0.002			0.005		
Maximum			57.700		7.190	0.300						0.0003						0.069			0.270			0.0010			0.046			0.180		
Mean			14.382		6.464	0.091						0.0002						0.045			0.089			0.0004			0.019			0.037		
Standard Deviation (SD)			22.150		0.475	0.087						0.0001						0.014			0.090			0.0003			0.013			0.041		
Mean + (2 x SD); for pH: Mean - (2 x SD)			58.682		5.514	0.265						0.0003						0.073			0.270			0.0009			0.044			0.120		
Narrative Standard - SW-4					**5.24**	**0.74**			**NA**			**0.001**			**NA**			**0.172**			**1.726**			**0.005**			**0.79**			**0.66**		
SW-6	2-Oct-89	Hydrometrics	4		4.82				0.0050	0.0025	<	0.00100	0.0005	<				0.01	0.005	<	0.03	0.015	<				0.02	0.01	<	0.01	0.01	
SW-6	20-Oct-89	Hydrometrics	4.52		6.02	0.1	0.05	<	0.0050	0.0025	<	0.00100	0.0005	<				0.01	0.005	<	0.03	0.015	<	0.01	0.005	<	0.02	0.01	<	0.01	0.01	
SW-6	29-May-90	Hydrometrics	102.1		7.34	0.2	0.2		0.0050	0.0025	<	0.00010	0.00005	<	0.0200	0.01	<	0.035	0.035		0.23	0.23		0.002	0.001	<	0.02	0.02		0.02	0.02	
SW-6	6-Jun-90	Hydrometrics	123.2		7.25	0.1	0.1					0.00200	0.002		0.0200	0.01	<	0.02	0.02		0.13	0.13		0.01	0.01		0.02	0.01	<	0.01	0.01	
SW-6	7-Jun-90	Hydrometrics	138.6																													
SW-6	13-Jun-90	Hydrometrics	116.97		7.25	0.1	0.05	<				0.08000	0.08		0.0200	0.01	<	0.01	0.005	<	0.06	0.06		0.01	0.005	<	0.02	0.01	<	0.01	0.01	
SW-6	14-Jun-90	Hydrometrics	86																													
SW-6	20-Jun-90	Hydrometrics	167.97		8.75	0.2	0.2					0.00100	0.001		0.0200	0.01	<	0.03	0.03		0.26	0.26		0.01	0.005	<	0.02	0.02		0.15	0.15	
SW-6	22-Jun-90	Hydrometrics	273.3																													
SW-6	26-Jun-90	Hydrometrics	251.5		8.52	0.2	0.2		0.0050	0.0025	<	0.00010	0.00005	<	0.0200	0.01	<	0.037	0.037		0.4	0.4		0.002	0.001	<	0.02	0.02		0.02	0.02	
SW-6	29-Jun-90	Hydrometrics	218.48																													
SW-6	2-Jul-90	Hydrometrics	210.6		9.39	0.2	0.2					0.00100	0.0005	<	0.0200	0.01	<	0.039	0.039		0.35	0.35		0.01	0.005	<	0.02	0.02		0.04	0.04	
SW-6	4-Jul-90	Hydrometrics	165.4																													
SW-6	9-Jul-90	Hydrometrics	89.9		9.2	0.1	0.1					0.00100	0.0005	<	0.0200	0.01	<	0.03	0.03		0.14	0.14		0.01	0.005	<	0.02	0.01	<	0.02	0.02	
SW-6	11-Jul-90	Hydrometrics	72																													
SW-6	17-Jul-90	Hydrometrics	35.4		8.86	0.2	0.2											0.07	0.07		0.3	0.3								0.03	0.015	<
SW-6	19-Jul-90	Hydrometrics	26.4																													
SW-6	27-Jul-90	Hydrometrics	18.9		6.81	0.1	0.05	<	0.0050	0.0025	<	0.00010	0.00005	<	0.0200	0.01	<	0.03	0.03		0.1	0.1		0.002	0.001	<	0.02	0.01	<	0.03	0.015	<
SW-6	23-Aug-90	Hydrometrics	10.1		6.7																											
SW-6	25-Sep-90	Hydrometrics	3.3		5.5	0.1	0.05	<	0.0050	0.0025	<	0.00010	0.00005	<	0.0200	0.01	<	0.007	0.007		0.03	0.015	<	0.002	0.001	<	0.02	0.01	<	0.04	0.04	
SW-6	15-Mar-91	Hydrometrics	1		8.01	0.1	0.05	<	0.0050	0.0025	<	0.00100	0.0005	<	0.0200	0.01	<	0.01	0.005	<	0.06	0.06		0.01	0.005	<	0.02	0.01	<	0.02	0.02	
SW-6	5-Jun-91	Hydrometrics	201.7		6.67	0.2	0.2		0.0010	0.0005	<	0.00010	0.00005	<	0.0200	0.01	<	0.017	0.0085	<	0.18	0.18		0.002	0.001	<	0.02	0.01	<	0.01	0.005	<
SW-6	9-Jul-91	Hydrometrics	51.2		6.72	0.1	0.1		0.0050	0.0025	<	0.00010	0.0001		0.0200	0.01	<	0.033	0.033		0.14	0.14		0	0	J	0.02	0.01	<	0.03	0.03	

Notes: mg/l = milligrams/liter; su = standard units
n = number of samples

< = less than detection
J = estimated value

NA - not applicable

TABLE A-2 - STATISTICAL SUMMARY OF WATER QUALITY DATA 1989-2010

New World Mining District Response and Restoration Project

Sample Station	Sample Date	Data Source	Flow (cfs)	Flow Flag	Field pH (su)	Aluminum Total Rec. (mg/l)	Al(calc)	Al Flag	Arsenic Total Rec. (mg/l)	As(calc)	As Flag	Cadmium Total Rec. (mg/l)	Cd(calc)	Cd Flag	Chromium Total Rec. (mg/l)	Cr(calc)	Cr Flag	Copper Total Rec. (mg/l)	Cu(calc)	Cu Flag	Iron Total Rec. (mg/l)	Fe(calc)	Fe Flag	Lead Total Rec. (mg/l)	Pb(calc)	Pb Flag	Manganese Total Rec. (mg/l)	Mn(calc)	Mn Flag	Zinc Total Rec. (mg/l)	Zn(calc)	Zn Flag
Chronic Standard (for Hardness = 50 mg/l)						0.087			0.15			0.00016			0.049			0.0052			1			0.0013			NA			0.067		
Acute Standard (for Hardness = 50 mg/l)						0.75			0.34			0.001			1.02			0.0073			NA			0.034			NA			0.067		
Chronic Standard (for Hardness = 100 mg/l)						0.087			0.15			0.0027			0.086			0.0093			1			0.0032			NA			0.12		
Acute Standard (for Hardness = 100 mg/l)						0.75			0.34			0.0021			1.8			0.0140			NA			0.082			NA			0.12		
SW-6	14-Aug-91	Hydrometrics	3.9		7.31	0.1	0.05	<	0.0050	0.0025	<	0.00010	0.00005	<	0.0200	0.01	<	0.011	0.011		0.06	0.06		0.002	0.001	<	0.02	0.01	<	0.02	0.02	
SW-6	24-Sep-91	Hydrometrics	2.5		6.71	0.1	0.05	<	0.0050	0.0025	<	0.00010	0.00005	<	0.0200	0.01	<	0.013	0.0065	<	0.03	0.015	<	0.002	0.001	<	0.02	0.01	<	0.01	0.005	<
SW-6	19-Jul-92	Hydrometrics	30.67		7.52	1.6	1.6		0.0050	0.0025	<	0.00010	0.00005	<	0.0100	0.005	<	0.11	0.11		2.88	2.88		0.002	0.001	<	0.05	0.05		0.13	0.13	
SW-6	23-Sep-92	Hydrometrics	3.54		6.43	0.1	0.05	<	0.0050	0.0025	<	0.00010	0.0001		0.0100	0.005	<	0.016	0.016		0.2	0.2		0.002	0.001	<	0.02	0.02		0.05	0.05	
SW-6	21-Jul-93	Hydrometrics	38.11		7.46	0.2	0.2		0.0010	0.0005	<	0.00010	0.0001		0.0010	0.0005	<	0.062	0.062		0.24	0.24		0.002	0.001	<	0.03	0.03		0.01	0.01	J
SW-6	22-Sep-93	Hydrometrics	4.2		7.25	0.1	0.05	<	0.0010	0.0005	<	0.00010	0.0001		0.0010	0.0005	<	0.019	0.019		0.03	0.03		0.002	0.001	<	0.03	0.03		0.018	0.009	<
SW-6	14-Apr-94	Hydrometrics	19.2						0.0010	0.0005	<	0.00010	0.00005	<				0.001	0.0005	<												
SW-6	15-Jun-94	Hydrometrics	87.64		8.3	0.1	0.1		0.0010	0.0005	<	0.00010	0.00005	<	0.0010	0.0005	<	0.016	0.016	J	0.11	0.11		0.002	0.001	<	0.01	0.01		0.005	0.005	J
SW-6	21-May-96	Hydrometrics	45.62		4.86	0.1	0.1					0.00010	0.00005	<				0.021	0.021		0.15	0.15		0.003	0.0015	<	0.012	0.012		0.04	0.02	<
SW-6	10-Jul-96	Hydrometrics	149.2		5.41	0.1	0.05	<				0.00010	0.0001					0.024	0.024		0.01	0.01		0.003	0.0015	<	0.013	0.013		0.01	0.005	<
SW-6	11-Sep-96	Hydrometrics	2.91		6.63	0.1	0.05	<				0.00010	0.00005	<				0.011	0.011		0.02	0.02		0.003	0.0015	<	0.007	0.007		0.01	0.005	<
SW-6	6-May-99	Maxim	13.65		7.57	0.1	0.1					0.00010	0.00005	<				0.01	0.01		0.13	0.13		0.001	0.0005	<	0.008	0.008		0.01	0.005	<
SW-6	7-Jul-99	Maxim	148.39		7.64	0.2	0.2					0.00010	0.00005	<				0.034	0.034		0.27	0.27		0.001	0.0005	<	0.014	0.014		0.02	0.02	
SW-6	29-Sep-99	Maxim	3.727		7.43	0.1	0.05	<				0.00010	0.00005	<				0.016	0.016		0.06	0.06		0.001	0.0005	<	0.007	0.007		0.02	0.02	J
SW-6	13-Apr-00	Maxim	2.55		6.86	0.05	0.025	<				0.00010	0.00005	<				0.004	0.004		0.05	0.025	<	0.001	0.0005	<	0.005	0.0025	<	0.02	0.01	<
SW-6	8-Jul-00	Maxim	36.08		6.05	0.1	0.1	J				0.00010	0.00005	<				0.032	0.032	J	0.14	0.14	J	0.001	0.0005	<	0.018	0.018	J	0.01	0.01	J
SW-6	19-Oct-00	Maxim	3.34		6.5	0.1	0.05	<				0.00010	0.00005	<				0.005	0.005		0.05	0.025	<	0.001	0.0005	<	0.003	0.0015	<	0.01	0.005	<
SW-6	21-Apr-01	Maxim	2.67		8.02	0.1	0.05	<				0.00010	0.00005	<				0.004	0.004		0.02	0.02		0.001	0.0005	<	0.003	0.0015	<	0.01	0.005	<
SW-6	26-Jun-01	Maxim	60.42		6.95	0.1	0.05	<				0.00010	0.00005	<				0.027	0.027		0.12	0.12		0.001	0.0005	<	0.008	0.008		0.01	0.005	<
SW-6	11-Oct-01	Maxim	1.17		6.62	0.1	0.05	<	0.0030	0.0015	<	0.00010	0.00005	<				0.004	0.004		0.1	0.1		0.001	0.0005	<	0.008	0.008		0.03	0.03	J
SW-6	23-Apr-02	Maxim	0.64		6.56	0.1	0.05	<				0.0001	0.00005	<				0.004	0.004		0.06	0.06		0.001	0.0005	<	0.003	0.003		0.01	0.005	<
SW-6	1-Jul-02	Maxim	110		7.06	0.1	0.1	J				0.0002	0.0002					0.032	0.032		0.14	0.14		0.001	0.001		0.008	0.008		0.01	0.01	J
SW-6	8-Oct-02	Maxim	3.36		7.87	0.1	0.05	<				0.0001	0.0001					0.014	0.014		0.01	0.01		0.001	0.0005	<	0.006	0.006		0.05	0.05	J
SW-6	22-Apr-03	Maxim	4.13		6.49	0.05	0.025	<				0.0001	0.00005	<				0.005	0.005		0.12	0.12		0.001	0.0005	<	0.007	0.007		0.01	0.005	<
SW-6	1-Jul-03	Maxim	120.5		6.13	0.12	0.12					0.0001	0.00005	<				0.021	0.021		0.12	0.12		0.001	0.001		0.014	0.014		0.01	0.005	<
SW-6	30-Sep-03	Maxim	1.21		6.32	0.05	0.025	<				0.0001	0.00005	<				0.003	0.003		0.01	0.005	<	0.001	0.0005	<	0.02	0.02		0.03	0.03	
SW-6	6-Apr-04	Maxim	7.119		7.32	0.05	0.025	<				0.0001	0.00005	<				0.014	0.014		0.04	0.04		0.001	0.0005	<	0.005	0.0025	<	0.05	0.05	JF%
SW-6	28-Jun-04	Maxim	107.21		7.5	0.06	0.06					0.0001	0.00005	<				0.025	0.025		0.18	0.18		0.001	0.0005	<	0.008	0.008		0.03	0.03	
SW-6	5-Oct-04	Maxim	24.85		6.2	0.09	0.09					0.0001	0.00005	<				0.007	0.007	B	0.02	0.02		0.001	0.0005	<	0.003	0.0015	<	0.01	0.01	
SW-6	4/5/2005	Maxim	2.3		7.67	0.05	0.025	<			--	0.0001	0.00005	<			--	0.001	0.0005	<	0.01	0.01		0.001	0.0005	<	0.003	0.0015	<	0.01	0.01	JF%(1
SW-6	6/28/2005	Maxim	120.34		6.6	0.1	0.1				--	0.0001	0.00005	<			--	0.019	0.019		0.08	0.08		0.001	0.0005	<	0.01	0.01		0.01	0.01	
SW-6	10/11/2005	Maxim	2.37		7.27	0.05	0.025	<			--	0.0001	0.00005	<			--	0.005	0.005		0.01	0.005	<	0.001	0.0005	<	0.003	0.0015	<	0.01	0.005	<
SW-6	26-Apr-06	Maxim	5.58		7.3	0.05	0.025	<				0.0001	0.00005	<				0.003	0.003		0.01	0.01		0.001	0.0005	<	0.003	0.0015	<	0.01	0.005	<
SW-6	28-Jun-06	Maxim	72.63		6.04	0.07	0.07					0.0001	0.00005	<				0.024	0.024		0.12	0.12		0.001	0.0005	<	0.015	0.015		0.01	0.005	<
SW-6	26-Sep-06	Maxim	2.13		7.15	0.05	0.025	<				0.0001	0.00005	<				0.004	0.004		0.01	0.005	<	0.001	0.0005	<	0.003	0.0015	<	0.01	0.01	
SW-6	11-Apr-07	Tt	4.04		6.93	0.05	0.025	<			--	0.0001	0.00005	<			--	0.002	0.002		0.01	0.005	<	0.001	0.0005	<	0.003	0.0015	<	0.01	0.005	<
SW-6	12-Jun-07	Tt	101		7.3	0.07	0.07				--	0.0001	0.00005	<			--	0.018	0.018		0.08	0.08		0.001	0.0005	<	0.003	0.0015	<	0.01	0.005	<
SW-6	17-Sep-07	Tt	1.9		7.09	0.05	0.025	<			--	0.0001	0.00005	<			--	0.003	0.003		0.01	0.005	<	0.001	0.0005	<	0.003	0.0015	<	0.01	0.005	<
SW-6	17-Apr-08	Tt	1.93		6.15	0.05	0.025	<				0.0001	0.00005	<				0.005	0.005		0.07	0.07		0.001	0.0005	<	0.003	0.0015	<	0.01	0.005	<
SW-6	14-Jul-08	Tt	99.53		7.07	0.05	0.025	<				0.0001	0.00005	<				0.016	0.016		0	0		0.001	0.0005	<	0.008	0.008		0.01	0.005	<
SW-6	22-Sep-08	Tt	3.09		6.81	0.05	0.025	<				0.0001	0.00005	<				0.004	0.004		0.01	0.005	<	0.001	0.001	JF%	0.003	0.0015	<	0.01	0.005	<
SW-6	09-Apr-09	Tt	2.69		6.48	0.0064	0.0064					0.00004	0.00002	<				0.0024	0.0024		0.025	0.0125	<	0.00005	2.5E-05	<	0.001	0.001		0.0055	0.0055	
SW-6	23-Jun-09	Tt	177.5		7.1	0.11	0.11					0.00004	0.00002	<				0.015	0.015		0.11	0.11		0.00021	0.00021		0.0096	0.0096		0.0053	0.0053	
SW-6	29-Sep-09	Tt	1.74		5.52	0.071	0.071					0.00004	0.00002	<				0.0049	0.0049		0.04	0.04	J	0.00013	0.00013		0.0044	0.0044		0.0047	0.0047	J
SW-6	06-Apr-10	Tt	3.59		6.13	0.036	0.036	JF%				0.00008	0.00004	<				0.002	0.002		0.05	0.025	<	0.0001	0.00005	<	0.0016	0.0016		0.054	0.054	
SW-6	27-Sep-10	Tt	4.57		6.75	0.02	0.02					0.00008	0.00004	<				0.0043	0.0043		0.05	0.025	<	0.0001	0.00005	<	0.0014	0.0014		0.0055	0.0055	

Notes: mg/l = milligrams/liter; su = standard units
n = number of samples

< = less than detection
J = estimated value

NA - not applicable

TABLE A-2 - STATISTICAL SUMMARY OF WATER QUALITY DATA 1989-2010

New World Mining District Response and Restoration Project

Sample Station	Sample Date	Data Source	Flow (cfs)	Flow Flag	Field pH (su)	Aluminum Total Rec. (mg/l)	Al(calc)	Al Flag	Arsenic Total Rec. (mg/l)	As(calc)	As Flag	Cadmium Total Rec. (mg/l)	Cd(calc)	Cd Flag	Chromium Total Rec. (mg/l)	Cr(calc)	Cr Flag	Copper Total Rec. (mg/l)	Cu(calc)	Cu Flag	Iron Total Rec. (mg/l)	Fe(calc)	Fe Flag	Lead Total Rec. (mg/l)	Pb(calc)	Pb Flag	Manganese Total Rec. (mg/l)	Mn(calc)	Mn Flag	Zinc Total Rec. (mg/l)	Zn(calc)	Zn Flag
Chronic Standard (for Hardness = 50 mg/l)						0.087			0.15			0.00016			0.049			0.0052			1			0.0013			NA			0.067		
Acute Standard (for Hardness = 50 mg/l)						0.75			0.34			0.001			1.02			0.0073			NA			0.034			NA			0.067		
Chronic Standard (for Hardness = 100 mg/l)						0.087			0.15			0.0027			0.086			0.0093			1			0.0032			NA			0.12		
Acute Standard (for Hardness = 100 mg/l)						0.75			0.34			0.0021			1.8			0.0140			NA			0.082			NA			0.12		
Station SW-6: 1989 to 2003 Low Flow (n)			23		22	20			11			22			7			22			21			20			21			21		
Minimum			0.640		4.820	0.025			0.001			0.000			0.001			0.001			0.005			0.001			0.002			0.005		
Maximum			102.100		8.020	0.200			0.003			0.001			0.010			0.035			0.230			0.005			0.030			0.050		
Mean			10.580		6.719	0.059			0.002			0.0001			0.008			0.010			0.065			0.001			0.010			0.018		
Standard Deviation (SD)			22.122		0.883	0.038			0.001			0.0002			0.004			0.008			0.066			0.001			0.007			0.015		
Mean + (2 x SD); for pH: Mean - (2 x SD)			54.825		4.953	0.135			0.004			0.0004			0.015			0.026			0.196			0.004			0.024			0.047		
Station SW-6: 1989-2003 High Flow (n)			26		19	19			7			18			12			19			19			18			18			19		
Minimum			18.900		5.410	0.050			0.001			0.000			0.001			0.005			0.010			0.000			0.008			0.005		
Maximum			273.300		9.390	1.600			0.003			0.080			0.010			0.110			2.880			0.010			0.050			0.150		
Mean			116.482		7.471	0.206			0.002			0.005			0.008			0.035			0.321			0.002			0.016			0.027		
Standard Deviation (SD)			72.967		1.113	0.343			0.001			0.019			0.004			0.024			0.628			0.003			0.010			0.041		
Mean + (2 x SD); for pH: Mean - (2 x SD)			262.415		5.244	0.892			0.004			0.042			0.016			0.083			1.576			0.008			0.036			0.109		
Station SW-6: 1998 to 2003 All (n)			49		41	39			18			40			19			41			40			38			39			40		
Minimum			0.640		4.820	0.025			0.001			0.000			0.001			0.001			0.005			0.000			0.002			0.005		
Maximum			273.300		9.390	1.600			0.003			0.080			0.010			0.110			2.880			0.010			0.050			0.150		
Mean			66.773		7.067	0.131			0.002			0.002			0.008			0.021			0.186			0.002			0.013			0.022		
Standard Deviation (SD)			76.477		1.054	0.249			0.001			0.013			0.004			0.021			0.448			0.002			0.009			0.030		
Mean + (2 x SD); for pH: Mean - (2 x SD)			219.728		4.959	0.629			0.004			0.027			0.015			0.064			1.083			0.006			0.031			0.082		
Station SW-6: 2004 to 2010 Low Flow (n)			14		14	14			0			14			0			14			14			14			14			14		
Minimum			1.740		5.520	0.006						0.00002						0.001			0.005			0.000			0.001			0.005		
Maximum			24.850		7.670	0.090						0.00005						0.014			0.070			0.001			0.004			0.054		
Mean			4.850		6.769	0.032						0.00004						0.004			0.020			0.0004			0.002			0.013		
Standard Deviation (SD)			5.966		0.600	0.022						0.00001						0.003			0.019			0.0003			0.001			0.017		
Mean + (2 x SD); for pH: Mean - (2 x SD)			16.782		5.569	0.075						0.00007						0.011			0.058			0.001			0.003			0.046		
Station SW-6: 2004-2010 High Flow (n)			6		6	6			0			6			0			6			6			6			6			6		
Minimum			72.630		6.040	0.025						0.00002						0.015			0.000			0.000			0.002			0.005		
Maximum			177.500		7.500	0.110						0.00005						0.024			0.120			0.001			0.015			0.050		
Mean			113.035		6.935	0.073						0.00005						0.020			0.095			0.0005			0.009			0.010		
Standard Deviation (SD)			35.222		0.531	0.030						0.00001						0.004			0.059			0.0001			0.004			0.010		
Mean + (2 x SD); for pH: Mean - (2 x SD)			183.478		5.872	0.133						0.00007						0.028			0.213			0.001			0.017			0.030		
Station SW-6: 2004-2010 All (n)			20		20	20			0			20			0			20			20			20			20			20		
Minimum			1.740		5.520	0.006						0.00002						0.001			0.000			0.000			0.001			0.005		
Maximum			177.500		7.670	0.110						0.00005						0.025			0.180			0.001			0.015			0.054		
Mean			37.305		6.819	0.044						0.00004						0.009			0.042			0.0004			0.004			0.012		
Standard Deviation (SD)			54.204		0.572	0.030						0.00001						0.008			0.049			0.0002			0.004			0.015		
Mean + (2 x SD); for pH: Mean - (2 x SD)			145.712		5.676	0.105						0.00007						0.025			0.141			0.001			0.012			0.042		
Narrative Standard - SW-6					**5.7**	**0.763**			**NA**			**0.03472**			**NA**			**0.076**			**1.132**			**NA**			**0.034**			**0.110**		
DC-2	3-Oct-89	Hydrometrics	0.2		3.48				0.0050	0.0025	<	0.00100	0.0005	<				7.89	7.89		28.26	28.26					3.37	3.37		1.03	1.03	
DC-2	12-Jul-90	Hydrometrics	4.39		3.97	7.2	7.2		0.0050	0.0025	<	0.00500	0.005					2.74	2.74		17.9	17.9					0.71	0.71		0.31	0.31	
DC-2	15-Jun-94	Hydrometrics	2.86		3.18	9	9		0.0010	0.0005	<	0.00210	0.0021		0.0040	0.004		2.64	2.64	J	10.4	10.4		0.003	0.003		1.08	1.08		0.332	0.332	J
DC-2	26-Jul-94	Hydrometrics			3.96	16.4	16.4		0.0010	0.0005	<	0.00540	0.0054		0.0050	0.005		5.32	5.32		15.8	15.8		0.009	0.009		2.57	2.57		0.667	0.667	
DC-2	22-Aug-94	Hydrometrics			3.5	28.6	28.6		0.0020	0.002		0.00760	0.0076		0.0100	0.01		8.26	8.26		41.8	41.8		0.024	0.024		3.65	3.65		0.904	0.904	
DC-2	23-Aug-94	Hydrometrics			3.46	23.9	23.9		0.0010	0.0005	<	0.00740	0.0074		0.0060	0.006		7.27	7.27		20.4	20.4		0.006	0.006		3.43	3.43		0.886	0.886	
DC-2	20-Sep-94	Hydrometrics			4.21	25	25		0.0010	0.0005	<	0.00760	0.0076		0.0070	0.007		7.44	7.44		23.6	23.6		0.004	0.004		3.59	3.59		1.2	1.2	J
DC-2	13-Oct-94	Hydrometrics			5.29																											
DC-2	26-Sep-95	Hydrometrics	0.194		3.5	22	22		0.0010	0.0005	<	0.00520	0.0052		0.0060	0.006		6.33	6.33		16.2	16.2		0.005	0.005		2.99	2.99		0.894	0.894	
DC-2	21-May-96	Hydrometrics	0.467		4.69	8.3	8.3					0.00270	0.0027					1.91	1.91		5.55	5.55		0.004	0.004		1.12	1.12		0.43	0.43	
DC-2	30-May-96	Hydrometrics	1.116		4.45	6.9	6.9					0.00190	0.0019					1.62	1.62		5.52	5.52		0.004	0.004		0.785	0.785		0.31	0.31	
DC-2	5-Jun-96	Hydrometrics	2.79		3.38	7	7					0.00140	0.0014					1.83	1.83		19.3	19.3		0.008	0.008		0.629	0.629		0.24	0.24	
DC-2	12-Jun-96	Hydrometrics	10.8		3.35													1.25	1.25		10.7	10.7	J							0.21	0.21	J
DC-2	18-Jun-96	Hydrometrics	14.33		5.06	5	5					0.00120	0.0012					1.44	1.44		9.69	9.69		0.003	0.0015	<	0.481	0.481		0.19	0.19	
DC-2	26-Jun-96	Hydrometrics	11.3		5.03													1.52	1.52		8.54	8.54								0.19	0.19	
DC-2	2-Jul-96	Hydrometrics	13.79		4.5													1.38	1.38		6.76	6.76								0.24	0.24	J
DC-2	9-Jul-96	Hydrometrics	15.48		4	4.2	4.2	J				0.00080	0.0008					1.11	1.11		8.05	8.05		0.01	0.01		0.379	0.379		0.15	0.15	
DC-2	18-Jul-96	Hydrometrics	4.937		4.64													2.23	2.23		8	8								0.33	0.33	
DC-2	25-Jul-96	Hydrometrics	1.175		6.83													2.7	2.7		9.84	9.84								0.39	0.39	
DC-2	21-Aug-96	Hydrometrics	0.138		3.89													4.74	4.74		15.4	15.4								0.64	0.64	
DC-2	10-Sep-96	Hydrometrics	0.18		3.32	20.2	20.2					0.00580	0.0058					6.22	6.22		15.6	15.6		0.006	0.006		2.72	2.72		0.89	0.89	
DC-2	9-Jul-97	UOS Data				3.27	3.27		0.0100	0.005	<	0.00500	0.0025	<	0.0100	0.005	<	0.876	0.876		5.32	5.32					0.304	0.304		0.129	0.129	

Notes: mg/l = milligrams/liter; su = standard units
n = number of samples

< = less than detection
J = estimated value

NA - not applicable

TABLE A-2 - STATISTICAL SUMMARY OF WATER QUALITY DATA 1989-2010

New World Mining District Response and Restoration Project

Sample Station	Sample Date	Data Source	Flow (cfs)	Flow Flag	Field pH (su)	Aluminum Total Rec. (mg/l)	Al(calc)	Al Flag	Arsenic Total Rec. (mg/l)	As(calc)	As Flag	Cadmium Total Rec. (mg/l)	Cd(calc)	Cd Flag	Chromium Total Rec. (mg/l)	Cr(calc)	Cr Flag	Copper Total Rec. (mg/l)	Cu(calc)	Cu Flag	Iron Total Rec. (mg/l)	Fe(calc)	Fe Flag	Lead Total Rec. (mg/l)	Pb(calc)	Pb Flag	Manganese Total Rec. (mg/l)	Mn(calc)	Mn Flag	Zinc Total Rec. (mg/l)	Zn(calc)	Zn Flag
Chronic Standard (for Hardness = 50 mg/l)						0.087			0.15			0.00016			0.049			0.0052			1			0.0013			NA			0.067		
Acute Standard (for Hardness = 50 mg/l)						0.75			0.34			0.001			1.02			0.0073			NA			0.034			NA			0.067		
Chronic Standard (for Hardness = 100 mg/l)						0.087			0.15			0.0027			0.086			0.0093			1			0.0032			NA			0.12		
Acute Standard (for Hardness = 100 mg/l)						0.75			0.34			0.0021			1.8			0.0140			NA			0.082			NA			0.12		
DC-2	30-Mar-98	UOS Data	0.13			12.3	12.3											2.69	2.69		12.8	12.8					2.14	2.14		0.688	0.688	
DC-2	22-Apr-98	UOS Data	0.072		4.54	12.1	12.1											2.66	2.66		11.2	11.2					1.95	1.95		0.589	0.589	
DC-2	4-May-98	UOS Data	0.699		4.3	5.4	5.4											1.23	1.23		6.43	6.43					0.574	0.574		0.162	0.162	
DC-2	29-May-98	UOS Data	2.67		3.88	5.34	5.34											1.47	1.47		10	10					0.592	0.592		0.22	0.22	
DC-2	6-May-99	Maxim	0.028		4.49	9.2	9.2					0.00380	0.0038					1.94	1.94		16	16		0.006	0.006		1.61	1.61		0.51	0.51	
DC-2	8-Jul-99	Maxim	9.46		4.78	3.7	3.7					0.00120	0.0012					1.07	1.07		4.83	4.83		0.002	0.002		0.37	0.37		0.15	0.15	
DC-2	29-Sep-99	Maxim	0.464		4.48	12.4	12.4					0.00440	0.0044					3.98	3.98		13.6	13.6		0.002	0.002		1.93	1.93		0.6	0.6	J
DC-2	12-Apr-00	Maxim	0.012		4.88	10.7	10.7					0.00560	0.0056					2.51	2.51		13.5	13.5		0.004	0.004		2.02	2.02		0.02	0.01	<
DC-2	20-May-00	Maxim	1.57		4.26													1.42	1.42											0.19	0.19	
DC-2	20-May-00	Maxim	1.57		4.22													1.44	1.44											0.19	0.19	
DC-2	20-May-00	Maxim	1.61		4.24													1.89	1.89											0.26	0.26	
DC-2	20-May-00	Maxim	2.61		4.12	5.5	5.5					0.00110	0.0011					1.34	1.34		14.4	14.4		0.007	0.007		0.6	0.6		0.17	0.17	
DC-2	14-Jun-00	Maxim	5.16		4.5													1.59	1.59											0.24	0.24	
DC-2	14-Jun-00	Maxim	6.07		4.58													1.64	1.64											0.24	0.24	
DC-2	14-Jun-00	Maxim	6.44		4.42													1.61	1.61											0.22	0.22	
DC-2	14-Jun-00	Maxim	7.66			4.7	4.7					0.00140	0.0014					1.43	1.43		8.26	8.26		0.002	0.002		0.5	0.5		0.2	0.2	
DC-2	9-Jul-00	Maxim	3.5		4.61													1.59	1.59	J										0.23	0.23	J
DC-2	9-Jul-00	Maxim	2.4		4.5	6.1	6.1	J				0.00190	0.0019					2.01	2.01	J	8.55	8.55	J	0.003	0.003		0.72	0.72	J	0.26	0.26	J
DC-2	9-Jul-00	Maxim	2.83		4.47													2.04	2.04	J										0.28	0.28	J
DC-2	9-Jul-00	Maxim	3.35		4.69													1.75	1.75	J										0.26	0.26	J
DC-2	9-Oct-00	Maxim	0.2		3.28	14	14					0.00450	0.0045					3.77	3.77		6.54	6.54	J	0.007	0.007		2.23	2.23		0.54	0.54	
DC-2	20-Apr-01	Maxim	0.15		5.05	11.1	11.1					0.00370	0.0037					2.2	2.2		10.8	10.8		0.004	0.004		1.66	1.66		0.37	0.37	
DC-2	29-Jun-01	Maxim	3.217		4.95	5.5	5.5					0.00170	0.0017					1.34	1.34		10.3	10.3		0.022	0.022	J	0.63	0.63		0.29	0.29	
DC-2	10-Oct-01	Maxim	0.17		3.97	17.1	17.1		0.0030	0.0015	<	0.00540	0.0054					4.15	4.15		14.5	14.5		0.007	0.007		2.62	2.62		0.79	0.79	
DC-2	25-Apr-02	Maxim	0.31		3.98	10.8	10.8					0.0038	0.0038					2.2	2.2		12.1	12.1		0.003	0.003		1.91	1.91		0.6	0.6	
DC-2	2-Jul-02	Maxim	5		4.88	6.2	6.2	J				0.0016	0.0016					1.59	1.59		8.1	8.1		0.002	0.002		0.57	0.57		0.25	0.25	J
DC-2	18-Sep-02	Maxim			3.58	17.6	17.6					0.0047	0.0047					4.13	4.13		15.5	15.5		0.006	0.006		2.31	2.31		0.64	0.64	
DC-2	26-Sep-02	Maxim				14.3	14.3					0.0053	0.0053					4.65	4.65		10.1	10.1		0.005	0.005		2.21	2.21		0.64	0.64	
DC-2	9-Oct-02	Maxim	0.381		3.99	13.7	13.7					0.0038	0.0038					2.92	2.92		11.8	11.8		0.01	0.01		1.91	1.91		0.54	0.54	J
DC-2	22-Apr-03	Maxim	0.19		4.63	7.85	7.85					0.0038	0.0038					2.14	2.14		8.79	8.79		0.005	0.005		1.62	1.62		0.45	0.45	
DC-2	11-Jul-03	Maxim	2.36		4.8	6.17	6.17					0.0019	0.0019					1.92	1.92		4.86	4.86		0.003	0.003		0.88	0.88		0.25	0.25	
DC-2	31-Jul-03	Maxim			4.6	13.1	13.1		0.001	0.0005	<	0.0032	0.0032					3.57	3.57		12.2	12.2		0.005	0.005		1.83	1.83		0.57	0.57	JF%
DC-2	14-Aug-03	Maxim			4.1	15.9	15.9		0.001	0.0005	<	0.0044	0.0044					4.46	4.46		14.4	14.4		0.007	0.007		2.25	2.25		0.63	0.63	
DC-2	21-Aug-03	Maxim				15.3	15.3					0.0048	0.0048					4.37	4.37		13.3	13.3		0.007	0.007		2.29	2.29		0.65	0.65	
DC-2	22-Aug-03	Maxim				19.2	19.2					0.0051	0.0051					4.35	4.35		21.4	21.4		0.008	0.008		2.81	2.81		0.87	0.87	
DC-2	8-Sep-03	Maxim			3.6	18.5	18.5					0.0046	0.0046					5.03	5.03		19.4	19.4		0.013	0.013		2.8	2.8		0.81	0.81	
DC-2	29-Sep-03	Maxim	0.066		4.52	12.5	12.5					0.0043	0.0043					3.63	3.63		8.69	8.69		0.005	0.005		2.5	2.5		0.76	0.76	
DC-2	6-Apr-04	Maxim	0.181		5.82	10.1	10.1					0.0036	0.0036					2.15	2.15		5.94	5.94		0.005	0.005		1.67	1.67		0.5	0.5	JF%
DC-2	29-Jun-04	Maxim	9.56		6.8	2.97	2.97					0.0007	0.0007					0.58	0.58		4.16	4.16		0.003	0.003		0.31	0.31		0.1	0.1	
DC-2	11-Aug-04	Maxim	0.36		4.24	9.38	9.38					0.0032	0.0032					2.79	2.79		11.1	11.1		0.004	0.004		1.44	1.44		0.45	0.45	
DC-2	6-Oct-04	Maxim	0.53		4.8	6.58	6.58					0.0024	0.0024					1.9	1.9		7.36	7.36		0.002	0.002		1.25	1.25		0.35	0.35	
DC-2	6-Apr-05	Maxim	0.05		4.47	11.6	11.6					0.0046	0.0046					2.49	2.49		15.5	15.5		0.003	0.003		2.25	2.25		0.84	0.84	
DC-2	29-Jun-05	Maxim	6.8		5.8	2.37	2.37				--	0.0008	0.0008				--	0.31	0.31		3.42	3.42		0.002	0.002		0.31	0.31		0.14	0.14	
DC-2	27-Sep-05	Maxim	0.19		3.7	13.2	13.2				--	0.0035	0.0035				--	2.57	2.57		12.1	12.1		0.006	0.006		1.82	1.82		0.51	0.51	
DC-2	25-Apr-06	Maxim	0.08		4.74	9.15	9.15					0.003	0.003					1.54	1.54		10.2	10.2		0.002	0.002		1.95	1.95		0.5	0.5	
DC-2	27-Jun-06	Maxim	5.19		6.25	3.12	3.12					0.0005	0.0005					0.69	0.69		3.38	3.38		0.002	0.002		0.34	0.34		0.1	0.1	
DC-2	27-Sep-06	Maxim	0.14		3.76	12.4	12.4					0.0043	0.0043					3.17	3.17		7.78	7.78		0.004	0.004		2.14	2.14		0.55	0.55	
DC-2	11-Apr-07	Tt	0.05		6.93	8.3	8.3				--	0.0036	0.0036				--	1.44	1.44		12	12		0.003	0.003		1.76	1.76		0.46	0.46	
DC-2	13-Jun-07	Tt	10.2		7.1	3.7	3.7				--	0.0004	0.0004				--	0.41	0.41		5.36	5.36		0.009	0.009		0.23	0.23		0.07	0.07	
DC-2	18-Jul-07	Tt	0.507		4.72	8.9	8.9				--	0.0023	0.0023				--	2.2	2.2		10.2	10.2		0.002	0.002		1.12	1.12		0.34	0.34	
DC-2	18-Sep-07	Tt	0.154		4.15	13.4	13.4				--	0.0042	0.0042				--	3.58	3.58		12.9	12.9		0.004	0.004		2.37	2.37		0.61	0.61	
DC-2	17-Apr-08	Tt	0.022		5.48	8.53	8.53					0.0035	0.0035					1.79	1.79		13.3	13.3		0.003	0.003		1.93	1.93		0.5	0.5	
DC-2	15-Jul-08	Tt	9.229		6.35	2.3	2.3					0.0005	0.0005					0.52	0.52		2.32	2.32		0.002	0.002		0.29	0.29		0.08	0.08	
DC-2	24-Sep-08	Tt	0.395		3.84	14.1	14.1					0.004	0.004					3.54	3.54		10.3	10.3		0.005	0.005	JF%	2.12	2.12		0.56	0.56	
DC-2	08-Apr-09	Tt	0.0052		3.14	8.9	8.9					0.0036	0.0036					2.5	2.5		12	12		0.0025	0.0025		2.7	2.7		0.67	0.67	
DC-2	24-Jun-09	Tt	12.5		6.82	2.3	2.3					0.00043	0.00043					0.39	0.39		3.2	3.2		0.0046	0.0046		0.22	0.22		0.069	0.069	
DC-2	06-Jul-09	Tt	4.14		5.31	4.9	4.9					0.00077	0.00077					0.85	0.85		7.8	7.8		0.0086	0.0086		0.42	0.42		0.13	0.13	
DC-2	28-Sep-09	Tt	0.0852		4.57	10.1	10.1					0.0036	0.0036					2.6	2.6		7.4	7.4		0.0036	0.0036		2.1	2.1		0.51	0.51	
DC-2	07-Apr-10	Tt	0.106		4.49	9.1	9.1	JF%				0.0036	0.0036					1.8	1.8		13.7	13.7		0.0024	0.0024		2	2		0.51	0.51	
DC-2	28-Sep-10	Tt	0.0764		4.57	11.7	11.7					0.0033	0.0033					2.7	2.7		34.3	34.3		0.036	0.036		1.8	1.8		0.42	0.42	

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NA - not applicable

TABLE A-2 - STATISTICAL SUMMARY OF WATER QUALITY DATA 1989-2010

New World Mining District Response and Restoration Project

Sample Station	Sample Date	Data Source	Flow (cfs)	Flow Flag	Field pH (su)	Aluminum Total Rec. (mg/l)	Al(calc)	Al Flag	Arsenic Total Rec. (mg/l)	As(calc)	As Flag	Cadmium Total Rec. (mg/l)	Cd(calc)	Cd Flag	Chromium Total Rec. (mg/l)	Cr(calc)	Cr Flag	Copper Total Rec. (mg/l)	Cu(calc)	Cu Flag	Iron Total Rec. (mg/l)	Fe(calc)	Fe Flag	Lead Total Rec. (mg/l)	Pb(calc)	Pb Flag	Manganese Total Rec. (mg/l)	Mn(calc)	Mn Flag	Zinc Total Rec. (mg/l)	Zn(calc)	Zn Flag
Chronic Standard (for Hardness = 50 mg/l)						0.087			0.15			0.00016			0.049			0.0052			1			0.0013			NA			0.067		
Acute Standard (for Hardness = 50 mg/l)						0.75			0.34			0.001			1.02			0.0073			NA			0.034			NA			0.067		
Chronic Standard (for Hardness = 100 mg/l)						0.087			0.15			0.0027			0.086			0.0093			1			0.0032			NA			0.12		
Acute Standard (for Hardness = 100 mg/l)						0.75			0.34			0.0021			1.8			0.0140			NA			0.082			NA			0.12		
Station DC-2: 1989 to 2003 Low Flow (n)			24		30	28			7			25			4			33			30			24			29			33		
Minimum			0.012		3.280	5.340			0.001			0.001			0.006			1.230			5.520			0.002			0.574			0.010		
Maximum			2.670		5.290	28.600			0.003			0.008			0.010			8.260			41.800			0.024			3.650			1.200		
Mean			0.633		4.130	14.132			0.001			0.004			0.007			3.705			14.586			0.007			2.145			0.578		
Standard Deviation (SD)			0.795		0.521	6.132			0.001			0.002			0.002			2.061			7.360			0.004			0.866			0.285		
Mean + (2 x SD); for pH: Mean - (2 x SD)			2.223		3.087	26.396			0.003			0.008			0.011			7.827			29.305			0.015			3.877			1.147		
Station DC-2: 1989-2003 High Flow (n)			22		23	14			5			14			3			25			19			12			14			25		
Minimum			1.175		3.180	3.270			0.001			0.001			0.004			0.876			4.830			0.002			0.304			0.129		
Maximum			15.480		6.830	16.400			0.005			0.005			0.005			5.320			19.300			0.022			2.570			0.667		
Mean			6.332		4.508	6.967			0.002			0.002			0.005			1.927			9.863			0.006			0.832			0.273		
Standard Deviation (SD)			4.308		0.731	3.679			0.002			0.001			0.001			0.933			4.028			0.006			0.632			0.121		
Mean + (2 x SD); for pH: Mean - (2 x SD)			14.948		3.045	14.324			0.006			0.005			0.006			3.794			17.920			0.018			2.096			0.514		
Station DC-2: 1998 to 2003 All (n)			46		53	42			12			39			7			58			49			36			43			58		
Minimum			0.012		3.180	3.270			0.001			0.001			0.004			0.876			4.830			0.002			0.304			0.010		
Maximum			15.480		6.830	28.600			0.005			0.008			0.010			8.260			41.800			0.024			3.650			1.200		
Mean			3.359		4.294	11.744			0.001			0.004			0.006			2.939			12.755			0.006			1.717			0.446		
Standard Deviation (SD)			4.155		0.643	6.383			0.001			0.002			0.002			1.881			6.650			0.005			1.006			0.274		
Mean + (2 x SD); for pH: Mean - (2 x SD)			11.669		3.008	24.509			0.004			0.008			0.010			6.701			26.054			0.016			3.728			0.993		
Station DC-2: 2004 to 2010 Low Flow (n)			15		15	15			0			15			0			15			15			15			15			15		
Minimum			0.005		3.140	6.580						0.002						1.440			5.940			0.002			1.250			0.350		
Maximum			0.530		6.930	14.100						0.005						3.580			34.300			0.036			2.700			0.840		
Mean			0.162		4.580	10.436						0.004						2.437			12.392			0.006			1.953			0.529		
Standard Deviation (SD)			0.152		0.939	2.185						0.001						0.671			6.638			0.008			0.361			0.114		
Mean + (2 x SD); for pH: Mean - (2 x SD)			0.465		2.703	14.807						0.005						3.779			25.667			0.023			2.675			0.758		
Station DC-2: 2004-2010 High Flow (n)			8		8	8			0			8			0			8			8			8			8			8		
Minimum			0.507		4.720	2.300						0.000						0.310			2.320			0.002			0.220			0.069		
Maximum			12.500		7.100	8.900						0.002						2.200			10.200			0.009			1.120			0.340		
Mean			7.266		6.144	3.820						0.001						0.744			4.980			0.004			0.405			0.129		
Standard Deviation (SD)			3.875		0.819	2.234						0.001						0.614			2.706			0.003			0.296			0.089		
Mean + (2 x SD); for pH: Mean - (2 x SD)			15.015		4.506	8.287						0.002						1.971			10.392			0.010			0.996			0.307		
Station DC-2: 2004-2010 All (n)			23		23	23			0			23			0			23			23			23			23			23		
Minimum			0.005		3.140	2.300						0.000						0.310			2.320			0.002			0.220			0.069		
Maximum			12.500		7.100	14.100						0.005						3.580			34.300			0.036			2.700			0.840		
Mean			2.633		5.124	8.135						0.003						1.848			9.814			0.005			1.415			0.390		
Standard Deviation (SD)			4.094		1.164	3.874						0.001						1.042			6.587			0.007			0.824			0.221		
Mean + (2 x SD); for pH: Mean - (2 x SD)			10.821		2.797	15.883						0.006						3.933			22.989			0.019			3.063			0.832		
Narrative Standard - DC-2					**2.7**	**28.4**			**NA**			**0.009**			**NA**			**8.064**			**29.649**			**0.018**			**4.088**			**1.104**		

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New World Mining District Response and Restoration Project

Sample Station	Sample Date	Data Source	Flow (cfs)	Flow Flag	Field pH (su)	Aluminum Total Rec. (mg/l)	Al(calc)	Al Flag	Arsenic Total Rec. (mg/l)	As(calc)	As Flag	Cadmium Total Rec. (mg/l)	Cd(calc)	Cd Flag	Chromium Total Rec. (mg/l)	Cr(calc)	Cr Flag	Copper Total Rec. (mg/l)	Cu(calc)	Cu Flag	Iron Total Rec. (mg/l)	Fe(calc)	Fe Flag	Lead Total Rec. (mg/l)	Pb(calc)	Pb Flag	Manganese Total Rec. (mg/l)	Mn(calc)	Mn Flag	Zinc Total Rec. (mg/l)	Zn(calc)	Zn Flag
Chronic Standard (for Hardness = 50 mg/l)						0.087			0.15			0.00016			0.049			0.0052			1			0.0013			NA			0.067		
Acute Standard (for Hardness = 50 mg/l)						0.75			0.34			0.001			1.02			0.0073			NA			0.034			NA			0.067		
Chronic Standard (for Hardness = 100 mg/l)						0.087			0.15			0.0027			0.086			0.0093			1			0.0032			NA			0.12		
Acute Standard (for Hardness = 100 mg/l)						0.75			0.34			0.0021			1.8			0.0140			NA			0.082			NA			0.12		
DC-5	3-Oct-89	Hydrometrics	0.370		5.69				0.0050	0.0025	<	0.00300	0.003					2.54	2.54		6.88	6.88					1.16	1.16		0.4	0.4	
DC-5	12-Jul-90	Hydrometrics	8.910		7.43	2.7	2.7		0.0050	0.0025	<	0.00100	0.0005	<				0.97	0.97		4.3	4.3					0.28	0.28		0.12	0.12	
DC-5	28-Jul-93	Hydrometrics			7.2	3.2	3.2		0.0020	0.001	<	0.00100	0.0005	<	0.0020	0.002		1.09	1.09		4.19	4.19		0.002	0.002		0.35	0.35		0.12	0.12	
DC-5	23-Sep-93	Hydrometrics	0.540		6.61	5.3	5.3		0.0010	0.0005	<	0.00230	0.0023		0.0020	0.002		2.17	2.17		4.68	4.68		0.002	0.002		1.2	1.2		0.36	0.36	
DC-5	25-Aug-94	Hydrometrics	0.240		6.4	8.1	8.1	J	0.0010	0.0005	<	0.00270	0.0027		0.0020	0.002		2.85	2.85	J	5.7	5.7	J	0.002	0.002		1.23	1.23		0.42	0.42	
DC-5	13-Jul-95	Hydrometrics	30.430		7.1	2	2		0.0010	0.0005	<	0.00050	0.0005		0.0020	0.002		0.485	0.485	J	3.8	3.8	J	0.003	0.003		0.18	0.18		0.062	0.062	
DC-5	27-Sep-95	Hydrometrics	0.420		5.3	7.7	7.7		0.0010	0.0005	<	0.00230	0.0023		0.0020	0.002		2.45	2.45		2.38	2.38		0.003	0.003		1.18	1.18		0.391	0.391	
DC-5	18-Jun-96	Hydrometrics	30.740		7.63	1.4	1.4					0.00040	0.0004					0.346	0.346		3.12	3.12		0.003	0.0015	<	0.143	0.143		0.06	0.06	
DC-5	9-Jul-96	Hydrometrics	28.140		6.34	1.7	1.7	J				0.00040	0.0004					0.46	0.46		2.48	2.48		0.003	0.0015	<	0.166	0.166		0.07	0.07	
DC-5	10-Sep-96	Hydrometrics	0.312		6.13	7.2	7.2					0.00230	0.0023					2.62	2.62		4.42	4.42		0.003	0.0015	<	1.08	1.08		0.37	0.37	
DC-5	6-May-99	Maxim	1.180		6.29	1.4	1.4					0.00060	0.0006					0.33	0.33		0.65	0.65		0.001	0.001		0.25	0.25		0.08	0.08	
DC-5	8-Jul-99	Maxim	23.830		7.46	1.2	1.2					0.00040	0.0004					0.31	0.31		1.54	1.54		0.001	0.001		0.124	0.124		0.07	0.07	
DC-5	29-Sep-99	Maxim	1.484		2.64	4	4					0.00120	0.0012					1.26	1.26		2.67	2.67		0.002	0.002		0.5	0.5		0.17	0.17	J
DC-5	12-Apr-00	Maxim	0.429		6.59	2.9	2.9					0.00140	0.0014					1.04	1.04		1.38	1.38		0.004	0.004		0.041	0.041		0.02	0.01	<
DC-5	9-Jul-00	Maxim	8.900		7.65	1.6	1.6	J				0.00050	0.0005					0.54	0.54	J	2.11	2.11	J	0.001	0.0005	<	0.19	0.19	J	0.07	0.07	J
DC-5	9-Oct-00	Maxim	1.200		7.17	2.7	2.7					0.00460	0.0046					0.61	0.61		1.3	1.3	J	0.003	0.0015	<	0.23	0.23		0.08	0.08	
DC-5	29-Jun-01	Maxim	5.107		6.95	1.8	1.8					0.00060	0.0006					0.55	0.55		3.02	3.02		0.002	0.002	J	0.21	0.21		0.09	0.09	
DC-5	10-Oct-01	Maxim	0.340		7.73	3.5	3.5		0.0030	0.0015	<	0.00100	0.001					0.71	0.71		1.19	1.19		0.003	0.003		0.41	0.41		0.15	0.15	
DC-5	25-Apr-02	Maxim		ice	5.6	0.1	0.05	<				0.0004	0.0004					0.024	0.024		0.01	0.005	<	0.001	0.0005	<	0.16	0.16		0.04	0.04	
DC-5	2-Jul-02	Maxim	12.600		6.5	1.6	1.6	J				0.0005	0.0005					0.54	0.54		2.48	2.48		0.002	0.002		0.19	0.19		0.08	0.08	J
DC-5	18-Sep-02	Maxim			5.86	5.9	5.9					0.0021	0.0021					1.61	1.61		3.66	3.66		0.003	0.003		0.93	0.93		0.21	0.21	
DC-5	26-Sep-02	Maxim				0.3	0.3					0.0004	0.0004					0.079	0.079		0.25	0.25		0.001	0.0005	<	0.086	0.086		0.02	0.02	
DC-5	9-Oct-02	Maxim	0.740		7.1	3.7	3.7					0.001	0.001					0.76	0.76		2.07	2.07		0.003	0.003		0.45	0.45		0.15	0.15	J
DC-5	21-Apr-03	Maxim	0.570		6.26	2.07	2.07					0.0009	0.0009					0.56	0.56		1.3	1.3		0.002	0.002		0.35	0.35		0.13	0.13	
DC-5	11-Jul-03	Maxim	5.460		6.37	2.1	2.1					0.0006	0.0006					0.48	0.48		1.55	1.55		0.001	0.001		0.29	0.29		0.07	0.07	
DC-5	8-Sep-03	Maxim			5.7	7.84	7.84					0.0017	0.0017					2.01	2.01		15.7	15.7		0.018	0.018		1.05	1.05		0.38	0.38	
DC-5	29-Sep-03	Maxim	0.185		7.01	5.34	5.34					0.0012	0.0012					1.44	1.44		3	3		0.003	0.003		0.62	0.62		0.3	0.3	
DC-5	7-Apr-04	Maxim	1.197		6.44	2.18	2.18					0.0007	0.0007					0.52	0.52		1.1	1.1		0.001	0.001		0.34	0.34		0.13	0.13	JF%
DC-5	29-Jun-04	Maxim	19.210		7.7	0.73	0.73					0.0002	0.0002					0.16	0.16		1.23	1.23		0.001	0.001		0.1	0.1		0.04	0.04	
DC-5	11-Aug-04	Maxim	0.820		7.35	3.03	3.03					0.0011	0.0011					0.87	0.87		3.69	3.69		0.001	0.001		0.46	0.46		0.15	0.15	
DC-5	6-Oct-04	Maxim	1.800		6.62	1.93	1.93					0.0007	0.0007					0.51	0.51		2.13	2.13		0.001	0.0005	<	0.33	0.33		0.11	0.11	
DC-5	4/6/2005	Maxim	0.24		7.23	2.43	2.43				--	0.001	0.001				--	0.54	0.54		1.74	1.74		0.001	0.001		0.51	0.51		0.35	0.35	JF%
DC-5	6/29/2005	Maxim	19.26		6.9	0.7	0.7				--	0.0002	0.0002				--	0.17	0.17		0.98	0.98		0.001	0.001		0.095	0.095		0.1	0.1	
DC-5	9/27/2005	Maxim	0.43		6.3	3.88	3.88				--	0.0015	0.0015				--	0.97	0.97		2.61	2.61		0.004	0.004		0.73	0.73		0.22	0.22	
DC-5	25-Apr-06	Maxim	0.46		6.94	0.96	0.96					0.0005	0.0005					0.23	0.23		0.64	0.64		0.001	0.0005	<	0.29	0.29		0.06	0.06	
DC-5	27-Jun-06	Maxim	15.78		6.62	1.13	1.13					0.0001	0.00005	<				0.21	0.21		1.13	1.13		0.001	0.0005	<	0.11	0.11		0.04	0.04	
DC-5	27-Sep-06	Maxim	0.28		6.73	2.83	2.83					0.0014	0.0014					0.79	0.79		0.91	0.91		0.001	0.001		0.66	0.66		0.17	0.17	
DC-5	11-Apr-07	Tt	0.432		6.93	1.23	1.23				--	0.0007	0.0007				--	0.25	0.25		1.03	1.03		0.001	0.0005	<	0.32	0.32		0.09	0.09	
DC-5	13-Jun-07	Tt	30.7		5.7	1.39	1.39				--	0.0002	0.0002				--	0.019	0.019		1.73	1.73		0.003	0.003		0.099	0.099		0.02	0.02	
DC-5	18-Sep-07	Tt	0.418		6.92	4.23	4.23				--	0.0014	0.0014				--	1.16	1.16		5.04	5.04		0.002	0.002		0.74	0.74		0.22	0.22	
DC-5	17-Apr-08	Tt	0.25		7.33	1.19	1.19					0.0007	0.0007					0.31	0.31		1.3	1.3		0.001	0.0005	<	0.37	0.37		0.09	0.09	
DC-5	15-Jul-08	Tt	17.66		7.04	0.89	0.89					0.0002	0.0002					0.18	0.18		0.98	0.98		0.002	0.002		0.11	0.11		0.03	0.03	
DC-5	24-Sep-08	Tt	0.641		7.64	6.53	6.53					0.0013	0.0013					1.48	1.48		5.34	5.34		0.005	0.005	JF%	0.71	0.71		0.21	0.21	
DC-5	08-Apr-09	Tt	0.0522		5.79	2.3	2.3					0.00095	0.00095					0.7	0.7		1.3	1.3		0.0011	0.0011		0.43	0.43		0.15	0.15	
DC-5	24-Jun-09	Tt	27.9		7.1	0.81	0.81					0.00015	0.00015					0.14	0.14		1	1		0.0019	0.0019		0.077	0.077		0.026	0.026	
DC-5	28-Sep-09	Tt	0.294		7.81	3.5	3.5					0.001	0.001					1	1		2.9	2.9		0.0019	0.0019		0.42	0.42		0.18	0.18	
DC-5	07-Apr-10	Tt	0.0684		6.67	1.6	1.6	JF%				0.00081	0.00081					0.39	0.39		1	1		0.0007	0.0007		0.42	0.42		0.12	0.12	
DC-5	28-Sep-10	Tt	0.435		7.51	2.4	2.4					0.001	0.001					0.8	0.8		2.5	2.5		0.00085	0.00085		0.52	0.52		0.14	0.14	

Notes: mg/l = milligrams/liter; su = standard units
n = number of samples

< = less than detection
J = estimated value

NA - not applicable

TABLE A-2 - STATISTICAL SUMMARY OF WATER QUALITY DATA 1989-2010

New World Mining District Response and Restoration Project

Sample Station	Sample Date	Data Source	Flow (cfs)	Flow Flag	Field pH (su)	Aluminum Total Rec. (mg/l)	Al(calc)	Al Flag	Arsenic Total Rec. (mg/l)	As(calc)	As Flag	Cadmium Total Rec. (mg/l)	Cd(calc)	Cd Flag	Chromium Total Rec. (mg/l)	Cr(calc)	Cr Flag	Copper Total Rec. (mg/l)	Cu(calc)	Cu Flag	Iron Total Rec. (mg/l)	Fe(calc)	Fe Flag	Lead Total Rec. (mg/l)	Pb(calc)	Pb Flag	Manganese Total Rec. (mg/l)	Mn(calc)	Mn Flag	Zinc Total Rec. (mg/l)	Zn(calc)	Zn Flag
Chronic Standard (for Hardness = 50 mg/l)						0.087			0.15			0.00016			0.049			0.0052			1			0.0013			NA			0.067		
Acute Standard (for Hardness = 50 mg/l)						0.75			0.34			0.001			1.02			0.0073			NA			0.034			NA			0.067		
Chronic Standard (for Hardness = 100 mg/l)						0.087			0.15			0.0027			0.086			0.0093			1			0.0032			NA			0.12		
Acute Standard (for Hardness = 100 mg/l)						0.75			0.34			0.0021			1.8			0.0140			NA			0.082			NA			0.12		
Station DC-5: 1989 to 2003 Low Flow (n)			13		16	16			5			17			3			17			17			16			17			17		
Minimum			0.185		2.640	0.050			0.001			0.000			0.002			0.024			0.005			0.001			0.041			0.010		
Maximum			1.484		7.730	8.100			0.003			0.005			0.002			2.850			15.700			0.018			1.230			0.420		
Mean			0.616		6.130	4.250			0.001			0.002			0.002			1.357			3.367			0.003			0.643			0.215		
Standard Deviation (SD)			0.415		1.141	2.641			0.001			0.001			0.000			0.939			3.723			0.004			0.439			0.148		
Mean + (2 x SD); for pH: Mean - (2 x SD)			1.446		3.849	9.531			0.003			0.004			0.002			3.235			10.812			0.011			1.520			0.512		
Station DC-5: 1989-2003 High Flow (n)			9		10	10			3			10			2			10			10			9			10			10		
Minimum			5.107		6.340	1.200			0.001			0.000			0.002			0.310			1.540			0.001			0.124			0.060		
Maximum			30.740		7.650	3.200			0.003			0.001			0.002			1.090			4.300			0.003			0.350			0.120		
Mean			17.124		7.063	1.930			0.001			0.000			0.002			0.577			2.859			0.002			0.212			0.081		
Standard Deviation (SD)			10.982		0.507	0.609			0.001			0.000			0.000			0.253			1.007			0.001			0.072			0.022		
Mean + (2 x SD); for pH: Mean - (2 x SD)			39.088		6.049	3.149			0.003			0.001			0.002			1.084			4.873			0.003			0.356			0.125		
Station DC-5: 1998 to 2003 All (n)			22		26	26			8			27			5			27			27			25			27			27		
Minimum			0.185		2.640	0.050			0.001			0.0004			0.002			0.024			0.005			0.001			0.041			0.010		
Maximum			30.740		7.730	8.100			0.003			0.0046			0.002			2.850			15.700			0.018			1.230			0.420		
Mean			7.369		6.489	3.358			0.001			0.0013			0.002			1.068			3.179			0.003			0.483			0.166		
Standard Deviation (SD)			10.726		1.043	2.375			0.001			0.0010			0.000			0.844			2.990			0.003			0.406			0.134		
Mean + (2 x SD); for pH: Mean - (2 x SD)			28.822		4.403	8.108			0.003			0.0034			0.002			2.756			9.159			0.009			1.296			0.434		
Station DC-5: 2004 to 2010 Low Flow (n)			15		15	15			0			15			0			15			15			15			15			15		
Minimum			0.052		5.790	0.960						0.0005						0.230			0.640			0.001			0.290			0.060		
Maximum			1.800		7.810	6.530						0.0015						1.480			5.340			0.005			0.740			0.350		
Mean			0.521		6.947	2.681						0.0010						0.701			2.215			0.001			0.483			0.159		
Standard Deviation (SD)			0.457		0.546	1.440						0.0003						0.358			1.484			0.001			0.157			0.072		
Mean + (2 x SD); for pH: Mean - (2 x SD)			1.435		5.855	5.561						0.0016						1.418			5.184			0.004			0.797			0.302		
Station DC-5: 2004-2010 High Flow (n)			6		6	6			0			6			0			6			6			6			6			6		
Minimum			15.780		5.700	0.700						0.0001						0.019			0.980			0.001			0.077			0.020		
Maximum			30.700		7.700	1.390						0.0002						0.210			1.730			0.003			0.110			0.100		
Mean			21.752		6.843	0.942						0.0002						0.147			1.175			0.002			0.099			0.043		
Standard Deviation (SD)			6.049		0.663	0.268						0.0001						0.067			0.290			0.001			0.012			0.029		
Mean + (2 x SD); for pH: Mean - (2 x SD)			33.849		5.517	1.478						0.0003						0.280			1.754			0.003			0.123			0.101		
Station DC-5: 2004-2010 All (n)			21		21	21			0			21			0			21			21			21			21			21		
Minimum			0.052		5.700	0.700						0.0001						0.019			0.640			0.001			0.077			0.020		
Maximum			30.700		7.810	6.530						0.0015						1.480			5.340			0.005			0.740			0.350		
Mean			6.587		6.918	2.184						0.0008						0.543			1.918			0.001			0.373			0.126		
Standard Deviation (SD)			10.290		0.567	1.455						0.0005						0.396			1.340			0.001			0.221			0.082		
Mean + (2 x SD); for pH: Mean - (2 x SD)			27.167		5.784	5.095						0.0017						1.335			4.598			0.004			0.816			0.290		
Temporary Standard - DC-5					**4.6**	**9.51**			**NA**			**0.004**			**NA**			**3.53**			**6.83**			**NA**			**1.71**			**0.54**		
SW-7	28-May-90	Hydrometrics	40.30		7.02	0.1	0.1		0.0050	0.0025	<	0.00010	0.00005	<	0.0200	0.01	<	0.03	0.03		0.2	0.2		0.002	0.001	<	0.02	0.01	<	0.02	0.02	
SW-7	5-Jun-90	Hydrometrics	81.11		7.23	0.4	0.4											0.11	0.11		0.99	0.99								0.02	0.02	
SW-7	6-Jun-90	Hydrometrics	115.10																													
SW-7	13-Jun-90	Hydrometrics	69.81		7.15	0.26	0.26											0.07	0.07		0.61	0.61								0.02	0.02	
SW-7	15-Jun-90	Hydrometrics	56.30																													
SW-7	20-Jun-90	Hydrometrics	97.51		7.28	0.5	0.5											0.14	0.14		0.99	0.99								0.02	0.02	
SW-7	22-Jun-90	Hydrometrics	129.15																													
SW-7	27-Jun-90	Hydrometrics	138.80		8.76	0.6	0.6		0.0050	0.0025	<	0.00020	0.0002		0.0200	0.01	<	0.147	0.147		1.02	1.02		0.002	0.001	<	0.05	0.05		0.03	0.03	
SW-7	28-Jun-90	Hydrometrics	140.13																													
SW-7	3-Jul-90	Hydrometrics	122.90		9.58	0.4	0.4											0.11	0.11		0.78	0.78					0.05	0.05		0.03	0.03	
SW-7	10-Jul-90	Hydrometrics	50.20			0.3	0.3					0.00100	0.0005	<	0.0200	0.01	<	0.11	0.11		0.67	0.67		0.01	0.005	<	0.04	0.04		0.04	0.04	
SW-7	12-Jul-90	Hydrometrics	41.70																													
SW-7	17-Jul-90	Hydrometrics	24.70		9.09	0.5	0.5											0.17	0.17		0.93	0.93								0.03	0.015	<
SW-7	19-Jul-90	Hydrometrics	20.90																													
SW-7	26-Jul-90	Hydrometrics	10.40		6.65	0.5	0.5		0.0050	0.0025	<	0.00020	0.0002		0.0200	0.01	<	0.21	0.21		1.05	1.05		0.003	0.003		0.07	0.07		0.04	0.04	
SW-7	22-Aug-90	Hydrometrics	5.60		7.41																											
SW-7	25-Sep-90	Hydrometrics	2.20		6.63	0.1	0.05	<	0.0050	0.0025	<	0.00010	0.00005	<	0.0200	0.01	<	0.02	0.02		0.14	0.14		0.002	0.001	<	0.05	0.05		0.02	0.02	
SW-7	15-Mar-91	Hydrometrics	1.50		6.54	0.1	0.05	<	0.0050	0.0025	<	0.00100	0.0005	<	0.0200	0.01	<	0.01	0.005	<	0.24	0.24		0.01	0.005	<	0.04	0.04		0.01	0.01	
SW-7	6-Jun-91	Hydrometrics	157.60		7.75	0.3	0.3		0.0050	0.0025	<	0.00010	0.00005	<	0.0200	0.01	<	0.06	0.03	<	0.74	0.74		0.002	0.002	J	0.03	0.03		0.04	0.04	
SW-7	10-Jul-91	Hydrometrics	37.70		7.84	0.4	0.4		0.0050	0.0025	<	0.00010	0.0001		0.0200	0.01	<	0.18	0.18		1.2	1.2		0.024	0.024	J	0.05	0.05		0.04	0.04	
SW-7	13-Aug-91	Hydrometrics	4.10		7.81	0.1	0.1		0.0050	0.0025	<	0.00020	0.0002		0.0200	0.02		0.034	0.034		0.15	0.15		0.002	0.001	<	0.07	0.07		0.06	0.06	
SW-7	24-Sep-91	Hydrometrics	3.50		8.23	0.1	0.05	<	0.0050	0.0025	<	0.00010	0.0001		0.0200	0.01	<	0.017	0.017		0.21	0.21		0.002	0.001	<	0.06	0.06		0.01	0.01	

Notes: mg/l = milligrams/liter; su = standard units
n = number of samples

< = less than detection
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NA - not applicable

TABLE A-2 - STATISTICAL SUMMARY OF WATER QUALITY DATA 1989-2010

New World Mining District Response and Restoration Project

Sample Station	Sample Date	Data Source	Flow (cfs)	Flow Flag	Field pH (su)	Aluminum Total Rec. (mg/l)	Al(calc)	Al Flag	Arsenic Total Rec. (mg/l)	As(calc)	As Flag	Cadmium Total Rec. (mg/l)	Cd(calc)	Cd Flag	Chromium Total Rec. (mg/l)	Cr(calc)	Cr Flag	Copper Total Rec. (mg/l)	Cu(calc)	Cu Flag	Iron Total Rec. (mg/l)	Fe(calc)	Fe Flag	Lead Total Rec. (mg/l)	Pb(calc)	Pb Flag	Manganese Total Rec. (mg/l)	Mn(calc)	Mn Flag	Zinc Total Rec. (mg/l)	Zn(calc)	Zn Flag
Chronic Standard (for Hardness = 50 mg/l)						0.087			0.15			0.00016			0.049			0.0052			1			0.0013			NA			0.067		
Acute Standard (for Hardness = 50 mg/l)						0.75			0.34			0.001			1.02			0.0073			NA			0.034			NA			0.067		
Chronic Standard (for Hardness = 100 mg/l)						0.087			0.15			0.0027			0.086			0.0093			1			0.0032			NA			0.12		
Acute Standard (for Hardness = 100 mg/l)						0.75			0.34			0.0021			1.8			0.0140			NA			0.082			NA			0.12		
SW-7	19-Jul-92	Hydrometrics	20.00		8.02	0.5	0.5		0.0050	0.0025	<	0.00010	0.00005	<	0.0100	0.005	<	0.17	0.17		0.07	0.07		0.002	0.001	<	0.07	0.07		0.03	0.03	
SW-7	22-Sep-92	Hydrometrics	3.23		7.58	0.1	0.1		0.0050	0.0025	<	0.00020	0.0002		0.0100	0.005	<	0.087	0.0435	<	0.2	0.1	<	0.002	0.001	<	0.08	0.08		0.04	0.04	
SW-7	23-Sep-93	Hydrometrics	3.71		8.11	0.2	0.2		0.0010	0.0005	<	0.00010	0.0001		0.0010	0.0005	<	0.06	0.06		0.29	0.29		0.002	0.001	<	0.07	0.07		0.016	0.016	
SW-7	25-Aug-94	Hydrometrics	1.69		8.18	0.02	0.02	J	0.0010	0.0005	<	0.00010	0.00005	<	0.0010	0.0005	<	0.007	0.007	J	0.16	0.16	J	0.002	0.001	<	0.027	0.027		0.008	0.004	<
SW-7	13-Jul-95	Hydrometrics	113.48		6.93	0.6	0.6		0.0010	0.0005	<	0.00010	0.0001		0.0030	0.003		0.098	0.098	J	0.97	0.97	J	0.002	0.001	<	0.05	0.05		0.02	0.02	
SW-7	27-Sep-95	Hydrometrics	2.80		5.4	0.1	0.05	<	0.0010	0.0005	<	0.00010	0.00005	<	0.0010	0.0005	<	0.021	0.021		0.17	0.17		0.002	0.001	<	0.03	0.03		0.027	0.0135	<
SW-7	18-Jun-96	Hydrometrics	223.08		8.04	0.5	0.5					0.00020	0.0002					0.087	0.087		1.05	1.05		0.003	0.0015	<	0.046	0.046		0.02	0.02	
SW-7	9-Jul-96	Hydrometrics	97.63		6.84	0.3	0.3	J				0.00010	0.0001					0.096	0.096		0.53	0.53		0.003	0.0015	<	0.038	0.038		0.02	0.02	
SW-7	10-Sep-96	Hydrometrics	2.12		7.36	0.1	0.05	<				0.00010	0.00005	<				0.019	0.019		0.13	0.13		0.003	0.0015	<	0.025	0.025		0.01	0.01	
SW-7	6-May-99	Maxim	6.48		6.32	0.4	0.4					0.00010	0.00005	<				0.008	0.008		0.62	0.62		0.001	0.0005	<	0.036	0.036		0.01	0.005	<
SW-7	8-Jul-99	Maxim	111.83		7.58	0.4	0.4					0.00010	0.0001					0.064	0.064		0.53	0.53		0.001	0.0005	<	0.027	0.027		0.02	0.02	
SW-7	29-Sep-99	Maxim	2.49		6.47	0.1	0.05	<				0.00010	0.00005	<				0.001	0.0005	<	0.42	0.42		0.001	0.0005	<	0.023	0.023		0.03	0.03	J
SW-7	12-Apr-00	Maxim	0.41		7.01	0.05	0.025	<				0.00010	0.00005	<				0.004	0.004		0.43	0.43		0.001	0.0005	<	0.066	0.066		0.05	0.05	
SW-7	9-Jul-00	Maxim	32.25		7.67	0.3	0.3	J				0.00010	0.00005	<				0.072	0.072	J	0.36	0.36	J	0.001	0.0005	<	0.029	0.029	J	0.02	0.02	J
SW-7	9-Oct-00	Maxim	1.81		8.1	0.01	0.005	<				0.00010	0.00005	<				0.001	0.0005	<	0.22	0.22	J	0.003	0.0015	<	0.02	0.01	<	0.01	0.005	<
SW-7	29-Jun-01	Maxim	36.63		7.29	0.2	0.2					0.00080	0.0008					0.12	0.12		0.53	0.53		0.004	0.004	J	0.035	0.035		0.01	0.005	<
SW-7	10-Oct-01	Maxim	1.53		7.63	0.1	0.05	<	0.0030	0.0015	<	0.00010	0.00005	<				0.005	0.005		0.12	0.12		0.001	0.001		0.015	0.015		0.02	0.02	J
SW-7	25-Apr-02	Maxim			6.14	0.1	0.05	<				0.0001	0.00005	<				0.003	0.003		0.26	0.26		0.001	0.0005	<	0.028	0.028		0.01	0.005	<
SW-7	2-Jul-02	Maxim	74.60		7.06	0.3	0.3	J				0.0001	0.00005	<				0.089	0.089		0.49	0.49		0.001	0.0005	<	0.024	0.024		0.02	0.02	J
SW-7	9-Oct-02	Maxim	2.42		7.1	0.1	0.1					0.0001	0.0001					0.019	0.019		0.23	0.23		0.001	0.0005	<	0.038	0.038		0.06	0.06	J
SW-7	21-Apr-03	Maxim			6.43	0.05	0.025	<				0.0001	0.0001					0.007	0.007		0.31	0.31		0.001	0.0005	<	0.018	0.018		0.01	0.01	
SW-7	11-Jul-03	Maxim	39.60		6.58	0.31	0.31					0.0001	0.0001					0.067	0.067		0.27	0.27		0.001	0.0005	<	0.02	0.01	<	0.01	0.005	<
SW-7	29-Sep-03	Maxim	1.42		7.11	0.05	0.025	<				0.0001	0.00005	<				0.005	0.005		0.29	0.29		0.001	0.001		0.023	0.023		0.01	0.01	
SW-7	6-Apr-04	Maxim			7	0.05	0.025	<				0.0001	0.00005	<				0.003	0.003		0.46	0.46		0.001	0.0005	<	0.046	0.046		0.02	0.02	JF%
SW-7	29-Jun-04	Maxim	88.54		7.9	0.2	0.2					0.0001	0.00005	<				0.037	0.037		0.34	0.34		0.001	0.0005	<	0.02	0.02		0.01	0.005	<
SW-7	6-Oct-04	Maxim	7.83		7.13	0.08	0.08					0.0001	0.00005	<				0.02	0.02		0.17	0.17		0.001	0.0005	<	0.038	0.038		0.01	0.005	<
SW-7	4/6/2005	Maxim	1.22		7.26	0.05	0.025	<			--	0.0001	0.00005	<			--	0.001	0.001		0.47	0.47		0.001	0.0005	<	0.037	0.037		0.01	0.01	)
SW-7	6/29/2005	Maxim	81.8		6.5	0.15	0.15				--	0.0001	0.00005	<			--	0.026	0.026		0.2	0.2		0.001	0.0005	<	0.016	0.016		0.01	0.005	<
SW-7	9/27/2005	Maxim	3.18		6.8	0.05	0.025	<			--	0.0001	0.00005	<			--	0.015	0.015		0.18	0.18		0.001	0.0005	<	0.037	0.037		0.04	0.04	
SW-7	25-Apr-06	Maxim	2.04		6.69	0.11	0.11					0.0001	0.00005	<				0.003	0.003		0.49	0.49		0.001	0.0005	<	0.051	0.051		0.01	0.005	<
SW-7	27-Jun-06	Maxim	68.62		6.28	0.14	0.14					0.0001	0.00005	<				0.028	0.028		0.26	0.26		0.001	0.0005	<	0.02	0.02		0.01	0.005	<
SW-7	27-Sep-06	Maxim	1.95		7.55	0.05	0.025	<				0.0001	0.00005	<				0.003	0.003		0.13	0.13		0.001	0.0005	<	0.008	0.008		0.01	0.005	<
SW-7	11-Apr-07	Tt	1.89		6.93	0.05	0.025	<			--	0.0001	0.00005	<			--	0.002	0.002		0.19	0.19		0.001	0.0005	<	0.018	0.018		0.01	0.005	<
SW-7	13-Jun-07	Tt	81		7.3	0.25	0.25				--	0.0001	0.00005	<			--	0.041	0.041		0.31	0.31		0.001	0.0005	<	0.012	0.012		0.01	0.005	<
SW-7	18-Sep-07	Tt	2.51		6.9	0.11	0.11				--	0.0001	0.00005	<			--	0.007	0.007		0.16	0.16		0.001	0.0005	<	0.024	0.024		0.01	0.005	<
SW-7	17-Apr-08	Tt	0.62		3.64	0.05	0.025	<				0.0001	0.00005	<				0.003	0.003		0.16	0.16		0.002	0.002		0.022	0.022		0.01	0.005	<
SW-7	15-Jul-08	Tt	72.1		7.04	0.2	0.2					0.0001	0.00005	<				0.036	0.036		0.3	0.3		0.001	0.0005	<	0.026	0.026		0.01	0.005	<
SW-7	24-Sep-08	Tt	2.58		7.62	0.05	0.025	<				0.0001	0.00005	<				0.009	0.009		0.19	0.19		0.001	0.001	JF%	0.018	0.018		0.01	0.005	<
SW-7	08-Apr-09	Tt		--	6.49	0.0046	0.0046					0.00004	0.00002	<				0.002	0.002		0.19	0.19		0.00005	2.5E-05	<	0.029	0.029		0.0039	0.0039	J
SW-7	24-Jun-09	Tt	101.1		7.17	0.19	0.19					0.00004	0.00002	<				0.029	0.029		0.26	0.26		0.00037	0.00037		0.017	0.017		0.0061	0.0061	
SW-7	28-Sep-09	Tt	0.818		7.05	0.18	0.18					0.000057	5.7E-05	J				0.013	0.013		0.38	0.38		0.00066	0.00066		0.037	0.037		0.0061	0.0061	
SW-7	07-Apr-10	Tt	0.205		6.89	0.037	0.037	JF%				0.00008	0.00004	<				0.0023	0.0023		0.13	0.13		0.0001	0.00005	<	0.029	0.029		0.059	0.059	
SW-7	28-Sep-10	Tt	2.6		7.33	0.048	0.048					0.00008	0.00004	<				0.0068	0.0068		0.19	0.19		0.00043	0.00043		0.028	0.028		0.005	0.0025	<

Notes: mg/l = milligrams/liter; su = standard units
n = number of samples

< = less than detection
J = estimated value

NA - not applicable

TABLE A-2 - STATISTICAL SUMMARY OF WATER QUALITY DATA 1989-2010

New World Mining District Response and Restoration Project

Sample Station	Sample Date	Data Source	Flow (cfs)	Flow Flag	Field pH (su)	Aluminum Total Rec. (mg/l)	Al(calc)	Al Flag	Arsenic Total Rec. (mg/l)	As(calc)	As Flag	Cadmium Total Rec. (mg/l)	Cd(calc)	Cd Flag	Chromium Total Rec. (mg/l)	Cr(calc)	Cr Flag	Copper Total Rec. (mg/l)	Cu(calc)	Cu Flag	Iron Total Rec. (mg/l)	Fe(calc)	Fe Flag	Lead Total Rec. (mg/l)	Pb(calc)	Pb Flag	Manganese Total Rec. (mg/l)	Mn(calc)	Mn Flag	Zinc Total Rec. (mg/l)	Zn(calc)	Zn Flag
Chronic Standard (for Hardness = 50 mg/l)						0.087			0.15			0.00016			0.049			0.0052			1			0.0013			NA			0.067		
Acute Standard (for Hardness = 50 mg/l)						0.75			0.34			0.001			1.02			0.0073			NA			0.034			NA			0.067		
Chronic Standard (for Hardness = 100 mg/l)						0.087			0.15			0.0027			0.086			0.0093			1			0.0032			NA			0.12		
Acute Standard (for Hardness = 100 mg/l)						0.75			0.34			0.0021			1.8			0.0140			NA			0.082			NA			0.12		
Station SW-7: 1989 to 2003 Low Flow (n)			18		20	19			10			19			9			19			19			19			19			19		
Minimum			0.405		5.400	0.005			0.001			0.0001			0.001			0.001			0.100			0.001			0.010			0.004		
Maximum			40.300		8.230	0.400			0.003			0.0005			0.020			0.060			0.620			0.005			0.080			0.060		
Mean			4.851		7.129	0.079			0.002			0.0001			0.007			0.016			0.247			0.001			0.038			0.021		
Standard Deviation (SD)			8.975		0.776	0.089			0.001			0.0001			0.006			0.016			0.129			0.001			0.022			0.018		
Mean + (2 x SD); for pH: Mean - (2 x SD)			22.801		5.577	0.258			0.004			0.0003			0.020			0.048			0.505			0.003			0.082			0.058		
Station SW-7: 1989-2003 High Flow (n)			25		18	19			6			14			7			19			19			14			15			19		
Minimum			10.400		6.580	0.200			0.001			0.0001			0.003			0.030			0.070			0.001			0.010			0.005		
Maximum			223.080		9.580	0.600			0.003			0.0008			0.010			0.210			1.200			0.024			0.070			0.040		
Mean			81.724		7.630	0.398			0.002			0.0002			0.008			0.113			0.725			0.003			0.041			0.024		
Standard Deviation (SD)			52.978		0.830	0.117			0.001			0.0002			0.003			0.047			0.310			0.006			0.016			0.011		
Mean + (2 x SD); for pH: Mean - (2 x SD)			187.681		5.969	0.633			0.004			0.0006			0.014			0.206			1.344			0.016			0.074			0.045		
Station SW-7: 1998 to 2003 All (n)			43		38	38			16			33			16			38			38			33			34			38		
Minimum			0.405		5.400	0.005			0.001			0.0001			0.001			0.001			0.070			0.001			0.010			0.004		
Maximum			223.080		9.580	0.600			0.003			0.0008			0.020			0.210			1.200			0.024			0.080			0.060		
Mean			49.545		7.366	0.239			0.002			0.0001			0.008			0.064			0.486			0.002			0.039			0.022		
Standard Deviation (SD)			55.758		0.831	0.192			0.001			0.0002			0.005			0.060			0.337			0.004			0.019			0.015		
Mean + (2 x SD); for pH: Mean - (2 x SD)			161.060		5.705	0.622			0.004			0.0005			0.018			0.184			1.160			0.010			0.078			0.052		
Station SW-7: 2004 to 2010 Low Flow (n)			12		14	14			0			14			0			14			14			14			14			14		
Minimum			0.205		3.640	0.005						0.00002						0.001			0.130			0.000			0.008			0.003		
Maximum			7.830		7.620	0.180						0.00006						0.020			0.490			0.002			0.051			0.059		
Mean			2.287		6.806	0.053						0.00005						0.006			0.249			0.001			0.030			0.013		
Standard Deviation (SD)			1.966		0.963	0.049						0.00001						0.006			0.135			0.000			0.012			0.017		
Mean + (2 x SD); for pH: Mean - (2 x SD)			6.218		4.879	0.152						0.00006						0.018			0.520			0.002			0.054			0.046		
Station SW-7: 2004-2010 High Flow (n)			6		6	6			0			6			0			6			6			6			6			6		
Minimum			68.620		6.280	0.140						0.00002						0.026			0.200			0.0004			0.012			0.005		
Maximum			101.100		7.900	0.250						0.00005						0.041			0.340			0.0005			0.026			0.006		
Mean			82.193		7.032	0.188						0.00005						0.033			0.278			0.0005			0.019			0.005		
Standard Deviation (SD)			11.708		0.582	0.040						0.00001						0.006			0.049			0.0001			0.005			0.000		
Mean + (2 x SD); for pH: Mean - (2 x SD)			105.610		5.868	0.268						0.00007						0.045			0.377			0.0006			0.028			0.006		
Station SW-7: 2004-2010 All (n)			18		20	20			0			20			0			20			20			20			20			20		
Minimum			0.205		3.640	0.005						0.00002						0.001			0.130			0.0000			0.008			0.003		
Maximum			101.100		7.900	0.250						0.00006						0.041			0.490			0.0020			0.051			0.059		
Mean			28.922		6.874	0.094						0.00005						0.014			0.258			0.0006			0.027			0.010		
Standard Deviation (SD)			39.309		0.858	0.078						0.00001						0.014			0.115			0.0004			0.011			0.014		
Mean + (2 x SD); for pH: Mean - (2 x SD)			107.540		5.158	0.250						0.00007						0.042			0.489			0.0013			0.049			0.039		
Temporary Standard - SW-7					5.5	0.67			NA			NA			NA			0.2			1.32			0.013			0.086			0.049		
SW-2	2-Aug-89	Hydrometrics				0.1	0.05	<				0.001	0.0005	<				0.01	0.005	<	0.03	0.015	<	0.01	0.005	<	0.02	0.01	<	0.01	0.005	<
SW-2	16-Sep-89	Hydrometrics	0.53			0.1	0.05	<				0.001	0.0005	<				0.01	0.01		0.08	0.08		0.01	0.005	<	0.02	0.01	<	0.04	0.04	
SW-2	19-Oct-89	Hydrometrics	0.71		6.98	0.1	0.05	<				0.001	0.0005	<				0.01	0.005	<	0.03	0.015	<	0.01	0.005	<	0.02	0.01	<	0.01	0.005	<
SW-2	6-Jun-90	Hydrometrics	10.9		7.32	0.1	0.05	<				0.0001	0.00005	<				0.026	0.026		0.18	0.18		0.002	0.001	<	0.02	0.01	<	0.02	0.02	
SW-2	7-Jun-90	Hydrometrics	14.7																													
SW-2	13-Jun-90	Hydrometrics	19.52		7.38	0.1	0.05	<										0.02	0.02		0.13	0.13								0.01	0.005	<
SW-2	14-Jun-90	Hydrometrics	13.5																													
SW-2	20-Jun-90	Hydrometrics	30.65		8.52	1.6	1.6											0.25	0.25		4.5	4.5								0.04	0.04	
SW-2	22-Jun-90	Hydrometrics	33.3																													
SW-2	26-Jun-90	Hydrometrics	48.7		9.13	0.9	0.9					0.0004	0.0004					0.132	0.132		1.9	1.9		0.014	0.014		0.09	0.09		0.03	0.03	
SW-2	28-Jun-90	Hydrometrics	43.3																													
SW-2	3-Jul-90	Hydrometrics	44		8.55	0.2	0.2											0.02	0.02		0.49	0.49								0.01	0.005	<
SW-2	5-Jul-90	Hydrometrics	27.3																													
SW-2	10-Jul-90	Hydrometrics	17.7			0.1	0.05	<										0.02	0.01	<	0.05	0.05								0.01	0.005	<
SW-2	11-Jul-90	Hydrometrics	12																													
SW-2	17-Jul-90	Hydrometrics	7.4		8.51	0.1	0.05	<										0.01	0.01		0.06	0.06								0.01	0.005	<
SW-2	19-Jul-90	Hydrometrics	4.4																													
SW-2	27-Jul-90	Hydrometrics	2.5		6.39	0.1	0.05	<				0.0001	0.00005	<				0.007	0.007		0.03	0.015	<	0.002	0.001	<	0.02	0.01	<	0.02	0.01	<
SW-2	23-Aug-90	Hydrometrics	1.6		7.48																											
SW-2	25-Sep-90	Hydrometrics	0.6		6	0.1	0.05	<				0.0001	0.00005	<				0.006	0.006		0.15	0.15		0.002	0.001	<	0.02	0.01	<	0.02	0.02	
SW-2	5-Jun-91	Hydrometrics	38.7		7.3	1.9	1.9					0.0001	0.0001					0.07	0.035	<	3.35	3.35		0.042	0.042		0.15	0.15		0.05	0.05	
SW-2	9-Jul-91	Hydrometrics	9.1		8.55	0.1	0.05	<				0.0001	0.00005	<				0.027	0.027		0.06	0.06		0	0	J2	0.02	0.01	<	0.02	0.02	

Notes: mg/l = milligrams/liter; su = standard units
n = number of samples

< = less than detection
J = estimated value

NA - not applicable

TABLE A-2 - STATISTICAL SUMMARY OF WATER QUALITY DATA 1989-2010

New World Mining District Response and Restoration Project

Sample Station	Sample Date	Data Source	Flow (cfs)	Flow Flag	Field pH (su)	Aluminum Total Rec. (mg/l)	Al(calc)	Al Flag	Arsenic Total Rec. (mg/l)	As(calc)	As Flag	Cadmium Total Rec. (mg/l)	Cd(calc)	Cd Flag	Chromium Total Rec. (mg/l)	Cr(calc)	Cr Flag	Copper Total Rec. (mg/l)	Cu(calc)	Cu Flag	Iron Total Rec. (mg/l)	Fe(calc)	Fe Flag	Lead Total Rec. (mg/l)	Pb(calc)	Pb Flag	Manganese Total Rec. (mg/l)	Mn(calc)	Mn Flag	Zinc Total Rec. (mg/l)	Zn(calc)	Zn Flag
Chronic Standard (for Hardness = 50 mg/l)						0.087			0.15			0.00016			0.049			0.0052			1			0.0013			NA			0.067		
Acute Standard (for Hardness = 50 mg/l)						0.75			0.34			0.001			1.02			0.0073			NA			0.034			NA			0.067		
Chronic Standard (for Hardness = 100 mg/l)						0.087			0.15			0.0027			0.086			0.0093			1			0.0032			NA			0.12		
Acute Standard (for Hardness = 100 mg/l)						0.75			0.34			0.0021			1.8			0.0140			NA			0.082			NA			0.12		
SW-2	13-Aug-91	Hydrometrics	0.7		7.96	0.1	0.05	<				0.0001	0.0001					0.009	0.009		0.05	0.05		0.001	0.0005	<	0.02	0.01	<	0.02	0.02	
SW-2	24-Sep-91	Hydrometrics	0.7		8.26	0.1	0.05	<				0.0002	0.0002					0.007	0.0035	<	0.04	0.04		0.002	0.001	<	0.02	0.01	<	0.01	0.005	<
SW-2	27-May-92	Hydrometrics	30.81		8.02	0.1	0.1					0.0001	0.00005	<				0.029	0.029		0.42	0.42		0.002	0.001	<	0.02	0.02		0.03	0.03	
SW-2	18-Jul-92	Hydrometrics	3.5		8.02	0.1	0.05	<				0.0001	0.00005	<				0.012	0.012		0.05	0.05		0.002	0.001	<	0.02	0.01	<	0.19	0.19	
SW-2	22-Sep-92	Hydrometrics	0.77		7.73	0.1	0.05	<				0.0001	0.00005	<				0.009	0.009		0.04	0.04		0.002	0.001	<	0.02	0.01	<	0.01	0.01	
SW-2	21-Jul-93	Hydrometrics	7.24		8.23	0.1	0.05	<				0.0001	0.0001					0.029	0.029		0.04	0.04		0.002	0.001	<	0.01	0.005	<	0	0	J4
SW-2	23-Sep-93	Hydrometrics	0.43		7.65	0.1	0.05	<				0.0001	0.00005	<				0.006	0.006		0.04	0.04		0.002	0.001	<	0.01	0.005	<	0.008	0.008	
SW-2	16-Jun-94	Hydrometrics	10.03		7.84	0.1	0.05	<				0.0001	0.00005	<				0.017	0.017	J4	0.05	0.05		0.002	0.001	<	0.01	0.005	<	0.01	0.01	J4
SW-2	15-Sep-95	Hydrometrics	0.863		7.5																										
SW-2	26-Sep-95	Hydrometrics	0.71		7.9																										
SW-2	30-Sep-99	Maxim	0.841		7.4	0.1	0.05	<				0.0001	0.00005	<				0.003	0.003		0.05	0.05		0.001	0.0005	<	0.005	0.0025	<	0.03	0.03	JF%
SW-2	14-Apr-00	Maxim	0.288		10.14	0.05	0.025	<				0.0001	0.00005	<				0.01	0.01		0.05	0.025	<	0.001	0.0005	<	0.005	0.0025	<	0.02	0.01	<
SW-2	7-Jul-00	Maxim	9.2		7.95	0.1	0.05	<				0.0001	0.00005	<				0.014	0.014	JF%	0.09	0.09	JF%	0.001	0.0005	<	0.005	0.0025	<	0.01	0.005	<
SW-2	10-Oct-00	Maxim	0.62		8.04	0.1	0.05	<				0.0001	0.00005	<				0.001	0.001		0.13	0.13	JF%	0.003	0.0015	<	0.02	0.01	<	0.01	0.005	<
SW-2	19-Apr-01	Maxim	0.62		6.14	0.1	0.05	<				0.0001	0.00005	<				0.008	0.008		0.04	0.04		0.001	0.0005	<	0.003	0.0015	<	0.01	0.005	<
SW-2	26-Jun-01	Maxim	10.04		7.1	0.1	0.05	<				0.0001	0.00005	<				0.015	0.015		0.07	0.07		0.001	0.0005	<	0.003	0.0015	<	0.01	0.005	<
SW-2	12-Oct-01	Maxim	0.29		8.18	0.1	0.05	<	0.003	0.0015	<	0.001	0.0005	<				0.004	0.004		0.05	0.025	<	0.001	0.0005	<	0.003	0.003		0.08	0.08	
SW-2	24-Apr-02	Maxim	0.27		6.78	0.1	0.05	<				0.0001	0.00005	<				0.006	0.006		0.02	0.02		0.001	0.0005	<	0.003	0.0015	<	0.01	0.005	<
SW-2	2-Jul-02	Maxim	14.8		6.95	0.1	0.05	<				0.0001	0.00005	<				0.017	0.017		0.15	0.15		0.001	0.001		0.003	0.0015	<	0.05	0.05	JF%
SW-2	24-Jul-02	Maxim	2.237		5.53	0.1	0.1					0.0001	0.00005	<				0.011	0.011		0.08	0.08		0.002	0.002		0.003	0.0015	<	0.03	0.03	
SW-2	7-Oct-02	Maxim	0.63		7.5	0.1	0.05	<				0.0001	0.0001					0.006	0.006		0.04	0.04		0.001	0.001		0.004	0.004		0.04	0.04	JF%
SW-2	22-Apr-03	Maxim	0.32		6.26	0.05	0.025	<				0.0001	0.00005	<				0.012	0.012		0.2	0.2		0.001	0.0005	<	0.008	0.008		0.02	0.02	
SW-2	30-Jun-03	Maxim	31.4		7.28	0.28	0.28					0.0001	0.00005	<				0.017	0.017		0.38	0.38		0.004	0.004		0.015	0.015		0.01	0.005	<
SW-2	29-Sep-03	Maxim	0.247		6.03	0.05	0.025	<				0.0001	0.00005	<				0.015	0.015		0.03	0.03		0.004	0.004		0.003	0.0015	<	0.01	0.005	<
SW-2	6-Apr-04	Maxim	0.885		6.64	0.05	0.025	<				0.0001	0.00005	<				0.02	0.02		0.06	0.06		0.001	0.0005	<	0.005	0.0025	<	0.08	0.08	JF%
SW-2	29-Jun-04	Maxim	27.93		7.8	0.26	0.26					0.0001	0.00005	<				0.019	0.019		0.29	0.29		0.002	0.002		0.09	0.09		0.01	0.01	
SW-2	5-Oct-04	Maxim	1.38		7.2	0.05	0.025	<				0.0001	0.00005	<				0.005	0.005	B	0.04	0.04		0.001	0.0005	<	0.003	0.0015	<	0.01	0.005	<
SW-2	6-Apr-05	Maxim	0.15		7.6	0.05	0.025	<				0.0001	0.00005	<				0.005	0.005		0.05	0.05		0.001	0.0005	<	0.006	0.006		0.25	0.25	JF%
SW-2	27-Jun-05	Maxim	31.6		7.3	0.13	0.13					0.0001	0.00005	<				0.02	0.02		0.16	0.16		0.002	0.002		0.009	0.009		0.01	0.01	
SW-2	28-Sep-05	Maxim	0.5		7.57	0.05	0.025	<				0.0001	0.00005	<				0.007	0.007		0.02	0.02		0.001	0.0005	<	0.005	0.005		0.01	0.005	<
SW-2	25-Apr-06	Maxim	0.22		6.96	0.05	0.025	<				0.0001	0.00005	<				0.01	0.01		0.03	0.03		0.001	0.0005	<	0.003	0.0015	<	0.01	0.005	<
SW-2	26-Jun-06	Maxim	15.54		7.32	0.06	0.06					0.0001	0.00005	<				0.014	0.014		0.13	0.13		0.001	0.0005	<	0.014	0.014		0.01	0.005	<
SW-2	25-Sep-06	Maxim	0.73		7.45	0.05	0.025	<				0.0001	0.00005	<				0.006	0.006		0.05	0.05		0.001	0.0005	<	0.003	0.0015	<	0.01	0.005	<
SW-2	11-Apr-07	Tt	0.681		6.93	0.05	0.025	<			--	0.0001	0.00005	<			--	0.008	0.008		0.05	0.05		0.001	0.0005	<	0.004	0.004		0.01	0.005	<
SW-2	14-Jun-07	Tt	26.1		8	0.11	0.11				--	0.0001	0.00005	<			--	0.017	0.017		0.2	0.2	B	0.001	0.0005	<	0.003	0.0015	<	0.01	0.005	<
SW-2	19-Sep-07	Tt	0.634		6.9	0.05	0.025	<			--	0.0001	0.00005	<			--	0.004	0.004		0.06	0.06		0.001	0.0005	<	0.003	0.0015	<	0.01	0.005	<
SW-2	15-Apr-08	Tt	0.201		7.35	0.05	0.025	<				0.0001	0.00005	<				0.01	0.01		0.07	0.07		0.001	0.0005	<	0.004	0.004		0.01	0.005	<
SW-2	16-Jul-08	Tt	23.9		7.14	0.05	0.025	<				0.0001	0.00005	<				0.015	0.015		0.06	0.06		0.001	0.0005	<	0.003	0.0015	<	0.01	0.005	<
SW-2	23-Sep-08	Tt	0.762		7.09	0.05	0.025	<				0.0003	0.0003					0.006	0.006		0.03	0.03		0.001	0.001	JF%	0.003	0.003		0.01	0.005	<
SW-2	08-Apr-09	Tt	0.161		7.14	0.055	0.055					0.000043	4.3E-05	J				0.016	0.016		0.25	0.25		0.00067	0.00067		0.0087	0.0087		0.0078	0.0078	
SW-2	22-Jun-09	Tt	35.2		5.77	0.12	0.12					0.00004	0.00002	<				0.018	0.018		0.14	0.14		0.00092	0.00092		0.0065	0.0065		0.0063	0.0063	
SW-2	29-Sep-09	Tt	0.16		5.13	0.062	0.062					0.00004	0.00002	<				0.0051	0.0051		0.054	0.054		0.00021	0.00021		0.0033	0.0033		0.0025	0.00125	<
SW-2	05-Apr-10	Tt	0.0838		7.68	0.028	0.028	JF%				0.00008	0.00004	<				0.0051	0.0051		0.05	0.025	<	0.0001	0.00005	<	0.0038	0.0038		0.03	0.03	
SW-2	27-Sep-10	Tt	0.597		7.84	0.022	0.022					0.00008	0.00004	<				0.006	0.006		0.05	0.025	<	0.0001	0.00005	<	0.0026	0.0026		0.005	0.0025	<

Notes: mg/l = milligrams/liter; su = standard units
n = number of samples

< = less than detection
J = estimated value

NA - not applicable

TABLE A-2 - STATISTICAL SUMMARY OF WATER QUALITY DATA 1989-2010

New World Mining District Response and Restoration Project

Sample Station	Sample Date	Data Source	Flow (cfs)	Flow Flag	Field pH (su)	Aluminum Total Rec. (mg/l)	Al(calc)	Al Flag	Arsenic Total Rec. (mg/l)	As(calc)	As Flag	Cadmium Total Rec. (mg/l)	Cd(calc)	Cd Flag	Chromium Total Rec. (mg/l)	Cr(calc)	Cr Flag	Copper Total Rec. (mg/l)	Cu(calc)	Cu Flag	Iron Total Rec. (mg/l)	Fe(calc)	Fe Flag	Lead Total Rec. (mg/l)	Pb(calc)	Pb Flag	Manganese Total Rec. (mg/l)	Mn(calc)	Mn Flag	Zinc Total Rec. (mg/l)	Zn(calc)	Zn Flag
Chronic Standard (for Hardness = 50 mg/l)						0.087			0.15			0.00016			0.049			0.0052			1			0.0013			NA			0.067		
Acute Standard (for Hardness = 50 mg/l)						0.75			0.34			0.001			1.02			0.0073			NA			0.034			NA			0.067		
Chronic Standard (for Hardness = 100 mg/l)						0.087			0.15			0.0027			0.086			0.0093			1			0.0032			NA			0.12		
Acute Standard (for Hardness = 100 mg/l)						0.75			0.34			0.0021			1.8			0.0140			NA			0.082			NA			0.12		
Station SW-2: 1989 to 2010 Low Flow (n)			34		33	32			1			32			0			32			32			32			32			32		
Minimum			0.084		5.130	0.022						0.00002						0.001			0.015			0.000			0.002			0.001		
Maximum			30.810		10.140	0.100						0.00050						0.029			0.420			0.005			0.020			0.250		
Mean			1.462		7.316	0.040			0.002			0.00012						0.008			0.070			0.001			0.006			0.024		
Standard Deviation (SD)			5.196		0.873	0.017						0.00015						0.006			0.083			0.001			0.004			0.046		
Mean + (2 x SD); for pH: Mean - (2 x SD)			11.854		5.569	0.075						0.00043						0.019			0.236			0.004			0.014			0.115		
Station SW-2: 1989-2010 High Flow (n)			31		23	24			0			19			0			24			24			19			19			24		
Minimum			2.237		5.530	0.025						0.00002						0.007			0.015			0.000			0.002			0.000		
Maximum			48.700		9.130	1.900						0.00040						0.250			4.500			0.042			0.150			0.190		
Mean			20.206		7.560	0.262						0.00007						0.032			0.526			0.004			0.023			0.022		
Standard Deviation (SD)			13.426		0.884	0.494						0.00008						0.052			1.125			0.010			0.041			0.039		
Mean + (2 x SD); for pH: Mean - (2 x SD)			47.059		5.791	1.249						0.00023						0.137			2.777			0.023			0.104			0.099		
Station SW-2: 1998 to 2010 All (n)			65		56	56			1			51			0			56			56			51			51			56		
Minimum			0.084		5.130	0.022						0.0000						0.001			0.015			0.000			0.002			0.000		
Maximum			48.700		10.140	1.900						0.0005						0.250			4.500			0.042			0.150			0.250		
Mean			10.401		7.416	0.135			0.002			0.0001						0.018			0.265			0.002			0.012			0.023		
Standard Deviation (SD)			13.691		0.878	0.338						0.0001						0.036			0.765			0.006			0.026			0.043		
Mean + (2 x SD); for pH: Mean - (2 x SD)			37.783		5.660	0.812						0.0004						0.091			1.795			0.014			0.064			0.108		
Chronic Aquatic Standard - SW-2 (hardness 100)						0.087			0.15			0.00027			0.086			0.009			1			0.0032			NA			0.12		
SW-5	15-Sep-89	Hydrometrics	0.44			0.1	0.05	<				0.001	0.0005	<				0.01	0.005	<	0.03	0.015	<	0.01	0.005	<	0.02	0.01	<	0.03	0.03	
SW-5	20-Oct-89	Hydrometrics	0.47		6.29	0.1	0.05	<				0.001	0.0005	<				0.01	0.005	<	0.03	0.015	<	0.01	0.005	<	0.02	0.01	<	0.01	0.005	<
SW-5	29-May-90	Hydrometrics	14.34		7.04	0.2	0.2					0.0001	0.00005	<				0.019	0.019		0.34	0.34		0.003	0.003		0.02	0.01	<	0.02	0.02	
SW-5	6-Jun-90	Hydrometrics	19.93		7.16	0.1	0.05	<										0.01	0.01		0.16	0.16								0.01	0.01	
SW-5	12-Jun-90	Hydrometrics	29.84		7.65	0.1	0.1											0.01	0.01		0.3	0.3								0.09	0.09	
SW-5	14-Jun-90	Hydrometrics	23.6																													
SW-5	20-Jun-90	Hydrometrics	41.26		8.33	1.3	1.3											0.2	0.2		3	3								0.03	0.03	
SW-5	26-Jun-90	Hydrometrics	90		8.75	1.4	1.4					0.0004	0.0004					0.153	0.153		3.22	3.22		0.022	0.022		0.13	0.13		0.04	0.04	
SW-5	29-Jun-90	Hydrometrics	80																													
SW-5	2-Jul-90	Hydrometrics	55.5		9.24	0.1	0.05	<										0.01	0.005	<	0.07	0.07								0.01	0.005	<
SW-5	4-Jul-90	Hydrometrics	34.4																													
SW-5	9-Jul-90	Hydrometrics	18.2			0.1	0.05	<										0.01	0.005	<	0.09	0.09								0.02	0.02	
SW-5	11-Jul-90	Hydrometrics	14																													
SW-5	17-Jul-90	Hydrometrics	6.7		7.97	0.1	0.05	<										0.01	0.005	<	0.05	0.05								0.02	0.02	
SW-5	19-Jul-90	Hydrometrics	5.1																													
SW-5	27-Jul-90	Hydrometrics	2.9		6.36	0.1	0.05	<				0.0001	0.00005	<				0.004	0.004		0.08	0.08		0.002	0.001	<	0.02	0.01	<	0.04	0.02	<
SW-5	23-Aug-90	Hydrometrics	2.2		7.81																											
SW-5	25-Sep-90	Hydrometrics	0.7		6	0.1	0.05	<				0.0001	0.00005	<				0.003	0.003		0.03	0.015	<	0.002	0.001	<	0.02	0.01	<	0.46	0.46	
SW-5	5-Jun-91	Hydrometrics	50.6		7.64	1.8	1.8					0.0004	0.0004					0.09	0.045	<	3.12	3.12		0.003	0.003		0.11	0.11		0.01	0.01	
SW-5	9-Jul-91	Hydrometrics	11.1		8.37	0.1	0.05	<				0.0001	0.00005	<				0.021	0.021		0.06	0.06		0	0	J2	0.02	0.01	<	0.02	0.02	
SW-5	13-Aug-91	Hydrometrics	0.7		8.27	0.1	0.05	<				0.0001	0.00005	<				0.001	0.001	J4	0.05	0.05		0.002	0.001	<	0.02	0.01	<	0.06	0.06	
SW-5	24-Sep-91	Hydrometrics	0.5		8.41	0.1	0.1					0.0001	0.00005	<				0.006	0.003	<	0.05	0.05		0.002	0.002		0.02	0.01	<	0.01	0.01	
SW-5	27-May-92	Hydrometrics	38.13		8.1	0.2	0.2					0.0001	0.00005	<				0.029	0.029		0.54	0.54		0.002	0.001	<	0.02	0.02		0.02	0.02	
SW-5	18-Jul-92	Hydrometrics	5.5		7.55	0.1	0.05	<				0.0001	0.00005	<				0.006	0.006		0.07	0.07		0.002	0.001	<	0.02	0.01	<	0.13	0.13	
SW-5	23-Sep-92	Hydrometrics	0.63		8.14	0.1	0.05	<				0.0001	0.00005	<				0.004	0.004		0.06	0.06		0.002	0.001	<	0.02	0.01	<	0.01	0.005	<
SW-5	21-Jul-93	Hydrometrics	7.62		7.43	0.1	0.05	<				0.0001	0.00005	<				0.009	0.009		0.03	0.015	<	0.002	0.001	<	0.01	0.005	<	0.006	0.006	J4
SW-5	23-Sep-93	Hydrometrics	0.53		8.24	0.1	0.05	<				0.0001	0.00005	<				0.005	0.005		0.03	0.015	<	0.002	0.001	<	0.01	0.005	<	0.008	0.008	
SW-5	16-Jun-94	Hydrometrics	9.4		7.37	0.1	0.05	<				0.0001	0.00005	<				0.002	0.002	J4	0.04	0.04		0.002	0.001	<	0.01	0.005	<	0.008	0.008	J4
SW-5	15-Sep-95	Hydrometrics	0.546		7.3																											
SW-5	26-Sep-95	Hydrometrics	0.34		8.1																											
SW-5	7-Jul-99	Maxim	22.33		7.95	0.1	0.1					0.0001	0.00005	<				0.014	0.014		0.13	0.13		0.001	0.001		0.005	0.0025	<	0.01	0.01	
SW-5	24-Jul-02	Maxim	1.403		5.45	0.1	0.05	<				0.0009	0.0009					0.006	0.006		0.06	0.06		0.001	0.001		0.003	0.0015	<	0.04	0.04	
SW-5	22-Apr-03	Maxim	0.14		6.44	0.05	0.025	<				0.0001	0.00005	<				0.004	0.004		0.16	0.16		0.001	0.0005	<	0.008	0.008		0.01	0.005	<
SW-5	30-Jun-03	Maxim	21		7.27	0.21	0.21					0.0001	0.00005	<				0.014	0.014		0.32	0.32		0.003	0.003		0.01	0.01		0.01	0.005	<
SW-5	6-Apr-04	Maxim	0.327		7.32	0.05	0.025	<				0.0001	0.00005	<				0.006	0.006		0.02	0.02		0.001	0.0005	<	0.005	0.0025	<	0.07	0.07	JF%
SW-5	29-Jun-04	Maxim	20.68		8.1	0.18	0.18					0.0001	0.00005	<				0.013	0.013		0.21	0.21		0.001	0.001		0.004	0.004		0.02	0.02	
SW-5	5-Oct-04	Maxim	0.37		7.2	0.05	0.025	<				0.0001	0.00005	<				0.001	0.0005	<	0.01	0.005	<	0.001	0.0005	<	0.003	0.0015	<	0.01	0.005	<
SW-5	27-Jun-05	Maxim	17.83		6.9	0.12	0.12					0.0001	0.00005	<				0.016	0.016		0.21	0.21		0.001	0.001		0.006	0.006		0.01	0.005	<
SW-5	28-Sep-05	Maxim	0.08		7.6	0.05	0.025	<				0.0001	0.00005	<				0.004	0.004		0.01	0.005	<	0.001	0.0005	<	0.004	0.004		0.01	0.01	
SW-5	26-Jun-06	Maxim	8.56		6.81	0.05	0.025	<				0.0001	0.00005	<				0.01	0.01		0.1	0.1	B	0.001	0.0005	<	0.005	0.005		0.01	0.005	<
SW-5	11-Apr-07	Tt	0.002		7.04	0.05	0.025	<			--	0.0001	0.00005	<			--	0.004	0.004		0.05	0.05	J	0.001	0.0005	<	0.003	0.0015	<	0.01	0.005	<
SW-5	14-Jun-07	Tt		--	8	0.07	0.07				--	0.0001	0.00005	<			--	0.013	0.013		0.08	0.08		0.001	0.0005	<	0.003	0.0015	<	0.01	0.005	<

Notes: mg/l = milligrams/liter; su = standard units
n = number of samples

< = less than detection
J = estimated value

NA - not applicable

TABLE A-2 - STATISTICAL SUMMARY OF WATER QUALITY DATA 1989-2010

New World Mining District Response and Restoration Project

Sample Station	Sample Date	Data Source	Flow (cfs)	Flow Flag	Field pH (su)	Aluminum Total Rec. (mg/l)	Al(calc)	Al Flag	Arsenic Total Rec. (mg/l)	As(calc)	As Flag	Cadmium Total Rec. (mg/l)	Cd(calc)	Cd Flag	Chromium Total Rec. (mg/l)	Cr(calc)	Cr Flag	Copper Total Rec. (mg/l)	Cu(calc)	Cu Flag	Iron Total Rec. (mg/l)	Fe(calc)	Fe Flag	Lead Total Rec. (mg/l)	Pb(calc)	Pb Flag	Manganese Total Rec. (mg/l)	Mn(calc)	Mn Flag	Zinc Total Rec. (mg/l)	Zn(calc)	Zn Flag
Chronic Standard (for Hardness = 50 mg/l)						0.087			0.15			0.00016			0.049			0.0052			1			0.0013			NA			0.067		
Acute Standard (for Hardness = 50 mg/l)						0.75			0.34			0.001			1.02			0.0073			NA			0.034			NA			0.067		
Chronic Standard (for Hardness = 100 mg/l)						0.087			0.15			0.0027			0.086			0.0093			1			0.0032			NA			0.12		
Acute Standard (for Hardness = 100 mg/l)						0.75			0.34			0.0021			1.8			0.0140			NA			0.082			NA			0.12		
SW-5	19-Sep-07	Tt	0.0695		8.11	0.05	0.025	<			--	0.0001	0.00005	<			--	0.002	0.002		0.01	0.005	<	0.001	0.0005	<	0.003	0.0015	<	0.01	0.005	<
SW-5	15-Apr-08	Tt	0.0022		7.05	0.05	0.025	<				0.0001	0.00005	<				0.003	0.003		0.01	0.005	<	0.001	0.0005	<	0.01	0.01		0.01	0.005	<
SW-5	16-Jul-08	Tt		--	6.7	0.05	0.025	<				0.0001	0.00005	<				0.011	0.011		0.09	0.09		0.001	0.0005	<	0.003	0.0015	<	0.01	0.005	<
SW-5	23-Sep-08	Tt	0.425		7.78	0.05	0.025	<				0.0001	0.00005	<				0.002	0.002		0.01	0.005	<	0.001	0.001	JF%	0.003	0.0015	<	0.01	0.005	<
SW-5	08-Apr-09	Tt	0.027	V	8.05	0.014	0.014					0.00004	0.00002	<				0.0024	0.0024		0.025	0.0125	<	0.00005	2.5E-05	<	0.00038	0.00038	J	0.0059	0.0059	
SW-5	22-Jun-09	Tt		--	7.82	0.19	0.19					0.00004	0.00002	<				0.017	0.017		0.31	0.31		0.0014	0.0014		0.0089	0.0089		0.0069	0.0069	
SW-5	29-Sep-09	Tt	0.26		7.7	0.029	0.029					0.00004	0.00002	<				0.0031	0.0031		0.025	0.0125	<	0.000051	5.1E-05	J	0.00085	0.00085		0.0025	0.00125	<
SW-5	05-Apr-10	Tt		Flow				--						--						--			--			--			--			--
SW-5	28-Sep-10	Tt	0.0043		7.57	0.062	0.062					0.00008	0.00004	<				0.0064	0.0064		0.11	0.11		0.00067	0.00067		0.0044	0.0044		0.0069	0.0069	
Station SW-5: 1989 to 2010 Low Flow (n)			23		22	20			0			20			0			20			20			20			20			20		
Minimum			0.002		6.000	0.014						0.0000						0.001			0.005			0.000			0.000			0.001		
Maximum			38.130		8.410	0.200						0.0005						0.029			0.540			0.005			0.020			0.460		
Mean			2.662		7.525	0.055						0.0001						0.006			0.075			0.001			0.007			0.037		
Standard Deviation (SD)			8.270		0.677	0.053						0.0001						0.007			0.135			0.001			0.005			0.101		
Mean + (2 x SD); for pH: Mean - (2 x SD)			19.202		6.172	0.162						0.0004						0.019			0.345			0.004			0.017			0.240		
Station SW-5: 1989-2010 High Flow (n)			24		21	22			0			16			0			22			22			16			16			22		
Minimum			1.403		5.450	0.025						0.0000						0.002			0.015			0.000			0.002			0.005		
Maximum			90.000		9.240	1.800						0.0009						0.200			3.220			0.022			0.130			0.130		
Mean			24.894		7.563	0.274						0.0001						0.027			0.536			0.002			0.020			0.023		
Standard Deviation (SD)			23.466		0.846	0.508						0.0002						0.050			1.053			0.005			0.039			0.031		
Mean + (2 x SD); for pH: Mean - (2 x SD)			71.826		5.872	1.290						0.0006						0.126			2.641			0.013			0.099			0.085		
Station SW-5: 1998 to 2010 All (n)			47		43	42			0			36			0			42			42			36			36			42		
Minimum			0.002		5.450	0.014						0.0000						0.001			0.005			0.000			0.000			0.001		
Maximum			90.000		9.240	1.800						0.0009						0.200			3.220			0.022			0.130			0.460		
Mean			14.015		7.544	0.170						0.0001						0.017			0.316			0.002			0.013			0.030		
Standard Deviation (SD)			20.838		0.755	0.382						0.0002						0.037			0.794			0.004			0.027			0.073		
Mean + (2 x SD); for pH: Mean - (2 x SD)			55.691		6.034	0.933						0.0005						0.092			1.904			0.009			0.066			0.175		
Chronic Aquatic Standard - SW-5 (hardness 100)						**0.087**			**0.15**			**0.00027**			**0.086**			**0.009**			**1**			**0.0032**			**NA**			**0.12**		

Notes: mg/l = milligrams/liter; su = standard units
n = number of samples

< = less than detection
J = estimated value

NA - not applicable

Table A-3
Water Quality and Flow at Daisy Creek Adit Discharge Monitoring Stations
New World Mining District Response and Restoration Project
Adit Discharge EECA

Station Name	Sample Date	Flow (gpm)	Field pH (su)	Hardness (mg/L CaCO3)	Sulfate (mg/l)	Concentration (Total Recoverable in Milligrams Per Liter)						
						Aluminum	Cadmium	Copper	Iron	Lead	Manganese	Zinc
D-18	9/13/1989	1.8	3.41		268							
D-18	7/13/1990	25.1	6.82		246	0.2	0.001	0.01	13.8		0.91	0.09
D-18	7/25/1990	20.2		353	280							
D-18	8/1/1990	22.4	6.49	370	311	*0.1*	*0.001*	*0.01*	17.5	*0.01*	0.86	0.03
D-18	8/22/1990	18.0		393	324	*0.1*	*0.001*	*0.01*	17.3	*0.01*	0.88	0.03
D-18	9/6/1990	9.0		386	324	0.4	*0.001*	*0.01*	22.3	*0.01*	0.9	0.05
D-18	9/25/1990	6.7	5.5	423	350	*0.1*	*0.0001*	0.002	19.2	*0.002*	0.93	0.06
D-18	7/10/1991	18.0	7.1	276	214	0.9	0.0049	0.08	14.7		0.86	0.05
D-18	9/25/1991	6.7	7.02	414	336	0.2	0.0017	0.018	14.6	*0.002*	0.94	0.03
D-18	7/20/1995	20.2	5.9	230	180	1.3	0.0005	0.078	14.4	0.006	0.62	0.028
D-18	9/26/1995	5.6	5.4		349	0.2	0.0008	*0.011*	24	*0.002*	1.07	*0.028*
D-18	7/10/1996	18.0	5.43	252	158	0.3	0.0004	0.045	9.8	*0.003*	0.534	0.02
D-18	8/15/1996	15.0										
D-18	9/10/1996	6.7	6.36	358	333	0.2	0.0009	0.005	38	*0.003*	1.14	0.04
D-18	10/5/1996				333	*0.234*	*0.002*	*0.007*	27.6	0.002	1.06	0.0313
D-18	10/5/1996	3.1	5.7		339	0.1	0.0006	0.003	27	*0.003*	1.1	0.02
D-18	7/6/2001	8.1	6.59	314	264	0.2	0.0017	0.026	20.8	*0.001*	1.04	0.01
D-18	7/2/2002	29.6	6.48	249	149	0.1	0.0001	0.017	6.69	0.001	0.49	0.02
D-18	9/26/2002	6.9	6.6	385	299	*0.1*	0.0003	*0.001*	7.39	*0.001*	1	0.02
D-18	10/7/2002	5.4	7.08	354	288	0.2	0.0004	0.033	14.7	0.002	0.096	0.08
D-18	7/28/2003	10.0	5.4	338	332	4.95	0.0005	0.14	8.35	*0.001*	0.92	0.09
D-18	8/7/2003	7.0	6.8	348	302	0.2	*0.0001*	0.03	3.64	0.002	0.6	*0.01*
D-18	10/1/2003	3.6	6.77	449	379	0.1	*0.0001*	0.025	19.1	*0.001*	0.96	0.05
D-18	7/29/2004	7.3	6.7									
D-18	8/10/2004	7.6	6.65									
D-18	9/23/2004	4.7	6.5	404	363	0.08	*0.0001*	0.018	20	*0.001*	0.97	0.01
D-18	9/23/2005	4.9	6.2									
D-18	8/28/2006	6.3	5.8									
D-18	8/20/2007	4.488	6.73	424	389	0.7	*0.0001*	0.044	34	0.004	1.24	0.09
D-18	9/18/2007	4.80216	6.28	436	395	0.17	*0.0001*	0.02	29.3	*0.001*	1.13	0.08
D-18	9/23/2008	5.96904	5.9	430	421	0.32	*0.0001*	0.027	30.3	0.001	1.18	0.09
Total number of samples	31	30	26	21	26	24	24	24	24	22	24	24
Number of high flow samples	10	10	9	8	9	8	8	8	8	6	8	8
Total number of samples after plugging inflow to McLaren Adit (September, 2003)	9	9	9	5	5	5	5	5	5	5	5	5

gpm = gallons per minute
s.u. = standard units
mg/l CaCO3 = milligrams per liter as calcium carbonate
mg/l = milligrams per liter
Italices indicate analyte was below detection limit or flow rates that were estimated as equal to or less than the displayed value.

Table A-4
Water Quality and Flow at Fisher Creek Adit Discharge Monitoring Stations
New World Mining District Response and Restoration Project
Adit Discharge EECA

Station Name	Sample Date	Flow (gpm)	Field pH (su)	Hardness (mg/L CaCO3)	Sulfate (mg/l)	Concentration (Total Recoverable in Milligrams Per Liter)						
						Aluminum	Cadmium	Copper	Iron	Lead	Manganese	Zinc
F-8A	18-Sep-89	67.3	2.84	217	392	7.9	*0.001*	1.24	45.6	0.02	4.1	0.32
F-8A	13-Jul-90	85.3	3.16		447	13.4	*0.001*	6.81	79.7	0.02	4.18	0.51
F-8A	13-Jul-90	85.3	3.16		447	13.5	*0.001*	6.89	80.6		4.24	0.52
F-8A	07-Aug-90	76.3										
F-8A	07-Aug-90	76.3	3.51	174	397	9.3	*0.001*	4.3	57	0.05	3.92	0.41
F-8A	23-Aug-90	65.1	3.68	206	445							
F-8A	06-Sep-90	44.9		206	394	7.9	*0.001*	2.37	51.1	0.03	4.16	0.34
F-8A	25-Sep-90	58.3	4	215	391	7.7	0.0016	1.42	46.6	0.022	4.04	0.39
F-8A	05-Jun-91	219.9	2.72	23	71	1.8	0.0002	1.01	12.4	0.004	0.41	0.08
F-8A	09-Jul-91	44.9	2.59	162	426	12	0.0015	5.1	71.7	0.017	4	0.43
F-8A	14-Aug-91	44.9	2.9	216	423	9.1	0.0012	2.76	60	0.016	4.6	0.42
F-8A	24-Sep-91	38.6	3.01	213	379	7.8	0.0036	0.84	47.1	0.007	3.69	0.29
F-8A	08-Jul-93	35.9										
F-8A	13-Jul-93	53.9										
F-8A	14-Jul-93	58.3										
F-8A	15-Jul-93	58.3										
F-8A	19-Jul-93	58.3										
F-8A	20-Jul-93	62.8	2.91	182	520	15.9	0.003	8.66	92.1	0.03	5.39	0.78
F-8A	27-Jul-93	62.8										
F-8A	04-Aug-93	62.8										
F-8A	17-Aug-93	62.8										
F-8A	26-Aug-93	58.3										
F-8A	01-Sep-93	44.9		214	448							
F-8A	10-Sep-93	44.9										
F-8A	16-Sep-93	53.9										
F-8A	21-Sep-93	53.9										
F-8A	21-Sep-93	56.1	3.1	221	433	9.3	0.0022	2.35	67.8	0.028	5.97	0.34
F-8A	26-May-94	0.0	4.11		14	1.6	0.0003	0.84	0.62	0.002	0.09	0.03
F-8A	14-Jun-94	49.4	2.89		359	7.7	0.0011	1.85	56.9	0.019	4.19	0.346
F-8A	30-Aug-94	44.9	3.45	208	367	8.3	0.0013	1.36	46.7	0.03	4.44	0.258
F-8A	28-Jun-95	58.3	4		357	10.3	0.0004	3.61	54.2	0.006	3.69	0.346
F-8A	12-Jul-95	112.2	3.17		497	17.8	0.0038	9.09	68.1	0.018	6.19	0.895
F-8A	12-Jul-95	112.2	3.17		511	17.5	0.0039	9.11	68.9	0.018	6.27	0.908
F-8A	26-Sep-95	53.9	3.1		456	11.4	0.0014	3.35	59.7	0.028	5.29	0.494
F-8A	26-Sep-95	53.9	3.1		470	11.3	0.0016	3.33	59.7	0.029	5.28	0.491
F-8A	21-May-96	19.7	2.34	206	336	5.6	0.0008	0.316	29.7	0.025	3.5	0.28
F-8A	29-May-96	19.7	2.98	186	290	5.2	0.0008	0.28	28.4	0.022	3.32	0.29
F-8A	05-Jun-96	19.7	2.96	181	327	5.7	0.0008	0.495	30	0.022	3.4	0.3
F-8A	12-Jun-96	53.9	2.09	107	274			1.86	43.1			0.24
F-8A	20-Jun-96	25.1	2.73	145	352	9.3	0.0015	2.32	49	0.017	3.81	0.41
F-8A	20-Jun-96	25.1	2.73	146	350	9.79	0.005	2.61	55	0.023	4.12	0.45
F-8A	26-Jun-96	80.8	3.44	96	199			1.48	29.5			0.23
F-8A	02-Jul-96	112.2	3.29	107	229			2.46	41.4			0.37
F-8A	12-Jul-96	49.4	3.87	145	333	11.6	0.0012	4.53	56.3	0.015	4.35	0.58
F-8A	18-Jul-96	31.9	2.92		540			6.73	76.6			0.76
F-8A	25-Jul-96	53.9	2.84		262			7.4	84.1			0.81
F-8A	21-Aug-96	41.3	2.62		437			3.78	59.9			0.52
F-8A	11-Sep-96	53.9	2.99	197	403	10.1	0.0016	2.48	54.2	0.029	4.86	0.43
F-8A	08-Oct-96	0.0			396							
F-8A	08-Oct-96	27.8	3.05		364	7.8	0.0015	1.11	41.8	0.028	3.94	0.3
F-8A	08-Jul-97	143.2			1200			0.01				
F-8A	08-Jul-97	123.4			1200			0.519				
F-8A	27-Mar-98	24.7	1.77		490	6.95		0.19	37.6		3.84	0.289
F-8A	23-Apr-98	16.6	3.09		460	6.92		0.231	39.7		4.06	0.299
F-8A	05-May-98	14.8	4.03		640	6.84		0.262	36.7		3.88	0.284
F-8A	13-May-98	0.0	5		14	6.04		0.386	35.2		3.63	0.269
F-8A	29-May-98	60.6	2.85		450	5.98		0.643	35.5		3.15	0.255
F-8A	08-Jul-00	57.0										

Table A-4 (continued)
Water Quality and Flow at Fisher Creek Adit Discharge Monitoring Stations
New World Mining District Response and Restoration Project
Adit Discharge EECA

Station Name	Sample Date	Flow (gpm)	Field pH (su)	Hardness (mg/L CaCO3)	Sulfate (mg/l)	Concentration (Total Recoverable in Milligrams Per Liter)						
						Aluminum	Cadmium	Copper	Iron	Lead	Manganese	Zinc
F-8A	21-Aug-00	6.7	3.1		390	7.5	0.0014	2.22	48	0.028	4.29	0.43
F-8A	21-Aug-00	6.7	3.1									
F-8A	27-Aug-00	4.0	3.1									
F-8A	28-Aug-00	3.6	3									
F-8A	29-Aug-00	4.0	2.9									
F-8A	30-Aug-00	4.0	3									
F-8A	12-Sep-00	5.6	3.3									
F-8A	24-Sep-00	7.4	3.06									
F-8A	01-Oct-00	35.0	3.29									
F-8A	12-Oct-00	0.0	3.2									
F-8A	13-Oct-00	0.0	3.18									
F-8A	01-Jul-03	40.4	2.37	168	450	15	0.0018	6.9	77.6	0.022	6.12	0.63
F-8A	01-Oct-03	48.0	3.43	208	332	4.79	0.0012	0.73	55.5	0.026	4.25	0.35
F-8A	17-Jun-04	49.4		214	380	6.32	0.001	1.82	30.6	0.02	3.95	0.34
F-8A	28-Jun-04	51.2	3.7									
F-8A	29-Jul-04	62.8	2.79	262	446	10	0.0017	4.66	47.4	0.022	5.01	0.6
F-8A	06-Oct-04	22.4	10.16									
F-8A	22-Nov-04	13.0	7.52	110	164	0.94	0.0007	0.23	5.07	0.01	2	0.19
F-8A	11-Oct-05	2.1		170	199	0.43	0.0004	0.3	8.16	0.005	0.59	0.11
F-8A	27-Oct-05	2.1										
F-8A	28-Jun-06	0.4	6.37	167	138	0.07	*0.0001*	0.038	2.32	*0.001*	0.29	0.03
F-8A	12-Jun-07	0.0	6.9	131	96	1.01	0.0003	0.39	23.6	0.005	0.63	0.09
Total number of samples	80	80	58	31	53	42	37	50	48	36	42	48
Number of high flow samples	33	33	23	15	25	18	18	25	23	17	18	23
F-8B	9/18/1989	26.9	3.4		103							
F-8B	8/7/1990	0.8	3.52		98		*0.001*	0.11	7.45		1	0.12
F-8B	8/9/1993	1.0	3.85	38.8	77		*0.00257*	0.121	14.2	0.00245	1.02	0.127
F-8B	8/18/1996	5.0										
F-8B	7/1/2003	3.0	3.1	23	54	0.32	0.0001	0.24	6.46	0.001	0.66	0.05
F-8B	7/29/2004	5.0	3.3									
F-8B	8/20/2007	1.1	3.56	44	91	0.31	0.0002	0.097	41	0.002	1.13	0.13
F-8B	9/17/2007	1.8	3.41	44	88	0.19	0.0001	0.07	7.46	*0.001*	1.1	0.11
F-8B	8/15/2008	3.1		84	118	0.34	0.0002	0.045	19	0.002	1.07	0.13
Total number of samples	9	9	7	5	7	4	6	6	6	5	6	6
Number of high flow samples	2	2	2	1	1	1	1	1	1	1	1	1
FCSI-96-5	8/18/1996	5.0										
FCSI-96-5	7/5/2001	1.8	6.8	99	49	*0.1*	0.0002	0.004	0.12	0.001	0.074	0.04
FCSI-96-5	7/16/2003	0.6	7.1	102	58	*0.05*	0.0001	0.003	0.15	*0.003*	0.12	0.02
FCSI-96-5	7/28/2004	4.0	6.3									
FCSI-96-5	9/22/2004	1.4	6.1	95	51	*0.05*	0.0001	0.003	0.21	0.001	0.13	0.02
FCSI-96-5	8/20/2007	1.8	6.76	99	45	0.29	0.0003	0.008	0.62	0.003	0.27	0.06
FCSI-96-5	9/17/2007	0.3	6.74	99	45	0.16	0.0002	0.005	0.43	0.003	0.2	0.04
FCSI-96-5	9/22/2008	1.5	5.91	98	48	*0.05*	0.0001	0.002	0.17	0.001	0.11	0.04
Total number of samples	8	8	7	6	6	6	6	6	6	6	6	6
Number of high flow samples	3	3	3	2	2	2	2	2	2	2	2	2
FCSI-99-1	8/5/1999	10.0	7.5									
FCSI-99-1	7/5/2001	0.4	6.92	31	17	0.4	0.0002	0.035	1.01	0.015	0.069	0.05
FCSI-99-1	7/23/2002	0.5	5.46	45	21	*0.1*	0.0009	0.01	0.06	0.004	*0.003*	0.07
FCSI-99-1	7/15/2003	2.0	6.17	24	16	*0.05*	*0.0001*	0.005	0.19	0.007	*0.02*	*0.01*
FCSI-99-1	7/28/2004	4.0	6.1									
FCSI-99-1	8/20/2007	0.04	8.29	151	66	1.36	0.0014	0.21	7.15	0.3	0.29	0.22
FCSI-99-1	9/17/2007	0.003	7.26	187	82	0.11	0.0002	0.013	0.43	0.009	0.026	0.04
Total number of samples	7	7	7	5	5	5	5	5	5	5	5	5
Number of high flow samples	4	4	4	3	3	3	3	3	3	3	3	3
AE-17	8/8/1990	0	6.87	79	32	*0.1*	*0.001*	0.01	0.67	*0.01*	0.12	0.04
AE-17	8/9/1993	0	6.81	75.8	72		*0.00257*	0.0234	1.61	0.00568	0.102	0.0366
AE-17	8/6/1999		7.3									
AE-17	7/7/2001	0										
AE-17	7/23/2002	0.1	6.41	94	35	*0.1*	0.001	0.013	0.87	*0.001*	0.08	0.11
AE-17	7/15/2003	5.0	6.65	68	29	0.11	0.0001	0.022	1.54	*0.003*	0.08	0.05
AE-17	7/27/2004	2.0	6.2									
Total number of samples	7	6	6	4	4	3	4	4	4	4	4	4
Number of high flow samples	4	4	3	2	2	2	2	2	2	2	2	2

Table A-4 (continued)
Water Quality and Flow at Fisher Creek Adit Discharge Monitoring Stations
New World Mining District Response and Restoration Project
Adit Discharge EECA

Station Name	Sample Date	Flow (gpm)	Field pH (su)	Hardness (mg/L CaCO3)	Sulfate (mg/l)	Concentration (Total Recoverable in Milligrams Per Liter)						
						Aluminum	Cadmium	Copper	Iron	Lead	Manganese	Zinc
F-28	9/20/1989	1.3	7.17		258	*0.1*						
F-28	8/8/1990	4.0	7.31	284	214		*0.001*	*0.01*	0.52	*0.01*	0.02	0.02
F-28	8/23/1990	1.3		283	219	*0.1*						
F-28	9/6/1990	4.5	7.08	341	240	*0.1*	*0.001*	*0.01*	0.28	*0.01*	0.07	*0.03*
F-28	9/25/1990	1.8	5	381	259	*0.1*	*0.0001*	0.002	0.31	*0.002*	0.07	0.06
F-28	7/10/1991	11.2	7.79	236	181	0.1	*0.0001*	0.009	0.34		0.05	0.04
F-28	8/14/1991			414	301	1.6	0.0002	0.008	1.2	*0.002*	0.2	0.04
F-28	9/26/1991	1.8	7.76	431	304	0.1	0.0018	0.108	33.4	0.014	5.76	0.3
F-28	3/2/1992			557	396	0.4	*0.0001*	0.006	1.99	0.004	0.78	0.02
F-28	3/16/1992			577	424	0.4	0.0004	0.03	16.7	0.02	1.19	0.1
F-28	3/27/1992			592	466	1	*0.0001*	0.02	4.11	0.008	0.72	0.03
F-28	3/29/1992			558	412	*0.1*	*0.0002*	0.03	7.99	0.015	0.91	0.06
F-28	4/21/1992	5.8		545	441		0.0001	0.009	1.06	0.003	0.56	0.04
F-28	5/20/1992	13.5		481	304							
F-28	7/22/1992			438	348							
F-28	7/23/1992	13.5										
F-28	8/9/1993	42.6	7.35	381	282		0.00257	0.00653	144	0.00217	0.0557	0.0111
F-28	6/16/1994	26.9	7.24									
F-28	7/14/1995	18.0	6.88		163	*0.1*	0.0001	*0.003*	0.78	0.015	0.04	*0.021*
F-28	9/26/1995	13.5	6.7		376	*0.1*	*0.0001*	*0.003*	0.78	*0.002*	0.07	*0.007*
F-28	8/17/1996	15.0										
F-28	9/12/1996	9.4	6.23	477	351	*0.1*	*0.0001*	*0.001*	0.09	*0.003*	0.04	*0.02*
F-28	7/8/1997	29.2			270	0.206	*0.005*	*0.01*	2.23	*0.003*	0.152	*0.02*
F-28	8/10/1999	15.0										
F-28	7/11/2001	31.4	7.54	595	451	*0.1*	*0.0001*	0.004	0.35	*0.001*	0.073	0.01
F-28	6/30/2002	26.0	7.12	378	233	*0.1*	*0.0001*	0.002	0.18	*0.001*	0.029	0.01
F-28	7/23/2002	9.0	6.3	683	405	*0.1*	0.0009	0.002	0.21	0.001	0.054	0.01
F-28	10/8/2002	4.9	7.38	759	591	*0.1*	0.0003	*0.001*	0.19	*0.001*	0.004	0.03
F-28	7/1/2003	246.9	6.75	376	275	0.06	*0.0001*	0.002	0.26	*0.001*	0.047	*0.01*
F-28	8/14/2003	12.0	7.5	640	469	*0.05*	*0.0001*	0.002	0.38	*0.001*	0.08	*0.01*
F-28	9/30/2003	14.8	7.49	660	484	*0.05*	*0.0001*	0.012	0.23	*0.001*	0.085	*0.01*
F-28	7/29/2004	20.5	7.62	507	371	*0.05*	*0.0001*	0.005	0.2	0.001	0.065	0.05
F-28	9/16/2004	19.7	7.47	668	497	*0.05*	*0.0001*	0.003	0.13	*0.001*	0.082	0.05
F-28	8/15/2005	32.8	7.5	634	460	0.06	*0.0001*	0.002	0.64	0.002	0.18	0.05
F-28	9/22/2005	3.4	7.7	334	282	0.06	*0.0001*	*0.001*	*0.01*	*0.001*		*0.01*
F-28	10/11/2005	4.0										
F-28	10/27/2005	4.1										
F-28	6/28/2006	18.9	6.12	181	142	0.35	*0.0001*	0.01	2.64	0.005	0.25	0.03
F-28	9/26/2006	3.6	6.77	416	323	0.06	*0.0001*	*0.001*	0.62	0.001	0.13	0.04
F-28	6/12/2007	24.2	6.6	64	145	*0.05*	*0.0001*	0.002	0.45	*0.001*	0.03	*0.01*
F-28	8/20/2007	4.5	7.59	388	266	0.08	*0.0001*	0.003	0.42	0.002	0.093	0.02
F-28	9/17/2007	3.9	7.14	411	289	*0.05*	*0.0001*	0.002	0.22	*0.001*	0.079	*0.01*
F-28	9/22/2008	4.4	6.87	423	313	0.05	*0.0001*	0.002	0.37	0.001	0.092	0.02
Total number of samples	43	37	28	33	37	32	33	33	33	32	32	33
Number of high flow samples	12	11	9	8	10	9	9	9	9	8	9	9

gpm = gallons per minute
s.u. = standard units
mg/l CaCO3 = milligrams per liter as calcium carbonate
mg/l = milligrams per liter
Italices indicate analyte was below detection limit or flow rates that were estimated as equal to or less than the displayed value.

Table A-5

Station Name	Sample Date	Flow (gpm)	Field pH (su)	Hardness (mg/L CaCO3)	Sulfate (mg/l)	Concentration (Total Recoverable in Milligrams Per Liter)						
						Aluminum	Cadmium	Copper	Iron	Lead	Manganese	Zinc
M-1	8/31/1989	5.4	6.1	630	541	*0.1*	*0.001*	0.02	33.7	0.08	3.05	0.33
M-1	9/14/1989	179.5	5.85									
M-1	7/17/1990	12.1			291	*0.1*		*0.01*	1.11			0.03
M-1	7/25/1990	14.8		522	297							
M-1	8/8/1990	9.0	6.41	584	382	*0.1*	*0.001*	*0.01*	7.24	*0.01*	1.5	0.11
M-1	8/22/1990	16.2		562	368							
M-1	9/6/1990	7.2		573	390	*0.1*	*0.001*	*0.01*	6.68	*0.01*	1.57	0.11
M-1	7/11/1991		7.19	215	156	0.2	0.0009	*0.016*	2.1		1.02	0.26
M-1	9/26/1991	0.5	7.27	461	264	0.2	0.0005	0.033	4.13	0.039	0.54	0.06
M-1	7/22/1993		6.84	452	254	*0.1*	0.0003	0.035	1.13	0.02	0.9	0.08
M-1	9/24/1993	3.5										
M-1	6/16/1994	1.6	6.99									
M-1	8/15/1996	10.0										
M-1	8/20/1996	10.0	6.6									
M-1	9/14/1996	5.0	6.99									
M-1	10/12/1996		6.99									
M-1	7/6/2001	1.8	6.97	417	201	0.1	*0.0001*	0.013	1.05	0.047	0.18	*0.01*
M-1	7/16/2003	7.9	7.18	424	246	0.06	0.0001	0.008	0.58	0.015	0.42	0.01
M-1	7/21/2004	20.0										
M-1	9/23/2004	2.9	6.8	618	464	*0.05*	0.0004	0.002	4	0.001	2.53	0.14
M-1	7/12/2005		7.02	313	7							
M-1	8/20/2007	6.3	6.52	633	425	0.33	0.0004	0.051	13.4	0.15	2.42	0.18
M-1	9/18/2007	5.5	7.35	624	393	*0.05*	0.0001	0.004	3.53	0.001	1.52	0.06
M-1	9/23/2008	8.9	6.79	629	452	*0.05*	0.0003	*0.001*	13.6	0.001	2.24	0.15
Total number of samples	24	20	17	15	16	13	12	13	13	11	12	13
Number of high flow samples	9	6	6	6	7	5	4	5	5	3	4	5
M-25	9/1/1989	1.8	7.01									
M-25	8/9/1990	4.5	5.6	12	20	0.2	*0.001*	0.56	*0.03*	*0.01*	*0.02*	0.1
M-25	7/31/1997	25.0										
M-25	8/20/1997	25.0										
M-25	9/14/1997	15.0										
M-25	10/7/1997	12.0										
M-25	7/10/2003	2.0	4.51	8	18	0.59	0.0001	0.29	*0.05*	0.011	*0.02*	*0.01*
M-25	7/21/2004	5.0	5.9									
M-25	8/20/2007	0.04	7.05	54	39	0.15	0.0013	0.46	0.34	0.051	0.024	0.17
Total number of samples	9	9	5	3	3	3	3	3	3	3	3	3
Number of high flow samples	3	3	2	1	1	1	1	1	1	1	1	1

Table A-5 (continued)

Station Name	Sample Date	Flow (gpm)	Field pH (su)	Hardness (mg/L CaCO3)	Sulfate (mg/l)	Concentration (Total Recoverable in Milligrams Per Liter)						
						Aluminum	Cadmium	Copper	Iron	Lead	Manganese	Zinc
M-8	8/9/1993	2.0	7.22	127	25		*0.00257*	0.0234	1.32	0.0898	0.065	0.43
M-8	7/31/1996	2.5	7.67									
M-8	8/14/1996	10.0										
M-8	8/20/1996	0.5	8.22									
M-8	9/14/1996	0.1	8.01									
M-8	10/12/1996	0.7	7.81									
M-8	11/9/1996	0.5										
M-8	7/17/1997	2.1										
M-8	7/31/1997	5.9										
M-8	8/20/1997	2.9										
M-8	9/14/1997	2.9										
M-8	10/7/1997	0.4										
M-8	8/4/1999	10.0										
M-8	7/11/2001	0.1	7.49	142	43	*0.1*	0.002	0.015	0.55	0.066	0.023	0.42
M-8	7/16/2003	7.9	7.42	106	23	*0.05*	0.001	0.002	0.04	0.006	*0.02*	0.24
M-8	7/21/2004	10.0	7.2									
M-8	9/23/2004	8.1	7.0	147	27	*0.05*	0.0005	*0.001*	0.02	0.001	*0.003*	0.1
M-8	8/20/2007	0.08976	7.54	170	50	16.3	0.0047	0.041	19.8	0.2	0.54	1.21
M-8	9/18/2007	0.26928	7.14	201	66	57.9	0.011	0.16	83.5	1.36	2.06	2.96
Total number of samples	19	19	11	6	6	5	6	6	6	6	6	6
Number of high flow samples	6	6	4	2	2	2	2	2	2	2	2	2
MCSI-96-3	8/9/1993	*1.0*										
MCSI-96-3	8/14/1996	0.5										
MCSI-96-3	8/4/1999	*1.0*										
MCSI-96-3	7/16/2003	2.0	7.57	61	12	*0.05*	0.0004	*0.001*	0.02	*0.003*	*0.02*	0.11
MCSI-96-3	7/21/2004	2.0	6.5									
MCSI-96-3	8/20/2007	0.04488	6.46	90	30	10.4	0.0046	0.03	19.1	0.61	0.88	0.96
MCSI-96-3	9/18/2007	0.26928	5.93	99	33	9.5	0.0093	0.03	16.4	0.36	3.64	1.48
Total number of samples	7	7	4	3	3	3	3	3	3	3	3	3
Number of high flow samples	2	2	2	1	1	1	1	1	1	1	1	1

gpm = gallons per minute
s.u. = standard units
mg/l CaCO3 = milligrams per liter as calcium carbonate
mg/l = milligrams per liter
Italices indicate analyte was below detection limit or flow rates that were estimated as equal to or less than the displayed value.

Table A-6
Water Quality and Flow From McLaren Pit Cap Sub-Grade Drains
New World Mining District Response and Restoration Project
Adit Discharge EECA

Station Name	Sample Date	Flow (gpm)	Field pH (su)	Field SC (uS/cm)	Hardness (mg/L CaCO3)	Sulfate (mg/l)	Concentration (Total Recoverable in Milligrams Per Liter)						
							Aluminum	Cadmium	Copper	Iron	Lead	Manganese	Zinc
DCSW-101	7/13/2004	19.5	2.6	1120	125	628	29.3	0.01	15.8	117	0.012	3.08	1.7
DCSW-101	8/10/2004	15.8	2.28	1372	125	560	26	0.0094	13.5	106	0.009	2.91	1.59
DCSW-101	10/6/2004	5.6	2.92	1240	176	686	34.3	0.016	20.7	173	0.007	5.1	2.82
DCSW-101	6/29/2005	24.6	2.7	1259	142	736	33.7	0.011	15.8	147	0.014	2.81	1.85
DCSW-101	9/27/2005	3.3	2.73	1415	185	748	31.5	0.012	14.2	199	0.01	3.64	2.09
DCSW-101	6/27/2006	20.6	4.36	1198	114	515	26.1	0.0082	13.5	105	0.012	2.74	1.50
DCSW-101	9/27/2006	2.2	2.93	1374	175	797	29	0.01	13.2	178	0.005	3.41	1.87
DCSW-101	7/18/2007	16.6	2.8	1021	104	450	23.3	0.0069	9.91	92	0.007	2.38	1.29
DCSW-101	9/18/2007	3.9	3.04	1134	155	607	25.4	0.01	12.6	133	0.006	3.34	1.77
DCSW-101	7/15/2008	26.0	2.64	1225	122	555	25.5	0.0074	10.5	94	0.016	2.28	1.32
DCSW-101	9/24/2008	6.5	2.74	1299	144	612	27	0.0084	11.3	142	0.008	2.86	1.44
DCSW-101	7/6/2009	18.8	2.51	2870	104	548	22.5	0.0061	9.4	89	0.012	2.10	1.20
DCSW-101	9/28/2009	2.3	2.95	1093	141	552	23	0.0082	9.6	109	0.005	2.80	1.50
DCSW-101	9/28/2010	3.4	3.05	1073	140	674	24.3	0.0091	11.2	121	0.005	3.00	1.60
DCSW-102	7/13/2004	10.5	2.4	1540	186	862	33.5	0.017	19	142	0.002	4.62	2.69
DCSW-102	8/10/2004	5.8	2.39	1765	155	641	23.2	0.011	13.8	90	0.001	3.47	1.95
DCSW-102	10/6/2004	0.3	2.54	1900	275	1160	39.1	0.017	27.7	265	0.002	6.31	3.18
DCSW-102	6/29/2005	18.8	2.5	1874	240	1030	42.2	0.029	19.6	187	0.005	6.22	4.29
DCSW-102	9/27/2005	0.0	2.55	1613	234	791	24.8	0.016	15.9	146	0.009	4.69	2.33
DCSW-102	6/27/2006	14.8	4.17	1833	192	771	32.5	0.015	19	135	0.002	4.76	2.66
DCSW-102	9/27/2006	0.04	2.69	1537	220	876	24.2	0.012	14.2	116	0.002	4.04	1.97
DCSW-102	6/13/2007	23.3	2.8	1733	244	875	31.4	0.019	16.4	163	0.004	4.88	3.49
DCSW-102	7/18/2007	4.9	2.59	1522	162	595	24.3	0.011	13.3	96.3	0.001	3.54	1.98
DCSW-102	9/18/2007	0.0	2.65	1704	235	828	27.1	0.012	16.2	132	0.002	4.38	2.13
DCSW-102	7/15/2008	15.3	2.36	1814	218	852	34.4	0.02	15.2	115	0.003	5.22	3.32
DCSW-102	9/24/2008	0.0	2.5	1444	172	651	22.2	0.01	13.0	101	0.001	3.51	1.74
DCSW-102	7/6/2009	12.1	2.74	1709	197	833	26	0.01	13.9	108	0.0024	4.2	2.4
DCSW-102	9/28/2009	0.0	2.79	1560	215	748	24	0.01	13.2	100	0.0016	3.8	1.9
DCSW-102	9/28/2010	0.0	2.76	1513	198	852	24.2	0.012	14.8	108	0.0017	4.3	2
DCSW-103	7/13/2004	2.4	2.3	3700	723	2920	108	0.026	44.6	632	0.002	13.3	4.24
DCSW-103	8/10/2004	1.7	2.53	3349	591	2220	88.1	0.026	34.8	363	0.002	12.5	4.29
DCSW-103	10/6/2004	0.8	2.52	3040	745	2550	110	0.023	46.1	505	0.002	16.7	4.84
DCSW-103	6/29/2005	1.8	2.4	3530	750	3050	122	0.032	47.3	678	0.004	14.2	5.25
DCSW-103	9/27/2005	0.3	2.42	2897	642	1910	76.6	0.028	31	352	0.003	11.8	4.33
DCSW-103	6/27/2006	1.8	4.13	3264	619	2210	81.1	0.024	36	434	0.002	13.1	4.44
DCSW-103	9/27/2006	0.9	2.62	2711	688	1980	77.3	0.022	29	315	0.002	12.5	4.07
DCSW-103	7/18/2007	1.3	2.44	2674	570	1760	76.1	0.022	30	316	0.003	10.7	4.07
DCSW-103	9/18/2007	0.7	2.59	2940	686	2220	87.9	0.023	30	374	0.004	12.7	4.09
DCSW-103	7/15/2008	1.3	2.19	3160	553	2080	89.9	0.023	29	347	0.002	9.95	3.92
DCSW-103	9/24/2008	0.9	2.31	2750	523	1740	66.1	0.02	25	270	0.003	10.7	3.73
DCSW-103	7/6/2009	1.2	2.79	3050	445	1880	62.2	0.017	24	266	0.002	8.7	3.2
DCSW-103	9/28/2009	0.4	2.52	2821	573	1830	71.1	0.019	23	254	0.002	12.0	3.6
DCSW-103	9/28/2010	0.4	2.64	2749	590	2090	64.1	0.02	25	293	0.002	12.5	4.1

gpm = gallons per minute
s.u. = standard units
mg/l CaCO3 = milligrams per liter as calcium carbonate
mg/l = milligrams per liter

APPENDIX B

HUMAN HEALTH RISK EVALUATION CALCULATIONS

Adit Discharge Response Action EE/CA
New World Mining District Response and Restoration Project

Hazard Index Calculations for Adit Discharges

Adit Name	Flow (gpm)	Field ph (su)	Cadmium			Copper			Lead	
			Concen-tration (mg/l)	Ingestion Dose	Dermal Dose	Concen-tration (mg/l)	Ingestion Dose	Dermal Dose	Concen-tration (mg/l)	Ingestion Dose
D-18 -- McLaren Mine	11.5	6.2	0.0008	1.56556E-06	2.34834E-08	0.026	5.08806E-05	1.14481E-06	0.002	3.91389E-06
McLaren Pit Drains	21.7	2.6	0.014	2.73973E-05	4.10959E-07	17.7	0.034637965	0.000779354	0.007	1.36986E-05
F-8B --Glengarry Millsite Adit	7	3.4	0.0006	1.17417E-06	1.76125E-08	0.16	0.000313112	7.04501E-06	0.002	3.91389E-06
Lower Tredennic	2.6	6.6	0.0001	1.95695E-07	2.93542E-09	0.003	5.87084E-06	1.32094E-07	0.002	3.91389E-06
Sheep Mt. # 1	3.4	6.4	0.0004	7.82779E-07	1.17417E-08	0.017	3.32681E-05	7.48532E-07	0.009	1.76125E-05
AE-17 -- Henderson Mt. Dump # 7	1.2	6.7	0.0007	1.36986E-06	2.05479E-08	0.017	3.32681E-05	7.48532E-07	0.003	5.87084E-06
F-28 --Gold Dust Adit	3.63	6.8	0.00005	9.78474E-08	1.46771E-09	0.0005	9.78474E-07	2.20157E-08	0.001	1.95695E-06
M-1 --Little Daisy Adit	18.1	6.8	0.0004	7.82779E-07	1.17417E-08	0.013	2.54403E-05	5.72407E-07	0.026	5.08806E-05
M-25 -- Henderson Mountain	11.3	5.8	0.0003	5.87084E-07	8.80626E-09	0.43	0.000841487	1.89335E-05	0.008	1.56556E-05
M-8 -- Black Warrior Adit	3.9	7.6	0.0012	2.34834E-06	3.5225E-08	0.01	1.95695E-05	4.40313E-07	0.041	8.02348E-05
MCSI-96-3 Upper Miller Ck Dump	1.3	7	0.0004	7.82779E-07	1.17417E-08	0.0005 <	9.78474E-07	2.20157E-08	0.0015 <	2.93542E-06

Notes: Concentrations are total recoverable mean concentrations (milligrams per liter);
< indicates the mean value was less than detection for all samples; mean concentration is listed as half the detection limit)

	Value	***Variable***		
		Cw =	concentration in micrograms per liter	
(ingestion)	0.001	CF =	conversion factor	0.000001 (dermal)
	1	IR =	ingestion rate in liters/day	
	50	EF =	exposure frequency (days/year)	
	30	ED =	exposure duration (years)	
	70	BW =	body weight (kg)	
	10950	AT =	Average time for pathway-specific exposure period (days)	
	2500	SA =	surface area of skin (square centimeters)	
	6	ET =	exposure time (hours/day)	
		PC=	chemical specific dermal permeability constant	

Ingestion Formula: (Cw*CF*IR*EF*ED)/(BW*AT)
Dermal Formula: (Cw*SA*PC*CF*ET*EF*ED)/(BW*AT)
HQ Formula: Dose/Reference Dose
HI Formula: Sum of Ingestion and Dermal HQ

	PC Values	***Reference Dose (mg/kg/day)***
Cadmium	0.001	0.0005
Copper	0.0015	0.037
Lead	0.000004	0.00043
Manganese	0.0015	0.005
Zinc	0.000004	0.3

Recalculated Hazard Index

Adit Name	Flow (gpm)	Field ph (su)	Cadmium			Copper			Lead	
			Concen-tration (mg/l)	Ingestion Dose	Dermal Dose	Concen-tration (mg/l)	Ingestion Dose	Dermal Dose	Concen-tration (mg/l)	Ingestion Dose
McLaren Pit Drains	21.7	2.6	0.014	1.36986E-06	4.10959E-07	17.7	0.001731898	0.000779354	0.007	6.84932E-07

Notes: Assumptions for the following variables changed:

0.25	IR =	ingestion rate in liters/day
10	EF =	exposure frequency (days/year)

Hazard Index Calculations for

Adit Name	Lead	Manganese			Zinc			Hazard Quotient (Ingestion)		
	Dermal Dose	Concen-tration (mg/l)	Ingestion Dose	Dermal Dose	Concen-tration (mg/l)	Ingestion Dose	Dermal Dose	Cadmium	Copper	Lead
D-18 -- McLaren Mine	2.34834E-10	0.85	0.001663405	3.74266E-05	0.04	7.82779E-05	4.69667E-09	3.13E-03	1.38E-03	9.10E-03
McLaren Pit Drains	8.21918E-10	4.5	0.008806262	0.000198141	2.3	0.004500978	2.70059E-07	5.48E-02	9.36E-01	3.19E-02
F-8B --Glengarry Millsite Adit	2.34834E-10	0.89	0.001741683	3.91879E-05	0.1	0.000195695	1.17417E-08	2.35E-03	8.46E-03	9.10E-03
Lower Tredennic	2.34834E-10	0.11	0.000215264	4.84344E-06	0.03	5.87084E-05	3.5225E-09	3.91E-04	1.59E-04	9.10E-03
Sheep Mt. # 1	1.05675E-09	0.03	5.87084E-05	1.32094E-06	0.04	7.82779E-05	4.69667E-09	1.57E-03	8.99E-04	4.10E-02
AE-17 -- Henderson Mt. Dump # 7	3.5225E-10	0.1	0.000195695	4.40313E-06	0.06	0.000117417	7.04501E-09	2.74E-03	8.99E-04	1.37E-02
F-28 --Gold Dust Adit	1.17417E-10	0.13	0.000254403	5.72407E-06	0.04	7.82779E-05	4.69667E-09	1.96E-04	2.64E-05	4.55E-03
M-1 --Little Daisy Adit	3.05284E-09	1.3	0.002544031	5.72407E-05	0.11	0.000215264	1.29159E-08	1.57E-03	6.88E-04	1.18E-01
M-25 -- Henderson Mountain	9.39335E-10	0.01 <	1.95695E-05	4.40313E-07	0.06	0.000117417	7.04501E-09	1.17E-03	2.27E-02	3.64E-02
M-8 -- Black Warrior Adit	4.81409E-09	0.03	5.87084E-05	1.32094E-06	0.3	0.000587084	3.5225E-08	4.70E-03	5.29E-04	1.87E-01
MCSI-96-3 Upper Miller Ck Dump	1.76125E-10	0.01 <	1.95695E-05	4.40313E-07	0.11	0.000215264	1.29159E-08	1.57E-03	2.64E-05	6.83E-03

Notes: Concentrations are total recoverable mean concentrations (milligrams per liter);
< indicates the mean value was less than detection for all samples; mean concentration is listed as half the detection limit)

	Value	***Variable***
		Cw = concentration in micrograms per liter
(ingestion)	0.001	CF = conversion factor 0.000001 (dermal)
	1	IR = ingestion rate in liters/day
	50	EF = exposure frequency (days/year)
	30	ED = exposure duration (years)
	70	BW = body weight (kg)
	10950	AT = Average time for pathway-specific exposure period (days)
	2500	SA = surface area of skin (square centimeters)
	6	ET = exposure time (hours/day)
		PC= chemical specific dermal permeability constant

Ingestion Formula: (Cw*CF*IR*EF*ED)/(BW*AT)
Dermal Formula: (Cw*SA*PC*CF*ET*EF*ED)/(BW*AT)
HQ Formula: Dose/Reference Dose
HI Formula: Sum of Ingestion and Dermal HQ

	PC Values	***Reference Dose (mg/kg/day)***
Cadmium	0.001	0.0005
Copper	0.0015	0.037
Lead	0.000004	0.00043
Manganese	0.0015	0.005
Zinc	0.000004	0.3

Recalculated Hazard Index

Adit Name	Lead	Manganese			Zinc			Hazard Quotient (Ingestion)		
	Dermal Dose	Concen-tration (mg/l)	Ingestion Dose	Dermal Dose	Concen-tration (mg/l)	Ingestion Dose	Dermal Dose	Cadmium	Copper	Lead
McLaren Pit Drains	8.21918E-10	4.5	0.000440313	0.000198141	2.3	0.000225049	2.70059E-07	2.74E-03	4.68E-02	1.59E-03

Notes: Assumptions for the following variables changed:

0.25	IR =
10	EF =

Hazard Index Calculations for

Adit Name	Hazard Quotient (Ingestion)			Hazard Quotient (Dermal)						Hazard Index
	Manganese	Zinc	Sum	Cadmium	Copper	Lead	Manganese	Zinc	Sum	
D-18 -- McLaren Mine	3.33E-01	2.61E-04	0.3466	4.70E-05	3.09E-05	5.46E-07	7.49E-03	1.57E-08	0.00756	0.35411
McLaren Pit Drains	1.76E+00	1.50E-02	2.7991	8.22E-04	2.11E-02	1.91E-06	3.96E-02	9.00E-07	0.06152	2.86059
F-8B --Glengarry Millsite Adit	3.48E-01	6.52E-04	0.3689	3.52E-05	1.90E-04	5.46E-07	7.84E-03	3.91E-08	0.00806	0.37697
Lower Tredennic	4.31E-02	1.96E-04	0.0529	5.87E-06	3.57E-06	5.46E-07	9.69E-04	1.17E-08	0.00098	0.05388
Sheep Mt. # 1	1.17E-02	2.61E-04	0.0554	2.35E-05	2.02E-05	2.46E-06	2.64E-04	1.57E-08	0.00031	0.05574
AE-17 -- Henderson Mt. Dump # 7	3.91E-02	3.91E-04	0.0568	4.11E-05	2.02E-05	8.19E-07	8.81E-04	2.35E-08	0.00094	0.05777
F-28 --Gold Dust Adit	5.09E-02	2.61E-04	0.0559	2.94E-06	5.95E-07	2.73E-07	1.14E-03	1.57E-08	0.00115	0.05706
M-1 --Little Daisy Adit	5.09E-01	7.18E-04	0.6301	2.35E-05	1.55E-05	7.10E-06	1.14E-02	4.31E-08	0.01149	0.64160
M-25 -- Henderson Mountain	3.91E-03	3.91E-04	0.0646	1.76E-05	5.12E-04	2.18E-06	8.81E-05	2.35E-08	0.00062	0.06525
M-8 -- Black Warrior Adit	1.17E-02	1.96E-03	0.2055	7.05E-05	1.19E-05	1.12E-05	2.64E-04	1.17E-07	0.00036	0.20587
MCSI-96-3 Upper Miller Ck Dump	3.91E-03	7.18E-04	0.0131	2.35E-05	5.95E-07	4.10E-07	8.81E-05	4.31E-08	0.00011	0.01316

Notes: Concentrations are total recoverable mean concentrations (milligrams per liter);
< indicates the mean value was less than detection for all samples; mean concentration is listed as half the detection limit)

	Value	***Variable***	
		Cw =	concentration in micrograms per liter
(ingestion)	0.001	CF =	conversion factor 0.000001 (dermal)
	1	IR =	ingestion rate in liters/day
	50	EF =	exposure frequency (days/year)
	30	ED =	exposure duration (years)
	70	BW =	body weight (kg)
	10950	AT =	Average time for pathway-specific exposure period (days)
	2500	SA =	surface area of skin (square centimeters)
	6	ET =	exposure time (hours/day)
		PC=	chemical specific dermal permeability constant

Ingestion Formula: (Cw*CF*IR*EF*ED)/(BW*AT)
Dermal Formula: (Cw*SA*PC*CF*ET*EF*ED)/(BW*AT)
HQ Formula: Dose/Reference Dose
HI Formula: Sum of Ingestion and Dermal HQ

	PC Values	***Reference Dose (mg/kg/day)***
Cadmium	0.001	0.0005
Copper	0.0015	0.037
Lead	0.000004	0.00043
Manganese	0.0015	0.005
Zinc	0.000004	0.3

Recalculated Hazard Index

Adit Name	Hazard Quotient (Ingestion)			Hazard Quotient (Dermal)						Hazard Index
	Manganese	Zinc	Sum	Cadmium	Copper	Lead	Manganese	Zinc	Sum	
McLaren Pit Drains	8.81E-02	7.50E-04	1.40E-01	8.22E-04	2.11E-02	1.91E-06	3.96E-02	9.00E-07	6.15E-02	0.20147

Notes: Assumptions for the following variables changed:

0.25	IR =
10	EF =

APPENDIX C

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

Adit Discharge Response Action EE/CA
New World Mining District Response and Restoration Project

Identification of Applicable or Relevant and Appropriate Requirements
Adit Discharge 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 Adit Discharge 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
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

Identification of Applicable or Relevant and Appropriate Requirements
Adit Discharge Response Action

Standard, Requirement Criteria Or Limitation	Citation	Description	ARAR Status
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
Regulations Establishing Ambient Surface Water Quality Standard	ARM 17.30.601 et seq.	Provides the water use classification for various streams and imposes specific water quality standards per classification.	Applicable
	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 17.30.1006	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 Adit Discharge Response Action			
Standard, Requirement Criteria Or Limitation	**Citation**	**Description**	**ARAR Status**
STATE CONTAMINANT-SPECIFIC (continued)			
Clean Air Act Of Montana	75-2-101, 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	Applicable

Identification of Applicable or Relevant and Appropriate Requirements Adit Discharge Response Action			
Standard, Requirement Criteria Or Limitation	**Citation**	**Description**	**ARAR Status**
		specified levels.	
STATE LOCATION-SPECIFIC			
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
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.	Relevant and Appropriate
	ARM 17.30.1203 and 1344	Technology-based treatment for MPDES permits.	Relevant and Appropriate
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 17.8.1401-1404	Sets forth emission standards for hazardous air pollutants	Applicable

Applicable or Relevant and Appropriate Requirements (ARARs)

Section 300.415(i) of the National Contingency Plan (NCP) and guidance issued by the EPA require that removal actions attain Applicable or Relevant and Appropriate Requirements (ARARs) under federal or state environmental laws or facility siting laws, to the extent practicable considering the urgency of the situation and the scope of the removal (EPA, 1993). In addition to ARARs, the lead Agency may identify other federal or state advisories, criteria, or guidance to be considered for a particular release. ARARs were identified in the Como Basin/Glengarry Adit/Fisher Creek Response Action EE/CA.

ARARs are either applicable or relevant and appropriate. Applicable requirements are those standards, requirements, criteria, or limitations promulgated under federal or state environmental or facility siting laws that specifically address a hazardous substance, pollutant, or contaminant found at a site and would apply in the absence of a CERCLA cleanup. Relevant and appropriate requirements are those standards, requirements, criteria, or limitations promulgated under federal environmental or state environmental or facility siting laws that are not applicable to a particular situation but apply to similar problems or situations, and therefore may be well suited requirements for a response action to address.

ARARs are divided into contaminant specific, location specific, and action specific requirements. Contaminant specific ARARs are listed according to specific media and govern the release to the environment of specific chemical compounds or materials possessing certain chemical or physical characteristics. Contaminant specific ARARs generally set health or risk based numerical values or methodologies which, when applied to site-specific conditions, result in the establishment of numerical values. These values establish the acceptable amount or concentration of a chemical that may be found in, or discharged to, the ambient environment.

Location specific ARARs are restrictions placed on the concentration of hazardous substances or the conduct of cleanup activities because they are in specific locations. Location specific ARARs generally relate to the geographic location or physical characteristics or setting of the site, rather than to the nature of the site contaminants. Action specific ARARs are usually technology or activity based requirements or limitations on actions taken with respect to hazardous substances.

Only the substantive portions of the requirements are ARARs. Administrative requirements are not ARARs and do not apply to actions conducted entirely on-site. Provisions of statutes or regulations that contain general goals expressing legislative intent but are non-binding are not ARARs. In addition, in instances like the present case where the cleanup is proceeding in stages, a particular phase of the remedy may not comply with all ARARs, so long as the overall remedy does meet ARARs.

Under Section 121 of CERCLA, 42 U.S.C. §9621, only those state standards that are more stringent than any federal standard are considered to be an ARAR provided that these standards are identified by the state in a timely manner. To be an ARAR, a state standard must be "promulgated," which means that the standards are of general applicability and are legally enforceable. State of Montana ARARs set forth below have been identified in cooperation with, and with assistance from, the State of Montana Department of Environmental Quality.

APPENDIX D

DETAILED COST SPREADSHEETS

Adit Discharge Response Action EE/CA
New World Mining District Response and Restoration Project

Alternative EC-1 Cost Estimate
Two Plug System - Open Adit
New World Mining District Response and Restoration Project
Adit Discharge EE/CA

TASK	UNIT COST	UNITS	QUANTITY	COST
MOBILIZATION/DEMOBILIZATION				
Mobilization	$40,000	/ls	1	$40,000
Site clean-up, restoration, reclamation	$20,000	/ls	1	$20,000
Demobilization	$40,000	/ls	1	$40,000
Subtotal				**$100,000.00**
EQUIPMENT				
Excavator	$730	/day	4	$2,920
Mucker	$325	/day	61	$19,825
Front-end loader	$295	/day	71	$20,945
Generator	$232	/day	61	$14,152
Compressor	$85	/day	61	$5,185
Water truck	$200	/day	71	$14,200
Ready-mix plant	$700	/day	16	$11,200
Concrete pump	$1,225	/day	16	$19,600
Grout plant	$400	/day	16	$6,400
Pick-up trucks	$75.00	/day	122	$9,150
Misc. plant (fan, pumps, drills etc.)	$200	/day	61	$12,200
Subtotal				**$135,777.00**
MATERIALS, SUPPLIES, and FUEL				
Fuel	$200	/day	71	$14,200
15 cm Schd. 40 pipe, fittings, and hangers	$105	/m	250	$26,250
Vent bag	$10.53	/m	100	$1,053
Ground support	$10,000	/ls	1	$10,000
Form materials	$10,200	/ls	1	$10,200
Pre-mix	$137	/m^3	90	$12,330
Cement	$12	bag	720	$8,640
Aggregate	$32	yd	120	$3,840
Cement Admixtures	$23	yd	120	$2,700
Bentonite based grout	$220	/tonne	18	$4,000
Miscellaneous	$10,000	/ls	1	$10,000
Subtotal				**$103,213.00**
LABOR				
5 man crew	$4,200	/day	71	$298,200
Subtotal				**$298,200.00**
SUBTOTAL				**$637,190.00**
Contingency (10%)				$63,719
TOTAL CONSTRUCTION ESTIMATE				**$700,909.00**
Engineering Evaluation and Design (5%)				$35,045
Construction Oversight (8%)				$56,073
TOTAL ESTIMATED COST				**$792,027.17**

Assumptions:

Mine is accessible.

Underground work: 71 days total (mining contractor)	71
site/utilities set-up: 10 days	10
excavate, support, and clean plug site: 10 days/plug	20
forms: 6 days/plug	12
place concrete and grout: 8 days/plug	16
remove utilities: 3 day	3
reclmation and restoration 10 days	10

Volume of plug = 4.88 x 3.05 x 3.05 = 45 m^3

Number of plugs: 2

Alternative EC-2 Cost Estimate
Easy Access - Collapsed Adit
New World Mining District Response and Restoration Project
Adit Discharge EE/CA

TASK	UNIT COST	UNITS	QUANTITY	COST
MOBILIZATION/DEMOBILIZATION				
Mobilization	$40,000	/ls	1	$40,000
Site clean-up, restoration, reclamation	$20,000	/ls	1	$20,000
Demobilization	$40,000	/ls	1	$40,000
Subtotal				**$100,000.00**
EQUIPMENT				
Excavator	$730	/day	4	$2,920
Mucker	$325	/day	101	$32,825
Front-end loader	$295	/day	101	$29,795
Generator	$232	/day	101	$23,432
Compressor	$85	/day	101	$8,585
Water truck	$200	/day	121	$24,200
Ready-mix plant	$700	/day	16	$11,200
Concrete pump	$1,225	/day	16	$19,600
Grout plant	$400	/day	16	$6,400
Pick-up trucks	$75.00	/day	242	$18,150
Misc. plant (fan, pumps, drills etc.)	$200	/day	101	$20,200
Subtotal				**$197,307.00**
MATERIALS, SUPPLIES, and FUEL				
Fuel	$200	/day	121	$24,200
15 cm Schd. 40 pipe, fittings, and hangers	$105	/m	250	$26,250
Vent bag	$10.53	/m	100	$1,053
Ground support	$15,000.00	/ls	1	$15,000
Form materials	$10,200	/ls	1	$10,200
Pre-mix	$137	/m^3	90	$12,330
Cement	$12	bag	720	$8,640
Aggregate	$32	yd	120	$3,840
Cement Admixtures	$23	yd	120	$2,700
Bentonite based grout	$220	/tonne	18	$4,000
Miscellaneous	$10,000	/ls	1	$10,000
Subtotal				**$118,213.00**
LABOR				
5 man crew	$4,200	/day	121	$508,200
Subtotal				**$508,200.00**
SUBTOTAL				**$923,720.00**
Contingency (10%)				$92,372
TOTAL CONSTRUCTION ESTIMATE				**$1,016,092.00**
Engineering Evaluation and Design (5%)				$50,805
Construction Oversight (8%)				$81,287
TOTAL ESTIMATED COST				**$1,148,183.96**

Assumptions:

- Mine is not accessible.
- Contractor can dig an infiltration pond and divert mine water to it for disposal.
- A 1cyd mucker will fit in portal; if it does not, then a slusher can be substituted with the same pricing.
- Ground conditions will require minimal new support.
- Drift will be mucked out from the portal to 250 feet in from portal.
- Muck will be disposed of on-site or will be hauled off-site under a separate contract.
- U/G work: 41 days total (mining contractor) 121
  - site/utilities set-up: 10 days 10
  - reopen portal and drift: 10 days 10
  - mine rehab and ground support 40
  - excavate, support, and clean plug site: 10 days/plug 20
  - forms: 6 days/plug 12
  - place concrete and grout: 8 days/plug 16
  - remove utilities: 3 day 3
  - reclamation and restoration 10
- Volume of plug = 4.88 x 3.05 x 3.05 = 45 m^3
- Number of plugs: 2

Alternative EC-2 Cost Estimate
Difficult Access - Collapsed Adit
New World Mining District Response and Restoration Project
Adit Discharge EE/CA

TASK	UNIT COST	UNITS	QUANTITY	COST
MOBILIZATION/DEMOBILIZATION				
Mobilization	$40,000	/ls	1	$40,000
Site clean-up, restoration, reclamation	$30,000	/ls	1	$30,000
Demobilization	$40,000	/ls	1	$40,000
Subtotal				**$110,000.00**
EQUIPMENT				
Excavator	$730	/day	4	$2,920
Mucker	$325	/day	141	$45,825
Front-end loader	$295	/day	141	$41,595
Generator	$232	/day	141	$32,712
Compressor	$85	/day	141	$11,985
Water truck	$200	/day	161	$32,200
Ready-mix plant	$700	/day	16	$11,200
Concrete pump	$1,225	/day	16	$19,600
Grout plant	$400	/day	16	$6,400
Pick-up trucks	$75.00	/day	322	$24,150
Misc. plant (fan, pumps, drills etc.)	$200	/day	141	$28,200
Subtotal				**$256,787.00**
MATERIALS, SUPPLIES, and FUEL				
Fuel	$200	/day	161	$32,200
15 cm Schd. 40 pipe, fittings, and hangers	$105	/m	250	$26,250
Vent bag	$10.53	/m	100	$1,053
Ground support	$20,000.00	/ls	1	$20,000
Form materials	$10,200	/ls	1	$10,200
Pre-mix	$137	/m^3	90	$12,330
Cement	$12	bag	720	$8,640
Aggregate	$32	yd	120	$3,840
Cement Admixtures	$23	yd	120	$2,700
Bentonite based grout	$220	/tonne	18	$4,000
Miscellaneous	$10,000	/ls	1	$10,000
Subtotal				**$131,213.00**
LABOR				
5 man crew	$4,200	/day	161	$676,200
Subtotal				**$676,200.00**
SUBTOTAL				**$1,174,200.00**
Contingency (10%)				$117,420
TOTAL CONSTRUCTION ESTIMATE				**$1,291,620.00**
Engineering Evaluation and Design (5%)				$64,581
Construction Oversight (8%)				$103,330
TOTAL ESTIMATED COST				**$1,459,530.60**

Assumptions:

Mine is not accessible.
Contractor can dig an infiltration pond and divert mine water to it for disposal.
A 1cyd mucker will fit in portal; if it does not, then a slusher can be substituted with the same pricing.
Ground conditions will require minimal new support.
Drift will be mucked out from the portal to 250 feet in from portal.
Muck will be disposed of on-site or will be hauled off-site under a separate contract.

U/G work: 41 days total (mining contractor)	161
site/utilities set-up: 10 days	10
reopen portal and drift: 10 days	10
mine rehab and ground support	80
excavate, support, and clean plug site: 10 days/plug	20
forms: 6 days/plug	12
place concrete and grout: 8 days/plug	16
remove utilities: 3 day	3
reclamation and restoration	10

Volume of plug = 4.88 x 3.05 x 3.05 = 45 m^3

Number of plugs: 2

Alternative WT-1 Cost Estimate
Infiltration - Group 5 Discharges (3 gpm Design Flow)
New World Mining District Response and Restoration Project
Adit Discharge EE/CA

DIRECT CAPITAL COSTS

Component	Unit	Unit Cost	Total Quantity	Total Cost	Source
Capital Costs					
Clear site	ls	$ 1,134	1	$ 1,134	
Grading	ls	$ 567	1	$ 567	
Adit Flow Collection System	ls	$ 2,574	1	$ 2,574	
influent piping	lf	$ 9.68	200	$ 1,935	02620 660 0040
perforated piping	lf	$ 9.68	60	$ 581	02620 660 0030
Drain gravel	cy	$ 66	10	$ 659	Local vendor estimate
Geotextile	ls	$ 103	1	$ 103	023400 300 1550
Backfill	ls	$ 515	1	$ 515	
Revegetation	ac	$ 2,268	0.5	$ 1,134	

TOTAL DIRECT CAPITAL COSTS **$ 9,201**

INDIRECT CAPITAL COSTS

Testing and analysis (30% of direct)	$ 2,760
Engineering and design (10% of direct)	$ 920
Contingency (25% of direct)	$ 2,300
Mobilization and Demobilization (15%)	$ 1,380

TOTAL INDIRECT CAPITAL COSTS **$ 7,361**

TOTAL CAPITAL COSTS **$ 16,561**

POST REMOVAL SITE CONTROL COST

Discount: 4.00% for present worth analysis

Component	Unit	Unit Cost	Quantity	Each/yr	$/year	Years	Present Worth, 4%
DIRECT OPERATION AND MAINTENANCE COSTS							
Replace System after 20 years	ls	$ 9,201	1			20	$ 4,536
OPERATION AND MAINTENANCE PRESENT WORTH (20 YEARS)							**$ 4,536**
					GRAND TOTAL		**$ 21,097**

Original cost estimate from December 2005 was updated using ENR Construction Cost Index, ENR Material Price Index, and ENR Labor Index (March 2010)
Assumptions

Discharges would be collected and infiltrated in a sub-surface drain field. Assuming a discharge of 3 gpm and an infiltration rate of 1 inch/hr, an infiltration area of 290 sf would be required. Perforated pipe laterals would be installed every 10 feet, bedded in gravel, covered with a geotextile, and buried to a depth of 2 ft. Cost estimate sources are from; R.S. Means Heavy Construction Cost Data, 2005 where reference numbers are provided or professional judgement if blank

Alternative WT-2 Cost Estimate
McLaren Subsurface Drains Combined Flow - 22 gpm
Liquid Reactant Sulfate Reducing Bioreactor (LSBR) with Holding Pond and Oxic Limestone Drain (OLD)
Adit Discharge EE/CA

DIRECT CAPITAL COSTS

Component	Unit	Unit Cost	Total Quantity	Total Cost	Source	
Holding Pond						
Gravel (includes placement)	cy	$ 70.16	657	$ 46,093		
Fill from borrow area (placement)	cy	$ 7.80	1030	$ 8,033		
Excavation, 1 1/2 cy bucket	cy	$ 19.42	1687	$ 32,762		
Liner & Cover (installed)	sy	$ 13.65	1756.6	$ 23,969		
Clear & Grub	ac	$ 2,619.20	0.08	$ 210	AMD Treat	
Revegetation	ac	$ 2,643.60	0.08	$ 211	AMD Treat	
System Bypass	ls	$ 2,541.92	1	$ 2,542		
Holding Pond Total					**$**	**113,820**
Settling Pond						
Gravel (includes placement)	cy	$ 70.16	6274	$ 440,165		
Fill from borrow area (placement)	cy	$ 7.80	6274	$ 48,928		
Excavation, 1 1/2 cy bucket	cy	$ 19.42	12548	$ 243,686		
Liner & Cover (installed)	sy	$ 13.65	9682	$ 132,111		
Clear & Grub	ac	$ 2,619.20	1	$ 2,619	AMD Treat	
Revegetation	ac	$ 2,643.60	1	$ 2,644	AMD Treat	
Settling Pond Total				**$ 870,153**		
Liquid Substrate Bioreactor						
Piping and valves from drains to pond (400 feet)	ls	$ 61,913.04	1	$ 61,913	AMD Treat	
Chemical Feed Systems and Storage	ls	$ 10,167.68	1	$ 10,168		
Gravel/Rock Fill for Cell (includes placement)	cy	$ 70.16	896	$ 62,861		
Manure for bacterial inoculation	ton	$ 3.77	59.7	$ 225		
Fill from borrow area (placement)	cy	$ 7.80	896	$ 6,988		
Excavation, 1 1/2 cy bucket	cy	$ 19.42	1882	$ 36,549	AMD Treat & Const.Costs	
Liner & Cover (installed)	ls	$ 20,332.32	1	$ 20,332		
Clear & Grub	ac	$ 2,619.20	0.33	$ 864		
Revegetation	ac	$ 2,643.60	0.33	$ 872		
LSBR Bypass System	ls	$3,559	1	$ 3,559		
Liquid Substrate Bioreactor Total				**$ 204,331**		
Oxic Limestone Channel						
Oxic Limestone Channel with Liner Installed	ls	$ 9,356.30	1	$ 9,356	AMD Treat	
Oxic Limestone Channel Total				**$ 9,356**		
TOTAL DIRECT CAPITAL COSTS					**$**	**1,197,660**

Alternative WT-2 Cost Estimate
McLaren Subsurface Drains Combined Flow - 22 gpm
Liquid Reactant Sulfate Reducing Bioreactor (LSBR) with Holding Pond and Oxic Limestone Drain (OLD)
Adit Discharge EE/CA

INDIRECT CAPITAL COSTS

Component	Unit	Unit Cost	Total Quantity	Total Cost	Source
Material Delivery Costs					
Gravel for pond, limestone for OLC & Gravel/rock mix for bioreactor	ton-mile	$ 0.072	344250	$ 24,620	
Material Delivery Costs Total				**$ 24,620**	
Mobilization/Demobilization					
Mobilization	ls	$ 50,838.41	1	$ 50,838	
Backhoe. Grader, Dump Truck and Dozer (<50 miles round trip)	each	$ 220.64	4	$ 883	
Mileage	5 miles	$ 22.43	200	$ 4,487	
Mobilization/Demobilization Total				**$ 56,208**	
Engineering and Design (10% of Direct)				**$ 119,766**	
Contingency (25% of direct)				**$ 299,415**	
TOTAL INDIRECT CAPITAL COSTS					**$ 500,009**
TOTAL CAPITAL COSTS					**$ 1,697,669**

DIRECT OPERATION AND MAINTENANCE COSTS

Component	Unit	Unit Cost	Years		
Annual sampling	ls	$ 9,799.61	20	$ 142,980	
Chemical Costs	ls	$ 15,049.19	20	$ 219,574	
Pipe Cleaning and Maintanance	ls	$ 5,083.84	20	$ 74,175	
Replace system every 15 years	ls	$ 204,330.67	20	$ 144,550	
Residual disposal every 15 years	ls	$ 45,551.22	20	$ 32,224	
OPERATION AND MAINTENANCE PRESENT WORTH (20YEARS)					**$ 613,504**
GRAND TOTAL					**$ 2,311,173**

Original cost estimate from April 2009 was updated using ENR Construction Cost Index, ENR Material Price Index, and ENR Labor Index (March 2010)

Assumptions:

A Liquid Reactant Sulfate Reducing Bioreactor (LSBR) would be constructed to treat the combined flow (22 gpm) from the McLaren Pit Cap drains. The flow from the drains would be conveyed into a holding pond before entering a settling pond for metals precipitation. The discharge from the settling pond then flows to the LSBR. The discharge from the LSBR would flow to an oxic limestone drain (OLD) prior to discharge. The LSBR was sized using a 2 day hydraulic retention time at a porosity of 35%. The holding pond and oxic limestone channel were sized using AMD Treat software Version 4.1c (see attachments). Sodium hydroxide (NaOH) would be fed to the system with a solar driven pump for alkalinity addition, and ethanol would be fed to the system using a solar driven pump for the carbon source for bacterial growth. The cell will be covered with 4 feet of soil from the borrow area for frost protection. The holding pond, SSRB and OLD are lined to minimize water loss. A system bypass is included for high flows which may not be accomodated by the SSBR. It is assumed that the cell would need replacement every 15 years.

Replacement would include disposal of the cell fill material at $50/ton. Access would not be required during winter-weather months. Cost estimate sources are from AMD Treat software Version 4.1c (Office of Surface Mining Reclamation and Enforcement (OSMRE), 2006); New World Mining District Actual Cost Data from McLaren Pit Response Action Construction Report, 2006 and Selective Source Response Action Construction Report, 2006 each adjusted using construction cost indicies, and professional judgement.

Alternative WT-3 Cost Estimate
Solid Reactant Sulfate Reducing Bioreactor w/OLC - 8.5 gpm Design Flow
New World Mining District Response and Restoration Project
Adit Discharge EE/CA

DIRECT CAPITAL COSTS

Component	Unit	Unit Cost	Total Quantity	Total Cost	Source
Capital Costs					
SSBR Cell	ls	$127,112	1	$127,112	AMD Treat
Geotextile	sy	$1.38	1,525	$2,104	023400 300 1550
Soil Backfill	cy	$31	1,010	$31,192	
OLC	ls	$2,947	1	$2,947	AMD Treat
Revegetation	ac	$2,268	0.6	$1,361	
TOTAL DIRECT CAPITAL COSTS					**$164,716**
INDIRECT CAPITAL COSTS					
Treatment Testing (10% of direct)				$16,472	
Engineering and design (10% of direct)				$16,472	
Contingency (25% of direct)				$41,179	
Mobilization and Demobilization (10%)				$16,472	
TOTAL INDIRECT CAPITAL COSTS					**$90,594**
TOTAL CAPITAL COSTS					**$255,309**

POST REMOVAL SITE CONTROL COST

Discount: 4.0% for present worth analysis

Component	Unit	Unit Cost	Each/yr	$/year	Years	Present Worth, 4%
DIRECT OPERATION AND MAINTENANCE COSTS						
Replace system every 5 years	ls	$164,716			20	$323,164
Residual disposal every 5 years	ls	$86,927			20	$221,112
TOTAL						**$544,276**
OPERATION AND MAINTENANCE PRESENT WORTH (20 YEARS)						**$544,276**
				GRAND TOTAL		**$799,585**

Original cost estimate from December 2005 was updated using ENR Construction Cost Index, ENR Material Price Index, and ENR Labor Index (March 2010)

Assumptions:

A Solid Reactant Sulfate Reducing Bioreactor (SSBR) would be constructed to treat a flow of 8.5 gpm. The discharge from the SSBR would flow to an Open Limestone Channel (OLC). The SSBR was designed using AMD Treat software (see attachments). The cell was designed to have a water residence time in the organic matter of 5 days and includes a limestone layer with a 24 hr residence time to buffer the inflow. The cell would be covered with 2-feet of soil for frost protection. It is assumed that the SSBR would need to be replaced every 5 years due to plugging with metal precipitates and loss of permeability in the solid reactant. Access would not be required during winter-weather months. Cost estimate sources are from AMD Treat 3.2 software (Office of Surface Mining); R.S. Means Heavy Construction Cost Data, 2005 where reference numbers are provided or professional judgment if blank.

Alternative WT-3 Cost Estimate
Solid Reactant Sulfate Reducing Bioreactor w/OLC - 1.4 gpm Design Flow
New World Mining District Response and Restoration Project
Adit Discharge EE/CA

DIRECT CAPITAL COSTS

Component	Unit	Unit Cost	Total Quantity	Total Cost	Source
Capital Costs					
SSBR cell	ls	$23,307	1	$23,307	AMD Treat
Geotextile	sy	$1.38	335	$462	023400 300 1550
Soil Backfill	cy	$31	225	$6,949	
OLC	ls	$3,097	1	$3,097	AMD Treat
Revegetation	ac	$2,268	0.6	$1,361	
TOTAL DIRECT CAPITAL COSTS					**$35,176**
INDIRECT CAPITAL COSTS					
Treatment Testing (10% of direct)				$3,518	
Engineering and design (10% of direct)				$3,518	
Contingency (25% of direct)				$8,794	
Mobilization and Demobilization (10%)				$3,518	
TOTAL INDIRECT CAPITAL COSTS					**$19,347**
TOTAL CAPITAL COSTS					**$54,522**

POST REMOVAL SITE CONTROL COST

Discount: 4.0% for present worth analysis

Component	Unit	Unit Cost	Each/yr	$/year	Years	Present Worth, 4%
DIRECT OPERATION AND MAINTENANCE COSTS						
Replace system every 10 years	ls	$35,176			20	$40,821
Residual disposal every 10 years	ls	$15,903			20	$18,143
TOTAL						**$58,963**
OPERATION AND MAINTENANCE PRESENT WORTH (20 YEARS)						**$58,963**
				GRAND TOTAL		**$113,486**

Original cost estimate from December 2005 was updated using ENR Construction Cost Index, ENR Material Price Index, and ENR Labor Index (March 2010)

Assumptions:

A Solid Reactant Sulfate Reducing Bioreactor (SSBR) would be constructed to treat a flow of 1.4 gpm. The discharge from the SSBR would flow to an Open Limestone Channel (OLC). The SSBR was designed using AMD Treat software (see attachments). The cell was designed to have a water residence time in the organic matter of 5 days and includes a limestone layer with a 24 hr residence time to buffer the inflow. The cell would be covered with 2-feet of soil for frost protection. It is assumed that the SSBR would need to be replaced every 10 years due to plugging with metal precipitates and loss of permeability in the solid reactant. Access would not be required during winter-weather months. Cost estimate sources are from AMD Treat 3.2 software (Office of Surface Mining); R.S. Means Heavy Construction Cost Data, 2005 where reference numbers are provided or professional judgment if blank.

Alternative WT-4 Cost Estimate
Manganese Removal Cell - Gold Dust Adit (13 gpm Design Flow)
New World Mining District Response and Restoration Project
Adit Discharge EE/CA

DIRECT CAPITAL COSTS

Component	Unit	Unit Cost	Total Quantity	Total Cost	Source
Capital Costs					
MRC Cell	ls	$40,687	1	$40,687	AMD Treat
Piping	ls	$4,118	1	$4,118	
Geotextile	sy	$1.38	475	$655	023400 300 1550
Soil Backfill	cy	$31	320	$9,883	
Revegetation	ac	$2,268	0.4	$907	
TOTAL DIRECT CAPITAL COSTS					**$56,250**
INDIRECT CAPITAL COSTS					
Treatment Testing (10% of direct)				$5,625	
Engineering and design (10% of direct)				$5,625	
Contingency (25% of direct)				$14,062	
Mobilization and Demobilization (10%)				$5,625	
TOTAL INDIRECT CAPITAL COSTS					**$30,937**
TOTAL CAPITAL COSTS					**$87,187**

POST REMOVAL SITE CONTROL COST

Discount: 4.0% for present worth analysis

Component	Unit	Unit Cost	Each/yr	$/year	Years		Present Worth, 4%
DIRECT OPERATION AND MAINTENANCE COSTS							
Replace system every 10 years	ls	$56,250			20	$	65,767
Residual disposal every 10 years	ls	$28,404			20	$	32,316
TOTAL						**$**	**98,083**
OPERATION AND MAINTENANCE PRESENT WORTH (20 YEARS)						**$**	**98,083**
				GRAND TOTAL			**$185,270**

Original cost estimate from December 2005 was updated using ENR Construction Cost Index, ENR Material Price Index, and ENR Labor Index (March 2010)

Assumptions:

A Manganese Removal Cell (MRC) would be constructed to treat a 13 gpm flow. The MRB was designed using AMD Treat software (see attachments). The cell was designed to have a water residence time in crushed limestone of 1 day. The cell would be covered with 2-feet of soil for frost protection. O+M would be minimal and has been neglected. It is assumed that the MRC would need to be replaced every 10 years due to plugging with metal precipitates or coating of the limestone. Cost estimate sources are from AMD Treat 3.2 software (Office of Surface Mining, 2002); R.S. Means Heavy Construction Cost Data, 2005 where reference numbers are provided or professional judgment if blank.

Alternative WT-5 Cost Estimate
Active Treatment - McLaren Pit Subsurface Drains (25-50 gpm Design Flow)
New World Mining District Response and Restoration Project
Adit Discharge EE/CA

DIRECT CAPITAL COSTS

Component	Unit	Unit Cost	Quantity	Total Cost	Source		
Capital Costs							
Water Collection Systems	ls	$34,017	1	$34,017			
Trenching	cy	$5.40	200	$1,079	02315 610 0062		
Influent piping	lf	$3.53	1,000	$3,531	02620 520 1000		
Packaged Treatment System	ls	$425,216	1	$425,216	US Filter		
Reagent Storage/distribution	ls	$25,736	1	$25,736			
Sludge Storage	ls	$11,339	1	$11,339			
Diesel Generator 50kW	ls	$25,736	1	$25,736	16230 450 2100		
Propane Heat System	ls	$25,736	1	$25,736	Unifield		
Shelter/Site Improvements	ls	$113,391	1	$113,391	2000 sf @ $50/sf		
TOTAL DIRECT CAPITAL COSTS						**$665,781**	
INDIRECT CAPITAL COSTS							
Testing (10% of direct)				$66,578			
Engineering and design (10% of direct)				$66,578			
Contingency (25% of direct)				$166,445			
Mobilization and Demobilization (10%)				$ 66,578			
TOTAL INDIRECT CAPITAL COSTS						**$366,180**	
TOTAL CAPITAL COSTS						**$1,031,961**	

POST REMOVAL SITE CONTROL COST

Discount: 4.0% for present worth analysis

Component	Unit	Unit Cost	Quantity	Each/yr	$/year	Years	Present Worth, 4%	
DIRECT OPERATION AND MAINTENANCE COSTS								
Reagents	ls	$1,484	1	12	$17,813	20	$242,089	$1.19/1000 gal
Sludge Disposal	ls	$1,191	1	12	$14,287	20	$194,168	10 tons/mo@$50/ton
Filter Replacement	ls	$1,029	1	12	$12,353	20	$167,884	
Generator Fuel	ls	$1,544	1	12	$18,530	20	$251,826	1 gal/hr @$2/gal
Propane	ls	$309	1	12	$3,706	20	$50,365	
Labor	ls	$87,328	2	1	$174,656	20	$2,373,634	2 full-time employees
Road Maintenance/Plowing	ls	$7,370	1	12	$88,445	20	$1,201,995	
TOTAL							**$4,481,962**	
OPERATION AND MAINTENANCE PRESENT WORTH (20 YEARS)							**$4,481,962**	
				GRAND TOTAL			**$5,513,922**	

Original cost estimate from December 2005 was updated using ENR Construction Cost Index, ENR Material Price Index, and ENR Labor Index (March 2010)

Assumptions

Packaged system from U.S. Filter 25-50 gpm - $350-375 K

One (1) Equalization tank
Two (2) forwarding pump skid
Two (2) two stage reaction tank system
One (1) Microfiltration skid
Two (2) sludge pump skid
One (1) sludge storage tank
One (1) 100 % duty filter press

One (1) filtered storage tank

McLaren Pit cap drains with a flow of 27 gpm would be combined with the 8 gpm flow from the McLaren Adit and treated using a packaged

Alternative WT-5 Cost Estimate
Active Treatment - Glengarry Millsite Adit (5-25 gpm Design Flow)
New World Mining District Response and Restoration Project
Adit Discharge EE/CA

DIRECT CAPITAL COSTS

Component	Unit	Unit Cost	Quantity	Total Cost	Source
Capital Costs					
Water Collection System	ls	$ 11,339	1	$ 11,339	
Trenching	cy	$ 10.79	100	$ 1,079	02315 610 0062
Influent piping	lf	$ 3.53	500	$ 1,765	02620 520 1000
Packaged Treatment System	ls	$ 340,173	1	$ 340,173	
Reagent Storage/distribution	ls	$ 11,339	1	$ 11,339	
Sludge Storage	ls	$ 5,670	1	$ 5,670	
Diesel Generator 50kW	ls	$ 25,736	1	$ 25,736	16230 450 2100
Propane Heat System	ls	$ 25,736	1	$ 25,736	Unifield
Shelter/Site Improvements	ls	$ 102,943	1	$ 102,943	2000 sf @ $50/sf

TOTAL DIRECT CAPITAL COSTS	**$**	**525,781**

INDIRECT CAPITAL COSTS

Testing (20% of direct)	$ 105,156
Engineering and design (10% of direct)	$ 52,578
Contingency (25% of direct)	$ 131,445
Mobilization and Demobilization (10%)	$ 52,578

TOTAL INDIRECT CAPITAL COSTS	**$**	**341,757**
TOTAL CAPITAL COSTS	**$**	**867,538**

POST REMOVAL SITE CONTROL COST

Discount: 4.0% for present worth analysis

Component	Unit	Unit Cost	Quantity	Each/yr	$/year	Years	Present Worth, 4%	
DIRECT OPERATION AND MAINTENANCE COSTS								
Reagents	ls	$ 10	1	12	$ 124	20	$ 1,679	$0.06/1000 gal
Sludge Disposal	ls	$ 14	1	12	$ 170	20	$ 2,312	3 tons per year
Filter Replacement	ls	$ 103	1	12	$ 1,235	20	$ 16,788	
Generator Fuel	ls	$ 1,544	1	12	$ 18,530	20	$ 251,826	1 gal/hr @$2/gal
Propane	ls	$ 309	1	12	$ 3,706	20	$ 50,365	
Labor	ls	$ 87,328	1	1	$ 87,328	20	$ 1,186,817	1 full-time employee
Road Maintenance/Plowing	ls	$ 7,370	1	12	$ 88,445	20	$ 1,201,995	
TOTAL							**$ 2,711,782**	

OPERATION AND MAINTENANCE PRESENT WORTH (20 YEARS)	**$**	**2,711,782**
GRAND TOTAL	**$**	**3,579,320**

Original cost estimate from December 2005 was updated using ENR Construction Cost Index, ENR Material Price Index, and ENR Labor Index (March 2010)

Assumptions:

One (1) Equalization tank
Two (2) forwarding pump skid
Two (2) two stage reaction tank system
One (1) Microfiltration skid
Two (2) sludge pump skid
One (1) sludge storage tank
One (1) 100 % duty filter press
One (1) filtered storage tank

Glengarry Millsite adit with a flow of 4 gpm would be treated using a packaged treatment system from U.S.Filter. The system would neutralize/precipitate the flow with sodium hydroxide and filter the precipitate. Reagent costs and sludge disposal assume average flows and water quality. Sodium hydroxide costs of $0.20 per lb of 50% NaOH and 90% mixing efficiency.

Alternative WT-6 Cost Estimate March 2010
Ion Exchange - Group 5 Discharges (1.4-2.5 gpm Design Flow)
New World Mining District Response and Restoration Project
Adit Discharge EE/CA

DIRECT CAPITAL COSTS

Component	Unit	Unit Cost	Total Quantity	Total Cost	Source - R.S. Means unless noted	
Capital Costs						
Clear site	ls	$1,134	1	$1,134		
Grading	ls	$567	1	$567		
Adit Flow Collection System	ls	$2,574	1	$2,574		
influent piping	lf	$9.68	200	$1,935	02620 660 0040	
6 ft dia manhole, 6' deep	ls	$1,776	1	$1,776	02630 400 1160	
Ion exchange system	ea	$5,147	1	$5,147		
Plumb system	ls	$2,911	1	$2,911		
TOTAL DIRECT CAPITAL COSTS						**$16,044**
INDIRECT CAPITAL COSTS						
Treatment Testing (10% of direct)				$1,604		
Engineering and design (10% of direct)				$1,604		
Contingency (25% of direct)				$4,011		
Mobilization and Demobilization (10%)				$ 1,604		
TOTAL INDIRECT CAPITAL COSTS						**$8,824**
TOTAL CAPITAL COSTS						**$24,868**

POST REMOVAL SITE CONTROL COST

Discount: 4.00% for present worth analysis

Component	Unit	Unit Cost	Quantity	Each/yr	$/year	Years	Present Worth, 4%
DIRECT OPERATION AND MAINTENANCE COSTS							
Annual system replacement	ls	$2,268	1	1	$2,268	20	$30,820
OPERATION AND MAINTENANCE PRESENT WORTH (20 YEARS)							**$30,820**
						GRAND TOTAL	**$55,688**

Original cost estimate from December 2005 was updated using ENR Construction Cost Index, ENR Material Price Index, and ENR Labor Index (March 2010)
Assumptions:

Flows would be collected and passed through a packaged ion exchange (IX) system that includes prefiltration. The system would be installed underground in a manhole to protect from freezing. It has been assumed that the IX system would be replaced annually

APPENDIX E

MCLAREN SUBSURFACE DRAIN ANAEROBIC BIOREACTOR SYSTEM REVIEW

Adit Discharge Response Action EE/CA

New World Mining District Response and Restoration Project

TETRA TECH

3801 Automation Way, Suite 100
For t Collins, Colorado 80525
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Technical Memorandum

To:	Mary Beth Marks US Forest Service On Scene Coordinator – New World Mining District	**From:**	Jennifer Hudson
Company:	Tetra Tech	**Date:**	April 6, 2009
Re:	McLaren Subsurface Drain Anaerobic Bioreactor System Review	**Project #:**	1157561506A
CC:	Allan Kirk, Tetra Tech		

1. Introduction

In the *Draft Adit Discharge Engineering Evaluation/Cost Analysis (EE/CA): New World Mining District Response and Restoration Project* (Tetra Tech, 2006) several alternative treatment technologies for acid rock drainage (ARD) and acid mine drainage (AMD) were evaluated and the recommended treatment technology was selected for each source in the New World Mining District. The reader is referred to that document for site history and detailed information regarding the New World Site.

The recommended treatment technology for the collective flow from the McLaren Pit subsurface drains was a passive or semi-passive bioreactor system. Passive or semi-passive treatment of acid mine drainage has been shown to be a relatively effective and low-maintenance alternative to active treatment under favorable conditions including providing an acceptable energy source and proper water quality conditions conducive for bacterial growth as discussed in detail in this report. This type of treatment takes advantage of natural chemical and biological processes and is particularly suited for remote locations and those which may be inaccessible during a portion of the year as is the case for the McLaren subsurface drains and the McLaren Adit discharge.

This review is a reexamination of the anaerobic bioreactor system proposed for the McLaren drains in the EE/CA. A passive solid substrate bioreactor (SSBR) and a semi-passive liquid substrate bioreactor system (LSBR) are compared. The water flow rate and quality data have been reevaluated for each source. An estimated cost analysis for bench scale pilot studies is presented, and the sensitivity of the system to changing flow and chemistry conditions is discussed. Finally, the construction, operations and maintenance cost analysis presented in the EE/CA has been updated to provide further detail and refined cost estimates for the SSBR and LSBR systems based on these analyses.

2. Site Description

The nature of the McLaren massive sulfide ore deposit, history of the open-pit mine and general site characteristics are detailed in the Adit EE/CA. Briefly, the site is located immediately north of Daisy Pass, on the west side of Fisher Mountain about four miles north of Cooke City, Montana. The open pit mine

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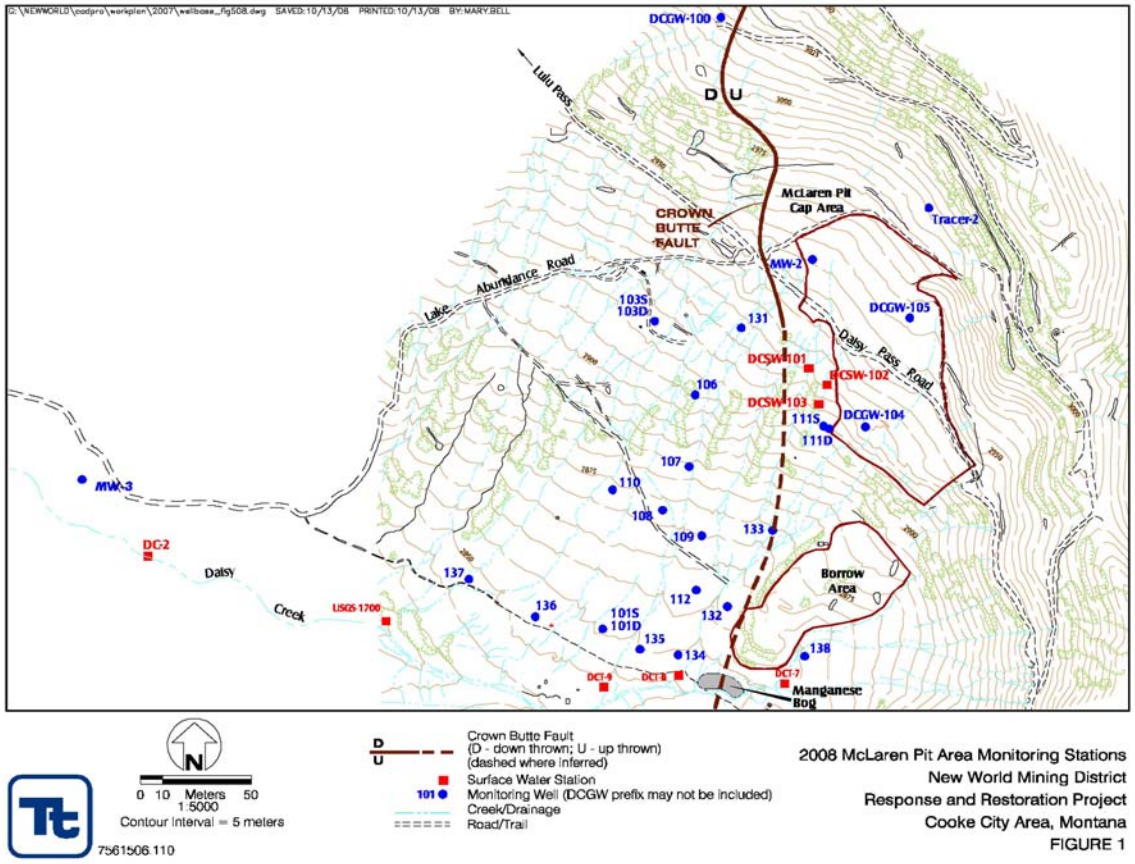
occurs at elevations between 9,600 to 9,800 feet, and access to the site is limited to only a few months each year due to adverse weather and snow conditions. As a result of the site conditions, a bioreactor treatment system for water treatment of flow from the drains was recommended as a possible treatment alternative in the EE/CA to reduce metals-loading to Daisy Creek. The technology is well-suited for remote locations, which are inaccessible for a portion of the year and where active treatment may not be feasible. The technology has been shown to be effective for treatment of AMD under favorable conditions, and improvements in long term operation of these systems are routinely being made. Although the currently constructed bioreactor treatment systems have not been in operation for more than a few years, in theory under the optimal operating conditions, passive or semi-passive bioreactor systems should operate effectively for many years without requiring a major system overhaul or ongoing construction, and should require only minimal operator input.

3. McLaren Pit Subsurface Drains

In July 2002 as a result of the McLaren Pit Response Action, the historically operated open pit was re-graded and capped with an impermeable geomembrane cover to minimize surface run-on, and the effects of precipitation and snowmelt infiltration into mine wastes back-filling the pit; thereby mitigating some of the acid generation and potential metals-loading to nearby Daisy Creek.

Four bedrock-hosted springs were encountered during excavation and drains were constructed during re-grading efforts to redirect subsurface drainage away from mine waste back-filled areas of the pit and the construction site. These drains were constructed to collect water in a perforated drain-pipe in a geotextile lined and covered, gravel-filled trench. The trenches were laid-out to bring the spring-fed groundwater near the base of the pit to the westernmost and downhill edge of the pit. These drains were left in place after regrading and completion of the capping. Three of the terminal ends are accessible as they drain into two separate constructed surface water tributary channels to Daisy Creek, immediately down-gradient of the pit. These three discharges to surface water are referred to as sample locations DCSW-101, DCSW-102 and DCSW-103 as shown in **Figure 1**. Construction of the McLaren cap was completed in October 2003.



The data for the combined flow of the three drains (see **Appendix A**) indicate an overall downward trend in combined peak flow since 2004, with the exception of the high flow sampling event in 2008, as shown in **Figure 2**. The sampling event on 7/15/2008 shows higher flow rates for the combined drain flow and indicate that 2008 precipitation and subsequent snowmelt was greater than that of 2006 or 2007. Although the flow rates measured in July 2008 indicate that the peak flow for this year was higher than peak flows measured in 2006 and 2007, the rapidly peaking flows generated by very high winter snowfalls/snowmelt quickly dropped back down to expected flow values for this time of year by the 8/12/2008 sampling event.

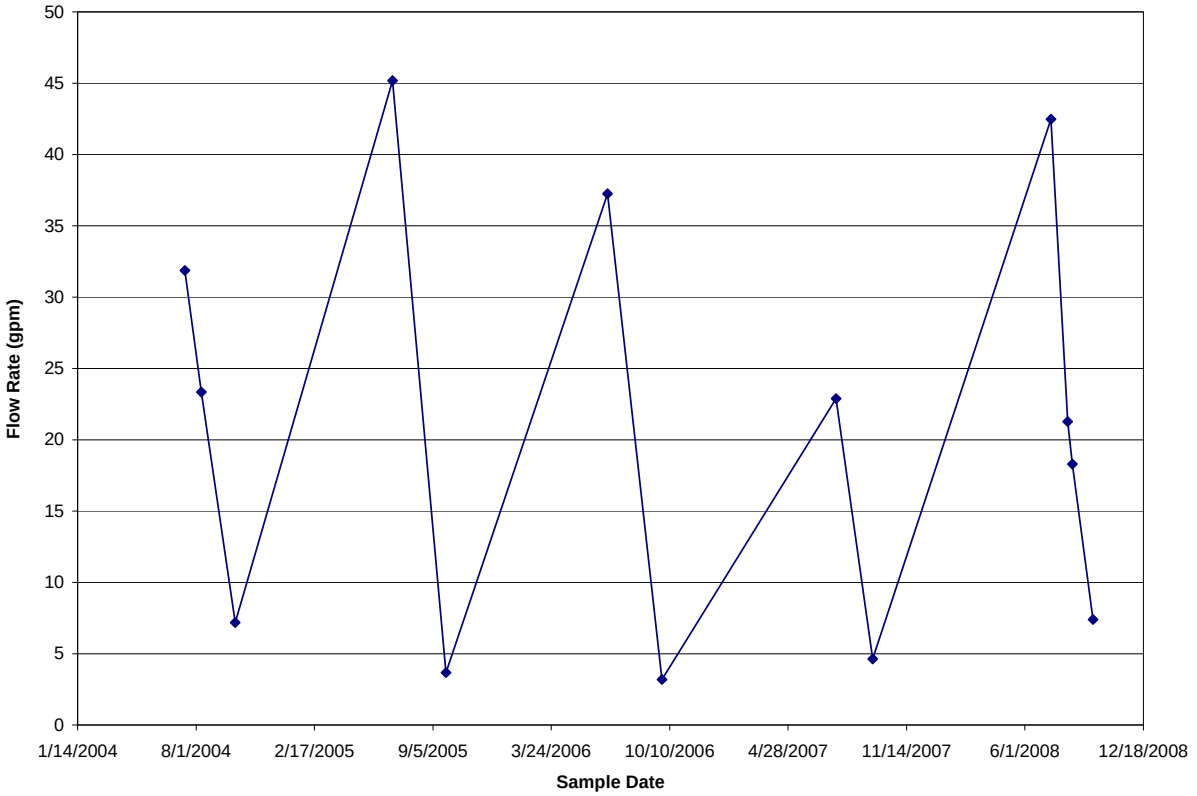


Figure 2 - Combined Flow for DCSW-101, -102, -103 Post-Capping

The combined metals concentrations show similar decreasing trends from the under-drains as seen in the combined drain concentration determined as a weighted average based on the flow rates for the three contributing drains (**Figure 3**) for each metal sampled. The exception to this relationship is lead during high flows of 2008, which was higher than any sample dating back to 2004. Typically, the total metals concentrations during the high flow periods decrease, due to the larger volumes of water, which act to dilute the metals and then increase during the lower flow periods. With the exception of lead, the overall trend for metals concentrations shows that the peak metals concentration decreases from each of the subsequent year over the period from 2004-2007. This trend indicates that the cap is effectively reducing the exposure for water to the source rock beneath the cap.

While a geo-synthetic membrane and revegetated cover soil prevent meteoric water and snowmelt from infiltrating into the backfilled McLaren Pit, groundwater continues to flow into and through the pit backfill. Spring 101, located along the pit margin at the base of the high wall, is the most upgradient source of groundwater entering the pit. Spring 101 flows at the most consistent flow rate compared to other flashier flowing springs originating further down gradient in bedrock, beneath the overlying pit footprint.

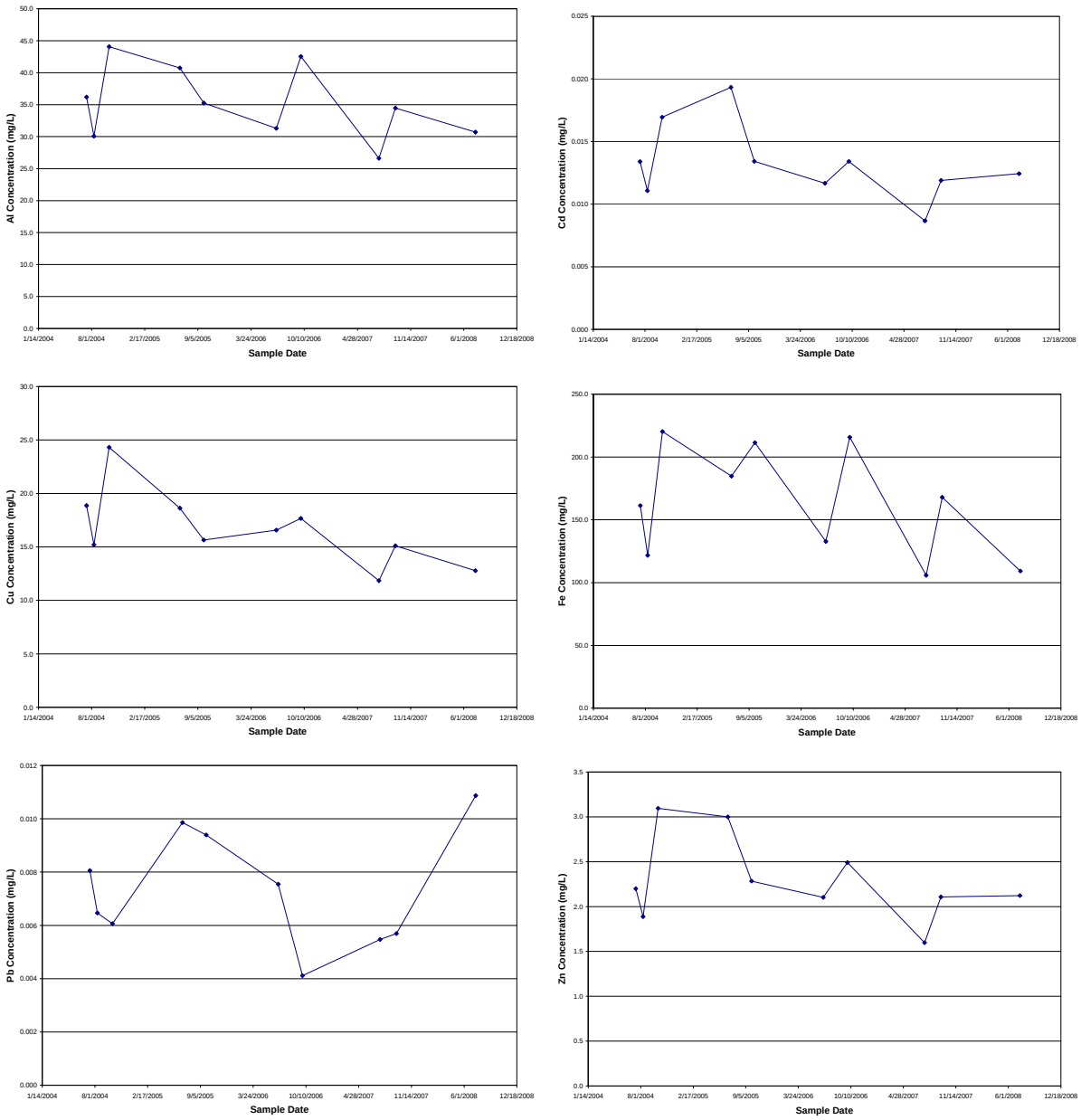


Figure 3 – DCSW-101, -102, -103 Combined Metals Concentrations

Flow from these springs and other springs that does not get captured by the sub-drain system, along with a seasonally fluctuating groundwater table, is the source of groundwater accumulation in the pit backfill. The elevation of this water is measured in two backfill monitoring wells, DCGW-105 close to the high wall near the middle of the pit, and DCGW-104 near the down gradient edge of the pit (**Figure 1**). Rising and falling water elevations are measured seasonally at each backfill well and also in nearby bedrock wells. Both the onset of rising and falling water elevations are initially detected first at DCGW-105 and about two to three weeks later at DCGW-104. Well DCGW-105 typically reaches its lowest level of the year in early November, whereas DCGW-104 often lags behind with the annual low water level being reached in late January.

Fluctuating water levels within the pit backfill promotes formation and subsequent dissolution of oxidation products and mobilization of soluble metals. Periods of falling groundwater head within the mine waste drives seepage of the resulting solute-rich water back into bedrock beneath the pit. This water is then sampled in both in groundwater wells within the pit, and from portions of the springs as it exits the pit at the three under-drain outlets.

Installation of the pit cap has decreased the overall maximum head of water in the pit backfill (7 feet lower at DCGW-104). The decrease in head reduces the magnitude of the backfill water level fluctuation, and therefore, reduces the volume of material that is intermittently saturated. Because less material is intermittently saturated, fewer oxidation products are generated and dissolved, therefore reducing the solute load delivered to groundwater underlying the pit. Reduced solute loading to groundwater beneath the McLaren Pit is believed to be the reason for decreasing trends in metal concentrations measured in under-drain water samples.

The original analysis presented in the Adit EE/CA for the drain flow and chemistry data used the data collected in June 2006 during the high flow sampling event. This analysis indicated that a substantial portion of the metals loading to Daisy Creek was from the McLaren drains. For the analysis presented in this report, the average metals loading at the nearest down-stream Daisy Creek sampling location (DC-2) was determined using the 2004-2007 mean flow data, average high flow and average low flow data from the various sampling events. Using these values, the total metals contribution to Daisy Creek from the under-drains ranged from 22.5% at mean flow rates to 39.3% at average low flow rates as shown in **Figure 4** and detailed in **Table 1**. Using the average data for flow is likely to give a better overall picture of volumes that would need to be treated in a SSBR or LSBR system, rather than using one point in time for evaluation such as was done with the 2006 data in the Adit EE/CA. However, for system sizing and cost purposes, rather than using high flow data, the mean flow data will be used in the analysis presented in this report. A provision for a system bypass will be included for the relatively short high flow period each season. This will minimize cost and system footprint, while ensuring that the greatest metals loading, during lower flows will be treated as effectively as possible. It is assumed for this analysis that the water quality will remain consistent from the under-drains. Under this assumption, the average combined drain flow and water quality values were used for analysis in the balance of this report.

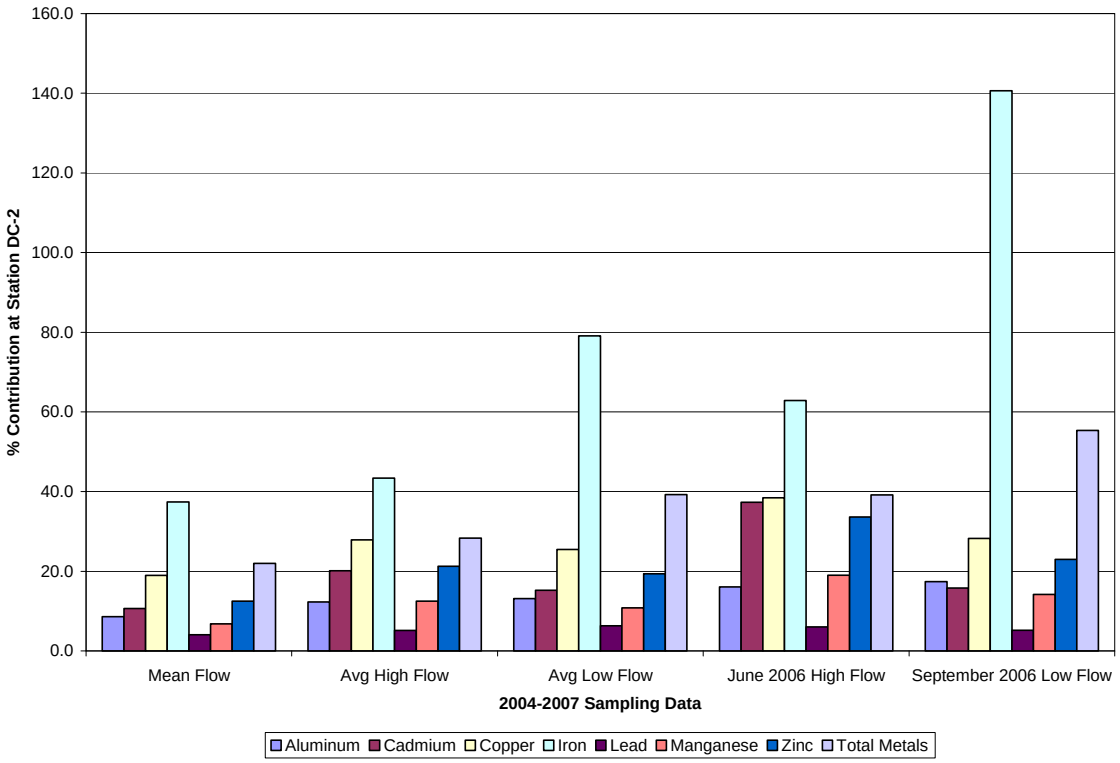


Figure 4 - Metals Loading at DC-2 from McLaren Pit Subsurface Drains

The combined total metals loading from the subsurface drains and the percent contribution at DC-2, the nearest down-stream sampling location in Daisy Creek, are shown in **Table 1** below for the June 2006 high flow and September 2006 low flow periods as presented in the EE/CA, as well as the loading using the average high flow and average low flow water chemistry data for 2004-2007. Also shown are the mean flow metals loading values used for the current analysis.

Table 1. Metals Loading from the McLaren Subsurface Drains

	Average High Flow Metals Loading (kg/month)	Average Low Flow Metals Loading (kg/month)	Mean Flow Metals Loading (kg/ month)	June 2006 Metals Loading (kg/month)	September 2006 Metals Loading (kg/month)
Aluminum	215.5	27.9	123.8	190.6	22.2
Cadmium	0.087	0.010	0.049	0.071	0.007
Copper	106.6	13.3	61.5	101.0	9.2
Iron	928	148	592	809	112
Lead	0.047	0.005	0.026	0.046	0.002
Manganese	26.26	3.80	16.03	24.62	3.12
Zinc	14.63	1.82	8.45	12.81	1.30
Total	1291.4	194.6	802.2	1138.0	148.2
% Contribution at DC-2	21.3%	39.3%	22%	39.1%	55.4%

This table indicates that while the percent contribution at DC-2 is higher for the 2006 sampling event data, the total metals loading to Daisy Creek is less when using 2006 data than for the data using average high flow values. This is a result of the average high flow and average low flow, 39.6 gpm and 4.6 gpm respectively, being greater than the 2006 high flow and 2006 low flow, 37.2 gpm and 3.2 gpm, respectively. The design flow rate used in the EE/CA was 22 gpm for the combined flow for the drains. The current analysis also indicates an average mean flow of 22 gpm which will be the flow rate used for the current analysis. The average values for metals concentrations determined as a weighted average based on the flow rates for the three contributing drains will be used for system sizing and design considerations in this evaluation as shown in **Table 2** and detailed in **Appendix A**.

Table 2. Mean Flow Rate and Water Quality Data for McLaren Drains

Station Name	Flow (gpm)[(1)]	Aluminum (mg/L)	Cadmium (mg/L)	Copper (mg/L)	Iron (mg/L)	Lead (mg/L)	Manganese (mg/L)	Zinc (mg/L)
DCSW-101	13.5	28.6	0.010	14.0	139	0.009	3.20	1.78
DCSW-102	7.2	30.6	0.016	17.3	145	0.003	4.74	2.72
DCSW-103	1.3	91.7	0.025	35.8	432	0.003	12.7	4.35
Combined	22.0	32.8	0.013	16.3	157	0.007	4.2	2.2

(1) Combined mean flow rate used for full scale design

4. Sulfate Reducing Bioreactor Systems

a. Anoxic Limestone Drains

In the Adit EE/CA it was suggested that the bioreactor systems incorporate an anoxic limestone drain (ALD) into the design, in order to add alkalinity and increase the pH of waters prior to entering the bioreactor. It is well known that armoring of the limestone can occur quickly when high levels of iron and aluminum are present and thereby risk clogging of the influent piping by their precipitation. In addition, armoring of the limestone with these chemical precipitates in the ALDs greatly reduces its effective acid buffering potential. It has been recommended that ALDs not be used when high levels of aluminum are present due to the complexity and lack of understanding of aluminum chemistry (Gusek, 2001). As an

alternative to an ALD, limestone is typically incorporated into the matrix of a SSBR system to add alkalinity to the water and raise the pH. When the limestone is incorporated into the matrix, the precipitation of metals which leads to the armoring effect in an ALD is minimized by effectively distributing the area for precipitation throughout the reactor rather than allowing precipitation to occur primarily at the location of the inlet pipe. This also reduces the armoring effect of the limestone at the inlet piping as discussed above. As a result, the ALD has been eliminated for consideration in the proposed design. For addition of alkalinity and increase in pH for a LSBR, in addition to the limestone incorporated into the matrix, sodium hydroxide is metered into the influent water upstream of the bioreactor and the resulting iron and aluminum precipitates formed are allowed to settle out of suspension in a settling pond prior to flowing through the bioreactor.

b. Solid Substrate Bioreactor

There are two types of sulfate reducing bioreactor systems commonly employed for treatment of AMD. The first, a solid substrate bioreactor (SSBR) is considered a passive system in that once the system is set up and running, there is little support needed for operations, assuming the conditions of the reactor bed are conducive for bacterial growth. There are challenges associated with this type of system as well, which are discussed below. The SSBR employs a solid matrix of organic material, which serves as both a physical support and carbon energy source for bacteria. The bacteria are used to oxidize the carbon source, which in turn results in a subsequent reduction of dissolved oxygen (DO), sulfate and ferric iron. As the DO is reduced, this system begins to operate as an anaerobic (without oxygen) system, where sulfate reducing bacteria biochemically reduce sulfate and iron to form iron-sulfides. The sulfate reducing bacteria function best at a pH of 5.5 or higher (URS, 2003), and typically the pH acidic waters at a mine site must be increased for successful operation of a bioreactor. The pH in a passive SSBR system is typically increased and alkalinity added to the system using limestone. The limestone also acts to oxidize and precipitate much of the iron present as an iron hydroxide phase, which in turn minimizes the load of metals that needs to be reduced biologically. In a SSBR, many of the metals in the pH adjusted water are reduced to metal sulfide precipitates within the reactor, and the treated water is then typically sent to an oxic limestone drain where additional alkalinity and oxygen are added to the water prior to discharge. This is important for maintaining conditions of pH and DO in the receiving stream favorable to aquatic life.

c. Liquid Substrate Bioreactor

The second type of bioreactor system considered is a semi-passive system called a liquid substrate bioreactor (LSBR). The LSBR is more complex and may require more operational support (semi-passive) than a SSBR in order to be successful. Like the SSBR, a LSBR also reduces metals in an anaerobic system; however, the support media for the bacteria is typically a mix of large and small rock, and the carbon source for the bacteria is a liquid carbon source, such as ethanol, that is fed into the system with the influent wastewater. As discussed above, the bacteria are more productive at a pH greater than 5.5. In a LSBR, the pH is typically raised through the upstream addition of sodium hydroxide (NaOH) liquid to the waste water stream and the resulting bulk metal precipitates allowed to settle from suspension in a settling pond prior to entering the bioreactor. This settling of precipitates reduces the metals load in the LSBR and results in a smaller metals load to be biologically treated in the reactor. The effluent from the LSBR is also sent to an oxic limestone drain to add alkalinity and oxygen to the water before discharge.

d. Discussion

The main differences between the SSBR and LSBR are the materials used for the support matrix for the bacteria and the nature of the carbon used as an energy source by the bacteria. A typical support matrix for a SSBR consists of a mixture of solid organic materials (i.e., hay, wood chips, etc.), manure for the establishment of a bacterial population, and limestone for addition of alkalinity. Theoretically, the bacteria will continue to reduce sulfate and form metal sulfide precipitates as long as there is sufficient limestone to ensure the incoming water is not too acidic for bacteria survival, and there is enough available organic

material to facilitate bacterial growth. The most common operational problems encountered with the SSBR are; invasion of plants resulting in the introduction of oxygen to the subsurface treatment system, creation of preferential flow pathways due to compaction and low permeability of the organic matrix, inundation of acidity and metals loading due to storm surges, and system desaturation (URS, 2003). It is possible that a passive system could run unattended for decades without intervention due to the small amount of process sludge generated, relative to active systems. In addition, it should be standard practice that passive treatment systems be designed to treat for several decades without a major system overhaul or substrate reconstruction (Gusek, 2001); however this has not been the case to date.

The system design for a SSBR may incorporate measures intended to mitigate some of these challenges such as burying the reactor below the root zone for most native plants at the site or covering the reactor in oxygen impenetrable membranes, providing a surge pond to minimize fluctuations in flow rate and metals loading to the bioreactor, and providing a bypass when the flows are too high to mitigate with a surge pond. Due to one or more of the problems cited above, the longest reported run time for a SSBR has only been 3 to 4 years before significant modifications were required (URS, 2003).

Many of the difficulties typically associated with the SSBR systems have been overcome through implementation of LSBR systems. The use of rock for the solid support matrix in the LSBR for bacterial growth allows for sufficient pore space for infiltration of wastewater to the system and steady-state permeability conditions for metals precipitation without forming preferential flow pathways such as those that form in a SSBR. Constant permeability is not possible in a SSBR because the organic matrix breaks down over the course of systems operation as the carbon source is used by the bacteria and results in a collapse of the matrix and filling of the pore spaces. Over time, the system is unable to treat the design flow of wastewater, and the system must be shut down for removal and replacement of the substrate.

In a LSBR the pH of the water is raised with the addition of NaOH liquid to the influent water. The NaOH can be added and the water sent to a settling pond where the metal hydroxides (primarily iron) are allowed to precipitate out of solution before entering the bioreactor. This reduces the metals loading in a LSBR from what is seen in a SSBR where the limestone is an integral part of the solid matrix. The carbon source in a LSBR is a liquid alcohol carbon substrate, such as ethanol, which is added to the influent water after pH adjustment and eliminates the problems associated with the breakdown of carbon substrate as discussed above for a SSBR. An additional benefit of using a liquid carbon source in a freezing climate is that the alcohol will act to reduce or eliminate freezing of the system during winter operations and result in higher bacterial efficiency. A full scale LSBR has been successfully operated at the Leviathan Mine in California from 2003-2007 (Zamzow, 2008) and indicates that continued operation of the system is feasible into the future.

5. Bioreactor System Sensitivity to Changing Parameters

When designing a treatment system, it is important to consider how changing conditions may affect the performance and effectiveness of the system. The flow rate and water chemistry, namely metals loading and sulfate concentration, are important in designing a bioreactor system. It is necessary for sulfate to be present in excess of the total metals for successful metals removal in this type of system. The pH and temperature of the influent water are critical to the health of the bacterial population. If the pH is too acidic (<5.5) or the temperature too low, the bacteria are less likely to flourish. It has been found that the effectiveness of a bioreactor treatment system is lower in the winter months than in the warmer months (Johnson & Hallberg, 2002); however, for the LSBR, this temperature fluctuation would be less important due to the addition of alcohol acting as an anti-freeze in the influent water.

The flow rate will affect the dynamics of a bioreactor system. If the system should become overwhelmed due to a higher flow rate than the design allows for, the bacterial population will be unable to treat the metals load and a severe die-off of the bacterial population may be seen in the system. It is also possible that at too high a flow rate, a portion of the bacterial population may be washed out of the system. In

either case the population may be unable to recover once the flow rate returns to normal and the bacterial population would therefore have to be reestablished. It is recommended that a holding pond be installed upstream of the bioreactor to minimize flow fluctuations during high flow events, and the system design should include a bypass should the holding pond have insufficient capacity to store high flows.

At a low sustained flow rate, some of the anaerobic substrate in a SSBR may become oxidized and precipitated metals may be flushed out of the system into the effluent. For the current design, it is suggested that in order to minimize the difficulties presented by flow variations, the system design should regulate flow through the use of a holding pond, and placement of a layer of inert gravel covering the SSBR to accommodate fluctuations in head (URS, 2003). To strike a balance between treating the high metals load to Daisy Creek present during the low flows, while accommodating higher flows when needed, the current system sizing is based on the average flows and water chemistry with a holding pond to provide surge protection to the system, and a system bypass to eliminate excessively large flows through the system. The SSBR design also contains a layer of inert gravel to further accommodate head fluctuations.

6. Bioreactor Bench-Scale Pilot Studies

The ability to size and design the proper bioreactor treatment system depends on the influent water quality, including flow rate and metals loading. Whether a SSBR or a LSBR is chosen, it is important to determine the operating conditions best suited for the particular AMD of concern. These factors are best determined through pilot studies. Through pilot testing, the determination of which carbon source is most effective under what pH conditions can be tested for each type of bioreactor, and the systems sensitivity to varying conditions may be verified. Using this information, combined with the cost analysis, the appropriate full scale treatment technology for the McLaren under-drains can be best evaluated.

It is assumed for purposes of the bench and pilot scale testing cost analyses that since this bioreactor technology has been established in the literature to be appropriate for the type of AMD from the McLaren drains, a laboratory-scale pilot test may be omitted and that a bench scale study would first be conducted. The bench scale testing can be performed in the laboratory or in the field; however, for this cost analysis, it is assumed that the testing for this phase would be performed in the laboratory to minimize travel and labor costs due to the location of the site. The bench scale testing would be conducted using the AMD collected in proper proportions from the three drains. At the bench scale, it is necessary to determine for a SSBR the mixture of organic materials best suited for this discharge as well as the optimal configuration; and for a LSBR, which liquid carbon source and dose is optimal for use by the bacteria. The ability to vary the water flow and quality for testing purposes are also much more controllable in a laboratory, prior to testing under field conditions. During the bench scale testing phase, the optimal pH can be determined and factors affecting the bioreactor such as temperature and flow fluctuations can be controlled and evaluated. The goal of the bench scale testing is to determine whether a SSBR or a LSBR would be the more appropriate technology for this site and to focus subsequent field scale pilot studies on one of these technologies.

The costs associated with laboratory scale testing include; raw materials necessary for each type of bioreactor including test units, carbon sources, limestone and/or chemical addition of NaOH; collection and shipment of source waters; setup and operating time for the laboratory technician; and sampling costs. Bench scale test units can typically be put together using items readily found in a hardware store such as trash cans and kiddie wading pools (Gusek, 2001). The assumed testing matrix includes a control reactor for each SSBR and LSBR, as well as one reactor for each SSBR and LSBR to study the effects of pH, temperature, flow variations and chemistry variations, for a total of 10 bioreactors.

The time required for inoculation and acclimatization of the bacteria can be on the order of weeks to months depending on the available carbon source and bacteria present. The bench scale testing design and setup is assumed to take approximately one week. The inoculation and establishment period for the

bacteria is assumed to be six weeks. During this period, one effluent sample per week per reactor should be sufficient to determine the establishment of a suitable bacterial population in each bioreactor, and in addition one influent sample should be collected each week, for a total of 11 samples/week. Once the bioreactors are established, the variable factors can be changed to determine the dynamic responses of the system. It is estimated that this may take up to an additional ten weeks. The cost for labor includes a full one week set up time, one hour per week during the acclimatization period and three hours per week during the ten week run time with changing variables.

The following table (**Table 3**) details the estimated cost for a bench scale pilot test for water from the McLaren under-drains.

Table 3. Cost Estimate for Bench Scale Testing

Component	Unit	Unit Cost	Quantity	Total Cost
Bioreactor/Raw Materials	each	$150	10	$1,500
Labor	hour	$110	76	$8,360
Sampling	week	$2,200	16	$35,200
Total Bench Scale Costs				$45,060

7. Bioreactor Field-Scale Pilot Studies

Once the appropriate type of bioreactor is determined through the bench scale testing, a field pilot scale test would be suitable to get a better picture of how the actual operating conditions at the site may affect the bioreactor. The cost associated with each type of bioreactor is discussed and costs presented below.

If during bench scale testing, it is determined that a SSBR is the desired technology for the McLaren site, the costs associated with the setup and pilot testing in the field include raw materials delivered to the site, travel to the site, shipping of miscellaneous items, mobilization/demobilization, chemicals, sampling and labor. For the field scale pilot test for a SSBR, AMD Treat software Version 4.1c was used for sizing and preparation of the cost estimate. Results from AMD Treat and system costs are found in **Appendix B**.

The assumptions for the SSBR field scale pilot testing system are as follows:

- The water chemistry used for sizing was taken directly from the mean values recorded during site sampling from 2004-2007 (**Table 1**),
- Flow rate is 2 gallons per minute,
- All raw materials for the system are delivered directly to the site,
- System setup requires two technicians, two weeks to install,
- Acclimatization time for the bacteria is six weeks from startup,
- System setup would commence in early July and would run through September (approximately 10 weeks run time after acclimatization),
- Sampling would be done weekly from startup for both influent and effluent and require one full day each week to complete,
- SSBR sizing from *AMDTreat* Software
- SSBR costs obtained from *RSMeans* and experience,
- Travel to the site for sampling is from the Tetra Tech Bozeman office,
- Freezing will not be an issue for the duration of the testing and therefore the reactor will be above ground,
- Once the system is set up, there is no additional maintenance or modification required for the duration of the testing,
- Some engineering would be required for system design, 10 percent of total is assumed.

Table 4. Cost Estimate for Field Pilot Scale SSBR

Component	Unit	Unit Cost	Quantity	Total Cost
Organic/Limestone Fill for Bed	Ls	$6,871	1	$6,871
Shipping/Delivery of Materials	ls	$2,500	1	$2,500
Bed Liner	ls	$2,587	1	$2,587
Miscellaneous Building Materials	ls	$1,500	1	$1,500
Labor	hour	$110	288	$31,680
Travel (mileage)	week	$135	18	$2,430
Estimated Per Diem	day	$112	18	$2,016
Sampling	week	$2200	16	$35,200
Sub Total Field Pilot Scale Costs SSBR				$84,784
Engineering	ls	$8,234	1	$8,478
Total Field Pilot Scale Costs SSBR				$93,262

The assumptions made for determining sizing and cost for a pilot scale LSBR are as follows:

- The residence time in the reactor is 2 days (Zamzow, 2008),
- The water chemistry used for sizing was taken directly from the mean values recorded during site sampling from 2004-2007 (**Table 1**),
- Flow rate is 2 gallons per minute,
- Bed porosity is 35 percent,
- All raw materials for the system are delivered directly to the site,
- System setup requires two technicians two weeks to install,
- Acclimatization time for the bacteria is six weeks from startup,
- System setup would commence in early July and would run through September (approximately 10 weeks run time after acclimatization),
- Sampling would be done weekly from startup for both influent and effluent,
- LSBR costs obtained from *RSMeans* and experience,
- Travel to the site for sampling is from the Tetra Tech Bozeman office,
- Freezing will not be an issue for the duration of the testing and therefore the reactor will be above ground,
- Once the system is set up, there is no additional maintenance or modification required for the duration of the testing,
- Some engineering would be required for system design, 10 percent of total is assumed.

Table 5. Cost Estimate for Field Pilot Scale LSBR

Component	Unit	Unit Cost	Quantity	Total Cost
Rock Fill for Bed	cy	$25	82	$2,050
Shipping/Delivery of Materials	ls	$2,500	1	$2,500
Bed Liner	sy	$3.00	110	$330
Miscellaneous Building Materials	ls	$1,500	1	$1,500
Chemical Costs	ls	$450	1	$450
Labor	hour	$110	288	$31,680
Travel (mileage)	week	$135	18	$2,430
Estimated Per Diem	day	$112	18	$2,016
Sampling	week	$2200	16	$35,200
Sub Total Field Pilot Scale Costs LSBR				$78,156
Engineering	ls	$7,810	1	$7,816
Total Field Pilot Scale Costs LSBR				$85,972

8. Full Scale Bioreactor Design Considerations and Cost Analysis

Several considerations must be taken into account for a full scale design of a bioreactor treatment system. The water quality and flow rate data are essential for design of either type of SBR system. In addition, the location must allow for a large area to accommodate the footprint of the system complete with holding pond, bioreactor unit and oxic limestone drain. It is also necessary to consider a settling pond for a LSBR system. The site near the McLaren drains is relatively steep at the location where they currently discharge. The slope decreases west of the drains, down towards the valley bottom and this is likely the best location for placement of the bioreactor system. The groundwater tends to be shallow along the hillside south of the sub-drain discharge points and as one moves closer to the tributary drainage to Daisy Creek, and is generally deeper west of the drains and north of the tributary drainage, again down towards the valley bottom; however while this valley bottom area may be a possible location for sighting of the facility, a detailed analysis of available land and water levels must be considered during the project engineering design phase.

The following general assumptions are made for either type of substrate bioreactor (SBR):

- All bulk fill materials are delivered directly to the site,
- Subsurface drain flows are combined at the existing discharge locations and piped downhill to the holding pond for the SBR,
- System flow rate is 22 gpm based on combined mean flow data,
- A geotextile will cover the holding pond and SBR to minimize infiltration of runoff, precipitation and snowmelt and to minimize oxygen infiltration,
- The holding pond, SBR and oxic limestone drain are lined with geotextile to minimize water loss,
- The holding pond hydraulic retention time is 24 hours at design flow,
- The holding pond will be filled with geochemically inert gravel so that pond can be buried,
- The holding pond and SBR will be buried and covered with 4 feet of soil to minimize freezing,
- Soil cover for the holding pond and SBR will be obtained locally, perhaps from the borrow area,
- The system would not require maintenance and sampling would be unnecessary during the winter weather months.
- Conservation of mass upon mixing of the drains is assumed,

Solid Substrate Bioreactor Costs

As discussed previously, the location of the discharge of the drains is in an area which is not conducive for placement of a bioreactor treatment system. It is assumed that a single pipe conveying the combined flow from the drains would extend from the existing drain outlets approximately 400 feet down slope to the west. The design allows for piping and associated valving for water conveyance to the system. The combined drain flow will feed the front end of the reactor system at the lined and covered holding pond (**Figure 5**), which will serve to minimize flow fluctuations into the SSBR. The influent will flow from the holding pond to the SSBR, which consists of a layer of geochemically inert gravel at the top to accommodate head fluctuations and at the bottom to minimize metals plugging of the piping at the influent to the SSBR. The SSBR will be lined and consist of a mix of limestone, organic substrate and manure. The limestone will add alkalinity and raise the pH, the manure is incorporated to provide an inoculum of bacteria necessary for sulfate reduction, and the organic substrate is the matrix which provides the carbon energy source and support for the bacteria. It is assumed that the organic substrate is a mixture of hay and wood chips, although the optimal material and mixture would be determined during the bench scale testing. The effluent from the SSBR is directed to an oxic limestone drain (OLD) before discharging to Daisy Creek. The system is fitted with a bypass from the holding pond to the discharge at the OLD for flows which may not be accommodated by the treatment system at the highest flow rates.

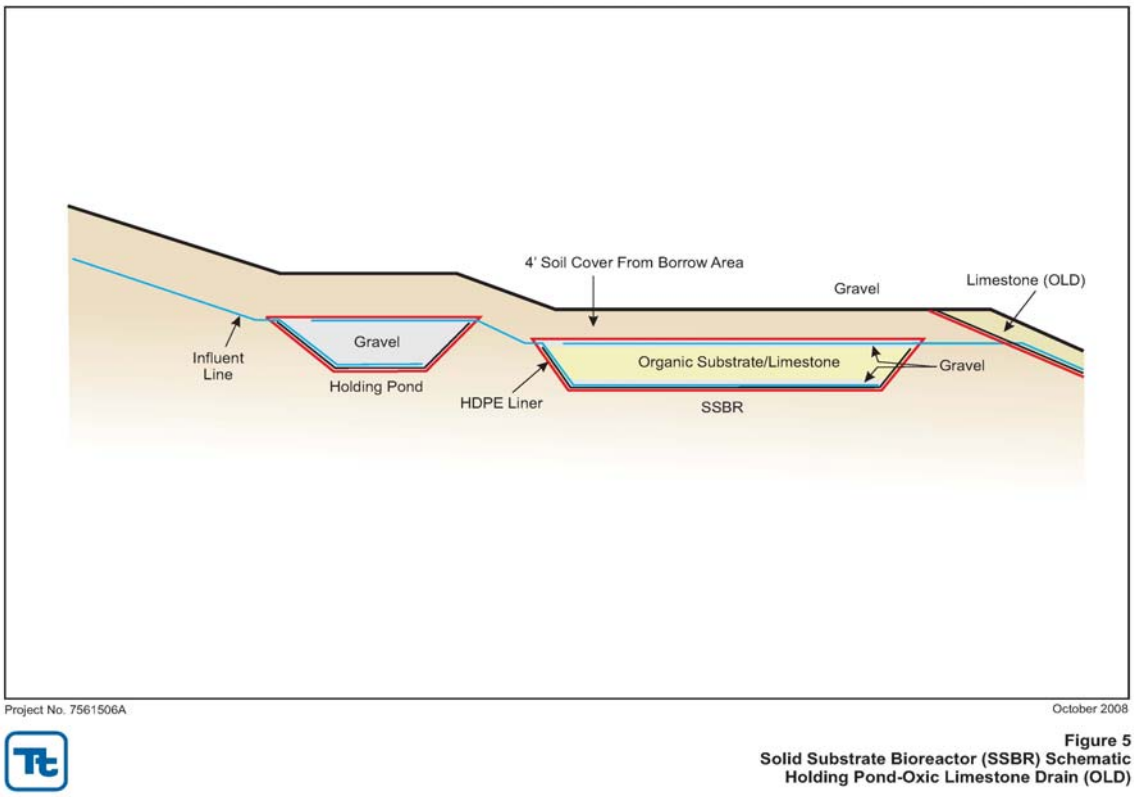


Figure 5
Solid Substrate Bioreactor (SSBR) Schematic
Holding Pond-Oxic Limestone Drain (OLD)

The total area required for the SSBR is just over 1 acre for the holding pond and the SSBR and a 100 foot long channel for the OLD.

It has been reported that sulfate concentrations typically do not drop below a few hundred milligrams per liter (mg/L) in a sulfate reducing bioreactor (URS, 2003). The measured sulfate in the combined drains is 804 mg/L. It is assumed that the sulfate reduction is 500 mg/L for purposes of design. The longest operating period for an SSBR has been reported to be only three or four years without requiring replacement of the organic substrate (URS, 2003). The expected life of the SSBR for this study is assumed to be five years before cell replacement is necessary. The present worth analysis for system operations and maintenance was assessed assuming a 20 year life for the project.

The SSBR was sized using *AMDTreat* Software Version 4.1c and cost estimates that would be expected for this type of project are provided using *AMDTreat*, *RSMeans* Building Construction Data for 2008 and project experience as detailed in Appendix C. A cost summary presented below in **Table 6**.

Table 6. Capital and Operational Cost Estimate Summary for Solid Substrate Reactant Bioreactor (SSBR) for Typical System

Total Direct Capital Costs	$329,632
Total Indirect Capital Costs	$144,682
O&M Costs (Present Worth)	$1,277,955
Total	**$1,752,270**

Experience at the New World site has proven that construction costs commonly exceed those typically expected. As a result, a comparative cost analysis was performed using construction cost data from former projects at the New World site. The cost analysis using information from the New World McLaren Pit Response Action Construction Report (Civil Consulting Services, PLLC, 2006) and the Selective Source Response Action Construction Report (Civil Consulting Services, PLLC, 2006) is presented in Appendix E. The changes from the above cost analysis are indicated in red. A summary of the project costs using this data is presented in **Table 7.**

Table 7. Capital and Operational Cost Estimate Summary for Solid Substrate Reactant Bioreactor (SSBR) Using New World Cost Data

Total Direct Capital Costs	$543,642
Total Indirect Capital Costs	$272,189
O&M Costs (Present Worth)	$1,623,790
Total	**$2,439,622**

Liquid Substrate Bioreactor Costs

Again, it is assumed that a single pipe conveying the combined flow from the drains would extend from the existing drain outlets approximately 400 feet downhill to the west. The design allows for piping and associated valving for the conveyance of water to the treatment system. The combined drain flow will feed the front end of the reactor system at the lined holding pond (**Figure 6**), which will serve to minimize flow fluctuations into the LSBR. The sodium hydroxide (NaOH) will be added to the effluent from the holding pond to increase the pH of the water to sustain the bacterial community and provide conditions conducive for bulk metals precipitation. The freezing temperature of 20% NaOH is -15°F. It is likely that the temperature at the McLaren site will reach temperatures lower than this during the winter months and a solar system or propane tank would be necessary to run heat tape to keep the solution from freezing and to run the chemical injection pump and has been included in the cost analysis. It is possible to design the system, such that should a problem occur with the chemical feed system, the operator of the site would be notified.

The holding pond effluent is directed into the lined settling pond. The settling pond is sized for a 14 day hydraulic residence time for metals precipitation, and will be buried to provide frost protection and lined and covered to minimize in/exfiltration. It is assumed that both ponds will be covered with four feet of soil cover from the borrow area at the site. The pH adjusted water will flow from the settling pond into the LSBR and the carbon source, assumed to be ethanol, added just before the flow enters the reactor. The reactor is lined and filled with a mixture of smaller and larger rock to balance the need for greater surface area while providing sufficient porosity to prevent plugging. The design also incorporates manure for inoculation of bacteria necessary for sulfate reduction. The hydraulic residence time for the LSBR is two days.

The treated water from the LSBR flows through a lined oxic limestone drain to further increase the pH and to add oxygen back into the discharge prior to discharging to Daisy Creek. The system is fitted with a bypass from the holding pond to the discharge at the OLD for flows which may not be accommodated by the treatment system at the highest flow rates. The expected life of the LSBR is assumed to be fifteen years before cell replacement is necessary. The present worth analysis for system operations and maintenance was assessed assuming a 20 year life for the project.

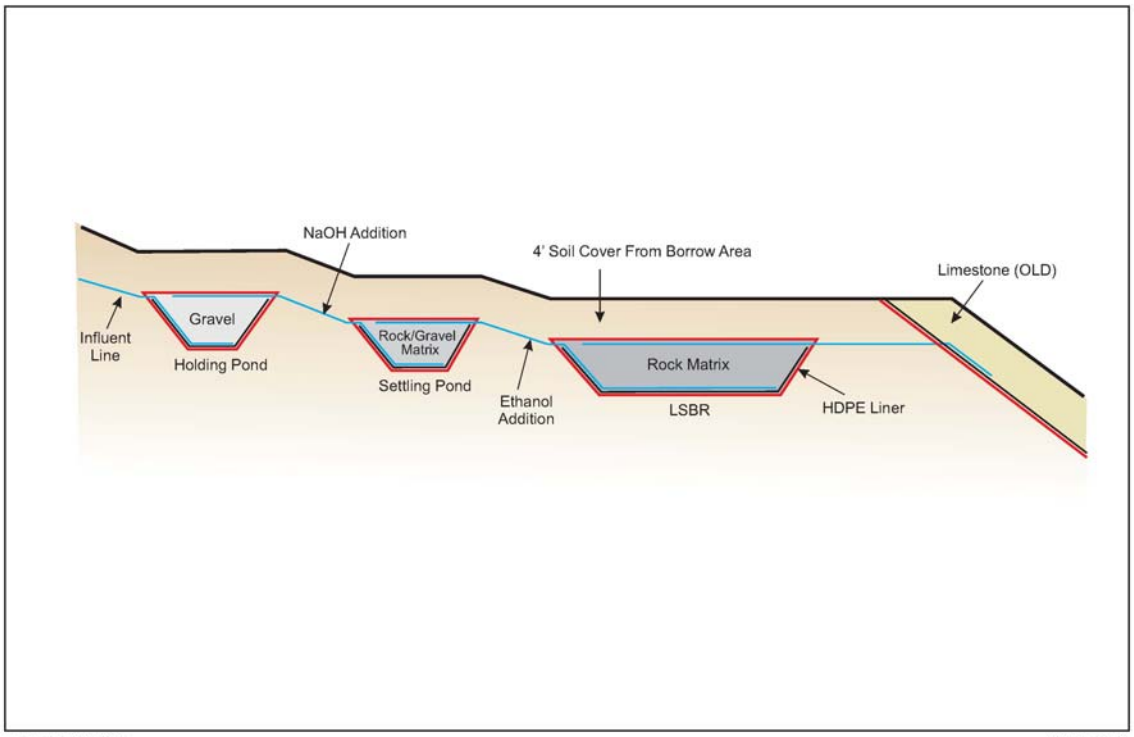


Figure 6
Liquid Substrate Bioreactor (LSBR) Schematic
Holding Pond-Settling Pond-Oxic Limestone Drain (OLD)

The total area required for the SSBR is just over 2 acres for the holding pond, settling pond and the LSBR and a 100 foot channel for the OLD.

Cost estimates that would be expected for this type of project are provided using *AMDTreat*, *RSMeans* Building Construction Data for 2008 and project experience as provided in **Appendix D**. A cost summary is presented below in **Table 8**.

Table 8. Capital and Operational Cost Estimate Summary for Liquid Substrate Reactant Bioreactor (LSBR) for Typical System

Total Direct Capital Costs	$476,917
Total Indirect Capital Costs	$194,999
O&M Costs (Present Worth)	$544,817
Total	**$1,216,733**

Experience at the New World site has proven that construction costs commonly exceed those typically expected. As a result, a comparative cost analysis was performed using construction cost data from former projects at the New World site. The cost analysis using information from the New World McLaren Pit Response Action Construction Report (Civil Consulting Services, PLLC, 2006) and the Selective Source Response Action Construction Report (Civil Consulting Services, PLLC, 2006) is presented in Appendix E. The changes from the above cost analysis are indicated in red. A summary of the project costs using this data is presented in **Table 9.**

Table 9. Capital and Operational Cost Estimate Summary for Liquid Substrate Reactant Bioreactor (LSBR) Using New World Cost Data

Total Direct Capital Costs	$1,177,089
Total Indirect Capital Costs	$492,664
O&M Costs (Present Worth)	$602,807
Total	**$2,272,559**

Comparison of SSBR and LSBR

The tables above indicate that while the capital cost of a solid substrate bioreactor is less than that of a liquid substrate bioreactor, the operations and maintenance costs result in greater overall project expenditure. This is due mainly to the breakdown of the organic matrix in the SSBR and the requirement of replacement of the entire bed at intervals assumed to be every five years. The cost information provided in the construction reports for the New World site indicate that the costs associated with construction are considerably more than what is expected for this type of project. The analyses indicate that the cost for the SSBR may be 140% and the LSBR almost 190% of what was determined using standard cost estimate data.

Summary and Comparison of Various Cost Estimates for SSBR and LSBR

Table 10 compares the cost estimates for the construction of the SSBR and LSBR prepared for this report, using New World Cost data (revised for the remote New World location and under more extreme climatic conditions), vs. those generated in the original EE/CA for the same site conditions (Tetra Tech 2006).

Table 10. Comparison of Cost Estimates.

	SSBR		LSBR	
Cost	**2005 EE/CA Costs**	**This Report New World Cost Data**	**2005 EE/CA Costs**	**This Report New World Cost Data**
Direct Capital	$573,046	$543,642	$865,525	$1,177,089
Indirect Capital	$315,175	$272,189	$471,089	$492,664
Total Capital	$888,221	$815,831	$1,327,614	$1,669,733
O & M Cost	$2,350,000	$1,623,790	$3,535,485	$602,807

When comparing costs in **Table 10**, it is important to note that for the EE/CA, cost analysis were developed for a system designed to treat an average flow of 35 gallons per minute that included flow from the combined McLaren Adit as well as the McLaren under-drains; whereas, the costs developed for this report were for a system designed for an average flow of 22 gallons per minute from the under drains only. Overall, direct and indirect costs from the two reports for the SSBR are reasonably similar; however, in the case of the LSBR the cost generated for this report are slightly higher.

Operational costs (**Table 10**) for the LSBR in the EE/CA assumed replacement of the entire system every 10-years, whereas; in this report the cost of the LSBR using adjusted New World costs assumed replacement of the liquid substrate portion of system only every 15-years. Therefore, the reason for the rather large discrepancy in operational and maintenance cost results principally from the frequency of

replacement of the liquid substrate and because the costs developed for both systems in this report did not call for replacement of the piping supply portion of the system, replacement of the gravel/rock materials contained in the holding or settling ponds, or site specific sampling costs, whereas the EE/CA did. In addition, bench and pilot scale testing costs for this report are not included in the overall cost of either the SSBR or the LSBR in **Tables 6 through 10**.

Expected Improvement in Water Quality at DC-2

The percent reduction in metals concentration for the LSBR treatment were taken from the results from the Leviathan Mine (EPA, 2006) and for the SSBR from the results of the Golinsky Mine (Golder Associates, 2007), and are presented in **Table 11**.

Table 11. Removal Efficiencies for Metals Concentrations

Parameter	SSBR Removal (%)	LSBR Removal (%)
Aluminum	99.0	99.0
Cadmium	99.0	65.3
Copper	99.0	99.0
Iron	92.0	98.0
Lead	90.0*	35.8
Manganese	10.0*	10.0*
Zinc	96.0	99.0

*Removal efficiencies assumed

While the results indicate a significant overall metals reduction from the McLaren under-drains (**Figure 7**), there is still a major contribution of metals loading from other sources. The total overall metals loading to DC-2 before treatment from the under-drains is 22 percent. This contribution drops to a total metals contribution post-SSBR treatment to 2.2 percent and post-LSBR treatment to 0.8 percent. While this reduction shows that the bioreactor treatment system is both appropriate and successful at metals removal from this type of discharge, the overall results indicate that the total reduction in metals loading to Daisy Creek will not be impacted significantly by implementing this technology.

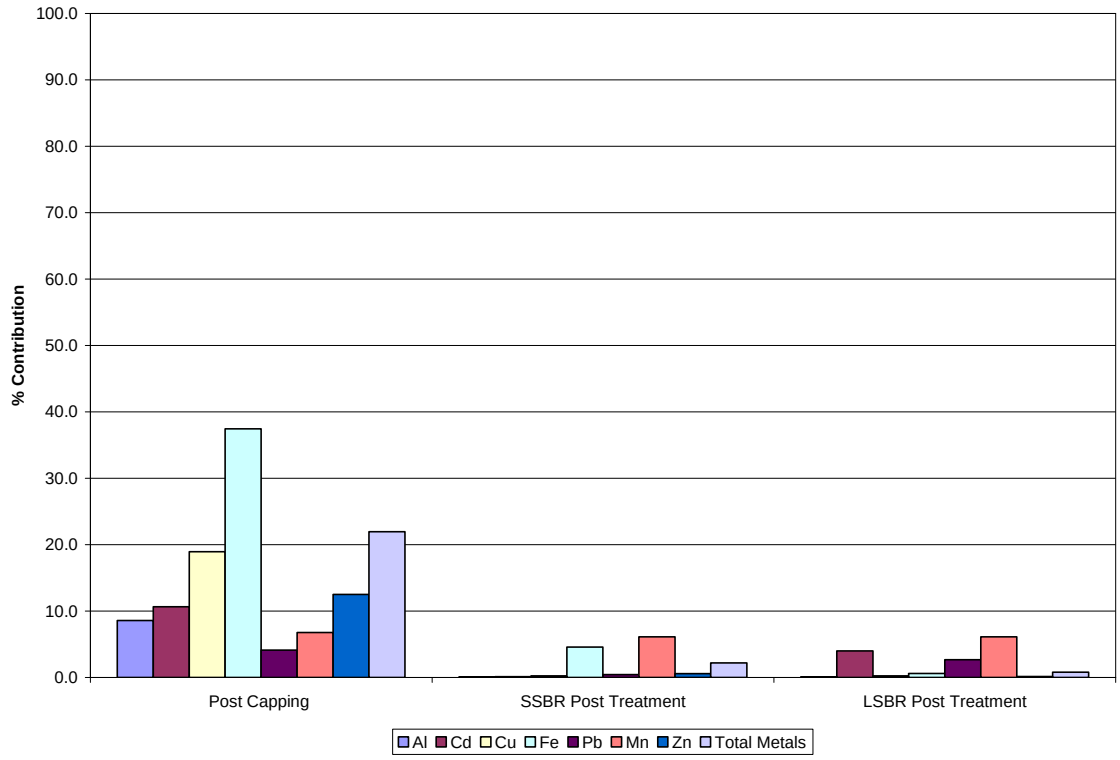


Figure 7. Total Metals Percent Contribution to DC-2 Before and After Treatment

The impact to the DC-2 sampling station after biological treatment is presented in **Figure 8**. The total metals loading from all sources including the McLaren under-drains to DC-2 prior to bioreactor treatment of the McLaren under-drains is 3,653 kilograms per month (kg/month). After SSBR treatment of the McLaren under-drains, the total metals contribution from all sources to DC-2 drops to 2,915 kg/month, an overall reduction in loading of only 20.2 percent. After LSBR treatment of the McLaren under-drains, this value drops to 2,873kg/month total metals loading resulting in an overall total metals reduction to DC-2 of 21.4 percent.

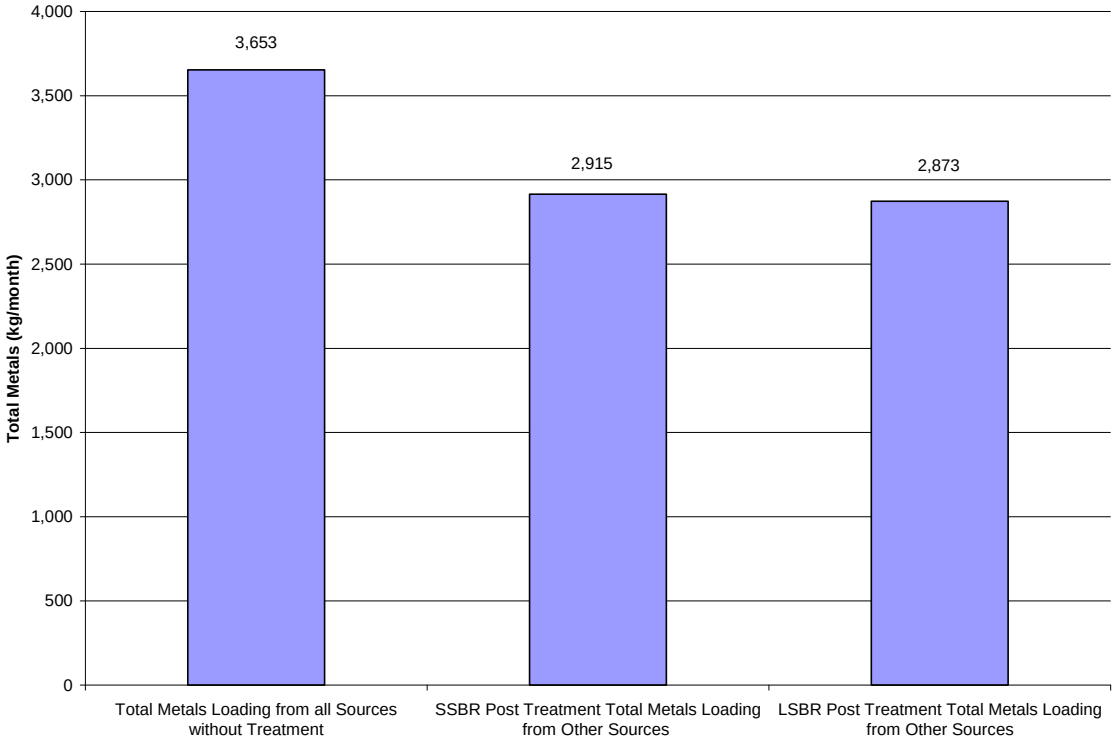


Figure 8. Total Metals Loading to Daisy Creek (DC-2)

The ideal situation of meeting or attempting to meet the Circular WQB-7 for aquatic life standards is unrealistic through treatment of the McLaren under-drain discharges. **Table 12** indicates the expected combined water quality from all sources to DC-2 before and after treatment and compares these values to the standards.

Table 12. Water Quality Standards[1] and Expected Water Quality After Treatment

Parameter	WQB-7 Chronic Aquatic Life Standard (Calculated for Hardness = 50 mg/L)	WQB-7 Chronic Aquatic Life Standard (Calculated for Hardness = 100 mg/L)	Mean Measured Concentration at DC-2 without Treatment	Estimated Concentration After SSBR Treatment[2]	Estimated Concentration After LSBR Treatment[2]
Concentration (mg/L)					
Al	0.087[3]	0.087	8.1	7.4	7.4
Cd	0.00016	0.00027	0.0026	0.0023	0.0025
Cu	0.005	0.009	1.82	1.48	1.48
Fe	1	1	8.88	5.82	5.59
Pb	0.001	0.003	0.004	0.003	0.003
Mn	0.05[4]	0.05	1.33	1.32	1.32
Zn	0.07	0.012	0.38	0.33	0.33

(1) Values as Reported in Tetra Tech EE/CA, 2006.
(2) Based on removal efficiencies presented in Table 8.
(3) Aluminum standard is based on dissolved concentrations and is applicable to water with pH between 6.6 to 9.0.
(4) Manganese standard is a secondary MCL based on aesthetic qualities.

The results clearly indicate that the $2.44 million and $2.28 million expenditures for the SSBR or LSBR system, respectively, would do little to bring the water quality in Daisy Creek near the values, which would make a significant impact to the water quality. The most to be gained from implementation of a bioreactor treatment system would be some reduction in metals loading resulting in modest improvement in the overall water quality to the creek.

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Appendix A

SURFACE WATER SUMMARY FOR McLAREN PIT DRAINS

Station Name	Sample Date	Flow Rate (cfs)	Flow Rate (gpm)	Anions (mg/L)									Cations (mg/L)												Total Recoverable Metals (mg/L)								
				Acidity as CaCO3	CaCO3 Flag	Alkalinity as HCO3	HCO3 Flag	Alkalinity as Total CaCO3	CaCO3 Flag	Chloride	Cl Flag	Sulfate	Calcium	Ca Flag	Hardness as CaCO3	Magnesium	Mg Flag	Potassium	K Flag	Sodium	Na Flag	Field SC (umhos/cm)	Field pH (s.u.)	Total Suspended Solids (mg/L)	TSS Flag	Total Metals	Aluminum	Cadmium	Copper	Iron	Lead	Manganese	Zinc	Zinc Flag
DCSW-101	7/13/2004	0.043	19.30	473		1	<	1	<	6		628	32		125	11		2		2		1270	2.9	2	<	166.9	29.3	0.01	15.8	117	0.012	3.08	1.7	
	8/10/2004	0.035	15.71	440		1	<	1	<	4		560	32		125	11		2		2		1140	3	29		150.0	26	0.0094	13.5	106	0.009	2.91	1.59	
	10/6/2004	0.013	5.83	586	JF%	1	<	1	<	8		686	44		176	16		2		3		1550	3	38	JF	235.9	34.3	0.016	20.7	173	0.007	5.1	2.82	
	6/29/2005	0.05481	24.60	548		1	<	1	<	3		736	37	d	142	12	d	2	d	3	d	1259	2.7	2		201.2	33.7	0.011	15.8	147	0.014	2.81	1.85	
	9/27/2005	0.0074	3.32	593		1	<	1	<	3		748	46	d	185	17	d	2	d	3	d	1415	2.73	3		250.5	31.5	0.012	14.2	199	0.01	3.64	2.09	
	6/27/2006	0.046	20.65	392		0		1	<	1		515	32		114	10		2		2		1198	4.36	10		148.9	26.1	0.0082	13.5	105	0.012	2.74	1.5	
	9/27/2006	0.005	2.24	577		1	<	1	<	1		797	39	d	175	17	d	1	d	3	d	1374	2.93	19	JF%	225.5	29	0.01	13.2	178	0.005	3.41	1.87	
	9/27/2006	--	--	584		1	<	1	<	1		826	43	d	181	18	d	1	d	3	d	--	--	13	JF%	230.9	30.6	0.01	14	181	0.005	3.51	1.79	
	7/18/2007	0.037	16.61	350		1	<	1	<	1		450	27		104	9		2		3		1021	2.8	30		128.5	23.3	0.0069	9.91	91.6	0.007	2.38	1.29	
	9/18/2007	0.0088	3.95	417		1	<	1	<	1		607	40		155	14		2		3		1134	3.04	7		176.1	25.4	0.01	12.6	133	0.006	3.34	1.77	
	7/15/2008	0.0575	25.81	406		1	<	1	<	1		555	35		122	10		2		2				1	<	133.3	25.5	0.0074	10.5	93.7	0.016	2.28	1.32	
	8/12/2008	0.0362	16.26																															
	8/20/2008	0.0321	14.40																															
n*=	11	Min	2.24	350		0		1		1		450	27		104	9		1		2		1021	2.70	1		128.4	23.3	0.007	9.9	92	0.005	2.28	1.29	
		Mean	14.06	488		1		1		3		646	37		146	13		2		3		1262	3.05	14		186.2	28.6	0.010	14.0	139	0.009	3.20	1.78	
		Max	25.81	593		1		1		8		826	46		185	18		2		3		1550	4.36	38		262.0	34.3	0.016	20.7	199	0.016	5.10	2.82	
		Avg High Flow	21.39	441		0.8		1		2.8		582	32		121	10.5		2		2.5		1187	3.19	11.0		161.4	28.1	0.009	13.8	115	0.011	2.75	1.59	
		Avg Low Flow	3.84	543		1.0		1		3.3		710	42		173	16.0		1.8		3		1368	2.93	16.8		222.0	30.1	0.012	15.2	171	0.007	3.87	2.14	
DCSW-102	7/13/2004	0.023	10.32	646		1	<	1	<	4		862	43		186	19		1	<	3		1710	2.6	2	<	201.8	33.5	0.017	19	142	0.002	4.62	2.69	
	8/10/2004	0.013	5.83	496		1	<	1	<	3		641	34		155	17		1	<	2		1360	2.6	4		132.4	23.2	0.011	13.8	90	0.001	3.47	1.95	
	10/6/2004	0.001	0.45	899	JF%	1	<	1	<	30		1160	59		275	31		1	<	3		2010	2.7	4	JF	341.3	39.1	0.017	27.7	265	0.002	6.31	3.18	
	6/29/2005	0.04184	18.78	745		1	<	1	<	2		1030	58	d	240	23	d	1	d<	2	d	1874	2.5	1	<	259.3	42.2	0.029	19.6	187	0.005	6.22	4.29	
	9/27/2005	0.0001	0.04	558		1	<	1	<	4		791	54	d	234	24	d	1	d<	3	d	1613	2.55	4		193.7	24.8	0.016	15.9	146	0.009	4.69	2.33	
	6/27/2006	0.033	14.81	588		0		1	<	1		771	52		192	18		1	<	2		1833	4.17	3		193.4	32.5	0.015	18.5	135	0.002	4.76	2.66	
	9/27/2006	0.0001	0.04	540		1	<	1	<	1	<	876	47	d	220	25	d	1	d<	3	d	1537	2.69	2	JF%	160.4	24.2	0.012	14.2	116	0.002	4.04	1.97	
	6/13/2007	0.052	23.34	665		1	<	1	<	1		875	83		244	20		2		3		1733	2.8	4	<	224.2	31.4	0.019	16.4	168	0.004	4.88	3.49	
	7/18/2007	0.011	4.94	455		1	<	1	<	1		595	40		162	15		1		3		1522	2.59	1	<	139.4	24.3	0.011	13.3	96.3	0.001	3.54	1.96	
	9/18/2007	0.00004	0.02	565		1	<	1	<	2		828	52		235	24		1	<	3		1704	2.65	1	<	181.8	27.1	0.012	16.2	132	0.002	4.38	2.13	
	7/15/2008	0.03420	15.35	609		1	<	1	<	2		852	60		218	21		1		2				1	<	173.2	34.4	0.02	15.2	115	0.003	5.22	3.32	
	8/12/2008	0.00869	3.90																															
	8/20/2008	0.00579	2.60																															
n=	11	Min	0.02	455		0		1		1		595	34		155	15		1		2		1360	2.50	1		131.9	23.2	0.011	13.3	90	0.001	3.47	1.95	
		Mean	7.73	615		1		1		5		844	53		215	22		1		3		1690	2.79	2		200.1	30.6	0.016	17.3	145	0.003	4.74	2.72	
		Max	23.34	899		1		1		30		1160	83		275	31		2		3		2010	4.17	4		345.5	42.2	0.029	27.7	265	0.009	6.31	4.29	
		Avg High Flow	16.52	609		0.8		1		2.0		815	48		195	18.8		1		2.5		1735	2.97	1.8		198.5	33.1	0.018	17.6	140	0.003	4.79	2.90	
		Avg Low Flow	0.14	641		1.0		1		9.3		914	53		241	26.0		1.0		3		1716	2.65	2.8		219.3	28.8	0.014	18.5	165	0.004	4.86	2.40	

DCSW-103	7/13/2004	0.005	2.24	2060		1	<	1	<	105		2920	118		7.23	104		1	<	5		3350	2.5	5		802.2	108	0.026	44.6	632	0.002	13.3	4.24	
	8/10/2004	0.004	1.80	1570		1	<	1	<	18		2220	108		591	78		1	<	5		2730	2.5	10	<	502.7	88.1	0.026	34.8	363	0.002	12.5	4.29	
	10/6/2004	0.002	0.90	1920	JF%	1	<	1	<	2		2550	127		745	104		1	<	5		3200	2.6	2	JF<	682.7	110	0.023	46.1	505	0.002	16.7	4.84	
	6/29/2005	0.00401	1.80	2290		1	<	1	<	30		3050	127	d	750	105	d	1	d<	5	d	3530	2.4	1		866.8	122	0.032	47.3	678	0.004	14.2	5.25	
	9/27/2005	0.0007	0.31	1340		1	<	1	<	4		1910	117	d	642	85	d	1	d<	5	d	2897	2.42	6		475.8	76.6	0.028	31	352	0.003	11.8	4.33	
	6/27/2006	0.004	1.80	1510		0		1	<	1		2210	120		619	83		1	<	5		3264	4.13	9		568.8	81.1	0.024	36.1	434	0.002	13.1	4.44	
	9/27/2006	0.002	0.90	1340		1	<	1	<	1		1980	129	d	688	89	d	1	d<	5	d	2711	2.62	2	JF%<	437.9	77.3	0.022	29	315	0.002	12.5	4.07	
	7/18/2007	0.003	1.35	1260		1	<	1	<	1		1760	113		570	70		1	<	5		2674	2.44	1	<	437.3	76.1	0.022	30.4	316	0.003	10.7	4.07	
	9/18/2007	0.0015	0.67	1360		1	<	1	<	3		2220	117		686	84		1	<	5		2940	2.59	2	<	508.5	87.9	0.023	29.8	374	0.004	12.7	4.09	
	7/15/2008	0.0029	1.31	1500		1	<	1	<	3		2080	108		553	72		1	<	4				1	<	480.1	89.9	0.023	29.3	347	0.002	9.95	3.92	
	8/12/2008	0.0025	1.11																															
	8/20/2008	0.0029	1.30																															
n=	10	Min	0.31	1260		0		1		1		1760	108		7	70		1		4		2674	2.40	1		434.0	76.1	0.022	29.0	315	0.002	10.0	3.92	
		Mean	1.29	1615		1		1		17		2290	118		585	87		1		5		3033	2.69	4		576.3	91.7	0.025	35.8	432	0.003	12.7	4.35	
		Max	2.24	2290		1		1		105		3050	129		750	105		1		5		3530	4.13	10		869.3	122.0	0.032	47.3	678	0.004	16.7	5.25	
		Avg High Flow	1.70	1805		0.8		1		34.8		2600	121		516	94.0		1		5.0		3271	2.91	4.3		686.6	99.8	0.026	39.5	530	0.003	13.33	4.51	
		Avg Low Flow	0.61	1465		0.8		1		2.0		2050	120		521	87.0		1.0		5		2871	2.51	2.8		507.6	85.0	0.024	33.8	372	0.002	12.74	4.29	

SURFACE WATER SUMMARY FOR McLAREN PIT DRAINS

Station Name	Sample Date	Flow Rate (cfs)	Flow Rate (gpm)	Anions (mg/L)									Cations (mg/L)												Total Recoverable Metals (mg/L)								
				Acidity as CaCO3	CaCO3 Flag	Alkalinity as HCO3	HCO3 Flag	Alkalinity as Total CaCO3	CaCO3 Flag	Chloride	Cl Flag	Sulfate	Calcium	Ca Flag	Hardness as CaCO3	Magnesium	Mg Flag	Potassium	K Flag	Sodium	Na Flag	Field SC (umhos/cm)	Field pH (s.u.)	Total Suspended Solids (mg/L)	TSS Flag	Total Metals	Aluminum	Cadmium	Copper	Iron	Lead	Manganese	Zinc	Zinc Flag
Combined Flow for DCSW-101, -102, 103	7/13/2004	0.071	31.87	640.8		1.0		1.0		12.3		865.2	41.6		136.5	20.1		1.6		2.5		1559.0	2.8	2.2		223.0	36.2	0.013	18.9	161.4	0.008	4.3	2.2	
	8/10/2004	0.052	23.34	540.9		1.0		1.0		4.8		707.9	38.3		168.3	17.7		1.7		2.2		1317.3	2.9	21.3		172.8	30.1	0.011	15.2	121.8	0.006	3.8	1.9	
	10/6/2004	0.016	7.18	772.3		1.0		1.0		8.6		948.6	55.3		253.3	27.9		1.8		3.3		1785.0	2.9	31.4		298.4	44.1	0.017	24.3	220.3	0.006	6.6	3.1	
	6/29/2005	0.10066	45.18	699.3		1.0		1.0		3.7		950.4	49.3		207.0	20.3		1.5		2.7		1605.1	2.6	1.5		251.9	40.8	0.019	18.6	184.8	0.010	4.7	3.0	
	9/27/2005	0.0082	3.68	656.3		1.0		1.0		3.1		847.7	52.2		224.6	22.9		1.9		3.2		1543.9	2.7	3.3		269.0	35.3	0.013	15.7	211.4	0.009	4.3	2.3	
	6/27/2006	0.083	37.25	523.8		0.0		1.0		1.0		698.5	44.2		169.3	16.7		1.6		2.1		1550.0	4.3	7.2		186.8	31.3	0.012	16.6	132.8	0.008	4.0	2.1	
	9/27/2006	0.0071	3.19	791.4		1.0		1.0		1.0		1131.4	64.5		320.1	37.4		1.0		3.6		1752.9	2.8	14.0		284.4	42.5	0.013	17.7	215.7	0.004	6.0	2.5	
	7/18/2007	0.051	22.89	426.2		1.0		1.0		1.0		558.3	34.9		143.9	13.9		1.7		3.1		1226.3	2.7	22.0		149.0	26.6	0.009	11.8	105.8	0.005	3.1	1.6	
	9/18/2007	0.01034	4.64	554.4		1.0		1.0		1.3		841.8	51.2		232.3	24.2		1.9		3.3		1398.2	3.0	6.3		224.4	34.5	0.012	15.1	168.0	0.006	4.7	2.1	
	7/15/2008	0.0946	42.47	513.1		1.0		1.0		1.4		709.4	46.3		170.0	15.9		1.6		2.1				1.0		158.4	30.7	0.012	12.8	109.2	0.011	3.6	2.1	
	8/12/2008	0.0474	21.27																														
	8/20/2008	0.0408	18.30																														
		Min	2.58	461.7		0.0		1.0		1.0		610.8	36.9		92.6	16.5		1.0		2.2		1224.9	2.7	1.0		165.7	29.7	0.009	12.3	118.8	0.005	3.2	1.6	
		Mean	23.07	593.5		0.9		1.0		4.2		804.3	46.9		193.4	20.1		1.5		2.8		1504.4	2.9	9.6		212.6	32.8	0.013	16.3	157.0	0.007	4.2	2.2	
		Max	51.39	806.1		1.0		1.0		22.2		1074.8	66.4		250.5	27.7		2.0		3.1		1845.4	4.3	21.3		326.4	41.7	0.023	25.0	249.9	0.012	6.2	3.6	
		Avg High Flow	39.61	569.2		0.8		1.0		3.8		765.7	42.6		168.9	17.5		1.5		2.6		1504.8	3.1	6.9		199.4	33.3	0.014	16.5	143.3	0.007	4.1	2.3	
		Avg Low Flow	4.58	668.1		1.0		1.0		3.3		892.9	52.9		220.8	25.7		1.6		3.2		1577.4	2.9	14.5		259.7	37.3	0.014	17.7	197.1	0.006	5.1	2.4	
DC-2	4/6/2004	0.181	81.24	54		1	<	1	<	3		271	67		213	11		2		2		500	4.4	7	JF	20.4	10.1	0.0036	2.15	5.94	0.005	1.67	0.5	JF%
	6/29/2004	9.56	4290.81	2	<	8		7		2		84	29		93	5		1		1		207	7.7	30		8.1	2.97	0.0007	0.58	4.16	0.003	0.31	0.1	
	8/11/2004	0.36	161.58	66		1	<	1	<	2	<	248	56		193	13		2		2		474	4.5	21		25.2	9.38	0.0032	2.79	11.1	0.004	1.44	0.45	
	10/6/2004	0.53	237.88	34	JF%	2		1		6		224	57		196	13		2		2		431	4.8	27	JF	17.4	6.58	0.0024	1.9	7.36	0.002	1.25	0.35	
	4/6/2005	0.05	22.44	95		1	<	1	<	9		339	80		270	17		2		2		609	4.47	15		32.7	11.6	0.0046	2.49	15.5	0.003	2.25	0.87	JF%(1)
	6/29/2005	6.8	3052.04	2	<	7		6		2		78	28	d	91	5	d	1	d	1	d	183.1	5.8	20		6.6	2.37	0.0008	0.31	3.42	0.002	0.31	0.14	
	9/27/2005	0.19	85.28	92		1	<	1	<	2		284	64	d	217	14	d	2	d	3	d	560	3.7	30		30.2	13.2	0.0035	2.57	12.1	0.006	1.82	0.51	
	4/25/2006	0.08	35.91	65		2		1		3		254	66		211	14		2		2		520	4.74	12		22.8	9.15	0.003	1.54	10.2	0.002	1.95	0..5	
	6/27/2006	5.19	2329.43	2	<	18		15		1	<	77	29		98	6		1		1	<	221	6.25	22		7.6	3.12	0.0005	0.69	3.38	0.002	0.34	0.1	
	9/27/2006	0.14	62.84	94		1	<	1	<	2		240	61		214	15		2		2		645	3.76	13	JF%	26.0	12.4	0.0043	3.17	7.78	0.004	2.14	0.55	
	4/11/2007	0.05	22.44	40		1	<	1	<	2		292	63		211	13		1		2		473	6.93	18		24.0	8.3	0.0036	1.44	12	0.003	1.76	0.46	
	6/13/2007	10.2	4578.07	6	<	11		9		1	<	53	19		64	4		1		1	<	121	7.1	41		9.8	3.7	0.0004	0.41	5.36	0.009	0.23	0.07	
	7/18/2007	0.507	227.56	58		1	<	1	<	1	<	197	47		167	12		1		2		387	4.72	28		22.8	8.9	0.0023	2.2	10.2	0.002	1.12	0.34	
	9/18/2007	0.154	69.12	96		1	<	1	<	1		366	75		270	20		2		3		699	4.15	23		32.9	13.4	0.0042	3.58	12.9	0.004	2.37	0.61	
	7/15/2008	9.229	4142.25																														
n=	15	Min	22.44	2		1		1		1		53	19		64	4		1		1		121	3.70	12		6.4	2.37	0.0004	0.31	3.38	0.002	0.23	0.07	
		Mean	1293.26	50		4		4		3		210	52		177	12		2		2		425	5.28	23		20.5	8.1	0.0026	1.82	8.88	0.004	1.33	0.38	
		Max	4578.07	96		18		15		9		366	80		270	20		2		3		699	7.70	41		35.7	13.4	0.0046	3.58	15.50	0.009	2.37	0.87	
		Avg High Flow	3678.52	16		8.5		7.3		1.5		109	33		112	7.0		1.0		1.3		250	6.12	25		11.3	4.3	0.001	0.9	5.3	0.002	0.52	0.17	
		Avg Low Flow	113.78	79		1.3		1.0		2.8		279	64		224	15.5		2.0		2.5		584	4.10	23		26.6	11.4	0.004	2.8	10.0	0.004	1.90	0.51	

Notes:

* - No duplicate flow data measured
cfs - Cubic feet per second
gpm - Gallons per minute
s.u. - Standard units
mg/L - Milligrams per liter
umhos/cm - Micromhos per centimeter
n - Number of samples
(1) - Verified by second analysis
(2) - High flow month for each year used
(3) - Low flow month for each year used

-- - Indicates data not collected or parameter not analyzed
< - Indicates analyte not detected above practical quantitation limit (PQL)
d - The associated values are dissolved not total recoverable metals
JF - The associated values are estimated quantities because field duplicate results exceed acceptable limits by absolute value determination
JF% - The associated values are estimated quantities because field duplicate results exceed acceptable limits by relative percent difference determination
Flow Rate - Some of the flow rates shown have been converted from gallons per minute (gpm) to cubic feet per second (cfs). Please refer to original field notes for exact values.

Appendix B

Company Name: Tetra Tech

Project: Solid substrate bioreactor pil

Site Name: New World

Printed on 01/08/2009

AMD TREAT
BIO REACTOR (BIO)

AMDTREAT

BIO Reactor Name: Solid Substrate Bioreactor Pilot Scale Test

☐ **Opening Screen Water Parameters**

Influent Water Parameters that Affect BIO Reactor

Calculated Acidity	689.60	mg/L
Alkalinity	1.00	mg/L
◉ Calculate Net Acidity (Acid-Alkalinity)		
○ Enter Net Acidity manually		
Net Acidity (Hot Acidity)	688.60	mg/L
Design Flow	2.00	gpm
Typical Flow	2.00	gpm
Total Iron	157.00	mg/L
Aluminum	32.80	mg/L
Manganese	4.20	mg/L
Sulfate	804.30	mg/L

Record Number
1 of 1

SIZING METHODS Select One

◉ **BIO Reactor Based on Sulfate Reduction**

1. Sulfate Reduction Rate: 0.300
2. Amount of Sulfate Reduction: 500.00

○ **BIO Reactor Based on Dimensions**

3. Length at Top of Freeboard: ft
4. Width at Top of Freeboard: ft

○ **BIO Reactor Based on Alkalinity Generation Rate**

5. Alkalinity Generation Rate: g/m2/day

	BIO Mixture % Volume		BIO Density	
6. Manure	5.00	%	40.80	lbs/ft3
7. Hay	19.00	%	8.30	lbs/ft3
8. Limestone	16.00	%	94.10	lbs/ft3
9. Wood Chips	60.00	%	18.10	lbs/ft3

10. Manure Unit Cost	20.00	$/ton
11. Hay Unit Cost	100.0	$/ton
12. Limestone Unit Cost	30.00	$/ton
13. Wood Chips Unit Cost	100.0	$/ton
14. Shrinkage Factor for BIO Mix	30.00	%
15. Limestone Purity	85.00	%
16. Limestone Efficiency	60.00	%
17. BIO Mix Placement Unit Cost	4.50	$/yd3

	Run of Slope		Rise of Slope
18. Slope of Pond Sides	2.0	:	1

19. Freeboard Depth	3.00	ft
20. Free Standing Water Depth	2.0	ft
21. BIO Mix Depth	3.0	ft
22. Excavation Unit Cost	0.00	$/yd3
23. Siphon System Cost	0.00	$
24. Nbr. of Valves	0	nbr
25. Unit Cost of Valves	3500.00	$ ea.

Liner Cost

○ No Liner

○ Clay Liner

26. Clay Liner Unit Cost: $/yd3

27. Thickness of Clay Liner: ft

◉ Synthetic Liner

28. Synthetic Liner Unit Cost: 3.00 $/yd2

☑ 29. Clearing and Grubbing?

◉ 30. Land Multiplier	1.50	ratio
○ 31. Clear/Grub Acres		acres
32. Clear and Grub Unit Cost	0.00	$/acre

Piping Cost

○ AMDTreat Piping Costs

33. Total Length of Effluent / Influent Pipe		ft
34. Pipe Install Rate		ft/hr
35. Labor Rate		$/hr
36. Segment Len. of Trunk Pipe		ft/pipe seg.
37. Trunk Pipe Cost		$/ft
38. Trunk Coupler Cost		$/coupler
39. Spur Cost		$/ft
40. Spur Coupler Cost		$/spur
41. "T" Connector Cost		$/T coupler
42. Segment Len. of Spur Pipe		ft/pipe seg.
43. Spur Pipe Spacing		ft

◉ Custom Piping Costs

	Length		Diameter		Unit Cost	
44. Pipe #1	0.00	ft	0.0	in	0.00	$
45. Pipe #2	0.00	ft	0.0	in	0.00	$
46. Pipe #3	0.00	ft	0.0	in	0.00	$

BIO Reactor Sizing Summaries

47. Length at Top of Freeboard	79.88	ft
48. Width at Top of Freeboard	49.94	ft
49. Freeboard Volume	362	yd3
50. Water Surface Area	2,575	ft2
51. Total Water Volume	1,250	yd3
52. Bio Mix Surface Area	1,793	ft2
53. Bio Mix Total Volume	241.92	yd3

54. Manure	9.4	yd3	5.1 tons
55. Hay	35.7	yd3	4.0 tons
56. Limestone	66.5	yd3	84.5 tons
57 Wood Chips	130.2	yd3	31.8 tons

58. Excavation Volume	1,395.3	yd3
59. Clear and Grub Area	0.1	acr.
60. Liner Area	862.5	ft2
61. Life of Limestone in Bio Mix	17.16	yrs

BIO Reactor Cost Summaries

62. Manure Cost	103	$
63. Hay Cost	400	$
64. Limestone Cost	2,536	$
65. Wood Chips Cost	3,181	$
66. BIO Mix Placement Cost	651	$
67. Excavation Cost	0	$
68. Siphon System Cost	0	$
69. Valve Cost	0	$
70. Liner Cost	2,587	$
71. Clear and Grub Cost	0	$
72 Pipe Cost	0	$
73. Total Cost	9,461	$

Appendix C

McLaren Subsurface Drains Combined Flow - 22 gpm
Solid Reactant Sulfate Reducing Bioreactor (SSBR) with Holding Pond and Oxic Limestone Drain (OLD)

A Solid Reactant Sulfate Reducing Bioreactor (SSBR) would be constructed to treat the combined average flow (22 gpm) from the three McLaren Pit Cap drains. The flow from the drains would flow into a holding pond before entering the SSBR. The discharge from the SSBR would flow to an oxic limestone drain (OLD). The SSBR, holding pond and OLD were designed using AMDTreat software Version 4.1c (see attachments). The SSBR cell was designed for a sulfate reduction rate of 500 mg/L and includes a geochemically inert layer of gravel at the top for head fluctuations and at the bottom for minimizing metals plugging at the inlet piping to the cell. The cell is comprised of a mixture of limestone for adding alkalinity and raising pH, manure to provide bacterial inoculum and organic matrix of hay and wood chips. The cell will be covered with 4 feet of soil for frost protection. The holding pond, SSRB and OLD are lined to minimize water loss. A system bypass is included for high flows which may not be accomodated by the SSBR. It is assumed that the cell would need replacement every five years due to Replacement would include disposal of the organic material and limestone at $50/ton. Access would not be required during winter-weather months. Cost estimate sources are from AMDTreat software Version 4.1c (Office of Surface Mining Reclamation and Enforcement (OSMRE), 2006); RSMeans Building Construction Cost Data, 2008 and professional judgement if blank.

DIRECT CAPITAL COSTS

Component	Unit	Unit Cost	Total Quantity	Total Cost	Source
Holding Pond					
Gravel (includes placement)	cy	$ 26.85	657	$ 17,640	RSMeans 31 23 23.17 0020
Fill from borrow area (placement)	cy	$ 1.54	1030	$ 1,586	RSMeans 31 23 23.13 1300
Excavation, 1 1/2 cy bucket	cy	$ 8.27	1687	$ 13,951	RSMeans 31 23 16.16 6050
Liner & Cover (installed)	sy	$ 3.00	1756.6	$ 5,270	
Clear & Grub	ac	$ 1,350.00	0.08	$ 108	AMD Treat
Revegetation	ac	$ 1,500.00	0.08	$ 120	AMD Treat
System Bypass	ls	$ 2,500.00	1	$ 2,500	
Holding Pond Total				**$ 41,176**	
Solid Substrate Bioreactor					
Piping and valves from drains to pond (400 feet)	ls	$ 61,904.00	1	$ 61,904	AMD Treat
Fill from borrow area (placement)	cy	$ 1.54	3197	$ 4,923	RSMeans 31 23 23.13 1300
Organic Matrix/Limestone Material	ls	$ 68,447.00	1	$ 68,447	AMD Treat
Bio Mix Placement	ls	$ 7,162.00	1	$ 7,162	AMD Treat
Excavation, 1 1/2 cy bucket	ls	$ 118,582.00	1	$ 118,582	AMD Treat & RSMeans 31 23 16.16 6050
Liner & Cover (installed)	ls	$ 17,303.00	1	$ 17,303	
Clear & Grub	ls	$ 1,350.00	1	$ 1,350	AMD Treat
Revegetation	ac	$ 1,500.00	1	$ 1,500	
SSBR Bypass System	ls	$3,500	1	$ 3,500	
Solid Substrate Bioreactor Total				**$ 284,671**	
Oxic Limestone Drain					
Oxic Limestone Drain with Liner Installed	ls	$ 3,785.00	1	$ 3,785	AMD Treat
Oxic Limestone Drain Total				**$ 3,785**	
TOTAL DIRECT CAPITAL COSTS				**$ 329,632**	

INDIRECT CAPITAL COSTS

Component	Unit	Unit Cost	Total Quantity	Total Cost	Source
Material Delivery Costs					
Gravel for pond, manure, hay, limestone, wood chips & piping for bioreactor, limestone for OLC	ton-mile	$ 0.074	360900	$ 26,707	
Material Delivery Costs Total				**$ 26,707**	
Mobilization/Demobilization					
Backhoe and Dozer (<50 miles round trip)	each	$ 217.00	2	$ 434	RSMeans 01 54 36.50 0020
Mileage	5 miles	$ 21.70	100	$ 2,170	RSMeans 01 54 36.50 0020
Mobilization/Demobilization Total				**$ 2,604**	
Engineering and Design (10% of Direct)				**$ 32,963**	
Contingency (25% of direct)				**$ 82,408**	
TOTAL INDIRECT CAPITAL COSTS				**$ 144,682**	
TOTAL CAPITAL COSTS				**$ 474,314**	

DIRECT OPERATION AND MAINTENANCE COSTS

Component	Unit	Unit Cost	Years	
Annual sampling	ls	$ 9,638.00	20	$ 140,622
Pipe Cleaning and Maintenance	ls	$ 5,000.00	20	$ 72,952
Replace system every 5 years	ls	$ 284,671.38	20	$ 714,297
Residual disposal every 5 years	ls	$ 139,520.00	20	$ 350,084
OPERATION AND MAINTENANCE PRESENT WORTH (20YEARS)				**$ 1,277,955**
GRAND TOTAL				**$ 1,752,270**

Company Name: Tetra Tech
Project: Solid substrate bioreactor
Site Name: New World

Printed on 01/08/2009

AMD TREAT
BIO REACTOR (BIO)

AMDTREAT

BIO Reactor Name: Solid Substrate Bioreactor

☐ **Opening Screen Water Parameters**

Influent Water Parameters that Affect BIO Reactor

Calculated Acidity	689.60	mg/L
Alkalinity	1.00	mg/L
◉ Calculate Net Acidity (Acid-Alkalinity)		
○ Enter Net Acidity manually		
Net Acidity (Hot Acidity)	688.60	mg/L
Design Flow	22.00	gpm
Typical Flow	22.00	gpm
Total Iron	157.00	mg/L
Aluminum	32.80	mg/L
Manganese	4.20	mg/L
Sulfate	804.30	mg/L

Record Number 1 of 1

SIZING METHODS Select One

◉ **BIO Reactor Based on Sulfate Reduction**

1. Sulfate Reduction Rate	0.300	
2. Amount of Sulfate Reduction	500.00	

○ **BIO Reactor Based on Dimensions**

3. Length at Top of Freeboard		ft
4. Width at Top of Freeboard		ft

○ **BIO Reactor Based on Alkalinity Generation Rate**

5. Alkalinity Generation Rate		g/m2 /day

	BIO Mixture % Volume		BIO Density	
6. Manure	5.00	%	40.80	lbs/ft3
7. Hay	19.00	%	8.30	lbs/ft3
8. Limestone	16.00	%	94.10	lbs/ft3
9. Wood Chips	60.00	%	18.10	lbs/ft3

10. Manure Unit Cost	20.00	$/ton
11. Hay Unit Cost	100.0	$/ton
12. Limestone Unit Cost	30.00	$/ton
13. Wood Chips Unit Cost	100.0	$/ton
14. Shrinkage Factor for BIO Mix	30.00	%
15. Limestone Purity	85.00	%
16. Limestone Efficiency	60.00	%
17. BIO Mix Placement Unit Cost	4.50	$/yd3

	Run of Slope	:	Rise of Slope
18. Slope of Pond Sides	2.0	:	1

19. Freeboard Depth	3.00	ft
20. Free Standing Water Depth	2.0	ft
21. BIO Mix Depth	3.0	ft
22. Excavation Unit Cost	8.27	$/yd3
23. Siphon System Cost	0.00	$
24. Nbr. of Valves	4	nbr
25. Unit Cost of Valves	3500.00	$ ea.

Liner Cost

○ No Liner
○ Clay Liner

26. Clay Liner Unit Cost		$/yd3
27. Thickness of Clay Liner		ft

◉ Synthetic Liner

28. Synthetic Liner Unit Cost	3.00	$/yd2

☑ 29. Clearing and Grubbing?

○ 30. Land Multiplier		ratio
◉ 31. Clear/Grub Acres	1	acres
32. Clear and Grub Unit Cost	1350.00	$/acre

Piping Cost

◉ AMDTreat Piping Costs

33. Total Length of Effluent / Influent Pipe	400	ft
34. Pipe Install Rate	11.00	ft/hr
35. Labor Rate	35.00	$/hr
36. Segment Len. of Trunk Pipe	20	ft/pipe seg.
37. Trunk Pipe Cost	15.00	$/ft
38. Trunk Coupler Cost	6.60	$/coupler
39. Spur Cost	7.00	$/ft
40. Spur Coupler Cost	3.00	$/spur
41. "T" Connector Cost	90.00	$/T coupler
42. Segment Len. of Spur Pipe	20	ft/pipe seg.
43. Spur Pipe Spacing	10.0	ft

○ Custom Piping Costs

	Length		Diameter		Unit Cost	
44. Pipe #1		ft		in		$
45. Pipe #2		ft		in		$
46. Pipe #3		ft		in		$

BIO Reactor Sizing Summaries

47. Length at Top of Freeboard	198.21	ft
48. Width at Top of Freeboard	109.10	ft
49. Freeboard Volume	2,203	yd3
50. Water Surface Area	18,083	ft2
51. Total Water Volume	9,550	yd3
52. Bio Mix Surface Area	15,880	ft2
53. Bio Mix Total Volume	2,661.17	yd3

54. Manure	103.4	yd3	56.9 tons
55. Hay	393.1	yd3	44.0 tons
56. Limestone	732.1	yd3	930.0 tons
57 Wood Chips	1,432.4	yd3	350.0 tons

58. Excavation Volume	11,141.8	yd3
59. Clear and Grub Area	1.0	acr.
60. Liner Area	3,370.0	ft2
61. Life of Limestone in Bio Mix	17.16	yrs

BIO Reactor Cost Summaries

62. Manure Cost	1,139	$
63. Hay Cost	4,405	$
64. Limestone Cost	27,902	$
65. Wood Chips Cost	35,001	$
66. BIO Mix Placement Cost	7,162	$
67. Excavation Cost	92,143	$
68. Siphon System Cost	0	$
69. Valve Cost	14,000	$
70. Liner Cost	10,110	$
71. Clear and Grub Cost	1,350	$
72 Pipe Cost	61,904	$
73. Total Cost	255,118	$

Company Name Tetra Tech

Project Solid substrate bioreactor

Site Name New World

Printed on 01/08/2009

AMD TREAT

PONDS

AMDTREAT

Pond Name: Holding Pond

Pond Design Based On:

- (•) Retention Time
  - 1. Desired Retention Time: 24.0 hours
  - [ ] 3. Sludge Removal Frequency: times/year
  - [ ] 4. Titration?
    - 5. Sludge Rate: gal sludge/ gal H2O
    - 6. Percent Solids: %
    - 7. Sludge Density: lbs./gal
- ( ) Pond Size
  - 8. Pond Length at Top of Freeboard: ft
  - 9. Pond Width at Top of Freeboard: ft

Run : Rise

10. Slope Ratio of Pond Sides: 2.0 : 1

11. Freeboard Depth: 2.0 ft

12. Water Depth: 4.0 ft

13. Excavation Unit Cost: 8.27 $/yd3

14. Total Length of Effluent / Influent Pipe: 0.00 ft

15. Unit Cost of Pipe: 10.00 $/ft

Liner Cost

- ( ) No Liner
- ( ) Clay Liner
  - 16. Clay Liner Unit Cost: $/yd3
  - 17. Thickness of Clay Liner: ft
- (•) Synthetic Liner
  - 18. Synthetic Liner Unit Cost: 3.00 $/yd2

[x] 19. Clearing and Grubbing?

- ( ) 20. Land Multiplier: ratio
- (•) 21. Clear/Grub Acres: 1.00 acres
- 22. Clear and Grub Unit Cost: 1350.00 $/acre

23. Revegetation Cost: 1500.00 $/acre

24. Cost of Baffles: 0 $

[ ] **Opening Screen Water Parameters**

Influent Water Parameters that Affect Ponds

Calculated Acidity: 689.60 mg/L

Alkalinity: 1.00 mg/L

- (•) Calculate Net Acidity (Acid-Alkalinity)
- ( ) Enter Net Acidity manually

Net Acidity (Hot Acidity): 688.60 mg/L

Design Flow: 92.28 gpm

Typical Flow: 92.28 gpm

Total Iron: 0.00 mg/L

Aluminum: 0.00 mg/L

Manganese: 0.00 mg/L

Record Number
1 of 1

Calculated Pond Dimensions per Pond

25. Length at Top of Freeboard: 114 ft

26. Width at Top of Freeboard: 61 ft

27. Freeboard Volume: 1,123 yd3

28. Water Volume: 657 yd3

29. Estimated Annual Sludge: 0 yd3/yr

30. Volume of Sludge per Removal: 0 yd3/ removal

31. Excavation Volume: 0.40 acre ft

32. Excavation Volume: 657 yd3

33. Clear and Grub Area: 1.00 acres

34. Liner Area: 984 yd2

35. Calculated Retention Time: 24 hours

Ponds Sub-Totals per Pond

36. Excavation Cost: 5,441 $

37. Pipe Cost: 0 $

38. Liner Cost: 2,953 $

39. Clearing and Grubbing Cost: 1,350 $

40. Revegetation Cost: 119 $

41. Baffle Cost: 0 $

42. Estimated Cost: 9,864 $

Company Name Tetra Tech

Project Solid substrate bioreactor

Site Name New World

Printed on 01/08/2009

AMD TREAT

Oxic Limestone Channel (OLC)

Oxic Limestone Channel Name: SSBR/LSBR OLC post-treat

1. Ditch Length Rock	100	ft
2. Bottom Width of the Ditch	4.0	ft
3. Ditch Depth	3.00	ft
4. Geo Textile Unit Cost	3.00	$/yd2
5. Length of GeoTextile	100	ft
6. Slope Ratio of Ditch Sides (Run : Rise)	2.00 : 1.00	
☐ 7. Surveying?		
8. Survey Rate		acres/day
9. Survey Unit Cost		$/day
☑ 10. Clearing and Grubbing?		
11. Clear and Grub Cost	1350.00	$/acre
12. Ditch Depth of Limestone	1.00	ft
13. Cost of Limestone	30.00	$/yd3
14. Cost to Place Limestone	4.50	$/yd3
15. Excavation Unit Cost	8.27	$/yd3
16. Revegetation Unit Cost	0.00	$/acre

OLC Sub-Totals

17. Excavation Cost	919	$
18. Survey Cost	0	$
19. Clear and Grub Cost	60	$
20. Limestone Cost	2,225	$
21. Filter Fabric Cost	581	$
22. Revegetation Cost	0	$
23. Total Cost	3,785	$

Record Number 1 of 1

Appendix D

McLaren Subsurface Drains Combined Flow - 22 gpm
Liquid Reactant Sulfate Reducing Bioreactor (LSBR) with Holding Pond and Oxic Limestone Drain (OLD)

A Liquid Reactant Sulfate Reducing Bioreactor (LSBR) would be constructed to treat the combined flow (22 gpm) from the McLaren Pit Cap drains. The flow from the drains would be conveyed into a holding pond before entering a settling pond for metals precipitation. The discharge from the settling pond then flows to the LSBR. The discharge from the LSBR would flow to an oxic limestone drain (OLD) prior to discharge. The LSBR was sized using a 2 day hydraulic retention time at a porosity of 35%. The holding pond and oxic limestone channel were sized using AMD Treat software Version 4.1c (see attachments). Sodium hydroxide (NaOH) would be fed to the system with a solar driven pump for alkalinity addition, and ethanol would be fed to the system using a solar driven pump for the carbon source for bacterial growth. The cell will be covered with 4 feet of soil from the borrow area for frost protection. The holding pond, SSRB and OLD are lined to minimize water loss. A system bypass is included for high flows which may not be accomodated by the SSBR. It is assumed that the cell would need replacement every 15 years.

Replacement would include disposal of the cell fill material at $50/ton. Access would not be required during winter-weather months. Cost estimate sources are from AMD Treat software Version 4.1c (Office of Surface Mining Reclamation and Enforcement (OSMRE), 2006); RSMeans Building Construction Cost Data, 2008 and professional judgement if blank.

DIRECT CAPITAL COSTS

Component	Unit	Unit Cost	Total Quantity	Total Cost	Source
Holding Pond					
Gravel (includes placement)	cy	$ 26.85	657	$ 17,640	RSMeans 31 23 23.17 0020
Fill from borrow area (placement)	cy	$ 1.54	1030	$ 1,586	RSMeans 31 23 23.13 1300
Excavation, 1 1/2 cy bucket	cy	$ 8.27	1687	$ 13,951	RSMeans 31 23 16.16 6050
Liner & Cover (installed)	sy	$ 3.00	1756.6	$ 5,270	
Clear & Grub	ac	$ 1,350.00	0.08	$ 108	AMD Treat
Revegetation	ac	$ 1,500.00	0.08	$ 120	AMD Treat
System Bypass	ls	$ 2,500.00	1	$ 2,500	
Holding Pond Total				**$ 41,176**	
Settling Pond					
Gravel (includes placement)	cy	$ 26.85	6274	$ 168,457	RSMeans 31 23 23.17 0020
Fill from borrow area (placement)	cy	$ 1.54	6274	$ 9,662	RSMeans 31 23 23.13 1300
Excavation, 1 1/2 cy bucket	cy	$ 8.27	12548	$ 103,772	RSMeans 31 23 16.16 6050
Liner & Cover (installed)	sy	$ 3.00	9682	$ 29,046	
Clear & Grub	ac	$ 1,350.00	1	$ 1,350	AMD Treat
Revegetation	ac	$ 1,500.00	1	$ 1,500	AMD Treat
Settling Pond Total				**$ 313,787**	

Liquid Substrate Bioreactor						
Piping and valves from drains to pond (400 feet)	ls	$	64,061.00	1	$ 64,061	AMD Treat
Chemical Feed Systems and Storage	ls	$	6,000.00	1	$ 6,000	
Gravel/Rock Fill for Cell (includes placement)	cy	$	26.85	896	$ 24,058	
Manure for bacterial inoculation	ton	$	20.00	59.7	$ 1,194	
Fill from borrow area (placement)	cy	$	1.54	896	$ 1,380	RSMeans 31 23 23.13 1300
Excavation, 1 1/2 cy bucket	cy	$	8.27	1882	$ 15,564	AMD Treat & RSMeans 31 23 16.16 6050
Liner & Cover (installed)	ls	$	4,472.00	1	$ 4,472	
Clear & Grub	ac	$	1,350.00	0.33	$ 446	
Revegetation	ac	$	1,500.00	0.33	$ 495	
LSBR Bypass System	ls		$3,500	1	$ 3,500	
Liquid Substrate Bioreactor Total					**$ 121,169**	

Oxic Limestone Channel						
Oxic Limestone Channel with Liner Installed	ls	$	3,785.00	1	$ 3,785	AMD Treat
Oxic Limestone Channel Total					**$ 3,785**	

TOTAL DIRECT CAPITAL COSTS	**$ 479,917**

INDIRECT CAPITAL COSTS

Component	Unit	Unit Cost	Total Quantity	Total Cost	Source
Material Delivery Costs					
Gravel for pond, limestone for OLC & Gravel/rock mix for bioreactor	ton-mile	$ 0.074	344250	$ 25,475	
Material Delivery Costs Total				**$ 25,475**	
Mobilization/Demobilization					
Backhoe and Dozer (<50 miles round trip)	each	$ 217.00	2	$ 434	RSMeans 01 54 36.50 0020
Mileage	5 miles	$ 21.70	100	$ 2,170	RSMeans 01 54 36.50 0020
Mobilization/Demobilization Total				**$ 2,604**	
Engineering and Design (10% of Direct)				**$ 47,992**	
Contingency (25% of direct)				**$ 119,979**	
TOTAL INDIRECT CAPITAL COSTS				**$ 196,049**	
TOTAL CAPITAL COSTS				**$ 675,966**	

DIRECT OPERATION AND MAINTENANCE COSTS

Component	Unit	Unit Cost	Years	
Annual sampling	ls	$ 9,638.00	20	$ 140,622
Chemical Costs	ls	$ 14,801.00	20	$ 215,953
Pipe Cleaning and Maintanance	ls	$ 5,000.00	20	$ 72,952
Replace system every 15 years	ls	$ 121,169.08	20	$ 85,719
Residual disposal every 15 years	ls	$ 44,800.00	20	$ 31,693
OPERATION AND MAINTENANCE PRESENT WORTH (20YEARS)				**$ 546,939**
GRAND TOTAL				**$ 1,222,905**

Appendix E

McLaren Subsurface Drains Combined Flow - 22 gpm
Solid Reactant Sulfate Reducing Bioreactor (SSBR) with Holding Pond and Oxic Limestone Drain (OLD)

A Solid Reactant Sulfate Reducing Bioreactor (SSBR) would be constructed to treat the combined average flow (22 gpm) from the three McLaren Pit Cap drains. The flow from the drains would flow into a holding pond before entering the SSBR. The discharge from the SSBR would flow to an oxic limestone drain (OLD). The SSBR, holding pond and OLD were designed using AMDTreat software Version 4.1c (see attachments). The SSBR cell was designed for a sulfate reduction rate of 500 mg/L and includes a geochemically inert layer of gravel at the top for head fluctuations and at the bottom for minimizing metals plugging at the inlet piping to the cell. The cell is comprised of a mixture of limestone for adding alkalinity and raising pH, manure to provide bacterial inoculum and organic matrix of hay and wood chips. The cell will be covered with 4 feet of soil for frost protection. The holding pond, SSRB and OLD are lined to minimize water loss. A system bypass is included for high flows which may not be accomodated by the SSBR. It is assumed that the cell would need replacement every five years due to pluging Replacement would include disposal of the organic material and limestone at $50/ton. Access would not be required during winter-weather months. Cost estimate sources are from AMDTreat software Version 4.1c (Office of Surface Mining Reclamation and Enforcement (OSMRE), 2006); New World Mining District Actual Cost Data from McLaren Pit Response Action Construction Report, 2006 and Selective Source Response Action Construction Report, 2006 each adjusted using construction cost indicies, and professional judgement.

DIRECT CAPITAL COSTS

Component	Unit	Unit Cost	Total Quantity	Total Cost	Source
Holding Pond					
Gravel (includes placement)	cy	$ 69.00	657	$ 45,333	
Fill from borrow area (placement)	cy	$ 7.67	1030	$ 7,900	
Excavation, 1 1/2 cy bucket	cy	$ 19.10	1687	$ 32,222	
Liner & Cover (installed)	sy	$ 13.42	1756.6	$ 23,574	
Clear & Grub	ac	$ 2,576.00	0.08	$ 206	AMD Treat
Revegetation	ac	$ 2,600.00	0.08	$ 208	AMD Treat
System Bypass	ls	$ 2,500.00	1	$ 2,500	
Holding Pond Total				**$ 111,942**	
Solid Substrate Bioreactor					
Piping and valves from drains to pond (400 feet)	ls	$ 61,904.00	1	$ 61,904	AMD Treat
Fill from borrow area (placement)	cy	$ 7.67	3197	$ 24,521	
Organic Matrix/Limestone Material	ls	$ 68,447.00	1	$ 68,447	AMD Treat
Bio Mix Placement	ls	$ 47,748.00	1	$ 47,748	AMD Treat
Excavation, 1 1/2 cy bucket	ls	$ 163,674.00	1	$ 163,674	AMD Treat & Construction Costs
Liner & Cover (installed)	ls	$ 47,528.00	1	$ 47,528	
Clear & Grub	ls	$ 2,576.00	1	$ 2,576	AMD Treat
Revegetation	ac	$ 2,600.00	1	$ 2,600	
SSBR Bypass System	ls	$3,500	1	$ 3,500	
Solid Substrate Bioreactor Total				**$ 422,498**	
Oxic Limestone Drain					
Oxic Limestone Drain with Liner Installed	ls	$ 9,202.00	1	$ 9,202	AMD Treat
Oxic Limestone Drain Total				**$ 9,202**	
TOTAL DIRECT CAPITAL COSTS				**$ 543,642**	

INDIRECT CAPITAL COSTS

Component	Unit	Unit Cost	Total Quantity	Total Cost	Source
Material Delivery Costs					
Gravel for pond, manure, hay, limestone, wood chips & piping for bioreactor, limestone for OLC	ton-mile	$ 0.074	360900	$ 26,707	
Material Delivery Costs Total				**$ 26,707**	
Mobilization/Demobilization					
Mobilization	ls	$ 50,000.00	1	$ 50,000	
Backhoe and Dozer (<50 miles round trip)	each	$ 217.00	4	$ 868	
Mileage	5 miles	$ 21.70	200	$ 4,340	
Mobilization/Demobilization Total				**$ 55,208**	
Engineering and Design (10% of Direct)				**$ 54,364**	
Contingency (25% of direct)				**$ 135,911**	
TOTAL INDIRECT CAPITAL COSTS				**$ 272,189**	
TOTAL CAPITAL COSTS				**$ 815,832**	

DIRECT OPERATION AND MAINTENANCE COSTS

Component	Unit	Unit Cost	Years	
Annual sampling	ls	$ 9,638.00	20	$ 140,622
Pipe Cleaning and Maintenance	ls	$ 5,000.00	20	$ 72,952
Replace system every 5 years	ls	$ 422,497.99	20	$ 1,060,132
Residual disposal every 5 years	ls	$ 139,520.00	20	$ 350,084
OPERATION AND MAINTENANCE PRESENT WORTH (20YEARS)				**$ 1,623,790**
GRAND TOTAL				**$ 2,439,622**

McLaren Subsurface Drains Combined Flow - 22 gpm
Liquid Reactant Sulfate Reducing Bioreactor (LSBR) with Holding Pond and Oxic Limestone Drain (OLD)

A Liquid Reactant Sulfate Reducing Bioreactor (LSBR) would be constructed to treat the combined flow (22 gpm) from the McLaren Pit Cap drains. The flow from the drains would be conveyed into a holding pond before entering a settling pond for metals precipitation. The discharge from the settling pond then flows to the LSBR. The discharge from the LSBR would flow to an oxic limestone drain (OLD) prior to discharge. The LSBR was sized using a 2 day hydraulic retention time at a porosity of 35%. The holding pond and oxic limestone channel were sized using AMD Treat software Version 4.1c (see attachments). Sodium hydroxide (NaOH) would be fed to the system with a solar driven pump for alkalinity addition, and ethanol would be fed to the system using a solar driven pump for the carbon source for bacterial growth. The cell will be covered with 4 feet of soil from the borrow area for frost protection. The holding pond, SSRB and OLD are lined to minimize water loss. A system bypass is included for high flows which may not be accomodated by the SSBR. It is assumed that the cell would need replacement every 15 years.

Replacement would include disposal of the cell fill material at $50/ton. Access would not be required during winter-weather months. Cost estimate sources are from AMD Treat software Version 4.1c (Office of Surface Mining Reclamation and Enforcement (OSMRE), 2006); New World Mining District Actual Cost Data from McLaren Pit Response Action Construction Report, 2006 and Selective Source Response Action Construction Report, 2006 each adjusted using construction cost indicies, and professional judgement.

DIRECT CAPITAL COSTS

Component	Unit	Unit Cost	Total Quantity	Total Cost	Source
Holding Pond					
Gravel (includes placement)	cy	$ 69.00	657	$ 45,333	
Fill from borrow area (placement)	cy	$ 7.67	1030	$ 7,900	
Excavation, 1 1/2 cy bucket	cy	$ 19.10	1687	$ 32,222	
Liner & Cover (installed)	sy	$ 13.42	1756.6	$ 23,574	
Clear & Grub	ac	$ 2,576.00	0.08	$ 206	AMD Treat
Revegetation	ac	$ 2,600.00	0.08	$ 208	AMD Treat
System Bypass	ls	$ 2,500.00	1	$ 2,500	
Holding Pond Total				**$ 111,942**	
Settling Pond					
Gravel (includes placement)	cy	$ 69.00	6274	$ 432,906	
Fill from borrow area (placement)	cy	$ 7.67	6274	$ 48,122	
Excavation, 1 1/2 cy bucket	cy	$ 19.10	12548	$ 239,667	
Liner & Cover (installed)	sy	$ 13.42	9682	$ 129,932	
Clear & Grub	ac	$ 2,576.00	1	$ 2,576	AMD Treat
Revegetation	ac	$ 2,600.00	1	$ 2,600	AMD Treat
Settling Pond Total				**$ 855,803**	

Liquid Substrate Bioreactor						
Piping and valves from drains to pond (400 feet)	ls	$	64,061.00	1	$ 64,061	AMD Treat
Chemical Feed Systems and Storage	ls	$	10,000.00	1	$ 10,000	
Gravel/Rock Fill for Cell (includes placement)	cy	$	69.00	896	$ 61,824	
Manure for bacterial inoculation	ton	$	3.90	59.7	$ 233	
Fill from borrow area (placement)	cy	$	7.67	896	$ 6,872	
Excavation, 1 1/2 cy bucket	cy	$	19.10	1882	$ 35,946	AMD Treat & Construction Costs
Liner & Cover (installed)	ls	$	19,997.00	1	$ 19,997	
Clear & Grub	ac	$	2,576.00	0.33	$ 850	
Revegetation	ac	$	2,600.00	0.33	$ 858	
LSBR Bypass System	ls		$3,500	1	$ 3,500	
Liquid Substrate Bioreactor Total					**$ 204,141**	
Oxic Limestone Channel						
Oxic Limestone Channel with Liner Installed	ls	$	9,202.00	1	$ 9,202	AMD Treat
Oxic Limestone Channel Total					**$ 9,202**	
TOTAL DIRECT CAPITAL COSTS					**$ 1,181,089**	

INDIRECT CAPITAL COSTS

Component	Unit	Unit Cost	Total Quantity	Total Cost	Source
Material Delivery Costs					
Gravel for pond, limestone for OLC & Gravel/rock mix for bioreactor	ton-mile	$ 0.074	344250	$ 25,475	
Material Delivery Costs Total				**$ 25,475**	
Mobilization/Demobilization					
Mobilization	ls	$ 50,000.00	1	$ 50,000	
Backhoe. Grader, Dump Truck and Dozer (<50 miles round trip)	each	$ 217.00	4	$ 868	
Mileage	5 miles	$ 21.70	200	$ 4,340	
Mobilization/Demobilization Total				**$ 55,208**	
Engineering and Design (10% of Direct)				**$ 118,109**	
Contingency (25% of direct)				**$ 295,272**	
TOTAL INDIRECT CAPITAL COSTS				**$ 494,064**	
TOTAL CAPITAL COSTS				**$ 1,675,152**	

DIRECT OPERATION AND MAINTENANCE COSTS

Component	Unit	Unit Cost	Years	
Annual sampling	ls	$ 9,638.00	20	$ 140,622
Chemical Costs	ls	$ 14,801.00	20	$ 215,953
Pipe Cleaning and Maintanance	ls	$ 5,000.00	20	$ 72,952
Replace system every 15 years	ls	$ 204,141.43	20	$ 144,416
Residual disposal every 15 years	ls	$ 44,800.00	20	$ 31,693
OPERATION AND MAINTENANCE PRESENT WORTH (20YEARS)				**$ 605,636**
GRAND TOTAL				**$ 2,280,788**