# Rico-Argentine Site
# Removal Action Work Plan
## Appendix A: Performance Evaluation and Technology Selection Report

## September 2021

### Administrative Settlement Agreement and Order on Consent

## TABLE OF CONTENTS

## LIST OF FIGURES



## LIST OF TABLES



## LIST OF ATTACHMENTS



## ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| AECOM | AECOM Technical Services, Inc. |
| ARAR | Applicable or Relevant and Appropriate Requirement |
| Atlantic Richfield | Atlantic Richfield Company |
| CDPHE WQCD | Colorado Department of Public Health and Environment Water Quality Control Division |
| CERCLA | Comprehensive Environmental Response, Compensation, and Liability Act |
| CWD | Constructed Wetland Demonstration |
| EPA | United States Environmental Protection Agency |

| | |
|---|---|
| EWD | Enhanced Wetlands Demonstration |
| gal | gallons |
| gpm | gallons per minute |
| $H_2S$ | hydrogen sulfide |
| HDS | high density sludge |
| HWTT | Horizontal Wetland Treatment Train |
| M | million |
| N/A | not applicable |
| NPDES | National Pollutant Discharge Elimination System |
| NPV | net present value |
| OM&M | operations, maintenance, and monitoring |
| ORP | oxidation reduction potential |
| Ponds System | St. Louis Ponds System |
| RAWP | Removal Action Work Plan |
| s.u. | standard units |
| Site | Rico-Argentine Site |
| SIMOPs | simultaneous operations |
| SLT | St. Louis Tunnel |
| UAO | Unilateral Administrative Order for Removal Action |
| USFS | Unites States Forest Service |
| VWTT | Vertical Wetland Treatment Train |
| Water Treatment System | preferred full-scale water treatment alternative for the for the St. Louis Tunnel adit discharge |

## EXECUTIVE SUMMARY

This Performance Evaluation and Technology Selection Report describes the removal action alternatives considered and the evaluation process used in identifying the preferred full-scale water treatment alternative for the for the St. Louis Tunnel (SLT) adit discharge (the Water Treatment System) at the Rico-Argentine Site (Site). Treatment system alternatives selected for evaluation were: 1) No Additional Action, 2) Expanded Constructed Wetlands, and 3) Lime Treatment with High Density Sludge (HDS). This document outlines the alternatives considered, the selection criteria used for decision making, and the rationale behind selection of the most applicable and effective removal action treatment alternative.

Based on its projected effectiveness, implementability, environmental impacts, and relative costs, the full-scale build-out of the Expanded Constructed Wetlands is the preferred water treatment alternative. The selected water treatment system will be an expansion of the existing demonstration-scale constructed wetlands treatment systems. It will provide improved solids management, increased hydraulic capacity, reduced maintenance, and redundancy to allow for continuous and effective water treatment.

# 1 INTRODUCTION

This *Performance Evaluation and Technology Selection Report* describes the removal action alternatives considered and the evaluation process used in identifying the preferred full-scale water treatment alternative for the for the St. Louis Tunnel (SLT) adit discharge (the Water Treatment System) at the Rico-Argentine Site (Site). The removal action treatment alternative selected in this report will be designed and constructed as part of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) removal action approved by the United States Environmental Protection Agency (EPA) for the Site, as documented in the December 21, 2010 Action Memorandum for the Site.

The SLT adit discharge is comprised of groundwater impounded within the underground workings of the Rico-Argentine Mine system and water infiltrating and flowing through the interconnected mine workings within Telescope Mountain and Dolores Mountain at the Site. The water contacts sulfidic mineralized rock and picks up metals and acidity prior to discharging from the SLT adit. Historically, the adit surface water discharge had been channelized through a series of settling ponds prior to discharge to the Dolores River. Some of those ponds are still involved in the current treatment process and are referred to as the St. Louis Ponds System (Ponds System). The Site location, layout, major features, and an overview of mine workings are shown on Figures 1 through 4, respectively.

Earlier response actions, investigations performed pursuant to the 2011 *Unilateral Administrative Order* (UAO) *for Removal Action* (Docket No. CERCLA-08-2011-0005) (EPA, 2011), and experience gained from designing, constructing, and operating the demonstration-scale wetland treatment systems provided supporting information for the comparative analysis summarized in this Report.

Although the Action Memorandum documented approval of a "time-critical removal action" for the SLT discharge, the alternatives evaluation process described in this Report used procedures and evaluation criteria generally consistent with those described in EPA's *Guidance on Conducting Non-Time-Critical Removal Actions Under CERCLA* (EPA, 1993). This is because removal action activities completed to date under the 2011 UAO, including ponds solids management as well as construction and operation of demonstration scale wetland treatment system components, have addressed many of the site conditions underlying EPA's initial determination that the removal action should be classified as time-critical. As the removal action transitions to the design and build-out of a full-scale water treatment system, the approach set forth in the 1993 EPA Guidance lends itself well to the identification and analysis of treatment system alternatives.

Detailed information about Site history, location, access, land use and ownership, climate, topography, geology, and Site features (including the SLT, demonstration wetland systems, Ponds System, stormwater controls, and repositories) is provided in the [February] 2021 *Rico-Argentine Mine Site Removal Action Work Plan* (2021 RAWP). Site characterization information, including measured SLT discharge flow rates, appears in Section 2 of the 2021 RAWP. This *Performance Evaluation and Technology Selection Report* is Appendix A to the 2021 RAWP. Performance criteria for the SLT water treatment system are provided in Appendix B to the 2021 RAWP. Previous investigations and removal action activities performed under the UAO are described in Appendix C to the 2021 RAWP.

# 2 WATER TREATMENT REMOVAL ACTION OBJECTIVES AND BASIS OF DESIGN

## 2.1 Water Treatment Objectives

As stated in the 2021 RAWP, the objectives of the water treatment removal action are to:

1. Reduce key contaminants loading to the Dolores River to improve water quality;
2. Reduce metals concentrations to achieve agreed-upon performance criteria;
3. Treat base flows and freshet flows up to the 25-year recurrence period (design permitting);
4. Provide safe, reliable, year-round / all-weather operations; and,
5. Minimize waste production and energy usage.

## 2.2 Basis of Design for Water Treatment System

The *Water Treatment System Basis of Design* will include the following elements: operational conditions, influent flow rate, influent chemical compositions, and proposed performance criteria.

Operational conditions for the water treatment system include: a 30-year design life; 24 hours/day, 7 days/week, 365 days/year operation; maximum utilization of passive operations; use of proven processes for operations; utilization of existing infrastructure wherever possible, including on-site waste management infrastructure; and minimizing the environmental footprint.

Maximum influent flow-rate conditions are based on hydrologic modelling of the peak SLT adit discharge flows. The model's framework is referred to as the "tank model." This model analogizes watershed basins to calculations based on tanks of water. These tanks of water simulate how a watershed might react. The main hydrologic input is precipitation. The ultimate output is the final base SLT discharge flow. The hydrologic output from these theoretical tanks is intended to replicate and forecast historic hydrographs and flow data for the basin of interest.

Based on the model, the predicted 10-year recurrence interval flow (Log Pearson Type III) for the SLT discharge is 1,150 gallons per minute (gpm). The predicted 25-year recurrence interval flow (Log Pearson Type III) is 1,250 gpm. The maximum observed flow rate since continuous flow monitoring was installed in 2011 at DR-3 is 1,250 gpm. The water treatment system will be sized for a peak influent flow rate of 1,150 to 1,250 gpm. The minimum influent flow rate is 400 gpm based on historical data collected at DR-3. Figures 5 and 6 provide the model output and the DR-3 hydrograph, respectively.

Influent composition based on DR-3 analytical data is shown in Table 1.

# 3 ANALYSIS OF REMOVAL ACTION ALTERNATIVES

The analysis of technology alternatives includes review of site characterization data, development of alternatives, and evaluation of alternatives for effectiveness, implementability, environment, and cost.

## 3.1 Preliminary Alternate Treatment Technology Screening

Technology alternatives previously considered and screened during preliminary evaluations were described in the *Preliminary Water Treatment Technology Screening Report* (Atlantic Richfield Company, 2011). Technologies were divided into three categories: biological treatment (microbial mats, sulfide reducing bioreactors, and constructed wetlands), chemical treatment (anoxic limestone drains, electrocoagulation, ion exchange, lime treatment with lagoon settling, conventional lime treatment, and sulfide precipitation), and physical treatment (electrodialysis, evaporation ponds, and reverse osmosis). The following alternatives were not retained for consideration:

- Microbial mats;
- Sulfate reducing bioreactors;
- Anoxic limestone drains;
- Electrocoagulation;
- Conventional lime treatment;
- Chemical sulfide precipitation;
- Electrodialysis;
- An evaporation ponds system; and
- Reverse osmosis.

Technologies that were retained for further consideration and on-site testing were: ion exchange, lime treatment with lagoon settling, lime treatment with high density sludge (HDS), and constructed wetlands. Bench scale testing of ion exchange treatment using multiple resins was completed at the Site in 2013. A lime treatment with lagoon settling system operated at the Site from 1984-1996. A pilot scale constructed wetlands system was trialed at the Site in 2012-2013. A separate investigation in 2012 evaluated the effectiveness of in-situ chemical treatment as an alternative to SLT water treatment. Performance results for these various technologies and systems are summarized in the following sections.

### 3.1.1 Ion Exchange

Ion exchange utilizes highly engineered resins to remove similarly sized and charged dissolved contaminants from water. The resin can be regenerated when resin capacity is spent. Resin regeneration produces waste with highly concentrated dissolved metals, which require proper handling and transport to an appropriate facility for disposal. Some metal contaminants may be difficult to remove with this method, and competing ions can make the process inefficient, possibly requiring an additional polishing step to meet treatability goals.

Bench scale testing was completed in 2013 for several resins and tested water collected from the Blaine, 517 Shaft, AT-2, and the SLT discharge (collected at DR-3). Results for the SLT discharge found that several resins had effective removal of cadmium and zinc but were generally not effective for arsenic or copper removal. Some resins were effective for manganese removal while others were not. Additional information on testing results and the resins that were trialed are discussed in the *Ion Exchange Test Results Technical Memorandum* (AECOM, 2013).

Based on the results of the 2013 bench-scale testing, ion exchange was eliminated from further consideration as a removal action treatment alternative.

### 3.1.2 Lime Treatment with Lagoon Settling and with HDS

Lime treatment with lagoon settling applies lime to the water causing the pH to increase and resulting in precipitation of heavy metals. Lime treatment with HDS uses a similar approach for pH neutralization but replaces lagoon settling with a flocculation and clarification step that generates a more manageable high-density sludge.

A lime treatment with lagoon settling system was operated at the Site during the 1980s and 1990s under a National Pollutant Discharge Elimination System (NPDES) permit. The system dosed the SLT adit discharge with slaked lime and a flocculant. Lime solids precipitated out and accumulated in the Ponds System. Table 2 summarizes the effluent parameters monitored during the operation of this system. Only a limited pool of parameters were recorded.

A preliminary assessment of the effluent monitoring results revealed inconsistent performance of the SLT lime treatment with lagoon settling system, particularly for cadmium, copper, and lead (Table 2). Atlantic Richfield currently operates HDS systems at several other acid-mine drainage sites. Those systems are generally performing well, although operating conditions at the other sites are not directly comparable to those at the Site.

Because lime treatment with HDS is a proven technology and offers several advantages over lime treatment with lagoon settling, including improved solids management efficiency; higher quality, denser solids; reduced footprint requirements; and improved operational control, it was retained for further consideration as a removal action treatment alternative.

### 3.1.3 Constructed Wetlands

A pilot-scale constructed wetland system was installed and trialed at the Site from December 2012 to September 2013. Pilot testing results are presented in the *St. Louis Tunnel Discharge Constructed Wetland Pilot Scale Test Completion Report* (Atlantic Richfield Company, 2013). The pilot test system utilized a limestone rock drain for manganese removal and an anerobic subsurface flow wetland for cadmium and zinc removal. It was tested at flow rates between 1.5-6 gpm. The aerobic rock drain effectively reduced dissolved manganese concentrations by greater than 99%. As much as 85% of dissolved cadmium and 65% of dissolved zinc were removed through the rock drain, and as much as 95% of dissolved cadmium and more than 99% of dissolved zinc entering from the rock drain was removed by the wetland cell. Successful removal of the target metals during the pilot test led to the design and implementation of the Constructed Wetland Demonstration (CWD) and Enhanced Wetland Demonstration (EWD) systems.

Decreased hydraulic conductivity in the wetland cell was observed at higher flows and was likely caused by accumulation of particulate iron, suspended and precipitated solids, and mobilization of fine sediment during flow increases. Gravitational settling of influent particulate iron was also observed in the rock drain, leading to the recommendation for adding settling ponds prior to treatment cells for the future demonstration systems.

Based on the pilot testing results and the positive performance of subsequently constructed demonstration-scale wetlands, expanded constructed wetlands technology was retained for further consideration as a removal action treatment alternative.

#### 3.1.4 In-Situ Chemical Treatment

A treatability study to assess the effectiveness of in-situ chemical treatment was conducted in 2012 and 2013. The study involved injecting alkaline solutions into the 517 Shaft to precipitate metals in the source water before it reaches the SLT. While some metals reduction was observed at the SLT discharge, results indicated that much of the chemical treatment was not reaching the SLT due to poor mixing within the 517 Shaft. In-situ treatment at the 517 Shaft also was generally ineffective in reducing metals concentrations reaching the SLT from other portions of the underground workings, including those entering the SLT from the NW crosscut. In-situ treatment also required ongoing injection and monitoring, presenting a potential safety risk in winter due to access restrictions and avalanche hazards. Additionally, there were concerns over the accumulation of metals precipitates in the underground workings over time and the potential for an uncontrolled release of those solids during a high-flow event.

Based on the results from the treatability study, in-situ chemical treatment was not retained for further consideration as a removal action treatment alternative (Atlantic Richfield Company, 2014).

### 3.2 Retained Alternative Treatment Technologies for Comparative Evaluation

Based on the technology screening described above, three alternatives were retained for further evaluation: No Additional Action, Lime Treatment – High Density Sludge, and Expanded Constructed Wetlands.

#### 3.2.1 No Additional Action

The No Additional Action alternative assumes that no additional improvements would be made at the Site and that the current demonstration-scale systems would continue to be operated "as-is" and maintained with the current operations, maintenance, and monitoring (OM&M). The existing demonstration-scale wetland systems and ponds would be utilized to treat the SLT adit discharge. Required sampling and OM&M tasks would be performed as necessary, including solids management. Aluminum chlorohydrate (or another coagulant/flocculant) would continue to be applied at the static mixer to aid in settling. Once the coagulant has been added, the water management would remain consistent with the current water treatment process. Flow rates that exceed the capacity of the wetland systems (610 gpm total) would be routed around the wetlands systems to Pond 12 for retention settling before discharge to the Dolores River. The process flow diagram for the No Additional Action alternative is presented in Figure 7.

The No Additional Action alternative would require minimal year-round staffing for monitoring and maintenance activities. Coagulant delivery would not be required during the winter months, eliminating the need for winter road maintenance and site access across avalanche routes. Solids generation would require regular maintenance. Any significant maintenance activities, such as media replacement (currently estimated at a 10-year life) or dredging solids (1-2 times per year), would require routing flow around the treatment systems for extended periods of time due to lack of redundancy in the design. This alternative would require minimal additional infrastructure construction.

### 3.2.2 Lime Treatment – High Density Sludge

Lime treatment with HDS would require construction of a new treatment plant and sludge dewatering facility. The SLT adit discharge would be dosed with lime and mixed in a reactor with recycled sludge from the clarifier. Then a polymer flocculant would be applied to the lime treated water and solids would be settled and collected in the clarifier. A multistage system may be required. This water would be discharged from the clarifier to the Ponds System or directly to the Dolores River. Solids would be recycled or wasted to containers for dewatering, neutralization, and disposal in the Solids Repository. Depending on design and performance criteria, it may be necessary to add a polishing step to the HDS effluent. Due to the limited size of the Solids Repository and the large quantities of treatment solids that would be generated, it is likely that stacking of treatment solids or construction of additional repository capacity would be needed (*see* 2021 RAWP, Section 1.1.4.4). Additional site infrastructure would be required, including a large, heated building, electrical utility upgrades, and significant road improvements to allow for year-round access and winter deliveries of consumables. The process flow diagram for Lime Treatment – High Density Sludge alternative is presented in Figure 7.

To handle system upsets and routine maintenance, an influent equalization/storage pond would need to be constructed. This pond would be sized to hold a minimum of 3.5 days (6.3 million gallons) of influent at the maximum flow rate described in Section 3.2. Operations would likely require a year-round presence on-site with clarifier clean-out and other major maintenance items occurring in the later part of the field season when SLT discharge has decreased from freshet levels and the Site remains easily accessible.

### 3.2.3 Expanded Constructed Wetlands Treatment System

A full-scale constructed wetlands treatment system would require expansion of the EWD system, providing increased hydraulic capacity, redundancy, and improved solids management. Additional system components would be added for redundancy to allow for continuous water treatment during higher spring flows, while performing needed maintenance and solids management. These would include settling basins, a biotreatment cell, rock drains, aeration cascades, and an expanded operations building with aeration and coagulation addition.

This alternative would incorporate the best performing components from the existing demonstration-scale constructed wetlands and add additional units to increase the hydraulic capacity and improve system performance. The system would be operated similarly to the current operations but at a larger scale. SLT flows that exceed the capacity of the expanded constructed wetland treatment system (in excess of 1,150-1,250 gpm) would still undergo aeration and coagulant addition, but they would be routed around the biotreatment steps to the Ponds System for retention settling prior to discharge to the Dolores River. With the expansion of system capacity, the duration, frequency, and amount of these re-routing episodes would be reduced. The process flow diagram for the Expanded Constructed Wetlands alternative is presented in Figure 8.

## 3.3 Comparative Evaluation of Alternatives

Treatment system alternatives were comparatively evaluated using the following primary criteria: effectiveness, implementability, environment, and costs. Effectiveness considers protectiveness of human health and the environment and the ability of the alternatives to achieve removal action objectives. Implementability considers the technical and administrative feasibility of each system and the availability of resources during and following implementation of the system. Environment considers waste production, energy usage, emissions, biodiversity, and footprint. Costs considers estimated capital and operations costs expressed as the net present value (NPV) expected for each alternative.

The results of the comparative analysis are summarized in Table 3 and Table 4 and discussed in the following sections.

### 3.3.1 Effectiveness

The effectiveness of an alternative is determined by assessing how successfully the alternative satisfies the removal action objectives and basis of design as outlined in Section 2. This evaluation includes discussion of protectiveness of human health and the environment by removal of contaminants. A ranking matrix comparing the effectiveness of alternatives meeting removal action objectives is presented in Table 5.

#### *3.3.1.1 Ability to Achieve Contaminant Removal*

Treatment and removal of metals from the SLT discharge are the main objectives for the treatment system. Treatment success for the alternatives is evaluated based on the ability to remove key contaminants. Treatment system effectiveness was evaluated based in part on an analysis of estimated metals mass removals and by comparing predicted effluent metals concentrations to the water quality based effluent limitations, antidegradation based average concentrations, and non-impact limits presented in the 2008 *Water Quality Assessment* (WQA) prepared by the Colorado Department of Public Health and Environment Water Quality Control Division (CDPHE WQCD, 2008).[1]

No Additional Action

Aside from the initial implementation stage, the three existing demonstration-scale systems under the No Additional Action alternative have been successful in reducing metal loading to the Dolores River and have generally been able to remove contaminants from the SLT water below the treatability goals. Spring runoff freshet episodes occur in most, but not all years, typically lasting from late spring through early summer. As explained further below, the resulting sharp increase in SLT discharge flow and contaminant loading may exceed the treatment capacity of the existing demonstration-scale systems, occasionally resulting in increased metals concentrations in the treatment system effluent. When flow exceeds the 610 gpm capacity of the three demonstration-scale systems, the excess water is routed directly to Pond 12 for retention settling. From Pond 12, the water flows through Ponds 11, 9, 8, 7, 6, and 5 before discharging to the Dolores River.

During low flow, non-freshet conditions, the EWD system is able to consistently meet treatability goals for aluminum, arsenic, cadmium, copper, iron, lead, manganese, nickel, and zinc. The increased flow and metals loading experienced during the freshet can exceed the removal capacity of the EWD system for aluminum, arsenic, manganese, and zinc. The EWD system has an average mass removal rate of greater than 98% for aluminum, cadmium, copper, iron, and lead. Average mass removal rates for other metals are: 93.3% for arsenic, 74.2% for

[1] Effluent limitations from the 2008 WQA and mass removal targets were not identified as chemical-specific Applicable or Relevant and Appropriate Requirements (ARARs) in the 2010 Action Memorandum.

manganese, 80.0% for nickel, and 90.4% for zinc. These removal rates translate into the following average total mass removals for the EWD system: 3,190 lbs/year for aluminum, 3.8 lbs/year for arsenic, 52.6 lbs/year for cadmium, 684 lbs/year for copper, 27,493 lbs/year for iron, 46.1 lbs/year for lead, 3,977 lbs/year for manganese, 9.7 lbs/year for nickel, and 8,460 lbs/year for zinc. Table 6 presents the annual mass removal rates for metals through the EWD from 2016 to August 2020. Solids accumulation in the system components over time may reduce metals removal effectiveness, resulting in the eventual need for media replacement.

The CWD Horizontal Wetlands Treatment Train (HWTT) is reliably able to remove most contaminants below the treatability goals during both low and high flows with the exception of aluminum and arsenic. The limestone rock drain in the HWTT has demonstrated success for efficient manganese removal with total manganese removal efficiency of greater than 96% through the HWTT system since 2016, including during freshet events. The CWD Vertical Wetlands Treatment System (VWTT) successfully removes cadmium, copper, iron, lead and zinc below treatability goals for both low and high flow periods. Increased loading during freshet flows creates difficulties with meeting treatability goals for aluminum, arsenic, manganese, and occasionally zinc.

Consistently meeting treatability goals for all metals year-round for the No Additional Action alternative is difficult due to limited capacity and removal efficiencies during periods of high metals loading as shown in historical data. Removal efficiency plots and historical influent/effluent contaminant concentrations for the demonstration-scale systems are provided in Attachment A. Attachment A plots contain monthly flow-volume average influent, effluent, and efficiency data for the EWD since the first complete year of operation (2016) to present. Horizontal lines in Attachment A represent the effluent limits presented in the 2008 WQA (CDPHE WQCD, 2008).

The plots show a consistently high rate of removal for most metals of interest for most of the year. During years when a freshet occurs, an increase in flow and metal concentrations is observed. The sudden, large increase in metal concentrations in the SLT discharge – particularly manganese and zinc – can affect the removal of some metals by the constructed wetland system for a short duration, generally during the May-August timeframe. Due to the passive and biotic nature of the EWD, sudden concentration changes of the influent waters can stress the system and reduce the removal efficiency of the treatment cells in the EWD. This is expressed by a dip in removal efficiency and an increase in effluent concentrations in the plots in Attachment A. Most metals, however, stay below the appropriate treatability goals during the freshet and return to higher removal efficiencies post-freshet.

*Lime Treatment – High Density Sludge*

Based on past performance of the lime-treatment-with-lagoon-settling system at the Site during the 1980s and 1990s and experience with lime treatment systems at other acid mine drainage sites, it is expected that lime treatment with HDS would achieve the treatability goals for most contaminants with some notable exceptions. Aluminum, cadmium, and manganese are present in the SLT discharge at levels well above the treatability goals and would be difficult to remove with a single-stage HDS system. Similar metal removal issues observed during operation of the lime treatment with lagoon settling technology (Section 3.1.2, and Table 2) would likely also affect the performance of an HDS system. Manganese and cadmium require a higher pH (in the range of 10-11 standard units [s.u.]) than the standard HDS system pH setpoint (typically 9-9.5

s.u.) to precipitate from the solution. Operating at a high enough pH required to meet treatability goals for cadmium and manganese would necessitate a finishing step for pH adjustment of the effluent prior to discharge. Additional polishing may also be needed to achieve desired removal rates for aluminum (which has increasing solubility as pH rises above ~7.5 s.u.) and total dissolved solids. Bench testing using SLT discharge water would be needed to evaluate the performance of process equipment, such as the clarifier, and to determine what pH adjustment and additional polishing steps are required.

Seasonal variations in SLT flow rate due to the freshet would be managed by collecting SLT discharge in an equalization pond to allow for controlled influent flow to the system. The capacity of the equalization pond would be limited by the available footprint (potential capacity of approximately 6.3 Mgal, or approximately 3.5 days of retention at 1,200 gpm SLT discharge) and may not be sufficient to accommodate the full SLT discharge at all times. Additionally, seasonal changes in metals loading during freshet conditions would require adjustments to raw materials dosing and possibly residence time or mixing conditions.

It is possible that during freshet periods there would be a reduction of efficiency across the system from increased metals loading and suspended solids that could result in failure to meet treatability goals for some metals (such as aluminum, cadmium, and manganese). Prior lime treatment with lagoon settling on the Site resulted in some discharge concentrations above the treatability goals for cadmium, copper, lead, and mercury (manganese and aluminum were not analyzed). Although lime treatment with lagoon settling is a different treatment approach, the basis of the lime treatment technology is similar, and freshet conditions would likely result in similar difficulties removing these metals from the SLT discharge utilizing Lime Treatment with HDS alternative.

*Expanded Constructed Wetlands*

The Expanded Constructed Wetlands design would add additional components to the existing EWD system to address the limitations described above for the No Additional Action alternative. Hydraulic capacity and residence time limitations for contaminant removal efficiencies would be resolved with additional settling basins and an additional biotreatment cell and aeration cascade, allowing the system to better handle the higher flows and metals loadings experienced during the freshet. The Expanded Constructed Wetlands system would also include the addition of limestone rock drains for manganese removal due to the success of this component in the existing HWTT.

With these design improvements, the Expanded Constructed Wetlands would be expected to meet the treatability goals for the vast majority of the year and effectively reduce metals loading to the Dolores River. However, SLT discharge flows during unusually high-water years could still exceed the hydraulic and treatment capacities of the system. Additionally, system effectiveness would likely decline slightly over time due to solids accumulation within the components as the matrix approaches the end of its lifespan. These effects could be mitigated through proactive solids management and maintenance-oriented system design. Flow above the design capacity of the Expanded Constructed Wetlands (greater than 1,150-1,250 gpm) would continue to be routed around the biotreatment cells to the Ponds System.

The Expanded Constructed Wetlands alternative would achieve greater metals removal and further improve water quality in the Dolores River, as compared to the No Additional Action alternative.

#### *3.3.1.2 Protectiveness*

Protectiveness evaluations consider how reliably an alternative supports the removal action objectives. In this section, alternatives were evaluated for longevity of the system and components, flexibility, system control, and time to implement the technology.

*No Additional Action*

Some integrity risk exists for the No Additional Action alternative. The demonstration-scale systems have limited hydraulic capacity and lack redundancy. Flow in excess of 610 gpm during high flow/freshet periods or system downtime result in routing portions of flows around certain treatment components. All flow that is routed around process units is discharged to Pond 12 for retention settling prior to reaching the Dolores River. Aside from freshet conditions, the risk for process upsets that could affect water quality is considered low. However, the semi-passive control and long residence time of the systems would make upsets challenging and time consuming to resolve. Wetland systems are not easily modified and have an inherent lag in response to process changes, which may make it difficult to meet some treatability goals, especially at maximum flows. The nature of the wetlands systems also reduces system flexibility, as most modifications or system upgrades would likely require substantial planning, construction, and time to implement. Some flexibility with flow management and residence time is achievable through the addition or removal of boards to/from effluent manholes.

Semi-passive control of the system means that minimal equipment is required for operation, which reduces the likelihood of critical equipment or instrumentation failures. The expected lifespan of the component media matrices is currently being evaluated but is anticipated to be approximately 10 years before replacement would be required. Water quality sondes require frequent calibration and some probes (specifically pH/Oxygen Reduction Potential [ORP]) need replacement on a regular basis.

*Lime Treatment – High Density Sludge*

The use of process controls and equipment allows for tight control of the process and immediate responses to system upsets. There would be an increased risk of process upsets as compared to other alternatives due to the higher opportunity for equipment or instrumentation failure that may temporarily affect effluent water quality. Equipment failure could result in extended downtime and the temporary inability to treat water until repairs could be made or a replacement could be procured. However, an equipment-based active treatment system allows for system flexibility, as timely modifications could be made with minimal interruption to treatment.

An HDS treatment system would have a relatively long design life overall, but individual equipment and components would require replacement as necessary to maintain performance. For example, equipment life could last as long as 20+ years for tanks and reactors or as little as a few months for some instrumentation (such as pH probes). Installation and shakedown for system performance evaluation is anticipated to take multiple field seasons; however, bench testing would be necessary to properly design and size equipment, which would delay construction. The Lime Treatment with HDS plant consists of a smaller footprint than the existing wetlands treatment systems, although some pond capacity would still be required for temporary storage and equalization, as noted above.

*Expanded Constructed Wetlands*

Many of the same risks, mitigations, and benefits would be experienced with the Expanded Constructed Wetlands alternative as with the No Additional Action alternative, including semi-passive system control, process upset management, flexibility, and longevity. However, design and implementation of the Expanded Constructed Wetlands utilizes lessons learned from the demonstration-scale systems to mitigate additional risks and improve system integrity and redundancy. Additional settling basins, as well as an additional biotreatment cell, aeration cascade, and dual rock drains, would increase hydraulic capacity and create system redundancy to allow maintenance to be conducted without routing flow around the treatment system, providing superior protection and increasing system flexibility. As with the demonstration system, the semi-passive design of the system tends to create a challenge for timely recovery from process upsets.

The expected lifespan of the component media matrices is approximately 10 years before replacement would be required. Design of the Expanded Constructed Wetlands would address maintenance difficulties for settled solids removal experienced during operation of the demonstration-scale systems, which is expected to extend the lifespan of the matrix media. Water quality sondes would similarly require frequent calibration and replacement of some probes.

The Expanded Constructed Wetlands would require two field seasons for construction, followed by inoculation of the new system components and a shakedown period for system performance evaluation. This alternative likely requires the full available footprint of the Site, including removal of some existing upper ponds for new construction. The final tie-in of the new components to the existing EWD system as well as the conversion of the manganese removal cell would require downtime of the EWD treatment system and may temporarily affect effluent water quality.

### 3.3.2 Implementability

Implementability is a measure of technical and administrative feasibility of the alternatives, implementation and operational risk, logistics considerations, and the availability of materials, services, and resources to implement and operate the technology.

The fact that water treatment systems similar to the No Additional Action, Lime Treatment – High Density Sludge, and Expanded Constructed Wetlands alternatives are operating at other locations has been considered in the implementability evaluation. These similar water treatment systems, constructed and operated at the other sites include the following:

1. Constructed Wetlands Systems including above-ground and below-ground wetlands/biochemical reactors:
    a. Empire Mine, Colorado (settling pond and aerobic wetlands);
    b. ASARCO's West Fork site, Missouri (settling pond, two anaerobic wetlands cells, a rock filter, and an aeration pond);
    c. Aspen Seep Bioreactor at the Leviathan Mine Site, California (two bioreactors and two settling ponds);
    d. Burleigh Tunnel, Colorado (anaerobic compost constructed wetlands system); and
    e. Captain Jack Mill, Colorado (in-situ bioreactor).

2. Lime Treatment – HDS Systems:
    a. High Density Sludge Treatment System at the Leviathan Mine Site, California;
    b. Horseshoe Bend Water Treatment Plant, Montana;
    c. Leadville Mine Drainage Tunnel, Colorado; and
    d. Gladstone Interim Water Treatment Plant, Colorado (non-HDS system).

#### *3.3.2.1 Technical and Administrative Feasibility*

Technical feasibility analyzes the potential for technical difficulties associated with each alternative that could cause delays in implementation or successful operations, including reliability of the technology, complexity of operations, maintenance, control systems, raw materials required, and Site-specific factors.

Administrative and regulatory factors for each alternative include items such as securing permits (if required), meeting non-environmental laws, impacts on adjoining properties, easements required (if any), and complying with regulatory requirements.

Atlantic Richfield owns much of the real property immediately surrounding the SLT portal, Solids Repository, and demonstration-scale constructed wetlands treatment systems, which are located north of and outside the Town of Rico boundary. Atlantic Richfield is also in the process of acquiring additional United States Forest Service (USFS) property associated with the Ponds System.

Site-specific characteristics will affect the design and operation of each treatment system option. Considerations include weather, terrain, the available footprint, winter operation and access (including avalanche hazards), and remoteness of the Site.

*No Additional Action*

The No Additional Action alternative results in low implementation risk since it requires minimal operations staff and intervention due to a mostly passive style treatment system. Some cells are not adequately designed for maintenance and require labor-intensive work to mobilize equipment for solids removal. Solids generation and management has been an ongoing issue with the demonstration-scale constructed wetlands. Solids accumulation in cells requires frequent maintenance and shortens the anticipated life expectancy of the components. Solids carryover/settling occurs in units downstream of the settling basins, resulting in frequent maintenance requirements and reducing efficiency of downstream cells. Settling basins also require multiple cleanouts per year. Solids currently can be disposed of on-site. Minimal intervention is required during winter months, which reduces risks due to winter conditions and avalanche hazards for site personnel. No winter deliveries of coagulant are required as sufficient storage is available on-site. The passive style treatment with constructed wetlands systems requires minimal utilities and consumables. Consumables include aluminum chlorohydrate coagulant (and potentially flocculant) and sampling supplies.

*Lime Treatment – High Density Sludge*

Construction of a Lime Treatment with HDS plant would require an array of skilled labor to complete, including masons, pipefitters, mechanics, electricians, automation experts, and general construction labor. Due to the remote location of the site, procuring contractors from outside locations would be necessary. Delivery of large equipment pieces may also take additional logistical time and coordination, as the only access to the Site is via a two-lane mountain highway, and special permits would be required for any transportation of wide or oversized loads. The Lime Treatment with HDS alternative would require construction of a new operations building to house process equipment for protection from winter conditions. Construction includes significant civil work with large heavy equipment, electrical, placement and assembly of process equipment and piping, and construction of equalization ponds. Large equipment would require permitted lifts for placement. Solids removal from Pond 15 and other components would also be necessary.

The Lime Treatment with HDS alternative would require a team of operators and maintenance personnel for year-round treatment. Additional expected maintenance includes annual system deep cleaning and pump rebuilds, daily inspections and calibrations, and regular intervals of various system component testing. Safe site access would require frequent snow removal from the main access road and off-site placement, avalanche hazard mitigation and monitoring, and increased traffic on winding mountain roads via Colorado Highway 145. Poor weather conditions may put delivery and operations staff at risk during travel and result in delivery and/or treatment delays. Winter access to raw materials delivery would also be unreliable and risky for travel, which may require large on-site storage capacity and materials handling logistics to stock up materials before winter to avoid weather- and travel-related delays.

Given temperature extremes at the Site, a heated building rated for heavy snow loads would be required to contain the system and prevent freezing during winter months. Due to the cost of the major equipment pieces, redundancy would be costly to achieve, and maintenance requirements would result in process down time. SLT discharge during periods of downtime would either be captured in equalization ponds or require temporary routing around the treatment plant. There would be a competing need for space for the HDS treatment system and backup treatment/storage in case of an upset condition. Certain scenarios could result in additional periods of non-compliance (such as inability to deliver reagents to the Site due to weather). HDS produces a dense sludge that is purged from the system and requires dewatering prior to disposal. As a result of the limited size of the Solids Repository, a second phase of the Solids Repository would need to be constructed for solids disposal over the 30-year project life. Off-site disposal could be required after 30 years. The Lime Treatment with HDS alternative would require the second phase of the Solid Repository be constructed much earlier (in about half the time) when compared to the Expanded Constructed Wetlands alternative. Utilities costs would be significant due to power required to run various equipment such as the clarifier, pumps, and mixers, as well as lime and flocculant delivery systems.

*Expanded Constructed Wetlands*

Construction of an Expanded Constructed Wetlands system would require a array of skilled labor to complete, including masons, pipefitters, electricians, and automation experts, but would primarily rely on general construction resources for excavation, solids removal, placement of liners, installation of HDPE piping, and civil work with heavy equipment. Less electrical would be required as compared to Lime Treatment with HDS and would primarily consist of power and telemetry for coagulant storage and dosing, water quality sondes, water level and flow, hydrogen sulfide ($H_2S$) gas monitors, and aeration. No equipment requiring special transportation permitting would need to be procured, with the possible exception of coagulant storage tanks. However, there would likely be significant traffic to and from the Site for delivery of borrow and other construction materials. Solids removal from Pond 15 and other components would also be necessary.

Expansion of the constructed wetlands would be designed to include redundancy to allow for routine maintenance without routing flow around the treatment system during base-flow conditions. Additional system components for the Expanded Constructed Wetlands design would require a significant footprint in an area with limited available land. However, minimal utilities would be required for this system. Consumable deliveries would not be required over the winter as adequate consumables storage would be available on-site. Overall solid and other waste generation, transportation, and disposal for expansion of the constructed wetlands would be comparatively low. Solids settling and accumulation would occur in the settling basins and would require periodic cleanout and maintenance. Solids would be disposed of on-site. New system components would be designed with maintenance capabilities in mind based on lessons learned from the existing demonstration-scale systems to reduce time, risks, and costs associated with current solids management requirements.

The Expanded Constructed Wetlands would be suited for the Site because of the comparatively low base metal contaminant levels, the circumneutral nature of the SLT discharge water, and a considerably reduced OM&M profile. Minimal operations staff would be required, and little intervention would be required during the winter months. No winter deliveries of coagulant would be required, as sufficient storage would be available on-site to stock the product prior to winter weather.

The Expanded Constructed Wetlands alternative would be expected to perform better than the demonstration-scale constructed wetland systems (CWD and EWD), as it would be designed with increased hydraulic capacity and have improved system performance by maintaining and using the best performing components from the existing systems. Periodic solids removals from settling basins and periodic media replacements would be required to maintain effectiveness. Year-round effectiveness would be maintained by including redundancy in the final design, which is intended to allow for routine maintenance without routing flow around the treatment system.

#### *3.3.2.2 Implementation Safety Risk*

There are general health and safety concerns with construction work at the Site that require proper safety management to reduce risk, such as biological elements, physical demands, high altitude, working around water and slippery slopes, and extreme and/or changing weather conditions. Construction for all alternatives will be scheduled during the spring to fall field season as much as possible to avoid hazards associated with the harsh winters in Rico. Additionally, special precautions will be taken to properly acclimate new workers to the high altitude at the Site. Weather will be monitored daily, and work will be ceased and rescheduled when weather, such as heavy rain or lightening, begins to create hazardous conditions. A water truck will be utilized when necessary to spray down roads to mitigate fugitive dust generated by implementation activities. All activities will be performed in accordance with health and safety plans and risk assessments. Safety risks associated with implementation were considered for each alternative as discussed in this section.

*No Additional Action*

The No Additional Action alternative operates the existing demonstration wetland systems and therefore requires no implementation tasks, as the implementation has already been completed.

*Lime Treatment – High Density Sludge*

Implementation of a Lime Treatment with HDS plant would require a wide array of skilled labor and significant construction that would involve the use of large, heavy equipment and simultaneous operations (SIMOPs) that would necessitate careful planning and execution. Civil and general construction would be required for construction of the plant building to house the equipment. Transportation, unloading, and installation of large or heavy equipment may require special permitting and scheduling for delivery via the two-lane highway. SIMOPS and increased traffic and personnel on-site would create a risk of collisions and would necessitate traffic control and spotters. The use of cranes and competent operators would be necessary for unloading deliveries and installation of large equipment pieces. Erection of the process equipment and piping would require working from heights and the use of scaffolding or manlifts. Installation of the system piping, electrical, and controls must be completed by competent and licensed personnel to ensure safety and functionality. Much of this work would involve energy isolation, hot work precautions, pinch point hazards, and working at heights. Additionally, assembly of internal components inside process equipment (such as the clarifier rake or reactor agitator) may necessitate entry into confined space. Chemical hazards exist for set up and delivery of the initial flocculant and lime stores as well as from possible dust or contact with solids removal from existing ponds to install the operations building, equalization pond, and sludge drying bed. Tear down and disposal of the historic lime silo and contents would create a lime dust exposure and demolition hazard. Fugitive dusts from construction and traffic would require mitigation by wetting roads and excavation sites as necessary. Additional hazards include pressure testing of piping, overhead utilities, and testing and assembly of rotating equipment.

*Expanded Constructed Wetlands Treatment System*

Most of the construction and implementation of the Expanded Constructed Wetlands system components could be completed by general construction companies. Competent and licensed personnel would be necessary for installation of electrical, instrumentation, and controls but on a far smaller scale than for Lime Treatment with HDS. Construction of the Expanded Constructed Wetlands would require significant civil work using large, heavy equipment. Additionally, the Site would receive significant traffic from materials deliveries. The increased traffic, SIMOPs, and number of construction personnel working on the site could create collision and struck by hazards that would necessitate monitoring and traffic control measures to reduce risk, such as spotters and SIMOPs coordination. The main hazards associated with construction of wetlands cells are excavation and engulfment if shoring of slopes is not completed properly. Engulfment hazards would also exist when dumping component media into new cells. Long stick excavators and long reach equipment would be utilized as necessary during media placement to avoid the need for equipment to enter component cells. Additional hazards include working around water near existing components, working near $H_2S$ exclusion zones, laying and pressure testing of piping, and working near overhead utilities. Inoculation of the new biotreatment cell would be completed by mixing in media (which includes manure, metals precipitates, and bacteria) from the existing biotreatment cell, and safe hygiene practices and PPE would be utilized to prevent exposure. Construction of the new biotreatment cells and conversion of the manganese removal cell to a settling basin would require the removal of existing settled solids and used media. Solids would be disposed of in the Solids Repository, but potential exposure risk would exist during removal and transport of the solids. Tear down and disposal of the historic lime silo and contents would create a lime dust exposure and demolition hazard. Excavation and traffic would also introduce a dust hazard due to the existence of metals, calcines, and waste rock from historic operations and could be mitigated by wetting roads and materials as necessary to control fugitive dust. Initial startup of the Expanded Constructed Wetlands system would produce a temporary increase in $H_2S$ generation as the biotreatment cell becomes anerobic but could be controlled and mitigated by closely monitoring the system and managing residence time of the cell.

#### *3.3.2.3 OM&M Safety Risk*

There are general health and safety concerns of OM&M field work at the Site that require proper safety management, such as biological elements, physical demands, high altitude, working around water and slippery slopes, and extreme and/or changing weather conditions associated with the Site.

*No Additional Action*

The No Additional Action alternative continues the current operations of the EWD and CWD treatments systems without modification. The existing OM&M tasks would continue to be performed, including water quality sampling, equipment maintenance, solids removal, chemical delivery and handling, inspections, and general site maintenance. Maintenance activities that have potential for chemical exposure include handling and storage of coagulant (aluminum chlorohydrate), settled solids removal from system components, calibration of sondes, on-Site laboratory testing, and $H_2S$ off-gassing from some system components. Safety management procedures and physical barriers are in place to protect operators from $H_2S$ exclusion zones; however, some activities do require controlled access to these areas. Solids removal activities require labor intensive equipment mobilization and have the potential risk for injury.

Minimal staff intervention is necessary for OM&M, especially during the winter, which reduces operational and safety risk by means of limiting staff exposure. Periodic winter access would still be required and would introduce environmental hazards including travel to and from the Site, working in cold weather and navigating over deep snow conditions and through existing avalanche paths.

*Lime Treatment – High Density Sludge*

Lime Treatment with HDS utilizes an active treatment plant that relies on process equipment, automation and controls, and competent staff to continuously operate. OM&M activities would include regular inspections and maintenance of equipment and instrumentation, sludge/solids management, chemical delivery and handling, and general Site maintenance (including snow removal in winter). OM&M tasks for Lime Treatment with HDS require handling of flocculant and lime, which pose chemical exposure risk to site personnel. Lime is a corrosive substance that can be dangerous to human health or the environment by means of exposure or loss of containment. Storage and handling of lime on Site would require rigorous safety management. The automated sludge recycle and wasting system for the clarifier largely eliminates solids exposure risk during operations. However, personnel would need to sample and manage disposal of dewatered solids. High risk potential maintenance tasks would require competent skilled technicians for performing lock-out tag-out and activities (such as tank cleaning) that require confined space entry.

Utilizing Lime Treatment with HDS would necessitate year-round full-time staffing and require safe access to the Site for personnel and deliveries in the winter. Possible risks to human health during winter operations include working in cold conditions, access to the Site through avalanche paths, and travel on snow- or ice-covered mountain roads. Frequent monitoring and mitigation for avalanche prevention and regular snow removal from the main access road and site access roads (i.e., access to sludge drying bed) would be necessary to reduce risk.

*Expanded Constructed Wetlands*

Again, many of the same risks, mitigations, and benefits would be experienced with the Expanded Constructed Wetlands alternative as with the No Additional Action alternative, including the potential for chemical exposure, working in winter conditions, semi-passive system control, process upset management, solids management, and minimal staffing or intervention required. However, design and implementation of the Expanded Constructed Wetlands would utilize lessons learned from the demonstration-scale systems to mitigate additional risks and improve system integrity. New settling basins would be designed to facilitate solid removal and reduce risk of injury by limiting labor intensive tasks and reducing exposure to solids. Components that generate $H_2S$ would be designed to minimize accumulation zones (such as installing open-air hydraulic control structures to allow gas to dissipate).

#### *3.3.2.4 Availability and Logistics*

The availability and logistics assessment addresses personnel and technical requirements, off-site waste disposal, laboratory analysis needs, and access to equipment and supplies. Lack of equipment availability, skilled labor, or logistic roadblocks may impact the time required to implement technologies. The ability to prevent or minimize downtime due to maintenance and operations procurement needs may also impact the implementability of the alternatives.

Logistics and availability of services and materials are an inherent challenge at the Site due to the remote mountain location and seasonal inclement weather. Rico is a small town with a population of approximately 250 people and limited services. A single two-lane highway connects the Town of Rico to larger city centers with significant elevation change between cities. Driving can be especially hazardous and difficult during winter months due to ice and snow, which may affect the ability for the site to receive equipment, raw materials, or skilled services. Hiring competent staff for implementation and especially for post-construction operations and maintenance is challenging, and recruitment may not be a timely process for all prospective alternatives.

*No Additional Action*

The No Additional Action alternative would operate the current treatment system and require staff of approximately five for year-round operation. During field season, which typically runs from May to October, field staff typically work 50 hours per week to perform OM&M and other project tasks. The semi-passive operation of the system allows OM&M tasks to be limited during winter months, and the Site is only accessed on a bi-weekly basis or as needed. The No Additional Action alternative does not include any additional improvements that would create availability or logistics concerns for implementation. Solids are currently disposed of on-site and do not require off-site disposal. Raw materials and supplies can be sourced as needed utilizing current vendors and suppliers. Materials are available for procurement most of the year. Raw materials and supplies required for Site operation include aluminum chlorohydrate, biotreatment cell media, clean water, and diesel. These materials are procured regularly, depending on the consumption rate on Site. Currently, coagulant is procured every 3-6 months. Biotreatment cell media is predicted to be procured every 10 years. Site access is sufficient for delivering and receiving raw materials when needed. The No Additional Action alternative is expected to be unavailable for treatment for several short periods during the year when maintenance activities such as solids removals from the settling basins occur. Additionally, when biotreatment cell media requires replacement, the system would be unavailable for an extended period of time (possibly up to two months while media is replaced).

*Lime Treatment – High Density Sludge*

Lime Treatment with HDS would require a year-round staff of approximately six to operate, including staff that would require technical skills for maintenance and/or electrical to address system issues in a timely manner. Staff requirements assume 40 hours per week to operate year-round. Procuring and retaining a qualified team in a remote area may be difficult to achieve. Additional expected operational maintenance includes annual system deep cleaning and pump rebuilds, daily inspections and calibrations, and regular intervals of testing various system components. Many of these maintenance items would require down time to perform, limiting the percent availability of the system to treat water. A more frequent maintenance schedule requiring extended periods of downtime could potentially allow for exceedances, especially during periods of poor influent water quality (freshet) unless a fully redundant system is available.

This treatment option would require several consumables, including flocculant and lime that would require year-round delivery. Winter access for raw materials delivery would also be unreliable and risky for travel, which may require large on-site storage capacity and materials handling logistics to stock up materials before winter to avoid weather- and travel-related delays. Delivery of large equipment pieces may take additional logistical time and coordination as the only access to the site is via a two-lane mountain highway. The Site access road may also require additional maintenance and/or re-routing to accommodate more frequent deliveries and avalanche mitigation for winter Site access, which would require major construction and additional non-removal action design changes to the Site.

*Expanded Constructed Wetlands*

The Expanded Constructed Wetlands treatment system would require a staff of approximately four for year-round operation. During field season, which typically runs from May to October, field staff would typically work 10-hour days Monday through Friday to perform OM&M tasks. The semi-passive operation of the system allows OM&M tasks to be limited during winter months and the Site would only be accessed on a bi-weekly basis or as needed. Required consumables would include aluminum chlorohydrate coagulant (potentially additional flocculant) and sampling supplies and are available as needed via current suppliers to the Site. Solids would be disposed of on-site.

Logistical concerns are nearly equivalent to the No Additional Action alternative. Procurement of consumables such as coagulant and diesel is similar, but biotreatment cell media life is expected to be vastly improved due to improvements in solids management design. Due to system redundancy, this alternative is anticipated to have minimal downtime and be available for treatment of water year-round, even when settling basin cleanouts and/or biotreatment cell media replacement occurs.

### 3.3.3 Environment

The environmental impact of each alternative regarding waste production, energy usage, emissions, biodiversity, and overall footprint was evaluated. Treatment alternatives that produce minimal waste, reduce energy consumption, minimize the overall footprint and maintain a sustainable environmental impact are favored over other alternatives.

*No Additional Action*

Under No Additional Action waste production, energy usage, emissions and the footprint would remain unchanged from current Site operations. The footprint of the systems consumes a large percentage of the Site, including the Ponds System. However, the semi-passive and natural feel of the wetlands and Ponds System have shown to positively impact biodiversity in the area, as wildlife has become established in the Ponds System. The rate of waste produced on Site (sludge, etc.) is not expected to increase significantly over time, and the Solids Repository has the capacity to accept all generated solids over the design life of the project. The energy usage on Site is minimal as the system is semi-passive and requires limited equipment for operations. Emissions would not be expected to increase following the implementation of the No Additional Action alternative.

*Lime Treatment – High Density Sludge*

Lime Treatment with HDS is dependent on the addition of lime and various coagulants, flocculants, and other water treatment solutions. These treatment materials add additional mass to waste produced by the water treatment system. Although producing denser sludge/waste materials than other treatment alternatives, waste production would significantly increase. Additional waste disposal facilities may be required. HDS sludge treatment would require active water treatment, with energy demands required for various pumps, monitoring systems, and dosing systems. Energy usage would be high in the winter months as the plant would require an enclosed heated building to prevent freezing of lines and equipment. Emissions would not be expected to increase. The energy consumption and energy demand footprint with this technology would be much larger than the semi-passive water treatment alternatives discussed in this report. The Lime Treatment with HDS plant would consist of a smaller physical footprint than the existing wetlands treatment systems and would effectively reduce the amount of land needed for operation of the Site. However, active treatment would increase operations activity and traffic at the Site, which may negatively impact biodiversity in the immediate area as noise and traffic may force established wildlife to seek new habitations.

*Expanded Constructed Wetlands*

Waste production is estimated to be directly proportional to the load treated from the SLT. Off-Site disposal would not be necessary as the Solids Repository has sufficient capacity to dispose of all generated solids over the project life. The energy use on Site would be low, as the semi-passive nature of the treatment technology takes advantage of gravity to move and distribute water throughout the treatment system instead of pumps. This alternative would require the largest footprint and a majority of the available space on the Site would be utilized in the design. However, the semi-passive and natural feel of wetlands and the Ponds System would be expected to positively impact biodiversity in the area over time as with the existing demonstration wetlands systems. Depending on future design, passive aeration techniques may be possible and eliminate the current active aeration treatment step. Gravity based passive systems allow for a small carbon/environmental footprint.

### 3.3.4 Cost

Capital investment, ongoing OM&M costs, and NPV have been estimated for each alternative and are presented in Table 7. High capital costs or consumables and operational costs may render some systems less favorable and impact the overall sustainability of the systems for long-term operation. Cost of closure was not considered due to the need for perpetual treatment at the Site.

#### *3.3.4.1 Capital Costs*

Capital investment costs estimated for each system include direct equipment and construction costs and indirect construction costs (administration, safety, engineering design, quality assurance, and oversight) for water treatment. Non-water treatment related infrastructure including hydraulic controls, an improved access road and avalanche/rock fall protections and shelters are not accounted for in the capital investment costs. Capital associated with solids repository construction are not included in the capital cost estimates but are accounted for in the NPV calculations. NPV calculations are provided on a consistent 30-year project life including design, construction, and OM&M.

*No Additional Action*

The No Additional Action alternative assumes that the existing systems would be operated as-is with no additional improvements or investment. Therefore, no capital investment would be required for this scenario.

*Lime Treatment – High Density Sludge*

The capital investment required for implementation of an HDS Lime Treatment system is estimated at $12.2 million (M). Required infrastructure would contribute to more than half the capital cost and include, but not be limited to, converting existing ponds into influent equalization ponds and a solids drying bed, constructing an influent pump station, and constructing a large, heated building to contain the full system and structures for housing utilities and power stations. Demolition of some existing structures and solids removal from existing ponds would be required. An HDS plant would require the purchase of a significant amount of process equipment, instruments, electrical, piping, and controls to operate. However, much of this equipment would retain value and be considered recoverable capital.

*Expanded Constructed Wetlands*

The capital investment required for implementation of the Expanded Constructed Wetlands system is estimated at $9.1M. This estimate includes solids removal from existing ponds within the new system footprint and construction of system components (settling basins, biotreatment cell, rock drains, and aeration cascade), instruments/telemetry, and piping. The existing EWD treatment system would also require some modification to be integrated into the full-scale system. The cost estimate of the expanded system includes structural costs for constructing a larger chemical feed building and installing and purchasing aeration and flocculation equipment.

#### *3.3.4.2 OM&M Cost*

OM&M costs were estimated for the 30-year design life of the systems based on previous experience at similar sites and available information. OM&M costs include sampling frequency, required manpower, raw materials, solids management and disposal, utilities, and many other considerations. Estimates also include matrix replacement costs adjusted to an annual basis for the No Additional Action and the Expanded Constructed Wetlands alternatives (assuming a 10-

year matrix life). As the Site is expected to treat SLT discharge water in perpetuity, OM&M costs are especially significant for evaluating the best fit for long-term operation.

*No Additional Action*

The No Additional Action alternative assumes the continuation of annual maintenance activities that are currently being performed at the Site and are expected to cost $2M annually at a cost of $6.35/1,000 gallons of treated water. Periodic replacement of biotreatment cell media, rock drain media, and wetlands plant matrix would be necessary due to solids buildup in the system. The cost for replacing these media is included on an annualized basis in the estimate assuming a 10-year replacement cycle. Annual OM&M costs include, but are not limited to, solids management, chemicals (flocculant/coagulant, analytical solutions), stormwater control, replacement equipment/instruments and oversight. The semi-passive nature of the system means that little equipment, maintenance and associated costs would be required for operation. There would be no need for a dedicated maintenance team on-site, and minimal full-time staffing would be required to run the system (Site currently treats water 24/7 with full time staff members working Monday through Friday day shift only).

*Lime Treatment – High Density Sludge*

The Lime Treatment with HDS alternative is an active treatment plant and the OM&M costs are estimated at $2.6M annually at a cost of $7.56/1,000 gallons of treated water. Lime Treatment with HDS depends on a large quantity of electrical components, programming, instrumentation, and process equipment to operate which would require periodic replacement or refurbishing. Regular maintenance, calibrations and sampling are essential to keep the system optimized and operating efficiently. As such, a dedicated on-site maintenance staff may be required to maintain equipment and address issues timely. Other maintenance activities include, but are not limited to, descaling clarifiers and other equipment, solids management and disposal of sludge waste, and raw materials costs (lime, analytical chemicals, flocculant, etc.). A critical equipment inventory would need to be maintained on-site so that critical spare parts are immediately available when needed to prevent downtime. Lime Treatment with HDS is an active treatment system and would have increased staffing needs as compared to the semi-passive wetlands alternatives to monitor equipment and system automation.

*Expanded Constructed Wetlands*

OM&M for the Expanded Constructed Wetlands is estimated to cost $1.95M annually at a cost of $5.67/1,000 gallons of treated water. OM&M requirements are very similar to the No Additional Action alternative. Periodic replacement of biotreatment cell media, rock drain media and wetlands plant matrix would be necessary due to solids buildup in the system. The cost for replacing these media is included on an annualized basis in the estimate assuming a 10-year replacement cycle. As with the No Additional Action alternative, annual OM&M costs include, but are not limited to, solids management, chemicals (flocculant/coagulant, analytical solutions), stormwater control, replacement equipment/instruments and oversight. The semi-passive nature of the system means that little equipment, maintenance and associated costs would be required for operation. There would be no need for a dedicated maintenance team on-site and minimal full-time staffing is required to run the system. Expected OM&M costs are reduced as compared to the No Additional Action alternative as the CWD systems would no longer be operated or maintained. Redundancy in the Expanded Constructed Wetlands system would also allow for maintenance to be conducted without needing to route flow around the treatment system.

#### *3.3.4.3 Net Present Value*

Estimated NPV is calculated on a pre-tax basis with a 7.0% discount rate and a 2.0% inflation rate over 30 years. These calculations are shown in Table 7. The calculations return a NPV of -$31.85M (at a cost of $3.37/1,000 gals treated water) for No Additional Action, -$53.0M (at a cost of $5.14/1,000 gals treated water) for the Lime Treatment with HDS system, and -$36.9M (at a cost of $3.58/1,000 gals treated water) for the Expanded Constructed Wetlands. NPV for all alternatives is shown as a deficit as the Site does not generate revenue as a result of implementation of the treatment system. NPV for the Expanded Constructed Wetlands costs approximately 15% more as compared to the No Additional Action alternative. However, the NPV of the Lime Treatment with HDS system is nearly 70% more than the No Additional Action alternative due to the cost of capital and OM&M expenditures over the design life of the system.

# 4 RECOMMENDED REMOVAL ACTION ALTERNATIVE

Based on the evaluation presented in this report, the Expanded Constructed Wetlands is the preferred removal action. The Expanded Constructed Wetlands would: 1) reduce key contaminants loading to the Dolores River to improve water quality; 2) best achieve the objective of meeting agreed upon performance criteria; 3) treat base flows and freshet flows up to a 25-year recurrence period (design permitting); 4) provide safe, reliable, year-round / all-weather operations; and 5) minimize waste production and energy usage.

The expansion of the EWD to implement the Expanded Constructed Wetlands system would reliably increase mass removal from the SLT discharge and reduce metals loading to the Dolores River. The demonstration-scale constructed wetlands have proven that wetlands treatment is viable for the Site and is especially amenable to the circumneutral pH and stable year-round temperatures of the SLT adit discharge. The EWD system has an average mass removal of greater than 98% for aluminum, cadmium, copper, iron, and lead, with removals of 93.3% for arsenic, 74.2% for manganese, 80.0% for nickel, and 90.4% for zinc. Mass removal efficiency percentages and total removals for the life of the EWD system are listed in Table 6, and efficiency plots are available in Attachment A. Seasonal increases in flow and metals loading associated with the freshet stress the demonstration-scale systems and result in difficulties meeting treatability goals, particularly for manganese and zinc. The Expanded Constructed Wetlands alternative would mitigate this issue by incorporating rock drains and increasing treatment capacity into the wetland system design. The rock drain in the HWTT has been able to effectively remove manganese and zinc to below treatability goals even during freshet periods. The improved removal efficiencies of the Expanded Constructed Wetlands would be protective of the environment by consistently reducing metals below treatability goals in most conditions and the design would have the capacity to treat influent flows up to the 25-year recurrence with the construction of the new treatment components for added capacity and redundancy.

The Expanded Constructed Wetlands is also the preferred alternative due to the protectiveness to human health and the environment by providing safe and reliable year-round operation. Wetlands treatment is considered a semi-passive system and requires minimal operations personnel as compared to Lime Treatment with HDS, especially during winter months. A reduced on-site presence required during the winter as compared to Lime Treatment with HDS allows for elimination or significant reduction of risk for exposure to avalanche hazards. Winter consumables delivery via trucks, such as coagulant delivery, would not be required for this alternative. The wetlands system would also be protective of the environment because minimal equipment and energy would be needed for operations as compared to the Lime Treatment with HDS system. Minimal equipment would improve reliability, as the system would not be as dependent on critical equipment, and downtime resulting from equipment failures could be easily avoided. Solids and waste generation would be considerably lower with a constructed wetland than for Lime Treatment with HDS, and the existing Solids Repository would have the capacity for disposal of all generated solids over the project life. Design improvements to facilitate solid removal from system components would reduce risk of injury by limiting labor intensive tasks and reducing exposure to solids. Although this alternative would require the largest on-site footprint for treatment, it does not include an off-site footprint, and adequate space would be available on-site to accommodate the design and the semi-passive nature of the system. Natural type features would lessen the impact to the surrounding environment. Wetlands blend well into the natural environment, and the existing Ponds System has positively influenced biodiversity and wildlife habitat.

Capital and OM&M cost estimations support selection of this alternative with significantly lower costs per 1,000 gallons of treated water ($3.58/1,000 gal NPV) when compared to the Lime Treatment – HDS alternative ($5.14/1,000 gal NPV).

Experiential knowledge and lessons learned from the pilot and demonstration-scale wetlands systems would inform the Expanded Constructed Wetlands design to produce a robust, safe, and effective treatment system that would reliably meet removal action objectives and provide protection of human health and the environment, protective integrity, and reduction of risk for the Site.

## 5 REFERENCES


Atlantic Richfield Company, 2011. *Preliminary Water Treatment Screening Report, Rico-Argentine Mine Site*, submitted by Atlantic Richfield Company to US EPA, dated November 29, 2011.

Atlantic Richfield Company, 2013. *St. Louis Tunnel Discharge Constructed Wetland Pilot Scale Test Completion Report, Rico-Argentine Mine Site – Rico Tunnels Operable Unit OU01, Dolores County, Colorado*, submitted by Atlantic Richfield Company to US EPA, dated November 4, 2013.

Atlantic Richfield Company, 2014. *Evaluation of source water controls, Revision 1, Rico-Argentine Mine Site—Rico Tunnels Operable Unit OU01, Rico Colorado*, submitted by Atlantic Richfield Company to US EPA, dated October 15, 2014.

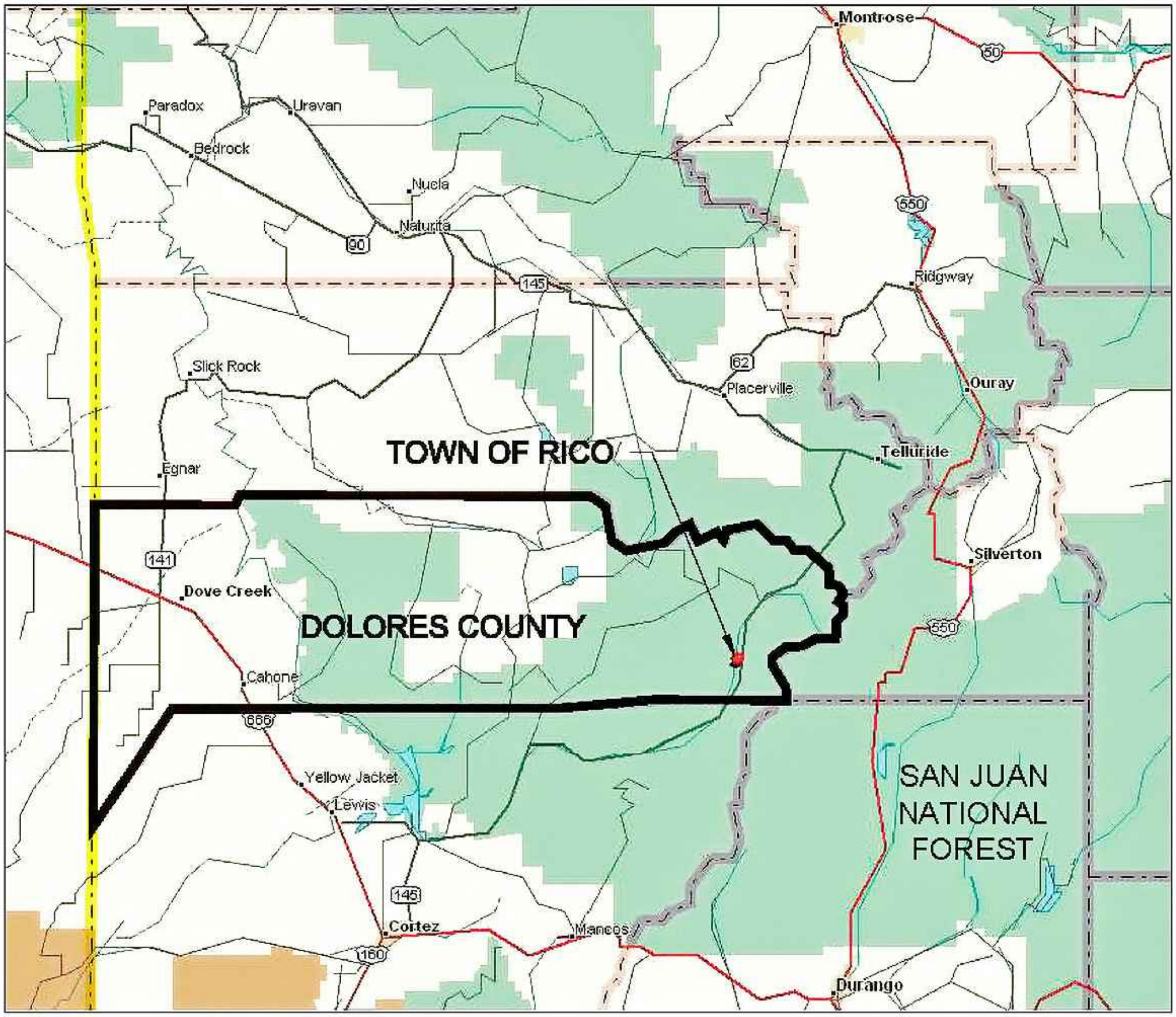
AECOM, 2013. *Ion Exchange Bench-Scale Test Results Technical Memorandum, Rico-Argentine Mine Site – Rico Tunnels Operable Unit OU01*, dated February 8, 2013.

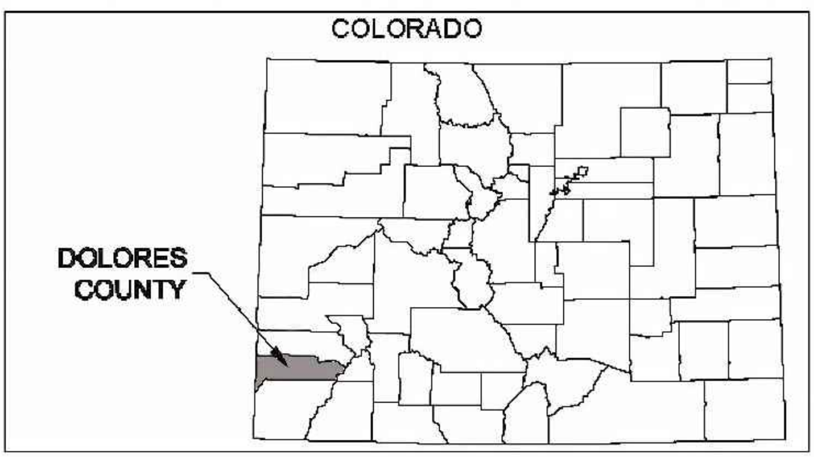
CDPHE WQCD, 2008. *Water Quality Assessment Mainstem of the Dolores River St. Louis Tunnel Discharge*, dated October 2008.

EPA, 1993. *Guidance on Conducting Non-Time-Critical Removal Actions Under CERCLA*, EPA/540R-93/057, OSWER 9360.0-32, dated August 1993.

EPA, 2011. *Unilateral Administrative Order for Removal Action, U.S. EPA Region 8, CERCLA Docket No. CERCLA-08-2011-0005*, dated March 23, 2011.

# Figures

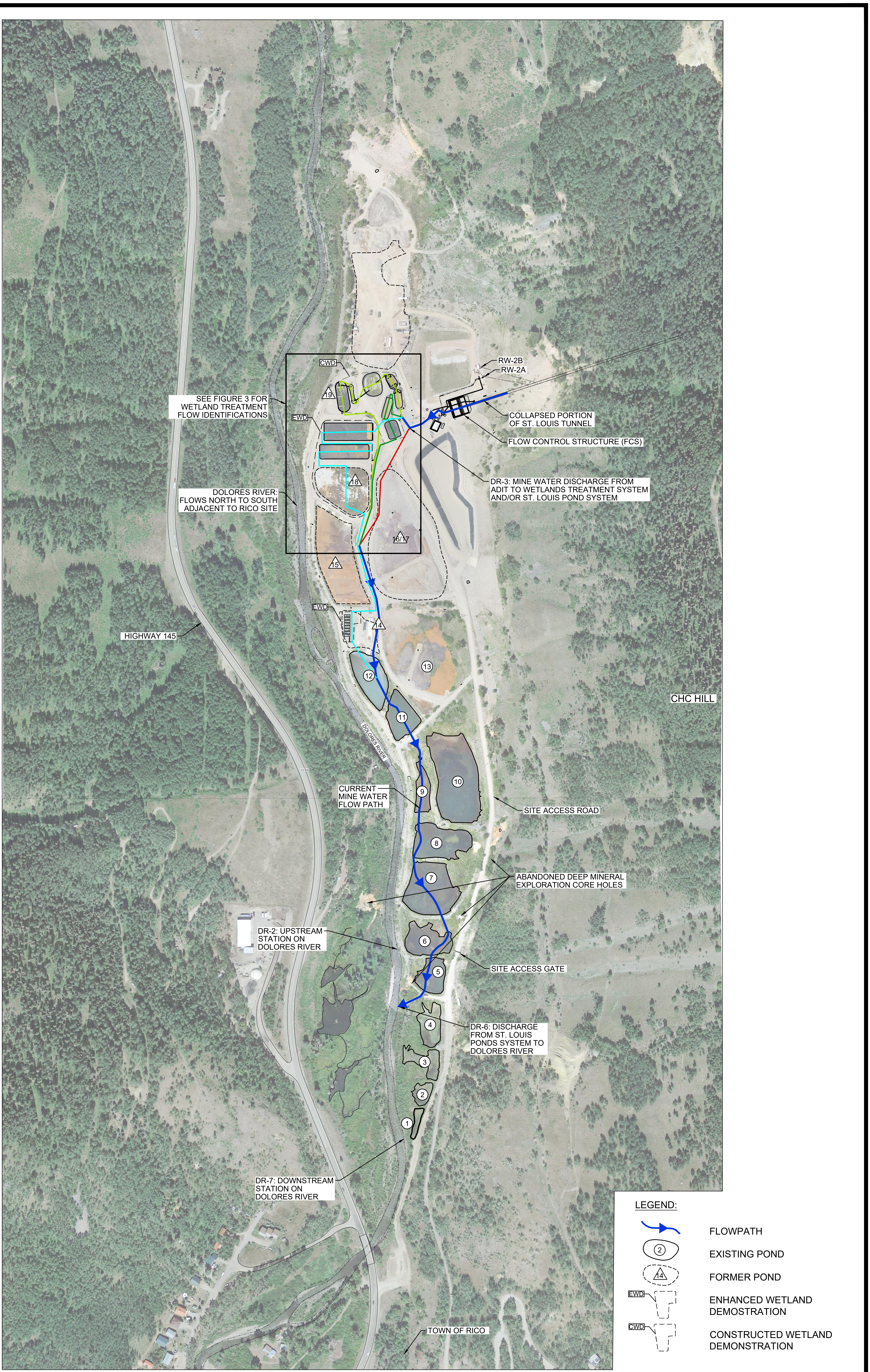



Jul 21, 2020 - 11:28am Patricia
U:\Copper\70817 Rico\CADD_PerformanceEvalRpt\70817-F001.dwg

| | | | |
|---|---|---|---|
| Copper Environmental Consulting<br>A PRISM SPECTRUM COMPANY | 7/21/2020<br>Atlantic Richfield Company<br>Project: 70817.20 | **Rico - Argentine Mine Site**<br>**Dolores County, Colorado** | **Figure 1**<br><br>**Site Location** |

Patricia F
Jan 08, 2021 - 6:03pm

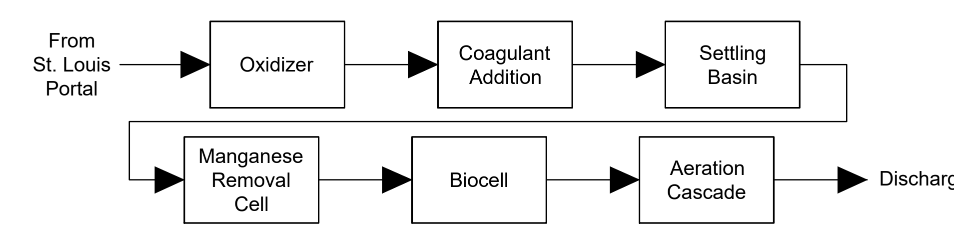



| | | | | |
|---|---|---|---|---|
| Copper Environmental Consulting<br>A PRISM SPECTRUM COMPANY | 7/21/2020<br>Atlantic Richfield Company<br>Project: 70817.20 | N W E S<br>200 0 200 400 FEET | **Rico - Argentine Mine Site**<br>**Dolores County, Colorado** | **Figure 2**<br>**Site Features** |

Jan 08, 2021 - 6:03pm
U:\Work Files\Copper\70817 Rico\CADD_PerformanceEvalRpt\70817-F002_PERpt.dwg Creator:


LEGEND:

- ST. LOUIS TUNNEL DISCHARGE FLOWPATH
- WETLANDS TREATMENT SYSTEM BYPASS
- ENHANCED WETLAND DEMONSTRATION FLOWPATH
- CONSTRUCTED WETLAND DEMONSTRATION FLOWPATH (HWTT)
- CONSTRUCTED WETLAND DEMONSTRATION FLOWPATH (VWTT)
- ENHANCED WETLAND DEMONSTRATION
- CONSTRUCTED WETLAND DEMONSTRATION
- SOLIDS REPOSITORY
- SOIL LEAD REPOSITORY
- RELIEF WELL
- FLOW CONTROL STRUCTURE LOCATION




***ENHANCED WETLANDS DEMONSTRATION (EWD)***

| NO: | DATE | CADD | CHECK | APP'D | ISSUE / REVISION DESCRIPTION |
|---|---|---|---|---|---|
| 0 | 07/23/18 | KWP | QC | KWP | PRELIMINARY REVIEW |

Copper Environmental Consulting
A PRISM SPECTRUM COMPANY

Atlantic Richfield Company

TITLE: MAJOR FEATURES

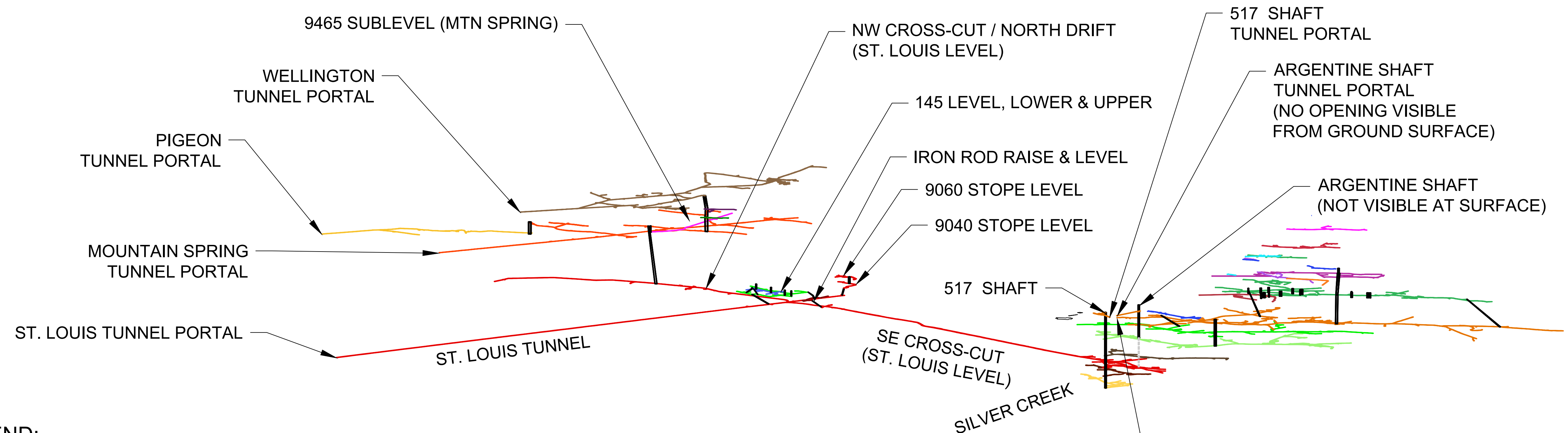
PROJECT: Rico - Argentine Mine Site
Dolores County, Colorado

FIGURE 3

Patricia
Jan 08, 2021 - 12:30pm
U:\Copper\70817 Rico\CADD_PerformanceEvalRpt\Rico OverviewDWG- Figure 3.dwg

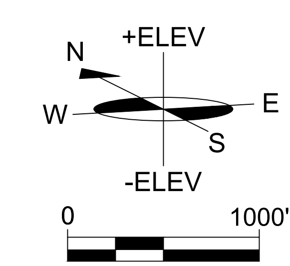
NOTES:

1. ALL MINE WORKINGS TRACED FROM "comp_Plan.tif", MAP #77 OF AECOM IMAGE INVENTORY, EXCEPT THE FOLLOWING:
   A. ARGENTINE SHAFT TUNNEL PER MAP #2, "scan02.tif", OF AECOM IMAGE INVENTORY. ("ARGENTINE MINE AND ST. LOUIS TUNNEL", DRAWN 5-21-55, P.L.J.)
   B. 517 SHAFT PER MAP #8, "scan08.tif", OF AECOM IMAGE INVENTORY. ("USGS/McKNIGHT PROFESSIONAL PAPER 723, PLATE 3")
   C. SILVER CREEK, BRIDGES & BUILDING FOOTPRINTS AT ARGENTINE TAILINGS PER ANDERSON ENGINEERING GROUND SURVEY, DATED AUGUST 2, 2011.
   D. ST. LOUIS SOUTHEAST CROSS CUT PER MAP #57, "00120110602202157.PDF", OF AECOM IMAGE INVENTORY. ("ST. LOUIS LEVEL, SHEET No. 2", DATED DEC. 1959 BY RT)
2. ALL LOCATIONS/DIMENSIONS APPROXIMATE ONLY.
3. ALL MINE LEVELS SHOWN AT SINGLE ELEVATION AND SEPARATED VERTICALLY PER USGS/McKNIGHT PROFESSIONAL PAPER 723 EXCEPT FOR LEVEL 700, WHICH IS SHOWN 100-FT BELOW 600 LEVEL.
4. NO EVIDENCE FOUND TO DATE ON HISTORIC MINE MAPS OF 517 SHAFT EXTENDING TO GROUND SURFACE.
5. ONLY SUGGESTIONS THAT ARGENTINE SHAFT EXTENDS BELOW 300 LEVEL ARE ON USGS/McKNIGHT PROFESSIONAL PAPER 723, PLATE 3, NOTATION ON MAP F (400 LEVEL) & MAP G (500 LEVEL): "ARGENTINE SHAFT (PROJECTED)". NOT SHOWN AT ALL ON MAP H (600 LEVEL); AND ON "ST. LOUIS LEVEL, SHEET No. 2", DATED DEC. 1959 BY RT.
6. FULL EXTENTS OF SOME LEVELS NOT SHOWN, AND INTERCONNECTIONS OF UPPER WORKINGS UNKNOWN AT THIS TIME.




LEGEND:

- WELLINGTON LEVEL
- 316 CROSS CUT / 425 DRIFT
- 417 DRIFT
- MOUNTAIN SPRINGS LEVEL
- MOUNTAIN SPRINGS 9465 SUBLEVEL
- PIGEON LEVEL
- IRON ROD LEVEL
- 145 LEVEL, LOWER & UPPER
- C TUNNEL LEVEL
- B TUNNEL LEVEL
- UNNAMED OLD TUNNEL
- UNNAMED OLD TUNNEL
- A TUNNEL LEVEL
- UNNAMED OLD TUNNEL
- ALLEGHANY LEVEL
- M TUNNEL LEVEL
- BLACKSMITH LEVEL
- BUNK HOUSE LEVEL
- DINING ROOM LEVEL
- CARBONATE LEVEL
- SMITH TUNNEL LEVEL
- BLACKHAWK / LOG CABIN LEVEL
- UNNAMED OLD TUNNEL
- RICO CONSOLIDATED UPPER LEVEL
- BERTHA S. UPPER LEVEL
- RICO CONSOLIDATED MIDDLE / ARGENTINE LEVEL
- BERTHA S. LOWER LEVEL
- RICO CONSOLIDATED LOWER LEVEL
- HUMBOLDT LEVEL
- BLAINE LEVEL
- 200 LEVEL
- 300 LEVEL
- 400 LEVEL
- ST. LOUIS / 500 LEVEL
- 600 LEVEL
- 700 LEVEL




Copper Environmental Consulting
A PRISM SPECTRUM COMPANY

Date: SEPTEMBER 2014

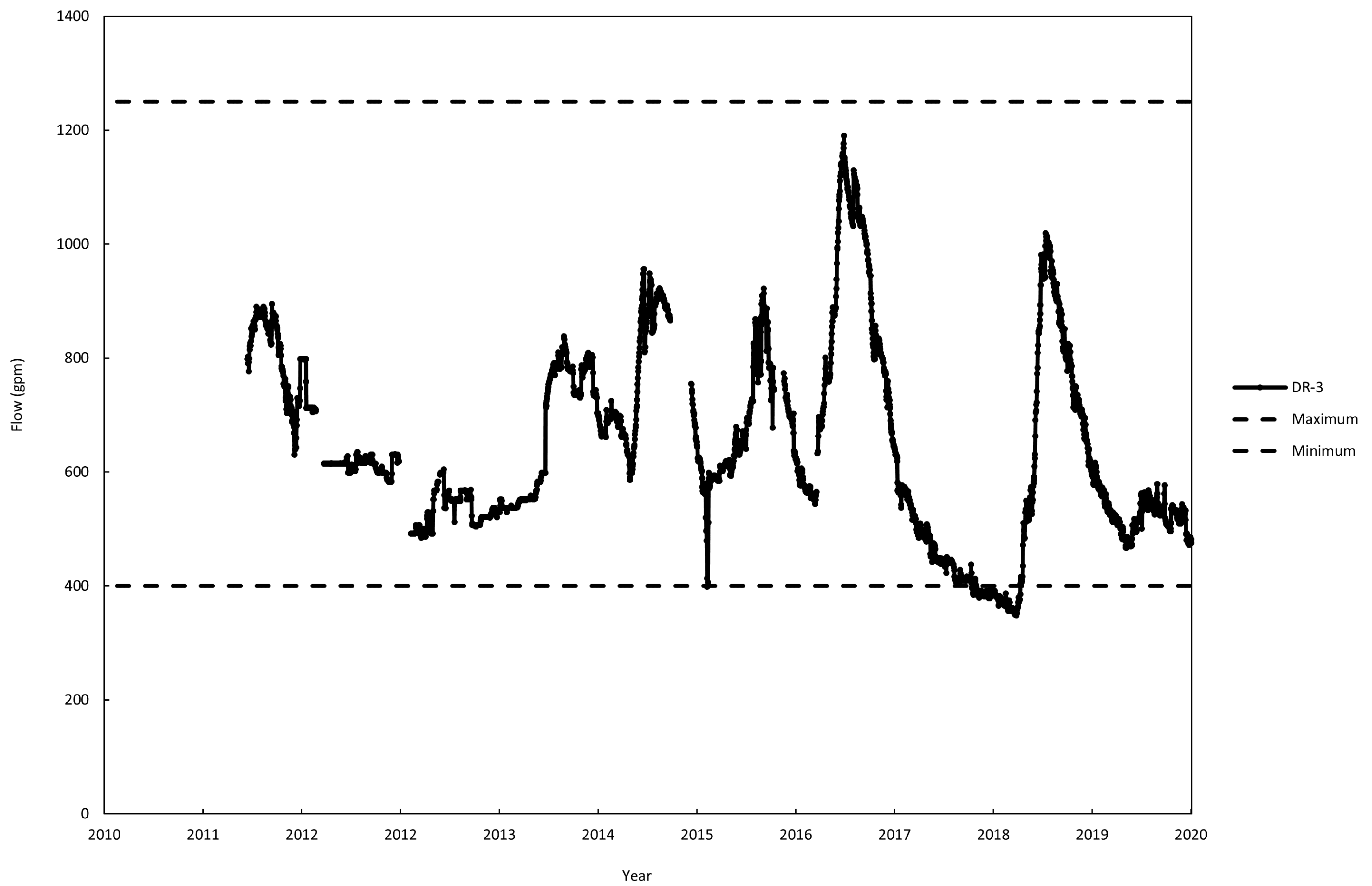
Atlantic Richfield Company

**Rico - Argentine Mine Site**
**Dolores County, Colorado**

**Figure 4**

**Mine Workings Overview**

Jun 16, 2020 - 9:43am Patricia
C:\Users\Patricia\Desktop_ACM_ORIGINAL-MINE-MODEL-FIGURES_ACM_ORIGINAL-MINE-MODEL-FIGURES - Standard_ACM_ORIGINAL-MINE-MODEL-FIGURES.dwg




| NO: | DATE | CADD | CHECK | APP'D | ISSUE / REVISION DESCRIPTION |
|---|---|---|---|---|---|
| 0 | 07/23/18 | PAF | TSL | KWP | PRELIMINARY REVIEW |
| | | | | | |
| | | | | | |
| | | | | | |

Copper Environmental Consulting
A PRISM SPECTRUM COMPANY

Atlantic Richfield Company

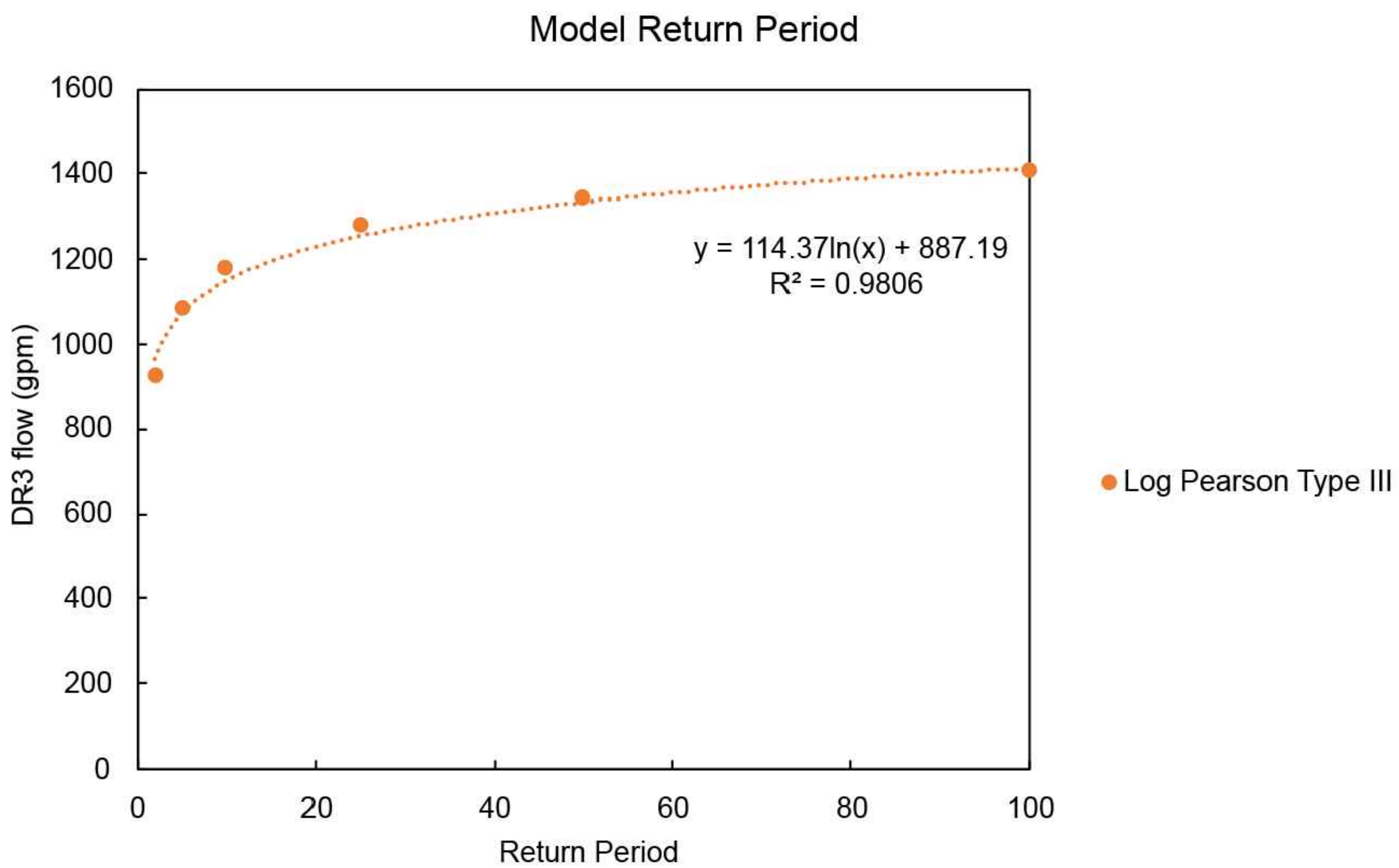
TITLE:
**DR-3 Hydrograph (2011-2020)**

PROJECT:
Rico - Argentine Mine Site
Dolores County, Colorado

FIGURE
5

Patricia F
Jan 08, 2021 - 5:58pm
U:\Work Files\Copper\70817 Rico\CADD_PerformanceEvalRpt\Rico OverviewDWG- Figure 3.dwg

| Event Year | Modeled DR3 Flow (gpm) Log Pearson Type III |
|---|---|
| **5** | 1071 |
| **10** | 1151 |
| **15** | 1197 |
| **20** | 1230 |
| **25** | 1255 |
| **50** | 1335 |
| **75** | 1381 |
| **100** | 1414 |
| **85%tile** | 942 |




Jan 08, 2021 - 5:59pm Patricia F
U:\Work Files\Copper\70817 Rico\CADD_PerformanceEvalRpt\Rico OverviewDWG- Figure 3.dwg

| NO: | DATE | CADD | CHECK | APP'D | ISSUE / REVISION DESCRIPTION |
|---|---|---|---|---|---|
| 0 | 07/23/18 | PAF | TSL | KWP | PRELIMINARY REVIEW |

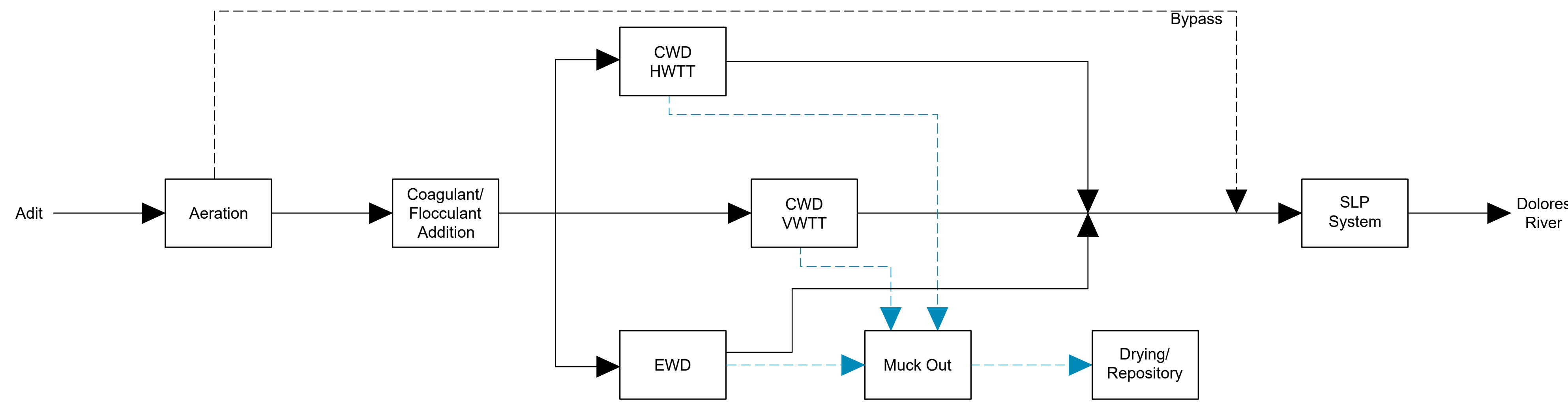
Copper Environmental Consulting
A PRISM SPECTRUM COMPANY

Atlantic Richfield Company

TITLE: Hydrologic Model Output

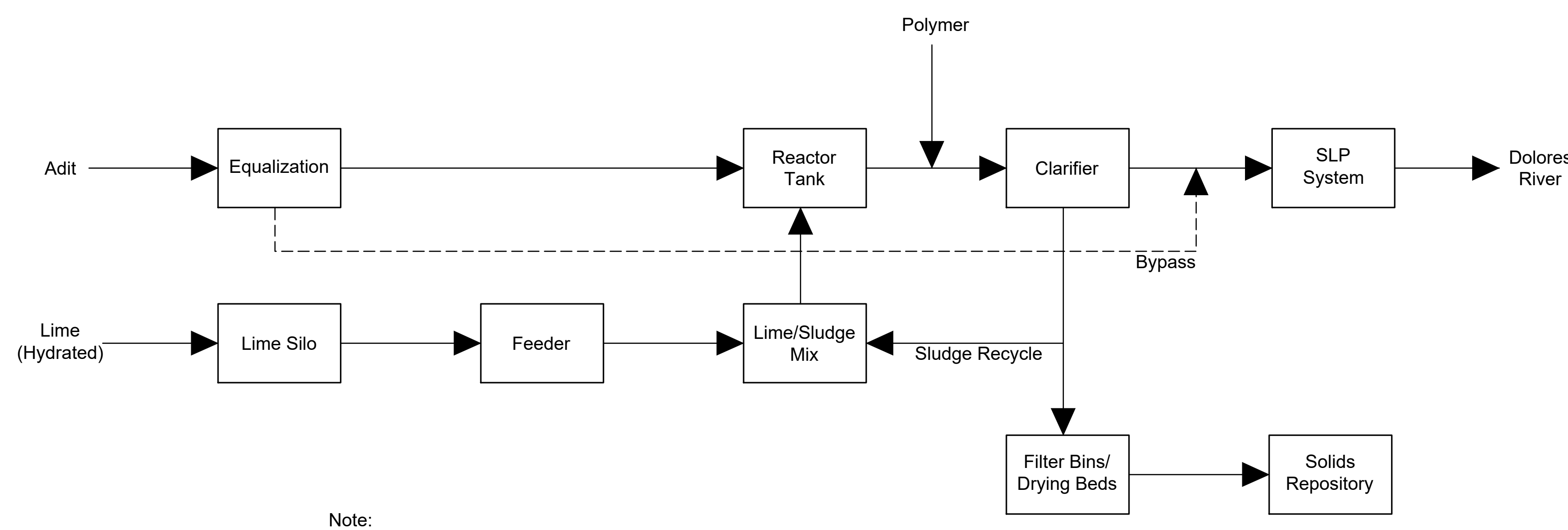
PROJECT: Rico - Argentine Mine Site
Dolores County, Colorado

FIGURE 6




## *NO ADDITIONAL ACTION*

(CURRENT CONFIGURATION)




Note:
Lime - HDS Alternative may require additional polishing/pH adjustment.

## *LIME - HDS*

LEGEND:

FLOW / MATERIAL STREAM (SOLID)

TEMPORARY/MAINTENANCE STREAM (DASHED)

UNIT PROCESS

| NO: | DATE | CADD | CHECK | APP'D | ISSUE / REVISION DESCRIPTION |
|---|---|---|---|---|---|
| 0 | 07/21/20 | PAF | SPB | KWP | PRELIMINARY REVIEW |
| | | | | | |
| | | | | | |
| | | | | | |

Copper Environmental Consulting
A PRISM SPECTRUM COMPANY

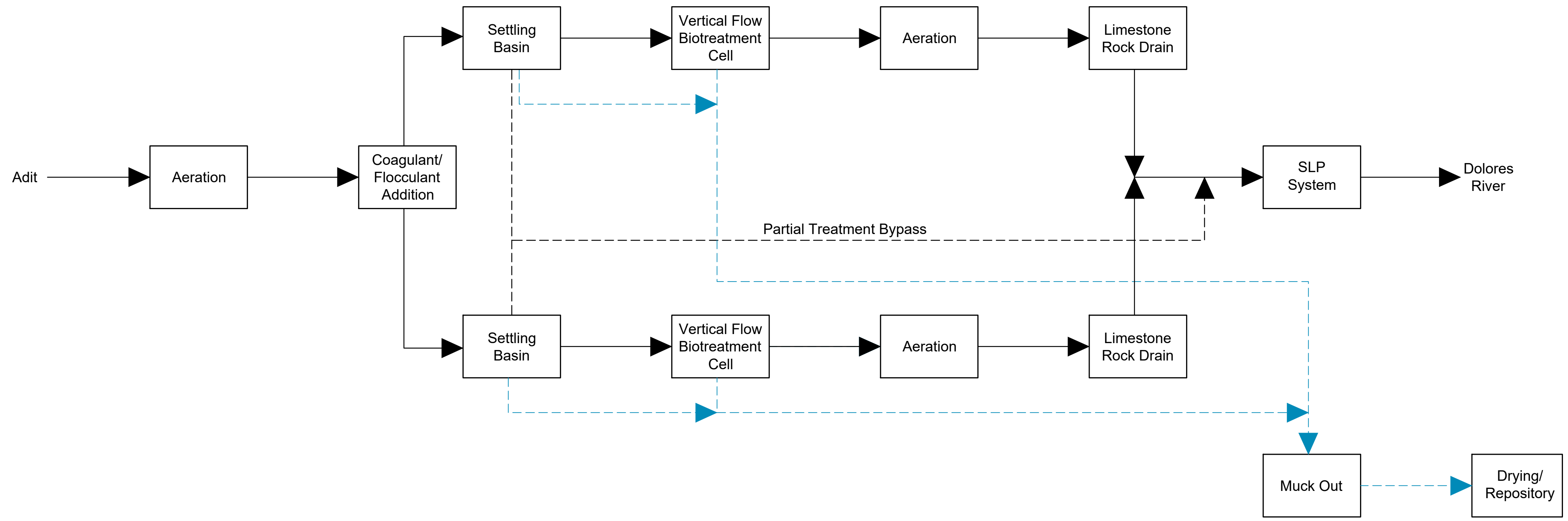
Atlantic Richfield Company

TITLE:
PROCESS FLOW DIAGRAMS:
No Additional Action, Lime Treatment - High-Density Sludge

PROJECT:
Rico - Argentine Mine Site
Dolores County, Colorado

FIGURE
7

Jan 08, 2021 - 5:59pm Patricia F
U:\Work Files\Copper\70817 Rico\CADD_PerformanceEvalRpt\Rico OverviewDWG- Figure 3.dwg




## *EXPANDED CONSTRUCTED WETLANDS*

LEGEND:
FLOW / MATERIAL STREAM (SOLID)
TEMPORARY/MAINTENANCE STREAM (DASHED)
UNIT PROCESS

| NO: | DATE | CADD | CHECK | APP'D | ISSUE / REVISION DESCRIPTION |
|---|---|---|---|---|---|
| 0 | 07/21/20 | PAF | SPB | KWP | PRELIMINARY REVIEW |

Copper Environmental Consulting
A PRISM SPECTRUM COMPANY

Atlantic Richfield Company

TITLE: PROCESS FLOW DIAGRAM: Expanded Constructed Wetlands

PROJECT: Rico - Argentine Mine Site Dolores County, Colorado

FIGURE 8

Jan 08, 2021 - 6:00pm Patricia F
U:\Work Files\Copper\70817 Rico\CADD_PerformanceEvalRpt\Rico OverviewDWG- Figure 3.dwg

# Tables

***Table 1.*** *Ranges of Contaminant Concentrations in SLT Discharge Water for both Freshet and Non-Freshet Conditions Rico-Argentine Site*

| Parameter | Non-Freshet Min | Non-Freshet Max | Freshet Min | Freshet Max |
|---|---|---|---|---|
| Temperature (°C) | 11.1 | 20.6 | 15.2 | 22.5 |
| pH (s.u.) | 6.27 | 7.48 | 5.63 | 7.4 |
| Aluminum, Total (μg/L) | 163 | 2190 | 218 | 6460 |
| Aluminum, Dissolved (μg/L) | <4 | 762 | 12.6 | 5440 |
| Arsenic, Total (μg/L) | <0.5 | 5.9 | <0.5 | 4.2 |
| Arsenic, Dissolved (μg/L) | <0.5 | 1.6 | <0.5 | 2.2 |
| Cadmium, Total (μg/L) | 13.8 | 34.9 | 16.5 | 151 |
| Cadmium, Dissolved (μg/L) | 10.0 | 34.2 | 13.2 | 150 |
| Calcium, Total (mg/L) | 194 | 270 | 192 | 311 |
| Copper, Total (μg/L) | 27.6 | 343 | 24 | 2570 |
| Copper, Dissolved (μg/L) | 2.5 | 148 | 2.7 | 2370 |
| Iron, Total (μg/L) | 2510 | 24100 | 2250 | 30500 |
| Iron, Dissolved (μg/L) | <50 | 9120 | <50 | 15600 |
| Lead, Total (μg/L) | 1.3 | 29.5 | 1.4 | 59.7 |
| Lead, Dissolved (μg/L) | <0.1 | 14.6 | <0.1 | 21.7 |
| Magnesium, Total (mg/L) | 17.4 | 21.8 | 17.6 | 26.2 |
| Manganese, Total (μg/L) | 1530 | 3530 | 1530 | 6760 |
| Manganese, Dissolved (μg/L) | 1590 | 3210 | 1540 | 6910 |
| Nickel, Total (μg/L) | 3.6 | 7.9 | 3.2 | 16.2 |
| Nickel, Dissolved (μg/L) | 3.5 | 7.6 | 3.8 | 20.0 |
| Potassium, Total (mg/L) | 1.46 | 19.3 | 1.56 | 5.42 |
| Sodium, Total (mg/L) | 8.2 | 14.3 | 7.16 | 38 |
| Zinc, Total (μg/L) | 2320 | 6290 | 3170 | 25500 |
| Zinc, Dissolved (μg/L) | 1400 | 6290 | 2500 | 24800 |
| Alkalinity (mg/L as $CaCO_3$) | 78.8 | 155 | <20 | 121 |
| Sulfate (mg/L) | 485 | 994 | 519 | 908 |
| Chloride (mg/L) | <1 | 40.2 | <1 | <1 |

Notes:
1. Data collected from 1979 to May 2020 at DR-3/DR-3A sampling locations and Demonstration-Scale Wetlands Treatment System influent sampling locations.
2. Freshet determined by pH decrease and specific conductance increase in the April-July timeframe.
3. Non-detect values reported as less than Reporting Limit.

***Table 2.*** *Historical Lime Treatment with Lagoon Settling Effluent Water Quality Summary*
*Rico-Argentine Site*

| Parameter | Unit | Effluent Value[1] | | |
|---|---|---|---|---|
| | | Minimum[2] | Flow-Volume Average[3] | Maximum[4] |
| Cd, Total | µg/L | 0.20 | 4.73 | 179.1 |
| Cu, Total | µg/L | 0.346 | 13.52 | 75.0 |
| Pb, Total | µg/L | 0 | 6.29 | 160.0 |
| Hg, Total | µg/L | 0.050 | 0.10 | 0.4 |
| pH | s.u. | 6.37 | 7.41 | 9.4 |
| Ag, Total | µg/L | 0.087 | 1.93 | 100.0 |
| TDS | mg/L | 735 | 1015 | 1878 |
| TSS | mg/L | 0.05 | 4.1 | 60 |
| Zn, Total | mg/L | 0.015 | 0.57 | 2.6 |
| Flow | gpm | 440 | 747 | 1736 |

Notes:
1. Monthly effluent values were digitized for compilation from scanned documents, with a somewhat incomplete period of record from October 1984 – July 1996.
2. Minimum value recorded in historical documents.
3. Flow volume average is calculated using the recorded flow measurements and the appropriate effluent concentration for each constituent.
4. Maximum value recorded in historical documents.

***Table 3.*** *Advantages and Disadvantages of Removal Action Alternatives*
*Rico-Argentine Site*

| | No Additional Action | Lime Treatment – HDS | Expanded Constructed Wetland |
|---|---|---|---|
| **Advantages** | • Low capital cost.<br>• Generally meet standards during non-freshet period at current designed flow rate of 610 gpm. | • Generally meet treatability study goals.<br>• Best process control and response to system upsets.<br>• Can be designed to better handle anticipated flows and metal loadings but would still require equalization/storage ponds.<br>• Reduced sludge volume vs. other active treatment methods.<br>• Possibly easier solids management vs. other active treatment methods.<br>• No replacement of media required.<br>• No $H_2S$ gas generation. | • Generally meet treatability study goals.<br>• High mass removal rates of cadmium and manganese.<br>• Lower OM&M cost.<br>• Much less support labor required.<br>• Lower safety risk during winter (avalanche risk, etc.) given lower winter support hours.<br>• No chemical deliveries required in winter.<br>• No harsh chemicals used.<br>• Chemical neutralization of discharge not required.<br>• Viewed favorably by EPA; EPA has a stated policy to consider “green remediation” aspects in Superfund.<br>• SLT water well-suited to wetland treatment (near-neutral pH, relatively low metals concentrations, relatively constant composition much of the year, generation of sulfide enables cadmium, copper, and zinc removal in neutral pH range). |

***Table 3.*** *Advantages and Disadvantages of Removal Action Alternatives (Continued)*
*Rico-Argentine Site*

| | No Additional Action | Lime Treatment – HDS | Expanded Constructed Wetland |
|---|---|---|---|
| **Disadvantages** | • Standards not met part of year.<br>• Small $H_2S$ gas generation may present a minor HSSE risk. $H_2S$ areas are gated to prevent unauthorized entry and accidental exposure. Probably more frequent replacement of media required due to more frequent media plugging.<br>• No redundancy, thus significant maintenance would likely result in bypass of treatment system.<br>• Slow response to system upsets. | • Much more complicated mechanical, electrical, and control systems than other wetland approaches.<br>• Need for lime deliveries year-round (remote location and site access, mountain driving, severe winter weather).<br>• Increased cost for maintenance and consumables.<br>• Increased year-round staffing (remote location, severe weather, avalanche hazard).<br>• Handling and HSSE issues associated with lime.<br>• Potential difficulties with meeting cadmium and manganese treatability study goals, requiring high pH target and downward pH adjustment for discharge.<br>• More sludge produced than wetland system.<br>• Regulators less likely to grant waivers.<br>• Regulators publicly demonstrate a bias away from lime treatment in Colorado due to experiences at Gold King, Argo Tunnel, Summitville, etc. | • Small $H_2S$ gas generation may present a minor HSSE risk. $H_2S$ areas are gated to prevent unauthorized entry and accidental exposure.<br>• System cannot be easily modified if needed.<br>• Replacement interval of media not well understood.<br>• Less active process control.<br>• More time required to recover from upsets.<br>• May need relief from performance criteria during freshet period via waiver or seasonal goals.<br>• Requires larger footprint than other alternatives. |

***Table 4.*** *Comparative Analysis of Removal Action Alternatives*
*Rico-Argentine Site*

| Treatment Alternative | Evaluation Criteria | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Effectiveness** | | | **Implementability** | | | | **Environment** | | | **Cost** |
| | **Contaminant Removal** | **Protectiveness/ Permanence** | **Time** | **Technical Feasibility** | **Implementation Safety Risk** | **OM&M Safety Risk** | **Availability/ Logistics** | **Waste Management** | **Energy Usage/ Emissions** | **Biodiversity/ Footprint** | **Total Cost** |
| **No Additional Action** | Effective but limited hydraulic and removal capacity | Current system unable to treat high flows (610 gpm maximum) and directs excess flow around treatment components; Moderate to high risk of regulatory exceedances | N/A | System continues with current success | N/A | Mild chemical exposure (coagulant, settled solids) and $H_2S$ generation risk | 5 FTEs, 50hr/week during field season, biweekly or as needed during winter | Organic media replacement required (~10-year media life) | Semi-passive treatment and minimal equipment requires low energy | Large footprint for wetlands and Pond System | Lowest capital cost ($0M) |
| | High flows or metals loading may overwhelm system (freshet) | Semi-passive system reduces likelihood of equipment or instrument failures | | Uncertainty of operability during high flows or during system maintenance, risk for exceedances | | Working near water | Suppliers established for consumables | Sufficient capacity for waste disposal in Solids Repository | Minimal emissions generated | Naturalistic and semi-passive system promotes biodiversity and wildlife benefits | Moderate OM&M cost ($6.35/1,000 gal treated) |
| | HWTT rock drain successful in Mn and Zn removal | Clogging and fouling of existing components can reduce efficiency | | Pre-freshet maintenance limited between snowmelt and freshet | | Maintenance required year-round | Infrequent deliveries required for raw materials and no winter delivery necessary | No off-site waste footprint required | | | High potential long-term costs |
| | Not able to treat up to 25-year recurrence flow (current max 610 gpm) | Semi-passive system creates lag in response to process changes and time to resolve upsets | | Clogging of media, media life uncertain | | Limited winter on-site activities and Site access required | Maintenance downtime could limit system availability | Unknown rock media replacement frequency | | | NPV cost of $3.20/1,000 gal treated |
| | | System not easily modified, some flexibility exists for residence time and flow | | | | Solids removal work is labor intensive and not efficient | | | | | |

***Table 4.*** *Comparative Analysis of Removal Action Alternatives (Continued)*
*Rico-Argentine Site*

| Treatment Alternative | Evaluation Criteria | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Effectiveness | | | Implementability | | | | Environment | | | Cost |
| | Contaminant Removal | Protectiveness/ Permanence | Time | Technical Feasibility | Implementation Safety Risk | OM&M Safety Risk | Availability/ Logistics | Waste Management | Energy Usage/ Emissions | Biodiversity/ Footprint | Total Cost |
| Lime Treatment - HDS | Effective when in operation but may struggle with removal efficiency at periods of high metals loading | Solids/Scale Management have greater potential to cause integrity losses in vessels and pipes | Multiple field seasons anticipated for construction and shakedown | Proven approach for mine water | Skilled labor required for piping, electrical, controls, etc. | More hazardous chemicals required (flocculant, lime) | 6 FTEs, 40hr/week year-round | Significant increase in solids/sludge generation | High energy usage due to process equipment | Smaller footprint required | Highest capital cost ($12.2M) |
| | Removal of Al, Cd, and Mn may prove difficult | High turnover of some equipment (instruments such as pH/ORP probes) | Bench/pilot testing for design could postpone implementation | Need polishing treatment for some metals and TDS | Chemical exposure risk for lime and floc system and clean out of existing ponds for new infrastructure (settled solids and fugitive dust) | Process plant hazards, working near water, confined space in tanks | Frequent deliveries year-round for raw materials | Sufficient capacity for 30-year waste disposal in Solids Repository (eventually fills) | High energy usage in winter for heated ops building and freeze protection | Noise and traffic could negatively impact biodiversity and wildlife | Highest OM&M cost ($7.56/1,000 gal treated) |
| | Additional stages may be required for polishing | Tight process control allows for immediate process changes and quick response to upsets | | Need bench/pilot scale testing for design | High SIMOPs risk and traffic control risk | Lime truck deliveries required year-round (winter truck access required) | Maintenance downtime could limit system availability | Potential for off-site waste footprint | Minimal emissions generated | Smaller on-site footprint could allow naturalization of unused land | High potential long-term costs |
| | Equalization pond can provide consistent flow rates | System depends on multiple pieces of critical equipment and failures could result in extended downtime | | Pre-freshet maintenance limited between snowmelt and freshet | Working at heights (scaffolding), energy isolation, working near water, confined space entry, pinch points, hot work, rotating equipment, overhead utilities, pressure testing of piping | Significant maintenance as compared to wetlands required year-round | Recruiting qualified staff could be challenging | Difficulty managing solids waste during winter operations | | Off-site footprint required in future for solids disposal | NPV cost of $4.92/1,000 gal treated |
| | Seasonal variations in meals loading may require frequent process adjustments | | | Sludge stabilization may be required | Transportation, delivery off-loading and lifting for installation risk for large scale equipment | Full time on-site winter staff required for operations and maintenance | | | | | |
| | Able to treat 25-year recurrence flow | | | | Demolition of historic lime silo, potential lime dust exposure | Snow removal for Site access roads and avalanche hazards | | | | | |

***Table 4.*** *Comparative Analysis of Removal Action Alternatives (Continued)*
*Rico-Argentine Site*

| Treatment Alternative | Evaluation Criteria | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Effectiveness | | | Implementability | | | | Environment | | | Cost |
| | Contaminant Removal | Protectiveness/ Permanence | Time | Technical Feasibility | Implementation Risk | OM&M Risk | Availability/ Logistics | Waste Management | Energy Usage/ Emissions | Biodiversity/ Footprint | Total Cost |
| **Expanded Constructed Wetlands** | Effective, able to meet criteria with few exceptions | Increased capacity and redundancy reduces downtime for maintenance and increased flexibility | Two field seasons anticipated for construction | Proven technology at the Site based on pilot and demonstration wetlands performance | Primarily requires general contractors and fewer specialty skilled labor | Mild chemical exposure (coagulant, settled solids) and $H_2S$ generation risk | 4 FTEs, 50hr/week during field season, biweekly or as needed during winter | Organic media replacement required (~10-year media life) | Semi-passive treatment and minimal equipment requires low energy | Large footprint required | Moderate capital cost ($9.1M) |
| | Improved redundancy, hydraulic capacity, and metals removal capacity from No Additional Action | Semi-passive system reduces likelihood of equipment or instrument failures | | Clogging of media, media life uncertain | Chemical exposure risk for new chemical feed system and clean out of existing ponds for new infrastructure (settled solids, fugitive dust) | Working near water | Could use same vendors as currently utilized for the Site | Sufficient capacity for waste disposal in Solids Repository | Minimal emissions generated | Naturalistic and semi-passive system promotes biodiversity and wildlife benefits | Lowest OM&M cost ($5.67/1,000 gal treated) |
| | All SLT discharge receives at least partial treatment even when capacity of wetlands is exceeded | Semi-passive system creates lag in response to process changes and time to resolve upsets | | Pre-freshet maintenance limited between snowmelt and freshet | High SIMOPs risk and traffic control risk | Maintenance is required year-round | Infrequent deliveries required for raw materials and no winter delivery necessary | No off-site waste disposal footprint required | | | Lower long-term cost than Lime - HDS |
| | Able to treat 25-year recurrence flow | System not easily modified, some flexibility exists for residence time and flow | | | Excavation, engulfment, working near water, working near $H_2S$ zones, overhead utilities, pressure testing of piping | Limited winter on-site activities and Site access required | System redundancy prevents downtime for maintenance | Unknown rock media replacement frequency | | | NPV cost of $3.42/1,000 gal treated |
| | | | | | Biotreatment cell media inoculation and $H_2S$ generation | Improved, less labor-intensive solids removal and maintenance design versus No Additional Action | | | | | |
| | | | | | Demolition of historic lime silo, potential lime dust exposure | | | | | | |

Abbreviations:
FTE - full-time equivalent
$H_2S$ – hydrogen sulfide
gal – gallons
M - million
N/A – not applicable
ORP – oxidation reduction potential
SIMOPS – simultaneous operations
TDS – total dissolved solids

*__Table 5.__ Removal Action Objectives Comparison Matrix*
*Rico-Argentine Site*

| Treatment Alternative | Remove key contaminants loading to the Dolores River to improve water quality | Reduce metals concentrations to agreed-upon performance criteria | Treat base and freshet flows up to 25-year recurrence period (design permitting) | Provide safe reliable year-round operations | Minimize waste production and energy usage | Total Ranking Value |
|---|---|---|---|---|---|---|
| **No Additional Action** | 1 | 1 | 1 | 2 | 3 | **8** |
| **Lime Treatment - HDS** | 2.5 | 2.5 | 3 | 1 | 1 | **10** |
| **Expanded Constructed Wetlands** | 2.5 | 2.5 | 2 | 3 | 2 | **12** |

**Risk Ranking:**

| | |
|---|---|
| Lowest/Best | 3 |
| | 2.5 |
| Moderate/Good | 2 |
| | 1.5 |
| Not Desirable/Worst | 1 |

***Table 6.*** *Enhanced Wetland Demonstration Annual Mass Removal Efficiencies*
*Rico-Argentine Site*

| Pollutant | 2016 Efficiency (%) | 2017 Efficiency (%) | 2018 Efficiency (%) | 2019 Efficiency (%) | 2020 Efficiency (%) | Average (%) | Annual Mass Removal Average (pounds)[3] |
|---|---|---|---|---|---|---|---|
| Aluminum, Total | 99.8% | 99.8% | 98.9% | 98.3% | 99.6% | 99.3% | 3,190 |
| Arsenic, Total | 95.7% | 92.7% | 89.7% | 93.0% | 94.9% | 93.3% | 3.8 |
| Cadmium, Total | 94.6% | 99.4% | 99.4% | 99.4% | 99.4% | 98.4% | 52.6 |
| Copper, Total | 99.9% | 100.0% | 99.6% | 99.8% | 99.9% | 99.8% | 684 |
| Iron, Total | 99.7% | 99.2% | 99.3% | 98.0% | 99.1% | 99.0% | 27,493 |
| Lead, Total | 99.6% | 99.6% | 99.3% | 99.6% | 99.5% | 99.5% | 46.1 |
| Manganese, Total | 69.3% | 63.9% | 82.5% | 71.6% | 84.1% | 74.2% | 3,977 |
| Nickel, Total | 75.9% | 88.4% | 83.6% | 46.7% | 81.6% | 80.0% | 9.7 |
| Zinc, Total | 82.9% | 95.1% | 97.8% | 80.0% | 97.3% | 90.4% | 8,460 |
| Average EWD Flow Rate[2] (gpm) | 495 | 475 | 420 | 495 | 510 | 480 | - |

Notes:
1. Annual mass removal efficiency calculated as a percentage removal of influent load (EWD treated flow).
2. Average EWD Flow Rate calculated from EWD flow measurements at FE-07.
3. Average EWD Mass Removal calculated for 2016-2019.

***Table 7.*** *Estimated Costs for Removal Action Alternatives*
*Rico-Argentine Site*

| Treatment Alternative | Estimated Total Capital Cost [1] | Estimated Annual Operations and Monitoring Cost [2] | Estimated Annual Operations and Monitoring Cost on 1,000 Gallons Treated Basis [3] | Estimated Net Present Value [4] | Estimated Net Present Value on 1,000 Gallons Treated Basis [5] |
|---|---|---|---|---|---|
| No Additional Action | $ - | $ 2,000,000 | $ 6.35/1,000 gallons treated | - $ 31,850,000 | - $ 3.37/1,000 gallons treated |
| Lime Treatment – HDS | $ 12,200,000 | $ 2,600,000 | $ 7.56/1,000 gallons treated | - $ 53,000,000 | - $ 5.14/1,000 gallons treated |
| Expanded Constructed Wetland | $ 9,100,00 | $ 1,950,000 | $ 5.67/1,000 gallons treated | - $ 36,900,000 | - $ 3.58/1,000 gallons treated |

Notes:

1. Includes direct equipment and construction costs and indirect construction costs (administration, safety, engineering design, quality assurance, and oversight). Does not include treatment solids repository costs any alternative. These costs are included in the Net Present Value calculation.
2. Includes costs for labor, materials, equipment, analytical services, utilities, and other direct and indirect costs. Includes matrix replacement costs adjusted to an annual basis for the No Additional Action and the Expanded Constructed Wetlands alternatives. Assumes 10-year life of matrix for No Additional Action and Expanded Constructed Wetlands alternatives.
3. Cost on 1,000 gallons treated basis based on current treatment capacity of approx. 600 gpm (315 million gallons per year) for No Additional Action. Cost on per 1,000 gallons treated basis based on complete treatment of average annual DR-3 flow from 2011-2020 of 655 gpm (344 million gallons per year) for Expanded Constructed Wetland and Lime-Treatment HDS.
4. Estimated Net Present Value calculated for a 30-year period on a pre-tax basis with an 7.0% discount rate and a 2.0% inflation rate.
5. Cost on 1,000 gallons treated basis based on current treatment capacity of approx. 600 gpm (315 million gallons per year) for 30 years for No Additional Action. Cost on per 1,000 gallons treated basis based on complete treatment of average annual DR-3 flow from 2011-2020 of 655 gpm (344 million gallons per year) for 30 years for Expanded Constructed Wetland and Lime Treatment – HDS.

# Attachment A: Enhanced Wetland Demonstration Efficiency Plots

**TABLE OF CONTENTS**

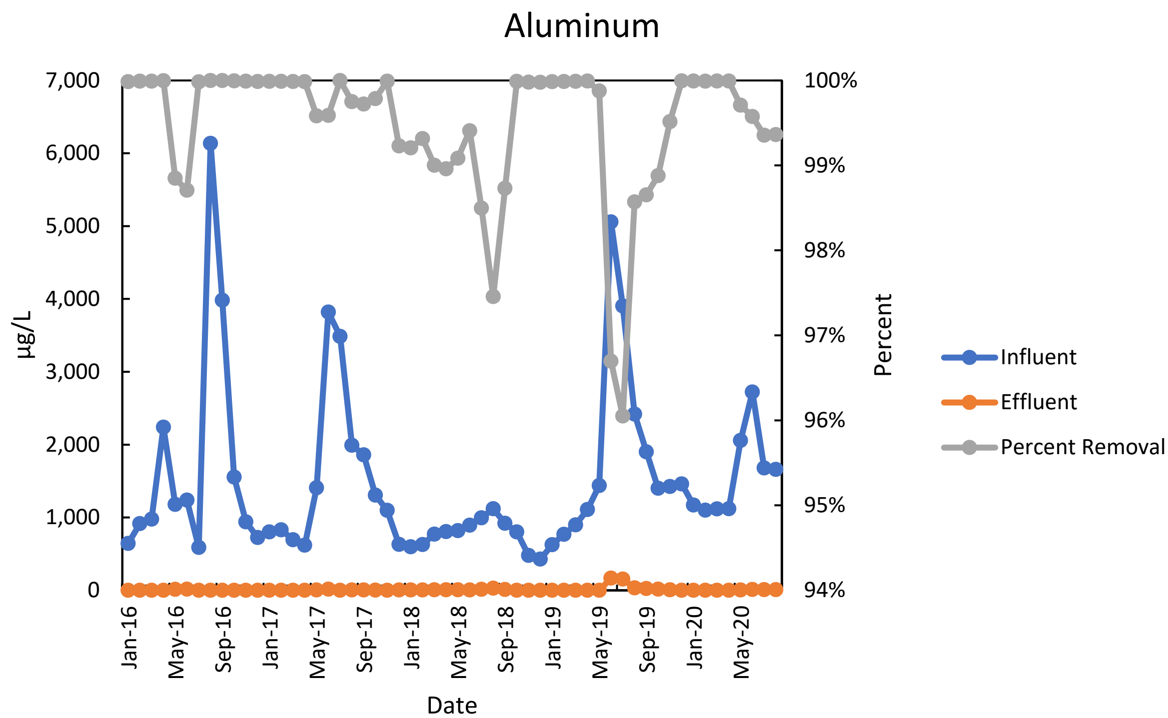
**ENHANCED WETLAND DEMONSTRATION (EWD) MONTHLY FLOW-VOLUME AVERAGE EFFICIENCY PLOTS**

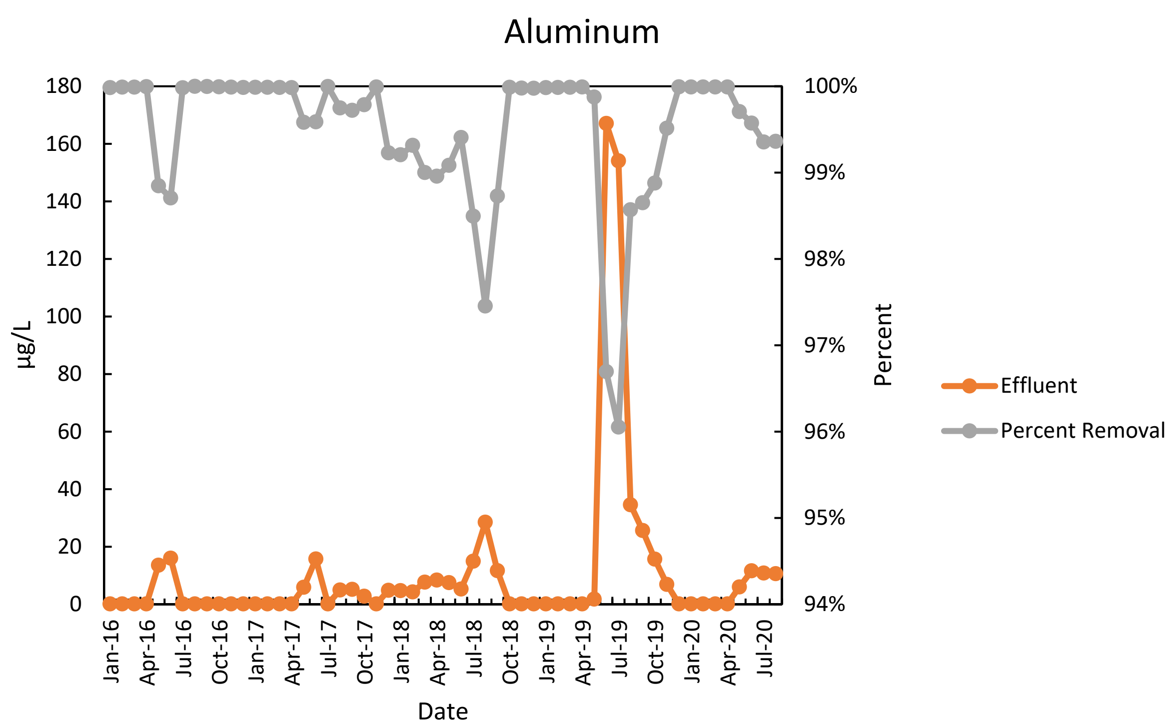
The below plots contain monthly flow-volume average influent, effluent, and efficiency data for the EWD since the first complete year of operation (2016) to present (2020). All concentration data plotted is the total fraction of the element of interest.

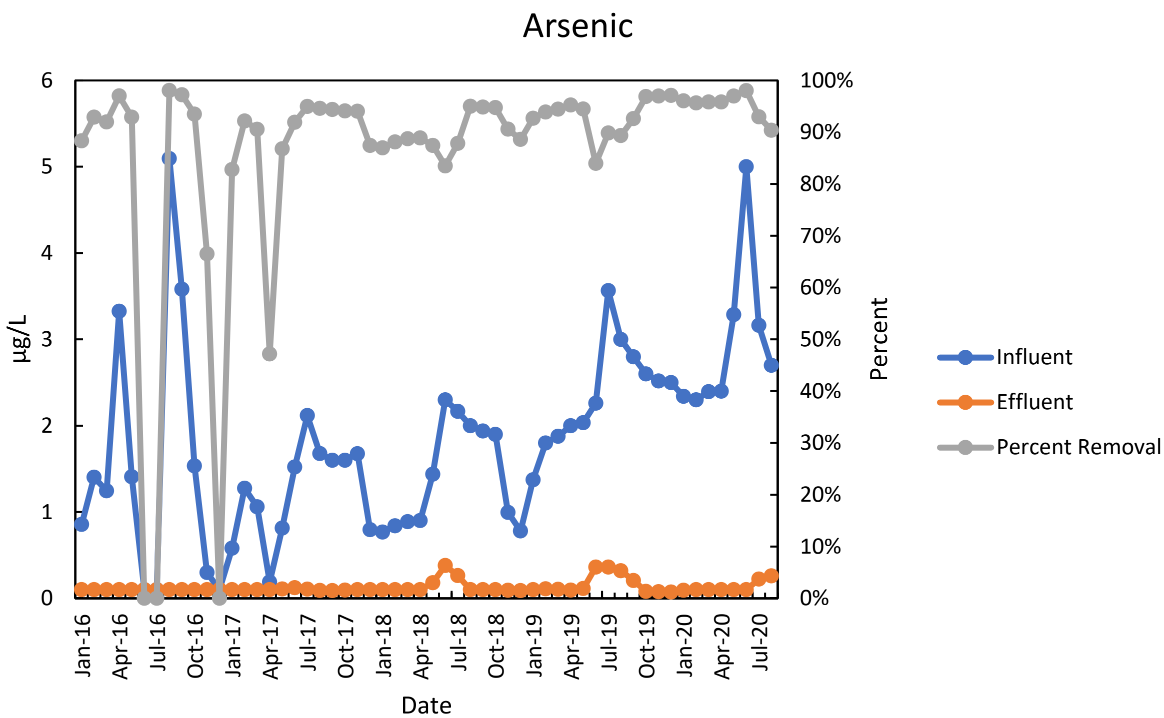
The plots show a steady removal of most metals of interest for most of the year. Flows to the EWD system have generally been maintained around 400-500 gpm, depending largely on the magnitude of the St. Louis Tunnel discharge and the Site maintenance schedule for EWD components. When influent flow exceeds the EWD design capacity, the excess flow is routed to Pond 12 for retention settling prior to being released to the Dolores River. Effluent concentrations shown in the plots and used for removal efficency calculations are for samples taken directly from the EWD effluent, before mixing with bypass and other treatment systems on Site (CWD).

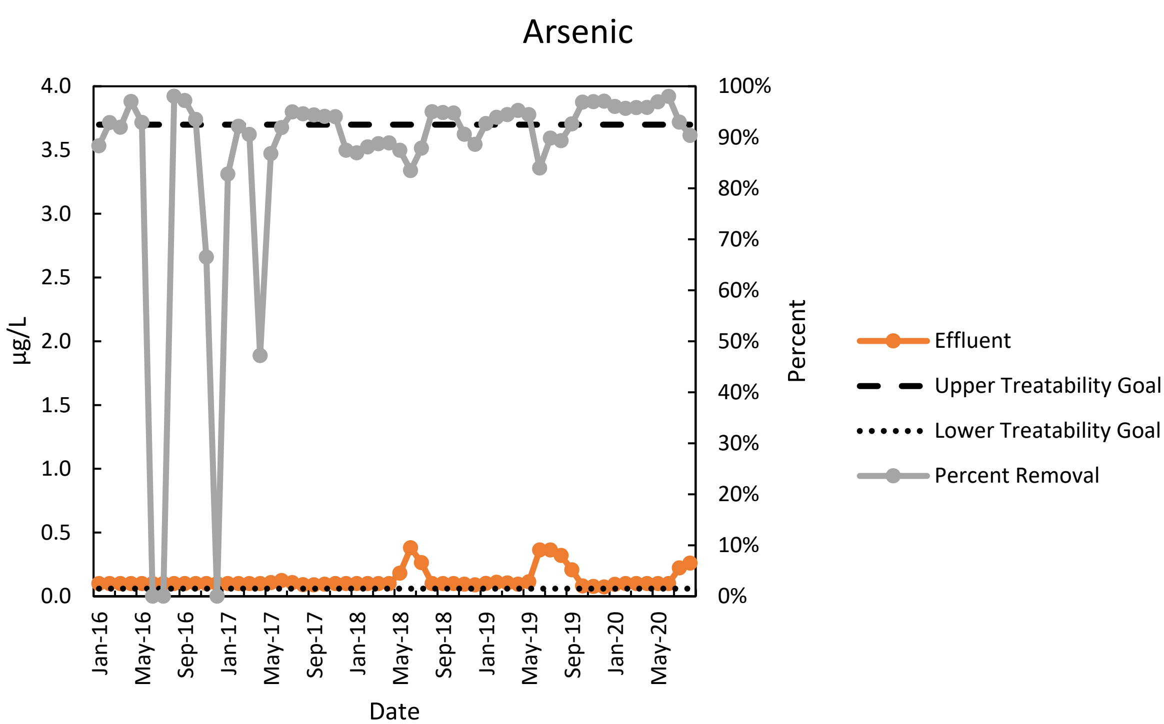
During years when a freshet is occuring, increases in flow and metals concentrations are observed. The sudden, large increase in metal concentrations can affect the removal of some metals for a short duration, as expressed in the below plots as a significant increase in influent concentrations during the May-August timeframe. Due to the passive and biotic nature of the EWD, sudden concentration changes of the influent waters can stress the system and reduce the removal efficiency of the treatment cells in the EWD. This is expressed by a dip in removal efficiency and an increase in effluent concentrations in the plots. Most metals stay below the appropriate treatability goal concentrations during the freshet and resolve back to normal removal efficiencies post-freshet.

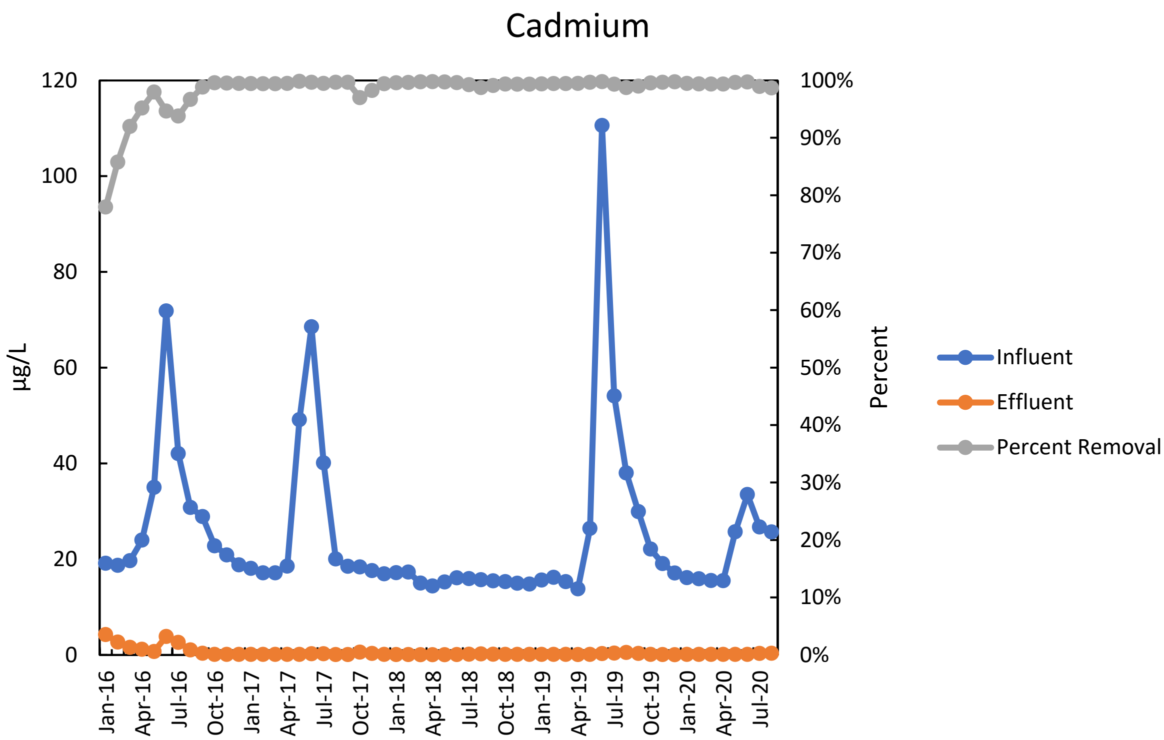
The freshet at the Site is characterised by a sharp increase (three to four times the low flow concentration) of influent manganese and zinc concentrations. The EWD was not initially designed to treat such large concentrations of manganese and zinc, which can result in a sudden but short decrease in removal efficiency as the increased metal load stresses the biotic processes. Looking forward, an additional treatment step to target additional manganese and zinc removal (such as a rock drain) should be considered.

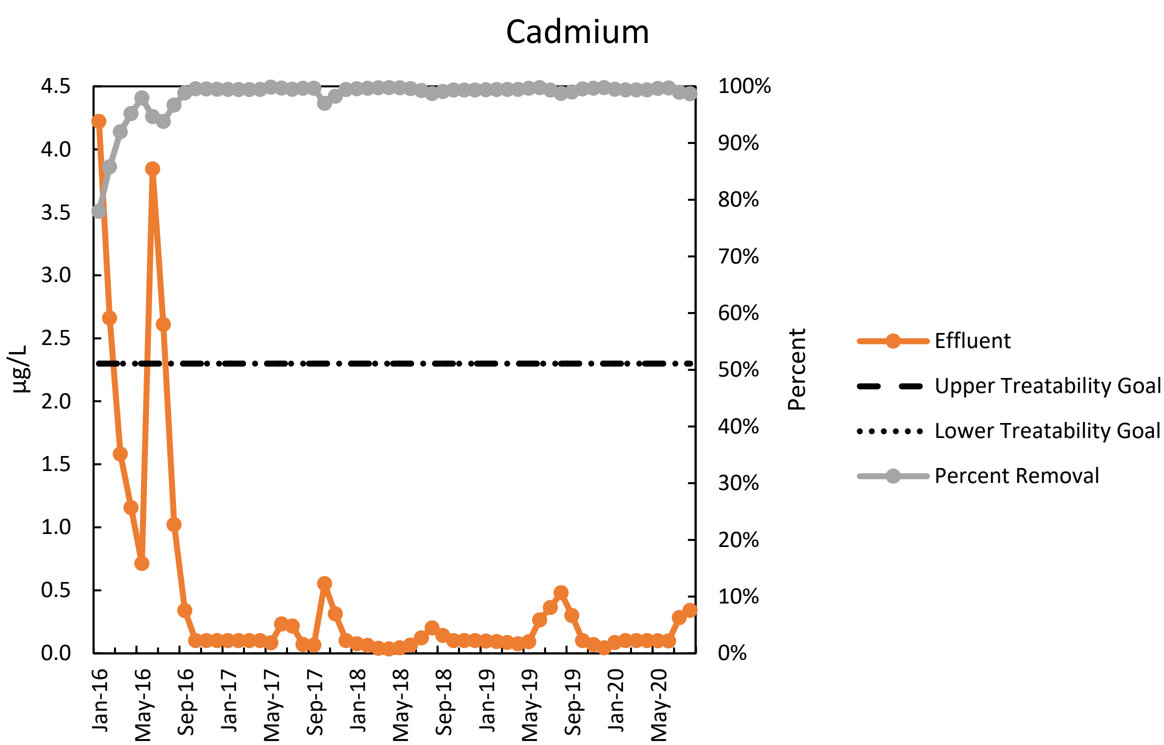

Aluminum
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
µg/L
100%
99%
98%
97%
96%
95%
94%
Percent
Jan-16
May-16
Sep-16
Jan-17
May-17
Sep-17
Jan-18
May-18
Sep-18
Jan-19
May-19
Sep-19
Jan-20
May-20
Date
Influent
Effluent
Percent Removal

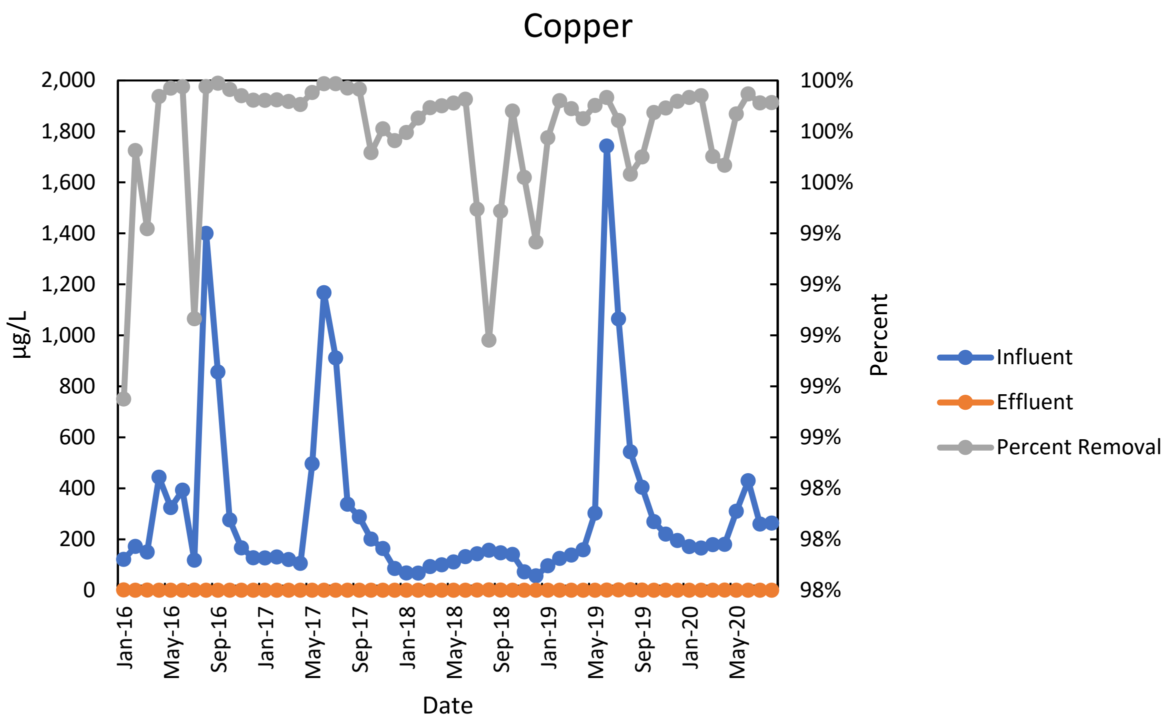

Aluminum
180
160
140
120
100
80
60
40
20
0
µg/L
100%
99%
98%
97%
96%
95%
94%
Percent
Jan-16
Apr-16
Jul-16
Oct-16
Jan-17
Apr-17
Jul-17
Oct-17
Jan-18
Apr-18
Jul-18
Oct-18
Jan-19
Apr-19
Jul-19
Oct-19
Jan-20
Apr-20
Jul-20
Date
Effluent
Percent Removal

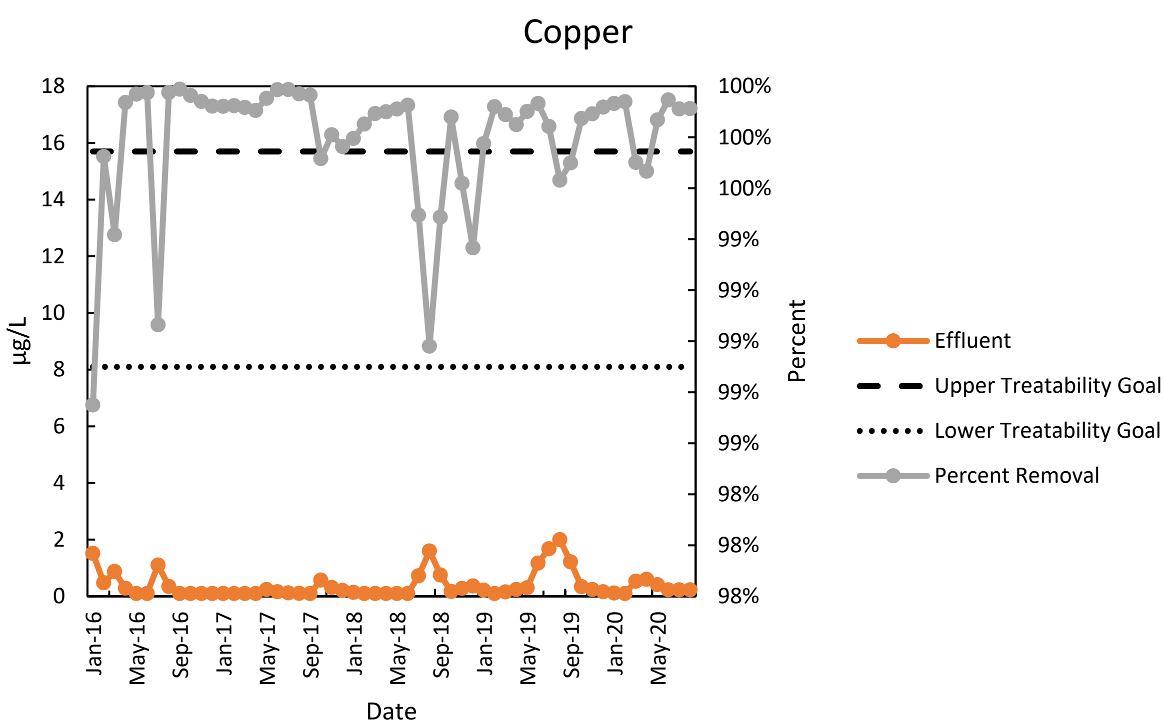

Arsenic
µg/L
Percent
Date
Influent
Effluent
Percent Removal

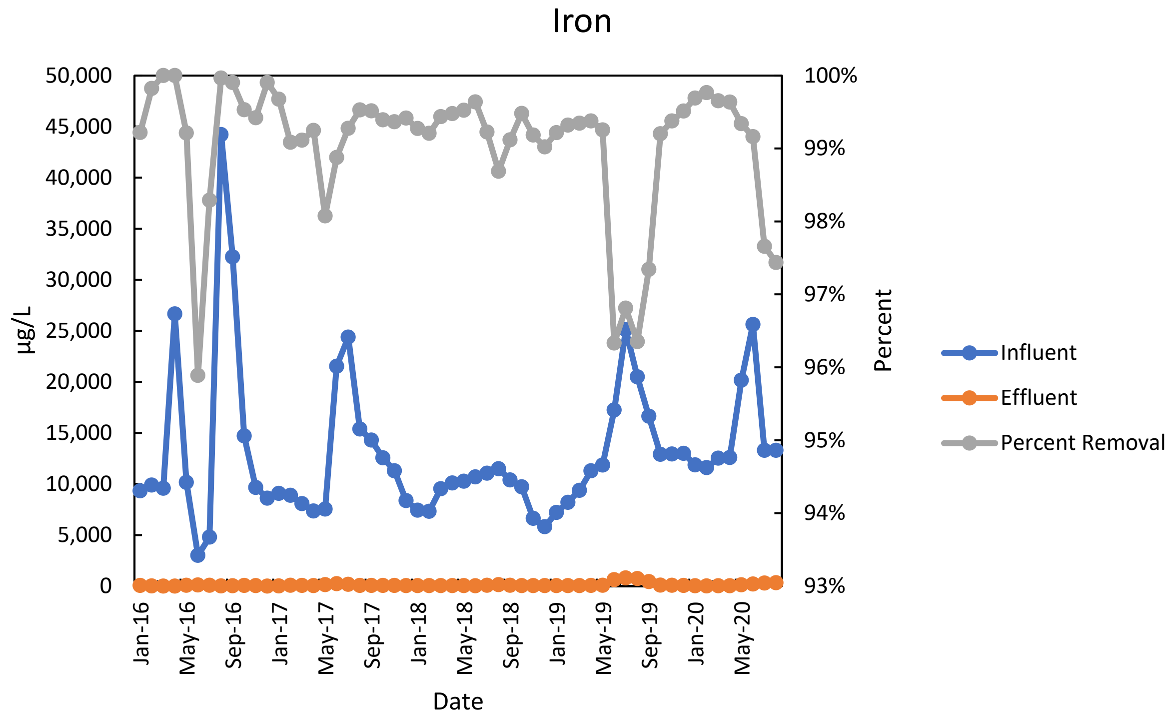

Arsenic
µg/L
Percent
Date
Effluent
Upper Treatability Goal
Lower Treatability Goal
Percent Removal

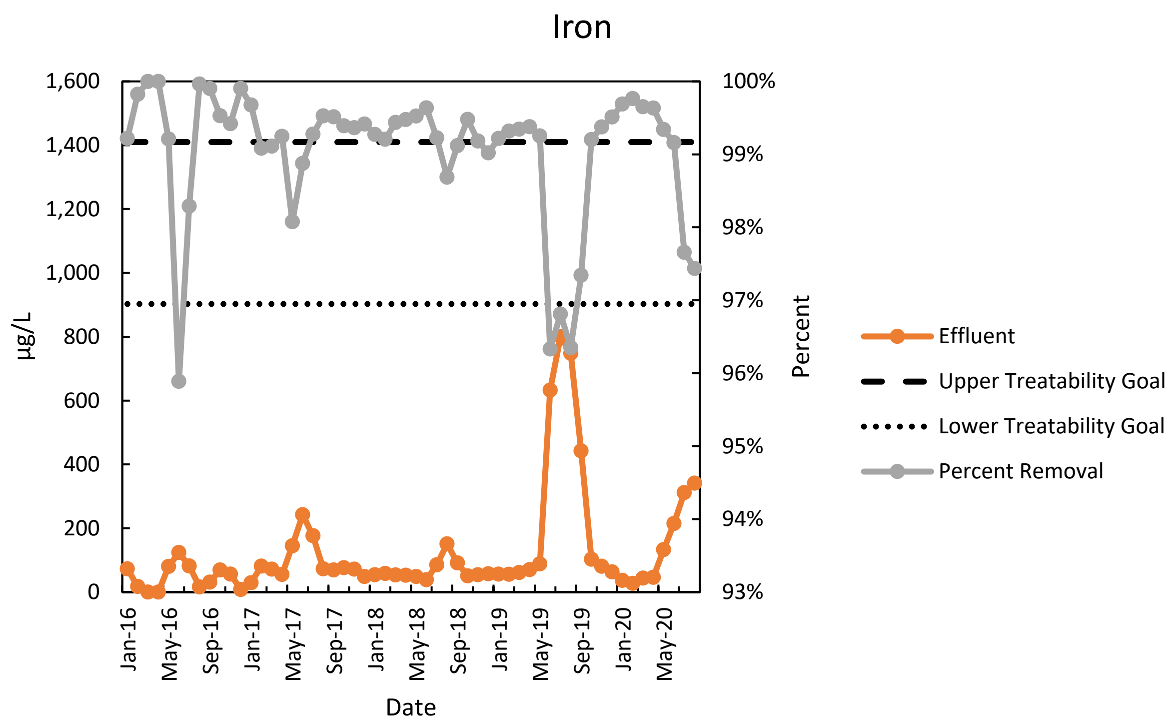

Cadmium
120
100
80
60
40
20
0
µg/L
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Percent
Jan-16
Apr-16
Jul-16
Oct-16
Jan-17
Apr-17
Jul-17
Oct-17
Jan-18
Apr-18
Jul-18
Oct-18
Jan-19
Apr-19
Jul-19
Oct-19
Jan-20
Apr-20
Jul-20
Influent
Effluent
Percent Removal

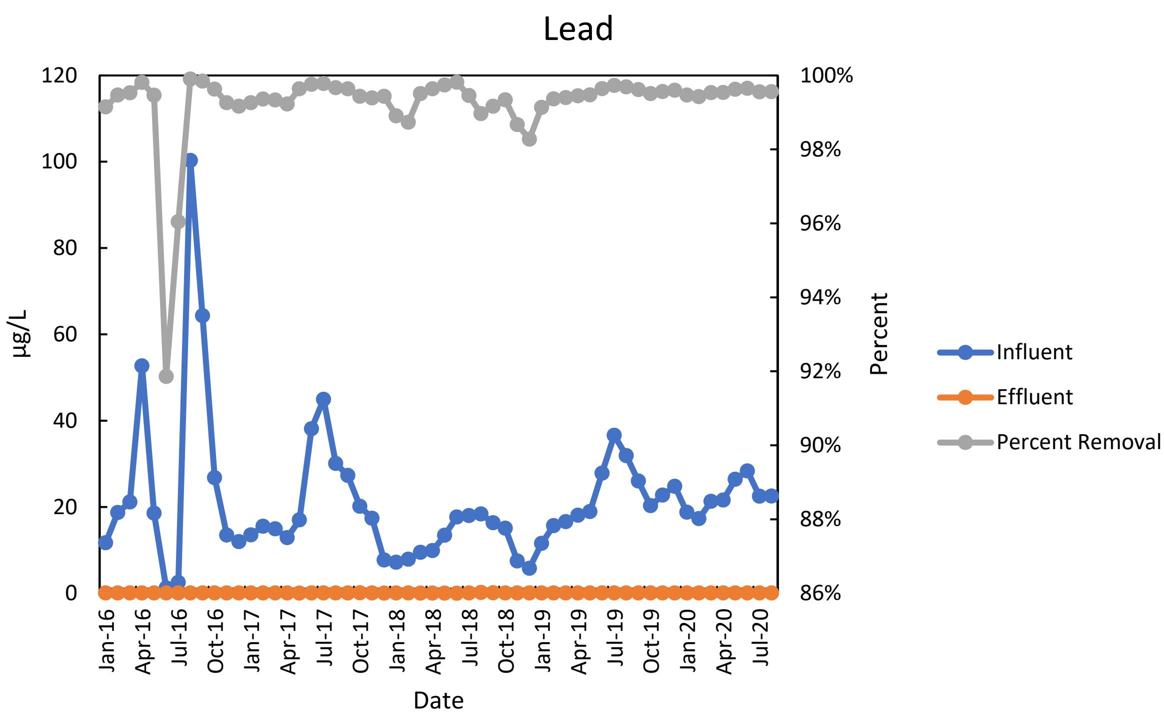

Cadmium
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
µg/L
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Percent
Jan-16
May-16
Sep-16
Jan-17
May-17
Sep-17
Jan-18
May-18
Sep-18
Jan-19
May-19
Sep-19
Jan-20
May-20
Effluent
Upper Treatability Goal
Lower Treatability Goal
Percent Removal

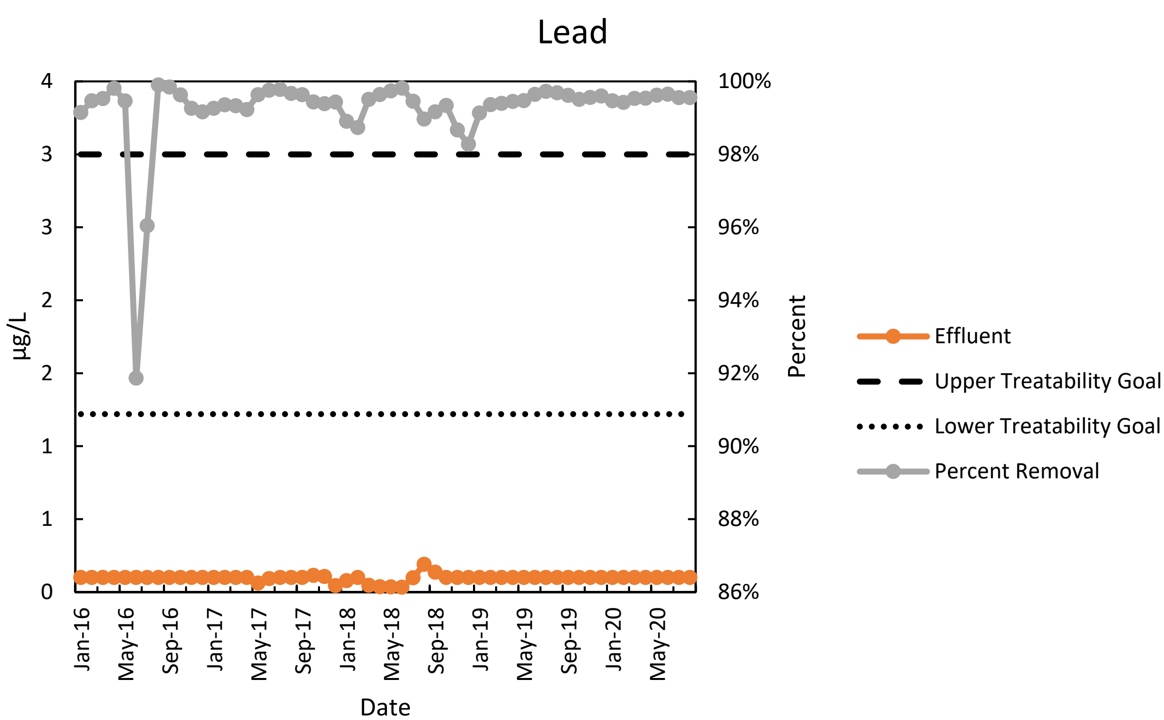

Copper
2,000
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
µg/L
100%
99%
98%
Percent
Jan-16
May-16
Sep-16
Jan-17
May-17
Sep-17
Jan-18
May-18
Sep-18
Jan-19
May-19
Sep-19
Jan-20
May-20
Date
Influent
Effluent
Percent Removal

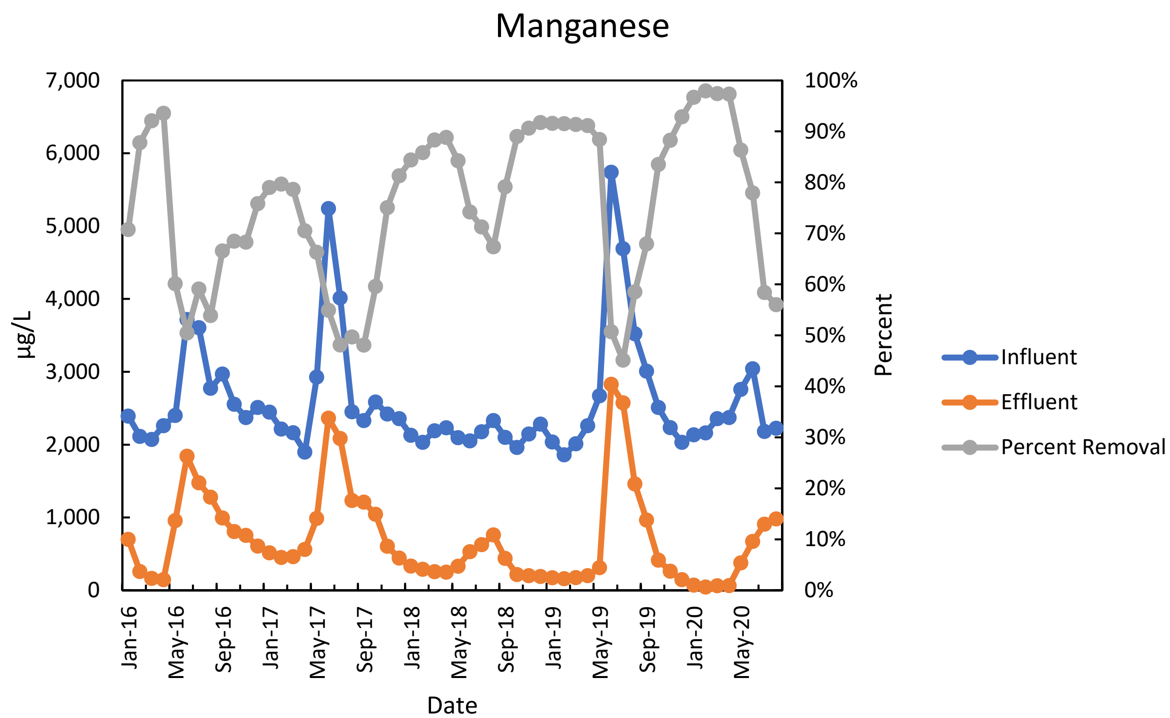

Copper
18
16
14
12
10
8
6
4
2
0
µg/L
100%
99%
98%
Percent
Jan-16
May-16
Sep-16
Jan-17
May-17
Sep-17
Jan-18
May-18
Sep-18
Jan-19
May-19
Sep-19
Jan-20
May-20
Date
Effluent
Upper Treatability Goal
Lower Treatability Goal
Percent Removal

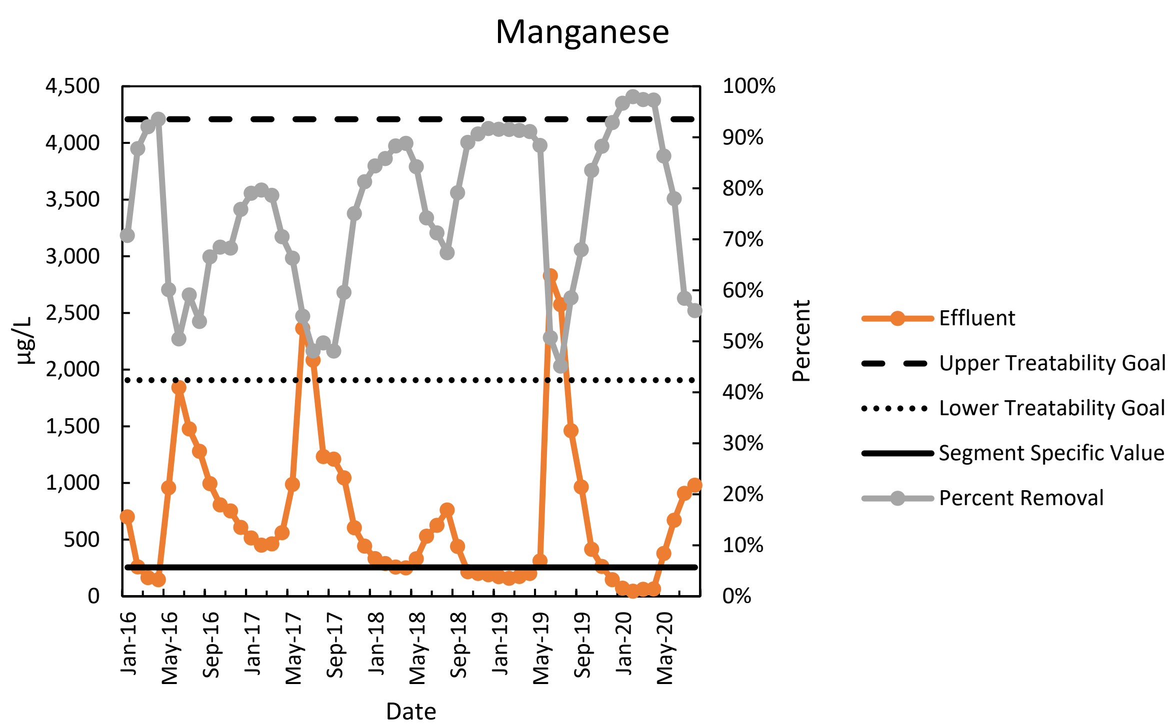

Iron
50,000
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
µg/L
100%
99%
98%
97%
96%
95%
94%
93%
Percent
Jan-16
May-16
Sep-16
Jan-17
May-17
Sep-17
Jan-18
May-18
Sep-18
Jan-19
May-19
Sep-19
Jan-20
May-20
Date
Influent
Effluent
Percent Removal

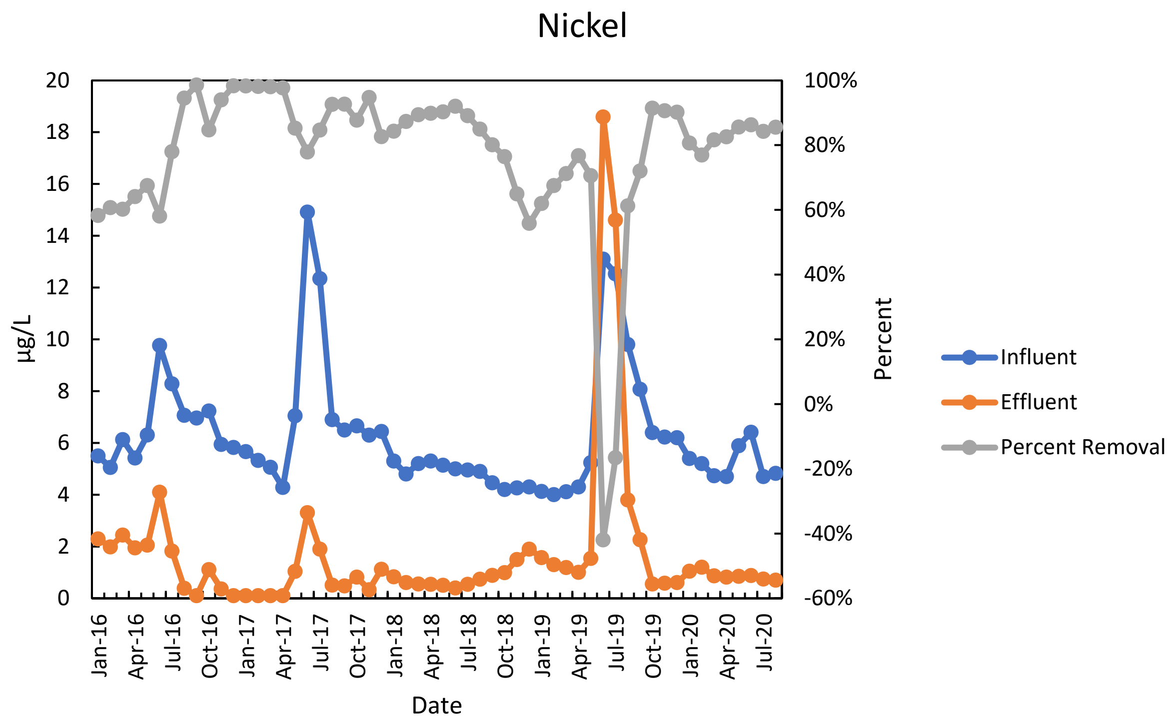

Iron
1,600
1,400
1,200
1,000
800
600
400
200
0
µg/L
100%
99%
98%
97%
96%
95%
94%
93%
Percent
Jan-16
May-16
Sep-16
Jan-17
May-17
Sep-17
Jan-18
May-18
Sep-18
Jan-19
May-19
Sep-19
Jan-20
May-20
Date
Effluent
Upper Treatability Goal
Lower Treatability Goal
Percent Removal

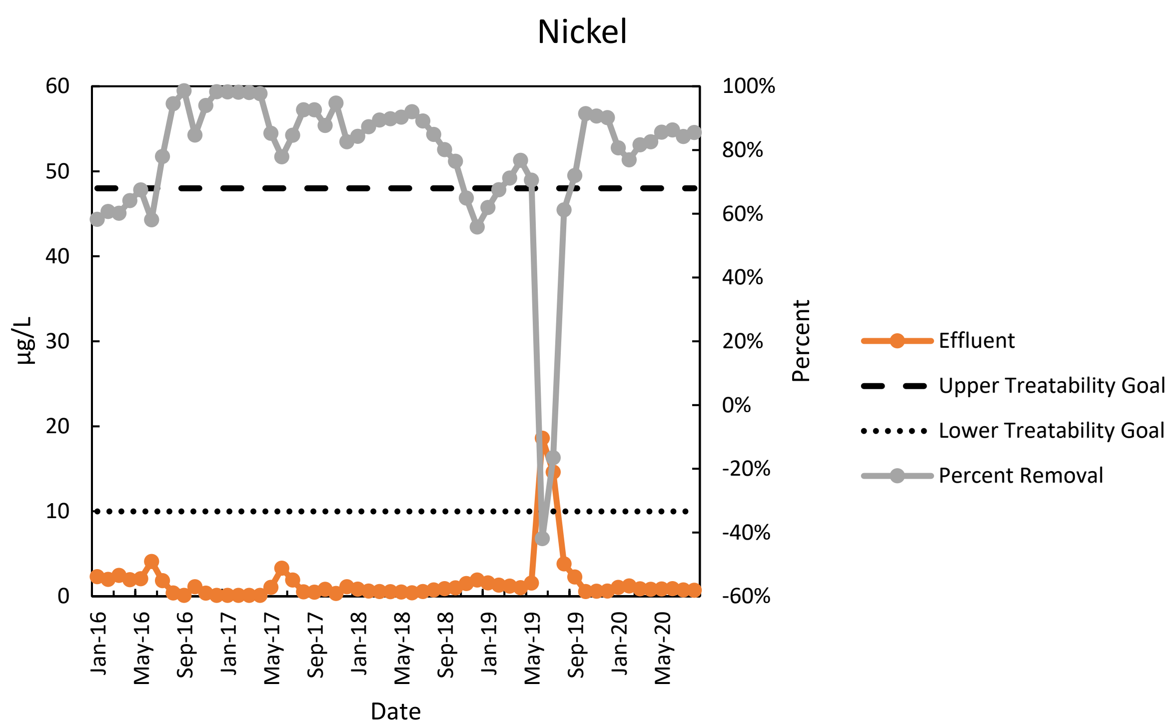

Lead
120
100
80
60
40
20
0
µg/L
100%
98%
96%
94%
92%
90%
88%
86%
Percent
Jan-16
Apr-16
Jul-16
Oct-16
Jan-17
Apr-17
Jul-17
Oct-17
Jan-18
Apr-18
Jul-18
Oct-18
Jan-19
Apr-19
Jul-19
Oct-19
Jan-20
Apr-20
Jul-20
Date
Influent
Effluent
Percent Removal

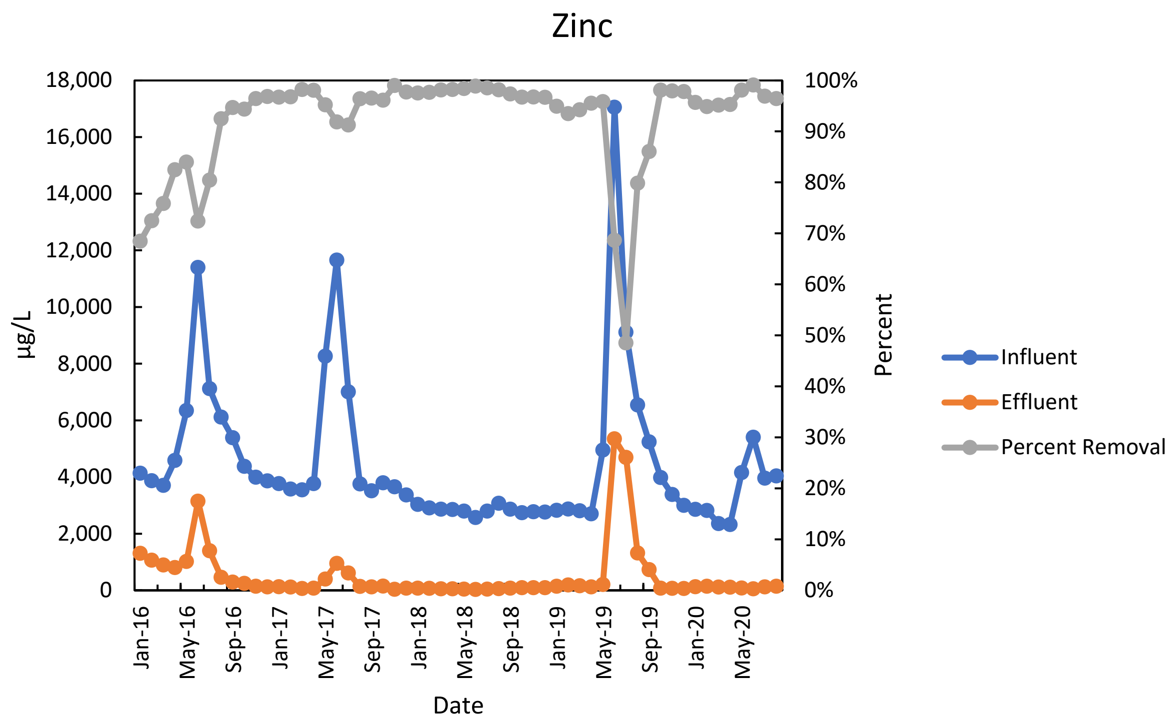

Lead
4
3
3
2
2
1
1
0
µg/L
100%
98%
96%
94%
92%
90%
88%
86%
Percent
Jan-16
May-16
Sep-16
Jan-17
May-17
Sep-17
Jan-18
May-18
Sep-18
Jan-19
May-19
Sep-19
Jan-20
May-20
Date
Effluent
Upper Treatability Goal
Lower Treatability Goal
Percent Removal

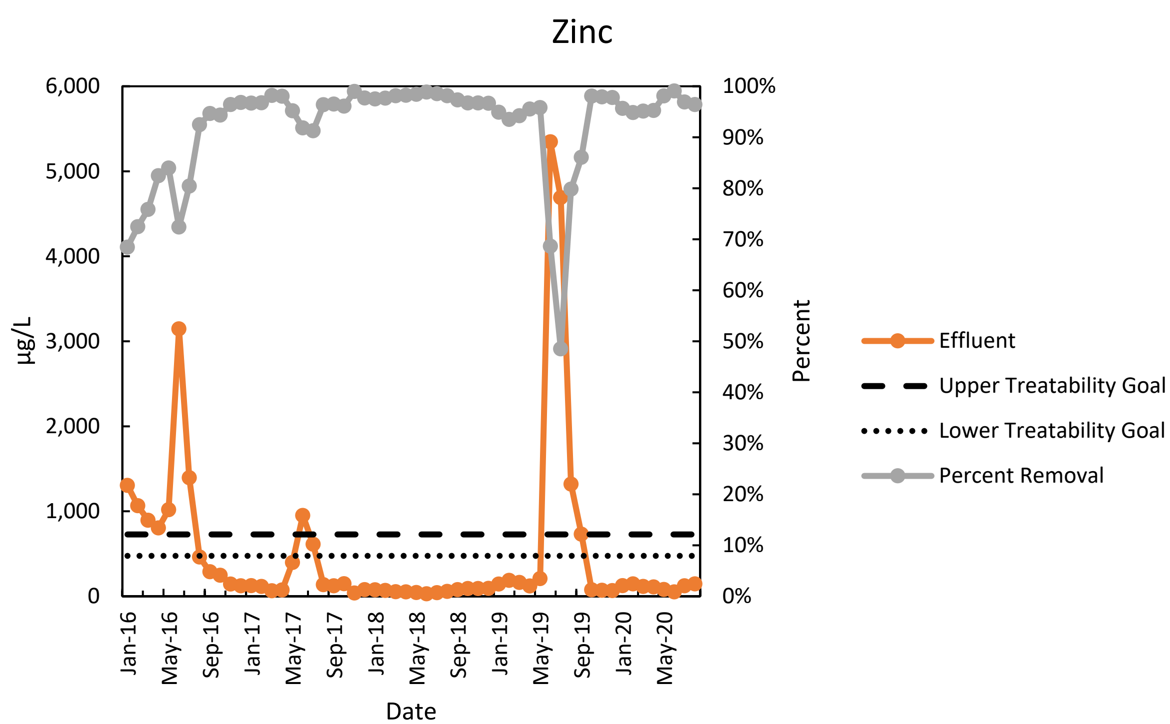

Manganese
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
µg/L
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Percent
Jan-16
May-16
Sep-16
Jan-17
May-17
Sep-17
Jan-18
May-18
Sep-18
Jan-19
May-19
Sep-19
Jan-20
May-20
Date
Influent
Effluent
Percent Removal


Manganese
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
µg/L
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Percent
Jan-16
May-16
Sep-16
Jan-17
May-17
Sep-17
Jan-18
May-18
Sep-18
Jan-19
May-19
Sep-19
Jan-20
May-20
Date
Effluent
Upper Treatability Goal
Lower Treatability Goal
Segment Specific Value
Percent Removal


Nickel
20
18
16
14
12
10
8
6
4
2
0
µg/L
100%
80%
60%
40%
20%
0%
-20%
-40%
-60%
Percent
Jan-16
Apr-16
Jul-16
Oct-16
Jan-17
Apr-17
Jul-17
Oct-17
Jan-18
Apr-18
Jul-18
Oct-18
Jan-19
Apr-19
Jul-19
Oct-19
Jan-20
Apr-20
Jul-20
Date
Influent
Effluent
Percent Removal


Nickel
60
50
40
30
20
10
0
µg/L
100%
80%
60%
40%
20%
0%
-20%
-40%
-60%
Percent
Jan-16
May-16
Sep-16
Jan-17
May-17
Sep-17
Jan-18
May-18
Sep-18
Jan-19
May-19
Sep-19
Jan-20
May-20
Date
Effluent
Upper Treatability Goal
Lower Treatability Goal
Percent Removal


Zinc
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
µg/L
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Percent
Jan-16
May-16
Sep-16
Jan-17
May-17
Sep-17
Jan-18
May-18
Sep-18
Jan-19
May-19
Sep-19
Jan-20
May-20
Date
Influent
Effluent
Percent Removal


Zinc
6,000
5,000
4,000
3,000
2,000
1,000
0
µg/L
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Percent
Jan-16
May-16
Sep-16
Jan-17
May-17
Sep-17
Jan-18
May-18
Sep-18
Jan-19
May-19
Sep-19
Jan-20
May-20
Date
Effluent
Upper Treatability Goal
Lower Treatability Goal
Percent Removal