Focused Engineering Evaluation / Cost Analysis (EE/CA) for Formosa 1 Adit

FINAL

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Technical Project Planning Support for the Replacement Acid Mine Drainage System and Adit #1 Reopening at Formosa Mine, Douglas County, Oregon
Contract No. W912DQ-11-D-3011, Task Order #EC02, TASK 1.3

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EXECUTIVE SUMMARY

INTRODUCTION

The U.S. Army Corps of Engineers (USACE) is assisting the U.S. Department of Interior Bureau of Land Management (BLM) in investigating options to replace a failing acid mine drainage (AMD) collection and treatment system, and open a portal that has been plugged since mine closure in 1994 near Riddle, Douglas County, Oregon. The overall goal of the project is to control, treat, reduce, or eliminate uncontrolled releases of hazardous constituents (metals and acidity) from Formosa 1 Adit discharge, thereby minimizing human and ecological risk exposure. The purpose of reopening the Formosa 1 Adit would be to evaluate the feasibility of permanently closing the adit using hydraulic adit plugs and provide information for the U.S. Environmental Protection Agency (EPA) and interagency technical team to support analysis of hydrology, hydrogeology, mineralogy, and rock mechanics to aid in overall solutions for the site. The Formosa Mine is a former copper and zinc mine (with trace amounts of silver and gold) that has operated since the beginning of the twentieth century and is now an EPA Superfund Site (the Formosa Superfund Site). A Remedial Investigation (RI) (EPA 2012) and Feasibility Study (FS) (EPA 2013) have been completed in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) for Operable Unit 1 (OU1). EPA is the lead agency for the Formosa Superfund Site remedial action.

This EE/CA, prepared for the BLM by the USACE, was developed by Tetra Tech using the Non-Time-Critical Removal Action process that is outlined in CERCLA, and the updated National Oil and Hazardous Substances Pollution Contingency Plan (NCP). The purpose of this EE/CA is to screen, develop, and evaluate response action alternatives that would be used to control, treat, reduce, or eliminate uncontrolled releases of hazardous substances (metals and acidity) from the Formosa 1 Adit. In addition to developing and evaluating potential response action alternatives, cost estimates are developed for each alternative for comparative purposes. The objective of this EE/CA is to provide a recommended preferred response action alternative to prevent the continued, uncontrolled release of AMD to surface water and soil adjacent to the Formosa 1 Adit.

SUMMARY OF SITE CONDITIONS

The Formosa Mine was actively mined for copper, gold, and silver in the 1920s and 1930s and again from 1990 to 1993. Reclamation, including adit closure, was conducted in 1993 and 1994, but has been unsuccessful in eliminating the AMD from the Formosa 1 Adit (EPA 2012). The Formosa 1 Adit is the lowest elevation adit accessing the underground mine workings, into which the drainage from the four other higher-elevation mine adits flows by gravity. Previous Formosa 1 Adit and underground closure included backfill of the workings using waste rock, tailings and low-grade ore. Near the portal, a pipeline drainage system passes through a wooden bulkhead, an anoxic crushed limestone drain treatment system, and a concrete and rebar portal cap at the portal proper. Water initially discharged through the portal in a 3-inch pipeline and into an infiltration system below the portal (DOGAMI 1995). Subsequently, the pipeline plugged, and contaminated adit water found its way around and through the portal plug via an 18-inch opening at the top of the Formosa 1 Adit portal with the effluent reportedly discharged in a single diffuse outfall into Upper Middle Creek.

The conveyance system exceeded its design life, making replacement of the system necessary. Iron hydroxide precipitates with adsorbed metals were deposited in the outfall area and metal loading occurred in the watershed downstream. The RI for OU1 (EPA 2012) characterized the quantity and water quality of the drainage, as well as the extent of downstream contamination. Among the recommendations of the study was the reopening of the adit to investigate means to close off sources of groundwater seepage, which was assumed to be under the direct influence of surface precipitation and contributes significant amounts of water to the adit drainage.

RESPONSE ACTION ALTERNATIVES

This EE/CA evaluates three Response Action Alternatives:

1. Alternative FA-1, the No Action Alternative, involves leaving the Formosa 1 Adit in its existing condition. No reopening or closure activities would be undertaken. No flow-reduction measures from the adit would be implemented to control contaminant migration from the mine portal or to reduce its toxicity or volume. Maintenance and continued operation of the existing adit water conveyance system would continue until the adit discharge could be addressed as part of an overall site-wide closure remedy under CERCLA. Surface water monitoring would be conducted annually as part of the ongoing CERCLA remedial action investigations being conducted by EPA.
2. Alternative FA-2, the Water Treatment and Replacement of AMD Conveyance System Alternative, includes water treatment of the existing adit discharge to control turbidity and to precipitate some of the ferri-hydroxide minerals with associated adsorbed metals, prior to discharge being conveyed downslope to a discharge point. Because there are no water quality standards in place to be met, no additional treatment would be undertaken in order to improve water quality prior to discharge to the existing Land Application Disposal (LAD) area. Replacement of the conveyance system until closure of the adit would be addressed as part of this alternative.
3. Alternative FA-3, the Installation of a Flow-Through Hydraulic Adit Plug Alternative, involves rehabilitation of the Formosa 1 Adit and potential elimination or reduction of the flow from the adit using a single flow-through hydraulic adit plugging method. Although final adit closure options (post installation of this initial plug) are described with this

alternative, implementation of any final adit closure is considered beyond the scope of any proposed response actions.

This EE/CA develops and evaluates each alternative listed above for effectiveness, implementability, and cost, and recommends a Preferred Alternative. Based on comments received, the BLM will prepare an Action Memorandum for the Project which will state the Response Actions that are to take place at the Formosa 1 Adit.

ANALYSIS OF ALTERNATIVES

Alternative FA-1, the No Action Alternative, involves leaving the Formosa 1 Adit in its existing condition. No reopening or closure activities would be started. No flow-reduction measures from the adit would be undertaken to control contaminant migration from the mine portal or to reduce its toxicity or volume. Repairs, maintenance, and continued operation of the existing AMD water conveyance system would continue presumably until the adit discharge could be addressed as part of an overall site-wide closure remedy under CERCLA. Continued operation will require annual high-pressure water jet cleaning to flush iron precipitates out of the upper portion of the pipeline system to prevent clogging. The existing treatment tanks will need to be inspected annually and cleaned out as necessary using vacuum trucks. The pipeline proper will need to be inspected and repaired as necessary (joints, segment damage by rock fall, leakage, and clogging). Water quality is expected to continue to be similar to that currently entering the system. Surface water flow and quality monitoring would be conducted annually under the CERCLA investigations.

Alternative FA-2, the Water Treatment and Replacement of AMD Conveyance System Alternative, would serve to control AMD discharge turbidity, precipitate and settle ferri-hydroxide minerals with associated adsorbed metals (co-precipitates), and increase the discharge pH through the addition of lime, prior to the AMD discharge being conveyed downslope to the existing discharge point. Because there are no water quality standards in place to be met, no additional treatment will be undertaken in order to improve discharge water quality prior to discharge in the LAD area. The existing conveyance system would be replaced in this FA-2 alternative.

Alternative FA-2 would include a semi-passive system in which lime would be added to the adit discharge to increase the pH of the flow-through adit water. This increased pH would result in precipitation of metal hydroxides, primarily ferri-hydroxides, prior to discharge and thereby mitigate, in part, current issues related to clogging of the conveyance system. Alternative FA-2 would also result in discharge of higher pH water with lower concentrations of metals to the LAD area. The discharge from the adit would be directed to a treatment system. Chemical addition to the treatment system feed flow would occur and precipitation of the metal hydroxides would take place in a series of two treatment tanks. The system discharge would be conveyed from the treatment tanks through the replacement discharge pipeline to the LAD area without further treatment or filtration. If this alternative is selected, the new discharge pipeline would be subject to a defined periodic maintenance program. Maintenance of the treatment tanks would also be necessary to remove precipitated solids and transfer them to an appropriate disposal facility. It is assumed for costing purposes of this EE/CA that the water treatment system would be an interim solution to the site discharge, and therefore, costs include capital costs for a new pipeline, water treatment equipment costs, as well as operations and maintenance costs for 10 years.

Alternative FA-3, the Installation of a Flow-Through Hydraulic Adit Plug Alternative, proposes the installation of a flow-through hydraulic adit plug to reduce or eliminate the flow of contaminated groundwater collecting in the mine-pool and discharging from the adit portal, and thereby minimizing impacts to down-gradient surface and local groundwater water receptors. Pressure grouting of the plug and outboard flowing fractures is proposed to further reduce flow from the adit. Alternative FA-3 would be highly effective, by eliminating the volume of contaminated flow from the adit portal and discharge to the LAD area, and has the potential to virtually eliminate the need for the pipeline conveyance system and greatly reduce impact to down gradient alluvial aquifers and surface water.

PREFERRED ALTERNATIVE

The preferred alternative is FA-3, Installation of a Flow-Through Hydraulic Adit Plug. Alternative FA-3 will include maintenance of the existing AMD Conveyance System for temporary conveyance during mine dewatering during construction, which is considered an essential step that must be implemented prior to and during construction of Alternative FA-3. Only by maintaining and repairing the pipeline can the adit plug be installed safely, with minimal impacts to downgradient surface and groundwater and to human and ecological receptors. It is only through the implementation of this preferred alternative that effective and substantial improvements in water quality including surface flow in Upper Middle Creek can be realized. Estimated costs to implement the Preferred Alternative are presented in Table ES-1 on the following page. Total estimated cost for the implementation of the Preferred Alternative **$1,372,131**. The detailed cost analysis can be found in **Appendix B**.

Table ES-1. Cost Estimate for Formosa 1 Adit Preferred Alternative

Adit Construction Pad, Staging Area and Sediment Pond	$88,063
Waste Rock Storage Pad Site Work	$32,251
O & M Costs - 10 Year at 3% per year Inflation	$292,361
Mobilization and Demobilization	$90,000
Mine Dewatering	$20,000
General Equipment / Construction Costs	$69,510
Materials / Supplies	$31,916
Labor	$74,000
General Equipment / Construction Costs	$48,315
Materials / Supplies	$76,049
Labor	$84,400
Bonding and Insurance (10%)	$92,586
Contingency (20%)	$185,173
Engineering Design (8%)	$96,290
Construction Oversight (6%)	$72,217

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ACRONYMS AND ABBREVIATIONS

μg/L	micrograms per liter
AMD	acid mine drainage
amsl	above mean sea level
ARARs	applicable or relevant and appropriate requirements
ARD	acid rock drainage
BERA	Baseline Ecological Risk Assessment
bgs	below ground surface
BLM	Bureau of Land Management
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
COC	contaminant of concern
COI	chemical of interest
COPC	contaminants of potential concern
CSF	cancer slope factor
CSM	conceptual site model
CTE	central tendency exposure
$CuFeS_2$	chalcopyrite
DTW	depth to water
EA	Exposure Area
ECLR	excess lifetime cancer risk
EE/CA	Engineering Evaluation/Cost Analysis
EPA	U.S. Environmental Protection Agency
EPC	exposure point concentration
ERA	Ecological Risk Assessment
ESL	ecological screening level
Fe^{2+}	ferrous iron
Fe^{3+}	ferric iron
FEI	Formosa Exploration, Inc.
FeS_2	pyrite
FS	Feasibility Study
ft	feet
GIS	geographic information system
gpm	gallon per minute
H^+	hydrogen
HDPE	high density polyethylene

HHRA	Human Health Risk Assessment
HI	hazard index
hp	horsepower
HQ	hazard quotient
IRAM	Interim Remedial Action Measure
LAD	Land Application Disposal
mg/L	milligrams per liter
MSHA	Mine Safety and Health Administration
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NTCRA	Non-Time Critical Removal Action
NTU	nephelometric turbidity unit
ODEQ	Oregon Department of Environmental Quality
OSHA	Occupational Safety and Health Administration
OU1	Operable Unit 1
OU2	Operable Unit 2
psi	pound per square inch
PWS	Performance Work Statement
RAO	response action objective
RI	Remedial Investigation
RSLs	Regional Soil Screening Levels
SLERA	Screening Level Ecological Risk Assessment
SO_4^{2-}	sulfate
Tetra Tech	Tetra Tech, Inc.
USACE	U.S. Army Corps of Engineers
UTM	Universal Transverse Mercator
ZnS	sphalerite

DEFINITIONS

The following definitions specific to mining are provided to aid in the understanding of subsequent discussions:

- Back – roof
- Sill – floor
- Ribs – walls
- Adit – variable dipping but approximately horizontal mine access (inclines and declines)
- Haulage level adit – adit driven as a cross-cut to ore for drainage or ore hauling
- Stope – actual mined-out area
- Drift – approximately horizontal workings driven in ore
- Cross-cut – approximately horizontal workings driven in barren rock to access ore
- Level – main haulage level drifts typically excavated on 100 foot vertical spacing to develop mine
- Mucker – short, squatty, front-end loader for use underground

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1.0 INTRODUCTION AND PROJECT BACKGROUND

The U.S. Army Corps of Engineers (USACE) is assisting the U.S. Department of Interior Bureau of Land Management (BLM) in investigating options to replace a failing acid mine drainage (AMD) collection and treatment system, and open a portal that has been plugged since mine closure in 1994 near Riddle, Douglas County, Oregon. The overall goal of the project is to control, treat, reduce, or eliminate uncontrolled releases of hazardous substances (metals and acidity) from Formosa 1 Adit discharge, thereby minimizing human and ecological risk exposure. The purpose of reopening the Formosa 1 Adit would be to evaluate the feasibility of permanently closing the adit using hydraulic adit plugs and provide information for the U.S. Environmental Protection Agency (EPA) and interagency technical team to support analysis of hydrology, hydrogeology, mineralogy, and rock mechanics to aid in overall solutions for the site.

The Formosa Mine is a former copper and zinc mine (with trace amounts of silver and gold) that has operated since the beginning of the twentieth century and is now a EPA Superfund Site (the Formosa Superfund Site). The site is divided into two Operable Units:

- Operable Unit 1 (OU1) includes surface and subsurface mine materials and contaminated soils located outside of the underground mine workings. These mine materials are defined as OU1 mine materials and include materials that were excavated during construction and operation of the mine, such as waste rock, ore, tailings, construction rock, road surfaces, and contaminated soils that are co-mingled with waste rock, affected by dispersion of contaminants from mine materials and/or affected by mining-influenced water discharges.

- Operable Unit 2 (OU2) includes all remaining media and site contamination areas, including surface water, stream sediment, groundwater, underground workings, and adit water drainage. Mine materials present within the underground workings are defined as OU2 mine materials.

A Remedial Investigation (RI; EPA 2012) and Feasibility Study (FS) (EPA 2013) have been completed in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), as amended in 1996, for OU1. The Final OU1 RI Report, dated January 31, 2012 (EPA 2012) and the Final OU1 FS Report, dated January 31, 2013 (EPA 2013) provide summaries of the investigations completed on the site and recommendations for remedial actions. The Draft Operable Unit 2 (OU2) Surface Water and Groundwater Data Summary Memorandum, dated February 5, 2014 (EPA 2014a), provides additional data regarding OU2.

The systematic planning support for the replacement acid mine drainage system and Formosa 1 Adit reopening was originally deemed a Time-Critical Removal Action. Following more detailed evaluation of current site conditions, the USACE and BLM changed the approach to a Non-Time Critical Removal Action (NTCRA) and interim adit closure. A 10% Concept Plan was completed in May 2013 (USACE 2013a) summarizing multiple options to be evaluated relative to the closure of the Formosa 1 Adit. The 10% Concept Plan recommended the completion of an evaluation of the Formosa Mine focused on the Formosa 1 Adit discharge. As part of additional data collection, an on-site pumping test (USACE 2013b) and a hydrologic evaluation of the geometry of the adit (USACE 2014) were completed to evaluate how the mine pool aquifer within the mine workings would respond to draw-down pump testing. Results of this testing determined that the mine could be safely and adequately dewatered so that implementation of hydraulic plug closure methods would be feasible at this site.

EPA is the lead agency for the overall Formosa Superfund Site remediation; BLM is exercising CERCLA authority for the Formosa 1 Adit NTCRA. Tetra Tech, Inc. (Tetra Tech) was contracted by the USACE on behalf of BLM to address technical planning and design and engineering support for the site. As part of that support, Tetra Tech has developed this Focused Engineering Evaluation/Cost Analysis (EE/CA) using the NTCRA process that is outlined in CERCLA, and the updated National Oil and Hazardous Substances Pollution Contingency Plan (NCP). The purpose of this EE/CA is to select and evaluate response action alternatives that would be used to control, treat, reduce, or eliminate uncontrolled releases of hazardous constituents (metals and acidity) from the Formosa 1 Adit, and evaluate the suitability and design of a hydraulic adit plug closure system to stem the flow of contaminated mine water from the Formosa 1 Adit. This EE/CA evaluates three alternatives:

1. The No Action Alternative (FA-1) involves leaving the Formosa 1 Adit in its existing condition. No reopening or closure activities would be undertaken. No flow-reduction measures from the adit would be implemented to control contaminant migration from the mine portal or to reduce its toxicity or volume. Maintenance and continued operation of the existing adit water conveyance system would continue until the adit discharge could be addressed as part of an overall site-wide closure remedy under CERCLA. Surface water monitoring would be conducted annually as part of the ongoing CERCLA remedial action investigations being conducted by EPA.
2. The Water Treatment and Replacement of AMD Conveyance System Alternative (FA-2) involves treatment of the existing adit discharge to control turbidity and to precipitate some of the ferri-hydroxide minerals with associated adsorbed metals, prior to discharge being conveyed downslope to the existing discharge site. Because there are no water quality standards in place to be met, no additional treatment would be undertaken in order to improve discharge water quality prior to discharge in the Land Application Disposal (LAD) area. The existing conveyance system would be replaced in this FA-2 alternative.

3. The Installation of a Flow-Through Hydraulic Adit Plug Alternative (FA-3) involves rehabilitation of the Formosa 1 Adit and elimination or reduction of the flow from the adit using a single flow-through hydraulic adit plugging method. Although final adit closure options (after installation of this initial plug) are described with this alternative, implementation of any final adit closure is considered beyond the scope of any proposed response actions.

This EE/CA develops and evaluates each alternative listed above, and recommends a Preferred Alternative. Based on comments received, the BLM will prepare an Action Memorandum for the Project which will state the Response Actions that are to take place at the Formosa 1 Adit.

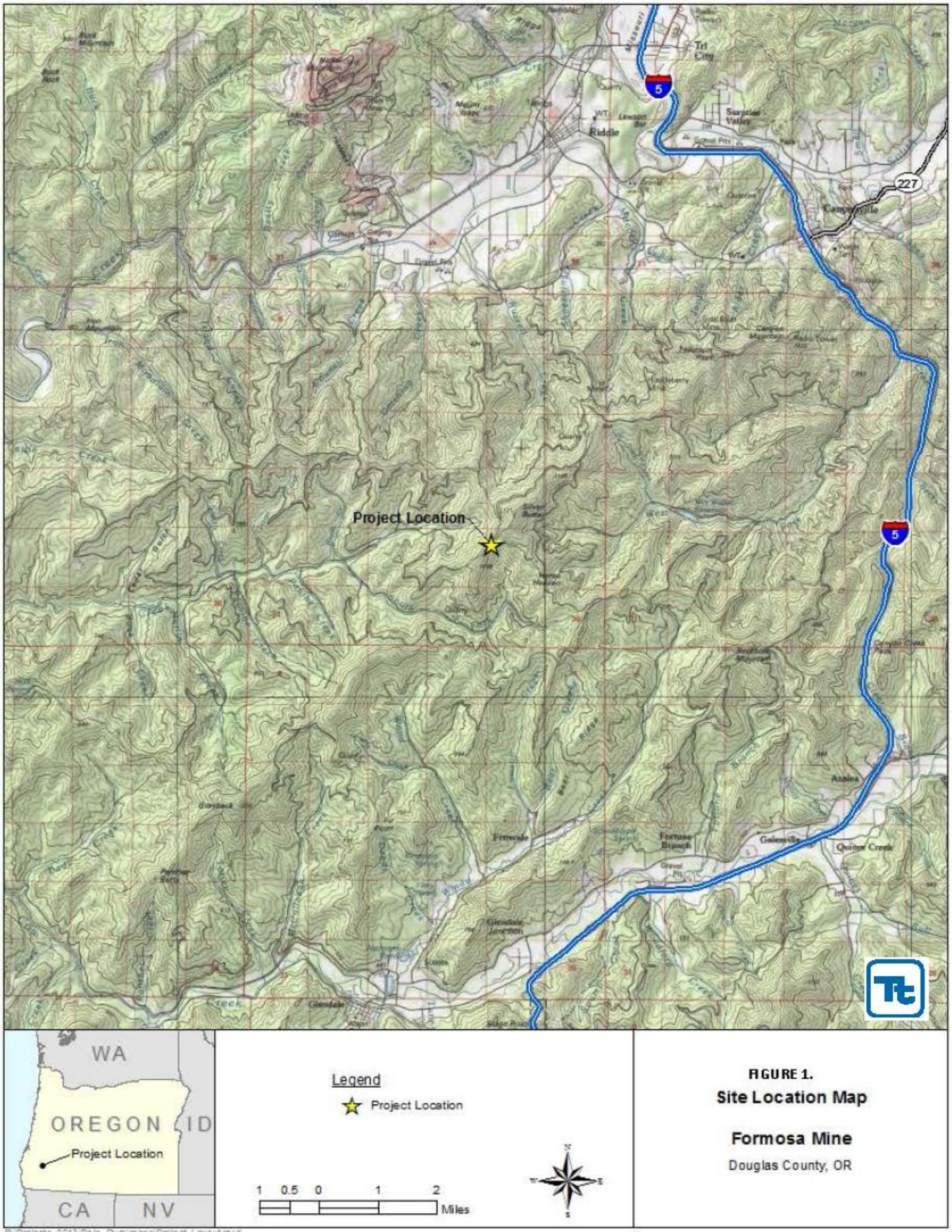
1.1 Purpose and Objectives

The purpose of this EE/CA is to screen, develop, and evaluate potential response action alternatives that would be used to control, treat, reduce, or eliminate uncontrolled releases of hazardous substances (metals and acidity) from the Formosa 1 Adit. Figure 1 illustrates the project location, and Figure 2 presents a plan map of the Formosa Mine Area. Figure 3 displays the NTCRA process as it applies to the discharge of water from the Formosa 1 Adit portal. An NTCRA is implemented by the lead agency to respond to “the cleanup or removal of released hazardous substances from the environment… as may be necessary to prevent, minimize, or mitigate damage to the public health or welfare or to the environment” (EPA 1993).

In addition to developing and evaluating potential response action alternatives, cost estimates are developed for each alternative for comparative purposes. The objective of this EE/CA is to provide a recommended preferred response action alternative. Following receipt of public comment on the preferred response action alternative identified in this document, the BLM will finalize the selection of an alternative in a decision document for the response action, an Action Memorandum. This NTCRA is considered an interim measure until EPA addresses the final remedy for the overall Formosa Superfund Site. Although final adit closure options are discussed in relation to the preferred alternative, implementation of the final adit closure is considered beyond the scope of the response action. Costs are given for a 10-year timeframe to allow for comparison between alternatives until final Formosa Superfund Site closure.

Numerous investigations have been conducted on this site. The data collected from these investigations have been used to support this EE/CA and these studies are referenced where appropriate. Site data were used to assess risks posed by AMD from the underground mine workings of the Formosa Mine to downgradient surface and groundwater.

With the exception of the Pumping Test Report and Hydrology Evaluation Technical Memorandum, no original data was generated for this evaluation. The information in this EE/CA was obtained from the RI Report for OU1 (EPA 2012), the Feasibility Study (EPA 2013), the Pumping Test Report (USACE 2013b), the OU2 Draft Surface Water and Groundwater Data Summary Report (EPA 2014a), and the Hydrology Evaluation Technical Memorandum (USACE 2014).


Project Location
Tri City
Riddle
Canyonville
Glendale
Galesville
Azalea
Quines Creek
Fortune Branch
Glendale Junction
WA
OREGON
ID
CA
NV
Project Location
Legend
Project Location
1 0.5 0 1 2
Miles
FIGURE 1.
Site Location Map
Formosa Mine
Douglas County, OR

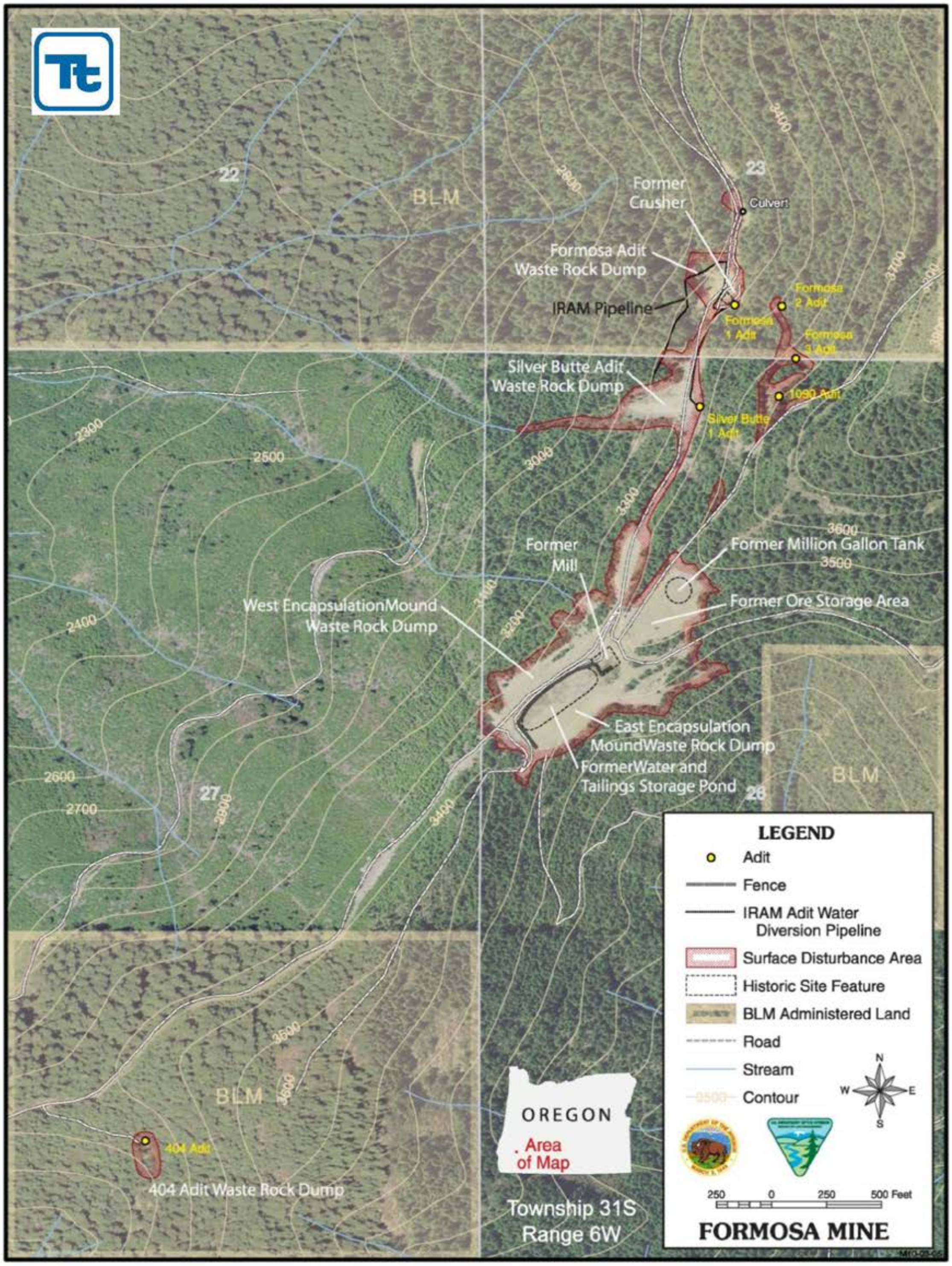
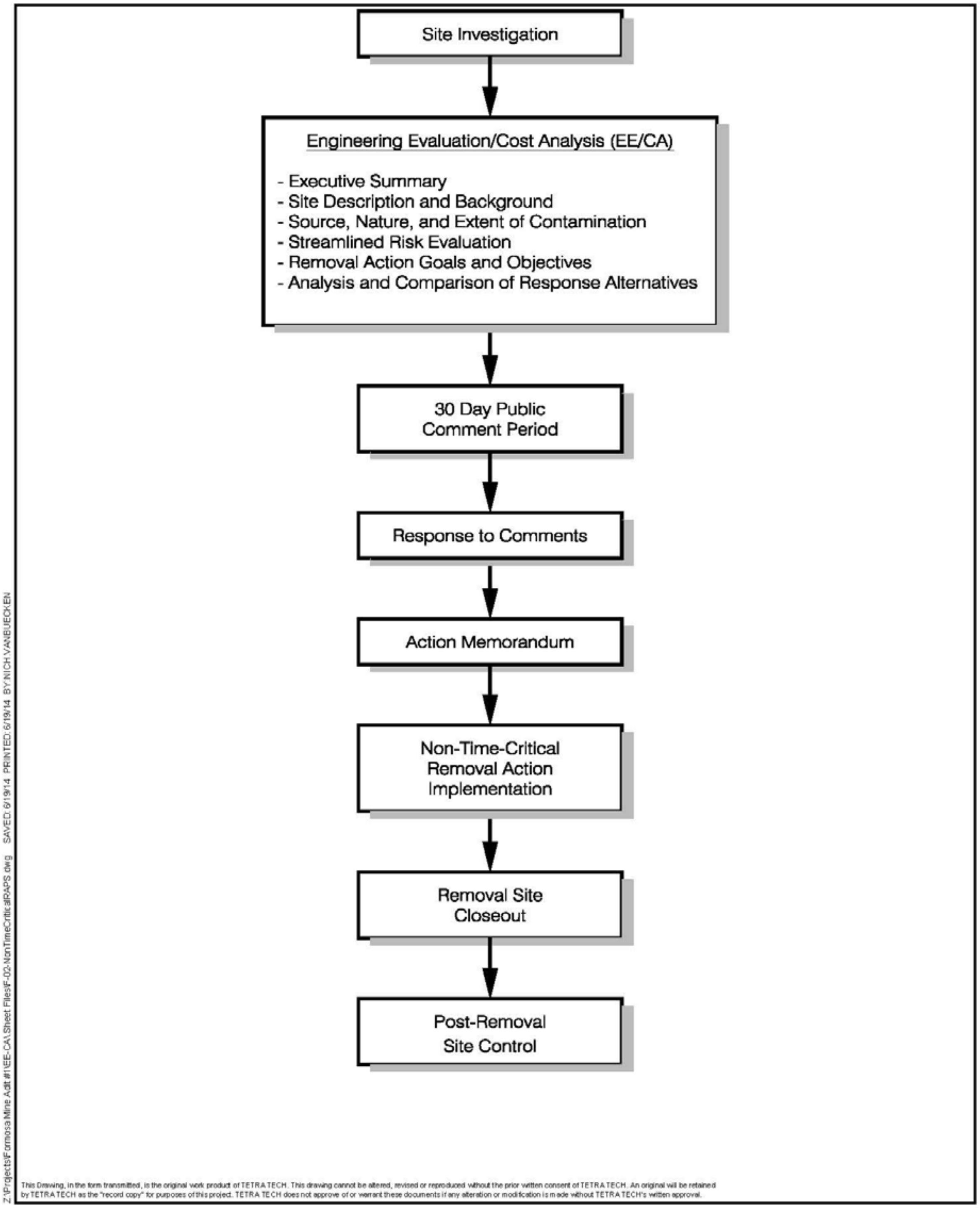


Figure 2. Plan Map of the Formosa Mine Area



Non-Time-Critical Removal Action Process
FORMOSA 1 ADIT
OPERABLE UNIT 1
DOUGLAS COUNTY, OREGON
FIGURE 3

1.2 Brief History of Acid Mine Drainage at Formosa 1 Adit

The Formosa Mine was actively mined for copper, gold, and silver in the 1920s and 1930s and again from 1990 to 1993. Reclamation, including adit closure, was conducted in 1993 and 1994, but has been unsuccessful in eliminating the AMD from the Formosa 1 Adit (EPA 2012). The Formosa 1 Adit is the lowest elevation adit into which the four other higher elevation mine adits', raises', and working levels' discharge flows by gravity. Previous adit and underground closure included backfill of the workings using waste rock, tailings, and low-grade ore. Near the portal, a pipeline drainage system passes through a wooden bulkhead, an anoxic crushed limestone drain treatment system, and a concrete and rebar portal cap at the portal proper. Water initially discharged through the portal in a 3-inch pipeline and into an infiltration system below the portal (DOGAMI 1995). Subsequently, the pipeline plugged, and contaminated adit water found its way around and through the portal plug via an 18-inch opening at the top of the adit portal, with the effluent reportedly discharged in a single diffuse outfall into Upper Middle Creek. Upper Middle Creek is a tributary of Cow Creek, which discharges to the Umpqua River near Roseburg, Oregon. Subsequently, in the early and mid-2000s (EPA 2012), a surface collection basin was installed by Hart Crowser that, combined with the original 3-inch drainage pipeline, redirects adit seepage to a corrugated high density polyethylene (HDPE) pipeline system that transports the contaminated adit water to a larger infiltration area located approximately 0.6 mile below the Formosa 1 Adit. Repeated plugging and failure due to joint breaching or rock fall damage has plagued the AMD conveyance system, resulting in contamination of the downstream receiving waters of Upper Middle Creek. Underground fracture grouting and bulkhead construction to direct AMD seepage into the adit and the drainage route to the portal were not part of the original reclamation program (EPA 2012). Approximate Universal Transverse Mercator (UTM) coordinates of the portal entrance are Zone 10 T, 468706.00 m E, 4744851.00 m N in Section 23, Township 31S, Range 6W.

The conveyance system exceeded its design life, making replacement of the system necessary. Iron hydroxide precipitates with adsorbed metals were deposited in the outfall area and metal loading occurred in the watershed downstream. The RI for OU1 (EPA 2012) characterized the quantity and water quality of the drainage, as well as the extent of downstream contamination. Among the recommendations of the study was the reopening of the adit to investigate means to close off sources of groundwater seepage, which was assumed to be under the direct influence of surface precipitation and contributes significant amounts of water to the adit drainage.

1.3 Report Organization

This EE/CA is arranged in eight sections. Following this Introduction section, the following sections are included:

- Section 2.0 includes the history and geologic, hydrologic, climatic, and underground mine/closure characteristics of the site.

- Section 3.0 presents pertinent data used to characterize contaminant sources and their nature, extents, and pathways of contaminant movement from the Formosa Mine underground workings and into the surface and groundwater of the Upper Middle Creek drainage.
- Section 4.0 summarizes the streamlined human health and ecologic risk assessment associated with discharges from the Formosa 1 Adit.
- Section 5.0 outlines the response action scope, response action objectives (RAOs), and goals for the site. The RAOs were developed and goals were identified based on both applicable or relevant and appropriate requirements (ARARs) and applicable cleanup guidelines.
- Section 6.0 includes the screening of the response action technologies and process options and the development of potentially applicable response alternatives.
- Section 7.0 presents a detailed analysis of alternatives using NCP evaluation criteria.
- Section 8.0 compares the alternatives against three primary criteria: effectiveness, implementability, and cost.

Figures and tables are incorporated into the text of the report. References cited in the document are listed in Section 9.0. Appendix A identifies ARARs, and Appendix B provides detailed cost estimates.

2.0 SITE CHARACTERIZATION

The Silver Peak Deposit has been mined both historically and more recently with most of the production from the deposit being derived from the Formosa Mine. The Formosa and Silver Butte Mines (formerly referred to as the Silver Peak Mine) primarily produced copper but also generated significant amounts of silver and zinc, and some gold. Historic workings from the 1920s and 1930s were constructed mainly by underground methods from the Formosa 1 Adit, a haulage level adit constructed in part to drain upper level workings of the deposit. Mining from the Formosa 1 Adit, Silver Butte Adit, and other higher level (Formosa) adits resulted in a network of mined-out voids, partially backfilled voids, and placement of mined and milled materials on the surface.

More recent mining activity was undertaken by Formosa Exploration Inc. (FEI) between 1990 and 1993, who mined the Silver Peak deposit below the Formosa 1 Adit level. As part of its mine closure plan, FEI attempted to mitigate acid rock drainage (ARD) from the mine by backfilling the underground workings with mine wastes and installing the pipeline drainage system that passes through a wooden bulkhead, an anoxic crushed limestone drain treatment system, and a concrete and rebar portal cap at the portal proper. FEI's effort was not completely successful, and the EPA, BLM, and the Oregon Department of Environmental Quality (ODEQ) have conducted mine water and ARD waste management at the site from 1994 to the present time. This includes management of the Formosa 1 Adit, which has perennial flow and discharges low pH, metal-laden waters to the surface (EPA 2012).

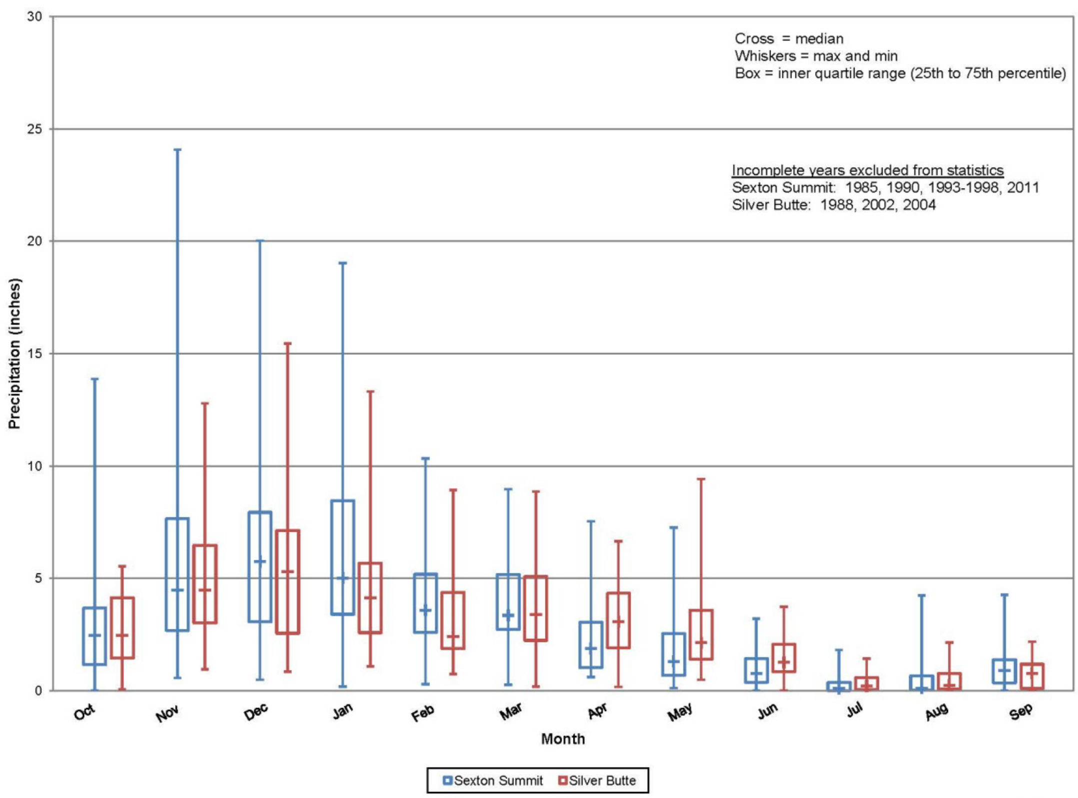
2.1 Formosa Mine Setting

The site is an abandoned mine located in southwest Oregon in Douglas County, approximately 25 miles south of Roseburg, Oregon, and 7 miles south of Riddle, Oregon (Figure 1). Specifically, the site is located within Sections 23, 26, and 27, Township 31 South, Range 6 West Willamette Meridian. Locally, it is situated in the Coast Range Klamath Mountains at elevations between 3,200 and 3,700 feet (ft) above mean sea level (amsl) near Silver Butte Peak (3,973 ft amsl). The Formosa Mine is located in the headwaters of Upper Middle Creek and South Fork Middle Creek in high mountainous country of southwestern Oregon. Both of these streams are perennial and flow as tributaries to Cow Creek. The area receives 34.5 inches of precipitation annually, and snow is present at irregular intervals during the winter. Summers are mild, with moderate temperatures and low precipitation. Streams typically reach their highest flows during the rainy season from late fall through winter. Groundwater discharges by way of alluvial and fracture-controlled bedrock aquifers at this site.

2.2 Climate

Historical climate data have been collected at two weather stations: Sexton Summit and Silver Butte. The Silver Butte weather station is located 1,000 ft north of the site at an elevation of 3,973 ft amsl and has a period of record of 1988 through 2010, with some lapses in data collection. The Sexton Summit weather station is approximately 30 miles south of the site at an elevation of 3,837 ft amsl and has collected data from 1949 through 2010 with some incomplete years. Because of the Sexton Butte station's longer period of record, it is considered to be more representative of overall regional climatic conditions (EPA 2012).

Annual precipitation varies from 15 to 70 total inches. Figure 4 shows the monthly precipitation statistics for Sexton Summit and Silver Butte weather stations. The wettest months of the year are November through March, with median precipitation being greatest in December at 5.75 inches. These wet months contribute to high surface water flow in streams. Peak stream flow generally occurs in March. During winter months, precipitation may fall as snow at higher elevations (EPA 2012).



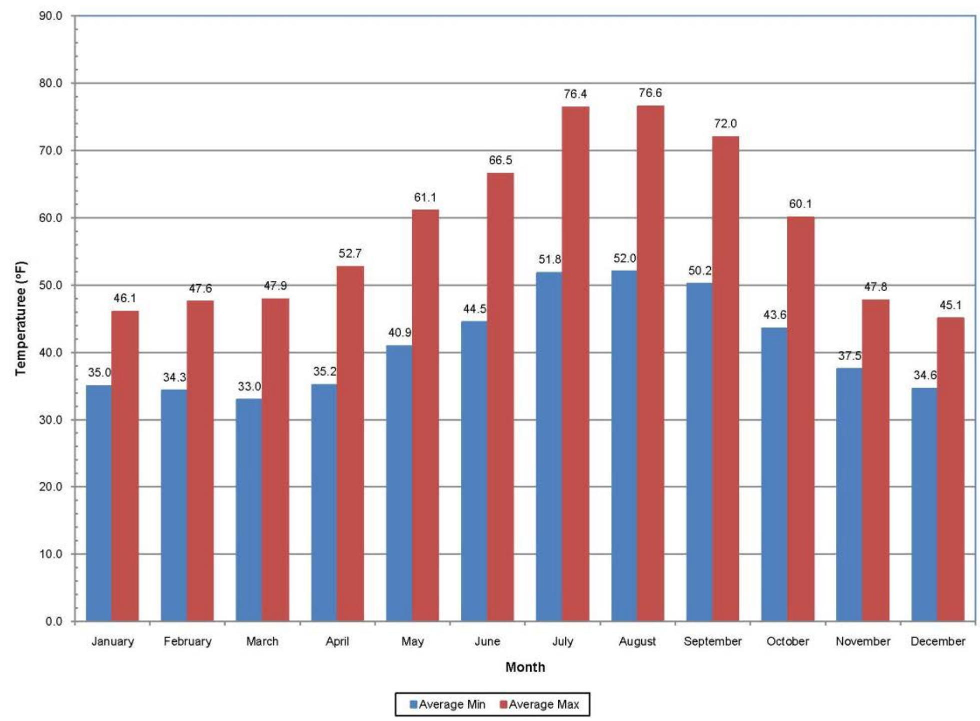
CDM

P:\3380-New RAC8\221 - Formosa\RI Report\Figures\Section 3\Figure 3.6-1 and 3.6-2.xlsx

Figure 4.
Combined Box Plot with Statistics on Average Monthly Precipitation Totals for the Sexton Summit and Silver Butte Weather Stations

Temperatures are warmest during July and August with the average high at approximately 76 degrees Fahrenheit. The coldest temperatures occur in January with an average low of 31 degrees Fahrenheit and an average high around 41 degrees Fahrenheit (Figure 5 and Figure 6; EPA 2012).

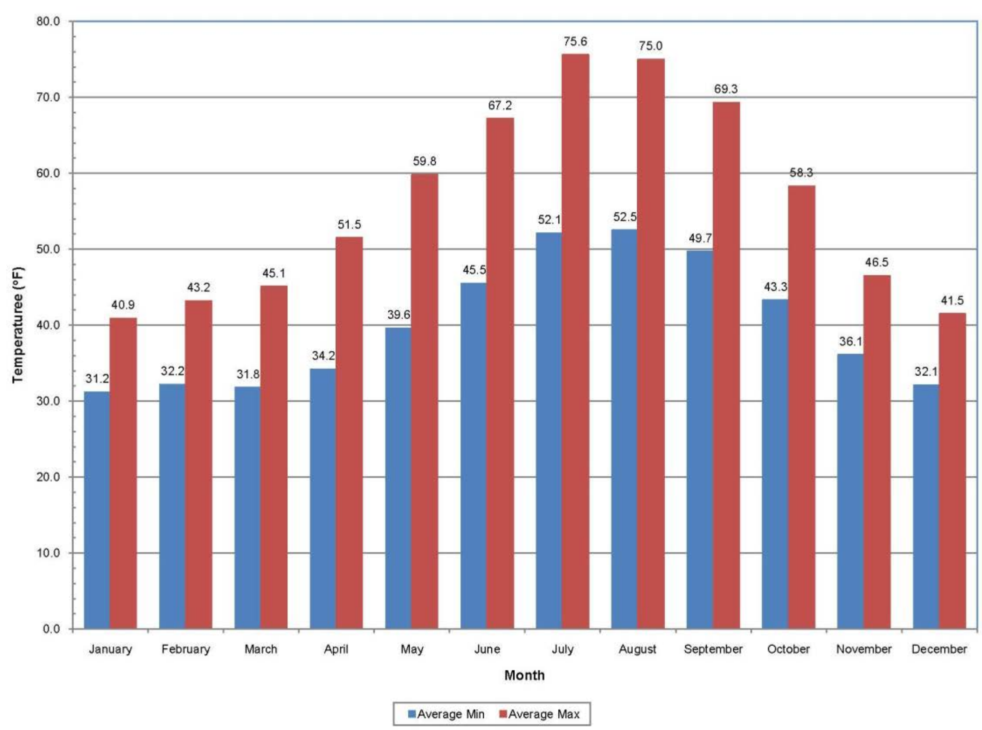
Prevailing winds come from the south-southwest (198 degrees). Westerly and northeasterly winds are also common, but winds rarely blow from the northwest in this area (Figure 7; EPA 2012).



CDM

P:\3380-New RAC8\221 - Formosa\RI Report\Figures\Section 3\Figure 3.6-4 Monthly Average Temperatures at teh Silver Butte Weather Station.xlsx

Figure 5.
Monthly Average Temperatures at the Silver Butte Weather Station



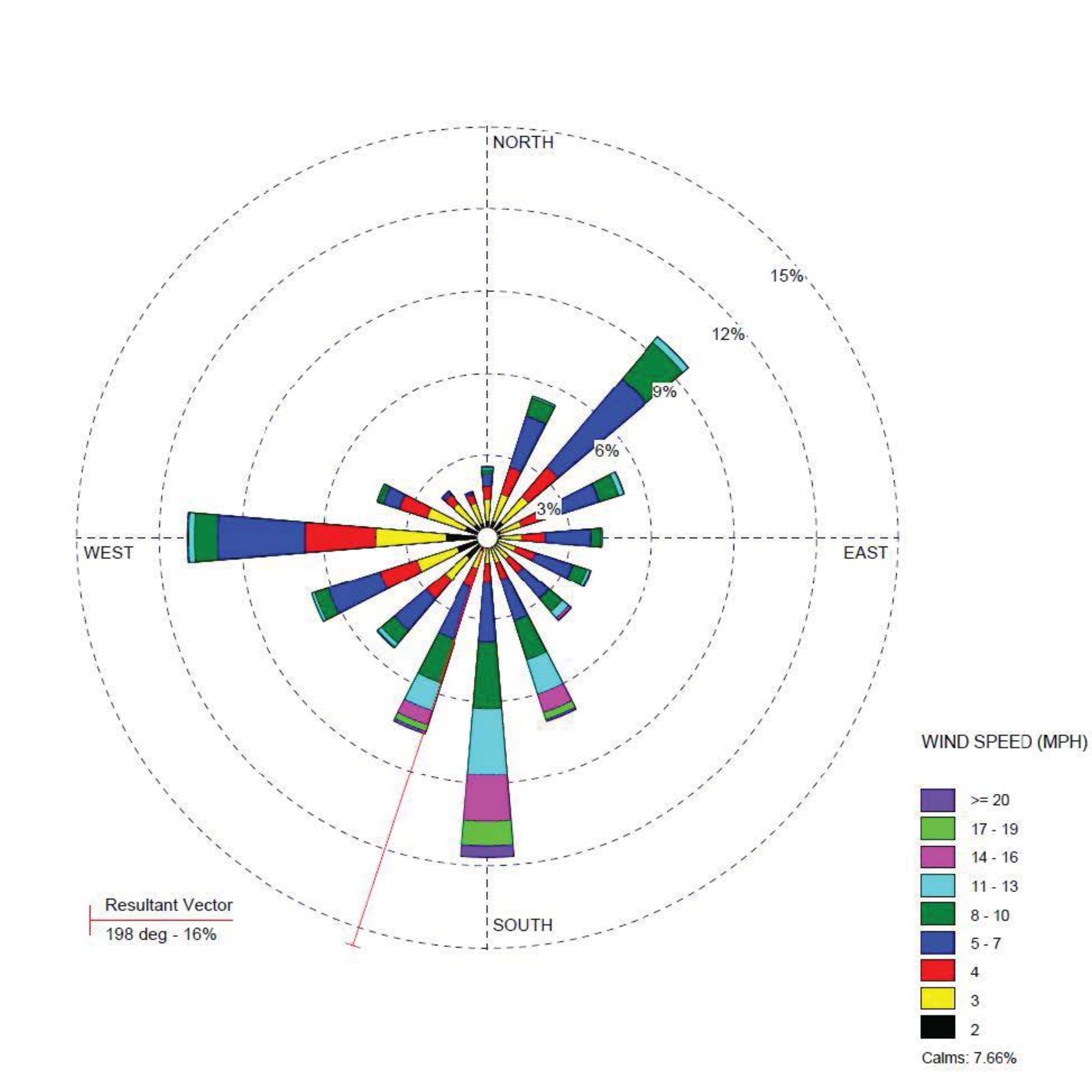
CDM

P:\3380-New RAC8\221 - Formosa\RI Report\Figures\Section 3\Figure 3.6-5 Monthly Average Temperatures at the Sexton Summit Weather Station.xlsx

Figure 6.
Monthly Average Temperatures at the Sexton Summit Weather Station

WIND ROSE PLOT:
Station #SVFO3 - SILVER BUTTE RANGER STATION, OREGON

DISPLAY:
Wind Speed
Direction (blowing from)



COMMENTS:	DATA PERIOD:	COMPANY NAME:	
BASED ON AVERAGE HOURLY WIND SPEED AUG 1986-DEC 2004	**1986-2004** **Jan 1 - Dec 31** **00:00 - 23:00**	**CDM**	
		MODELER: **Sue Pass-CDM Denver, CO**	Figure 7. Wind Rose Plot for Silver Butte
	CALM WINDS: **7.66%**	TOTAL COUNT: **160783 hrs.**	
	AVG. WIND SPEED: **5.59 MPH**	DATE: **4/23/2010**	PROJECT NO.: **FORMOSA MINE**

WRPLOT View - Lakes Environmental Software

2.3 Hydrology and Hydrogeology

2.3.1 Surface Water Characterization

The Formosa Superfund Site is located within the Lower Cow Creek Watershed of the South Umpqua Basin, one of three sub-basins that comprise the Umpqua Basin. The summit of nearby Silver Butte Peak acts as a point of division for several watersheds (Figure 8; EPA 2012). The Formosa Superfund Site is surrounded by the Riddle watershed to the north, the Upper Middle Creek watershed to the west and south, and the Canyon Creek watershed to the southeast and east. Russell Creek of the Riddle watershed and Upper West Fork Canyon Creek of the Canyon Creek watershed have headwaters near the site. Upper Middle Creek and South Fork Middle Creek drainages lie within the Upper Middle Creek watershed and also have headwaters located near the site. The Upper Middle Creek drainages coalesce with the Lower Middle Creek watershed and flow into the Upper Cow Creek watershed. Areal extents of each drainage or sub-watershed are shown in Table 1 (EPA 2012).

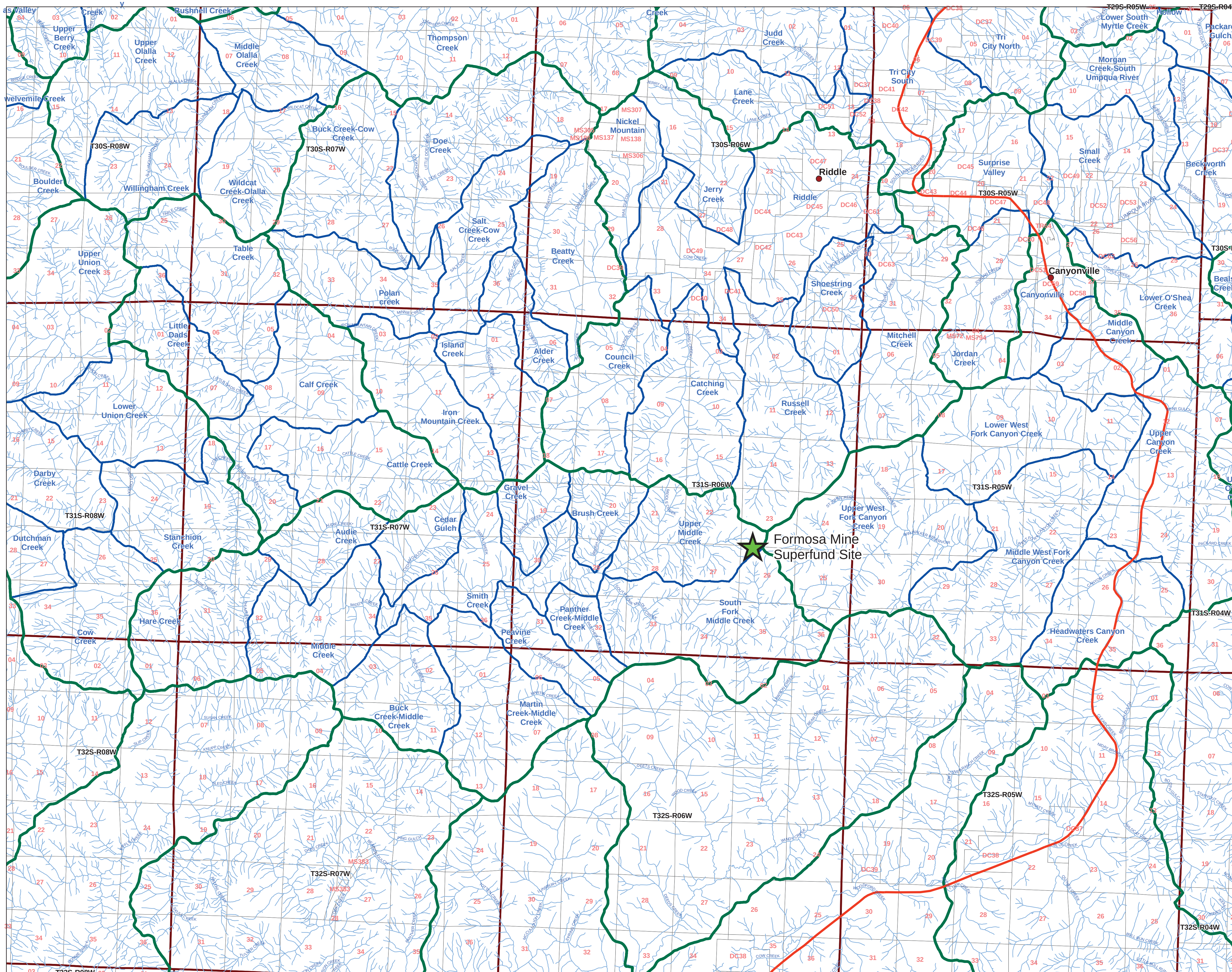
Table 1. Drainage/Sub-watershed Areal Extent

Drainage/Sub-watershed	Area (acres)
Upper Middle Creek Drainage	2,310
South Fork Middle Creek Drainage	4,157
Russell Creek Drainage	3,877
Upper West Fork Canyon Creek Drainage	5,108
Upper Middle Creek Sub-watershed	11,599
Lower Middle Creek Sub-watershed	15,321

Surface water flow is generally highest in the wet season, from December to March, and lowest in the dry season, from July to early November. Flow details can be found in the Impact Section of this report, Section 3.2.

Middle Creek is approximately 13 miles in length from the upper perennial section to its confluence with Cow Creek. The western portions of the site, which include the Formosa 1, 2, and 3 Adits; Silver Butte Adit; Formosa 1 Adit water diversion system; Formosa 1 and Silver Butte Adits waste rock dumps; the west encapsulation mound waste rock storage facility; and the Formosa Mine underground workings, are all within the Upper Middle Creek drainage, which is approximately 3 miles long and 2,310 acres in size (Table 1).

Investigation of surface water has included continuous monitoring of water quality, sampling of sites within Middle Creek and reference streams, and completion of biological surveys. Additional OU2 monitoring includes evaluation of downstream temporal variations, characterization of surface water quality below OU1, and further assessment to support ecological evaluation. Details on sampling and downstream impacts to surface water can be found in Section 3.2 of this report.



Legend

- Towns
- Highway
- Hydrology
- Subwatersheds
- Drainages
- Sections
- Township/Range

0 1 2 4 Miles

N

Geographic Data Standards:
Projected Coordinate System:
NAD 1983 State Plane Oregon FIPS

Data Sources:
Bureau of Land Management:
2001 Hydrography
2005 Township, Range, and Topography

CDM

Figure 8.

Watersheds

Formosa Mine
Douglas County, Oregon

2.3.2 Groundwater System Characterization

Groundwater at the Formosa Superfund Site can be divided into two dominant systems: the unconsolidated alluvial/colluvial groundwater system and the bedrock groundwater system. The three alluvial/colluvial monitoring wells in this area are MW-7A, MW-15A, and MW-16A. The four bedrock monitoring wells are MW-2, MW-5, MW-8, and MW-24. Figure 9 (EPA 2014a) shows groundwater sampling locations.

Alluvial aquifers exist in tributary drainages and are defined by areas of unconsolidated alluvium, colluvium, and/or accumulated fill. The MB and MA tributary drainages are shown in Figure 9 (EPA 2014a) ("MB" and "MA" refer to the MB and MA tributaries; see Figure 9 for tributaries locations). The upper reaches of the alluvial groundwater system are likely to have groundwater present only seasonally or after major storm events, while downstream alluvial groundwater water can persist perennially. This perennial shallow alluvial groundwater is in hydraulic communication with surface water, allowing water to move from the alluvial aquifer into surface water, or vice versa. In upland areas, runoff accumulates in the tributary drainages faster than it can infiltrate into the bedrock groundwater system. This scenario leads to perched alluvial aquifers that actively convey water towards Upper Middle Creek. Observations of this were made at road cuts during the spring seep and spring survey (EPA 2014a).

Monitoring well MW-7A and the MB alluvial aquifer (see Figure 9 for monitoring well locations) are important sites due to their relationship to the alluvial transport pathway connecting the Formosa 1 Adit drainage to discharge points in Upper Middle Creek. Similarities between water chemistry at the discharge of the Formosa 1 Adit with that sampled in the shallow alluvial aquifer well MW-7A are evidence of this pathway. Constituents of concern include cadmium, copper, iron, manganese, zinc, sulfate, total dissolved solids, and pH. Water level data from this well (Figure 10) are further evidence that the MB alluvial aquifer is most likely recharged by mine-impacted waters leaking perennially from the Formosa 1 Adit portal, as both perennial and contaminated water are present within the well (EPA 2014a).

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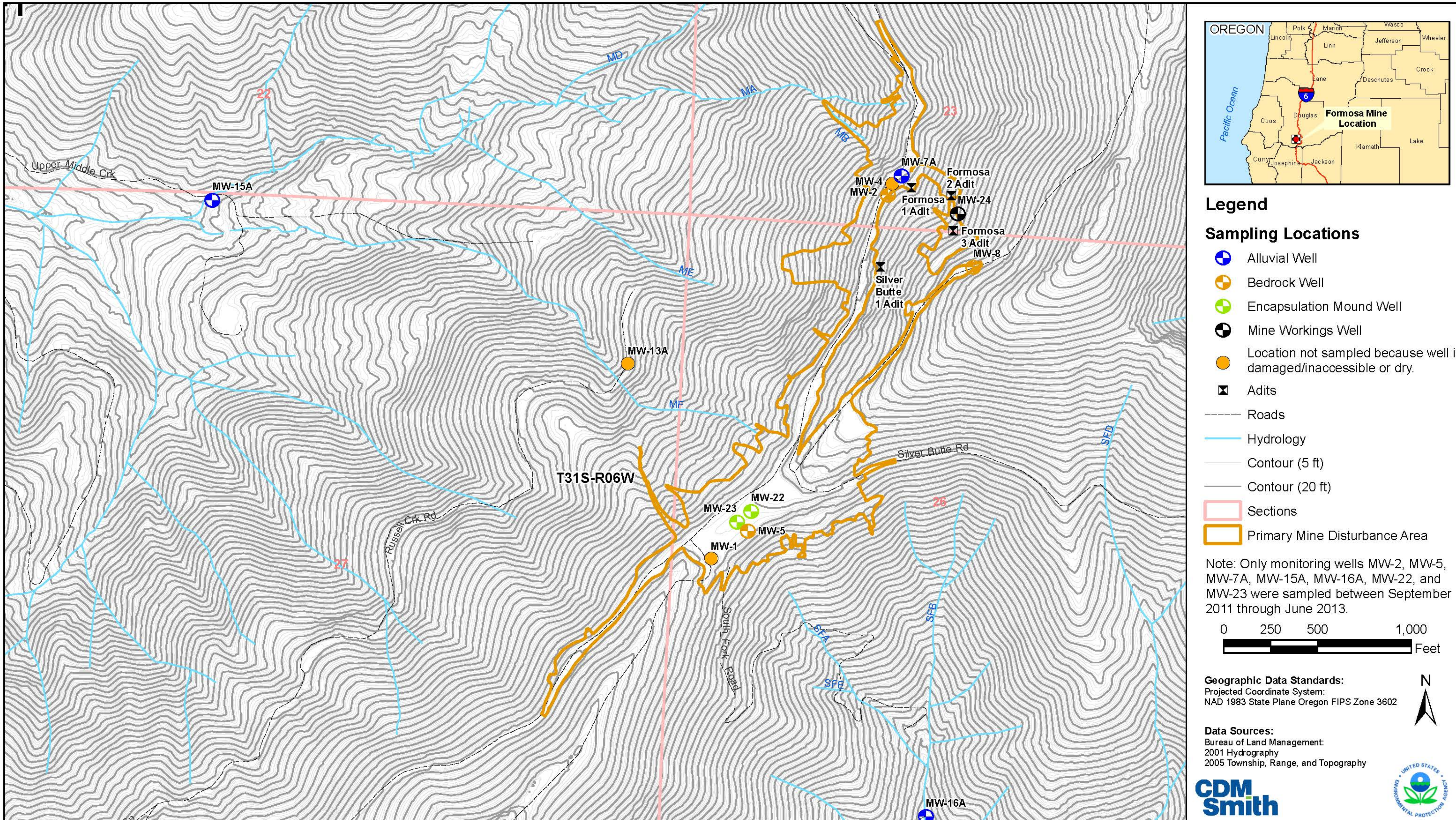
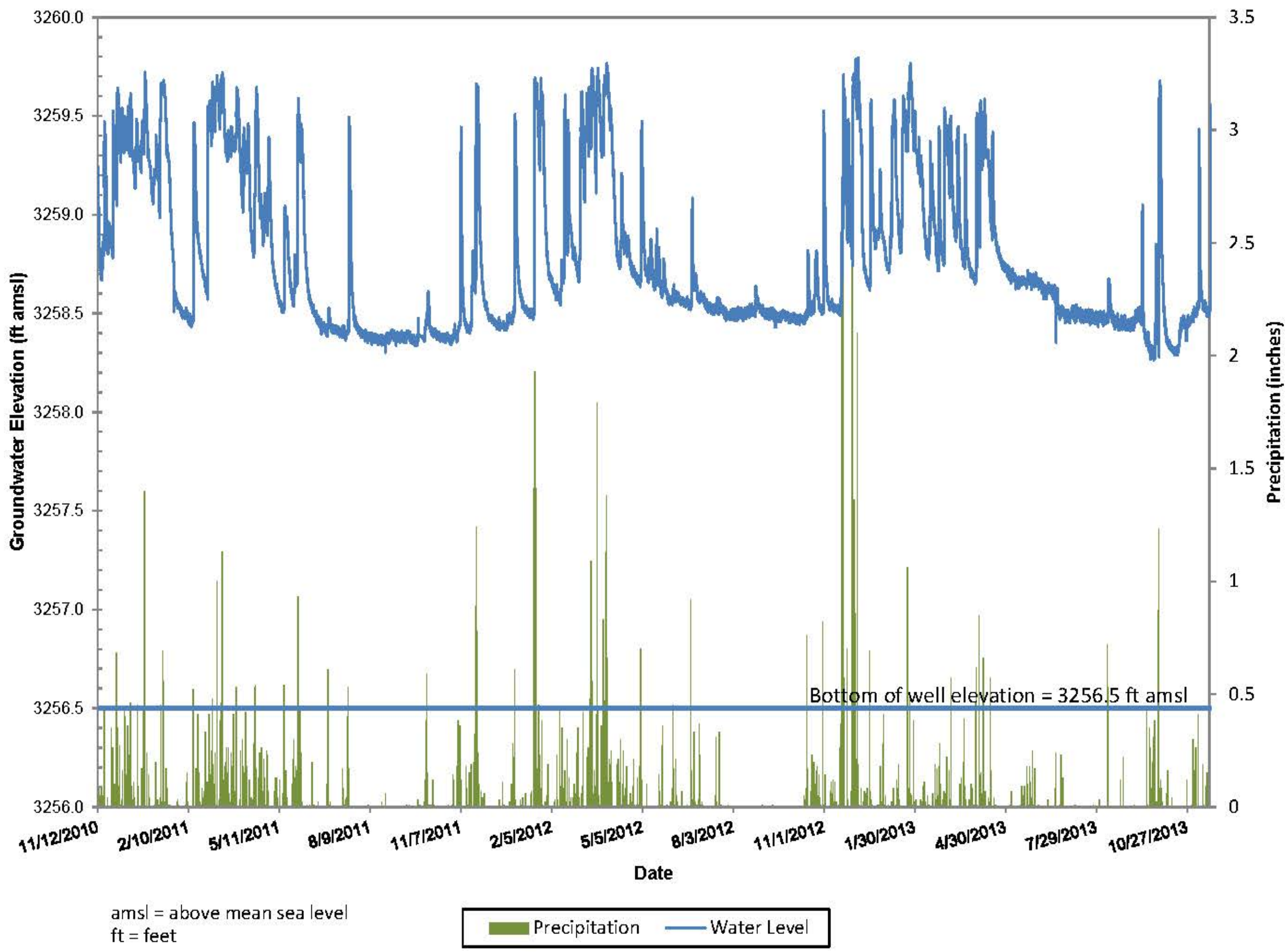


Figure 9.

Groundwater Sampling Locations

Formosa Mine
Douglas County, Oregon

Document Path: N:\55919-3380-RACII\221-Formosa\GIS\mxd\MN_131230\Figure2-3_SAP_GroundwaterSampling.mxd



CDM Smith

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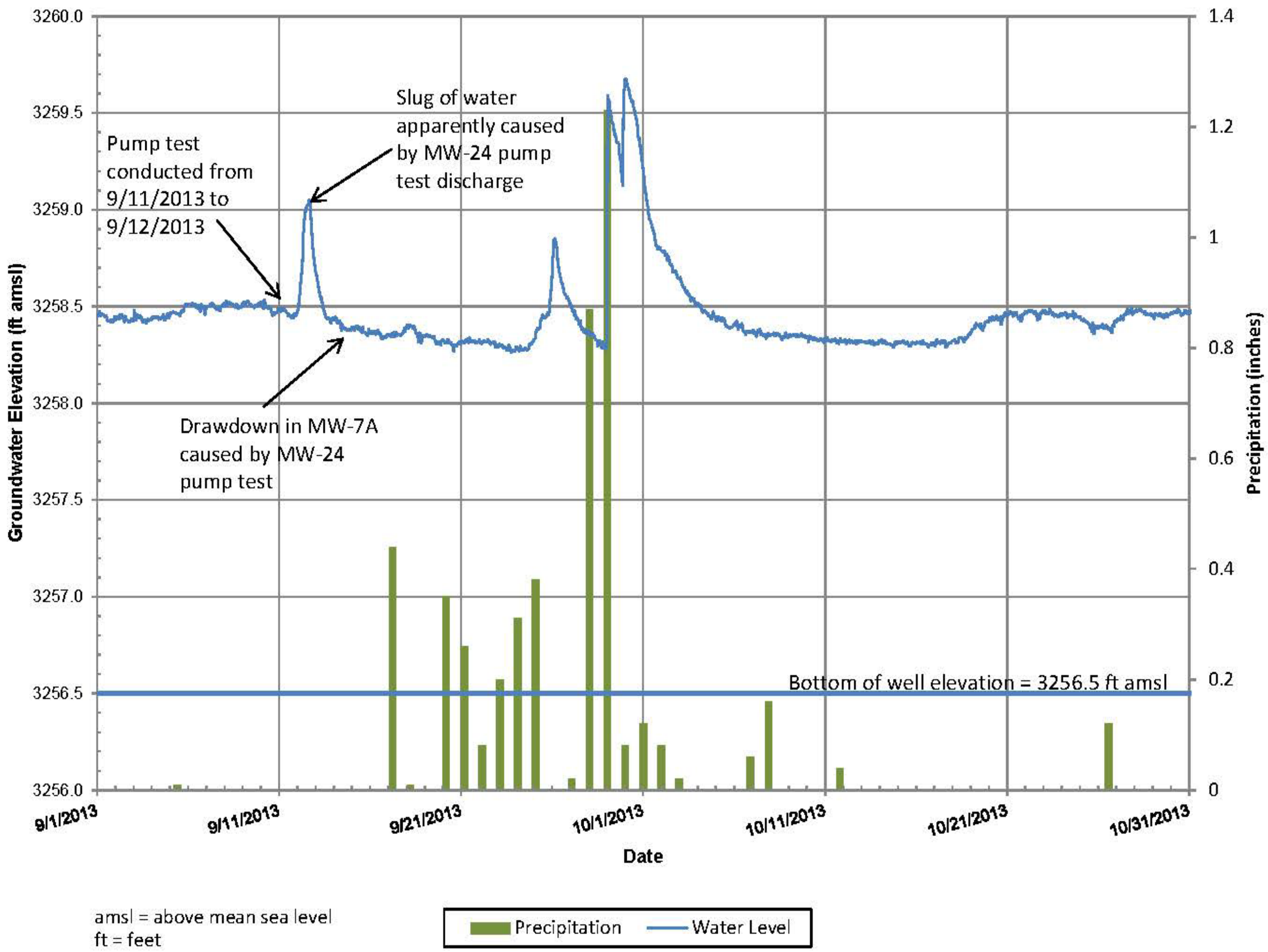
Figure 10.
Groundwater Levels vs. Precipitation at Alluvial Monitoring Well MW-7A

Under BLM direction, a pump test was conducted in September 2013 to learn more about potential dewatering of the mine pool dammed up behind Formosa 1 Adit portal plug and the effects the mine pool might have on the safe removal of the plug and on the controlled release of water from the portal (USACE 2013b). The test was performed at MW-24 after the well was converted from a 2-inch monitoring well (MW-24) to a 6-inch pumping well (MW-24-1) (Figure 9; USACE 2013b). Water level response was recorded by a pressure transducer in MW-7A as an observation well during the pump test (Figure 11). Figure 12 shows the direct relationship between precipitation and groundwater level in MW-24.

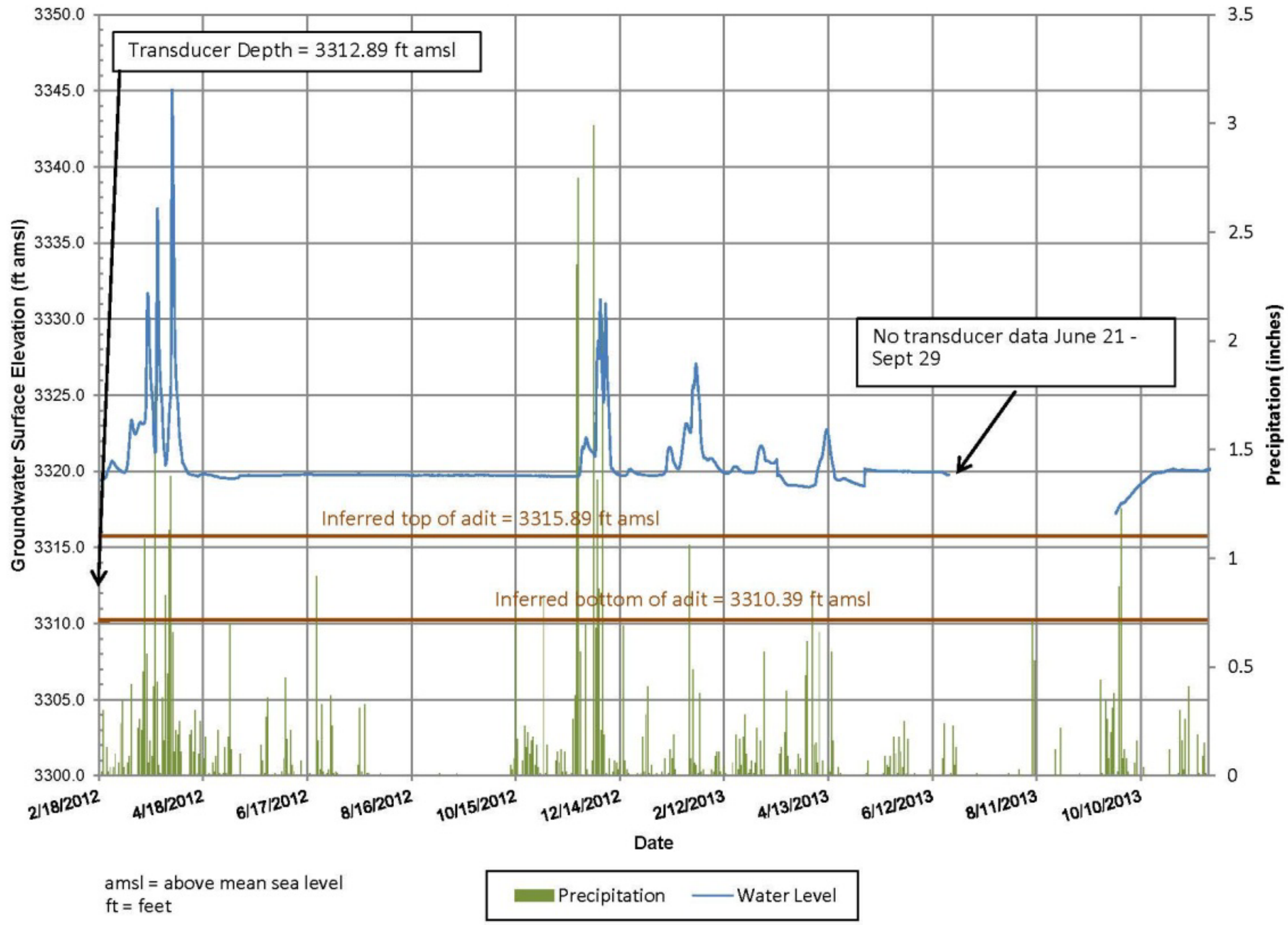
Monitoring well MW-15A is located near the MXR surface water sampling site (Figure 9). This particular well was installed to assess the potential for direct communication between surface water and groundwater transportation of mine-impacted water during times when the Upper Middle Creek flow stage height is higher than adjacent groundwater table. High levels of manganese and some intermittent changes in iron and pH in this well result in exceedance of Oregon groundwater standards, likely due to periods of high flow in Upper Middle Creek.

The bedrock groundwater system is controlled by secondary porosity in the form of fractures created by past tectonic events. One fracture zone was assessed due to its proximity to the Formosa 1 Adit area and its ability to convey several gallons per minute (gpm) of groundwater. The groundwater discharging from this fracture zone was not contaminated; therefore, the fracture zones are unlikely to be in direct contact with the mine pool and are unlikely to convey mine-impacted water towards Upper Middle Creek. MW-2 is a pre-existing monitoring well near the Formosa 1 Adit and is not significantly affected by mine impacted waters. Figure 13 shows pressure transducer data that support the conclusion that the fractures intersected by MW-2 are not interconnected with underground workings (EPA 2014a).



\\denfedsvr1\fedprojects\3210-Reg10AES\047 - Formosa Mine\OU2 SW and GW evaluations\Figures\Formosa OU2 Data Summary monitor well water level figures.xlsx

Figure 11.
Groundwater Levels vs. Precipitation at Alluvial Monitoring Well MW-7A During MW-24 Pump Test



CDM Smith

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Figure 12.
Groundwater Level vs. Precipitation at Bedrock Monitoring Well MW-24

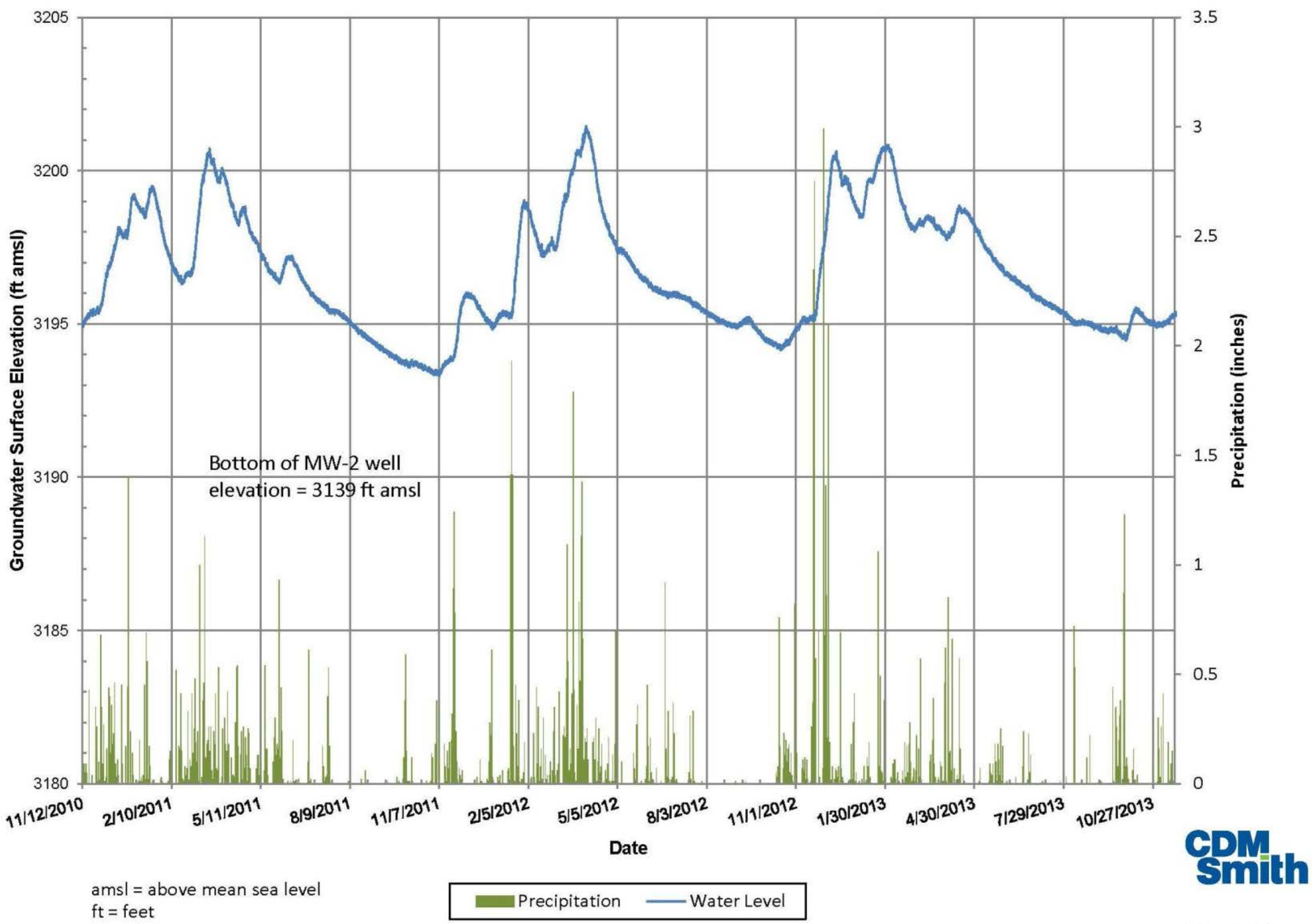

Figure 13.
Groundwater Level vs. Precipitation at Bedrock Monitoring Well MW-2

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2.4 Silver Butte Deposit and Formosa Mine Geology

The Silver Butte deposit is a volcanogenic massive sulfide ore deposit. This deposit occurs within a 500- to 650-foot-thick sequence of foliated ash fall tuff deposits in beds that dip 65 to 70 degrees to the southeast (EPA 2012). Host rock units include basalt flows, foliated dacite ash flow tuffs, ash flow tuff, bedded tuff and basaltic tuff. These units are, for the most part, subaqueously deposited volcanic rocks that are spatially, temporally, and genetically related to the massive sulfide mineralization of the Silver Butte deposit. The area is cross-cut by numerous faults including one that offsets the ore deposit. The deposit contains massive bedded sulfide mineralization within the tuffaceous beds that include the minerals pyrite (FeS_2), chalcopyrite ($CuFeS_2$), and sphalerite (ZnS), the latter two being mined economically for copper and zinc (EPA 2013). Minor amounts of other metallic sulfide minerals are also present. Mining a multi-level network of underground workings in this area excavated and exposed minerals hosted in various sulfidic ore and waste materials by bringing them to the surface. Minerals exposed in underground workings and mine wastes left on the surface included a variety of minerals (especially pyrite) that are sources of ARD generation from ore stockpiles, waste rock, and processed mine tailings (EPA 2013). Contact of these materials with atmospheric oxygen and water has produced ARD and results in the transfer of contaminants from these wastes to soils, surface water, and groundwater at the site.

There are key characteristics of the geologic setting other than sulfide mineralization that are important to environmental materials management and movement of contaminants at the site. For example, because the host rock units range from crystalline flows to indurated tuffs to soft, foliated and weakly indurated tuffs, the variation in the induration of the tuffs has a major influence on the movement of surface and groundwater through the rocks. It does this by affecting hydrogeological characteristics such as primary inter-granular porosity and/or secondary porosity along fractures. Another major factor in the geologic setting related to the development of ARD is the lack of carbonate rocks or carbonate minerals in the host rocks both within and downslope of the site that might provide neutralization potential to ARD generation (USACE 2014).

2.5 ARD Potential from Underground Sources

An important observation related to the ore mineral assemblage is that the entire foliated tuff host unit contains pyrite and other potentially ARD-generating minerals. Only the portions of this unit containing the highest copper, zinc, and silver concentrations were mined, but mine tunnels accessing the ore exposed ARD-generating minerals where they penetrated the massive sulfide and the foliated sulfidic tuff host units. In addition, pillars of massive sulfide mineralization were left unmined to provide ground support within the mine. For these reasons, exposed rock surfaces within the underground mine are an important source of acid generation.

In addition, mined-out areas in almost the entire Formosa Mine were backfilled during closure activities with sulfide-rich tailings, crushed ore, and other sulfidic mine waste (USACE 2014).

Understanding the slope of the Formosa 1 Adit incline provides assistance in developing an estimate of possible water volume handling requirements during adit reopening. To accomplish this, an understanding of the groundwater elevation is critical and can be determined through field measurements by transducers in the existing monitoring wells (MW-8 and MW-24). The measured elevation of the groundwater can then be compared with the adit portal sill elevation and spillover point within the mine workings.

The spillover point is the elevation that groundwater, along with infiltration from surface sources through fractures, must reach in the mined-out workings to flow down the Formosa 1 Adit and discharge from or be dammed up behind the portal. The available water level transducer data from MW-24 and MW-8 also provide an understanding of the seasonal variability of groundwater levels and related potential discharge volumes from the portal. These data are used here to provide information to be considered for development of a plan for water management and appropriate scheduling for adit reopening activities that would coincide with annually low groundwater levels.

The data available for reconstruction of the extent and location of the Formosa Mine underground workings consist of one AutoCAD drawing and a series of drawings that were generated by Mr. Jay Wilson, a former mine engineer for FEI. The AutoCAD file was obtained on compact disc from ODEQ files, and some compilation, geo-referencing of historical mine grids, and analysis of the information was made to combine the maps into a single drawing file.

The areal extent of the underground mine workings both above and below the Formosa 1 Adit level are shown in Figure 14. As can be seen from this figure and the cross-section of the deposit shown on Figure 15, the steeply dipping nature of the massive sulfide ore deposit (60 to 75 degrees southeast) results in a small footprint for the underground mine when projected to surface. Underground mine workings extend over a vertical distance of about 620 feet from approximately 2,890 feet amsl to 3,510 feet amsl (Figure 16).

Figure 17 is a plan view and Figure 18 is an oblique cross-sectional view of the adits and raise accessing working levels in the Formosa Mine. In all, five mine openings access the underground within the principal mining area. These openings include Formosa 1, Silver Butte, Formosa 2, and Formosa 3 adits and the 1090 raise (Figure 2 and Figure 18). Each of the adit mine openings accesses different working levels in the mine and has been backfilled to varying degrees. The trace of monitoring wells MW-8 and MW-24 and their intersection with 1100 level workings is also shown on Figure 18.

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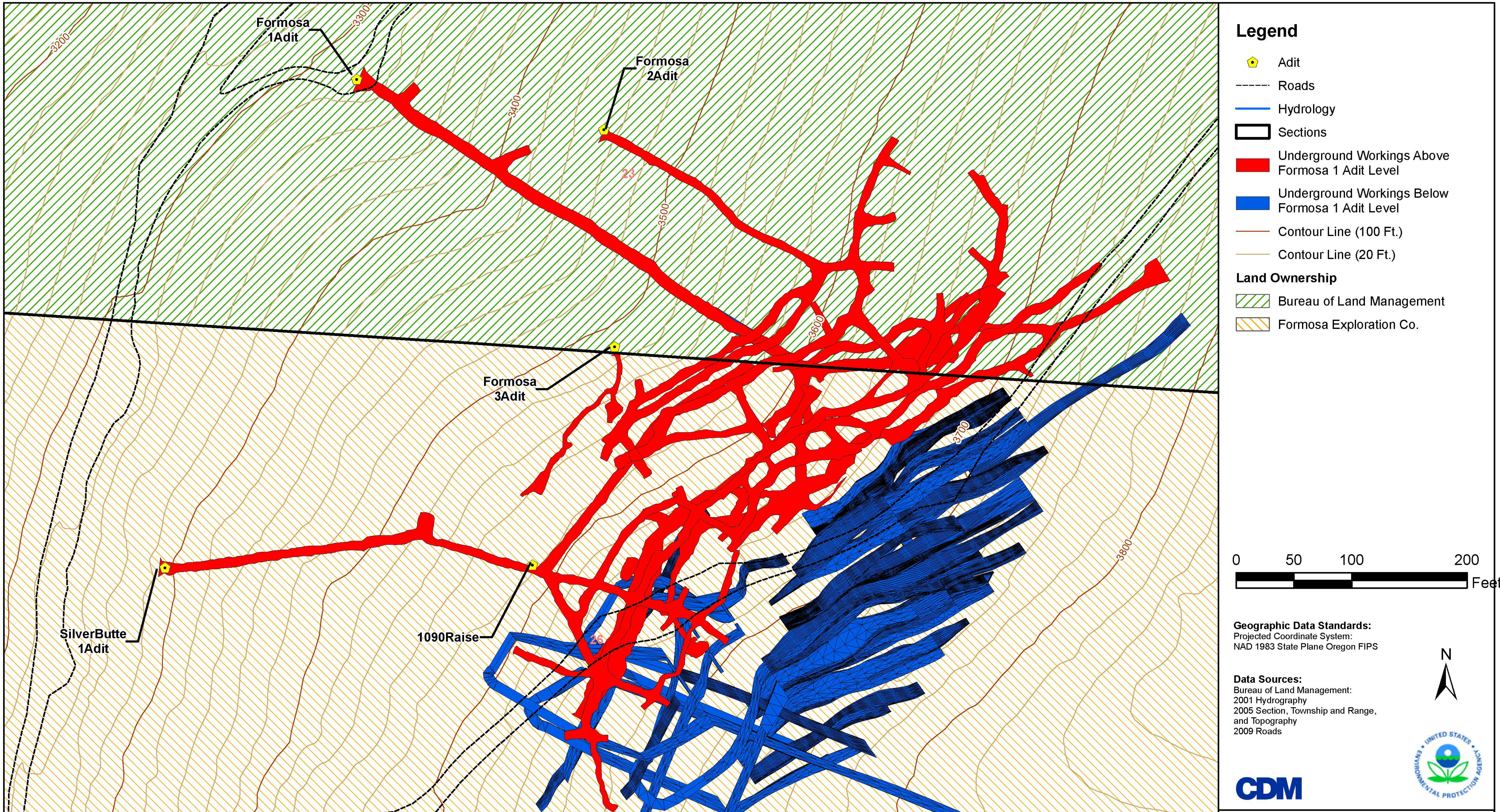
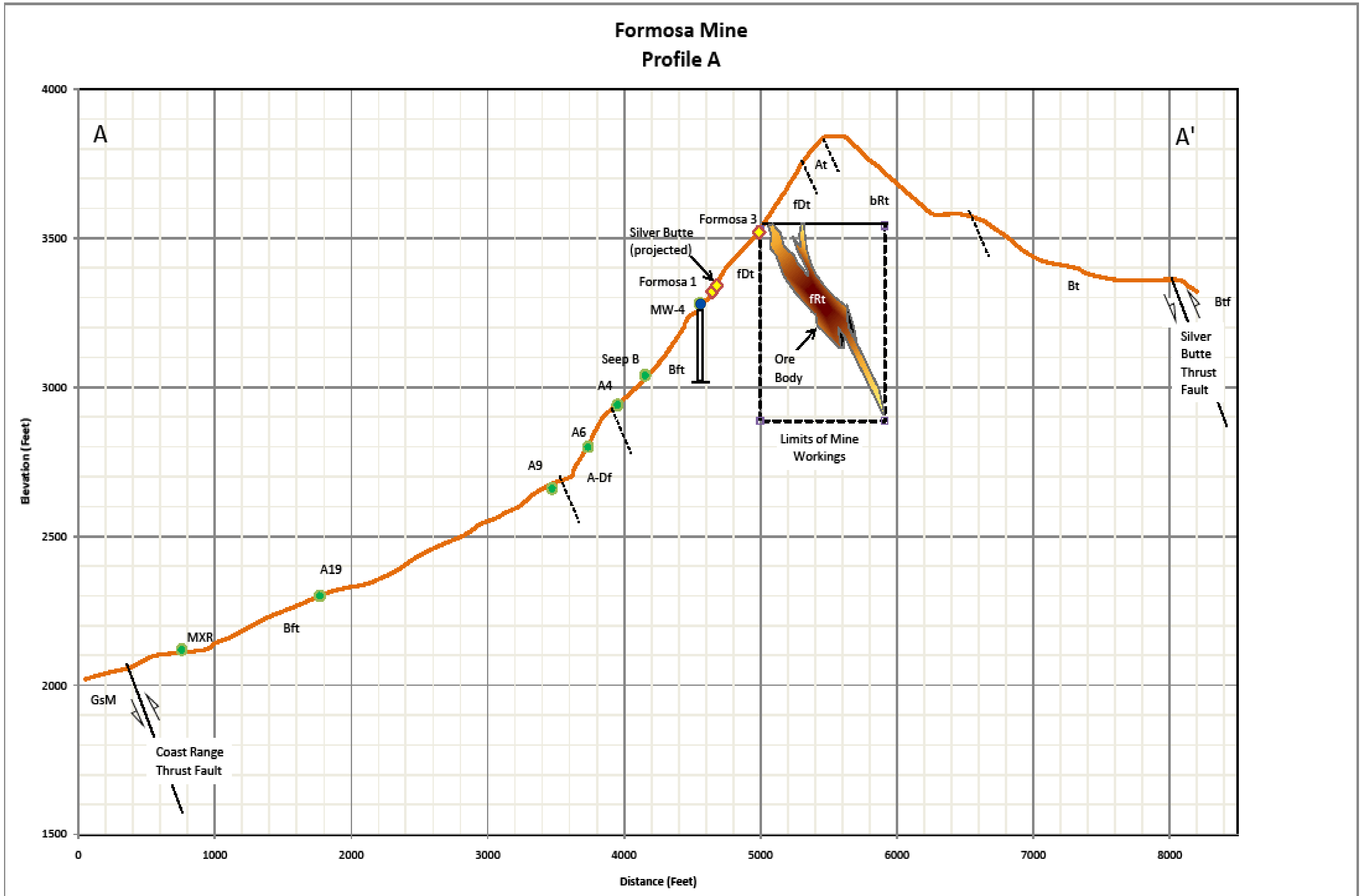
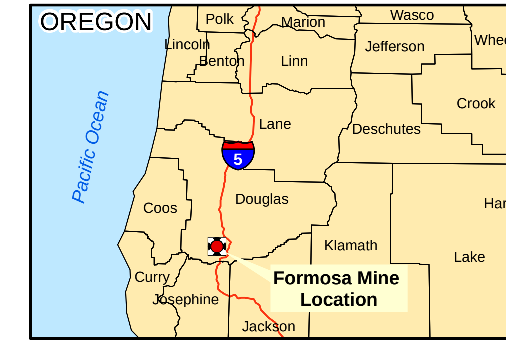


Figure 14.

Location of Underground Mine Workings

Formosa Mine
Douglas County, Oregon





Legend

- Adit
- Groundwater Sampling Locations
- Surface Water Sampling Locations
- Geological Boundary
- Thrust Fault
- Ground Surface

STRATIGRAPHIC UNITS
(Upper Jurassic)

Bft	Basaltic Tuffs and Flows
Bt	Basaltic Tuffs with Minor Flow Units
bRt	Well-Bedded Porcelanous to Med.-Gr. Rhyodacite Tuffs
At	Andesitic Tuffs
fRt	Foliated Rhyolitic Tuffs (hosts massive sulphide)
fDt	Foliated Dacitic Tuffs
Dt	Dacite Tuffs
A-Df	Andesite, Silicified Andesite to Dacitic Flows
Bft	Basaltic Flows, Agglomerates and Tuffs
AS	Andesite Sill (or dike)
GSM	Greywacke & Sandy Mudstones

Geographic Data Standards:
Projected Coordinate System:
NAD 1983 State Plane Oregon FIPS

Note: Geology - modified from FRC 1987

CDM

Figure 15.

Cross-section of the Silver Butte Deposit - Profile A - A'

Formosa Mine
Douglas County, Oregon

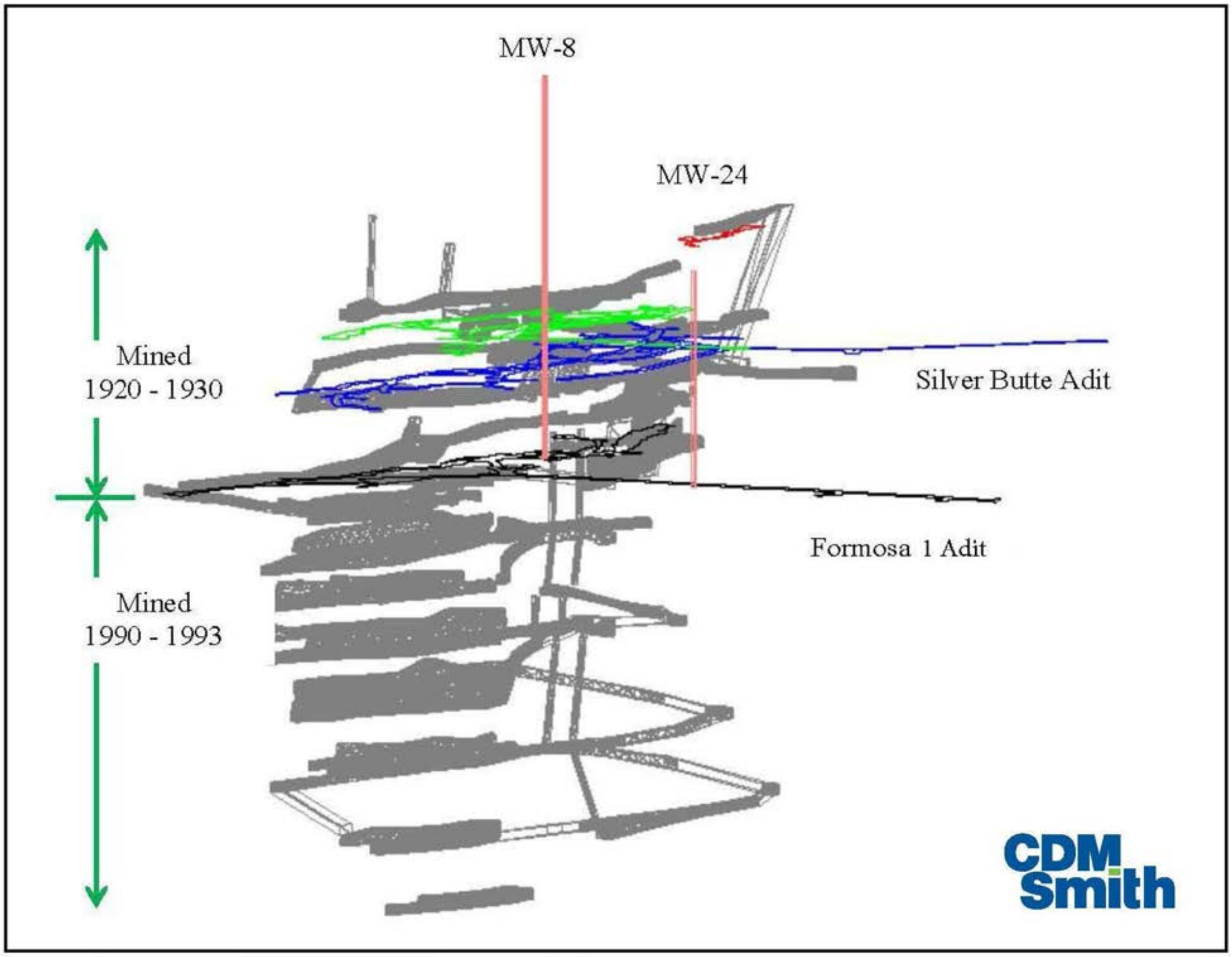


Figure 16. Cross-Section of Formosa Mine Workings

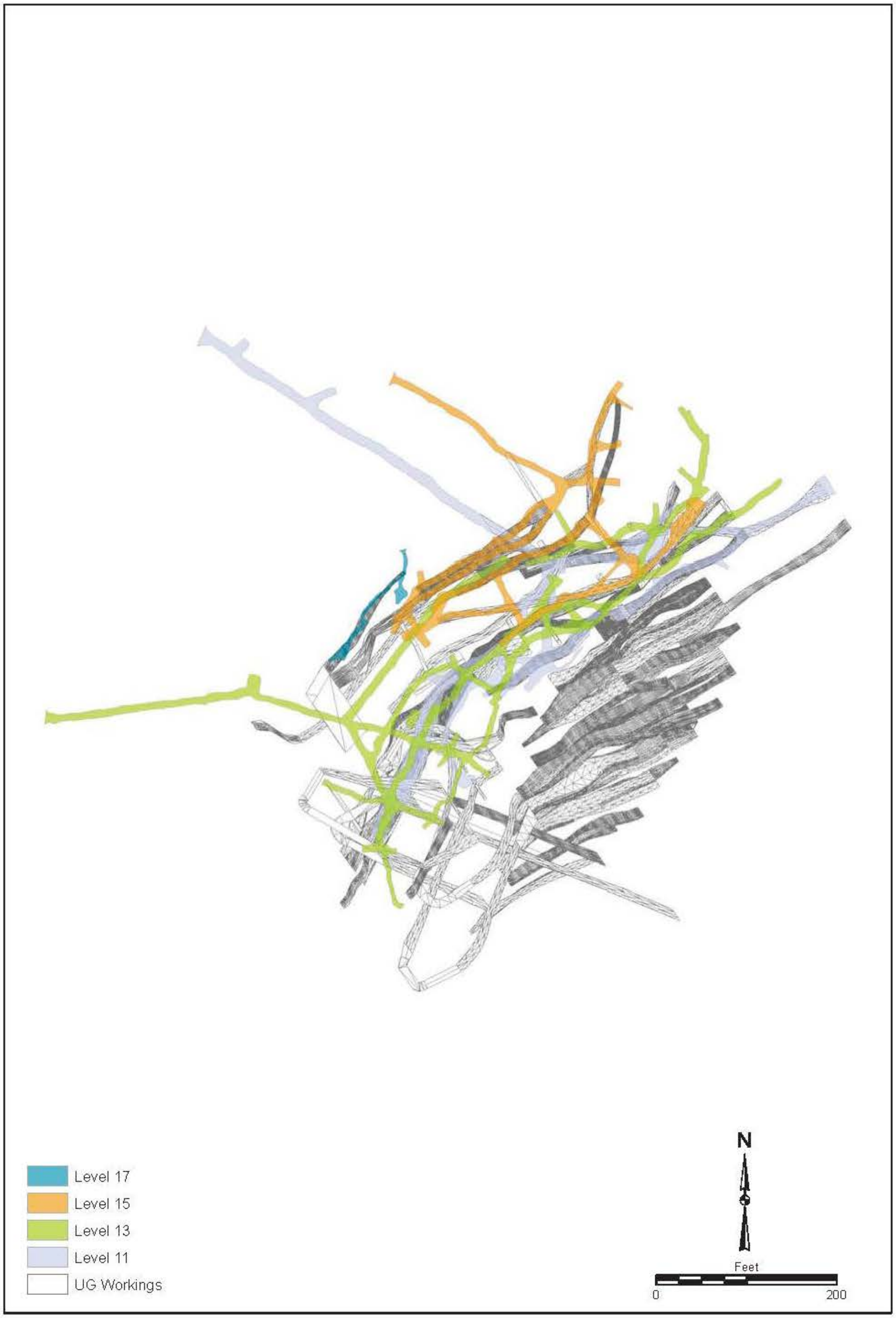


Figure 17. Plan View Showing Formosa Mine Upper Level Workings

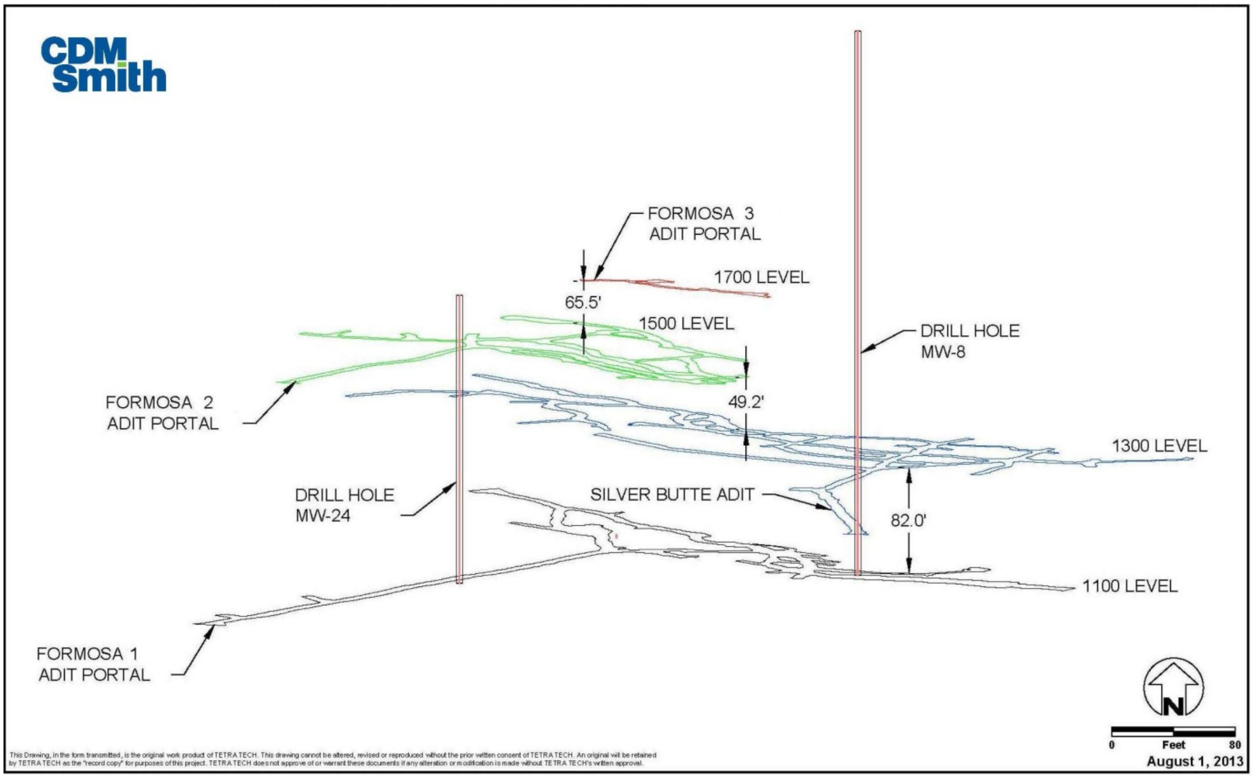


Figure 18. Oblique Cross-Section View—Formosa Mine Upper Level Workings

The earliest underground mining, through the 1930s, was conducted at the Formosa 1 Adit level up through the Formosa3 Adit level. More recent mining in the 1990s followed the ore body to depth below the Formosa 1 Adit level down to an elevation of about 2,890 feet amsl (Figure 15). Records indicate that mining in the 1990s also included expansion of the upper historic workings to access previously unmined intact ore zones.

2.6 Formosa Mine Closure

There are three principal components that need to be considered in closure planning of the underground working of the Formosa Mine. These include mine backfill, the construction characteristics of the 1994 closure of the mine portals, and the adit water diversion systems.

2.6.1 Backfill Placed in Underground Workings

Backfill was used in the Formosa Mine both operationally and in closure. Operationally, FEI left some mined sulfidic waste rock underground in previously mined out stopes as backfill, and they also pumped and slurried sulfide-bearing tailing and tailing mixed with cement back into portions of the mine to provide ground support. In addition to ground support, placing of tailing back underground helped to minimize the volume of potentially acid generated waste remaining on the surface. Most of this material was placed in mined out stopes located below the Formosa 1 Adit's 1100 level, the lowest drainage level adit in the mine (Figure 15 and Figure 16) and it was recognized that these wastes would ultimately be submerged beneath the groundwater table once the pumps were turned off and the mine was allowed to flood to the Formosa 1 Adit level. Placing these materials below the water table greatly reduces the availability of oxygen required to generate the ARD.

During reclamation and closure, the state agencies and FEI agreed that the mine tailings and crushed and stockpiled ore (the most reactive materials on the site) should be removed from storage on the surface and also be used to backfill portions of the underground mine. During 1994 and the first half of 1995, mine closure included backfill of most mine tunnels including the adits with stockpiled ore, waste rock, slurried tailings, cemented tailings, and stockpiled zinc ore concentrates. Crushed ore was placed in the workings below the Formosa 1 Adit, zinc concentrate was used to backfill the 1090 raise, and the mine openings above the Formosa 1 Adit were largely filled with sulfide-bearing tailings including those derived from clean-up of the upper Middle Creek area. Remaining mine waste material left on the surface could not be placed as backfill into the mine because of insufficient underground space at the end of the reclamation period. It should be clear that the drainage from the Formosa 1 Adit, including that derived from saturated backfill materials in the stopes and adits, is a likely major source of ARD.

No information was available at the time of writing to estimate how much actual backfill (thickness or depth) was placed in the mine workings during closure. However, hard-copy drawings have historically been obtained from ODEQ, and DOGAMI files also provide the location of various types of mine backfill within the underground mine workings. Detailed backfill reports may also be available from Northwest Environmental Resources (2003). These reports were not available during the preparation of this report.

2.6.2 Mine Adit Portal Closure

Both the Formosa 1 and Silver Butte 1 adit portals were closed in a more complex fashion than the other adits, because it was possible that they could discharge contaminated water from their portals once the mine was allowed to flood. The closure of these two adits is illustrated by the as-built diagram of the Formosa 1 Adit plug in Figure 19, and consisted of the following components (described from inside the mine toward the portal):

- An unknown portion of the adit backfilled with mine waste;
- A wooden, burlap-faced bulkhead;
- A crushed limestone backfill (as an anoxic limestone drain) to provide a potential source of alkalinity;
- An 8-inch-thick, acid-resistant, reinforced concrete cap; and
- An outer coarse rock cover.

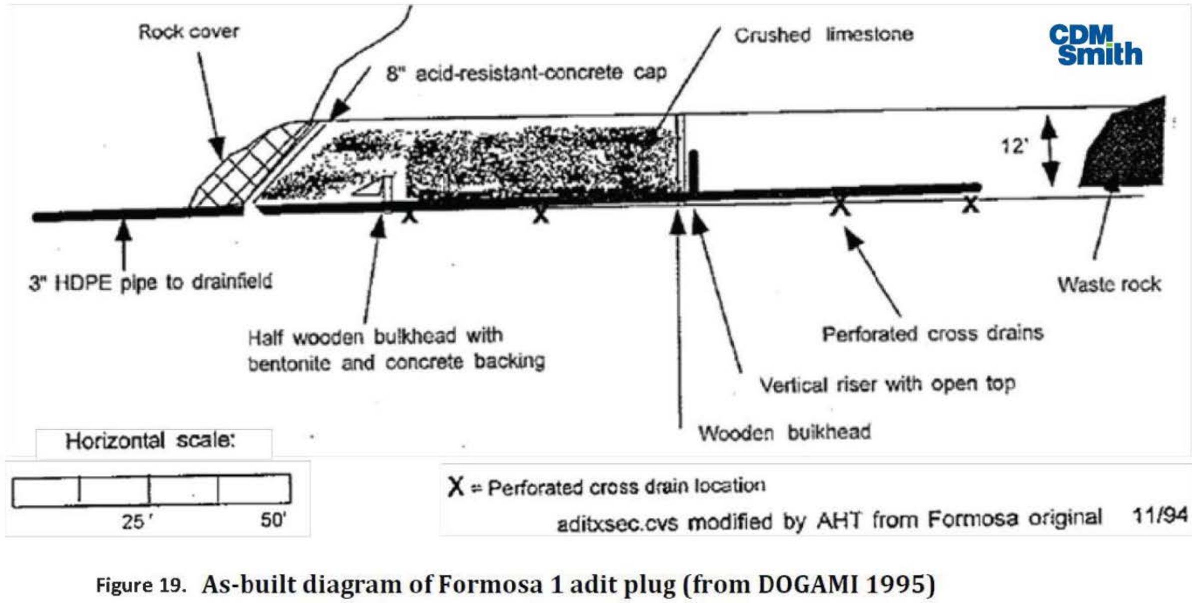


Figure 19. As-Built Diagram of the Formosa 1 Adit Plug (from DOGAMI 1995)

The adit portal plugging system was not intended to be a watertight hydraulic plug, and mine water drainage from behind the plug through the portal was provided by:

- 3-inch HDPE drainage pipes along the entire plug backfill area with perforated cross-drains spaced out along the trunk line, and
- Vertical HDPE riser pipes with open tops constructed inboard of the wooden bulkhead.

Original planning for the adit discharge assumed that the discharge piping system would likely be capable of transporting all of the water that accumulated on the 1100 level and reached the sill (floor) level threshold elevation at the junction of the adit incline with the floor of the 1100 level workings (3,314.8 feet, as illustrated on Figure 20). From there it would flow downhill to the adit portal closure discharge system. However, under closure conditions, mine water conveyance from behind the plug has been hampered by an undersized drainage system that is not capable of handling the entire volume of water that accumulates on the 1100 level. In addition, the drainage system has repeatedly plugged with ferri-hydroxide mud (a chemical precipitate) that further blocked discharge from behind the portal closure.

The backfill structures for the Formosa 2 and Formosa 3 adit closures were similar to that described for Formosa 1 Adit, but were modified because no adit outflow was anticipated. Differences were that no drainage piping or bulkheads were installed in either of these adits and no limestone backfill was placed in the Formosa 3 Adit. The fifth mine opening, the 1090 raise, was backfilled with non-reactive (non-acid-generating) zinc concentrate, a 3-foot-thick bentonite seal, a 6-inch steel reinforced acid-resistant concrete cap, and a soil cover (EPA 2012). All original mine portal reclamation work was completed by August 4, 1994.

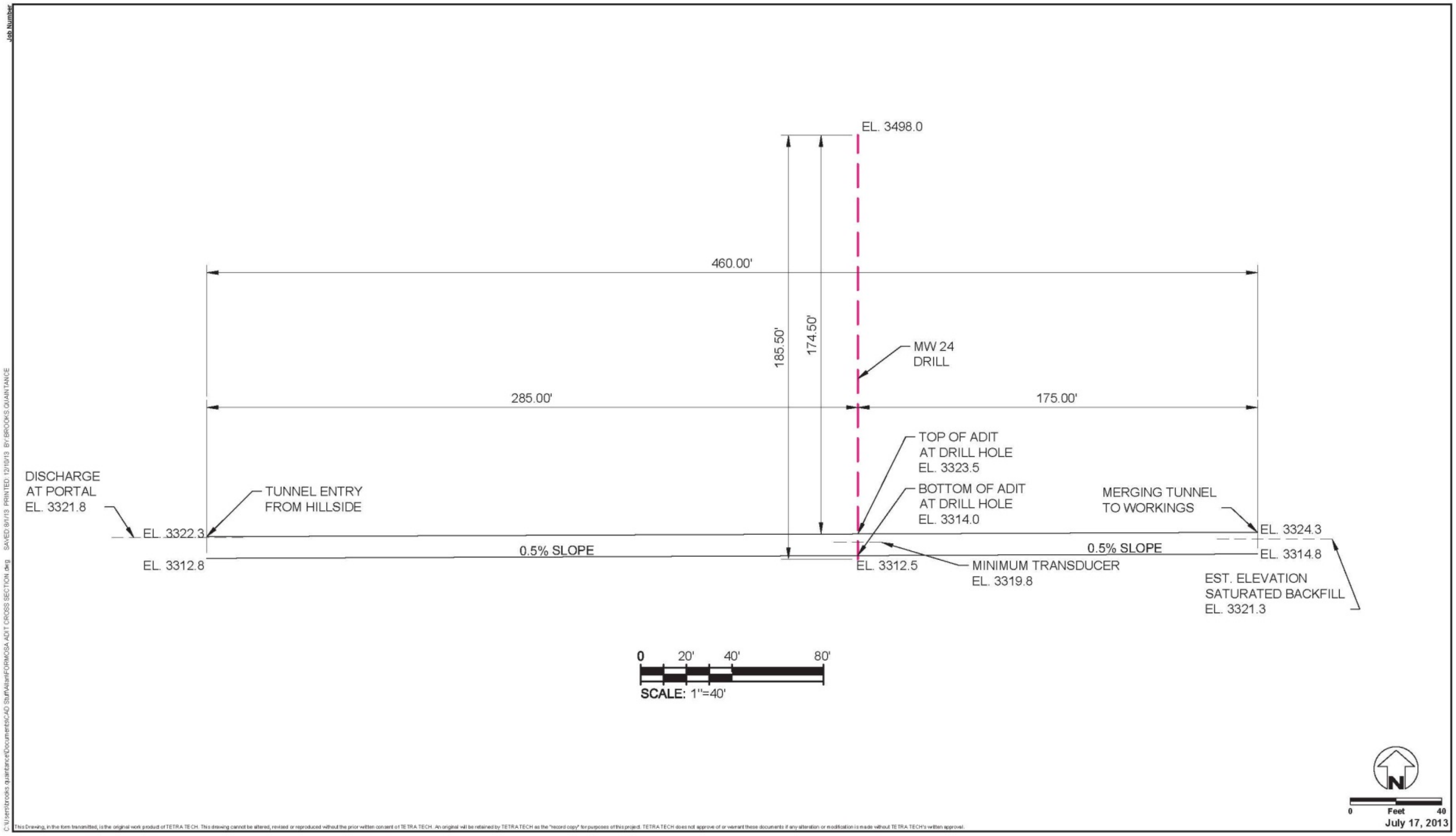


Figure 20. Formosa 1 Adit Long Section

2.6.3 Formosa 1 and Silver Butte Adit Flows

The Silver Butte Adit rarely flows and, when it does, it only flows at a rate of a few gallons per minute to as much as 20 gpm for short periods of time. Transducer data in MW-24 and MW-8 indicate that the 82-foot-thick zone between the 1300 level (Silver Butte Portal level) and the 1100 level (Formosa 1 Adit level) is not saturated (except in the lower 25 feet during highest seasonal water levels following major storm events). This suggests that water discharging from the Silver Butte Adit is from localized small volumes of seepage that collect on this level and infrequently discharge through the portal. This only occurs during the rainy season and following extreme high rainfall events. When this adit drains, the water is collected and diverted in an HDPE pipeline to the adit water diversion system at the portal of the Formosa 1 Adit.

However, the Formosa 1 Adit has perennial flow from the adit portal and drainage system. The Formosa 1 Adit discharge responds with significantly larger outflows in response to both rainy seasons and large individual storm events. Water flows in recent years during dry seasons have ranged from 0.8 to 2.0 gpm, and during high flow from 30 to 42 gpm. However, flows as large as 190 gpm have been historically recorded (Hart Crowser 2002) (see Figure 21).

Hart Crowser (2004) estimated annual discharge from the Formosa 1 Adit at about 5 million gallons per year. Table 2 calculates gallons per year for a given flow rate and indicates that an annual flow of about 10 gpm is needed to produce 5 million gallons of water per year. Flow measurements of the Formosa 1 Adit discharge collected between 1999 and 2005 were between 1 and 190 gpm, with a mean of 28 gpm (EPA 2009); this average flow should generate more than 14 million gallons of water per year. Note that not all AMD is captured by the conveyance system; transport of subsurface discharge is conveyed in alluvial groundwater (EPA 2014a).

Table 2. Gallons per Year for a Given Flow Rate

Flow Rate (gpm)	Gallons per Year
1	525,600
2	1,051,200
5	2,628,000
10	5,256,000
20	10,512,000
28	14,716,800
30	15,768,000

[1] One year = 525,600 minutes

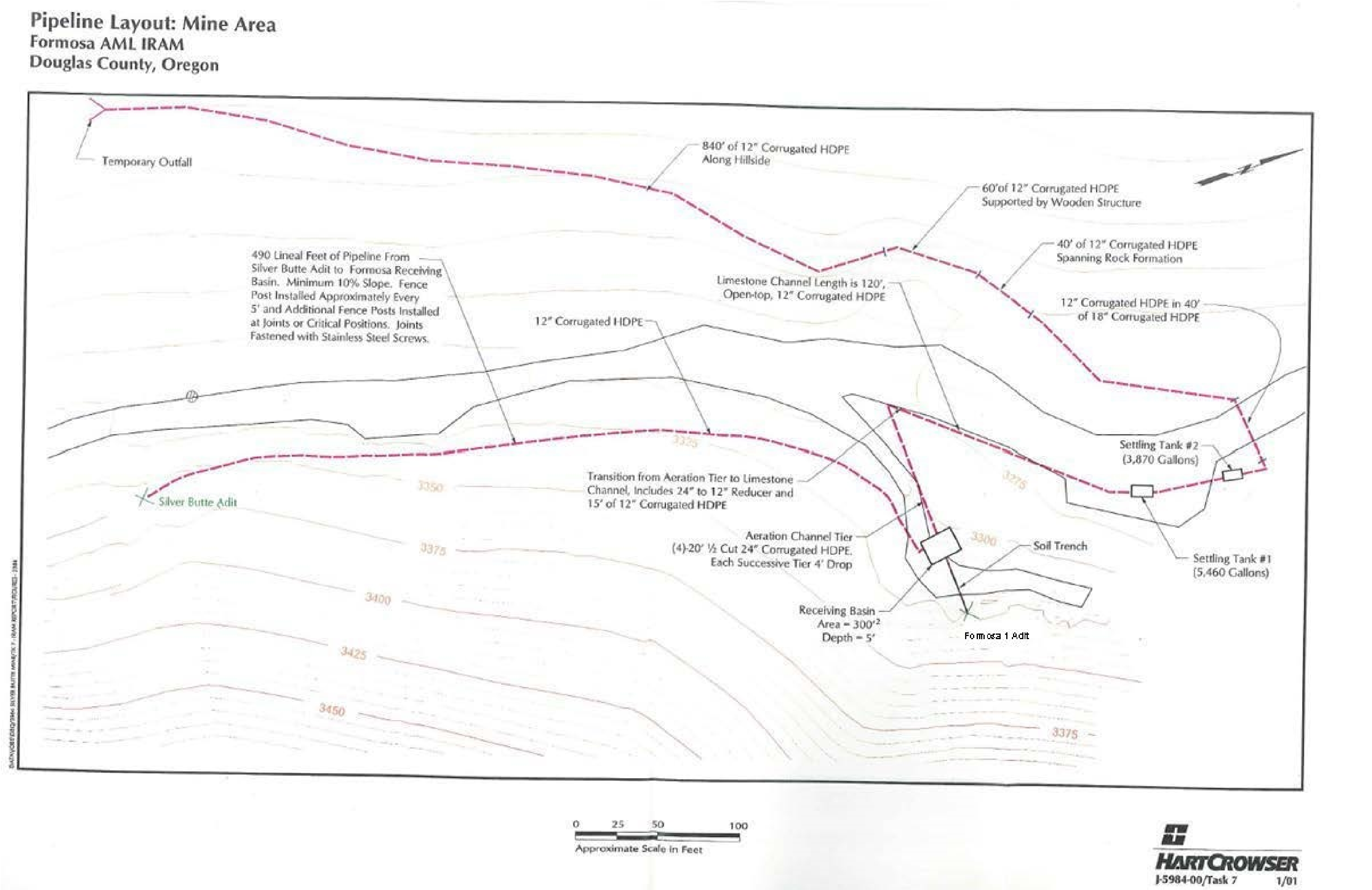


Figure 21. Pipeline Layout: Mine Area

2.6.4 Adit Water Diversion/Conveyance System

ARD from the Formosa 1 and Silver Butte adits is intended to be collected by an adit water diversion/conveyance system. The original reclamation plan implemented by FEI (EPA 2012) directed water discharged from the newly constructed adit portal plug drain lines into a 3-inch HDPE pipe that diverted water beneath the road, into a drain-field system and away from the headwaters of Upper Middle Creek. However, since this initial installation, iron-hydroxide and sediment precipitate has clogged the pipes and forced regular maintenance, repair, reconfiguration, and ultimately abandonment of the system.

Plugging of the piping system with ferri-hydroxide mud and overfilling of the 1100 level workings with water sometimes causes the Formosa 1 Adit to be entirely filled and creates a hydrostatic head against the various components of the adit portal closure system (Figure 19). This plugging of the original pipeline, overfilling of the adit, and resulting hydrostatic head has allowed mine drainage water to bypass the original pipeline collection system and discharge through the face of the adit plug. This is evidenced by water discharges from the back of the workings under a head of pressure which runs down the face of the rock-filled and capped portal closure. EPA describes water discharge through an 18-inch opening in the adit portal cap in the back (ceiling) of the adit portal area (EPA 2012; Figure 22). With this continued blockage of the original piping system, contaminated adit water found its way through the portal plug and the effluent reportedly discharged via a single diffuse outfall into Upper Middle Creek (Upper Middle Creek is a tributary of Cow Creek, which discharges to the Umpqua River near Roseburg, Oregon).

In the early and mid-2000s, the discharge system was significantly redesigned (Figure 23). Hart Crowser Inc. was contracted to implement the new Interim Remedial Action Measure (IRAM) adit water diversion and treatment system, which included piping water approximately 0.6 miles to level ground below the mine. Construction was completed by November 2000. Water bypassing the original drainage system is currently collected in a 20-ft by 15-ft receiving basin outside of the portal. The basin, constructed to a depth of 5 ft, is lined with limestone and bentonite. Flow is reintroduced along with adit pipeline drainage into a reconstructed open-top 24-inch HDPE pipe aeration system. Aeration is achieved through four stair-stepping tiers that drop 4 to 5 ft in elevation at each interval. The flow then travels through a 12-inch corrugated HDPE adit pipeline containing a 120-ft limestone drainage system. A series of two concrete vaults with capacities of 5,460 gallons and 3,870 gallons, respectively, collect precipitate downgradient of the limestone drain. The current adit water diversion system at the Formosa 1 Adit was installed at a steeper slope and the drainfield was located about 120 ft lower in elevation and farther south than the original field.

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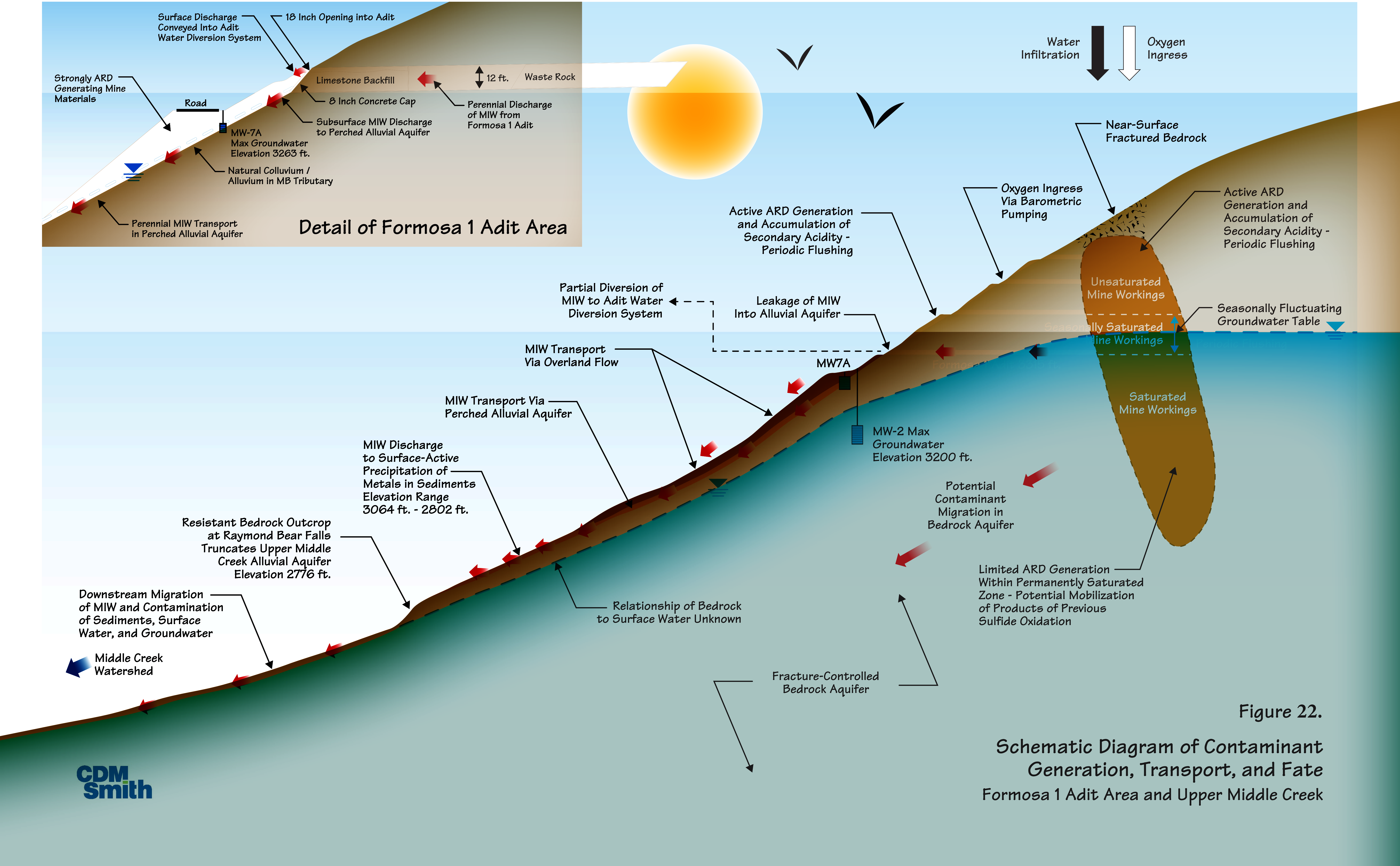


Figure 22.

Schematic Diagram of Contaminant Generation, Transport, and Fate

Formosa 1 Adit Area and Upper Middle Creek

Legend

- Field Measurement Sample Location
- Field Measurement and Laboratory Sample Location
- Adit
- Matchline
- IRAM_Discharge Adit Water Diversion Pipeline
- Roads
- Hydrology
- Sections

0 125 250 500 Feet

N

Geographic Data Standards:
Projected Coordinate System:
NAD 1983 State Plane Oregon FIPS

Data Sources:
Bureau of Land Management:
2001 Hydrography
2005 Township, Range, and Topography

CDM

Figure 23.

Subsurface Sample Identification Map
Northern Zoom

Formosa Mine
Douglas County, Oregon

Over the years, these changing diversion system configurations have resulted in soil contamination over a wide area as a result of the acidic and metal-bearing adit discharge (approximately 0.6 acres area) at the LAD area. In addition, observations made in the 1990s indicate the subsurface flow of adit water beneath the adit portal, which results in seeps within the portal fill material through a transport pathway that may contaminate Upper Middle Creek. The 2000 IRAM plan and implementation does not collect this subsurface flow (EPA 2012).

Not long after implementation of the new IRAM, the limestone channel became coated with ferri-hydroxide precipitates. Repeated plugging of the piping system with ferri-hydroxide precipitates and sediment requires annual maintenance and cleaning. Some remediation and repairs have taken place, including replacement of a section of limestone filled pipe with a new limestone-free section.

Other ways in which the redesigned pipeline has failed include joint breaching and rockfall damage. This damage, which sometimes is a direct result of the precipitate plugging, results in periodic leaks along the pipeline and contamination of the downstream receiving waters of Upper Middle Creek.

It is also likely that subsurface discharge through bedrock near the portal as a result of the hydrostatic head introduces contaminants to the alluvial and bedrock aquifers. The system is currently in need of both routine maintenance and repair.

2.7 Water Quality and Hydrology of Closed Formosa Adit

2.7.1 Formosa 1 Adit Water Quality

Table 3 summarizes the quality of water discharging from the Formosa 1 Adit and contrasts water quality during the wet and dry seasons.

Table 3. Formosa 1 Adit Discharge Water Quality Comparing Wet and Dry Seasons

	Dry Season Sampling		**Wet Season Sampling**	
Analyte	**10/19/2009**	**10/25/2010**	**1/26/2010**	**1/26/2011**
Aluminum (µg/L)	9,240	9,340	27,700	21,700
Cadmium (µg/L)	130	131	666	366
Copper (µg/L)	3,150	2,700	42,800	32,200
Iron (µg/L)	74,700	88,600	264,000	187,000
Lead (µg/L)	15.3	14.6	78.2	73.6
Zinc (µg/L)	61,200	61,500	146,000	88,100
pH (su)	2.98	2.15	3.13	2.85
Acidity (mg/L $CaCO_3$)	340	1,200	400	820
Flow (gpm)	2.0	0.8	42.91	29.94

µg/L – microgram per liter; su – standard unit; gpm – gallon per minute; mg/L – milligram per liter

As can be seen on Table 3, AMD discharging from the Formosa 1 Adit during the wet season contains a higher level of contaminants and higher rates of flow. As a result, the contaminant loading to downstream receptors is considerably higher during the wet season, which likely reflects contaminant flushing during high water periods from surfaces containing sulfide oxidation byproducts from mine wall-rock and sulfidic backfill materials.

The Silver Butte 1 Adit had a pH of 2.5, dissolved cadmium at 0.54 milligrams per liter (mg/L), dissolved copper at 83 mg/L, dissolved zinc at 98 mg/L, and sulfate at 1,048 mg/L as sampled in February 1989 (EPA 2012).

2.7.2 Water Level Elevations in Monitor Wells and Precipitation

The determination of groundwater elevations and estimates of the volume of water being held behind the Formosa 1 Adit portal are critical properties needed for identifying the appropriate alternatives for reopening of the Formosa 1 Adit, and ultimately for estimating the likelihood of success of the project. These elements are particularly important in characterizing the ability to control the rate of discharge and total volume of water released from the adit with respect to worker safety and ensuring adequate sizing for water storage and handling materials. This volume determination will allow for an engineered dewatering design of the mine workings and adit incline. The existing well data for MW-24 and MW-8, the elevation data gained from re-drilling of MW-24 as a pumping well MW-24-1, the resulting pump test data, and the existing geographic information system (GIS) and AutoCAD mine models were integrated to estimate expected volume of water storage in the Formosa 1 Adit and on the 1100 level.

Water levels in two monitoring wells completed on the 1100 level (MW-8) and in the Formosa 1 Adit (MW-24) are important for understanding water volume relationships with respect to adit water storage capacity and closure planning. Monitor well MW-8 (Figure 24) was completed to a depth 382 ft corresponding with the 1100 level workings of the Formosa Mine, and MW-24 (Figure 24) was completed to a depth of 185.5 ft in the Formosa 1 Adit (which accesses the 1100 level). The bottom of the MW-24 drill hole (the original well) is at an elevation of 3,312.5 ft amsl (based on the drill hole log and collar elevation), the open adit was drilled between 174.5 and 184 ft in depth (3,323.5 and 3,314.0 ft in elevation respectively (Figure 20), and the transducer was reportedly set about 2 feet off of the bottom of the hole (presumably at an elevation 3,312 ft) (Figure 20). Figure 24 is a plan view of the Formosa 1 Adit and the 1100 level of the Formosa Mine showing the location of monitoring wells MW-8 and MW-24. Figure 18 is an oblique cross-sectional view of the major mine levels and adits located above the Formosa 1 Adit access, and also shows the locations of MW-8 and MW-24.

Figure 25 is a hydrograph illustrating transducer-based water elevation data for monitoring wells MW-8 (completed at the elevation of the mine working on the 1100 level) and MW-24 (intercepts the Formosa 1 Adit about 285 feet from the adit portal). Figure 25 also graphically displays precipitation data for the period from February 16, 2011, to February 14, 2013, and includes the elevations of the top and bottom of the Formosa 1 Adit.

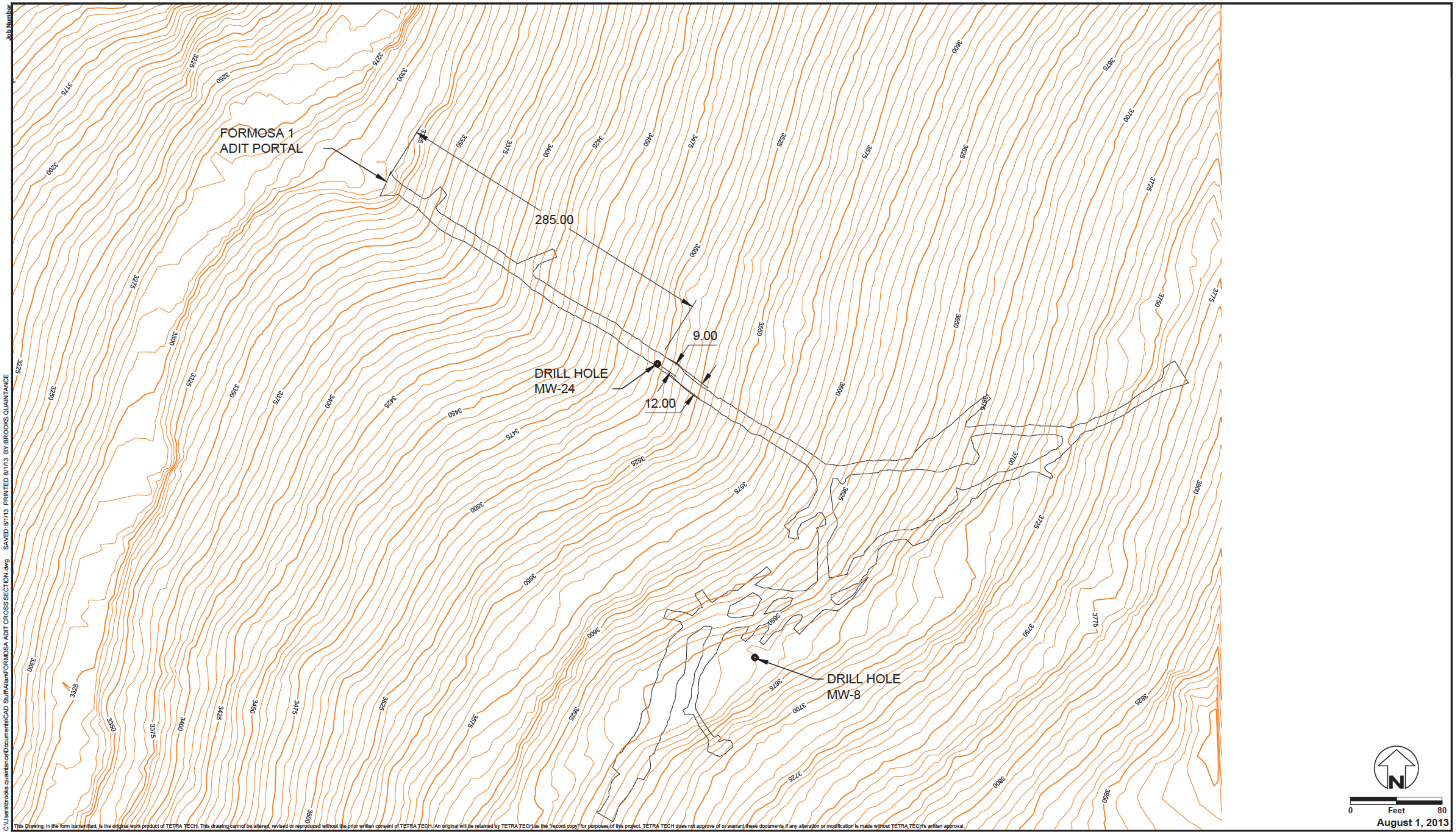


Figure 24. Plan view Formosa adit and 1100 level showing Monitor Well Locations

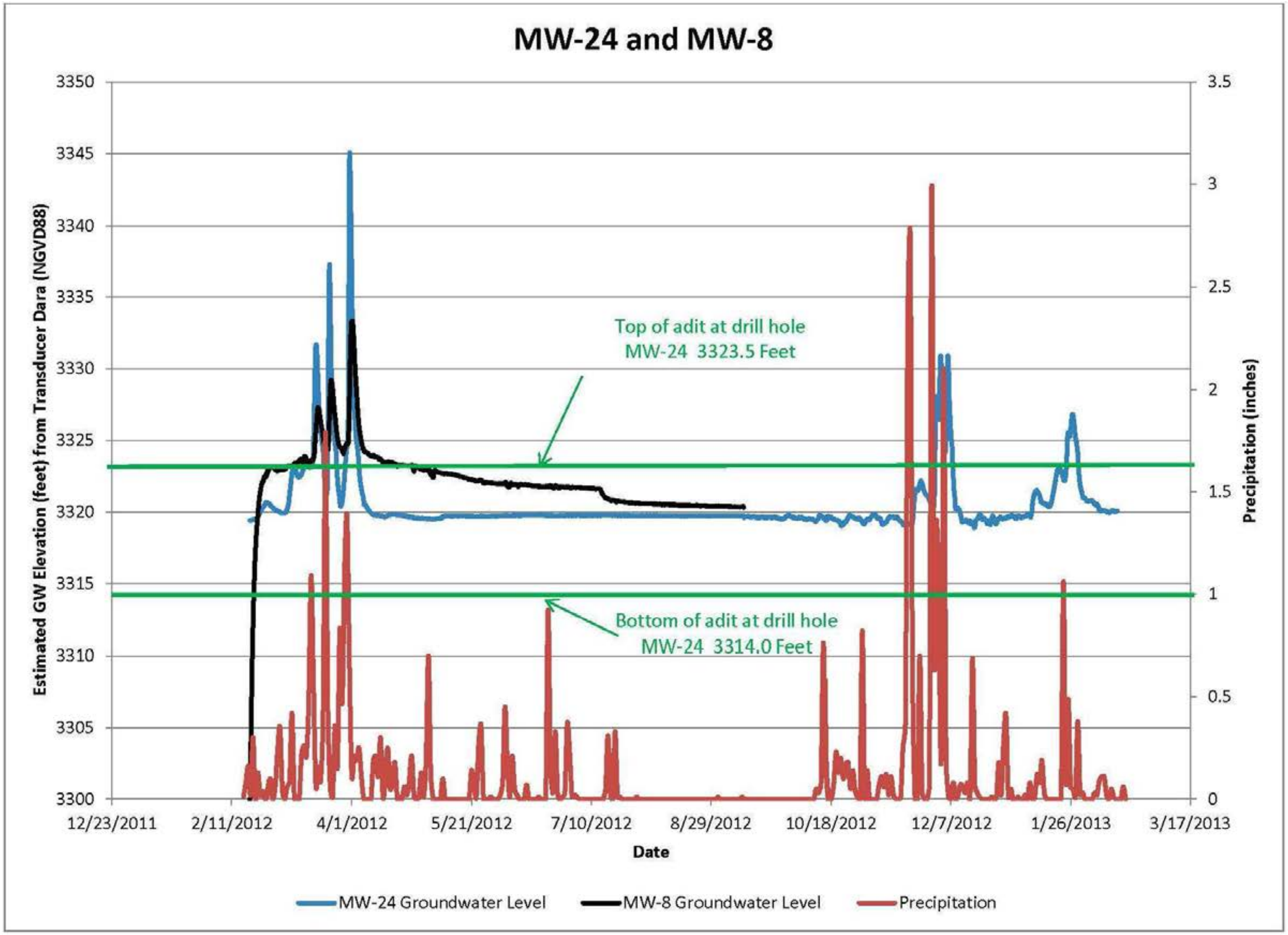


Figure 25. Graph of Monitor Well Transducer and Precipitation Data

The precipitation data show that rainfall in the area occurs as principally discrete storm events during a rainy period of the year, from approximately mid-October through March. Individual storm events with precipitation greater than 1 inch per event occur in the latter half of March and from mid-November through late January.

Estimated groundwater levels in the monitoring wells are depicted by the transducer data curves, blue (MW-24) and black (MW-8) lines on Figure 25. MW-8 has a shorter period of record (2/12/2012 to 9/7/2012) than MW-24 (2/21/2012 through 2/10/2013). Both water level curves seem to have elevation base levels, with MW-24 base level elevation at about 3,319.7 ft and MW-8 (less clearly) somewhere near 3,323.5 ft. As can be seen on Figure 25, groundwater levels in both MW-8 and MW-24 respond rapidly with significant increases in response to major storm events. For example, in the three major storm events from mid-March through early April, water levels in MW-8 rose 4.3, 6.6, and 10.2 ft, respectively, whereas water levels in MW-24 rose 11.9, 17.6, and 25.3 ft, respectively. Water levels in storm events from mid-November through early January resulted in about a 10.9-ft rise in MW-24. It is also notable that a 2.5-inch rainfall event on November 20, 2012 (at the end of the dry season) only resulted in a water level change in MW-24 of 1.3 ft. This likely occurs as infiltrated precipitation fills the mine void at the top of the 1100 level, below the back (ceiling) of the adit, and then begins to fill the overlying bedrock fracture system.

This type of rapid change in ground water elevation suggests that the storage capacity of the bedrock aquifer must be low, resulting in large increases in water levels in response to seasonal and individual storm event recharge by precipitation (i.e., because of the low storage capacity in the bedrock fracture systems, large volumes of precipitation can rapidly [in days] fill the available fractured open-spaces, thereby causing groundwater elevations to rise rapidly, by as much as 25 ft).

These observations are also supported by the rapidly falling head (that takes place in days) in the groundwater system for MW-24 following the storm events. It is notable however, that the falling head in the spring and summer of 2012 in MW-8 occurs much more slowly within the backfilled mine workings, suggesting that drain-down through the porous fine-grained tailings backfill media is slower than the drain-down in the adit and portal area. In this latter area, more of the flow likely moves by piping through open space mine voids and direct outflow through the portal discharge. In addition, the differential change in elevation of groundwater between the two monitoring wells in response to high-flow events may also suggest that overall the fracture systems intersected by the monitoring wells are not well interconnected.

Finally, this rapid change in groundwater elevations indicates a very large intake of water into the fracture system that hosts and overlies the Silver Butte deposit, and may warrant investigation of whether surface run-on into the fracture zone is producing the large influx of water to the groundwater system, further suggesting that surface water diversions may be warranted. Surface water diversions, if appropriate, may significantly limit the amount of inflow by infiltration into the mine and therefore water storage within, and discharge from, the mine.

The sensitivity of water levels in the adit monitoring well (MW-24), to both individual storm events and the wet season, and the backfilling of much of the underground mine, likely result in water flow from the underground workings toward the adit through both piped flow through the open workings, and porous media flow through bedrock fractures or backfill materials. The significant increase in flow rates (from 2 gpm at low water levels to 42 gpm at high water levels) from the adit portal during the wet season indicates a greater head difference between the mine pool and the portal than occurs during the dry season. In addition, the decrease in water quality during the high flow season (Table 3) likely results from flushing of stored acidity and oxidation byproducts from the mine wall rocks and backfill that have accumulated during the low water stage, dry season.

2.7.3 MW-24-1 and Pump Test Results

A 2003 report by Northwest Environmental Resources, LLC recommended reopening the adit to investigate means of closing off sources of groundwater seepage and inflow to the adit, which were assumed to be under the direct influence of surface precipitation and contribute significant amounts of water to the adit drainage. Other recommendations for opening the adit have been made, including those of the current technical team, to facilitate analysis of fracture pattern, mine inflow, and segregation of waters. A 10% Concept Plan (USACE 2013a) summarized multiple options to be evaluated concerning the closure of Formosa 1 Adit. The plan recommended completion of the on-site pumping test to determine if the adit could be successfully dewatered (as opposed to it tapping an extremely large volume of water stored in underground workings) as a major step in studies to examine the suitability of the use of hydraulic adit plugs and fracture grouting to stem the flow from the Formosa 1 Adit.

The pumping test was conducted in a new, nominally 6-inch-diameter well that over-drilled hole MW-24; the new well was labeled MW-24-1. A track-mounted air rotary drill was used to drill the hole. MW-24-1 was cased with 10-inch-diameter steel casing from 0 to 18 ft below ground surface (bgs), and then 6-inch permanent steel casing to 68 ft bgs. Below 68 ft, MW-24-1 was drilled open-hole to a total depth of 191 ft bgs and approximately 5 to 7 ft into the sill (floor) of the adit. Grab samples of drill cuttings were periodically collected and compared to the boring log previously prepared for MW-24. The 9-ft-tall adit void was encountered between 175 and 184 ft bgs (USACE 2013b).

Water within the adit after completion of drilling (prior to discharge during the pumping test) was field tested for general water quality parameters (temperature, specific conductivity, and pH) using a YSI 556 multi-parameter hand-held water quality meter.

The 7.5 horsepower (hp) submersible pump was successfully installed and placed approximately 2 ft from the floor of the adit (as a protective measure for the motor assembly). Tetra Tech attempted to place the pump within the 7 ft over-drilled sump created in the sill of the adit. However, the sump appeared to have collapsed and did not remain open while lowering the pump into the boring. Therefore, the sump was not used as previously planned. Intake of the pump was measured at approximately 180.5 ft bgs, or 3.5 ft above the sill (floor) of the adit (Figure 26).

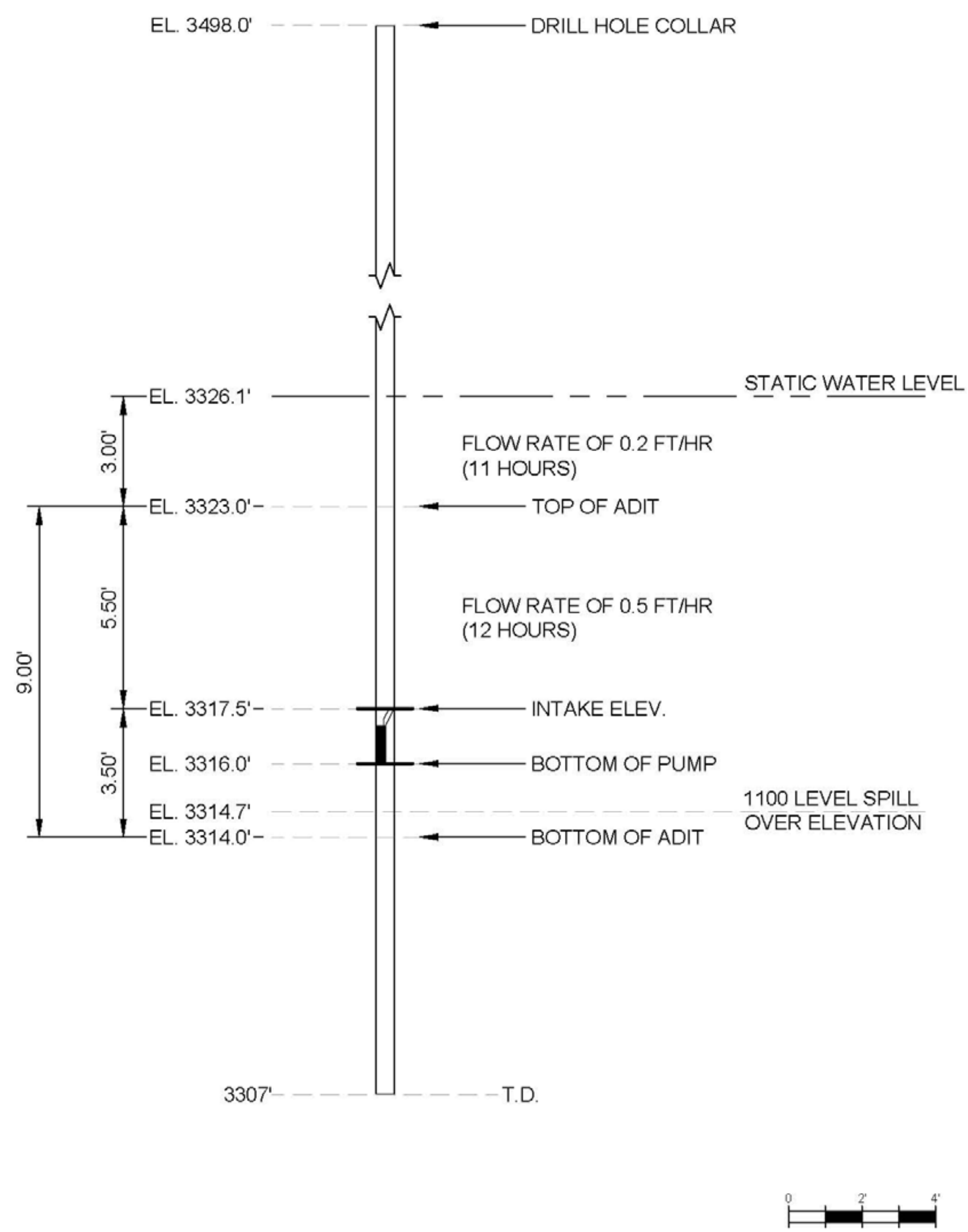
Surface completion of the pumping assembly consisted of an in-line mechanical flow meter with totalizer, a gate valve, and approximately 400 ft of 4-inch PVC discharge hose. Power for the well pump was provided by a portable tow-behind 25 kilovolt-ampere generator.

At the ground surface, a flow meter with totalizer and discharge hose were installed to the piping. The discharge hose was routed in a westerly direction toward the Formosa 1 Adit portal conveyance system, located approximately 400 feet southwest (downslope) of MW-24-1. The discharge hose was tied into the conveyance system so that the discharge water from the pumping test was captured by the conveyance system. A measurement of the amount of water flowing from the adit portal entrance prior to initiation of the pumping test was measured at the conveyance system using a 5-gallon bucket and a stopwatch. This volume of water was measured at approximately 5 gpm.

A constant discharge pumping test was conducted following pump installation and discharge hose layout. A depth-to-water (DTW) measurement was taken with a water level meter prior the start of the pumping test. The beginning water level was measured at 171.9 ft bgs.

The pumping test began at approximately 1645 on September 11, 2013, and ran for approximately 1,405 minutes (23.4 hours). Water level drawdown data in the pumping well were collected using a pressure transducer installed within a sounding tube secured above the pump intake. These pressure transducer readings were collected on a 3-minute interval. Pressure transducer readings were periodically backed up by hand measurements using a water-level meter. MW-8 was also equipped with a pressure transducer and was used as a water level observation well.

The pump discharge line was equipped with an inline mechanical flow meter and totalizer so that pump discharge could be constantly measured throughout the pumping test. The static water level at the beginning of the test was about 172 ft bgs at an elevation of about 3,327 ft, and about 3 ft above the top of the adit at this location. Numerous discharge measurements were taken from the flow meter during the first 2 hours of the pumping test and then periodically throughout the remainder of the test. Measured flow rates were relatively stable throughout the test and ranged from approximately 65 gpm to 75 gpm. An average flow rate was also calculated using the total gallons pumped recorded by the totalizer over the duration of the pumping test. The overall average flow rate was calculated to be 69 gpm, which is consistent with the instantaneous flow rates. This rate is within the range of “natural” discharge velocities; therefore, energy dissipaters at the terminus of the discharge pipe as discussed in planning meetings were not necessary.



C:\Users\mary.bell\Desktop\FORMOSA MINE\F-00-Pumping Well Cross-Section.dwg SAVED: 4/24/14 PRINTED: 4/24/14 BY: MARY.BELL

MW-24-1 PUMPING WELL CROSS-SECTION
FORMOSA MINE
FIGURE 26.

During the pumping test, numerous observations were made of the discharge hose, discharge water, and conveyance system. Water quality parameters, namely turbidity and pH, were also routinely monitored. Discharge water pH ranged from 1.0 to 3.0 during the test. Turbidity was very low (<50 nephelometric turbidity units [NTUs]) for the first portion of the test. Turbidity of the discharge water increased significantly (>1,000 NTUs) during the last hour of the pumping test and was observed to be orange in color.

After approximately 1,405 minutes (23.4 hours) of pumping, the flow rate rapidly diminished and the pump was turned off. This lack of flow was confirmed in the field at the outfall area of the discharge hose. It was also observed (and measured using a 5-gallon bucket and a stopwatch) that very little flow (approximately 1 gpm) was coming from the lower portion of the adit portal entrance.

Pump Test Results

Drawdown data gathered during the pumping test were evaluated using a time vs. drawdown plot. A plot of this data is provided as Figure 27. From this plot, an estimation of the drawdown rate can be obtained. For the pumping test that was conducted on MW-24-1, two different drawdown rates appear in the data plot. The first rate is estimated to be approximately 0.2 ft of drawdown per hour and is observed from the beginning of the test until approximately 660 minutes (11 hours) of pumping. The DTW measured at this point of the pumping test was approximately 175 feet bgs and is coincident with the top of the adit at this location. Below this point, to the end of the pumping test, an increased rate of drawdown was observed to be approximately 0.5 ft per hour. The change in the drawdown rate must be related to the storage capacity at the different elevations (i.e., smaller storage area represent in the interval from 175 to approximately 180.5 ft). Based on an average flow rate of 69 gpm, approximately 2,285,280 gallons, or 84,640 cubic feet, of water was pumped from the adit during this pumping test.

Monitoring well MW-8, which was used as an observation well, experienced approximately 1 ft of drawdown during the pumping test. The drawdown data were collected by hand measurement because the transducer data were not useable. Drawdown data for MW-8 are also shown on Figure 27.

Water level recovery data were also analyzed on a time vs. residual drawdown plot. A plot of this data is included as Figure 28. From this analysis, the rate of recovery was estimated to be approximately 0.03 ft per hour. The rate appears to be relatively constant with little fluctuation over the time period monitored. At the end of the recovery monitoring period (approximately 1 week following completion of the pumping test), the measured DTW was approximately 176 feet bgs, which is approximately 4 ft lower than the water level observed at the beginning of the pumping test. DTW was approximately 174 feet bgs 2 weeks after the completion of the pumping test, but did not recover to approximately 171.6 feet bgs until 35 days after completion of the pumping test.

Figure 27.
Discharge Rate and Observed Drawdown vs. Time
MW-24-1 (Pumping Well) & MW-8 (Observation Well)

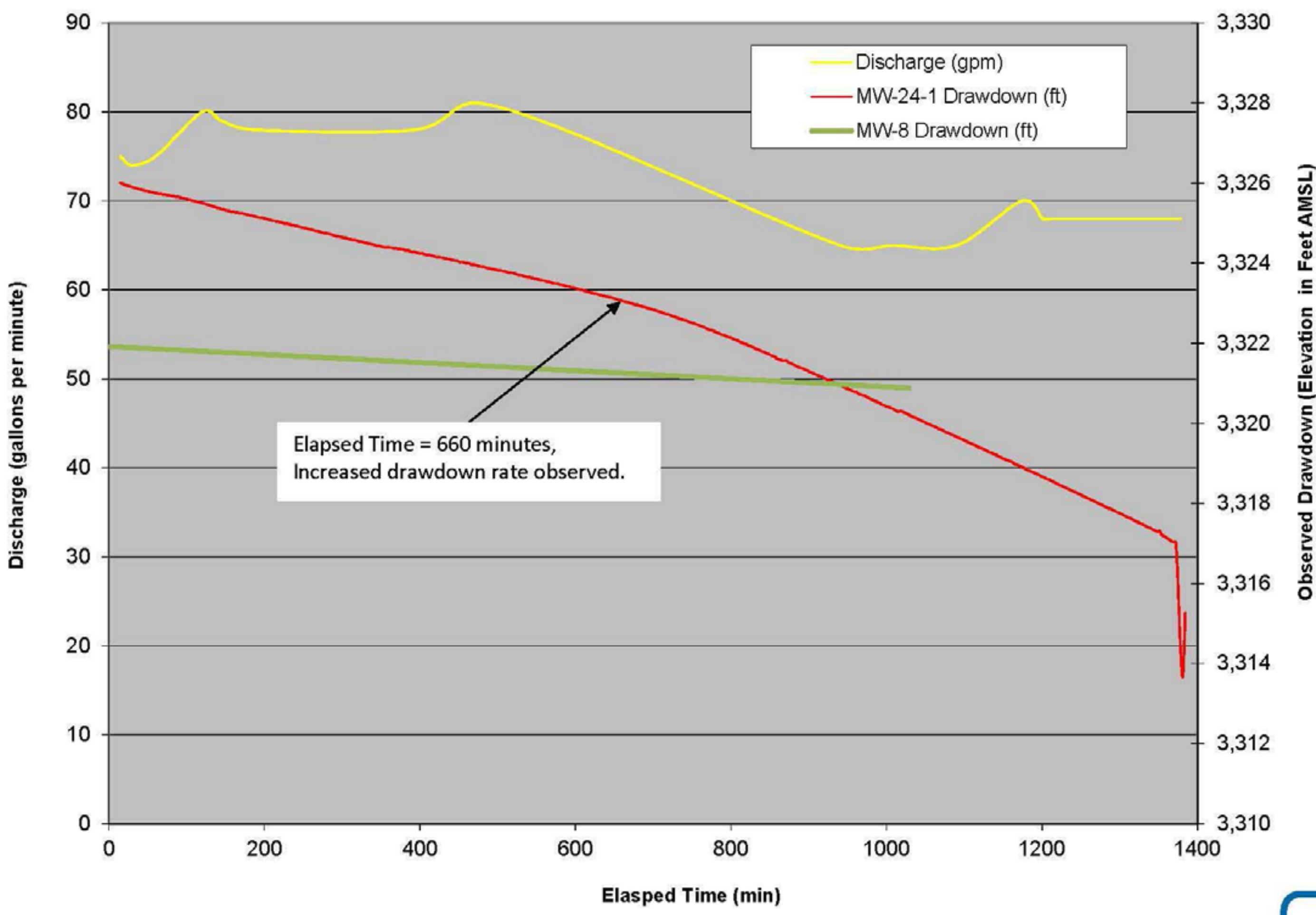
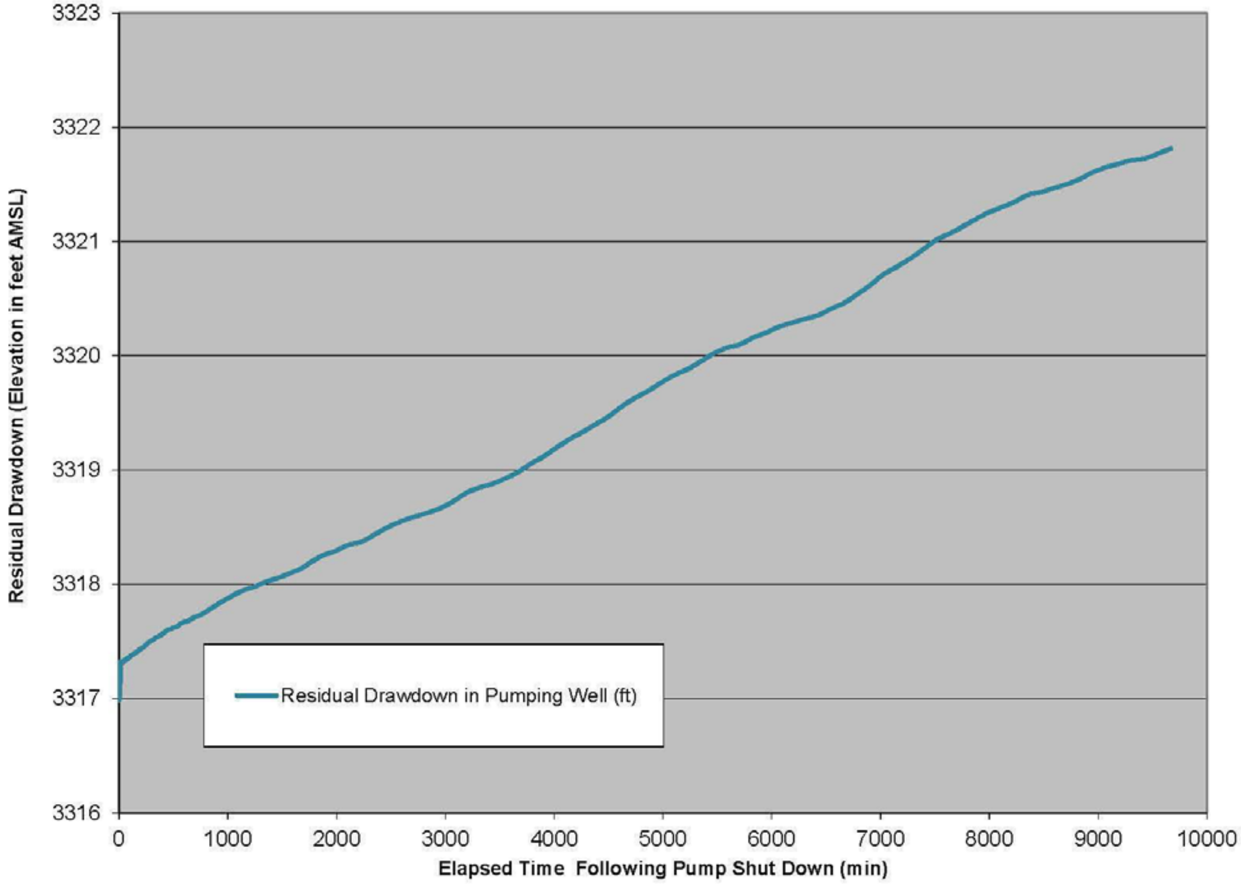


Figure 28.
Water Level Recovery vs. Time
MW-24-1 (Pumping Well)



Therefore, it appears that dewatering the Formosa 1 Adit is possible at flow rates of about 70 gpm, if the depths to the static groundwater elevation are initially about the same and weather conditions are about the same. The diminished flow rate over the last hour of pumping and the turbid and iron oxide-discolored discharge combined with the dramatically diminished flow rate in the last few minutes of pumping suggest that the water level in the adit was very near the intake level of the pump and that it may have been pumping some sediments associated with mine backfill deposits. If in fact this were near the top of the mine backfill (about 3.5 ft off the floor), there should be a minimum of about 410 cubic yards of backfill material in the adit (3.5 ft x 7 ft x 450 ft).

Based on these results, it appears to be likely that the Formosa 1 Adit can be dewatered to very low-flow volumes that are safe for mine personnel to work at and that will greatly reduce the risk of any major adit discharge, at a pumping rate of about 70 gpm for about 24 hours. In addition, based on the recharge rates (about 10 percent of the pumping rate, or about 7 gpm) it would appear that the water within the adit could be adequately and safely controlled during the period of adit plug construction if timed to coincide with the approximately 7-month-long dry period of the year, with the safest window (for low precipitation) during the 5½ months from May through mid-October. This assumes that no sustained, significant rain events occur during the construction period.

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3.0 SOURCE, NATURE, AND EXTENT OF CONTAMINATION

Numerous environmental samples have been collected from mine discharges associated with the Formosa Mine and from surface and groundwater samples from Upper Middle Creek to identify and characterize the source, nature, and extent of contamination. The data used to support this EE/CA include the following: water quality information from surface water, adit discharges, and groundwater sources; and geochemical loading calculations.

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

3.1 Conceptual Model

This section describes a current conceptual model for contaminant sources and movement of contaminants of concern in the vicinity of the Formosa Mine. This conceptual model provides a framework for reviewing environmental impacts and understanding the benefits and consequences of potential alternatives. The conceptual model considers important site components including mining and reclamation practices, geology and mineralogy, topography, climate, surface and groundwater flow, hydrogeology, and fate and transport of contaminants.

Figure 22 is a schematic representation of fate and transport focusing on the Formosa 1 Adit and Upper Middle Creek. There are two categories of primary source materials that interact with water and/or oxygen to result in AMD entering Upper Middle Creek: mine wastes stored at the surface and contaminated soils (Formosa Superfund Site OU1) and mine wastes placed underground, oxidation of exposed sulfide underground, and adit discharges (Formosa Superfund Site OU2). OU1 source materials include waste rock, tailings, ore, construction rock, comingled waste rock and natural soils, and waste rock placed on or along access roads. OU2 source materials consist of waste rock, ore, tailings, concentrates, and exposed rock surfaces within the underground mine workings that generate contaminants by sulfide oxidation and result in contaminated adit discharges to surface and groundwater. Both OU1 and OU2 source materials are ARD-generating due to the oxidation of sulfide minerals and release of byproducts of previous acid generation. The ARD contaminant transport pathway for OU-1 is primarily percolation of precipitation though the primary source materials, discharge of ARD from the mine materials into groundwater, transport through alluvial and (potentially) bedrock aquifers, and discharge from groundwater to surface water. Periodic overland flow from mine material piles may occur. The ARD contaminant transport pathway for OU2 is infiltration of water into the underground workings, interaction of this water with OU2 mine materials (waste rock and tailings backfilled in the mine and exposed rock surfaces within the mine), pipe and porous media flow through open and backfilled tunnels, discharge at the Formosa 1 Adit, and subsurface transport of a portion of this discharge via the MB and MA alluvial aquifers to discharge points on Upper Middle Creek (the remainder of the water is conveyed to a land application area via the adit diversion system).

OU2 source materials refer to underground storage of waste rock, tailings, ore, concentrates, exposed rock surfaces, and dewatered slurries placed as mine backfill in closure. The underground mine has three geochemical zones that control ARD generation from OU2 source materials and resulting migration of mine-impacted water: the permanently unsaturated zone, the seasonally saturated zone, and the permanently saturated zone. The saturated portion of the mine is termed *mine pool*. The permanently unsaturated zone has high rates of ARD generation due to near-surface fractures in bedrock and portals that introduce water by infiltration and oxygen via barometric pumping. Mobilized ARD byproducts are then transported downward towards the mine pool contained within the Formosa Mine workings via unsaturated flow through bedrock fractures and mine workings or voids. The seasonally saturated zone is also a significant contributor to ARD generation because ARD byproducts that accumulate during the unsaturated period (when this zone is exposed to oxygen) are mobilized when this zone becomes saturated, releasing ARD to receiving waters through the Formosa 1 Adit discharge. As for the saturated zones, ARD generation tends to occur during drier periods of the year, when the mine pool level has fallen. Periodically, as the water level rises during wetter months, ARD byproducts are flushed out of fractures and voids, and some ARD byproducts are released to receiving waters through the Formosa 1 Adit discharge. Direct hydraulic communication exists between the underground mine and surrounding bedrock. The quality of water in the permanently saturated zone, as well as the extent of connection between it and the seasonally fluctuating groundwater table, is unknown, though it is likely that at least the upper portion of the mine pool has been impacted by ARD byproduct generation. It is also likely that some mobilization of byproducts resulting from previous sulfide oxidation occurs in the permanently saturated mine workings. Alternatively, deeper in the mine pool, sulfide oxidation may have consumed available oxygen such that oxidation reactions stop and abiotic or biotic production of alkalinity may begin to raise the pH of the waters which in turn decreases metal solubility, a concept that has been shown to be effective on numerous other similar mine sites.

Discharge occurs perennially at the Formosa 1 Adit. Flow through the adit portal varies seasonally, with greatest discharge occurring during the wet seasons of late fall and winter. This is due to greater hydraulic head difference between the adit portal and the mine pool during wetter months, and is evidence of seasonally variable water levels in the mine pool. The nature of the flow is most likely a combination of piped flow through open mine workings, porous media flow processes through mine waste backfill, and fracture flow through bedrock. Water quality of the discharge has been found to be poorest during periods of high flow when ARD byproducts are flushed from previously oxidized underground workings.

The previously constructed IRAM AMD conveyance system is designed to capture the mine-impacted water discharging from the Formosa 1 Adit and convey it away from surface water bodies. It appears that not all discharged mine-impacted water is, in fact, collected. Therefore, some amount of discharge is bypassing the diversion system (probably as underflow at the adit portal) and in turn recharging the alluvial aquifer. Contaminated water then flows subsurface and discharges as seeps and dispersed inflows to surface water upstream from Raymond Bear Falls, thus impacting surface water.

Applicable contaminant release mechanisms for this site can be described in terms of sulfide oxidation and ARD generation, development and dissolution of secondary acidity, and remobilization of secondary precipitates and contaminated sediments. In regard to sulfide oxidation and ARD generation, pyrite is the greatest contributor. The most dominant reaction at the Formosa 1 Adit is the oxidation of pyrite to produce ferrous iron (Fe^{2+}), sulfate (SO_4^{2-}) and hydrogen (H^+). This is an exothermic reaction that is catalyzed by microbacteria. Further biotic oxidation to form ferric iron (Fe^{3+}) also occurs. Fe^{3+} can precipitate as amorphous to microcrystalline iron hydroxide phases, which builds up in existing pipes, preventing proper collection and discharge by the IRAM diversion system. Secondary acidity is represented by ARD-generated metals/metalloids that precipitate out in a variety of secondary mineral phases. Secondary acidity often develops in saturated void space that is in contact with the atmosphere but does not regularly get flushed. The dissolution of secondary acidity impacts the chemistry of mine drainage and may affect remediation efforts, as these secondary minerals can control the seasonal (wet season) flush of contaminants from the Formosa 1 Adit, resulting in impacts to the Middle Creek watershed. Secondary precipitates form at the discharge end of the adit water diversion pipeline, and in Upper Middle Creek and South Fork Middle Creek. Downstream dispersion of these precipitates is most likely occurring through both hydrogeochemical re-dissolution processes and physical dispersion as suspended sediment.

Fate and persistence of contaminants of concern related to the movement of mine-impacted waters through the ecosystem is dependent on the water pH, metal solubility, and the sequestration of contaminants into soils and sediment. Initially, the low pH conditions caused by ARD increase the solubility of aluminum, cadmium, copper, iron, zinc, and other metals. As this mine-impacted water moves downstream, the pH of the water increases. This lower acidity leads to the formation and release of precipitates and associated sequestration of metals as they are sorbed into sediments. Precipitates include amorphous to microcrystalline metal oxides, hydroxides, or hydroxysulfates (oxy-hydroxides). Ferric iron oxy-hydroxide precipitates form at pH levels greater than approximately 3 to 3.5 standard units (EPA 2012). In the case of Formosa Mine waters, under these conditions the high concentration of metals in solution leads to rapid sorption along with the precipitation reactions (Figure 29). The high concentration of metals in solution can also lead to precipitation of metals at lower pH values than normal. As water flows down Middle Creek, less acidic surface and groundwater with more alkalinity enters the creek and changes the chemistry of the water, raising the pH and diluting metal concentrations. As a result, settling of colloidal metals and co-precipitation of dissolved metals with ferric-hydroxides produces an overall improvement in water quality so that water quality impacts, over even short distances downstream, become less significant and eventually negligible.

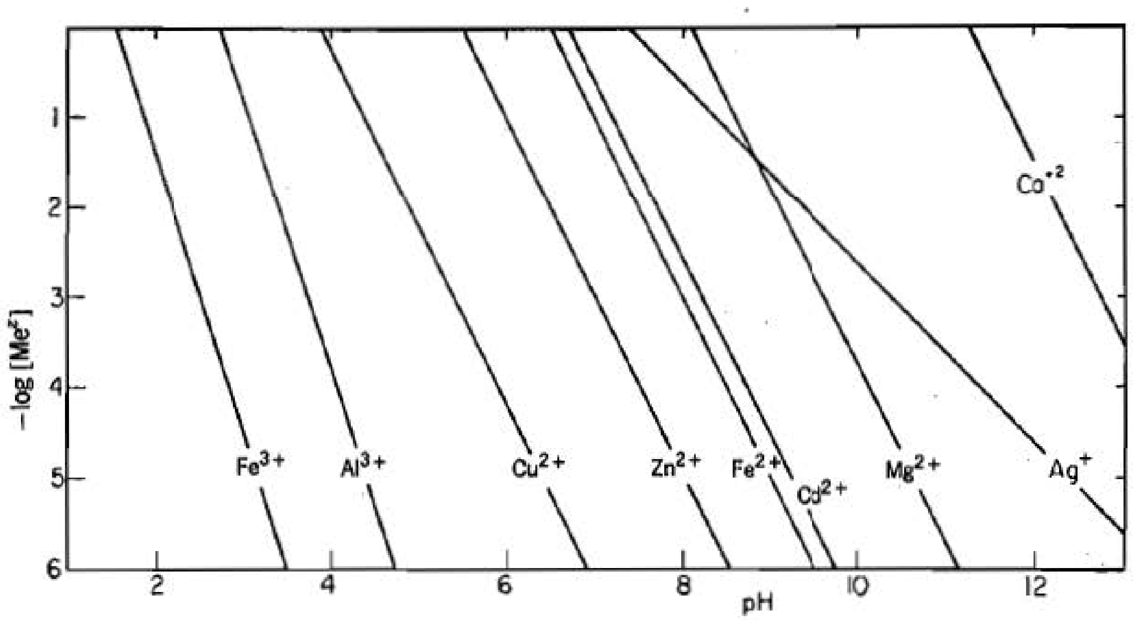

Figure 29. Solubility of Oxide and Hydroxide Phases at Equilibrium with Free Metal Ion Concentration (Stumm and Morgan 1996)

Adsorption, a two-dimensional accumulation of a solute on a solid, is an important mechanism in the fate and transport of contaminants. In this case, iron hydroxide and hydroxysulfate precipitates are the most significant adsorbent media. Precipitation of ferric iron occurs at the discharge of the IRAM adit water diversion system and within the Upper Middle Creek drainage. The precipitation oxidation reaction occurs rapidly in response to increased solution pH. Extensive ferric iron precipitates are found in the Formosa 1 Adit area, the diversion system discharge area, pipeline leak areas, and along Upper Middle Creek. High levels of arsenic at the discharge of the IRAM diversion system and at pipeline leak areas are caused by adsorption of arsenic to iron hydroxide precipitates caused by the mine impacted water discharge.

Potential routes of pollutant migration include runoff and groundwater. Runoff is the term used for both overland flow and interflow. Overland flow is surficial flow on the land surface towards streams, while interflow occurs within the sub-soil or near-surface fractured bedrock zone. In this case, interflow conveys runoff into the shallow alluvial/colluvial groundwater system or directly into a stream. As for groundwater, very little characterization of contamination has been done. It is known that the alluvial groundwater is contaminated in both the Upper Middle Creek and South Fork Middle Creek areas, and bedrock groundwater is contaminated in the area of the encapsulation mound.

Physical dispersion of mine materials via downslope movement, erosion, and wind also contributes to pollutant migration.

3.2 Impacts to Water

3.2.1 Impacts to Ground Water

Contaminants are released to groundwater as rain or snowmelt percolates through mine waste materials. Transportation of contaminants into surface water occurs through both shallow unconsolidated colluvial aquifers and deeper fracture-controlled bedrock groundwater systems. Most of the contaminated surface water in Upper Middle Creek appears to be attributed to alluvial groundwater pathways that enter the tributary drainages as base-flow to the streams. Bedrock aquifer data are limited to only one functioning monitoring well (MW-2), the findings of which show very little effect to water quality.

3.2.2 Impacts to Surface Water

The Formosa 1 Adit is located within the Upper Middle Creek watershed, which contains both Upper Middle Creek and South Fork Middle Creek. The Upper Middle Creek watershed is in turn located within the Lower Cow Creek watershed of the South Umpqua Basin.

Available data indicate surface water quality at Upper Middle Creek has been affected by mining-influenced water discharges, particularly those originating from the Formosa 1 Adit and the discharge from its diversion/conveyance pipeline. The Formosa 1 Adit water is introduced into Middle Creek upstream from Raymond Bear Falls (an andesitic sill truncates the alluvial aquifer forcing flow to discharge to surface water), below which the water's contaminant concentrations are observed to decrease as they are slowly diluted downstream by the inflow of cleaner surface and groundwater. Both Upper Middle Creek and South Fork Middle Creek have accumulations of metal precipitates downstream of where mining-influenced water discharges from groundwater. These metal precipitates are a result of dissolved metals precipitating when mixing with higher pH water in the stream. As a result, there are greater dissolved metal concentrations in the surface water and accumulation of these precipitated contaminants in sediment in this area compared with areas further downstream.

Mine-impacted groundwater that discharges to Upper Middle Creek has similar contaminant parameter values to that of Formosa 1 Adit discharge water, being strongly acidic calcium- and sulfate-rich waters with high concentrations of iron, copper, zinc, and other trace metals.

Surface water quality at South Fork Middle Creek is also affected by mine-influenced water. The impact at the South Fork is likely not caused by Formosa 1 Adit discharge, but by other on-site factors.

3.2.3 Formosa 1 Adit and Surface and Groundwater Interaction

Water discharged from the Formosa 1 Adit AMD system is observed to flow on the surface for approximately 170 ft downslope before becoming subsurface flow.

Contaminants originating from Formosa Superfund Site OU1 source materials deposited near the adit portals are found to be transported towards Upper Middle Creek. Leaching from the Formosa 1 Adit waste rock dump and road areas result in contaminated groundwater seeps that affect Upper Middle Creek water quality. The seeps are found to start approximately 200 ft horizontally and 100 ft vertically below the main road at the Formosa 1 Adit portal site.

Contaminants present in Formosa Superfund Site OU2 source materials (backfilled waste rock, tailings, ore, concentrates and exposed rock present underground) are transported by pipe and porous media flow through open and backfilled tunnels and discharged at the Formosa 1 Adit. A portion of this discharge is transported subsurface via the MB and MA alluvial aquifers to discharge points on Upper Middle Creek (the remainder of the water is conveyed to a land application area via the adit diversion system).

3.2.4 Surface Water Loading and Flows

The biggest contributor to contaminant mass loading to Upper Middle Creek is thought to be the alluvial groundwater system. Flow values for seeps and springs in Upper Middle Creek range from less than 0.1 gpm to about 12 gpm in the wet season.

The four representative sampling locations along Upper Middle Creek are:

- **Location MA:** This site is located in the MA tributary upstream of the confluence between the MA and MB tributaries. It is unclear whether this site is a seep or an in-stream sample site. Dry season flow values have ranged from no flow to 2.4 gpm, and wet season flows ranged from 12.1 gpm to 200 gpm over the course of past sampling events. See Figure 30 for complete flow data.
- **Location A4:** This in-stream sampling site is located 35 ft downstream from the confluence of MA and MB tributary drainages (drainages are shown in Figure 9). Dry season flow values ranged from no flow to 2.6 gpm, while wet season flow ranged from 12.1 gpm to 128.9 gpm. Degradation has occurred in this area as a result of acid seep/springs; therefore samples are often taken to assess loading. See Figure 31 for complete flow data.

- **Location MXR:** This in-stream site is located approximately 0.75 miles downstream of the Middle Creek headwaters and sits on the border between BLM and private logging company land. Dry season flow values ranged from 9.5 gpm to 66 gpm, while wet season values ranged from 58 gpm to 2,038 gpm. Note that the 2,038 gpm maximum value is from historic documents; peak flow measured in the last 4 years is approximately 1,000 gpm, per EPA. See Figures 32 and 33 for complete flow data.
- **Location M13.0:** This in-stream site is the farthest downstream flow sampling location, located just above the confluence of Middle Creek and Cow Creek. This flow is representative of the entire Upper and Lower Middle Creek watersheds. Fewer sampling events have taken place at this particular site. Of the data collected, flow values range from 1,638 gpm to 102,033 gpm. See Figure 34 for complete flow data.

These four representative sampling locations were selected based on the RI, which indicates that these four locations on Middle Creek are some of the most frequently sampled surface water locations associated with the Formosa Superfund Site (EPA 2012). EPA currently has a monitoring program that is designed to track seasonal changes in Upper Middle Creek which EPA plans to continue through the EE/CA process and afterwards. EPA and BLM will coordinate on revising this monitoring plan to track changes in water chemistry and biotic factors after implementation of the selected alternative for the Formosa 1 Adit.

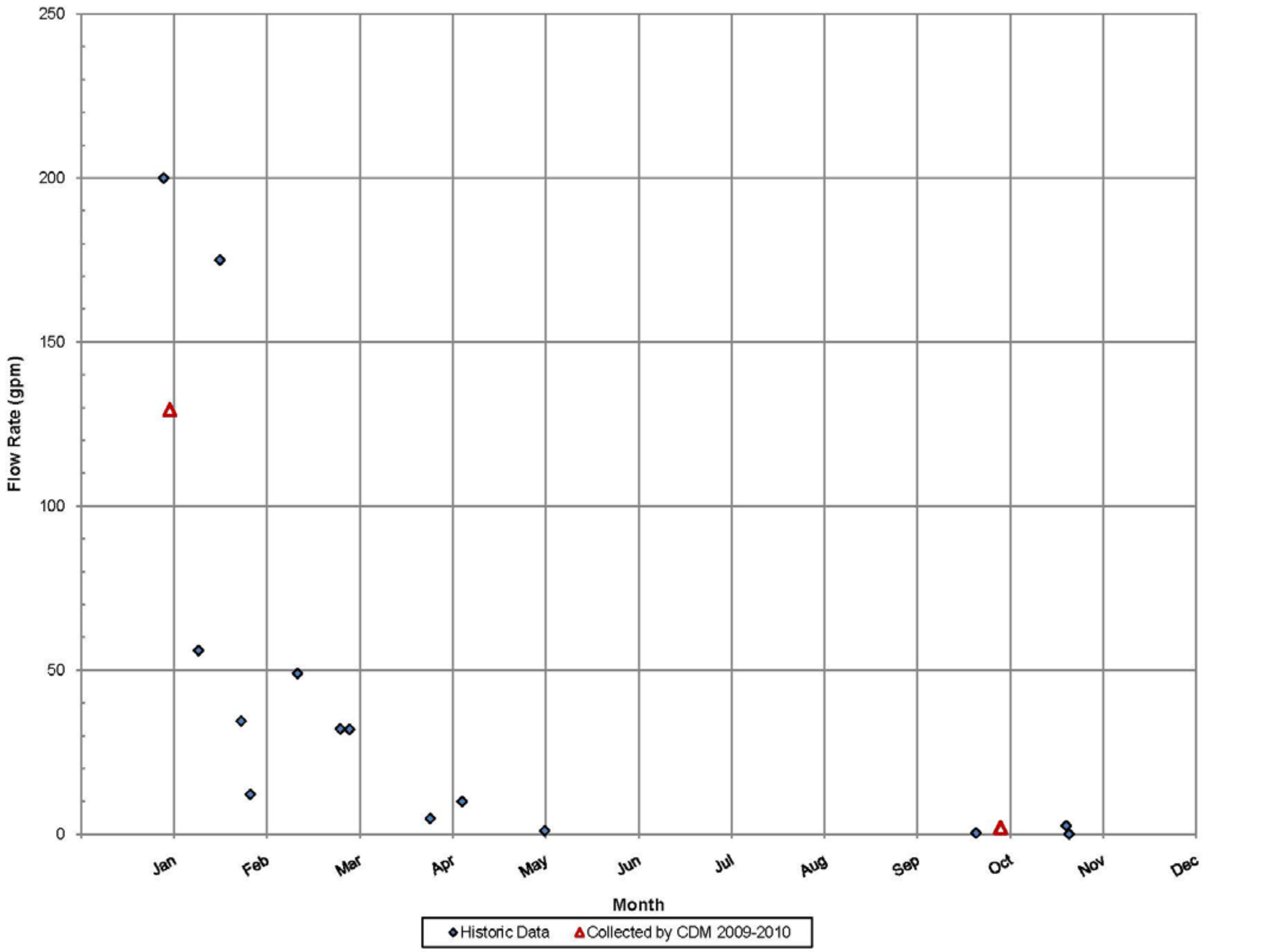

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Figure 30.
MA Flow Data

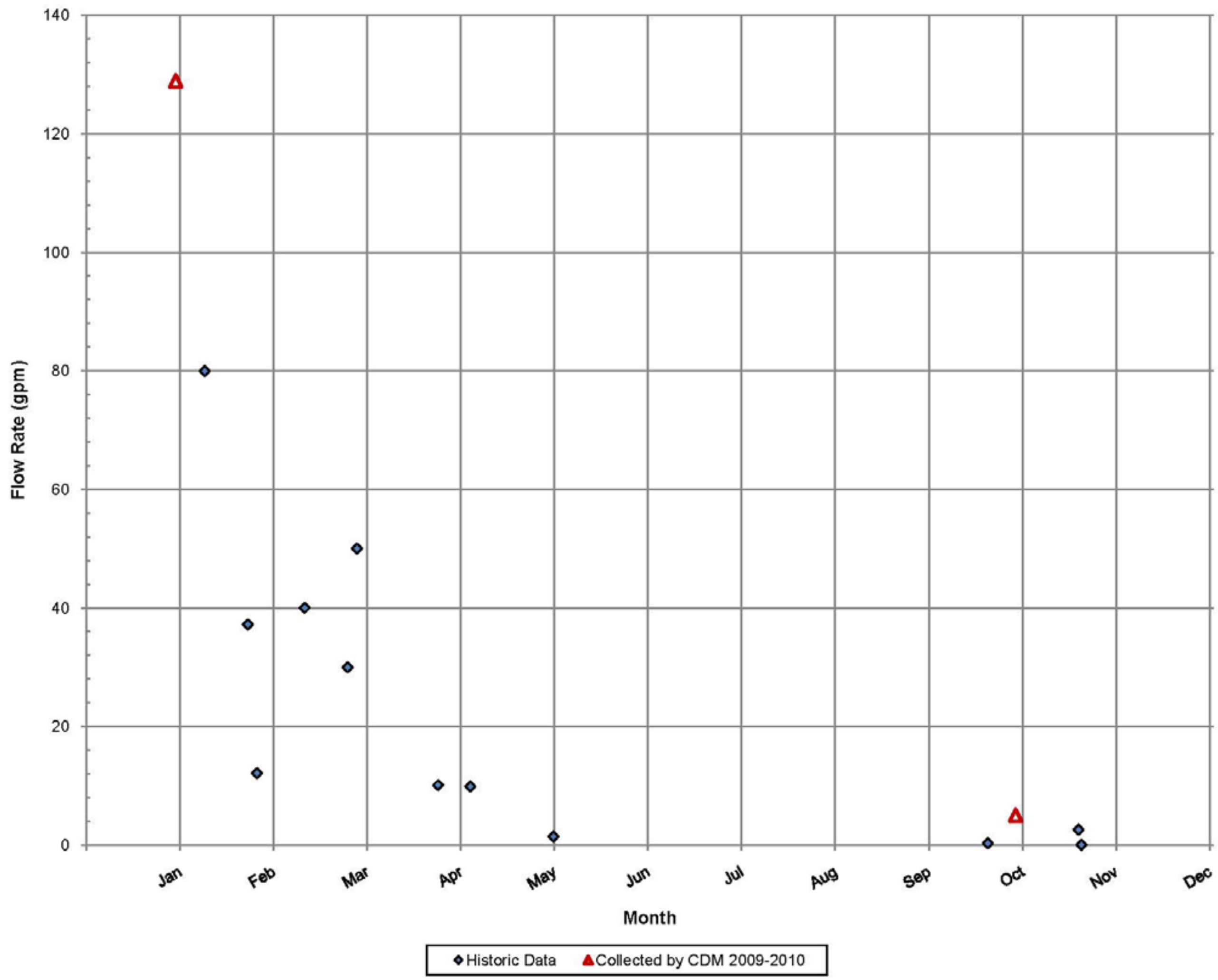

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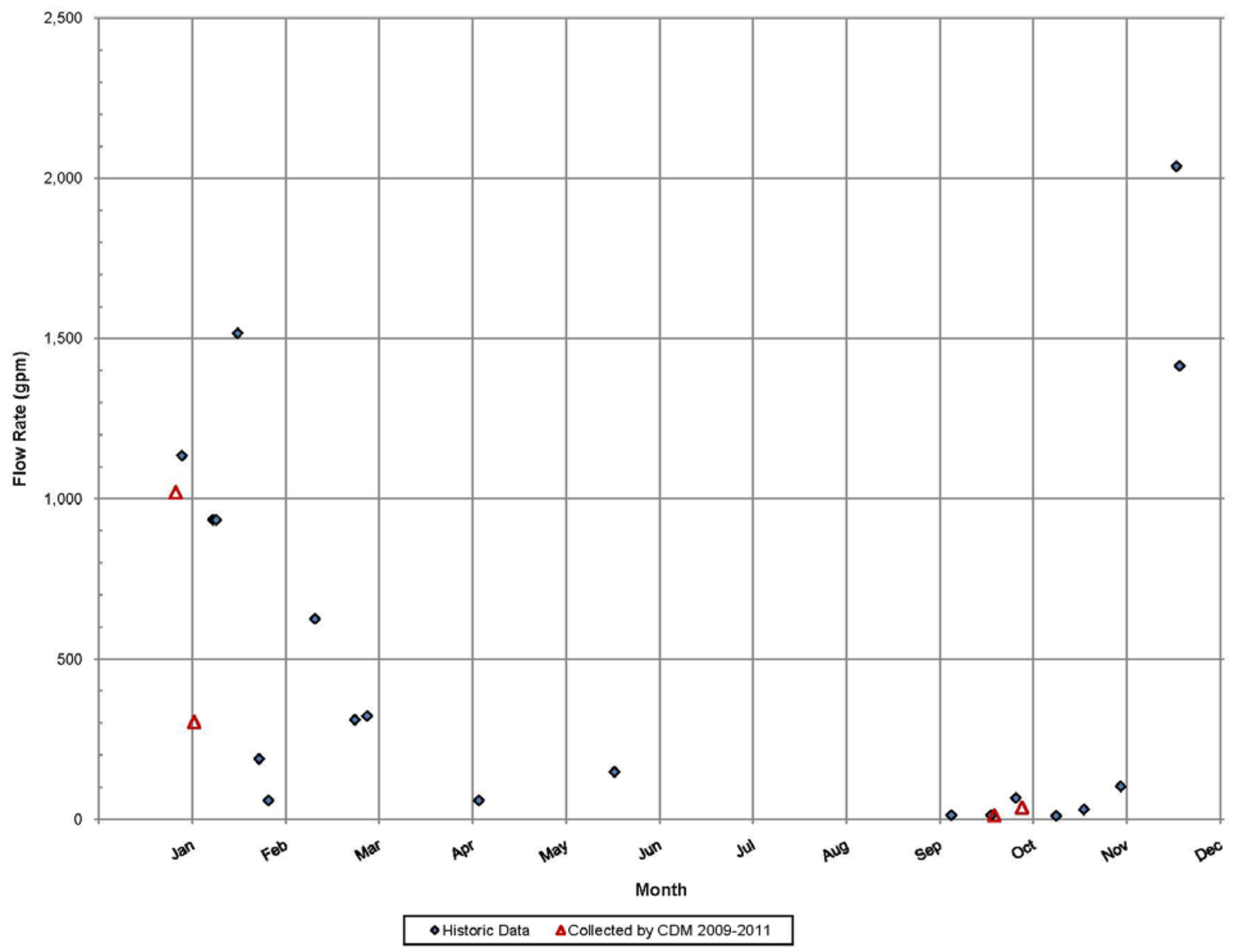
Figure 31.
A4 Flow Data



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P:\3380-New RAC8\221 - Formosa\RI Report\Figures\Section 3\Figure 3.2-4 Selected Flow Data for MXR.xlsx

Figure 32.
MXR Flow Data

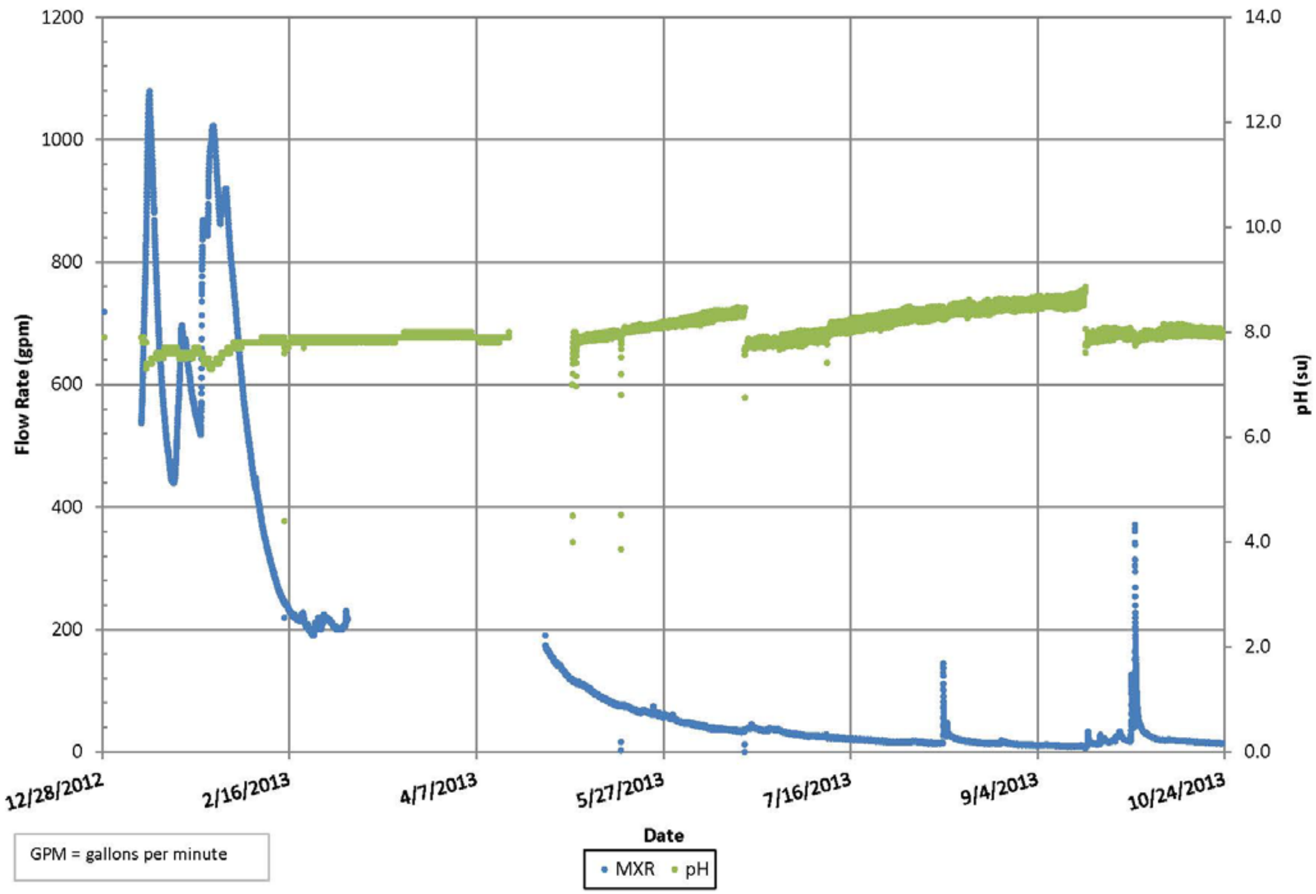
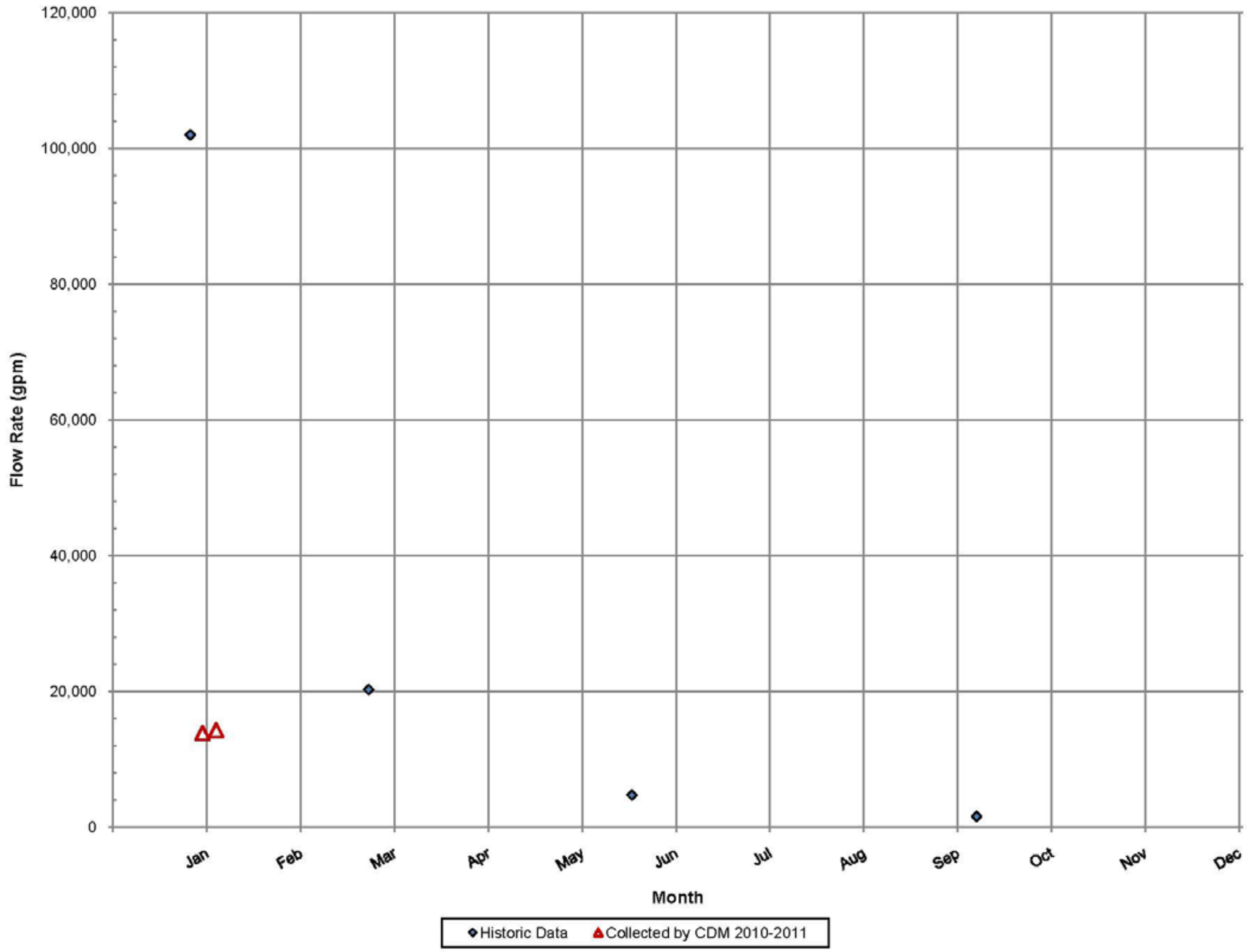


Figure 33.
Discharge of the Middle Creek at MXR



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P:\3380-New RAC8\221 - Formosa\RI Report\Figures\Section 3\Figure 3.2-5 Selected Flow Data for M13.0.xlsx

Figure 34.
M13.0 Flow Data

3.2.5 Surface Water Sampling and Chemistry

Surface water chemistry at sampling locations is provided in Table 4. Laboratory samples and field measurements of Upper Middle Creek were collected with the purpose of assessing mine-impacted water effects, contaminant transport pathways, and potential ARD sources.

Table 4. Surface Water Chemistry

Analyte	Location: End of Pipe (Average)	Location: MA (Average)	Location: A4 (Average)	Location: MXR (Average)	Location: M13 (Average)
Flow (gpm)	24.0	43.5	22.8	476.9	32,185.6
pH (su)	2.44	6.42	3.815	6.635	7.67
Aluminum (mg/L)	26.5571	0.5814	10.085	2.0092	0.111
Antimony (mg/L)	0.00067	0.00093	0.00055 U	0.00179 U	0.002 U
Arsenic (mg/L)	0.04867	0.00162	0.25154	0.00128	0.00163 U
Copper (mg/L)	19.7788	0.7016	5.55	1.60089	0.00929
Iron (mg/L)	233.563	0.1606	0.9965	0.20928	0.11068
Lead (mg/L)	0.07496	0.00161	0.00135	0.00106	0.002 U
Mercury (mg/L)	0.0002 U	0.0002 U	0.0002 U	0.0002 U	*
Silver (mg/L)	0.001 U	0.0002	0.00052 U	0.00054 U	0.0006 U
Zinc (mg/L)	150	4.398	19.7	7.47	0.04538
Sulfate (mg/L)	1540.67	82.8625	206.157	211.083	9.96667
TSS (mg/L)	20.3333	5.71429 U	20.2143	9.63636	2.5

Constituent values reported are average historic data recorded intermittently from 1999 to 2005 (EPA 2012). Metal concentrations recorded as *total recoverable.* *No historic data was found for this analyte.

gpm – gallon per minute; su – standard units; mg/L – milligram per liter; U - Nondetect

Specific conductivity can also be a useful measure of relative cumulative concentrations of dissolved metals in mine impacted water. Figures 4-3 through 4-7 in EPA (2014a) show the relationship between specific conductivity and metal concentrations.

Most OU2 surface water sampling is conducted only semiannually (late spring and late summer), which leaves the question of whether or not this is adequate given the major variation and fluctuation in acidity and metals concentration that occur during intermittent flushing events.

3.2.5.1 Continuous Water Chemistry Monitoring at MXR

Sampling location MXR (see Table 4) is particularly important because it receives drainage from the major affected tributaries in the Upper Middle Creek watershed. After water is discharged out of alluvium into surface water at MA, it travels downstream towards MXR. Continuous measures of conductivity, pH, and temperature data collected at MXR are shown in Figures 4-14, 4-15, and 4-16 of EPA (2014a).

3.2.6 Conclusions: Extent of Downstream Surface Water Impacts

As evident in the Table 4, contaminants of concern are present in concentrations most similar to the highly impacted discharge coming directly from the Formosa 1 Adit water diversion pipeline at location A4 (35 ft downstream from the confluence of MA and MB sub-drainages). Contaminants of concern are generally lower at location MXR (approximately 0.75 mile downstream of the Middle Creek headwaters) as a result of dilution and other attenuation processes, and samples collected at MA have the lowest amounts of all contaminants of concern.

Due to the fact that surface water sampling is conducted only on a semiannual basis, observations of biological organisms may be a more accurate portrayal of water quality given the degree of short-term temporal variation in mine-impacted water discharged over a limited area of stream segments from the site.

4.0 RISK EVALUATION

EPA performed a baseline human health risk assessment (HHRA) and an ecological risk assessment (ERA) for OU1 and presented the results in the Final OU1 RI Report (EPA 2012). A risk assessment is also being performed for OU2. OU1 includes surface and subsurface mine materials at the site. OU2 addresses groundwater, surface water, and mine materials within the underground mine workings. OU2 will evaluate the effect of managing the surface and subsurface mine materials and its impact on surface water and groundwater. The BLM is conducting a NTCRA on the Formosa 1 Adit due to its discharge of contaminated water from the mine to Middle Creek. The removal action is intended to plug the adit to prevent the unrestricted flow of contaminated water to Middle Creek.

The risk assessments evaluated the potential for adverse effects to human health and the environment, and ecological receptors from site-related concerns. Risks were assessed using site-specific chemical concentration data, applicable exposure scenarios, and pertinent risk-based cleanup guidelines or ecological criteria. The risk assessments were performed assuming no cleanup activities are performed at the site. The risk assessments defined three exposure areas (EAs), as follows:

- EA-1—Represents the primary area of mine disturbance at the site (Figure 2) and is defined by the mine materials boundary. The EA-1 risk assessment included evaluation of the surface and subsurface material samples collected within the boundary.
- EA-2—Represents the area immediately downslope of EA-1, which was characterized to evaluate materials outside of the mine materials boundary.
- EA-3—Represents the areas visibly impacted from the adit water diversion system pipeline and LADs. This includes both the existing pipeline as well as previous pipelines that discharged adit water to an LAD upgradient of the existing pipeline. Areas impacted by the adit water and included in EA-3 are only those materials where there are discernible iron hydroxide precipitates. Other impacted soils within this visually defined boundary are not included in EA-3.

This EE/CA focuses on EA-3 related to adit water discharge and associated impacts. Mine materials and soil will be referred to collectively as “soils” in the following sections. The following sections provide a brief summary of the risk evaluation performed by EPA as part of the RI (EPA 2012). Detailed discussion of the HHRA and ERA, along with associated tables and figures, can be found in the RI (EPA 2012).

The risk assessment evaluated available site data for the risk assessments. Using available site data or data collected for other investigations, while economical, may result in some uncertainty with respect to assessing risk. Some of the influencing factors that could result in uncertainty and affect a risk assessment include: 1) analytical method(s) used; 2) method and laboratory detection limits; 3) field and laboratory quality assurance/quality control; 4) field collection methods and documentation; 5) meeting data quality objectives; 6) number of samples collected for an area; and 7) whether background media was collected and with a sufficient number of samples.

4.1 Human Health Risk Assessment

EPA performed the HHRA in accordance with EPA guidelines and using a variety of EPA guidance documents and the EPA regional soil screening levels (RSLs) table (EPA 2012). The HHRA involved four steps: 1) identifying contaminants of potential concern (COPCs) in soil; 2) completing an exposure assessment to identify human health exposure pathways; 3) performing a toxicity assessment; and 4) characterizing possible cancer and non-cancer risks related to potential current and future exposure to site soils. COPCs are chemicals identified in site media that are at concentrations that could pose a health risk.

The four tasks were accomplished by evaluating available site data to select COPCs, identifying applicable human populations and exposure routes, reviewing toxicity data, and characterizing overall risk by comparing COPC concentrations in soil to previously derived, risk-based cleanup guidelines. The HHRA quantified health risks associated with direct exposure to site soils for OU1 but did not evaluate pathways related to contaminants that may migrate from site soils to groundwater or surface water, which is being addressed in the risk assessment for OU2.

4.1.1 Contaminants of Concern

The HHRA used inorganic data from five surface soils collected within EA-3 from the 0- to 6-inch depth interval to evaluate current exposure scenarios and soil from 0 to 10 ft bgs for possible future use scenarios. EPA compared the maximum concentrations for each constituent against EPA industrial RSLs. Current use of the site is limited to occasional site workers (e.g., monitoring and maintenance, sampling events, etc.), recreationalists, and trespassers. EPA considered future development of the site as reasonable, despite a lack of electrical service and limited winter access. Possible future development could include forest service activities (e.g., installation of worker cabins or a fire lookout) to re-opening of the mine. Construction activities, such as building new structures, would likely result in soil disturbance.

Industrial RSLs were selected over residential RSLs as residential use of the site is not expected. The duration of exposure for recreational users or trespassers is expected to be less than industrial users of the site (EPA 2012). Therefore, EPA concluded industrial RSLs should be protective of users of the site. Scenarios evaluated include direct contact by site users (e.g., forestry workers, trespassers, and other visitors) and indirect exposure (e.g., off-site residents) via inhalation of airborne dust. The nearest off-site residents are located approximately 3 miles from mine impacts.

Based on EPA's assessment, COPCs in surface soil include antimony, arsenic, and iron for EA-3.

4.1.2 Exposure Assessment

An exposure assessment identifies potentially exposed human populations, exposure pathways, and typical exposure durations. Exposure assessment results are later combined with chemical-specific toxicity criteria to characterize risks associated with exposure.

The site is currently used on occasion by forestry workers. Use by forestry workers in the future is possible. However, development, while possible, will include challenges such as lack of electrical service and limited winter access (EPA 2012). Potential future development may consist of constructing a fire lookout or further mine development. Because there is a lack of specific development plans, EPA evaluated possible risks related to general site workers that may inhabit the site on a limited basis as well as others that may visit on occasion. Visitors considered in EPA's assessment included all-terrain vehicle riders, hunters, campers, hikers, and trespassers. EPA also assessed exposure via airborne dust to residents that do not visit or occupy the site but that live near the site. The nearest residents to the site are approximately 3 miles from the mine-impacted areas.

Exposure pathways consider four components: 1) a source and mechanism of release of the chemical to the environment; 2) transport medium (e.g., water or soil); 3) exposure point where human contact with the medium occurs; and 4) the exposure route at the exposure point (e.g., inhalation of dust or dermal contact with soil). The exposure pathway is considered complete if all four components are present. All receptors were considered in the evaluation to have full and unrestricted use of the site, assuming appropriate site land use. Reasonable maximum exposure (RME) and central tendency exposure (CTE) scenarios were developed for current and future site workers, construction workers, visitors, and off-site residents. RMEs evaluate higher end exposures while CTEs provide more moderate estimates of exposure. EPA's risk assessment (EPA 2012) provides the assumptions used in their estimates.

EPA (EPA 2012) quantitatively evaluated exposure via inhalation of dust, incidental ingestion of soil, and dermal contact with soil for on-site receptors (e.g., forestry workers). Exposure to off-site receptors via airborne dust was also evaluated. EPA also evaluated the potential future scenario for construction workers that may become exposed to subsurface soil through site development activities. Construction workers were evaluated for exposure via inhalation of dust, ingestion of soil, and dermal contact with soil. EPA also evaluated potential exposure to downstream receptors related to the migration of impacted groundwater downstream. EPA's conceptual site model for human and ecological exposures (Figure 22) shows the exposure pathways and exposure evaluation. Potential surface water exposures were evaluated as part of OU2. As of the date of this EE/CA, the OU2 risk assessment has not yet been completed.

COPCs evaluated for EA-3 include antimony, arsenic, and iron. EPA used the maximum concentration of each constituent because there were only five samples collected from the area.

4.1.3 Toxicity Assessment

A toxicity assessment provides information on the potential for contaminants of concern (COCs) to cause carcinogenic and non-carcinogenic adverse health effects. EPA performed a toxicity assessment which correlates chemical intake (dose) to expected health effects (response) for both carcinogens and non-carcinogens. EPA used a tiered approach for EPA toxicity values (EPA 2012). Toxicity values for COPCs are derived from dose-response evaluations performed by EPA. Sources of toxicity data used by EPA for Tier 1 were EPA's Integrated Risk Information System, EPA's Provisional Peer Reviewed Toxicity Values for Tier 2, and other toxicity values from EPA and non-EPA sources for Tier 3 (EPA 2012). EPA's risk assessment provides details on the toxicity assessment.

4.1.4 Risk Characterization

Risk characterization is the final step in the risk assessment process. Risk characterization integrates all the information from the hazard identification, exposure assessment, and toxicity assessment to produce a quantitative measure of non-carcinogen and carcinogen risk. Each type of visitor/worker was evaluated for EA-3. EPA (EPA 2012) presents details on the risk calculations for each EA.

EPA calculated an excess lifetime cancer risk (ECLR) associated with exposure to the chemical via a specified route of exposure. ELCR is a unitless probability of an excess cancer rate due to contamination from the site. The ECLR is based on lifetime average daily dose and cancer slope factor (CSF). CSF is calculated at a 95 percent upper confidence level so exposure to the potential carcinogen will likely not be underestimated. To evaluate potential cancer risk, the potential toxicity of chemicals is assumed to be additive. Therefore, cancer risks for each chemical were summed for each receptor to obtain an estimate of total ECLR.

Non-carcinogenic risk is measured in terms of a hazard quotient (HQ) for exposure to a single chemical and a hazard index (HI) for exposure to multiple chemicals. The HI is a unitless ratio of a receptor's exposure level (or dose) to the "acceptable" or allowable exposure level. Similar to carcinogenic toxicity, it is assumed that for potential non-carcinogenic risk the toxicity of chemical mixtures is additive. Therefore, the HQs for each chemical are added for each receptor to produce a cumulative HI. EPA uses an HI benchmark of 1 as a point of departure for non-carcinogenic risk, where an HI of 1 or less indicates that a receptor's exposure is equal to or less than the allowable exposure level. In other words, if an HI is 1 or less, it is unlikely that adverse health effects will occur in relation to exposure. Therefore, a conclusion of "no significant risk" of harm to human health is made based on non-cancer health effects. An exceedence of the reference dose/reference concentration indicates an increased hazard for non-carcinogenic health effects but cannot provide an accurate estimate of adverse effects.

EPA (EPA 2012) quantitatively evaluated exposure to surface soils at the site for current workers, visitors, and off-site residents. They also quantitatively evaluated future construction workers, workers, visitors, and off-site resident exposure to surface soil, subsurface (EA-1 only). Specific cancer risks for EA-3 are listed below:

- On-site Workers: Cancer risk of 6E-05 or less
- Visitors (adult and child): Cancer risk of 2E-05 or less
- Off-site Residents (via inhalation): Cancer risk of 2E-06 or less

EPA (EPA 2012) stated that in all of the above cases, the cancer risks are due to arsenic. All EA-3 site-related cancer risks fell within EPA's acceptable range of 10E-4 and 10E-6 and all non-cancer hazards for the same populations were all below the acceptable hazard benchmark of 1.0. Refer to EPA's risk assessment (EPA 2012) for specific tables listing all the HQs, HIs, and other risk calculations.

4.1.5 Human Health Risk Summary

Human health risks from exposure via inhalation, ingestion, and direct contact (dermal) to mine materials were evaluated for current and future workers, visitors, and offsite residents. The study included evaluation of exposure to off-site residents to dust caused by wind dispersion.

Estimated cancer risks for all populations, both current and future, are within or below the EPA acceptable range of one in ten thousand (1 in 10,000) to one in one million (1 in 1,000,000) over a person's lifetime. The maximum carcinogenic risk was 6 in 100,000 to an outdoor worker exposed to arsenic at EA-3, primarily through ingestion of soils. Arsenic within mine materials in EA-3 result in cancer risk greater than the other EAs, but the extra risk is within EPA's acceptable range. Human exposure to groundwater is being addressed in the OU2. Current and future non-cancer risks were all less than a HI of 1, with the exception of a HI of 2 for future on-site construction worker at EA-1 from ingesting arsenic contaminated soils. However, the HI of 2 does not represent an actual risk because when segregated by target organ, individual hazard quotients are all below the acceptable hazard benchmark of 1.0.

The risk evaluation demonstrated that none of the contaminants of concern (arsenic, cadmium, copper, iron, lead, and zinc) present in surface water or waste rock from the EA-3 area pose a significant risk to human health related to ingestion and inhalation. In all cases, the cancer risks are due to arsenic. All EA-3 site-related cancer risks fell within EPA's acceptable range of 10E-4 and 10E-6. All non-cancer hazards for the same populations were below the acceptable hazard benchmark of 1.0.

4.2 Ecological Risk Evaluation

An ecological risk evaluation was completed to assess the potential risk that mine wastes at the Formosa Superfund Site pose to plants and animals (ecological receptors) due to exposure to a single or multiple chemical stressors. Risk effects result from contact between the ecological receptor and the stressor (e.g., mine contaminants). The ERA (EPA 2012) was performed to identify and describe actual or potential adverse effects to current or future ecological receptors due to conditions at the site. The ERA includes a Screening Level Ecological Risk Assessment (SLERA) and the initial step of the Baseline Ecological Risk Assessment (BERA) process. Chemicals of interest (COIs) are evaluated as part of the SLERA to preliminarily identify COPCs and receptors and estimate risk using a conservative approach. As per EPA guidance, COPCs with the greatest potential to cause or contribute to ecologically significant adverse effects were later designated as COCs for the ERA.

The primary mine disturbance area and buffer zone around the disturbance area comprise OU1. Soil, mine materials, groundwater and runoff to surface water are considered potential sources of impacts to down-gradient receptors and resources. However, OU1 does not fully address these downgradient receptors; instead, these receptors are evaluated in the OU2 BERA (EPA 2014b). The RI report stated that ecological exposure to surface water is evaluated in the OU2 BERA (EPA 2014b) that documents the adverse effects of mine materials to aquatic receptors. Calculated risks to terrestrial receptors is identified in the OU1 RI and determined to be insignificant because receptor exposure is limited by marginal habitat at the Formosa Superfund Site.

In EPA’s risk assessment (EPA 2012), EPA indicates that a decision to terminate the ERA process for OU1 at the SLERA/ERA stage, rather than continue on to the BERA, is supported. EPA listed several reasons for this decision. These reasons are summarized below:

- Limited habitat quality and quantity in OU1 due to highly disturbed and unsuitable habitats.
- Limited exposure potential in OU1 with planned remedial action that will address surface soils and mine materials. Therefore, these changes to the site will not reflect near future conditions.
- Characterization of contamination in OU1 indicated that surface soil and mine materials are potential risk sources to down-gradient ecological receptors in OU2 due to migration of contaminants from OU1.
- Site-related effects to OU2 abiotic and biological media are being addressed by conducting a BERA for OU2.

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

4.2.1 Contaminants of Concern

EPA (EPA 2012) identified the medium of interest for the ERA as surface soil and mine materials that terrestrial ecological receptors may be exposed to. Because the surface in OU1 is highly disturbed, EPA concluded that exposures are likely infrequent, of short duration, and limited to a group of ecological receptors tolerant of marginal habitat quality. More importantly, EPA concluded surface soil and mine materials are potential sources of down-gradient impacts to surface water, groundwater, sediment, and other terrestrial media. This ERA also considers surface water in the upper reaches of OU2 that is immediately down-gradient of OU1 for the purpose of supporting the preliminary assumption that OU1 surface soil and mine materials affect OU2 surface water and related media, such as sediment and biota.

COIs for the ERA included all potentially hazardous inorganic chemicals detected in OU1 surface soil and mine materials (EPA 2012). Exceptions include essential nutrients and electrolytes (calcium, magnesium, sodium, potassium). Dissolved metals in the upper reaches of surface waters in OU2 were also of interest to evaluate surface water quality at locations near OU1. Dissolved COIs include cadmium, copper, lead, nickel, and zinc.

4.2.2 Exposure Assessment

EPA (EPA 2012) identified terrestrial and aquatic ecological receptors for the OU1 ERA. Terrestrial receptors included disturbed areas of the site and on-site and adjacent Douglas-fir (*Pseudotsuga menziesii*)-dominated forest habitats. Aquatic receptors identified by EPA included those found in the upper reaches of streams in the OU2 (e.g., Upper Middle Creek and South Fork Middle Creek). These aquatic receptors are included in the OU1 ERA as a screening level assessment on potential mine-related impacts from surface soil, mine materials, and groundwater on OU2 surface water.

EPA's risk assessment (EPA 2012) provides detailed lists of vegetation, wildlife, aquatic, and riparian species found at the site. In general, terrestrial receptors include various types of vegetation and wildlife (e.g., salamanders, frogs, toads, lizards, snakes, birds, and mammals, including bats). Many of these species would use the coniferous forest ecosystem in OU1 occasionally or infrequently because the areas nearby are disturbed. Aquatic receptors for OU1 are those reported to occur in OU2 surface waters and included aquatic plants, water column invertebrates, fish, larval amphibians, and other potential receptors that may be present and not observed. EPA (EPA 2012) presented tables listing the aquatic vegetation and wildlife evaluated. Threatened and endangered species and species of special concern were also listed by EPA.

Terrestrial exposure scenarios and receptor groups were identified by EPA. These are as follows:

1. Complete and significant exposure pathways include direct contact/dermal exposure and direct contact/uptake.
   - Direct contact/dermal exposure receptors include soil-associated invertebrates and birds, small mammals, and terrestrial amphibians and reptiles.
   - Direct contact/uptake exposure receptors include terrestrial plants.
2. Complete but insignificant pathways or pathways where risks cannot be quantified include inhalation for burrowing animals.
3. Incomplete or minor exposure pathways include dietary pathways for birds and mammals with large foraging ranges.

EPA focused the ERA on those receptors for which there was a complete and significant exposure pathway. Inhalation by burrowing animals was not evaluated by EPA because metals are not volatile and data were insufficient to quantify inhalation exposures (EPA 2012). The dietary pathway was also not evaluated because OU1 is small compared to the surrounding foraging area, and the habitat with in OU1 is degraded with limited foraging opportunities.

Aquatic exposure pathways and receptor groups identified by EPA include:

1. Complete and significant exposure pathways for direct contact/ingestion and direct contact/uptake.
   - Direct contact/ingestion receptors include water column and benthic aquatic invertebrates, larval amphibians, and fish.
   - Direct contact/uptake receptors include aquatic plants.

Assessment endpoints were identified by EPA. The endpoints identify the ecological values to be protected and are directly related to remedial action goals and objectives. EPA selected OU1 assessment endpoints based on site characteristics, COIs, toxic mechanisms, and exposure pathways. EPA selected soil-based assessment endpoints for protection of terrestrial plants and wildlife and surface water–based assessment endpoints for the protection of aquatic invertebrates and fish, and avian and mammalian wildlife.

Measurement endpoints were used in conjunction with assessment endpoints. Measurement endpoints are used where assessment endpoints cannot be directly measured or evaluated, and are defined as qualitative expressions of observed or measured biological responses to stressors which are relevant to the selected assessment endpoints. Measurement endpoints selected by EPA were primarily chemical-specific ecological screening levels (ESLs) selected from or based on accepted sources (e.g., EPA or other regulatory agencies).

EPA also used the conceptual site model (CSM; Figure 22) developed for the site to guide and support the selection of appropriate assessment and measurement endpoints (EPA 2012). Potential exposure pathways identified through the CSM included contaminant sources, fate and transport processes, and exposure routes.

4.2.3 Ecological Effects Assessment

Chemical properties evaluated in the ERA include environmental persistence, bioavailability, bioconcentration, and bioaccumulation. Some of the factors that govern whether chemicals will affect a receptor include the type of chemical (e.g., metal), environmental factors (e.g., pH, hardness, temperature, etc.) of water or solid media; and retention ability of the receptor (EPA 2012).

For EA-3, EPA used the maximum concentration of each COI detected in the ERA. The concentrations were compared to conservative ESLs to select preliminary COPCs for that medium (EPA 2012). ESLs for ecological receptor categories include terrestrial plants, soil invertebrates, birds, and mammals. EPA (EPA 2012) presents ESL values and sources for each receptor category. At the conclusion of the SLERA step of the ERA, EPA identified several preliminary COPCs. EPA selected the arithmetic mean for EA-3 surface soil and surface water as the refined exposure point concentration (EPC) because 95 percent upper confidence limits could not be confidently derived due to the lack of a sufficient number of samples.

EPA stated that the primary exposure scenarios of interest for OU1 are those based on direct contact, uptake (plants), and incidental ingestion of metals in surface soils and mine materials (EPA 2012). Terrestrial plants and soil-associated invertebrates tolerant of disturbed conditions are the most likely receptors. Direct contact/ingestion exposures for birds and mammals with small home or foraging ranges are also a primary exposure scenario for OU1. The exposure scenario for downgradient surface waters primarily includes aquatic life (plants and wildlife).

4.2.4 Risk Characterization

EPA first quantified screening level risk estimates by comparing preliminary EPCs to one or more ESLs based on direct contact/ingestion exposure scenarios for all COIs (EPA 2012). These comparisons resulted in screening level HQs. HQs equal to or greater than 1.0 identified preliminary COPCs. EPA then went on to develop refined HQs based on site-specific biological information (e.g., habitat, habitat quantity, and presence or absence of sensitive habitats or suitable habitats in or near OU1).

EPA identified 26 inorganic chemicals that were detected in surface soils of EA-3. Twenty-one of these chemicals were initially retained for additional evaluation because the maximum detected concentration exceeded one or more ESL or the ESL for one or more of the four receptor categories (plants, invertebrates, birds, and mammals) was unavailable. These chemicals were further evaluated by EPA under the BERA process, which includes refinement of input parameters used to derive the HQs.

EPA (EPA 2012) further evaluated the chemicals not only based on chemical concentrations but also other factors such as chemical form, data availability, receptor behavior and exposure, and habitat quality and quantity. Based on this review, EPA selected arsenic, cadmium, copper, lead, and zinc as the more ecologically significant (regardless of HQ) chemicals for soil and/or surface water. These chemicals were designated as the final COCs and are viewed as risk drivers, or chemicals with the greatest potential to cause ecologically significant adverse effects to exposed receptors (EPA 2012).

4.2.5 Ecological Risk Summary

The following summarizes the terrestrial and aquatic findings of the ecological risk assessment. In general, arsenic, cadmium, copper, lead, and zinc were found as the more ecologically significant chemicals and have been designated as the final COCs. These COCs are considered the risk drivers, or chemicals with the greatest potential to cause ecologically significant adverse effects to exposed receptors (EPA 2012). Environmental risks associated with mine wastes in the EA-3 area, and in particular downgradient of the Formosa 1 Adit discharge, also appear in surface water and local groundwater due to migration of contaminants from the adit discharge area. These contaminants (arsenic, cadmium, copper, iron, lead, and zinc) present ecological risks to aquatic life.

Based on the results of the risk assessment, removal action is required to address these risks to terrestrial and aquatic ecological receptors. Section 5 discusses removal action scope, goals, and objectives.

4.2.5.1 Ecological Terrestrial Risks

The ecological risk assessment identified COCs in surface and subsurface soils that occur at concentrations that may cause adverse effects to terrestrial wildlife (mammals, birds, invertebrates) and vegetation. The COCs are presented below:

- **EA-1:** Arsenic (HQ of 6 for plants), cadmium (HQ of 14 for mammals), copper (HQ of 36 for birds), lead (HQ of 15 for birds), mercury (HQ of 33 for soil invertebrates), nickel (HQ of 5 for plants), selenium (HQ of 5 for plants), and zinc (HQ of 22 for birds).
- **EA-2**: Cadmium (HQ of 5 for mammals), copper (HQ of 11 for birds), manganese (HQ of 12 for plants), and zinc (HQ of 9 for birds).

- **EA-3**: Arsenic (HQ 23 for plants), copper (HQ of 13 for birds), and zinc (HQ of 3 for birds).

Because there is no foraging or nesting habitat within the primary mine disturbance area, these risks are considered an overestimation of actual risk for receptors in the area. EPA is presenting them to be consistent with information in the OU1 RI.

4.2.5.2 Ecological Aquatic Risks

EPA has completed the OU2 BERA (EPA 2014b) demonstrating the current risks to aquatic life by releases from the mine. Although these risks cannot be solely attributed to the OU1 materials (soils), there is a reasonable expectation that soils are contributing to the adverse impacts being identified in the OU2 BERA, as follows:

- **Middle Creek**: Cadmium (HQ of 57 for fish), copper (HQ of 58 for fish), zinc (HQ of 27 for fish), cumulative HQ is 141.
- **South Fork Middle Creek**: Cadmium (HQ of 38 for fish), copper (HQ of 41 for fish), zinc (HQ of 23 for fish); cumulative HQ is 102.

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5.0 REMOVAL ACTION SCOPE, GOALS, AND OBJECTIVES

The risk evaluation demonstrated that none of the contaminants of concern (arsenic, cadmium, copper, iron, lead, and zinc) present in surface water or waste rock from the EA-3 area pose a significant risk to human health related to ingestion and inhalation. In all cases, the cancer risks are due to arsenic. All EA-3 site-related cancer risks fell within EPA's acceptable range of 10E-4 and 10E-6. All non-cancer hazards for the same populations were below the acceptable hazard benchmark of 1.0.

Based on their review, EPA selected arsenic, cadmium, copper, lead, and zinc as the more ecologically significant chemicals. These chemicals were designated as the final COCs and are viewed as risk drivers, or chemicals with the greatest potential to cause ecologically significant adverse effects to exposed receptors (EPA 2012). Environmental risks associated with mine wastes in the EA-3 area and in particular down-gradient of the Formosa 1 Adit discharge also appear in surface water and local groundwater due to migration of contaminants from the adit discharge area. These contaminants (arsenic, cadmium, copper, iron, lead, and zinc) present ecological risks to aquatic life. Removal action is required to address the risks posed to terrestrial and aquatic ecological receptors.

This section of the EE/CA presents the scope of the Formosa 1 Adit RAOs to meet project goals and ARARs.

5.1 Scope of the Response Action

The scope of this response action is directed at controlling, treating, eliminating, or reducing uncontrolled releases of hazardous constituents (metals and acidity), thereby minimizing human and ecological risk exposure to the Formosa 1 Adit discharge. This response action addresses the discharge from the Formosa 1 Adit from a source control approach. The source control approach is considered to be a first step in attempting to reduce contaminant loading from a point source discharge. Source control is preferred to long-term water treatment in mitigating impacts to water quality in Upper Middle Creek, as water treatment options are often expensive to construct, difficult to operate and without additional mitigation, need to be run in perpetuity.

5.2 Response Action Objectives

The overall goal for the response actions is typically to assure the achievement of the highest and best water quality practicably attainable at the site, considering the natural geology, hydrology, and background conditions, and to protect the environment by reducing the migration of contaminants into receiving areas or waters.

Project-specific RAOs are:

- Reduce human and ecological exposure to hazardous substances, resulting from the discharge of waters containing high concentrations of metals and low pH from the Formosa 1 Adit.
- Prevent or minimize soluble contaminants or contaminated solid materials from migrating into adjacent/nearby drainages or groundwater to the extent practicable.
- Reduce or eliminate concentrated discharges that generate metals contamination to adjacent surface water and groundwater to the extent practicable.
- Prevent potential exposure of ecological receptors to metal contaminants from acid discharges to the extent practicable.
- Prevent or limit future releases of metals-enriched and low pH water through source contaminant removal activities and reduction in source water discharges.
- Comply with ARARs (Appendix A) to the extent practicable, considering the exigencies of the circumstances.

5.3 Response Action Justification

When a threat to human health or the environment is identified, the implementation of an appropriate response action is justified. Response actions are typically undertaken to minimize or eliminate the release or threat of release at a site. Eight factors are identified in the NCP for justifying the implementation of an appropriate Response Action. Applicable factors related to the Formosa 1 Adit discharge are:

- Actual or potential exposure to nearby human populations, animals or other ecological receptors from hazardous substances, pollutants or contaminants;
- Actual or potential contamination of drinking water supplies or sensitive ecosystems; and
- High levels of hazardous substances, pollutants or contaminants in soils (i.e., in the diversion pipeline discharge) largely at or near the surface that may migrate.

Long-term response actions for the Formosa 1 Adit will be handled as part of the overall closure of the site.

5.4 Response Action Schedule

The response actions considered in this EE/CA should be able to be completed within a period of about 18 to 24 months and include the completion of this EE/CA and selection of a preferred alternative, engineering design of the selected response actions, review by the client and appropriate regulatory bodies, public comment, preparation of a bid/specification package, selection of a contractor, implementation of the selected response actions, and final construction reporting.

5.5 ARAR-Based Response Goals

Response action goals are primarily contaminant-based concentrations that are set by federal or state laws and regulations. For the Formosa 1 Adit, the primary contaminant-specific ARARs apply to groundwater and surface water. A preliminary list of ARARs is presented in Appendix A. The BLM will issue final ARARs in the Action Memorandum, which documents the decision involved with the selection of the preferred response alternative. No contaminant-specific ARARs for soil media have been included; however, soils in the current adit discharge area may need to be remediated in final closure of the Formosa Superfund Site under CERCLA.

5.5.1 Surface Water

Aquatic life standards and human health standards are common ARARs for surface water. Generally, the more stringent of the two standards is identified as the ARAR-based reclamation goal. Because the aquatic life standards are more stringent than the human health standards for COCs, and ecological risks predominate at this site, aquatic standards represent the surface water ARARs for this site. These goals are presented in Table 5 for COCs (arsenic, cadmium, copper, iron, lead, and zinc) identified by EPA as the more ecologically significant elements that are viewed as risk drivers, or chemicals with the greatest potential to cause ecologically significant adverse effects to exposed receptors (EPA 2012). Cow Creek, Middle Creek, and the South Fork of Middle Creek are habitat for the Oregon Coast Evolutionarily Significant Unit of coho salmon (*Oncorhynchus kisutch*), which is listed as threatened under the Endangered Species Act (ESA).

Those goals that are hardness dependent have been calculated based on a hardness of 25 mg/L. Enforcement of cleanup goals may be executed at specific water quality stations, in which case the cleanup standard for the hardness dependent contaminants should be calculated based on the hardness at those specific stations.

Table 5. ARAR-Based Reclamation Goals for Surface Water

	Total Recoverable Metals (μg/L)[1]					
	Arsenic	**Cadmium**	**Copper**	**Iron**	**Lead**	**Zinc**
Goal	10	5	2.85	1,000	0.545	37

[1] Standards are in terms of total recoverable concentrations. Hardness based criteria (copper, lead, and zinc) are calculated for hardness = 25 mg/L.

Although cleanup actions need not immediately achieve surface water quality standards for area streams, the most restrictive standards (Table 5) remain the cleanup goal for this Removal Action. While there are currently no water quality standards defined for the Formosa Superfund Site, cleanup goals will be determined in the Final Record of Decision.

5.5.2 Groundwater

ARAR-based reclamation goals for groundwater are human health standards. Using these standards, ARAR-based goals for COCs in groundwater (arsenic, cadmium, copper, iron, lead, and zinc) are shown in Table 6. Site-specific groundwater quality data are available from monitor wells from the mine area and dissolved concentrations of some of these constituents exceed these standards only at MW-7 and MW-15.

Table 6. ARAR-Based Reclamation Goals for Groundwater

Chemical	Type [1]	Concentration (μg/L)
Arsenic	HHS (MCL)	10
Cadmium	HHS/MCL	5
Copper	HHS/MCL	1,300
Iron		23 (secondary)
Lead	HHS/MCL	15
Zinc	HHS (MCL)	2,000

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

6.0 SCREENING AND DEVELOPMENT OF RESPONSE ALTERNATIVES

The description of the source, nature, and extent of contamination (Section 3); the conceptual model that portrays contaminant sources, release mechanisms, and exposure pathways (Section 3.1); and the RAOs developed for this phase of the project (Section 5.0) provide the basis for screening and development of response alternatives for the Formosa 1 Adit discharge and the existing discharge conveyance system. The process presented in this section follows EPA guidance for NTCRAs (EPA 1993) by first identifying potential response technologies and process options, screening these options through consideration of practical applications of the technologies to the scope of the response action, and then assembling the remaining technologies and options into response alternatives.

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

6.1 Response Technology and Process Option Screening

The purpose of identifying and screening technology types and process options is to eliminate those technologies that are obviously unfeasible or ineffective, while retaining potentially effective options. General source control response actions and process options are specifically applied to the mitigation of contaminant release from the Formosa 1 Adit discharge conveyance system as well as for decreasing or stopping the flow of contaminated water from the adit portal. A source control approach is considered a first step in attempting to reduce contaminant loading from point sources.

No evaluation was conducted for technologies that directly address contaminated groundwater or transported, contaminated stream sediments or mine wastes, as these environmental media are expected to be addressed in future response actions resulting from the site-wide closure as implemented under the CERCLA program. Addressing environmental impacts associated with disturbed soils, waste rock dumps, and the adit discharge presumes that some reduction in contaminant concentrations will occur in surface water, groundwater, and newly transported stream sediment as a result of removing or controlling these sources of contamination. Stemming the flow of acidic and metal-laden waters from the Formosa 1 Adit will also lead to a direct improvement in resulting surface water quality in the receiving waters of Upper Middle Creek. Improvements in surface water and groundwater quality are expected to result from implementation of all of the other response actions; however, the absolute amount of improvement is difficult to quantify and is expected to be quite variable between specific response actions. This is because other significant sources of contamination remain throughout the larger Formosa Mine area.

General response actions potentially capable of achieving RAOs and goals for the Formosa 1 Adit discharge are screened for applicability in Table 7. Response actions include no action, institutional controls and engineering controls that include water treatment. The general response actions, technology types, and process options are discussed in text following the table. Screening comments are found in Table 7, and all of the technologies and options presented in Table 7 are retained for use in alternative development.

6.1.1 No Action

No action typically involves no further response or monitoring. However, in this case no action includes activities that require the repair, maintenance and continued operation of the adit discharge conveyance system. No action is generally used as a baseline against which other response options are compared so ***the no action alternative is retained*** for detailed analysis.

6.1.2 Institutional Controls

Institutional controls are used to restrict or control access to or use of a site. Land use and access restrictions are potentially applicable institutional controls. Land use restrictions would limit the possible future uses of the land through modification and inclusion of the restrictions in the Roseburg District BLM Resource Management Plan (BLM 1995). Institutional controls do not achieve clean-up goals but involve access restrictions via mine portal closures, fencing and gates (around ponds) and/or land use restriction controls. However, in addition to limiting access, these controls can provide for long-term public safety. ***Institutional controls are retained*** to complement clean-up and safety actions and will be combined with other process options.

6.1.3 Engineering Controls

Engineering controls are used to reduce the mobility of contaminants by establishing barriers that limit contaminant exposure, reduce contaminant reactivity, and prevent or limit migration or flow of contaminated surface water or groundwater. Engineering controls typically include containment, capping, run-on/run-off controls, re-vegetation and/or disposal. In underground applications, the engineering controls presented are used to stem water flow or provide structural support or strength to materials or workings. These underground engineering controls may include grout curtains, unconsolidated structural fills, cemented backfill, or water-tight cement hydraulic plugs. Engineering controls generally do not reduce the toxicity of hazardous materials; however, they can significantly reduce the mobility of contaminants. ***Engineering controls are retained.***

Table 7. Response Technology Screening Summary

General Response Action	Response Technology	Process Option	Description	Screening Comment
No Action	None	Not Applicable	No Action.	Retained for comparison with other options. Requires maintenance and continued operation of discharge conveyance system.
Institutional Controls	Access Restrictions	Fencing and Gates	Install fences around contaminated areas to limit access. Gating of access roads or mine portals.	Potentially effective in conjunction with other technologies; readily implementable; not considered as a stand-alone alternative.
		Land Use Controls	Legal restrictions to control current and future land use.	Potentially effective in conjunction with other technologies; readily implementable; not considered as a stand-alone alternative.
		Portal Closures	Close mine portals with backfill, plugging or installation of locking barred gates. Also necessary for public safety.	Potentially effective closure option, readily implementable; may be considered as a stand-alone alternative or used in conjunction with other technologies; readily implementable.
Engineering Controls	Adit Discharge Water Treatment	Semi-passive Lime Addition Treatment to Increase the pH of the Flow-through Adit Water	Increased pH would result in precipitation of metal hydroxides prior to discharge thereby mitigating, in part, current issues related to clogging of the conveyance system and also resulting in discharge of higher pH water with lower concentrations of metals to the LAD area.	Potentially effective treatment option as treatment of adit discharge prior to it entering the pipeline conveyance system will enable water of higher quality to be delivered to the LAD area and reduce impacts to down-gradient soils in the LAD area and Upper Middle Creek. May be considered as a stand-alone alternative or used in conjunction with other technologies; readily implementable.
	Underground Flow Control	Flowing Fracture Grout Curtain	Drilling fractured rock zones and filling fractures using high-pressure cement or bentonite grouting techniques to stem or divert water flow into the adit.	Effective in stopping or reducing flow through fractures adjacent to workings. Diverts flow around workings. Implementable; best when used with backfill for optimum structural support.
		Backfill of Workings	Placing unconsolidated mine waste backfill or aggregate based cemented backfill along sections of adit for structural support and strength, to protect grout curtains and plugs and to restrict flow along workings.	Effective as structural support to prevent collapse; significantly restricts flow when installed tight to back; readily implementable.
		Acid Resistant Cement Hydraulic Adit Plugs	Placing a high strength, acid-resistant concrete plug to block and seal workings in raises or drifts and act as a seal or barrier to groundwater flow.	Effective as a barrier or seal to water flow along workings or for isolating select areas of underground workings in order to prevent the mixing of groundwater; readily implementable, most effective when used with backfill (but not required).

6.1.3.1 Adit Discharge Water Treatment

Chemical addition for pH adjustment and metals removal, as proposed in Alternative FA-2, has proven to be effective for concentration reduction in heavily metals laden water. The system effectiveness for the Formosa 1 Adit would be expected to be somewhat effective in metals concentration reduction over the short-term and, if the system is properly maintained, somewhat effective over the long-term. The proposed system would rely on enhanced settling in the treatment tanks without filtration and it is expected that there may be some residual suspended solids in the conveyance system and discharge. In addition to the residual solids, it would be expected that the discharge would still contain some concentration of dissolved metals and therefore, the resulting discharge will be improved from current water quality but is not likely to be in compliance if any future water quality standards were imposed at the site. The treatment system would be highly effective in inducing rapid and local precipitation of ferri-hydroxides and co-precipitation of other metals from the mine discharge waters and improving water quality prior to it entering the conveyance pipeline and being discharged to the LAD area. ***Adit discharge water treatment is retained*** as a possible response action.

6.1.3.2 Underground Flow Control

Underground flow control technologies such as hydraulic adit plugs are used as contaminant source and migration control measures. They are used to minimize, divert, or eliminate contaminated water flows from either entering and/or leaving underground mine workings. By doing so, they minimize the impacts of discharging contaminated water to the surface and to down-gradient surface water flows. Typically, these flow controls are not thought to reduce the toxicity or volume of the water because some portion of the underground flows are usually diverted to other pathways, typically bedrock fracture system pathways that controlled groundwater flow before the underground workings were excavated. Methods, such as grout curtains around flowing fracture systems within the adit, can also significantly reduce water flow along workings. Cement plugs that act as barriers or seals to groundwater flow are appropriate alternatives when underground flows need to be controlled, diverted, or eliminated.

In addition, because adit plugs raise groundwater levels behind the plug, they are capable of placing sulfide-rich rock below the water table as well. Sulfide oxidation continues below the water table, but at a significantly reduced rate that eventually consumes the available oxygen from the groundwater and creates chemically reducing conditions. This stops the sulfide oxidation process and the generation of acid, thereby raising pH levels in the groundwater and greatly reducing metal solubility. Both of these processes can provide the opportunity to significantly improve groundwater quality behind the plug. Plugging and grouting flow control alternatives use common underground mining practices, with equipment that is readily available, and site- or application-specific designs. ***Underground flow techniques are retained*** as a possible response action.

6.2 Response Alternative Development

Only the most promising technologies and process options that were identified and retained through the screening process are summarized in Table 7. These options appear to be effective and readily implementable for a reasonable cost and were used to identify and develop the focused response action alternatives for further consideration.

EPA guidance for NTCRAs suggests that only the most qualified technologies that apply to the media or source of contamination be evaluated in detail in the EE/CA. Using this guidance, response action alternatives for the Formosa 1 Adit are developed by combining reclamation technologies and process options such that each alternative fulfills in whole or part the RAOs and goals for the project. The No Action alternative is the one exception to this statement but the No Action alternative is used in the detailed analysis as a baseline against which the other alternatives can be compared. Assembling the alternatives was accomplished by combining process options so that each alternative either offered a distinct benefit over another alternative, or provided a different approach to meeting the RAOs and goals. The alternatives also cover a reasonable range of costs, an important factor that will be considered in the detailed analysis.

There are two distinct types of problems being addressed in this particular response action, one pertains to contaminated inflow into an underground mine that subsequently flows out of the mine and contaminates down-gradient surface water and groundwater; the other pertains to the handling of AMD discharge by management of the flow and treatment of the discharge to improve water quality. Both are potentially very important with respect to overall contaminant loading to Upper Middle Creek based on the loading analysis presented in Section 3.2.4. That analysis indicates that during both low and high flow, the Formosa 1 Adit is the largest single source of metal loading to Upper Middle Creek even when compared with other waste rock sources and repositories at the site.

6.2.1 Formosa 1 Adit-Focused Response Alternative Development

Table 8 lists response action alternatives that will be considered for contaminated inflow and outflow at the Formosa 1 Adit. Also listed in Table 8 are the relevant process options and technologies that constitute each alternative.

Institutional controls, in the form of a portal closure or gate for closure and safety purposes, are assumed to be an essential part of all of the alternatives developed below. The response action alternatives, with the exception of the no action alternative, are all engineering controls designed to control contaminated underground water flows out of the Formosa 1 Adit and or treat water discharge from the adit.

Table 8. Response Action Alternatives for the Formosa 1 Adit Source Area

Alternative		Response Technology/Process Options
FA-1	No Action	None. Continue maintenance and operation of the existing conveyance system 'as is' until closure of the adit can be addressed as part of an overall site-wide closure remedy.
FA-2	Water Treatment and Replacement of AMD Conveyance System	Water treatment of the existing AMD discharge for turbidity, iron removal and pH adjustment, and replacement of the existing AMD conveyance system.
FA-3	Installation of a Flow-Through Hydraulic Adit Plug	Elimination or reduction of the flow from the Formosa 1 Adit using hydraulic adit plugging methods. Construct a water-tight concrete plug with a flow-through pipe within the Formosa 1 Adit near the 1100 level workings, approximately 350 to 425 ft in from the portal. Flow through the pipe would be controlled with valves allowing no flow or controlled flow through the water-tight plug. Backfilling various portions of the Formosa Adit with cemented backfill and waste rock aggregate for structural support and strength needed to help protect grout curtains and reduce or minimize flow along a particular portion of the drift.

7.0 DETAILED ANALYSIS OF RESPONSE ALTERNATIVES

Response alternatives developed that passed the initial screening process in the previous section are carried forward for final analysis in this section and are compared in detail in the next section (Section 8). Response alternatives represent a range of potential actions that can meet, to some degree, RAOs for the project, and achieve distinct levels of protectiveness to human health and the environment for a reasonable range of costs.

7.1 Evaluation Criteria

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

1. Effectiveness
2. Implementability
3. Cost

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

Implementability addresses the technical and administrative feasibility of implementing an alternative and the availability of various services and materials required to accomplish its implementation. Technical feasibility considerations include the applicability of the alternative to the waste source, availability of the required equipment and expertise to implement the alternative, and overall reliability of the alternative. Administrative feasibility evaluates logistical and scheduling constraints, as well as overall acceptance of the response action by the State public, and other stakeholders.

Evaluating the *cost* of alternatives involves developing conservative cost estimates based on the materials needed and the construction elements associated with implementing the alternative. These costs do not necessarily represent the cost that may actually be incurred during construction of the alternative because many design details are preliminary at this stage. However, a similar set of assumptions is used for all the alternatives so that the relative differences in cost between alternatives are fairly represented. Unit costs were developed by analyzing data available from nationally published cost estimating guides. Where possible, cost data incorporate past engineering experience, actual operating costs and unit costs which have been realized during similar reclamation projects. Unit costs for construction, often referred to as hard costs, are based on assessments of construction techniques, equipment, site accessibility, material handling distances and methods, as well as site conditions. A construction contingency is added to the subtotal of all the construction costs. Soft costs which include construction administration, surveying and engineering costs are valued at a percentage of the total construction cost estimate. In line with EPA guidance, the total estimated cost is expected to be within plus 50 percent and minus 30 percent of actual costs. The costs for operation and maintenance of each alternative are included for a 10-year period of operation, assuming the final site remedy for the Formosa Superfund Site will be determined and constructed within that time. Total costs for each alternative are presented in the cost discussion for each alternative with the detailed supporting unit cost spreadsheets presented in Appendix B.

7.2 Formosa Adit Source Control Alternatives

This section presents the detailed analysis of alternatives listed in Table 8.

7.2.1 No Action—Alternative FA-1

Alternative FA-1 involves leaving the Formosa 1 Adit in its existing condition. No reopening or closure activities would be started. No flow-reduction measures from the adit would be undertaken to control contaminant migration from the mine portal or to reduce its toxicity or volume. Repairs, maintenance and continued operation of the existing adit water conveyance system would continue presumably until the adit discharge could be addressed as part of an overall final remedy for the Formosa Superfund Site under CERCLA. Continued operation, which will be under the direction of BLM, will require annual high-pressure water jet cleaning to flush iron precipitates out of the upper portion of the pipeline system and prevent clogging. The existing treatment tank will need to be inspected annually and cleaned-out using vacuum trucks as necessary. The pipeline will need to be inspected and repaired as necessary (joints, segment damage by rock fall, leakage, and clogging). Water quality is expected to be similar to that currently entering the system. Surface water flow and quality monitoring would be conducted annually under the Formosa Superfund Site investigations.

7.2.1.1 Effectiveness

For Alternative FA-1, effectiveness was gauged by the ability of repair and minimal maintenance of the conveyance system to collect, contain, and provide transport of adit waters to the discharge point with minimal leakage along the pipeline until a site-wide closure plan is developed. Overall effectiveness of Alternative FA-1 is poor. Under existing conditions, acidic water, dissolved metals and sediment will continue to flow from the portal and into the pipeline conveyance system to its discharge in the LAD area. The system is also likely to continue to have issues with overall disrepair due to its age the fact it is beyond its intended design life. Alternative FA-1 does not address Middle Creek surface water or near portal groundwater impacts, nor does it provide any controls on contaminant migration via direct contact or ingestion. Toxicity, mobility, and volume of contaminants would not be reduced under

Alternative FA-1. Surface and groundwater ARARS would not be met at the point of discharge or in receiving waters.

Alternative FA-1 is not expected to move water quality toward compliance with ARARs or water quality standards. Protection of the environment would not be achieved under this alternative.

7.2.1.2 Implementability

Alternative FA-1 is both technically and administratively feasible. However, it is not a viable means of controlling the migration of contaminants that flow from the mine and significantly impact down gradient surface water quality and various environmental receptors. The system requires regular inspection and activities to repair and maintain the system.

7.2.1.3 Cost

No capital costs would be incurred under Alternative FA-1. However, annual maintenance costs including repair crews and materials would be incurred. These activities are currently carried out on an annual basis on behalf of the BLM by a contractor. Recent annual costs have been about $22,000. The cost of implementing the Alternative FA-1 would be $259,772 for 10 years, assuming an annual three percent increase for inflation. There are also likely external costs associated with Alternative FA-1, including the loss of certain ecological functions.

7.2.2 Water Treatment and Replacement of AMD Conveyance System—Alternative FA-2

Alternative FA-2 would serve to control turbidity of AMD discharge and to precipitate and settle ferri-hydroxide minerals with associated adsorbed metals and result in increased pH prior to it being conveyed through the discharge pipeline system downslope to the LAD area. No additional treatment will be undertaken in order to meet surface or groundwater quality standards prior to discharge in the LAD area. The AMD conveyance system will be replaced and designed to operate for a 10-year period until the final remedy for the Formosa Superfund Site is determined and implemented (Figure 35).

It is recognized that EPA has investigated water treatment as an option for the final remedy. The proposed water treatment for Alternative FA-2 is an interim system intended to reduce metals concentration in the adit discharge by increasing the pH with the addition of lime to promote precipitation of metals prior to discharging to the existing LAD. This would result in less metal precipitation within the replacement discharge pipeline and a decrease in the metals concentration and acidity of the discharge to the LAD. It is not this intent of Alternative FA-2 to meet surface or groundwater discharge standards as would be required for final closure.

Alternative FA-2 would include a semi-passive system in which lime would be added to the adit discharge to increase the pH of the flow-through adit water. This increased pH would result in precipitation of metal hydroxides, primarily ferri-hydroxides, upstream of the AMD conveyance system and result in mitigation, in part, current issues related to clogging of the conveyance system. Alternative FA-2 would also result in discharge of higher pH water with lower concentrations of metals to the LAD area and ultimately into Upper Middle Creek.

The AMD discharge from the adit would be directed into a series of two baffled treatment tanks to allow for settling of the precipitated solids from the flow (Figure 35). Chemical addition, in the form of quicklime pellets, to the treatment system feed (AMD discharge) flow would promote the precipitation of metal hydroxides. The discharge from the treatment tanks is expected to be at a higher pH with lower metals concentrations and would be conveyed through the replacement discharge pipeline to the existing LAD area without further treatment or filtration. If Alternative FA-2 is selected for interim water treatment and management, the existing discharge pipeline would be replaced with an 8-inch HDPE pipeline following the same pathway to the LAD as the current discharge pipeline and designed for a 10-year operating life. It is assumed for costing purposes of this EE/CA that the water treatment system would be an interim solution to the site discharge and costs include water treatment capital and operating costs, new pipeline costs, as well as maintenance and repairs of the replacement pipeline.

7.2.2.1 Effectiveness

For Alternative FA-2, effectiveness was measured by the ability of the response action to remove COCs such that adit discharge effluent more closely approaches human health or aquatic water quality standards (see Section 4.0). While there are currently no water quality standards in place for the Formosa Superfund Site, and Alternative FA-2 is not required to meet any discharge standards, it is intended to improve the water quality to be discharged as per the stated RAOs for the site, until the Record of Decision is published and implemented.

Long-Term and Short-Term Effectiveness and Permanence

Lime addition for pH adjustment and metals removal, as proposed in Alternative FA-2 has proven to be effective for concentration reduction in heavily metal-laden water. The system effectiveness for the Formosa site would be expected to be somewhat effective in metals concentration reduction over the short term and, if the system is properly maintained, somewhat effective over the long term. The proposed system would rely on enhanced settling in the treatment tanks without filtration and it is expected that there may be some residual suspended solids in the conveyance system and discharge. In addition to the residual solids, it would be expected that the discharge would still contain some concentration of dissolved metals and therefore, the resulting discharge will be improved from current water quality but is not likely to be in compliance should any future water quality standards be imposed at for the Formosa Superfund Site. The treatment system would be highly effective in inducing rapid and local precipitation of ferri-hydroxides and co-precipitation of other metals from the mine discharge waters, thereby improving water quality prior to it entering the conveyance pipeline and being discharged to the LAD area. It is also expected that this treatment would result in enhanced operation and reduced maintenance of the discharge conveyance pipeline.

Overall Protection of Human Health and the Environment

Treatment with Alternative FA-2 of adit discharge prior to it entering the pipeline conveyance system will enable water of higher quality to be delivered to the LAD area. If treatment using Alternative FA-2 is not performed, water of poor quality will continue to enter the pipeline conveyance system to its discharge point at the LAD area. As stated previously, this treatment system is not necessarily recommended to comply with specific water quality standards for discharge, and would enhance the water quality discharge only compared to what is currently discharged.

Reduction of Toxicity, Mobility, or Volume through Treatment

Alternative FA-2 would chemically precipitate ferri-hydroxide along with other co-precipitates in holding tanks near the portal and allow the delivery of higher quality discharge with reduced contaminant volume and potentially reduced toxicity to the LAD area via the conveyance system.

Compliance with ARARs

Alternative FA-2 would likely comply with federal or state action-specific ARARs as it would assist with treatment of and enhanced quality of the adit discharge. Federal or state contaminant-specific ARARs would likely not be met as treatment of the water would only enhance iron hydroxide precipitation and removal of some metals by co-precipitation prior to entry into the conveyance pipeline system.

Meeting Response Action Objectives and Compliance with ARARs

Implementation of Alternative FA-2 would meet four of the RAOs for the project by reducing the contaminant loading of the adit discharge prior to release to the environment, thereby reducing exposure or potential exposure to low pH, heavy metals-laden waters currently being released at the LAD area and subsequently to the Upper Middle Creek. Compliance with ARARs may or may not be fully achieved under Alternative FA-2, as contaminant-specific standards associated with the ODEQ and federal water quality standards might not be achieved in receiving waters without the implementation of other response alternatives in the final site-wide closure plan for the Formosa Superfund Site under CERCLA to control contaminant release from other sources in the larger Formosa Mine area.

Surface water quality along Upper Middle Creek would improve as a direct result of Alternative FA-2 due to reduction in contaminant loading of the adit discharge. While improvements in water quality may in part be limited by control of water chemistry at the station immediately below the current discharge point, a considerable reduction in metal concentrations and loading should be realized with this alternative.

Contaminant-specific ARARs for ambient air would be met under this alternative, as air quality would not be impacted by water treatment operations. Action-specific State of Oregon air quality regulations related to dust suppression and control during construction activities would be met using best management practices.

Location-specific ARARs, particularly those associated with cultural and historic resources, would be met, as no cultural or historic features will be impacted if this alternative is implemented. Threatened and endangered species present in or near the site may experience a reduced risk due to the decrease in metals loading to the environment and otherwise would not be affected by this alternative as there will be no new disturbances, no permanent facilities, and implementation of the alternative would be completed in one season. No other location-specific ARARs apply.

Action-specific ARARs would be expected to be met in part by Alternative FA-2. Oregon and federal water quality standards would likely not be met under this alternative because the water treatment system is intended to reduce bulk metals concentration and does not address the other discharges of iron and other metals to surface water and groundwater from other sources within the Formosa Mine that exceed standards. Alternative FA-2 would comply with federal or state action-specific ARARs by further reducing the loading of contaminants from the adit discharge water.

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

7.2.2.2 Implementability

Alternative FA-2 is technically and administratively feasible. The pH adjustment system would need to be constructed at or near the portal. Depending on treatment system design, equipment may need to be shipped from outside the area. Area plumbing and electrical contractors would need to be hired to install the system. The system would require regular inspections and maintenance to replace the amendment (lime), and to remove and dispose of the ferri-hydroxide precipitates from the treatment tanks. Disposal is assumed to be at an off-site location. The replacement of the AMD conveyance pipeline would require removal and disposal of the existing pipeline and a pipeline contractor would be needed for removal of the existing and installation of the new discharge pipeline system. Materials removed from the existing pipeline would need to be hauled to the closest appropriate solid waste disposal facility.

7.2.2.3 Cost

Figure 35 illustrates the overall site plan for the water treatment. The proposed treatment system would consist of the following primary components: 1) chemical feeder, 2) treatment tanks, and 3) discharge pipeline. Pelletized lime would be added to the adit discharge flow and sent through a series of two treatment tanks. The discharge would then be directed into the replacement HDPE discharge pipeline and released at the existing LAD. The estimated cost for the treatment system is presented in Table 9 below. The cost is based on the assumption that this system will operate at the average flow rate of 28 gpm as presented in Section 2.6.3 above and is an interim system that would operate for 10 years until final closure. The treatment tanks are available for rent during this period of time and would not require a capital purchase. The pipeline costs include removal and disposal of the existing pipeline and above-ground installation for the replacement pipeline. Also included in this cost are ancillary equipment and security, including fencing, site grading, and set-up and start-up costs. Operating expenses are also presented in Table 9 for the assumed 10-year operating period.

Table 9. Water Treatment and Replacement of AMD Conveyance System Alternative Costs

Formosa Mine Adit Cost for Interim Water Treatment System	
Capital Costs for Interim Water Treatment System	$55,380.00
Water Treatment Pad Grading	$21,583
Discharge Pipeline System Replacement	$9,053
Operating Costs for Interim Water Treatment System - 10 Year (3% per yr inflation)	$1,276,045
O & M Costs - 10 Year (3% per yr inflation)	$146,181
Total Estimated Construction Costs:	**$1,508,241**
Bonding, and Insurance (10%):	$150,824
Contingency (20%):	$301,648
Total Estimated Construction:	**$1,960,713**
Engineering Design (8%)	$156,857
Construction Oversight (6%)	$117,643
TOTAL ESTIMATED PROJECT COSTS:	**$2,235,213**

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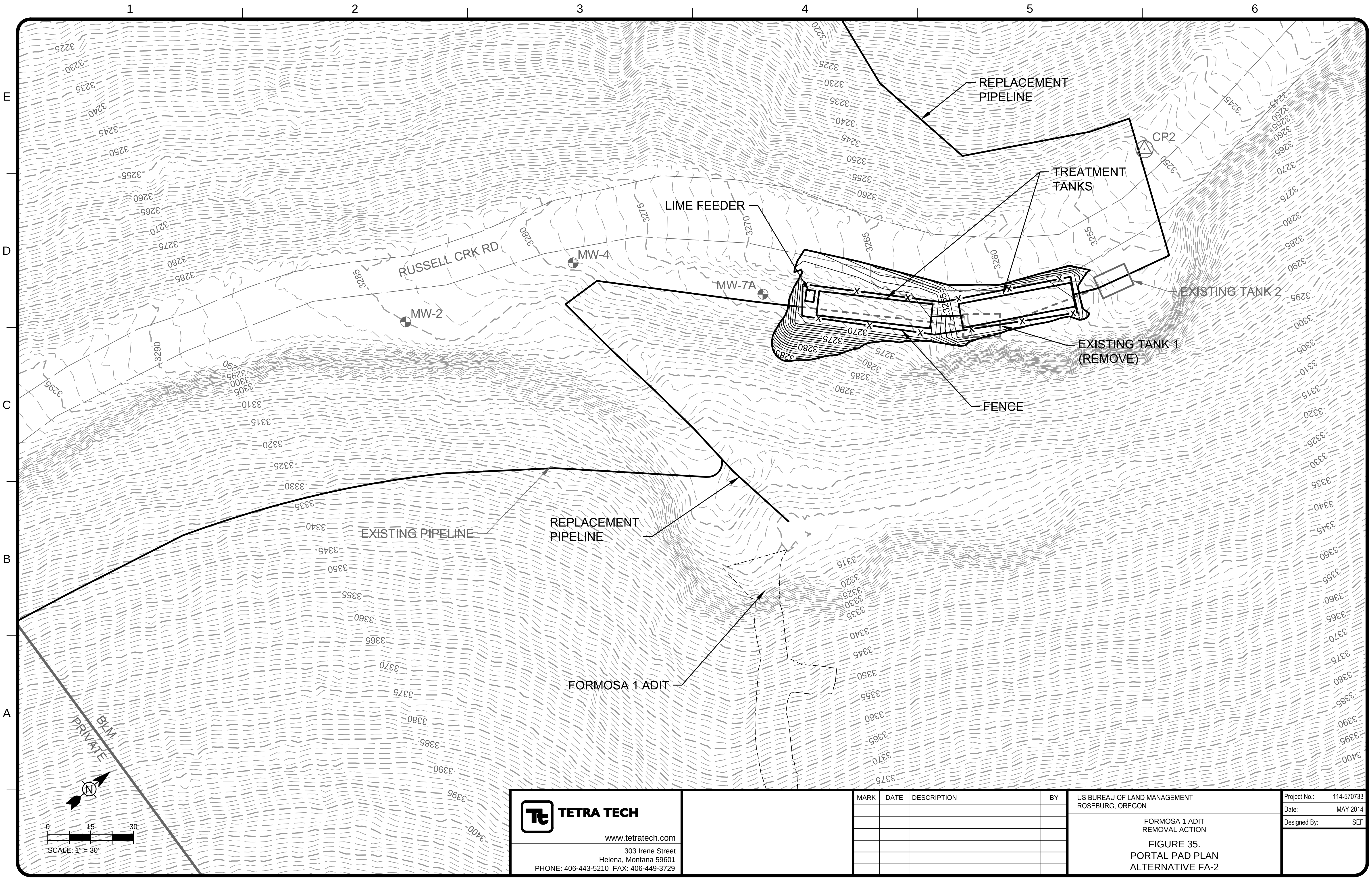

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7.2.3 Installation of a Flow-Through Hydraulic Adit Plug—Alternative FA-3

Alternative FA-3 includes rehabilitation of the Formosa 1 Adit and reduction or elimination of the flow from the adit using a single flow-through hydraulic adit plugging method combined with fracture flow grouting. Although some final adit closure options for the Formosa 1 Adit (occurring after installation of this initial plug) shall be described with this alternative, implementation of any final adit closure is considered beyond the scope of the proposed removal actions and will be addressed as part of the overall closure of the Formosa Superfund Site.

7.2.3.1 General Description

The Formosa 1 Adit is the lowest elevation adit portal in the Formosa Mine complex and is a haulage level adit collared in volcanic tuff units that accesses the 1100 level workings. The haulage level adit was driven for a distance of about 400 ft at a grade of about 0.5 percent from its portal to its intersection with the 1100 level workings. It is assumed that all water entering the Formosa 1 Adit drains down through the overlying workings or enters through fractures in the overlying bedrock. Increases in groundwater levels in MW-24 (completed in the Formosa 1 Adit) and MW-8 (completed in the 1100 level workings) strongly reflect increased precipitation associated with an annual rainy season typically lasting from October to March. This groundwater water level typically falls through the drier season from April through September to steady state elevations in MW-24 and MW-8. The principal purpose of Alternative FA-3 is to reduce or eliminate the flow of contaminated groundwater collecting in the mine-pool and discharging from the adit portal, thereby minimizing impacts to down-gradient surface and local groundwater water receptors.

Figure 36 a general site plan showing potential areas for laydown and waste rock, including their proximity to the Formosa 1 Adit portal pad. Figure 37 illustrates the conceptual construction plan for the Formosa 1 Adit portal pad, and Figure 38 is an overall site map showing various surface features that would be constructed in support of Alternative FA-3, which would consist of constructing a new water-tight, flow-through hydraulic adit plug approximately 400 to 450 ft from the portal, just down-gradient from the adit's intersection of workings on the 1100 level. Portal pad site preparation for mine rehabilitation support facilities (Figure 37 and Figure 39), mine dewatering, re-opening of the adit portal, and rehabilitation of the first 450 feet of the adit would need to be completed prior to plug construction. A temporary storage facility would also need to be constructed for mine-waste and backfill removed during the rehabilitation process (Figure 40). A more detailed list of the tasks involved in site preparation and mine rehabilitation is included in Section 7.2.3.2 – Alternative Task List. Although the possible location of a future outboard adit plug is shown on Figure 38, it is not a part of this removal action; final adit closure would be considered as part of the final remediation effort conducted by EPA.

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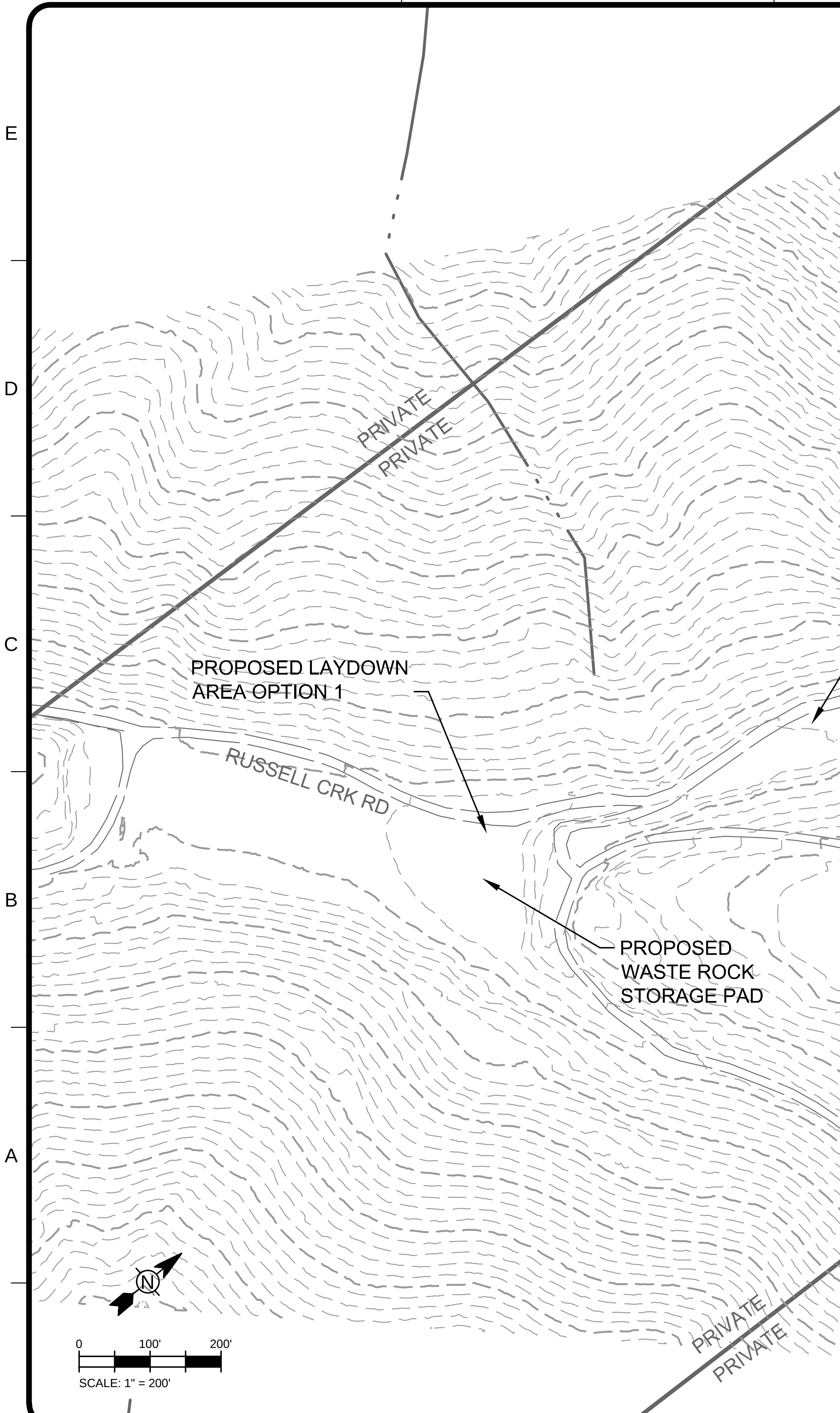

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FORMOSA 1 ADIT
REMOVAL ACTION

FIGURE 36.
GENERAL SITE PLAN
ALTERNATIVE FA-3

Project No.:	114-570733
Date:	JULY 2014
Designed By:	SEF

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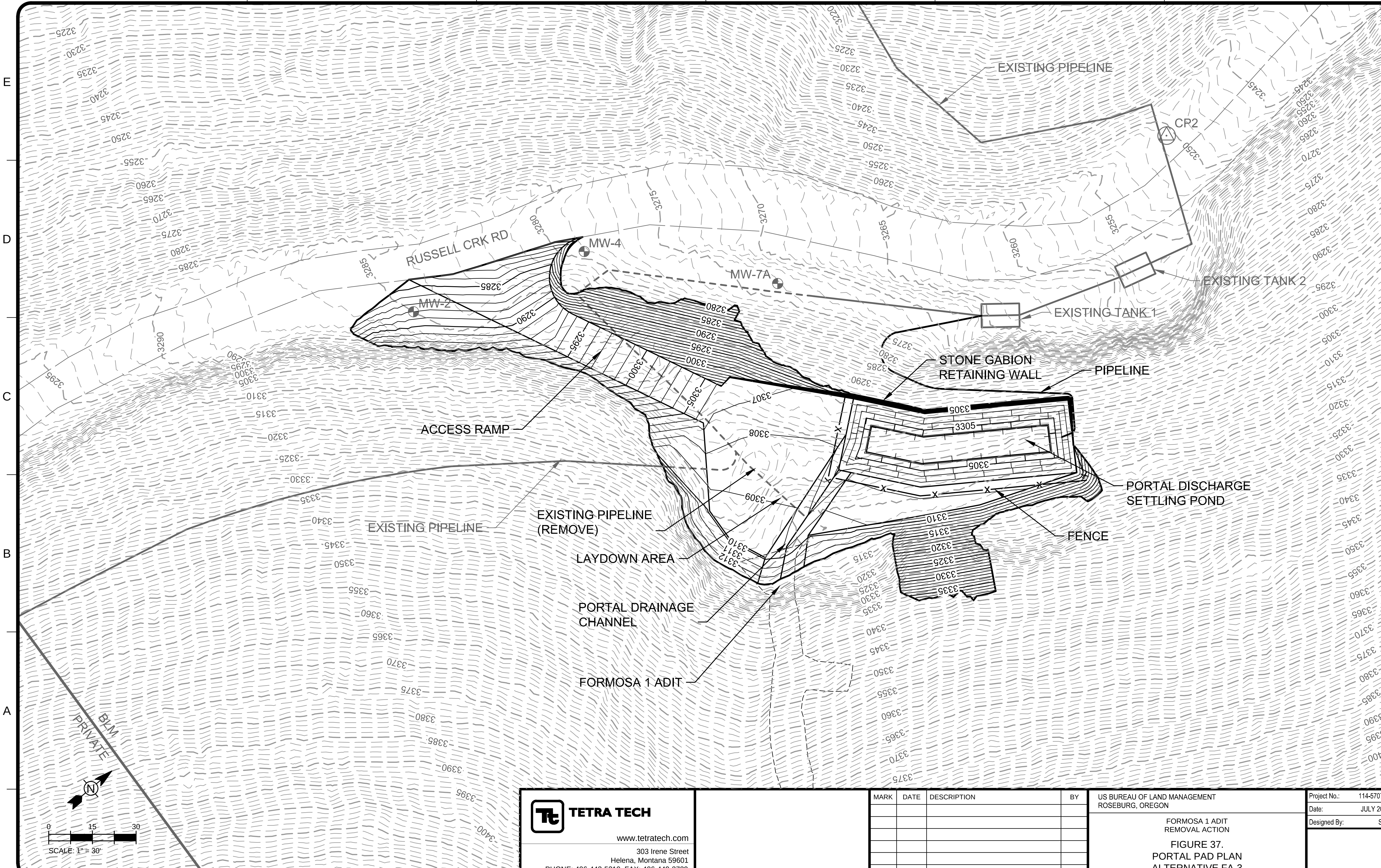

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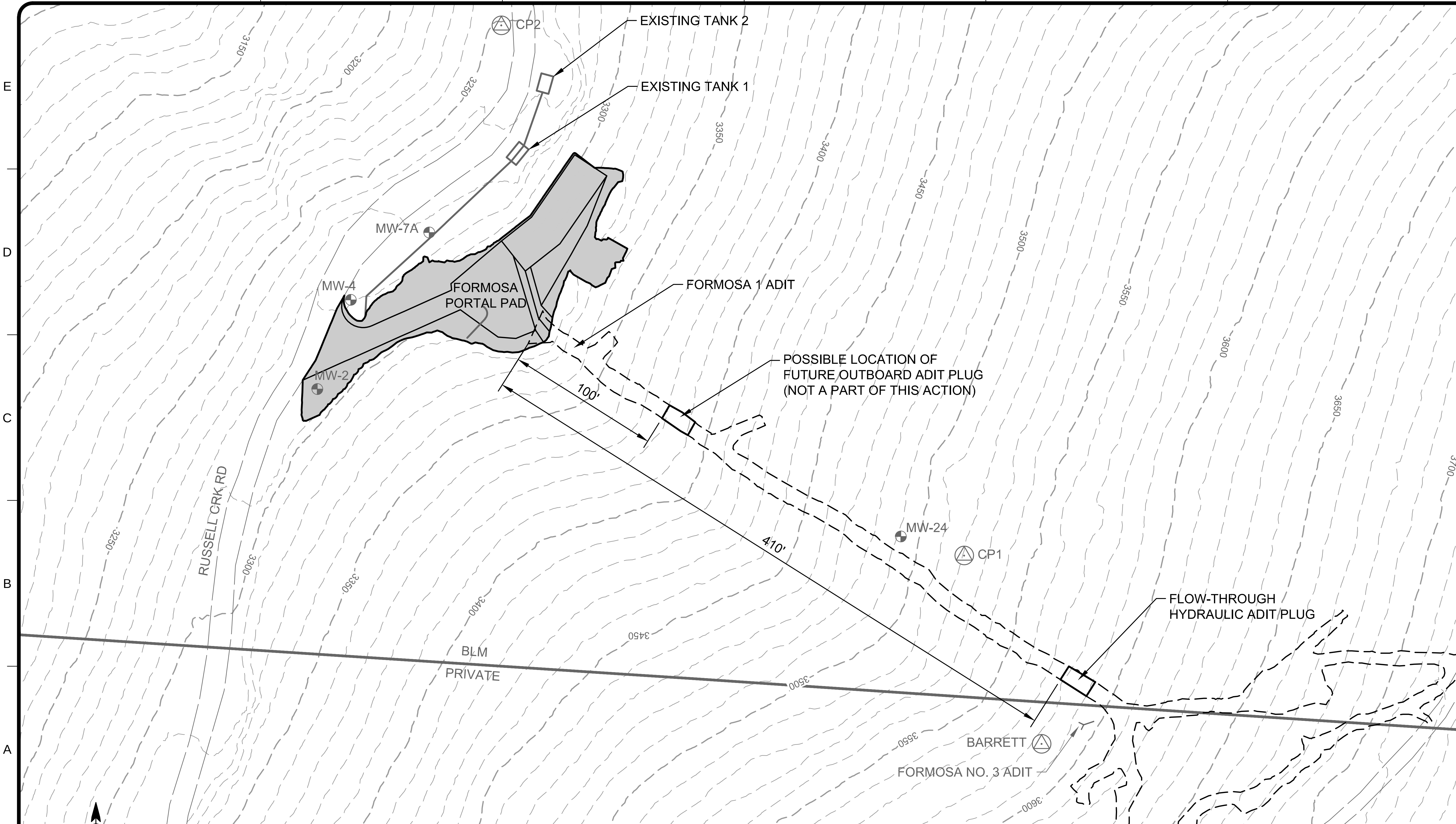
REMOVAL ACTION

FIGURE 37.
PORTAL PAD PLAN
ALTERNATIVE FA-3

Project No.:	114-570733
Date:	JULY 2014
Designed By:	SEF



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FORMOSA 1 ADIT
REMOVAL ACTION

FIGURE 38.
ADIT PLUG LOCATION PLAN
ALTERNATIVE FA-3

Project No.: 114-570733
Date: JULY 2014
Designed By: ARK

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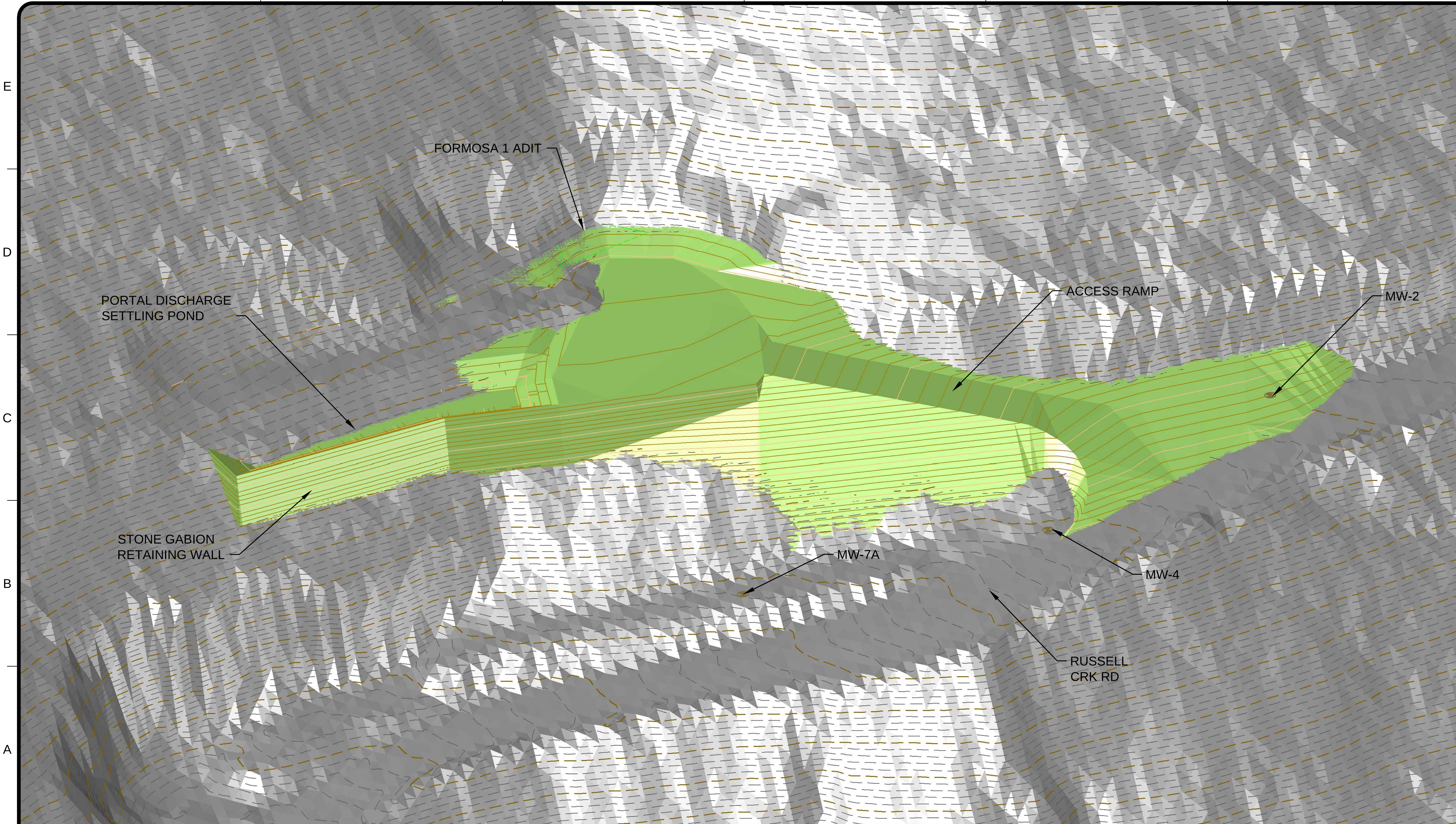

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FORMOSA 1 ADIT
REMOVAL ACTION

FIGURE 39.
PORTAL PAD 3-D VIEW
ALTERNATIVE FA-3

Project No.:	114-570733
Date:	JULY 2014
Designed By:	SEF

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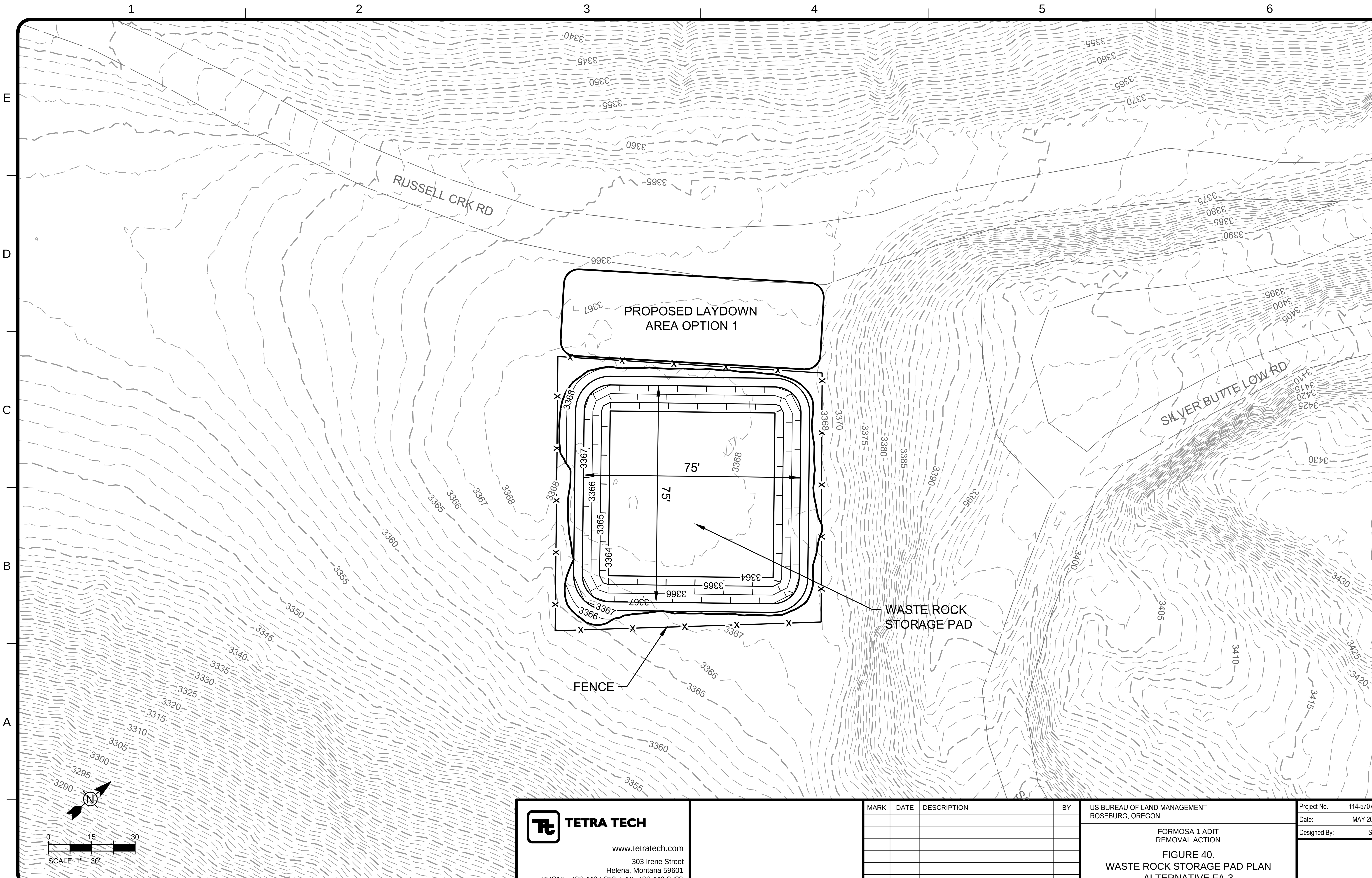

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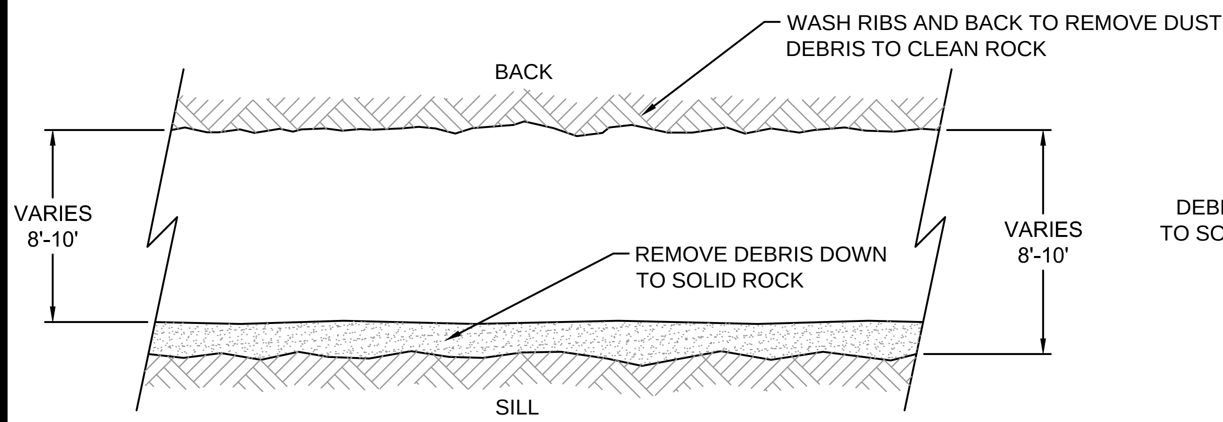
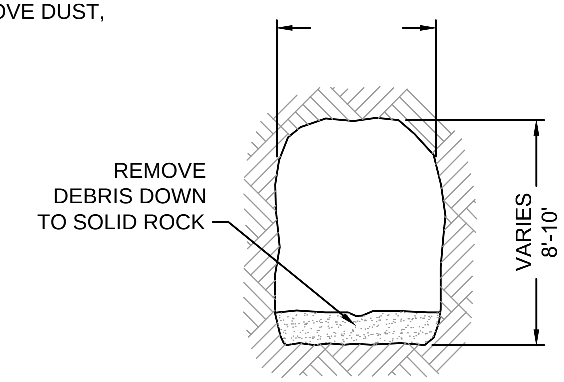
FORMOSA 1 ADIT
REMOVAL ACTION

FIGURE 40.
WASTE ROCK STORAGE PAD PLAN
ALTERNATIVE FA-3

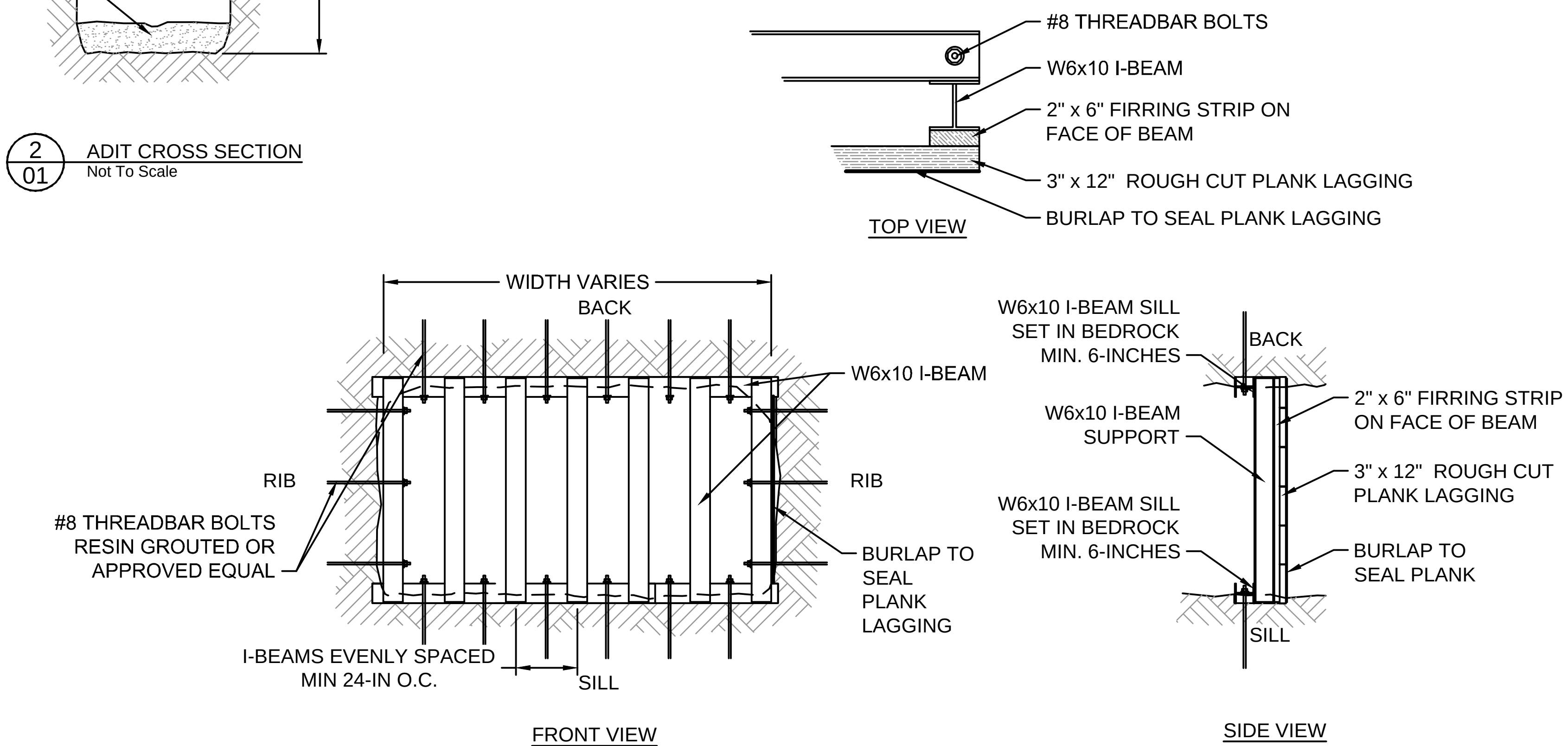
Project No.:	114-570733
Date:	MAY 2014
Designed By:	SEF



1/01 ADIT BEFORE PLUG SITE EXCAVATION - LONGITUDINAL VIEW
Not To Scale



2/01 ADIT CROSS SECTION
Not To Scale



4/01 BULKHEAD DETAIL
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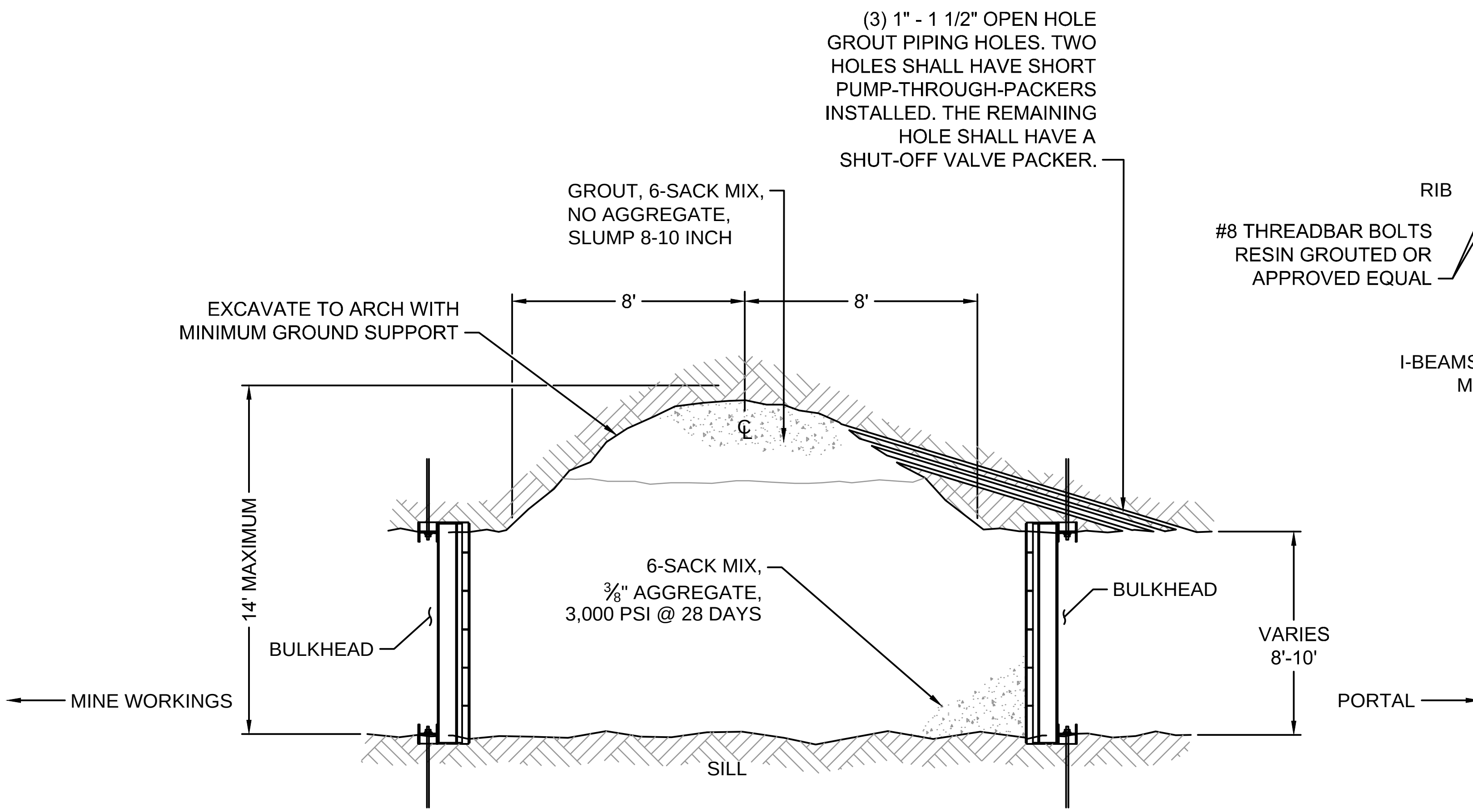

3/01 PLUG SITE EXCAVATION - LONGITUDINAL SECTION VIEW
Not To Scale

NOTES

1. TOP AND BOTTOM BEAMS INSET IN BEDROCK
2. EMBEDMENT DISTANCE FOR ROCK BOLTS IS 6-FT

PLUG SITE INFORMATION

PLUG SITE	DIST. FROM PORTAL	APPROX. WIDTH	APPROX. GROUT VOLUME
OUTER PLUG	100-FT	7-FT	1260 CF
PLUG 400	400-FT	7-FT	1260 CF

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U.S. Army Corps of Engineers
Delta Junction, Alaska

FORMOSA MINE ADIT

FIGURE 41.
ADIT PLUG CONCEPTUAL MODEL

Project No.:	106-4426
Date:	April 2014
Designed By:	RD
SHEET	01

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The rehabilitated adit would be inspected for fractures contributing significant water flows into the adit, and a plan would be developed and implemented to pressure grout these fractures to stem the flow of water into the workings. The hydraulic adit plug would be constructed in an area that is determined by a geotechnical survey to be favorable, consisting of low fracture density and high rock strength (rock quality) to insure its long-term stability and performance. A dam upstream of the plug station would be constructed to prevent water from entering the plug excavation during construction. A bypass drain pipe would be installed in the dam to pass water through the plug station and discharge the water downstream of the plug site. Figure 41 illustrates some of the construction features and details of the proposed plug installation. The sill, back, and ribs at the plug location would be notched (for hitches for the bulkheads), an arch would be cut in the back of the plug station to insure tight filling of the plug, and all surfaces would be scaled of loose debris. The plug station may be tapered towards the portal if rock surfaces in the plug station are not irregular enough to insure a tight, locking seal with the concrete. The plug area would be cleared of all rock fall debris and sediments, and all surfaces would be washed free of fine-grained materials to allow a water-tight bond between the concrete plug and the rock. Structural I-beam frames would be rock-bolted to the rock in the bulkhead locations and they would be faced (towards the inside of the plug) with 3-inch-thick wooden forms for each bulkhead, located approximately 16 to 20 ft apart, at the front and back of the plug. The interior of the bulkheads and the junction between the forms and the ribs would be covered with burlap to allow water inside the plug station (if any) to pass through the bulkhead. A 6-inch HDPE flow-through pipe would be placed through the plug with two butterfly valves on the downstream end. A pressure gauge and spigot would be installed between the two valves. To facilitate concrete pumping, a 4-inch-diameter steel Victaulic pipe would be installed from the portal to the plug site. A concrete pumper truck and over-the-road concrete trucks would be used to place approximately 50 to 70 cubic yards of concrete between the bulkheads to form the plug. Air would discharge through a breather pipe at the highest point of the arch excavated in the back of the plug station, in the void between the bulkheads. Cement would be returned through the breather pipe when the plug is full. The forms would be abandoned in place. If deemed necessary (based on rock quality and fracture density) a grout curtain would be installed by drilling and pressure grouting with either Microfine or Portland cement for fractures within 20 to 30 ft surrounding the plug. Shotcrete would be applied to the rock-bolted screen on the adit walls and back within approximately 20 ft of the plug. Backfill would be placed in the first 20 to 30 ft on both sides of the plug (if possible) as a buffer to help prevent damage to the plug in case of future adit collapses. Other open fracture systems in the adit at a distance of about 100 ft from the portal to the adit plug would be pressure grouted either during adit rehabilitation or following construction of the plug. Locking gates would be installed at the adit portal and remain in place until a final adit closure is developed.

A transducer could be installed through the plug to measure head behind the plug. However, this could also be measured in MW-24. The maximum head on the plug at this location would need to be less than 75 pounds per square inch (psi) for the estimated 175 ft of overburden above the plug to prevent hydraulic jacking of the overlying bedrock. Based on the adit/topography cross-section (Figure 42), the 75 psi head is not likely to be achieved without first resulting in leakage as springs and seeps in adjacent valleys. Continued monitoring of MW-24 for the depth to groundwater (head) as measured by a transducer and sampling for water quality is recommended to evaluate changes in the chemistry of the mine adit water over time to measure closure system performance.

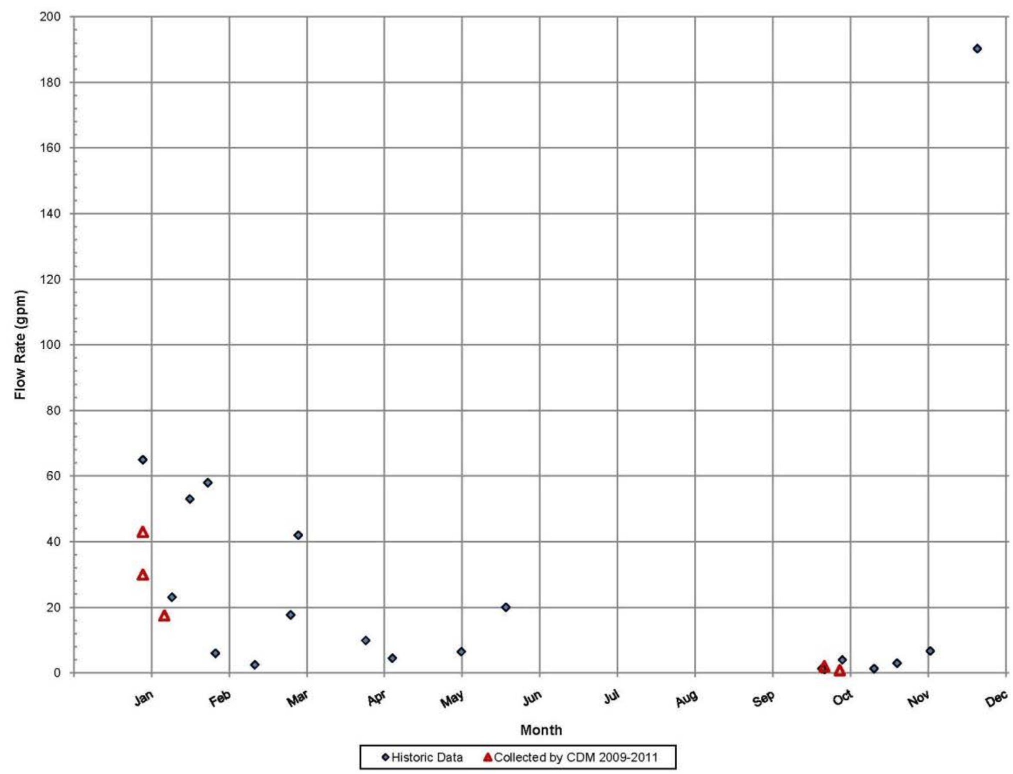

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Figure 42.
Formosa 1 Adit Flow Data

Alternative FA-3 would include maintenance of the existing conveyance system to reduce the possibility of system clogging during construction. The discharge from the adit would be directed to a surge and settling pond that would provide some residence time to allow settling and precipitation of metal hydroxides, primarily ferri-hydroxides, from the flow. The discharge from the pond would be conveyed through the existing discharge pipeline to the existing LAD area without further treatment or filtration.

Once the concrete in the plug is cured (approximately 30 days) the valve(s) in the flow through pipe would be closed and the upper level workings would be allowed to flood with rising groundwater confined behind the hydraulic plug. The hydrologic system would be observed over a period of time (one to several years) with the objective of observing if rising groundwater levels would create a discharge from the overlying Silver Butte Adit located approximately 82 ft in elevation above the 1100 level workings. Flow (if any) out of the Formosa 1 Adit would be monitored and water quality sampled over this period of time. It is likely that the flow from the Formosa 1 Adit would be significantly reduced to 1.5 gpm or less, and the quality might be expected to improve over time as relatively clean regional groundwater moves laterally into the mine's cone of depression behind the plug and sulfide mineralization is placed into a reducing geochemical environment below the regional groundwater table.

EPA currently has a monitoring program designed to track seasonal changes in Upper Middle Creek which they plan to continue through the EE/CA process and afterwards. EPA and BLM will coordinate on revising this monitoring plan to track changes in water chemistry and biotic factors after implementation of the selected alternative for the Formosa 1 Adit.

Once the flow-through plug is in place, if AMD discharges from the Silver Butte Adit during the reestablishment of the regional groundwater system, the valves on the flow-through pipeline in the original Formosa 1 Adit plug would be opened to provide a constant flow of water to any future water treatment or conveyance system to dispose of the adit discharge. This alternative would then have to be re-evaluated to see if other modifications could be made to prevent the discharge of AMD from the Silver Butte Adit. Alternatively, plugging of the Silver Butte Adit might be considered based on the volume and quality of flow from the adit.

Only the initial flow through plug describe above is considered as a possible response action for this EE/CA. The following closure scenario would be analyzed and perhaps implemented pending initial performance evaluation of the first hydraulic plug. If a sufficient rise in groundwater elevation over time does not result in additional discharge from the Silver Bullet Adit, it is envisioned that the Formosa 1 Adit's flow-through pipe in the new plug would be cemented shut and a second hydraulic plug (without a flow through pipe) would be constructed ideally at a distance of about 100 to 150 ft from the portal. Mine wastes from the adit's rehabilitation would be used as backfill between the two plugs (to be later flooded below the regional groundwater table), and the existing conveyance system removed. The mine portal would be closed with a flow-through portal plug via a pipe constructed below the adit portal grade, from which water is collected and discharged into a small subsurface infiltration basin (drain field) constructed near the portal. The surface area in the vicinity of the portal would be re-graded, top-soiled and re-vegetated.

7.2.3.2 Alternative Task List

The following work would be included in the implementation of Alternative FA-3:

- Site preparation for construction (mobilization and laydown areas) (Figure 36).

- Clean out, repair and establishment of a maintenance plan for existing adit discharge conveyance system (Alternative FA-1).
- Construction of a holding or settling pond on the portal pad for use during initial mine dewatering (Figure 37).
- Construction of a new portal pad for mine rehabilitation:
    - Construction of a 50-ft by 100-ft, gently sloping area in front of the portal;
    - Storage areas for an air compressor, generator, ventilation fans, water storage, Conex storage, office and portable toilet; and
    - Design of a near portal waste dewatering pad.
- Designation and construction of a waste storage pad (footprint, stacking height, liner system, and seepage collection/disposal system), which would likely be located near the tailing containment facility in the old mill area; maximum expected capacity is approximately 600 cubic yards (adit 9-ft x 6-ft x 450-ft, ½ full) and includes a storage pad (75-ft x 75-ft lined pad, stacked 6-ft-high; 1/2 below grade), drainage collection system, and temporary cover (Figure 40).
- Dewatering of the adit using MW-24 as a pumping well (no treatment before discharging to existing repaired conveyance system).
- Portal stabilization and drainage control.
- Removal of existing portal plug with continued dewatering and limited treatment:
    - Concrete/rebar portal plug,
    - Limestone backfill, and
    - Wooden bulkhead.
- Removal of mine waste and tailings backfill (0 to 450 ft) (Figure 38).
- Rehabilitation of adit with ground control (bolts, screen, and shotcrete as necessary).
- Installation of underground utilities (drill water and compressed air lines, and ventilation) as adit rehabilitation advances.
- Inspection of rehabilitated adit for fracture flow into the workings, and if flow is significant, design and implement a fracture grouting program:
    - Measure fracture flow and sample water quality;
    - Design grouting plan;
    - Cut drill station;
    - Drill 4 to 20, 40- to 75-ft-long percussion drill holes in a circular pattern around the fracture system in the adit; and
    - Pressure grout fractures to stem the flow.
- Geotechnical survey for plug location(s).

- Conceptual plug design confirmed or altered for actual site conditions (taking maximum head into account) (Figure 41).
- Construction of plug bulkheads and layout of cement pumping line.
- Construction of flow-through hydraulic adit plug (ideally somewhere between 400-450 ft from portal):
  - Design and install pipe cementing plan.
- Pouring cement and allow to cure (approximately 30 days).
- Shutting valves on flow-through pipe.
- Considering grouting open fractures from 100 ft in from the portal to the plug station (at this time or prior to second plug installation).
- Installation of secure locking metal gates at adit portal and potentially air doors just inside the portal.

7.2.3.3 Effectiveness

For the Installation of a Flow-Through Hydraulic Adit Plug Alternative, effectiveness was gauged primarily by the ability of the alternative to either reduce or eliminate the discharge (contaminant loading and/or flow). Concrete plugs to stop water flow are commonly used in dams and similar water retention structures as well as in mines. Recent successful examples include the Glengarry Mine in Montana and the World's Fair Mine in Arizona (Kirk 2013a). In the past for some mine reclamation applications, plugs have been inadequate because they have been installed too closely to the portal. Over time, hydrostatic head behind the plug has risen to a level sufficient to force water through fractures (hydraulic jacking), bypassing the plug, and exiting the mine at the portal or elsewhere. Other single plug closures constructed too closely to portals have failed.

Alternative FA-3 addresses the problem of high head behind the plugs by installing a flow-through plug approximately 400 to 450 ft in from the portal where the surrounding rock is selected to be tight and the hydrostatic head will not be large enough to force significant amounts of water around the pressure grouted plug and grouted fracture systems within the adit to the surface through fractures to access and discharge through the portal.

Alternative FA-3 is proposed as a grouted-in-place, permanent, watertight plug and is expected to be effective over the long term. It would eliminate the risk of impact from a potential failure and blowout of the existing portal plug and because it is backfilled, would minimize the risk of future adit collapse from impacting the hydraulic plug. Alternative FA-3 would also be effective in significantly reducing or eliminating seepage from the adit as all flow (i.e., water from seeps, fractures, or formation water) would be contained behind the new plug.

Pressure grouting of fractures discharging water into the adit is critical in advance of the installation of hydraulic adit plugs. This is because plugs create a considerable hydrostatic head behind them that in turn can significantly increase the flow from outlying fracture systems. Stemming the flow under low flow conditions, before placing the plug, is much easier and more effective than doing so under higher flow conditions. Placing a grout curtain in flowing fractures adjacent to the adit, if completely successful, would eliminate water inflow into the workings and therefore, some amount of the discharge from the portal. The grout curtain can be viewed as an impermeable 40-ft-diameter "donut" in the permeable plane of the fracture. The adit would be represented by the hole in the donut. Water flowing in the plane of the fracture system will flow around the donut ring and continue traveling down gradient (probably in the direction and volume of flow under pre-mining conditions). Thus, the grout curtain will not stop the flow of water along the fracture system or cause an increase in hydrostatic pressure around the drift; it will just keep the water from entering the adit.

Short-Term Effectiveness – Protection of Workers and Communities

The effect of installation of adit plug(s) will be immediate. Upon completion of the first plug and the surrounding grout curtain, the flow-through pipe valves would be shut and water flow from Formosa Mine to the Formosa 1 Adit portal will be substantially reduced or eliminated.

No impacts to the community or the environment are expected during the implementation of this alternative. Only a limited amount of equipment and supplies will be required, all of which will travel on existing roads. Protection to workers will be afforded through standard work practices. Exposure to hazardous substances will be minimal, although direct contact with the water draining the mine will not be eliminated. All underground work will be conducted using standard work practices and protective devices. Contractor's employees working at the site will be Hazardous Waste Operations and Emergency Response and Mine Safety and Health Administration (MSHA) certified as appropriate.

Long-Term Effectiveness and Permanence

Fracture grouting and the installation of hydraulic adit plug(s) are proven long-term methods of constructing a nearly impermeable barrier in fractured rock. Upon completion of grouting and plug installation, identified fracture inflow and adit portal discharge will be reduced or nearly eliminated. The long-term effect will be a reduction or elimination of metals loading to the Upper Middle Creek via the Formosa 1 Adit discharge.

Alternative FA-3 should greatly reduce or permanently eliminate the Formosa 1 Adit as a significant conduit transporting metal-laden, acidic groundwater from the Formosa Mine to the Upper Middle Creek.

The long-term effectiveness of rock fracture grouting and hydraulic plug installation to prevent water flow can be lost due to future ground movement and re-opening of fractures. Ground instability in the Formosa 1 Adit could have the potential to cause eventual failure of the plugs. However, the plan for the Formosa 1 Adit is to grout the plug, rock-bolt, screen and shotcrete the walls for 20 to 30 ft on either side of the plug, and backfill adjacent to the plug (on both sides if possible) for at least 20 ft, all of which should greatly increase the long-term stability of the plug and significantly extend its life expectancy by preventing future roof failures from damaging the grout curtain and plug installation(s).

Overall Protection of Human Health and the Environment

Grouting flowing fracture systems in the adit closer to the portal than the proposed hydraulic plug installation provides a reasonable measure for controlling the discharge of contaminated water into the adit and out of the portal and therefore reduces the risk to the environment. It reduces the volume of metals-laden water flowing directly into the conveyance system and subsequently into Upper Middle Creek by constructing a physical barrier to water movement.

Installation of a flow-through adit plug would significantly reduce the flow of metal-laden water from the Formosa 1 Adit directly into Upper Middle Creek by constructing a water-tight hydraulic barrier from the Formosa Mine through the Formosa 1 Adit. Therefore, Alternative FA-3 provides a considerable measure of control of the release of contaminated water and reduces the risk to human health and the environment.

The removal of as much as a few gallons per minute of metal-bearing water from the Formosa 1 Adit discharge will significantly lessen the exposure of humans and the environment to contaminated water. While this alternative alone has the potential to significantly diminish or eliminate the flow of water from the Formosa 1 Adit, substantial redundancy, safety, and a longer period of performance can be attained by the cementing of the flow-through pipe and installation of an additional plug closer to the adit portal in final closure.

Combining FA-3 with routine water quality sampling and water level (transducer) monitoring of MW-24 would provide critical information on closure system performance. It would also act as an “alert system” such that any significant changes in the system head or water quality would indicate potential concerns associated with the closure system, or changes in water quality of the mine pool that could affect the groundwater system. Changes in both surface water and groundwater quality as a result of closure could also be evaluated over time.

Meeting Response Action Objectives and Compliance with ARARs

Implementation of Alternative FA-3 would meet two of the RAOs for the project by preventing soluble contaminants and acidity from flowing into the mine workings and out the mine portal, where the discharge ultimately impacts shallow groundwater and surface water in the Middle Creek drainage. Compliance with ARARs may or may not be fully achieved under Alternative FA-3, as contaminant-specific standards associated with the ODEQ and Federal water quality standards might not be achieved in receiving waters without the implementation of other response alternatives in the final site-wide closure plan under CERCLA to control contaminant release from other sources in the larger Formosa Mine area.

Surface water quality at stations along Upper Middle Creek would improve as a direct result of setting a plug in the Formosa 1 Adit. While improvements in water quality may in part be limited by control of water chemistry at the station immediately below the current discharge point, a considerable reduction in metal concentrations and loading should be realized with this alternative.

Contaminant-specific ARARs for ambient air would be met under this alternative, as air quality would not be impacted by construction operations. Action-specific State of Oregon air quality regulations related to dust suppression and control during construction activities would be met using best management practices.

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

Action-specific ARARs would be expected to be met in part by this alternative. Oregon and Federal water quality standards may not be met under this alternative as the Formosa 1 Adit might continue to discharge iron and other metals to surface water and groundwater from other sources within the Formosa Mine that exceed standards. Alternative FA-3 would comply with federal or state action-specific ARARs by further reducing the flow of water from the mine. The flow may be reduced to less than 1 to 2 gpm, which may be low enough to be handled with an infiltration basin, instead of continued use of the existing mine water conveyance system. Other requirements for treating surface drainage, sediment control, construction and maintenance of sedimentation ponds, discharge from sedimentation ponds, and provisions for groundwater would be met operationally by using best available techniques.

OSHA requirements would be met by requiring appropriate safety training for all on-site workers during construction phase. Site activities would be conducted under the guidance of a Health and Safety Plan for the site per OSHA 29 Code of Federal Regulations (CFR) 1910.120. Site personnel would complete 40-hour hazardous waste operations and emergency response training and would be current with the 8-hour annual refresher training as required by OSHA 29 CFR 1910.120. Mine workers would complete the 40-hour MSHA underground miner certification and be up-to-date on annual 8-hour refreshers under 30 CFR Part 48.

Reduction of Toxicity, Mobility, or Volume through Treatment

With installation of the proposed flow-through plug, the volume of water discharging from the portal and requiring treatment or conveyance away for the portal site should be minimal. The mobility of metals would also be substantially reduced or eliminated by Alternative FA-3. The Formosa 1 Adit would no longer be a significant conduit for transporting metals-laden water to the Middle Creek. There may be little to no reduction in toxicity (but see following paragraph).

Alternative FA-3 would be effective in reducing the volume of water requiring conveyance from the site, and ultimate post-plug water discharge may well be such that the existing conveyance system could be replaced by a small infiltration basin at the portal. If this turns out to be the case, the existing conveyance system could be removed and the area reclaimed. As the mine pool builds behind the plug, oxygen in the groundwater is consumed by continued oxidation of sulfide minerals. With less oxygen in the system, a reduced/anoxic environment is created in which anaerobic bacteria can begin buffering the pH of the system by producing biogenic carbon dioxide, which increases the pH and reduces solubility as well as the mobility of metals (Kirk 2013b). During flooding of the historic workings, regional water will move laterally into the cone of depression and mix with the mine-pool water, further improving water quality by dilution. Any minor seepage or flow downstream of the 400-ft plug would be subject to oxidation and possibly precipitation of ferri-hydroxides, most of which should precipitate in the oxygenated atmosphere of the adit, rather than being precipitated outside of the portal. Nevertheless, some minor amount of adit water may discharge from the portal and could be captured in an infiltration basin if the volume were small enough.

7.2.3.4 Implementability

Grouting of fractured bedrock has been commonly used to stop groundwater in-flow in tunneling, dams, and construction sites for over a century. The proposed application for flowing fracture grouting in Alternative FA-3 is not significantly different. The success of the grouting program from fracture flow can be monitored as the grout is pumped. The success of the grouting can be further determined by measuring water flows along the sill of the drift upstream and downstream of the fracture zone and calculating the difference in flow.

Alternative FA-3 is technically and administratively feasible and implementable. However, it is unknown how difficult reopening and rehabilitation of the 450-ft-long Formosa 1 Adit might be. Ground conditions are also unknown. In addition, the dimensions of the site are such that careful planning and layout of facilities for mine support, water treatment and waste management would need to be undertaken to accommodate everything that needs to be at or near the portal. An experienced mining crew, equipped with a mucker, generator, air compressor, ventilation fans, water storage, air-line, ventilation bags, and a variety of hand tools, would be needed to prepare the adit and install the flow-through plug. Mining subcontractors are available in Oregon and adjacent states, and local cement contractors are undoubtedly capable of supply and delivery of cement to the formed plug. Final adit closure and portal site reclamation are not within the scope of this EE/CA because of the proposed period of post audit plug installation observation and monitoring prior to final closure. Final closure and reclamation of the portal area may well be completed under the CERCLA action currently being conducted at the site.

7.2.3.5 Cost

Estimated costs for Alternative FA-3 are shown in the detailed cost estimates found in Appendix B. Total cost for this alternative is approximately $1,372,131. A considerable amount of the estimated Alternative FA-3 cost is associated with direct labor costs from a qualified mining contractor.

Table 10. Summary of Alternative FA-3 Estimated Cost

Formosa Mine Adit Site Preparation Work	
Mobilization and Demobilization	$19,000
Adit Construction Pad, Staging Area and Sediment Pond	$88,063
Waste Rock Storage Pad Site Work	$32,251
O & M Costs - 10 Year at 3% per year Inflation	$292,361
Formosa Mine Adit Site Preparation Work Subtotal:	**$431,675**
Rehabilitation of Formosa Mine Adit	
Mobilization and Demobilization	$90,000
Mine Dewatering	$20,000
General Equipment / Construction Costs	$69,510
Materials / Supplies	$31,916
Labor	$74,000
Rehabilitation of Formosa Mine Adit Subtotal:	**$285,426**
Water Tight Plug Construction	
General Equipment / Construction Costs	$48,315
Materials / Supplies	$76,049
Labor	$84,400
Water Tight Plug Construction Subtotal:	**$208,764**
Total Estimated Construction Costs:	**$925,864**
Bonding and Insurance (10%)	$92,586
Contingency (20%)	$185,173
Total Estimated Construction:	**$1,203,624**
Engineering Design (8%)	$96,290
Construction Oversight (6%)	$72,217
TOTAL ESTIMATED PROJECT COSTS:	**$1,372,131**

8.0 COMPARATIVE ANALYSIS OF ALTERNATIVES

This section compares the alternatives evaluated in detail in Section 7.0. The comparative analysis is performed for each of the three primary criteria – effectiveness, implementability, and cost. A preferred alternative is also identified at the end of the section.

8.1 Formosa 1 Adit Alternatives

Issues associated with the Formosa 1 Adit source area are inflow into the underground mine workings and contaminated outflow from the mine-pool via a pipeline conveyance to an LAD area. The principal impacts are contaminated outflow and sediment deposition in the LAD area and ultimately impacts to both surface water and the alluvial aquifer in the Upper Middle Creek area, and groundwater in bedrock of the immediate vicinity of the portal area. Therefore, each of the proposed engineering controls and alternatives for the Formosa 1 Adit involve controlling or treating flow into and out of the mine.

8.1.1 Effectiveness

Alternative FA-1 involves leaving the Formosa 1 Adit in its existing condition. No effort to treat or control flow from the adit will be undertaken. Under existing conditions, acidic water, dissolved metals, and sediment will continue to flow from the mine portal via the conveyance pipeline to its discharge point in the LAD area with resulting impacts to Upper Middle Creek. Overall short- and long-term effectiveness of the Alternative FA-1 is poor compared to Alternative FA-2 or Alternative FA-3. Maintenance in the form of cleaning of the pipeline and existing treatment tanks and repair of the pipeline, currently funded by the BLM, would continue as necessary under FA-1.

Alternative FA-2 for the existing AMD discharge would include a semi-passive system in which lime would be added to the adit discharge inflow through treatment tanks to increase the pH of the flow-through adit water. This increased pH would result in precipitation of metal hydroxides, primarily ferri-hydroxides, prior to discharge, thereby mitigating, in part, current issues related to clogging of the conveyance system. This treatment would also result in reduced toxicity by discharging of higher pH water with lower concentrations of metals to the LAD area. Chemical addition for pH adjustment and metals removal, as proposed in Alternative FA-2, has proven to be effective for concentration reduction in heavily metal-laden water. The treatment system would be highly effective in inducing rapid and local precipitation of ferric-hydroxides and co-precipitation of other metals from the mine discharge waters and improving water quality prior to it entering the conveyance pipeline and being discharged to the LAD area. Alternative FA-2 would likely comply with federal or state action-specific ARARs as it would assist with treatment of and enhanced quality of the adit discharge. Federal or state contaminant-specific ARARs would likely not be met as treatment of the water would only enhance iron hydroxide precipitation and removal of some metals by co-precipitation, prior to entry into the conveyance pipeline system. No additional treatment would be undertaken in order to meet surface water or groundwater quality standards prior to discharge in the LAD area. Replacement of the AMD conveyance system would be implemented in this alternative.

Alternative FA-3 proposes the construction of a flow-through hydraulic adit plug to reduce or eliminate the flow of contaminated groundwater collecting in the mine-pool and discharging from the adit portal, thereby minimizing impacts to down-gradient surface and local groundwater water receptors. Pressure grouting of the plug and outboard flowing fractures is proposed to further reduce flow from the adit. Alternative FA-3 would be highly effective in eliminating the volume of contaminated flow from the adit portal and discharge to the LAD area, and has the potential to virtually eliminate the need for the pipeline conveyance system and greatly reduce impacts to down gradient alluvial aquifers and surface water.

Both the short-term and long-term effectiveness of Alternative FA-2 for the Formosa Superfund Site would be expected to be somewhat effective in metals concentration reduction over the short term and, if the system is properly maintained, somewhat effective over the long term. Water treatment in and of itself, as a long-term means of reduction of contaminant volume and mobility, requires operation in perpetuity.

The short-term effectiveness of Alternative FA-3 will be immediate. Upon completion of the first plug and the surrounding grout curtain, the valves in the flow-through pipe would be shut and water flow from Formosa Mine workings to the Formosa 1 Adit portal will be substantially reduced or eliminated.

Both the short-term and long-term effectiveness for Alternative FA-3 are greater than both Alternatives FA-1 and FA-2 because it would significantly reduce or eliminate the Formosa 1 Adit as a significant conduit transporting metal-laden, acidic groundwater from the Formosa Mine to the Middle Creek drainage.

8.1.1.1 Response Action Objectives

Alternative FA-1 does not meet the RAOs of the project. Alternative FA-2 partially meets the objective of reducing the potential of soluble contaminants from migrating into Upper Middle Creek. However, Alternative FA-3 has the potential to eliminate all or most of the AMD contaminants from reaching Upper Middle Creek and the potential to prevent future releases of contaminants from the Formosa Mine. None of the alternatives meet all project objectives.

8.1.1.2 Overall Protection of Human Health and the Environment

Alternative FA-1 does not add to the protection of human health and the environment over the existing condition. Treatment with Alternative FA-2 of AMD discharge prior to it entering the pipeline conveyance system will enable water of higher quality to be delivered to the LAD area.

If treatment using Alternative FA-2 is not performed, water of poor quality will continue to enter the pipeline AMD conveyance system, causing partial or full clogging of the system, requiring increased maintenance and repair, and continued potential impacts to down-gradient surface and alluvial groundwater and human and ecological receptors.

Alternative FA-3 would significantly reduce or completely halt the flow of metal-laden water out of the Formosa 1 Adit and significantly reduce down-gradient impacts to Upper Middle Creek. Therefore, Alternative FA-3 provides a considerable measure of control of the release of contaminated water and greater reduction of the risks to human health and the environment.

8.1.1.3 Compliance with ARARs

Alternative FA-1 is not expected to move water quality toward compliance with ARARs or water quality standards. Alternative FA-2 would likely comply with federal or state action-specific ARARs as it would assist with treatment of and enhance the quality of adit discharge. Federal or state contaminant-specific ARARs would likely not be met as treatment of the water would only enhance iron hydroxide precipitation and removal of some metals by co-precipitation, prior to entry into the conveyance pipeline system.

Alternative FA-3 meets two of the RAOs for the project by preventing soluble contaminants and acidity from flowing into the mine workings and out the mine portal, where the discharge ultimately impacts shallow ground and surface water in the Middle Creek drainage. Alternative FA-3 also has the potential to greatly reduce or eliminate all flow (volume) from the Formosa 1 Adit. Compliance with ARARs may or may not be fully achieved under Alternative FA-3, as contaminant-specific standards associated with Oregon and Federal water quality standards may not be achieved in receiving waters without the implementation of other response alternatives in the final site-wide closure plan for the Formosa Superfund Site under CERCLA to control contaminant release from other sources in the larger Formosa Mine area.

8.1.1.4 Reduction of Toxicity, Mobility, or Volume through Treatment

Alternative FA-1 involves leaving the Formosa 1 Adit in its existing condition. No reopening or closure activities would be started. No flow-reduction or treatment of the adit water would be undertaken to control contaminant migration from the mine portal or to reduce its toxicity or volume.

Alternative FA-2 would precipitate ferri-hydroxide along with other metal co-precipitates in holding tanks near the portal and allow the delivery of higher quality discharge with reduced contaminant volume and potentially reduced toxicity to the LAD area via the conveyance system.

With Alternative FA-3, the volume of water discharging from the portal and requiring treatment or conveyance away for the portal site should be greatly reduced or completely eliminated. The mobility of metals will also be substantially reduced or eliminated by Alternative FA-3. As a result of the elimination or significant reduction in flow volume from the Formosa 1 Adit it will no longer be a significant conduit for transporting metals-laden water to the Middle Creek.

8.1.2 Implementability

Each of the alternatives proposed could be readily implemented. Existing and established technologies are available and have been proven and previously tested.

Alternative FA-1 is both technically and administratively feasible. However, it is not a viable means of controlling the migration of contaminants that flow from the mine and significantly impact down gradient surface water quality and various environmental receptors. The system requires regular inspection and repair and maintenance.

Alternative FA-2 is also both technically and administratively feasible. The pH adjustment system would need to be constructed at or near the portal. Depending on the treatment system design, equipment may need to be shipped from outside the area. The system would require regular inspections and maintenance to replace the lime amendment, and to remove and dispose of the ferri-hydroxide precipitates from the treatment tanks. Disposal is assumed to be at an on-site location.

Alternative FA-3 is also both technically and administratively feasible. However, it is unknown how difficult the reopening and rehabilitation of the 450-ft-long Formosa 1 Adit might be. Ground conditions within the adit are also unknown. In addition, the dimensions of the site are such that careful planning and layout of facilities for mine support and waste management would need to be undertaken to accommodate everything that needs to be at or near the portal. An experienced mining crew, equipped with a mucker, generator, air compressor, ventilation fans, water storage, air-line, ventilation bags, and a variety of hand tools, would be needed to prepare the adit and install the flow-through plug.

8.1.3 Cost

Cost estimates are presented for each alternative in Section 7 and Appendix B. Table 11 below presents these costs summarized by alternative.

Table 11. Summary of Costs by Alternative

Alternative	Cost Estimate
FA-1 No Action	**$259,772**
FA-2 Water Treatment and Replacement of AMD Conveyance System	**$2,235,213**
FA-3 Installation of a Flow-Through Hydraulic Adit Plug	**$1,372,131**

8.2 Preferred Alternative

The preferred alternative is FA-3, Installation of a Flow-Through Hydraulic Adit Plug. Alternative FA-3 will include maintenance of the existing pipeline for temporary conveyance during mine dewatering during construction, which is considered an essential step that must be implemented prior to and during construction of Alternative FA-3. Only by maintaining and repairing the pipeline can the adit plug be installed safely, with minimal impacts to downgradient surface and groundwater and to human and ecological receptors. It is only through the implementation of this preferred alternative that effective and substantial improvements in water quality including surface flow in Upper Middle Creek can be realized. Estimated costs to implement the Preferred Alternative are presented in Table 12. The total estimated cost for the implementation of the Preferred Alternative is **$1,372,131**. The detailed cost analysis can be found in Appendix B.

Table 12. Cost Estimate for Formosa 1 Adit Preferred Alternative (FA-3)

Formosa Mine Adit Site Preparation Work	
Mobilization and Demobilization	$19,000
Adit Construction Pad, Staging Area and Sediment Pond	$88,063
Waste Rock Storage Pad Site Work	$32,251
O & M Costs - 10 Year at 3% per year Inflation	$292,361
Formosa Mine Adit Site Preparation Work Subtotal:	**$431,675**
Rehabilitation of Formosa Mine Adit	
Mobilization and Demobilization	$90,000
Mine Dewatering	$20,000
General Equipment / Construction Costs	$69,510
Materials / Supplies	$31,916
Labor	$74,000
Rehabilitation of Formosa Mine Adit Subtotal:	**$285,426**
Water Tight Plug Construction	
General Equipment / Construction Costs	$48,315
Materials / Supplies	$76,049
Labor	$84,400
Water Tight Plug Construction Subtotal:	**$208,764**
Total Estimated Construction Costs:	**$925,864**
Bonding and Insurance (10%)	$92,586
Contingency (20%)	$185,173
Total Estimated Construction:	**$1,203,624**
Engineering Design (8%)	$96,290
Construction Oversight (6%)	$72,217
TOTAL ESTIMATED PROJECT COSTS:	**$1,372,131**

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APPENDIX A
APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs)

Table A-1. Summary of Potential Federal and State Applicable or Relevant and Appropriate Requirements (ARARs) and To Be Considered Information (TBCs), Formosa Mine Superfund Site

Federal ARARs and TBCs					
National Historic Preservation Act	16 U.S.C. 470 36 CFR Part. 800 40 CFR 6.301(b)	Applicable	A requirement for a property included in or eligible for the National Register of Historic Places. The NHPA requires federally funded projects to identify and mitigate impacts of project activities on properties included in or eligible for the National Register. This statute and implementing regulations require federal agencies to take into account the effect of this response action upon any district, site, building, structure, or object that is included in or eligible for the National Register of Historic Places (generally, 50 years old or older). If cultural resources in or eligible for the National Register are present, it will be necessary to determine if there will be an adverse effect and, if so, how the effect may be minimized or mitigated, in consultation with the appropriate State Historic Preservation Office.	No property or resources at the site are included in the National Register; however, substantive portions of the NHPA would be applicable if BLM determines that response actions may impact property and/or resources eligible for listing in the National Registry.	✓
Archaeological and Historic Preservation Act	16 U.S.C. 469 40 CFR 6.301(c)	Applicable	The AHPA requires that for federally approved projects that may cause irreparable loss to significant scientific, prehistoric, historic, or archaeological data, the data must be preserved by the agency undertaking the project or the agency undertaking the project may request DOI to do so. This statute and implementing regulations establish requirements for the evaluation and preservation of historical and archaeological data, which may be destroyed through alteration of terrain as a result of a federal construction project or a federally licensed activity or program.	No prehistoric or historic sites were identified in existing data for the area that potentially could be impacted by the remedial action. However, because much of the area has not been previously surveyed, Phase I archaeological surveys will be conducted if any remedy components are to be located in a previously undisturbed area. If response activities impact archaeological resources at the site, substantive portions of this law would be applicable.	✓

Table A-1. Summary of Potential Federal and State Applicable or Relevant and Appropriate Requirements (ARARs) and To Be Considered Information (TBCs), Formosa Mine Superfund Site (continued)

Historic Sites, Buildings, and Antiquities Act of 1935	16 U.S.C. 461–467	Applicable	For areas designated as historic sites, the action should avoid undesirable impacts on landmarks and encourage the long-term preservation of nationally significant properties that illustrate or commemorate the history and prehistory of the United States. In conducting an environmental review of a proposed action, the responsible official shall consider the existence and location of natural landmarks using information provided by the National Park Service pursuant to 36 CFR § 62.6(d) to avoid undesirable impacts on such landmarks.	Substantive portions of this law would be applicable if BLM determines that response activities will impact areas eligible for listing on the Historic Site, Building, Objects, and Antiquities Register.	✓	
Archaeological Resources Protection Act of 1979, as Amended 1988	16 U.S.C. 470aa–470mm	Applicable	Archaeological Resources Protection Act provides for the preservation of archaeological and historical data that might be destroyed through alternation of terrain during a federal construction project or federally licensed activity.	The site has undergone extensive excavations and disturbances; therefore, it is unlikely to contain potential archaeological resources. However, substantive portions of this law would be applicable if BLM determines that remedial activities would cause loss or adverse impacts to significant scientific, prehistoric, historic, or archaeological data.	✓	
Resource Conservation and Recovery Act: Location Standards for Hazardous Waste Facilities-100 Year Floodplains	42 U.S.C. 6901 40 CFR 264.18(b)	Relevant and Appropriate	Hazardous waste TSDFs located in a 100-year floodplain must be designed, constructed, operated, and maintained to prevent washout of any 100-year floodplain.	Relevant and appropriate provisions will be identified for waste repositories constructed on site.	✓	✓

Table A-1. Summary of Potential Federal and State Applicable or Relevant and Appropriate Requirements (ARARs) and To Be Considered Information (TBCs), Formosa Mine Superfund Site (continued)

Resource Conservation and Recovery Act: Subtitle C—Exemption for Extraction, Beneficiation and Processing Mining Waste	40 CFR 261.4(b)(7)	Applicable	EPA exempts mining wastes from the extraction, beneficiation, and some processing of ores and minerals, in accordance with the Bevill amendment to RCRA.	OU1 mine materials may meet this exemption.	✓	✓
Resource Conservation and Recovery Act: Subtitle C—Hazardous Waste Characteristics	40 CFR 261.20 Characteristics of Hazardous Waste	Applicable	Generators of solid waste must determine whether the waste is hazardous. A solid waste is hazardous if it exhibits the toxicity characteristic (based on extraction procedure Method 1311).	Applicable to solid waste generated during remediation.	✓	
Resource Conservation and Recovery Act: Subtitle C—Hazardous Remediation Waste Management Requirements (HWIR Media)	40 CFR 264.554 Staging Piles	Relevant and Appropriate	The use of staging piles facilitates short-term storage of remediation wastes for shipment offsite or onsite treatment. The regulations contain performance standards for these piles but piles are not subject to LDRs.	Relevant and appropriate provisions will be identified if hazardous waste is managed in a staging pile.	✓	✓
Resource Conservation and Recovery Act Subtitle C—Hazardous Waste Treatment and Storage	40 CFR 264 Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities	Relevant and Appropriate	Requirements for storing or treating hazardous wastes in tanks, containers, or surface impoundments. Subpart F addresses groundwater monitoring at hazardous waste TSDFs. Closure requirements for hazardous waste repositories are covered under Subpart G. Hazardous waste landfills must meet minimum design standards under Subpart N.	Relevant and appropriate provisions will be identified after a preferred alternative is identified and further details are available during siting and pre-design phases. Relevant and appropriate, because an on-site mine waste disposal facility could be relatively similar to hazardous waste facility. Therefore, aspects of Subpart G and the design standards in Subpart N may be appropriate standards to use for design and construction of a disposal facility.		✓

Table A-1. Summary of Potential Federal and State Applicable or Relevant and Appropriate Requirements (ARARs) and To Be Considered Information (TBCs), Formosa Mine Superfund Site (continued)

Resource Conservation and Recovery Act: Subtitle D—Criteria for Classification of Solid Waste Disposal Facilities and Practices	42 U.S.C. 6901 et seq. 40 CFR 257	Relevant and Appropriate	Certain criteria are required to be met by solid waste disposal facilities and disposal practices. Relevant criteria such as not restricting the base flow of the floodplain, not taking threatened or endangered species, and not causing a discharge to navigable waters, may be useful for siting and design of a disposal facility.	After selection of the preferred alternative, relevant provisions will be identified.		✓
Resource Conservation and Recovery Act Subtitle D—Disposal of Nonhazardous Solid Waste	42 U.S.C. 6901 et. seq. 40 CFR Part 258	Relevant and Appropriate	Provides criteria for cover material, run-on/runoff control systems, access control, and restrictions on disposal of liquid wastes.	After selection of the preferred alternative, relevant provisions will be identified during siting and pre-design activity.		✓
Mineral Lands and Regulations in General (General Mining Act of 1872)	17 STAT.91; amended 30 U.S.C. 22.28 36 CFR 228.8-10	Not an ARAR	Authorizes and governs prospecting and mining for economic minerals, such as gold, platinum, and silver, on federal public lands.	This is not an environmental siting statute.		
Surface Mining Control and Reclamation Act of 1977	30 U.S.C. 120 et seq. 30 CFR 816	Not an ARAR	Provides for the cooperation between the Secretary of the Interior and the states with respect to the regulation of surface coal mining operations, and the acquisition and reclamation of abandoned mines.	No surface mining activity is ongoing; therefore, this is not a regulatory requirement. Although this statute provides performance criteria for surface mines such as coal mining, it is not appropriate for an underground hardrock mine.		
Resource Conservation and Recovery Act – Land Disposal Restrictions	40 CFR 260 268	Applicable	This part identifies hazardous wastes that are restricted from land disposal. The temporary or permanent placement of restricted hazardous wastes on the land at a CERCLA site may trigger RCRA land disposal restrictions as applicable requirements.	No Comments	✓	✓

Table A-1. Summary of Potential Federal and State Applicable or Relevant and Appropriate Requirements (ARARs) and To Be Considered Information (TBCs), Formosa Mine Superfund Site (continued)

Fish and Wildlife Coordination Act Responsible official requirements Rules implementing the Fish and Wildlife Conservation Act of 1980	16 U.S.C 661 et seq. 40 CFR 6.302(g) 50 CFR 83	Applicable	This statute and implementing regulations require coordination with federal and state agencies for federally funded projects to ensure that any modification of any stream or other water body affected by any action authorized or funded by the federal agency provides for adequate protection of fish and wildlife resources.	If the remedial action involves activities that affect wildlife and/or non-game fish, federal agencies must first consult with the USFWS and the relevant state agency with jurisdiction over wildlife resources.		✓	
Endangered Species Act Responsible official requirements Endangered and threatened wildlife and plants Interagency cooperation–Endangered Species Act of 1973, as amended	16 USC 1531 40 CFR 6.302(h) 50 CFR 17 50 CFR 402	Applicable	This statute and implementing regulations provide that federal activities not jeopardize the continued existence of any threatened or endangered species. ESA Section 7 requires consultation with the USFWS to identify the possible presence of protected species and mitigate potential impacts on such species.	If threatened or endangered species are identified within areas for remedial action, activities must be designed to conserve the species and their habitat. To date no threatened or endangered species have been identified in the PMDA area of the site. However, Cow Creek, Middle Creek, and the South Fork of Middle Creek are habitat for the Oregon Coast Evolutionarily Significant Unit (ESU) of coho salmon (*Oncorhynchus kisutch*), which is listed as threatened under the ESA.		✓	
Migratory Bird Treaty Act List of Migratory Birds	16 USC. 703, et seq. 50 CFR 10.13	Relevant and Appropriate	Makes it unlawful to "hunt, take, capture, kill," or take other various actions adversely affected a broad range of migratory birds, without the prior approval of the Department of the Interior.	The selected remedial actions will be carried out in a manner to avoid adversely affecting migratory bird species, including individual birds or their nests.		✓	
Clean Air Act	42 U.S.C. 7401, et seq.	Not an ARAR	The Clean Air Act establishes NAAQS for pollutants considered to be harmful to public health and the environment. The NAAQSs are not enforceable themselves, but the state translates these ambient standards into specific emission limitations in the SIP.	The selected remedial actions will be carried out in a manner that will comply with NAAQS. Although this is not an ARAR, the state requirements, in portions of the SIP, will be applicable.	✓	✓	✓

Table A-1. Summary of Potential Federal and State Applicable or Relevant and Appropriate Requirements (ARARs) and To Be Considered Information (TBCs), Formosa Mine Superfund Site (continued)

Clean Water Act/Water Pollution Control Act	33 U.S.C. 1251 Section 307 – Toxic and Pre-Treatment Standards Section 401—Water Quality Certification Section 402 – National Pollutant Discharge Elimination System Sections 301-302 – Effluent Limitations Section 303 – Water Quality Standards Section 304 – Federal Water Quality Criteria Section 306 – National Performance Standards	Relevant and Appropriate	These regulations govern water quality, including water discharged as part of a remedial process. Section 307—Pretreatment regulations under 40 CFR Part 403 provide for limits on discharge to a sanitary sewer system, protecting the municipal system from accepting wastewater that would cause it to exceed its NPDES permit discharge limits. Section 401—Water Quality Certification requires that EPA receive a water quality certification from a state that a given project requiring a federal permit that may result in a discharge to navigable water will comply with the state's water quality standards. Section 402—The NPDES program establishes a comprehensive framework for addressing processing water and stormwater discharges under the program. Requires that point- source discharges not cause the exceedance of surface water quality standards outside the mixing zone. Specifies requirements under 40 CFR 122.26 for point-source discharge of stormwater from construction sites to surface water and provides for Best Management Practices such as erosion control for removal and management of sediment to prevent run- on and runoff.	The remedial alternatives for OU1 address only mine materials. The substantive provisions are relevant and appropriate to OU1 remedial alternatives. These regulations include standards of control and other substantive environmental protection requirements that address situations similar to the circumstances of the proposed response action and are well suited to the conditions of the site. The remedial actions will be protective of surface water.	✓

Table A-1. Summary of Potential Federal and State Applicable or Relevant and Appropriate Requirements (ARARs) and To Be Considered Information (TBCs), Formosa Mine Superfund Site (continued)

Hazardous Waste Operations and Emergency Response	29 CFR 1910.120 and 40 CFR 311	Applicable	Worker protection during hazardous waste cleanup and CERCLA removal actions.	No Comments	✓		✓
Executive Order 11593 – Protection and Enhancement of the Cultural Environment	16 U.S.C. 470	Applicable	Requires federal agencies to consider the existence and location of potential and existing National Natural Landmarks to avoid undesirable impacts.	No Comments		✓	
Bald Eagle Protection Act	16 U.S.C. 668 et seq.	Applicable	Requires continued consultation with the USFWS during remedial design and remedial construction to ensure that any cleanup of the site does not unnecessarily adversely affect bald or golden eagles.	No Comments		✓	
Federal Land Policy and Management Act of 1976	43 U.S.C. 1701	Not an ARAR	Provides for multiple use and inventory, protection, and planning for cultural resources on public lands.	This statute provides the administrative framework for managing and protecting resources on federal land. Substantive provisions are included in other federal action and location-specific ARARs.			
Resource Management Plan	Northwest Forest Plan FSEIS, 1994 and ROD, 1994	To Be Considered – Not an ARAR	This is the current applicable approved Resource Management Plan for the area of BLM Managed Lands.	If BLM land is considered for a disposal facility or borrow source, this plan may provide useful guidance. Non-promulgated advisories, plans, or guidance issued by federal or state governments are not legally binding and do not have the status of ARARs. However, such requirements may be useful and are "to be considered." TBC requirements (40 CFR § 300.400[g][3]) complement ARARs but do not override them. They are useful for guiding decisions regarding cleanup levels or methods when regulatory standards are not available.			

Table A-1. Summary of Potential Federal and State Applicable or Relevant and Appropriate Requirements (ARARs) and To Be Considered Information (TBCs), Formosa Mine Superfund Site (continued)

Survey and Manage Settlement Agreement of 2011		To Be Considered – Not an ARAR	EPA is a signatory to this agreement. The 2011 Settlement Agreement relates to the Northwest Forest Plan Implementation – Survey and Manage Mitigation Measure. The Agreement provides direction regarding Survey and Manage species and the 2007 ROD removing the Survey and Manage Mitigation Measure. The specific species list is expanded, from the previous 2001 listing, for actions after 30 September 2012. Other criteria and exemptions are established for projects within the range of the northern spotted owl.	This agreement is not applicable or relevant and appropriate, because it is not a cleanup standard, standard of control, and other substantive environmental protection requirement, criterion, or limitation promulgated under federal or state law that specifically addresses circumstances at a CERCLA site and does not address problems or situations similar to the circumstances of the proposed response action. EPA and BLM are both a party to this agreement, and CERCLA is not exempted. The agreement will provide useful guidance for cleanup decisions, but may not have substantive provisions that are more stringent than other federal ARARs.	
Disposal of Solid Waste Criteria for Classification of Solid Waste Disposal Facilities and Practices	42 U.S.C. 6901 et seq. 40 CFR 257	Relevant and Appropriate	Facility or disposal practices in floodplains will not restrict flow of basic floods, reduce the temporary water-storage capacity of the floodplain, or otherwise result in a washout of solid waste. Establishes criteria for determining which solid waste disposal practices pose threats to human health and the environment.	May be considered relevant and appropriate for a disposal facility or repository located "onsite."	✓
BLM AML Handbook		To Be Considered	BLM Policies Management of Abandoned Mine Lands including, but not limited to, Section 9.4.7.2. Repositories.	The handbook may provide useful guidance for cleanup decisions or methods. After selection of a preferred alternative, the handbook can be used during the siting and design of a disposal facility.	

Table A-1. Summary of Potential Federal and State Applicable or Relevant and Appropriate Requirements (ARARs) and To Be Considered Information (TBCs), Formosa Mine Superfund Site (continued)

State of Oregon ARARs and TBCs				
Indian Graves And Protected Objects	ORS 97.740-97.750 Protection of Indian Graves	Not an ARAR	Governs Oregon Historical Preservation. Analogous to Federal Historic Preservation Act (36 CFR Parts 60 and 61), and NHPA.	Not a potential ARAR. The Formosa Mine Superfund Site is not included in or eligible for the National Register. The Oregon statutes are no more stringent that the federal requirements of the NHPA. The NHPA is not a potential ARAR. The NHPA requires federally funded projects to identify and mitigate impacts of project activities on properties included in or eligible for the National Register. No historic building or landmark is present at the Formosa Mine Superfund Site that could be impacted by the remedial action. In addition, no building in the project area was constructed prior to 1950, a date typically used as an initial screen for determining eligibility for the National Register. Therefore, the NHPA is not a potential ARAR.
Historic Property	ORS 358.475 Policy Special Assessment of Historic Property			
Historic Preservation Plan	ORS 358.612 Authorities of State Historic Preservation Officer			
Preservation Of Property Of Historic Significance	ORS 358.622 (State Advisory Committee on Historic Preservation)			
Oregon Property Management Program For Historic Sites And Properties	ORS 358.635 (Preservation of state- owned historic property)			
Archaeological Objects And Sites	ORS 358.680-690 (Oregon Property Management Program)			

Table A-1. Summary of Potential Federal and State Applicable or Relevant and Appropriate Requirements (ARARs) and To Be Considered Information (TBCs), Formosa Mine Superfund Site (continued)

Archaeological Sites and Historical Material	ORS 358.905 (General Archaeology) ORS 390.235 (Issuance of Archeological Permits						
Oregon Threatened or Endangered Wildlife Species, ORS 496.171-192	ORS 496.171-192	Not an ARAR	Sets forth standards for the Oregon Fish and Wildlife Commission to list species as threatened or endangered; authorizes the Commission to enact regulations necessary to ensure survival of listed species, such as protecting habitat; expressly provides that this regulation does not, by itself, require an owner of private land to take action to protect an endangered or threatened species.	The statute does not contain substantive requirements and is not more stringent than the federal ESA. The listed species might be different from the federal ESA. After the FS, both lists will be checked relative to the preferred alternative and in preparation of the ROD.			
General Emission Standards and Air Quality[c]	ORS 468A OAR 340-226-0100 Policy and application	Relevant and Appropriate	Provides general emission standards for fugitive emissions of air contaminants and requires highest and best practicable treatment or control of such emissions. EPA has established NAAQS for several pollutants. NAAQS may be applicable for conditions at a site that results in emissions to air of criteria pollutants. If a remedial activity may exceed regulatory criteria, the activity may be subject to preconstruction review in designated attainment areas. The source may qualify for emission exemption under OAR 340-020-0245. If a preconstruction permit is required, Oregon DEQ has statutory authority to waive it under ORS 465.315.	The Formosa Mine Superfund Site in Douglas County is not within a designated non- attainment or air quality maintenance area. Therefore, emission criteria and rules for Special Control Areas (defined in OAR-340-204) are not applicable. OAR 340-226-0100 are potential relevant and appropriate requirements for remedial alternatives being considered, because the EPA delegated them into the SIP per the CAA (42 U.S.C. §§ 7401–7671).	✓	✓	✓

Table A-1. Summary of Potential Federal and State Applicable or Relevant and Appropriate Requirements (ARARs) and To Be Considered Information (TBCs), Formosa Mine Superfund Site (continued)

Visible Emissions and Nuisance Requirements	OAR 340-208-0200-0210 - Fugitive Emission Requirements	Relevant and Appropriate	Prohibits any handling, transporting, or storage of materials, or use of a road, or any equipment to be operated, without taking reasonable precautions to prevent particulate matter from becoming airborne. These rules include areas other than "special control areas" where fugitive emissions may cause a nuisance and control measures are practicable.	Potentially relevant and appropriate as applicable parts pertain to areas and sources outside Special Control Areas defined in OAR-340-204. Substantive provisions of OAR 340-208-0200 are potentially applicable state requirements because they are not included in the SIP.			✓
Noise Control Regulations	OAR 340-035-0035	Relevant and Appropriate	Sets noise standards for equipment, facilities, operations, or activities including the production, storage, handling, sale, purchase, exchange, or maintenance of a product, commodity, or service, including the storage or disposal of waste products.	Potentially relevant to remedial activities and equipment that may generate noise.			✓
Removal or Remedial Action	ORS 465.200-465.900 Oregon Hazardous Substance Remedial Action Rules[c] OAR 340-122 *et seq.*	Relevant and Appropriate	Sets standards for degree of cleanup required. Establishes acceptable risk levels for human health at 1×10^{-6} for individual carcinogens, 1×10^{-5} for multiple carcinogens; and Hazard Index of 1.0 for non-carcinogens; and protection of ecological receptors at the individual level for threatened or endangered species and the population levels for all others.	May be relevant and appropriate if substantive cleanup standards are more stringent than federal requirements.	✓		✓

Table A-1. Summary of Potential Federal and State Applicable or Relevant and Appropriate Requirements (ARARs) and To Be Considered Information (TBCs), Formosa Mine Superfund Site (continued)

Oregon Hazardous Waste Management Act	ORS 466.005-466.225 Hazardous Waste Management Rules; OAR 340-100 *et. seq.*	Relevant and Appropriate	Establish a regulatory structure for the generation, transportation, treatment, storage, and disposal of hazardous wastes. OAR Chapter 340, Divisions 100 to 106, 109, 111, 113, 120, 124, and 142 incorporate, by reference, hazardous waste management regulations of the federal program, included in 40 CFR Parts 260 to 266, 268, 270, 273, and Subpart A and Subpart B of Part 124, into OAR.	May be relevant and appropriate if substantive cleanup standards are more stringent than federal requirements for remedial actions that generate listed or characteristic hazardous wastes including environmental media such as contaminated soil and/or groundwater. OAR Chapter 340, Divisions 100 to 106, 109, 111, 113, 120, 124, and 142 incorporate, by reference, hazardous waste management regulations of the federal program, included in 40 CFR Parts 260 to 266, 268, 270, 273, and Subpart A and Subpart B of Part 124, into OAR.	✓		✓
Solid Waste Management Solid Waste: General Provisions	ORS 459.005 - 418 OAR 340-093 - 097	Relevant and Appropriate	Regulations under this statute establish a regulatory structure for the collection, transportation, treatment, storage, and disposal of solid wastes.	May be relevant and appropriate if substantive cleanup standards are more stringent than federal requirements for on-site management and disposal of contaminated soil, groundwater, and mine materials.			✓
Solid Waste Management – Municipal	ORS 459.046- OAR 340-094	Not an ARAR	Regulations under this statute establish a regulatory structure for the collection, transportation, treatment, storage, and disposal of solid wastes at municipal solid waste landfills.	May be relevant and appropriate if substantive cleanup standards are more stringent that federal requirements for on-site management and disposal of contaminated soil, groundwater, and mine materials.			✓
Solid Waste Management	ORS 459 OAR 340-095 Land Disposal Sites Other than Municipal Solid Waste Landfills	Not an ARAR	Governs the management of solid wastes, and land disposal sites, other than municipal solid waste landfills.	May be relevant and appropriate if substantive cleanup standards are more stringent than federal requirements for on-site management or disposal of mine- impacted material.			✓

Table A-1. Summary of Potential Federal and State Applicable or Relevant and Appropriate Requirements (ARARs) and To Be Considered Information (TBCs), Formosa Mine Superfund Site (continued)

State of Oregon To Be Considered (TBCs)						
Final Guidance Consideration of Land Use In Environmental Remedial Actions	OAR 340-122 Oregon DEQ, July 1998	To Be Considered	Describes how to make a land use determination for use in a risk assessment and in the remedy selection process.	No Comments.	✓	✓
Guidance for identification of Hot Spots	OAR 340-122 Oregon DEQ, April 1998	To Be Considered	Describes procedures for delineating "hot spots" in water and other environmental media.	Guidance for hot spot determination for non-CERCLA state sites. For Superfund sites, this TBC may be relevant to the selection of remedial alternatives but only where consistent with overall EPA guidance and policy.	✓	✓
Final Guidance for Use of Institutional Controls	OAR 340-122 Oregon DEQ, April 1998	To Be Considered	Guidance for selection or approval of institutional controls as part or all of a remedy.	For Superfund sites, this TBC may be relevant to the selection of remedial alternatives but only where consistent with overall EPA guidance and policy.		✓
Guidance for Assessing Bioaccumulative Chemicals of Concern in Sediment, DEQ, 2007	OAR 340-122	To Be Considered	Describes a process to evaluate chemical found in sediment for their potential contribution to risk as a result of bioaccumulation. Provides alternative methods for developing sediment screening levels and bioaccumulation bioassay data.	Does not pertain to remedial actions considered for Formosa OU1. All remedial actions for OU1 address soil only. However, this guidance may have information pertinent to remedial actions adjacent to and within surface water bodies near Formosa OU1.		
Human Health Risk Assessment Guidance, DEQ, 2010	OAR 340-122	To Be Considered	Describes methods that may be used to perform human health risk assessments at cleanup sites in Oregon.	Does not pertain to remedial actions considered for Formosa OU1 because the risk assessment evaluations were completed in the remedial investigation phase. All remedial actions for OU1 have completed the risk assessment phase.		
Guidance for Ecological Risk Assessment: Levels I, II, III, IV DEQ 1998 and 2001	OAR 340-122	To Be Considered	Describes methods to be used in evaluating ecological risk at cleanup sites in Oregon and provides a Screening Benchmark Table for contaminants.	Does not pertain to remedial actions considered for Formosa OU1, because the risk assessment evaluations were completed in the remedial investigation phase. All remedial actions for OU1 have completed the risk assessment phase.		

[1] Statutes and policies, and their citations, are provided as headings to identify general categories of potential ARARs for the convenience of the reader. Listing the statutes and policies does not indicate acceptance of the entire statutes or policies as potential ARARs; specific potential ARARs are addressed in the table below each general heading. Only substantive requirements of the specific citations are considered potential ARARs.

[2] Only the substantive provisions of the requirements cited in this table are potential ARARs.

3 The preamble to the NCP indicates that state regulations that are components of a federally authorized or delegated state program are generally considered federal requirements and potential federal ARARs for the purposes of ARARs analysis (55 Federal Register 8666, 8742 [1990]). The Oregon DEQ received final authorization for the regulation of hazardous wastes on August 15, 1995 (Federal Register Volume 60, Number 116 (Friday, June 16, 1995)) and established rules in OAR 340-100 et seq. For the CAA, EPA approved Oregon's SIP and the air statutes were promulgated as ORS 468 and 468A.

Substantive RCRA requirements are applicable to response actions on CERCLA sites if the waste is a RCRA hazardous waste, and either: the waste was initially treated, stored, or disposed after the effective date of the particular RCRA requirement (1976 for RCRA, and 1984 for the amendments including land disposal restrictions); or the activity at the CERCLA site constitutes treatment, storage, or disposal as defined by RCRA (EPA 1988a CERCLA Compliance With Other Laws Manual, Draft Guidance (Part I). Interim Final EPA/540/G 89/006, Office of Emergency and Remedial Response, Washington, D.C. August.

EPA 1989a. CERCLA Compliance With Other Laws Manual: Part II – Clean Air Act and Other Environmental Statutes and State Requirements, EPA/540/G-89/009, OSWER Directive 9234.1-02, Office of Solid Waste and Emergency Response, Washington, D.C. August.

Acronyms and Abbreviations

AHPA	Archaeological and Historic Preservation Act
AML	Abandoned Mine Lands
ARAR	Applicable or Relevant and Appropriate Requirement
BLM	Bureau of Land Management
CAA	Clean Air Act
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
DOI	United States Department of Interior
EPA	United States Environmental Protection Agency
ESA	Endangered Species Act
FSEIS	Final Supplemental Environmental Impact Statement
LDR	Land Disposal Restrictions
NAAQS	National Ambient Air Quality Standards
NHPA	National Historic Preservation Act
NPDES	National Pollutant Discharge Elimination System
OAR	Oregon Administrative Rules
Oregon DEQ	State of Oregon Department of Environmental Quality
ORS	Oregon Revised Statutes
OSWER	Office of Solid Waste and Emergency Response
OU1	Operable Unit 1
ROD	Record of Decision
RCRA	Resource Conservation and Recovery Act
SIP	State Implementation Plan
TBCs	To Be Considered Information
TSDF	Treatment, Storage, and Disposal Facility
U.S.C.	United States Code
USFWS	United States Fish and Wildlife Service

APPENDIX B
DETAILED COST ESTIMATES

Table B-1. Alternative FA-1

Formosa Mine Adit Cost for Maintaining Existing Discharge Pipeline	
O & M Costs - 10 Year (3% per yr inflation)	**$259,772**
TOTAL ESTIMATED PROJECT COSTS:	**$259,772**

Table B-2. Alternative FA-2

Formosa Mine Adit Cost for Interim Water Treatment System	
Capital Costs for Interim Water Treatment System	$55,380.00
Water Treatment Pad Grading, Mobilization and Demobilization	$21,583
Discharge Pipeline System Replacement	$9,053
Operating Costs for Interim Water Treatment System - 10 Year (3% per yr inflation)	$1,276,045
O & M Costs - 10 Year (3% per yr inflation)	$146,181
Total Estimated Construction Costs:	**$1,508,241**
Bonding, and Insurance (10%):	$150,824
Contingency (20%):	$301,648
Total Estimated Construction:	**$1,960,713**
Engineering Design (8%)	$156,857
Construction Oversight (6%)	$117,643
TOTAL ESTIMATED PROJECT COSTS:	**$2,235,213**

Table B-3. Alternative FA-3

Formosa Mine Adit Site Preparation Work	
Mobilization and Demobilization	$19,000
Adit Construction Pad, Staging Area and Sediment Pond	$88,063
Waste Rock Storage Pad Site Work	$32,251
O & M Costs - 10 Year at 3% per year Inflation	$292,361
Formosa Mine Adit Site Preparation Work Subtotal:	**$431,675**
Rehabilitation of Formosa Mine Adit	
Mobilization and Demobilization	$90,000
Mine Dewatering	$20,000
General Equipment / Construction Costs	$69,510
Materials / Supplies	$31,916
Labor	$74,000
Rehabilitation of Formosa Mine Adit Subtotal:	**$285,426**
Water Tight Plug Construction	
General Equipment / Construction Costs	$48,315
Materials / Supplies	$76,049
Labor	$84,400
Water Tight Plug Construction Subtotal:	**$208,764**
Total Estimated Construction Costs:	**$925,864**
Bonding, and Insurance (10%):	$92,586
Contingency (20%):	$185,173
Total Estimated Construction:	**$1,203,624**
Engineering Design (8%)	$96,290
Construction Oversight (6%)	$72,217
TOTAL ESTIMATED PROJECT COSTS:	**$1,372,131**

Table B-4. Existing Discharge Pipeline

		Annual O&M Cost for Existing Discharge Pipeline
Per BLM	$	22,000.00
O&M With Inflation at year		**3%** **Annual WT O&M with Inflation**
1	$	22,660.00
2	$	23,339.80
3	$	24,039.99
4	$	24,761.19
5	$	25,504.03
6	$	26,269.15
7	$	27,057.23
8	$	27,868.94
9	$	28,705.01
10	$	29,566.16
Total	$	259,771.51

Table B-5. Site Work

Item	Rate ($/unit)	Unit	Number of Units	Total	Comments
Formosa Mine Site Preparation Work (FA-3)					
Mobilization and Demobilization					
Mobilization	$9,500.00	ls	1	$9,500	Assumes local contractors
Demobilization	$9,500.00	ls	1	$9,500	
SUBTOTAL:				**$19,000**	
Adit Construction Pad, Staging Area and Sediment Pond (FA-3)					
Equipment / Construction					
Msc. site Work	$7.98	cy	740	$5,905	RSMeans: G1030 120 1000, excavate common earth
Msc. Site Grading	$2.64	sy	1400	$3,696	RSMeans: 31 22 16.10 1050 Grading Small Irregular Areas
Staging Area Stone Gabion Retaining Wall (9 ft. height)	$468.75	lf	135	$63,281	RSMeans: 32 32 36.10 4990 Stone Gabion Retaining Walls
Sediment Pond Construction	$28.00	sy	220	$6,160	
Pick-up Trucks (2 trucks)	$75.00	da	10	$750	
Miscellaneous (support vehicles, tools, debris disposal)	$250.00	da	10	$2,500	
Materials and Supplies					
Fencing	$6.00	ft	130	$780	Assumes fence is placed 3 feet from pond edges.
Pond Liner Bedding (Sand)	$55.00	cy	55	$3,025	4 inches of sand above and below HDPE Liner including haul RSMeans: 04 05 13.95 030C
Pond Lining HDPE 30 Mil	$8.19	sy	240	$1,966	RSMeans: 33 47 13.53 1100 Reservoir Liners HPDE with Installation with Pacific Northwest Crew
SUBTOTAL:				**$88,063**	
Waste Rock Storage Pad Site Work (FA-3)					
Equipment / Construction					
Msc. Site Grading (Lay Down Area)	$2.64	sy	420	$1,109	RSMeans: 31 22 16.10 1050 Grading Small Irregular Areas
Waste Rock Storage Pad Excavation	$19.25	cy	740	$14,245	RSMeans: 31 23 16.16 6120, small building foundation, 1 YD Bucket, hyd machine with crew
Excavated material haul	$3.79	cy	740	$2,805	RSMeans: 31 23 23.18 0320, 0.5 mi RT, 12 yd DT
Pick-up Trucks (2 trucks)	$75.00	da	10	$750	
Miscellaneous (support vehicles, tools, debris disposal)	$250.00	da	10	$2,500	
Materials and Supplies					
Fencing	$6.00	ft	365	$2,190	Assumes fence is placed 3 feet from pond edges.
Miscellaneous (gates, locks, site closeout)	$500.00	ls	1	$500	
Pond Liner Bedding (Sand)	$55.00	cy	90	$4,950	4 inches of sand above and below HDPE Liner including haul RSMeans: 04 05 13.95 0300
Waste Rock Storage Pad HDPE 30 Mil	$8.19	sy	391	$3,202	RSMeans: 33 47 13.53 1100 Reservoir Liners HPDE with Installation
SUBTOTAL:				**$32,251**	
Annual O & M Costs (FA-3)					
Vacuum Truck (2,200 gal) Tank Cleanout	$132.00	hr	80	$10,560	
Cleanout Dump Disposal	$237.50	ton	16	$3,800	
Annual O & M Oversight	$130.00	hr	80	$10,400	
SUBTOTAL:				**$24,760**	
SUBTOTAL 10-YEAR				**$292,361**	
SUBTOTAL:				**$431,675**	
Bonding, and Insurance (10%):				$43,167	
Contingency (20%):				$86,335	
TOTAL CONSTRUCTION:				**$561,177**	
Engineering Design (8%)				$44,894	
Construction Oversight (6%)				$33,671	
TOTAL ESTIMATE:				**$639,742**	
Water Treatment Pad Grading (FA-2)					
Mobilization and Demobilization					
Mobilization	$9,500.00	ls	1	$9,500	Assumes local contractors
Demobilization	$9,500.00	ls	1	$9,500	
SUBTOTAL:				**$19,000**	
Equipment / Construction					
Msc. site Work	$7.98	cy	120	$958	RSMeans: G1030 120 1000, excavate common earth
Pick-up Trucks (2 trucks)	$75.00	da	5	$375	
Miscellaneous (support vehicles, tools, debris disposal)	$250.00	da	5	$1,250	
SUBTOTAL:				**$2,583**	
TOTAL ESTIMATE:				**$21,583**	

Table B-6. Water Treatment System

Item	Rate ($/unit)	Unit	Number of Units	Total	Comments
Capital Costs for Interim Water Treatment System (FA-2)					
Chemical Feeder with Shipping	$28,600.00	ea	1	$28,600	
Security Fencing	$30.00	ft	250	$7,500	
Tank Delivery	$5,640.00	ea	2	$11,280	
Labor					
Set-up and Start-up (3 days) (2 man crew)	$8,000.00	ls	1	$8,000	
SUBTOTAL:				**$55,380**	
Discharge Pipeline System Replacement (FA-2)					
8-inch HDPE Pipe	$5.85	lf	1200	$7,020	
Dumpster Delivery and Haul	$166.50	ea	2	$333	
Dumpster Rental	$47.50	ea	2	$95	
Waste Disposal	$48.50	ton	1.98	$96	
Contingency (20%):				$1,509	
SUBTOTAL:				**$9,053**	
Annual Operating Costs for Interim Water Treatment System - Alternative FA-2					
Tank Lease	$51,100.00	ea	2	$102,200	
Chemical	$1,500.00	bulk	1	$1,500	
Fuel	$4,368.00	bulk	1	$4,368	
SUBTOTAL:				**$108,068**	
SUBTOTAL 10-YEAR				**$1,276,045**	
Annual O & M Costs - Alternative FA-2					
Vacuum Truck (2,200 gal) Tank Cleanout	$132.00	hr	40	$5,280	
Cleanout Dump Disposal	$237.50	ton	8	$1,900	
Annual O & M Oversight	$130.00	hr	40	$5,200	
SUBTOTAL:				**$12,380**	
SUBTOTAL 10-YEAR				**$146,181**	
ALTERNATIVE FA-2					
FA-2 SUBTOTAL:				**$1,486,658**	
Bonding, and Insurance (10%):				$148,666	
Contingency (20%):				$297,332	
TOTAL CONSTRUCTION:				**$1,932,656**	
Engineering Design (8%)				$154,612	
Construction Oversight (6%)				$115,959	
TOTAL ESTIMATE:				**$2,203,227**	
ALTERNATIVE FA-3					
FA-3 SUBTOTAL:				**$0**	
Bonding, and Insurance (10%):				$0	
Contingency (20%):				$0	
TOTAL CONSTRUCTION:				**$0**	
Engineering Design (8%)				$0	
Construction Oversight (6%)				$0	
TOTAL ESTIMATE:				**$0**	

Table B-7. Rehabilitation of Formosa Mine Adit

Item	Rate ($/unit)	Unit	Number of Units	Total	Comments
Mobilization and Demobilization					
Mobilization	$45,000.00	ls	1	$45,000	
Demobilization	$45,000.00	ls	1	$45,000	
Mine Dewatering	$20,000.00	ls	1	$20,000	Existing well with drill rig setup and 7.5 hp pump
General Equipment / Construction Costs					
Mucker	$325.00	da	25	$8,125	
Compressor	$108.00	da	25	$2,700	RsMeans: 01.54.33.40.0400
Generator	$85.00	da	25	$2,125	RsMeans: 01.54.33.40.2400
Jackleg Drill	$35.00	da	20	$700	
Fuel tanks and pump	$20.00	da	40	$800	
Excavator	$164.00	hr	40	$6,560	
Bobcat	$70.00	hr	50	$3,500	
Front End Loader	$950.00	da	25	$23,750	
Water Storage	$250.00	da	15	$3,750	
Pick-up Trucks	$75.00	da	50	$3,750	
Ventilation Fans	$100.00	da	25	$2,500	RsMeans: 01.54.33.50.7100/ 2 fans at $50.00 ea
Air Lines	$200.00	da	25	$5,000	
Miscellaneous (pumps, welder, tools, etc.)	$250.00	da	25	$6,250	
Materials / Supplies					
Fuel	$200.00	da	25	$5,000	
Vent Bag	$3.69	lf	400	$1,476	
Shotcrete	$158.00	cy	80	$12,640	RsMeans: 03.37.13.60.0020
Ground Support	$4,000.00	ls	1	$4,000	
Bentonite Grout	$220.00	tn	40	$8,800	
Labor					
Mining Contractor (4 man crew)	$2,960.00	da	25	$74,000	Estimate of time requirements, Highly variable depending on actual conditions encountered.
SUBTOTAL:				**$285,426**	
Bonding, and Insurance (10%):				$28,543	
Contingency (20%):				$57,085	
TOTAL CONSTRUCTION:				**$371,054**	
Engineering Design (8%)				$29,684	
Construction Oversight (6%)				$22,263	
TOTAL ESTIMATE:				**$423,001**	

Table B-8. Water-tight Plug Construction

Item	Rate ($/unit)	Unit	Number of Units	Total	Comments
General Equipment / Construction Costs					
Mucker	$325.00	da	10	$3,250	
Compressor	$108.00	da	10	$1,080	RsMeans: 01.54.33.40.0400
Generator	$85.00	da	10	$850	RsMeans: 01.54.33.40.2400
Jackleg Drill	$35.00	da	12	$420	
Fuel tanks and pump	$20.00	da	10	$200	
Excavator	$164.00	hr	10	$1,640	
Bobcat	$70.00	hr	40	$2,800	
Front End Loader	$125.00	hr	25	$3,125	
Ready Mix Truck	$270.00	hr	30	$8,100	Assume 2.5 hr RT; 70 yds total needed
Concrete Pump	$1,175.00	da	2	$2,350	RsMeans: 01.54.33.10.2140
Core Drill	$625.00	da	12	$7,500	
Water Storage	$250.00	da	15	$3,750	
Grout Plant	$300.00	da	8	$2,400	
Pick-up Trucks	$75.00	da	20	$1,500	2 trucks at $75/day
Ventilation Fans	$100.00	da	17	$1,700	RsMeans: 01.54.33.50.7100/ 2 fans at $50.00
Air Lines	$200.00	da	17	$3,400	
Miscellaneous (pumps, welder, tools, etc.)	$250.00	da	17	$4,250	
Materials / Supplies					
Fuel	$200.00	da	41	$8,200	
Form Materials	$5,200.00	ls	1	$5,200	1 plug, Labor 5 days/ plug = 5 days
Vent Bag	$3.69	lf	300	$1,107	F & H Mine Supply, Butte
4" Victaulic Pipe	$13.80	lf	300	$4,140	MP& E, Helena
1.5" Poly Pipe	$3.08	lf	300	$924	RsMeans: 33.11 13.20 1140
Packers	$425.00	ea	18	$7,650	pump thru packers
Ground Support	$2,000.00	ls	1	$2,000	
Shotcrete	$158.00	cy	25	$3,950	RsMeans: 03.37.13.60.0020, assume 11'x11'x50'x0.4'
Bentonite Grout	$220.00	tn	20	$4,400	
Type II Portland Cement	$234.00	tn	20	$4,680	
Concrete	$250.00	cy	72	$18,000	Assume 11' x11' x16'
Cement Admixtures	$22.50	TN	35	$788	$22.50/ton of concrete
Backfill Material	$31.00	cy	150	$4,650	RsMeans: 31.23.23.13.0015 material handling costs; assume using mine waste for backfill
Miscellaneous	$10,000.00	ls	1	$10,000	
6" HDPE Pipe	$12.00	lf	30	$360	
Labor					
Drilling (2 man crew)	$1,800.00	da	14	$25,200	Assume 20 - 30' to 40' holes
Mining Contractor (4 man crew)	$2,960.00	da	20	$59,200	
SUBTOTAL:				**$208,764**	
Bonding, and Insurance (10%):				$20,876	
Contingency (20%):				$41,753	
TOTAL CONSTRUCTION:				**$271,393**	
Engineering Design (8%)				$21,711	
Construction Oversight (6%)				$16,284	
TOTAL ESTIMATE:				**$309,388**	