Remedial
Investigation/Feasibility Study
Program Work Plan
Leviathan Mine Site
Alpine County, California

Submitted to:
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Project 13091

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LIST OF ABBREVIATIONS AND ACRONYMS

AAA	Administrative Abatement Action
AAC	Annual Average Concentration
AADD	Annual Average Daily Dose
ACSA	Aspen Creek study area
AMD	acid mine drainage
AMEC	AMEC Geomatrix, Inc.
AO	Administrative Order
AOC	Administrative Order on Consent
ARAR	Applicable and/or Relevant and Appropriate Requirement
ARD	acid rock drainage
AS	Aspen Seep
ASB	Aspen Seep Bioreactor
bgs	below ground surface
BSA	background study area
Cal/EPA	California Environmental Protection Agency
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
cfs	cubic feet per second
CIMIS	California Irrigation Management Information System
CIP	community involvement plan
COC	chain of custody
COPC	chemical of potential concern
CQA	Coordinator of Quality Assurance
CSM	Conceptual Site Model
CT	central tendency
CUD	Channel Underdrain
cy	cubic yards
DFG	Department of Fish and Game
DFR	daily field record
DMP	Data Management Plan
DQO	Data Quality Objective
DS	Delta Seep
DSA	downstream study area
EDD	electronic data deliverable
EPC	exposure point concentration
ERA	Ecological Risk Assessment
FFS	Focused Feasibility Study
FRI	Focused Remedial Investigation
FS	feasibility study
FSP	Field Sampling Plan
ft.	feet
ft/day	feet per day
ft/ft	vertical feet per horizontal foot
ft/sec	feet per second
GIS	geographic information system
gpm	gallons per minute
GPS	global positioning system

LIST OF ABBREVIATIONS AND ACRONYMS (Continued)

GRA	General Response Action
HASP	Health and Safety Plan
HDS	high-density sludge
HHRA	Human Health Risk Assessment
HI	Hazard Index
HSSE	Health, Safety, Security, and Environment
IRA	interim response action
IRIS	Integrated Risk Information System
LAC	Lifetime Average Concentration
LADD	Lifetime Average Daily Dose
LCSA	Leviathan Creek Study Area
LD	laboratory duplicate
LRWQCB	Lahontan Regional Water Quality Control Board
LTF	lagoon treatment facility
LTS	lime treatment system
µg/L	micrograms per liter
mg	milligrams
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
mg/m^3	milligrams per cubic meter of air
MS	matrix spike
MSD	matrix spike duplicate
msl	mean sea level
MW	monitoring well
MWH	Montgomery Watson Harza
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NDEP	Nevada Division of Environmental Protection
NTCRA	Non-time Critical Removal Action
OSHA	Occupational Safety and Health Administration
OSWER	Office of Solid Waste and Emergency Response
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
PPE	personal protective equipment
ppm	parts per million
PPRT	Provisional Peer Reviewed Toxicity Value
PRISM	Parameter-Elevation Regressions on Independent Slopes Model
PSA	Pit study area
PUD	Pit Underdrain
PWP	Program Work Plan
PWTF	pond water treatment facility
PZ	piezometer
QA	quality assurance
QA/QC	quality assurance/quality control
QAPP	Quality Assurance Project Plan
QC	quality control

LIST OF ABBREVIATIONS AND ACRONYMS (Continued)

RA	remedial action
RAGS	Risk Assessment Guidance for Superfund
RAO	Remedial Action Objective
RAP	Remedial Action Plan
RCRA	Resource Conservation and Recovery Act
RCTS	rotating cylinder treatment system
RD	remedial design
RfC	reference concentration
RfD	reference dose
RI	remedial investigation
RI/FS	remedial investigation/feasibility study
RME	reasonable maximum exposure
ROD	Record of Decision
RPM	Remedial Project Manager
SAP	Sampling and Analysis Plan
SOP	standard operating procedure
SOW	statement of work
SMS	Site Management Strategy
SRK	SRK Consulting, Inc.
TAC	Technical Advisory Committee
TBC	to be considered
TRV	toxicity reference value
UAO	Unilateral Administrative Order
U.S.	United States
U.S. EPA	U.S. Environmental Protection Agency
USFS	U.S. Forest Service
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey

REMEDIAL INVESTIGATION/FEASIBILITY STUDY
PROGRAM WORK PLAN
Leviathan Mine Site
Alpine County, California

1.0 INTRODUCTION

This Remedial Investigation/Feasibility Study (RI/FS) Program Work Plan (PWP) has been prepared by AMEC Geomatrix, Inc. (AMEC), on behalf of Atlantic Richfield Company (Atlantic Richfield). This PWP fulfills a requirement of the Administrative Order for Remedial Investigation and Feasibility Study (Unilateral Administrative Order or UAO) issued on June 23, 2008, by the United States (U.S.) Environmental Protection Agency (EPA) for the Leviathan Mine site (Figures 1 and 2). This PWP follows the guidelines for the preparation of a work plan as outlined in the *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA* (U.S. EPA, 1988); CERCLA is the Comprehensive Environmental Response, Compensation, and Liability Act.

In accordance with the guidance, this PWP identifies the tasks to be conducted through the completion of the RI/FS. The PWP is designed to document the decisions and evaluations made during the scoping process and in the UAO Statement of Work (SOW) to present a prioritization of anticipated future investigation tasks. The initial scoping process, documented in the Draft Data Quality Objectives (DQO) Report (Atlantic Richfield, 2008), identified areas of concern and established an initial list of criteria by which these areas will be assessed. In addition, the PWP contains the RI/FS Health and Safety Plan (HASP) and Sampling and Analysis Plan (SAP), which consists of a Quality Assurance Project Plan (QAPP) and Field Sampling Plan (FSP), as required by the UAO.

1.1 REGULATORY HISTORY AND SITE LISTING

In May 1998, U.S. EPA issued an Administrative Order on Consent (AOC) for Removal Action to Atlantic Richfield. Under the 1998 AOC, Atlantic Richfield was required to remove certain quantities of liquids collected in the evaporation ponds, collect specific information on site conditions, and reimburse U.S. EPA and other agencies for certain response costs. The 1998 AOC was modified in February 2000 to include a Riparian Conservation Project. On November 22, 2000, U.S. EPA issued an Administrative Order for Early Response Actions, Remedial Investigation and Feasibility Study (CERCLA Docket No. 2000-09-05) (U.S. EPA, 2000a) to Atlantic Richfield to submit work plans for a phased RI/FS for developing long-term responses to releases from the site. This order also required Atlantic Richfield to plan and implement Early Response Actions (ERAs) to address known releases.

U.S. EPA added the Leviathan Mine site to the National Priorities List on May 11, 2000.

In July 2000, U.S. EPA issued Administrative Abatement Action (AAA) under Section 106 of CERCLA to the Lahontan Regional Water Quality Control Board (LRWQCB) to treat water in the evaporation ponds. The AAA was modified in 2001, 2002, 2003, and 2004 to provide similar removal actions each summer, which succeeded in eliminating overflow to the creek. U.S. EPA issued a new AAA in 2005 directing the LRWQCB to treat acid rock drainage (ARD) captured in the evaporation ponds each year until a final remedy is selected and implemented.

U.S. EPA issued a Non-time Critical Removal Action (NTCRA) memorandum (U.S. EPA, 2005) on July 12, 2005, selecting a phased program for testing the effectiveness and reliability of year-round ARD treatment (Appendix A). An additional objective of the NTCRA is to eliminate untreated ARD discharge to the watershed to provide an opportunity to evaluate the scope of subsequent phases of the RI/FS, given that such interception and treatment can be expected to substantially alter the nature and extent of threats posed by the site.

On June 23, 2008, U.S. EPA issued the RI/FS UAO (U.S. EPA, 2008a). The UAO contains an SOW for conducting the RI/FS at the site, including completing the DQO Report (Appendix A). On July 23, 2008, Atlantic Richfield submitted its notice of intent to comply with the UAO, including comments on certain provisions of the UAO and SOW and objections to certain of the UAO's terms. Atlantic Richfield is submitting this PWP subject to the same comments and objections articulated in the July 23, 2008 notice.

The SOW included in the UAO requires collecting information to supplement and verify existing information on the environmental setting and pathway characterization, source characterization, receptor identification and risk assessments, geotechnical engineering evaluations, and a feasibility study (FS) for the site.

On September 26, 2008, U.S. EPA modified (U.S. EPA, 2008b) the removal action NTCRA to include changes to the treatment approach and work conducted on the site between 2005 and 2008. The modified NTCRA includes interception and treatment of flows from the Channel Underdrain (CUD) and Delta Seep (DS) from spring (June 1) through autumn (September 30). It stresses the importance of lengthening the period for collecting and treating flows from the CUD and DS, while acknowledging that the design and implementation of winterized treatment of CUD and DS flows are more appropriate for consideration as a long-term remedy.

On January 21, 2009, U.S. EPA and Atlantic Richfield entered into the Administrative Settlement Agreement and Order on Consent for Removal Action (CERCLA Docket No. 2008-29) (the 2009 AOC) (U.S. EPA, 2009). Among other things, the 2009 AOC superseded the 2000 Administrative Order and set forth Atlantic Richfield's obligations for performing certain response actions at the site as specified in portions of the modified NTCRA.

In October 2008, Atlantic Richfield submitted the *Draft Data Quality Objectives Report: Remedial Investigation and Feasibility Study* to U.S. EPA for review (DQO Report) (Atlantic Richfield, 2008).

1.1.1 UAO

The RI/FS work to be performed by Atlantic Richfield under the UAO is described in Paragraph 50, Paragraph 51, Attachment 1, and Attachment 2 of the UAO.

Paragraph 50 of the UAO indicates that Atlantic Richfield shall conduct activities and submit deliverables as provided by the SOW. The general activities required to be performed are identified in the List of Major Submittals for the Leviathan Mine RI/FS, provided as Attachment 2 to the UAO.

Paragraph 51 of the UAO requires that within 60 days of U.S. EPA approval of the DQO Report, the respondent shall submit the Work Plan, as described in the SOW. The DQO Report was submitted to U.S. EPA on October 21, 2008. U.S. EPA approved the DQO Report with comments on April 23, 2009, and directed Atlantic Richfield to prepare the Work Plan for the RI/FS under Paragraph 51 of the UAO. In the same letter, U.S. EPA approved Atlantic Richfield's December 15, 2008, proposal for producing the RI/FS Work Plan in stages. These stages include this PWP as an organizational programmatic work plan and outline for the entire site, and a series of Focused Remedial Investigation (FRI) work plans and Focused Feasibility Study (FFS) work plans for specific investigation areas and activities.

The U.S. EPA directed Atlantic Richfield to submit the PWP within 60 days of its approval of the DQO Report, making the due date for this PWP June 22, 2009. In the same letter, U.S. EPA directed Atlantic Richfield to submit FRI work plans for subsurface water monitoring and for mapping of the downstream watershed also within 60 days. On June 15, 2009, U.S. EPA approved an extension of the due date for the PWP and FRI Work Plans until July 10, 2009. The FRI work plans are being submitted under separate cover from this PWP.

1.1.2 SOW

The SOW for implementation of the RI/FS is set forth as Attachment 1 to the UAO (Appendix A). The SOW identifies the objectives of the project and presents a framework of activities for the RI/FS as appropriate. The SOW defines the "Leviathan Mine" as "the area within the Leviathan Mine property boundaries and adjacent areas outside the property boundary which have been disturbed by mining activities, such as mine wastes, excavations, landslides, and runoff of surface water and groundwater."

General SOW requirements include: "plan and conduct those investigations necessary to characterize the Leviathan Mine site and actual or potential contaminant migration pathways (Environmental Setting and Pathway Characterization); define the source (Source Characterization); define the nature and extent of contamination (Contaminant Characterization); identify actual or potential receptors (Receptor Identification); and conduct an assessment of risks posed to actual or potential receptors (Risk Assessment)."

The SOW requires that "all planning will be based on DQOs." The SOW also provides a general list of scope items, "of which modifications may be required as the program proceeds." Per the RI/FS guidance, the actual scope and data collection needs of the RI/FS are based on the current and future risk assessment pathways and the need to assess remedial alternatives.

1.1.3 List of Major Submittals

Attachment 2 of the UAO lists the "major submittals" required for the Leviathan Mine RI/FS. Major submittals include the DQO Report; the RI/FS Work Plan, including a HASP and SAP, comprised of the QAPP and FSP; the Remedial Investigation (RI) Report; and the FS Report. The FRI work plans will effectively become part of the RI/FS Work Plan. Human health risk assessment (HHRA) and ecological risk assessment (ERA) work plans will also be prepared but these work plans were not listed on Attachment 2 of the UAO as "major submittals."

1.2 PURPOSE AND OBJECTIVES

The purpose of this PWP is to describe the overall RI/FS program and criteria for assessing the site. The overall objectives of the RI/FS, consistent with the UAO are as follows:

- Determine the nature and extent of contamination and any threat to public health, welfare, or the environment caused by the release or threatened release of hazardous substances, pollutants, or contaminants at or from the site by conducting an RI.

- Determine and evaluate alternatives for remedial action (if any) to prevent, mitigate, or otherwise respond to or remedy any release or threatened release of hazardous substances, pollutants, or contaminants at or from the site by conducting an FS.
- Support long-term restoration of surface water and/or groundwater.
- Minimize threats to the environment, especially sensitive habitats and critical habitats of species protected under the Endangered Species Act.

The first step in accomplishing these objectives was performing the initial scoping and preparing the DQO Report, which identifies areas of concern and establishes the criteria by which these areas will be assessed. Based on an assessment of past and future land use, previous investigations data, migration and exposure pathways, and related risks, the need for additional investigation will be developed in the PWP.

1.3 SCOPE AND RATIONALE OF THE RI/FS

Consistent with the RI/FS guidance (U.S. EPA, 1988) and the National Oil and Hazardous Substances Pollution Contingency Plan (NCP), the scope of the RI/FS is based on the data needs identified in the DQO Report. As stated above, the DQOs were developed following U.S. EPA's systematic process for identifying data needs to characterize the site, completing the conceptual site models (CSMs), better defining Applicable and/or Relevant and Appropriate Requirements (ARARs), and narrowing the range of the preliminary remedial alternatives. Stakeholder comments on the DQO report were considered in revising the CSM and the RI/FS data needs. Although the SOW was not developed based on the scoping process as recommended in the RI/FS guidance (U.S. EPA, 1988), the SOW and the DQO Report are similar in that they are both initial planning documents that identify tasks that may need to be conducted during the RI/FS. A comparison between the initial DQOs and the SOW is shown in Table 1. The use of the scoping process, CSMs, DQOs, stakeholder comments, and SOW to form the scope of the RI/FS is memorialized in the PWP consistent with the guidance (U.S. EPA, 1988).

1.3.1 Initial Scoping, CSMs, and DQOs

Scoping is the initial planning phase of the RI/FS process. The scoping process for the Leviathan Mine site was divided into two steps. The first step began with the scoping data evaluation and the development of the CSMs (Figure 3). The 2007 RI/FS scoping data evaluation was conducted to compile background information including the site history and data collected during previous investigations and interim treatability studies. The scoping data evaluation resulted in the development of separate CSMs for both human and ecological receptors. The CSMs were presented to the Stakeholders for review, comment, and discussion, and based on stakeholder input the Human Health and Ecological CSMs were revised and presented in the DQO Report.

From the data evaluation and the initial CSM, a site management strategy (SMS) for the RI/FS was developed that preliminarily identifies the types of actions that may be required to address the problems, the optimal sequence of site actions and activities, and the procedures that may be used to streamline the RI/FS process. The purpose of the SMS is to tailor the RI and FS to site physical characteristics and impacts.

Based on the scoping data evaluation, the CSMs, and the SMS, a preliminary range of remedial action alternatives was developed and associated technologies identified as presented in the DQO Report. The identification of technologies and alternatives is necessary to help ensure that the data needed to evaluate these technologies is collected. Preliminary identification of potential ARARs in the scoping phase assists in initially identifying remedial alternatives.

An important part of the scoping process is the identification of RI/FS data needs to characterize the site, to assess pathways identified in the CSM, better define ARARs, and narrow the range of the preliminary remedial alternatives identified. This data needs step was generally accomplished via Step 7 of the DQO process and will be refined in this Work Plan and in future FRI work plans.

1.3.2 U.S. EPA and Stakeholder Comments to DQOs

In the April 23, 2009, DQO Report Approval letter, U.S. EPA provided Atlantic Richfield with comments to the DQO Report including technical comments received from stakeholders. U.S. EPA requested that the comments be considered during preparation of the RI/FS PWP and that a more detailed analysis of the data gap statements presented in the DQO Report be addressed in the FRI work plans.

During preparation of this PWP, special attention has been given to addressing U.S. EPA and stakeholder comments. In certain sections of the PWP, direct responses to comments are called out and specifically addressed, while in other places additional information or consideration has been incorporated into the particular task. Additional detailed analysis of existing data utilized in scope preparation will be presented in the individual FRI work plans with more specific DQOs, as appropriate.

1.3.3 SOW

As stated above, the SOW indicates that all planning be based on the DQOs, and the SOW presents a framework of activities to be considered based on the DQOs to assess potential contaminant migration pathways (Environmental Setting and Pathway Characterization); define sources of contamination (Source Characterization); define the nature and extent of contamination (Contaminant Characterization); identify actual or potential receptors (Receptor Identification); and conduct an assessment of risks posed to actual or potential receptors (Risk Assessment).

1.3.4 NCP

The RI/FS scope includes continued use of the RI/FS process as defined in the guidance (U.S. EPA, 1988). The RI/FS process started with the scoping conducted in and presented in the DQO report and will continue with the site characterization process as defined in Chapter 3 of the guidance. As described in the guidance, the major components of the site characterization include

1. conducting field investigations as appropriate,
2. analyzing field samples in the laboratory,
3. evaluating results of the data analysis to characterize the site and develop a baseline risk assessment, and
4. determining if data is sufficient for developing and evaluating remedial alternatives.

1.4 RI/FS WORK PLAN PROCESS

The Work Plan constitutes the final planning phase of the RI/FS process (Figure 3). This process is built upon the concepts developed in the *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (U.S. EPA, 1988). The Work Plan documents the decisions and evaluations made during the planning process and presents the anticipated future tasks. It describes the approach for collecting additional investigations and feasibility studies, identifies critical success factors, assigns responsibilities, and sets the project's schedule. The guidance states that due to the dynamic nature of the RI/FS process, plans may be modified based on the results of the RI. As additional data is obtained, the Work Plan (and in this case, the FRI work plans) may need to be revised prior to conducting additional site characterization activities or RI studies.

In order to accommodate the complexities of the investigations likely to be required at the Leviathan Mine site and to allow for flexibility in the RI/FS process as investigations proceed, the RI/FS Work Plan will be completed in two steps: preparation of an RI/FS PWP for the entire site and preparation of FRI work plans.

The FRI work plans will establish the rationale and methodologies for investigations to address data gaps. Individual FRI work plans will contain more detailed descriptions of investigation work such as the locations, number of soil borings and/or monitoring wells to be installed, the number of samples of soil, surface water, groundwater, biota, and other applicable medium to be collected, the analytical program and a schedule for implementation and reporting. The FRI work plans will also include supplements to the HASP, SAP, QAPP, and FSP as necessary for each scope of work. Draft FRI work plans will be submitted to U.S. EPA for review and approval prior to implementation. These FRI work plans will be considered addenda to this PWP.

1.5 STUDY AREAS

The SMS includes the definition of study areas that were used to develop the DQOs and to facilitate the implementation of further investigations. Five study areas were defined and four of the five are presented on Figure 4. Defined study areas include the following:

- **The Aspen Creek Study Area (ACSA).** This area includes the overburden piles, the reach of Aspen Creek that passes by the eastern side of the historic landslide area (Figure 5).
- **The Pit Study Area (PSA).** This area includes the entire pit area (reclaimed and not reclaimed portions), the adit, the Pit Underdrain (PUD), and the clarifier areas (Figure 6).
- **Leviathan Creek Study Area (LCSA).** This area includes the area west and north of the pit, the storage ponds, the diversion channel and CUD, other surface water diversion structures, the DS, and the length of Leviathan Creek from above the on-property area to the confluence of Leviathan and Aspen creeks (Figure 7).
- **Downstream Study Area (DSA).** This area starts at the confluence of Leviathan and Aspen creeks and continues into the upper portion of Bryant Creek to the extent impacts from the site above background have been recorded (Figure 8).
- **Background Study Area (BSA).** The BSA(s) will include areas where analog sites can be established to conduct background studies; these areas have characteristics similar to those of the site

The location and boundaries, physical description, results of previous studies, and conceptual model for each study area are presented in Section 3. Figure 4 shows the approximate boundaries for the study areas. The area boundaries are approximate and are not intended to limit the RI/FS investigation if work outside of the study area is necessary. For example, the habitat for some of the ecological receptors to be evaluated in the RI/FS extends outside of the study area boundaries.

1.6 COMMUNITY RELATIONS

A community involvement plan (CIP) was prepared by U.S. EPA in June 2004. It includes the framework for public involvement activities that will be performed at the site. It is a living document meant to reflect the needs of the community over the life of the project.

1.7 TERMINOLOGY/ACRONYMS

New terminology and acronyms have been progressively introduced to the project over the years. To avoid confusion during the course of the RI/FS, the following key terms are clarified below: *site*, *on-property*, *off-property*, *acid mine drainage*, *acid rock drainage*, *overburden*, *waste rock*, *artificial fill*, and *mine waste.*

1.7.1 Clarification of Site, On-property and Off-property

For the purpose of this PWP, the word "site" is used generally to refer to the on- and off-property area described in the SOW. In order to facilitate the RI/FS presentation of work, the disturbed portion of the site is also referred to as "on-property" or the "mine." The largely undisturbed area beyond the former mine workings is referred to as "off-property" and the area below the confluence of Leviathan and Aspen creeks is referred to as "downstream."

1.7.2 Clarification of Acid Mine Drainage and Acid Rock Drainage

The DQO Report used two terms to describe the outflow of acidic waters: AMD and ARD. AMD is considered the outflow of acidic waters specifically from mine features (e.g., tunnels, pit). ARD is considered the outflow of acidic waters from other naturally occurring mineralization or features (e.g., landslides, seeps). ARD will be used more widely in this document and sometimes may refer to both ARD and AMD.

1.7.3 Clarification of Overburden, Waste Rock, Artificial Fill, and Mine Waste

"Overburden" is defined as geologic material that exists or previously existed on top of an ore body. On property, shallow geologic material was excavated and placed beside the pit to access the mineralized sulfur ore. This overburden may contain high sulfur content, which at the time of open-pit mining may not have been economical to process.

"Waste rock" is the material that remains after mineralized sulfur in the host rock is processed by crushing. Depending on the effectiveness of sulfur removal process, high concentrations of sulfur may remain in the waste rock.

"Artificial fill" is the placement of any non-native material. Artificial fill may have originated from across the mine, may have been brought in from off-property sources (to construct a road), or may include landslide movement.

"Mine waste" is a collective term for all disturbed material that may include overburden, waste rock, and artificial fill.

1.8 CONTENT OF THE WORK PLAN

The content of the PWP is outlined below.

Section 1.0: Introduction—UAO requirements, scope of the RI/FS, objectives, the Work Plan process, community relations, terminology, and content of the Work Plan

Section 2.0: Background and Physical Setting—site description, geology, hydrogeology, and discharge areas

Section 3.0: Initial Evaluation—previous investigation, summary and analysis of previous removal actions, a summary of the DQO scoping process and presentation of the CSMs

Section 4.0: RI/FS Rationale

Section 5.0: RI Approach—rationale and approach by sitewide studies and study areas

Section 6.0: Risk Assessment Approach—HHRA and ERA Work Plan summaries

Section 7.0: FS Approach—including a strategy and an approach

Section 8.0: Data Management Plan—a plan for receiving and managing data for the RI/FS

Section 9.0: Project Management Plan—a framework for project management during the RI/FS

Section 10.0: Schedule—a prioritization of activities as the basis for an RI/FS schedule

Section 11.0: References

Appendix A: The UAO

Appendix B: Previous Investigation Data

Appendix C: The SAP (which consists of the QAPP and the FSP)

Appendix D: Health and Safety Documents

2.0 BACKGROUND AND PHYSICAL SETTING

This section describes the site, physical setting, demographics, site history, geology, and hydrogeology on a regional and local scale.

2.1 SITE DESCRIPTION

Leviathan Mine is located in a remote mountain area of northeastern Alpine County, California, on the eastern slope of the central Sierra Nevada mountain range at an elevation of approximately 7,000 feet (ft.) above mean sea level (msl). The mine is located about 25 miles southeast of South Lake Tahoe and 6 miles east of Markleeville, California, as shown on Figure 1. The mine is located within a portion of Sections 14, 15, 22, and 23, Township 10 North, Range 21 East of the Topaz Lake and Mt. Siegel U.S. Geological Survey (USGS) quadrangles (Figure 1).

2.1.1 Site Ownership and Land Use

Leviathan Mine is a large, inactive open-pit sulfur mine that is closed to the public. At the time mining ceased, the boundary of the Leviathan Mine encompassed 32 patented mineral claims and a patented mill site, which together totaled approximately 656 acres (Figure 9; Science Applications International Corporations [SAIC], 2000). Historically, additional unpatented load claims ("Dot" Claim Nos. 1–5 and 8–44) surrounded the patented Leviathan claims. All unpatented mining claims associated with Leviathan Mine became void by 1995 (SAIC, 2000).

Ownership of the 32 patented mineral claims is currently divided between the government and the private sector (Table 2). Twenty-three of the 32 patented mineral claims are currently owned by the State of California and include Leviathan Claim Nos. 5–13, 17–18, 23–24, 26–29, 31–32, and 43, the Jenny Claim, the Pioneer Claim, and the Nutty Henry Claim. The remaining 9 patented mineral claims are currently held by private ownership and include Leviathan Claim Nos. 14–16, 19–22, 30, and the Copper Bar Claim (Figure 9; SAIC, 2000). Ownership of the possessory right to develop the "Dot" group of lode claims that surrounds the patented Leviathan claims reverted to the federal government before 1999 (SAIC, 2000).

Approximately 253 acres of the 656-acre Leviathan Mine have been identified as being disturbed either directly by or as a consequence of mining activity (SAIC, 2000). About 21.32 acres of the disturbed surface of Leviathan Mine is on federal lands administered by the U.S. Forest Service (USFS; Figure 9; SAIC, 2000). As identified, the disturbed surface on the USFS property is reported to be the locations of two former mining camps (Isbell Camp and Anaconda Camp) and a small borrow pit for road/dam improvements. Most of the disturbed acreage (231.39 acres) is on patented mining claims currently owned by the State of California and managed by the LRWQCB (SAIC, 2000). Mining-related disturbance does not appear to extend to parcels that are currently under private ownership (SAIC, 2000).

Land use considerations as they pertain to remedy selection decisions under CERCLA will presumably be in accordance with the Office of Solid Waste and Environmental Response (OSWER) Directive 9355.7-4 (U.S. EPA, 1995b).

2.1.2 Surrounding Property Ownership and Land Use

The following description of the surrounding land use includes an area that extends outward approximately 4 miles from the mine (Figure 10). Information for this map was originally developed by Greystone Development Consultants on March 22, 1991, and was updated with information from the most current 2006 USFS map (USFS, 2006) and from information obtained from the Alpine County Assessor's Office and Douglas County Assessor's Office between May 6 and 13, 2009 (AMEC, 2009a).

The mine property is adjoined by lands owned by the USFS to the north, east, and west. Privately owned lands adjoin the mine property to the south. Private property also exists approximately 0.2 mile northwest of the mine and approximately 8 miles north of the mine along Bryant Creek on the Nevada side of the state border. All other privately owned lands are outside of the Bryant Creek watershed or are a significant distance from the mine.

Nearby grazing allotments include the Campbell Loope allotment located approximately 0.2 mile southwest of the mine, the Leviathan allotment located approximately 0.75 mile east of the mine, and the Cottonwood allotment located approximately 1.25 miles northwest of the mine (Figure 10).

During the agricultural growing season, water from Bryant Creek has regularly been diverted for cattle and irrigation purposes to the River Ranch (Figure 10). This diversion (River Ranch Irrigation Channel) is located immediately downstream of the Doud Springs inlet to Bryant Creek. The diversion is located approximately 7.8 miles downstream on the west side of Bryant Creek. This diversion channel, which appears to be unlined and runs for approximately 2 to 3 miles before reaching the River Ranch, has been used for agricultural irrigation and livestock consumption on the River Ranch. This use might change in the near future as the USFS is considering purchasing the River Ranch property. Surface waters within Bryant Creek on the Nevada side of the border may also be used as a water supply for irrigation or livestock consumption.

The present-day Washoe Indian reservation lands are located outside of the Bryant Creek watershed. During the months when the snow has melted, the Washoe tribe has historically used the Bryant Creek watershed for hunting, fishing, and gathering (Walker, 2003). Details of the Washoe tribe's land use are discussed in Section 2.1.5.

Lands owned by the USFS are available for recreational use and are used by visitors for hiking and camping during the dry season. These lands are patrolled by USFS park rangers.

2.1.3 Demographics

The following demographic information was obtained for Alpine County from the 2006 U.S. Census Bureau (http://quickfacts.census.gov/qfd/states/06/06003.html).

- Alpine County comprises a land area of 739 square miles. The county has 1,180 residents and 1,708 housing units. The population density was 1.6 people per square mile.
- The racial makeup of the county was 73.4 percent white, 20.8 percent Native American, 4.7 percent from two or more races, and 1.1 percent "Other"; 95.0 percent spoke English, 3.1 percent Spanish, and 2.0 percent Washoe as their first language.
- The age distribution of Alpine County was 4.4 percent persons under 5 years old, 18.9 percent under 18, 65.3 percent between 18 and 65, and 11.4 percent over 65; 48.9 percent of the population is female.
- 88.3 percent of the population are high school graduates; 28 percent have a bachelors degree or higher.
- The median income for a household in the county was $42,827. The per capita income for the county was $24,431. About 13.4 percent of the population was below the poverty line.

2.1.4 Site Access

Access to the site is provided by Leviathan Mine Road (also known as Forest Service Road 10052), which is an unpaved road that connects to California (CA) State Route 89 (SR 89) over Monitor Pass to U.S. Highway 395 (U.S. 395) in the Double Spring Flat area between Gardnerville, Nevada, and Topaz Lake, Nevada (Figure 11). Leviathan Mine Road extends approximately 9 miles between U.S. 395 and the mine to the east (the Nevada access road) and approximately 3 miles from SR 89 to the mine on the west (the California access road). Leviathan Mine Road skirts the eastern boundary of the mine, with access through the mine via Forest Service Road 10348. Access through the mine is controlled by locked gates to prevent unauthorized access.

The elevation of Leviathan Mine Road varies from approximately 5,800 ft. above msl to 8,000 ft. above msl, with road conditions influenced by inherent extreme variations in weather. In normal years, wheeled-vehicle access is limited to late spring through fall; wheeled-vehicle travel is discouraged during heavy rains or wet conditions due to potential road hazards.

Leviathan Mine Road is a public access road (except for the gated on-property access roads) and is subject to recreational users such as campers, off-road 4x4 vehicles, all terrain vehicles (ATVs), bikers, hikers, and hunters.

2.1.5 Cultural Resources

Cultural resources can include property, structures, landscapes, and objects of some importance to a culture or community for scientific, traditional, religious, or heritage reasons. They include any material remains of past human life or activities that are preserved in their original setting that are important to understanding human history and culture. Potential cultural resources that may be encountered in the region may be related to miners, the Washoe Indian tribe, and the Basque people, who were known to utilize the area for livestock grazing.

Cultural resources may be encountered during field investigations performed at the site. Although it is not within the scope of this document to fully describe the cultural resources of the site and surrounding areas, it is important to understand the potential resources so that proper procedures can be implemented in the event that they are encountered during the RI/FS.

The primary cultural resources of concern within the area of investigation are related to land use by the Washoe Indian tribe. The Washoe Indian tribe has four communities, three in Nevada (Stewart, Carson, and Dresslerville), and one in California (Woodford). A Washoe community is also located within the Reno-Sparks Indian Colony. Information concerning the Washoe tribe area, resources, and lifestyle are summarized in “Washoe Tribe Human Health Risk Assessment Exposure Scenario for the Leviathan Mine Superfund Site” (Harper, 2005a), which was prepared for the Washoe Indian tribe by Dr. Barbara Harper of AESE, Inc.

2.2 PHYSICAL SETTING, TOPOGRAPHY, AND SURFACE DRAINAGE

Leviathan Mine is located near the eastern margin of the Sierra Nevada mountain range, approximately four miles west of the California/Nevada border. The regional topography consists of rugged mountains and high meadowlands that slope gradually toward the north. The region is seismically active and is classified as Seismic Zone 4.

2.2.1 Physical Site Features

Physical site features as a result of mining activities include an inactive open pit near the center of the site, regraded overburden/spoils piles adjacent to the open pit to the north, regraded mine waste rock piles to the south and west of the pit, the Delta landslide to the west of the pit, and the large Leviathan Creek basin landslide to the northwest of the pit (Figure 12).

The existing site layout is shown on Figure 13.

2.2.2 Site Topography and Surface Water Drainage

This section presents a discussion of the topographic changes on the site from 1940 (pre-open-pit mining) to the present day (post-mining), including those resulting from construction activities by the LRWQCB in the mid-1980s. Analysis of topographic changes may provide valuable information as to the locations of excavation and placement of overburden and mine waste rock at the site (i.e., fill depths). Such analysis also highlights changes in surface water flow, and provides an understanding of both shallow groundwater flow in areas of fill and contaminant transport.

The topography of the site in 1940 was dominated by a northwest-southwest ridge that extended from Leviathan Peak, located two miles southeast of the site, to the confluence of Leviathan and Aspen creeks to the north (Figure 14). This ridge bifurcated east of the location of the present-day open pit, with the southern portion of the ridgeline trending more to the northwest than the northern ridgeline and creating a small “upper valley” between Leviathan Creek to the southwest and Aspen Creek to the northeast (Figure 14). Topography on the south side of the former ridgeline used to have a steep slope toward Leviathan Creek in the bottom of the canyon. The topography of the “upper valley” had a more moderate slope to the northwest to the point where the valley broadened and the dip of the slope increased. East of the northern ridge the topography was more moderate sloping toward Aspen Creek (Figure 14).

As shown on Figure 14, in 1940, surface water on the south side of the southern ridgeline would have drained to Leviathan Creek, whereas surface water to the northeast of the northern ridgeline would have drained to Aspen Creek. Surface water flow in the “upper valley” would have drained to the northwest and eventually to Leviathan Creek. The drainage patterns and drainage divides are shown on the 1940 topographic map (Figure 14) with predicted surface flow patterns depicted by blue arrows. The drainage divide (shown by green dashed lines) delineates the boundary between the areas that drain to Leviathan Creek and those that drain to Aspen Creek. This information indicates that most of the site drained to Leviathan Creek in 1940.

From 1952 through 2006, a number of activities were performed that altered the topography at the site and are described in Section 2.3:

- development of the pit by Isbell Construction Company from 1952 to 1953,
- open-pit mining by Anaconda Mining Company from 1954 through 1962,
- regarding of the pit and construction of the ponds, the Leviathan Creek Channel, and other structures by the LRWQCB from 1983 through 1985,
- landslide activity in the northeastern and northwestern parts of the site (currently active), and,
- slope stabilization and improvements to remedial systems at the site from 2002 through the present.

The current site topography has been dramatically changed as a result of mining activity as shown on the 2006 topographic map of the site (Figure 15). The southern ridgeline present on the 1940 topographic map no longer exists due to excavation of the pit in the south-central portion of the site (Figure 15). The pit is characterized by very steep walls along the northwest and northeastern edges and high-walls on the southeast. Access to the interior of the pit is through a topographic low on the southwestern side.

In the southwestern part of the site, the base of the canyon observed on the 1940 topographic map has been filled (up to 130 ft.) and the steep slopes replaced by terraces. This change in topography is reportedly due to deposition of "waste rock" in this area of the site. North of the pit a very small portion of the "upper valley" remains as observed on the 2006 topographic map (Figure 15). To the north / northeast of the pit the broad gently sloping area along and to the east of the northern ridgeline has been filled (reportedly with overburden material) and terraced, and includes a series of flat ridges. A hummocky terrain exists to the northwest of the terraces and extends to Leviathan Creek to the northwest. This hummocky terrain is the result of land slide activity and slope failures of overburden material.

The existing drainage pattern and drainage divide is shown on the 2006 topographic map (Figure 15). Drainage in the southern part of the site is toward the pit and then west to Leviathan Creek. Drainage in the remaining portion of the "upper valley" appears to have been altered with surface flow draining to the northeast in the area of hummocky topography and then toward Aspen Creek, instead of to the northwest and to Leviathan Creek (Figure 15). All areas east of the drainage divide are along moderate to gradual slopes toward Aspen Creek.

Although surface water drainage has changed it should be noted that shallow groundwater flow in areas of overburden or mine waste rock fill most likely follow the original topographic surface in areas where it is unaltered.

2.2.3 Regional Watershed

The site is located within the Leviathan Creek watershed, which is part of the Bryant Creek watershed and the larger East Fork Carson River watershed (Figure 16).

The East Fork Carson River originates south of Ebbetts Pass in California in the Carson-Iceberg Wilderness at an elevation of 11,460 ft. above msl and ends near Genoa, Nevada. The East Fork Carson River is a main tributary of the larger Carson Valley watershed, which extends to the northeast approximately 90 miles into Nevada beyond the state border. Bryant Creek flows into the East Fork Carson River approximately one mile downstream from where the East Fork Carson River crosses the California-Nevada border (USFS, 2006).

The Bryant Creek watershed encompasses approximately 31.5 square miles. Bryant Creek forms at the confluence of Leviathan Creek and Mountaineer Creek. Bryant Creek continues to flow to the north approximately 4 miles to the California-Nevada border and then 3.5 miles to its confluence with the East Fork of the Carson River. Named tributaries to Bryant Creek include Barney Riley Creek and Doud Creek (Figure 2).

The Leviathan Creek watershed encompasses approximately 10.5 square miles and ranges in elevation from 8,963 ft. above msl at Leviathan Peak to 6,400 ft. above msl at the confluence of Leviathan and Mountaineer creeks. The named tributaries that join Leviathan Creek include Upper Tributary, Lower Tributary, 4L Creek, and Aspen Creek. The tributaries that join Aspen are known as unnamed Tributary #1 and unnamed Tributary #2. The confluence of Leviathan Creek and Aspen Creek is at the northern edge of the site and flows a mile to the north before coming to the confluence with Mountaineer Creek. The confluence with Mountaineer Creek represents the end of the Leviathan Creek watershed.

2.2.4 Climate and Meteorology

This section summarizes ranges of measured climatic variables that may be applicable to site remediation or understanding the potential effects of the climatic variables on the fate and transport of chemical constituents at the site. Of interest for this analysis are the ranges of measured temperature, precipitation, wind speed, and evaporation at the site during the typical field season (May/June to September) and non-field season (October to April/May). A meteorological station on site near Pond 1, maintained by the LRWQCB has been collecting climatic variable data since 2003. The data set obtained for the following discussion from this meteorological station extends from February 2003 to August 2008.

Climatic variables have been measured and modeled by various groups at the site (Brown and Caldwell, 1983; Montgomery Watson Harza [MWH], 2002a) and at locations near the site (e.g., weather stations at Monitor Pass, and modeled PRISM (Parameter-Elevation Regressions on Independent Slopes Model) values. A comparison of these different available data sets indicates the potential for substantial variation in the measured or estimated values for the same climatic variable. A discussion of the variability observed between the LRWQCB data set and a modeled data set for the site with respect to precipitation is provided in the DQO Report (Atlantic Richfield, 2008). As indicated in the DQO Report discussion, a potential weakness with the LRWQCB data set is that, depending on the variable of interest, a substantial amount of data may be missing. Regardless, the LRWQCB data set is considered to be applicable to on-property climatic conditions for the purpose of this section because: it provides a relatively long record of measurement, many variables were measured directly at the site from the same location, and measurement methods and equipment are documented and maintained by the LRWQCB.

Table 3 provides the measured ranges observed in the available data set for the indicated climatic variables. Additional details are provided in the water balance in Section 3.10.1.3

2.3 HISTORY OF MINING ACTIVITIES

Mining began on site in approximately 1863 and continued on an intermittent basis until 1962. Originally, the mine was opened to supply blue vitriol or chalcanthite (both copper sulfate minerals) for refining silver ore at the Comstock mines in and near Virginia City, Nevada. From 1863 until the early 1870s, approximately 500 tons of copper-sulfate-bearing rock was removed by the early miners. By 1870, at least two adits had been developed, blast furnaces and other mining machinery installed, and the mine was smelting up to six tons per day of copper.

Around 1869 miners began working the site for native copper; however, they found the copper to be mixed with too much sulfur to make copper extraction economically feasible (SAIC, 2000). Around 1872 mining activities ceased.

The Western Clay and Metals Company of Los Angeles optioned the mine in 1931. Between 1932 and 1935 additional mining claims were located, increasing the Leviathan Mine holdings to 90 unpatented lode claims (SAIC, 2000).

Development of the large sulfur deposit began in earnest in the mid-1930s and continued through the early 1940s. Numerous adits, raises, drifts, and stopes were excavated during this time period to explore and mine the sulfur. In 1933, there were four tunnels: Tunnel No. 1 at several hundred feet in length; a shorter tunnel, Tunnel No. 2; Tunnel No. 3 at 760 ft., which discharged mine drainage water at a rate of 30 gallons per minute; and Tunnel No. 4 at 300 ft. in length. Tunnel No. 5 was constructed a short time later. The locations of underground mine workings are shown on Figures 17 and 18.

By 1934 the Leviathan Sulfur Company, a subsidiary of Western Clay and Metals Company, had acquired an interest in the mine and was producing approximately 100 tons of sulfur per day. Between 1935 and 1941, the Calpine Corporation of Los Angeles, through a sublease from Texas Gulf Sulfur Company, constructed a mill and experimental plant for the recovery of sulfur; developed an extensive system of tunnels, drifts and rises; lengthened Tunnel No. 5 (the main adit) to 3,000 ft.; and produced 5,000 long tons (long ton = 2,240 pounds) of sulfur. The Siskon Mining Corporation, a subsidiary of Texas Gulf Sulfur Company, acquired the mine in 1945 and continued to mine and produce sulfur up through 1948. Between 1941 and 1949, additional mining claims were located and the mining claims changed ownership, culminating with a 1950 patent of 32 mining claims and a mill-site by the Siskon Mining Company. In 1950, the Siskon Mining Corporation sold its claims to the Calsul Mining Corporation.

Anaconda acquired the properties in 1951 from Calsul as a source of sulfur for processing copper ore at its mine near Yerington, Nevada. Between 1952 and 1953, Anaconda's contractor, Isbell Construction Company, further developed the underground mine into an open-pit mine by removing overburden material above the sulfur ore body.

Between 1954 and 1962, approximately 1.67 million long tons of ore were removed from Leviathan Mine. The main sulfur ore body contained as much as 28 percent elemental sulfur and occurred in a lenticular body with a maximum thickness of 100 ft. (Brown and Caldwell, 1983).

The main sulfur ore body was located beneath approximately 300 ft. of overburden/spoils. According to the LRWQCB (1995a), approximately 22 million tons of overburden/spoils containing large quantities of low-grade sulfur ore was removed and spread over more than 200 acres (Figure 12). Waste rock, consisting of low-grade ore from mining operations, was placed in the former Leviathan Creek canyon in the western part of the site (Figure 12).

The first mitigation and remediation activities at the site began in 1956 and continue to this day. The history of removal actions performed at the site is discussed in Section 3.

In 1962, Anaconda ceased all mining operations and closed the mine. In November 1962, Anaconda quitclaimed the mine (consisting of 32 patented mining claims, a patented mill site, and 44 unpatented load claims) to Chris Mann (SAIC, 2000). The Mann family then formed Alpine Mining Enterprises, Inc., and in May 1983 transferred to the new company all of the mining claims and the mill site, which included the mine. No mining production was reported from 1963 to 1971 (Clark, 1977).

On December 19, 1983, Alpine Mining Enterprises, Inc., conveyed ownership of 465 acres of the Leviathan Mine property to the State of California. No known mining activities have been performed at the site since that time.

2.4 GEOLOGY

The following sections describe the regional geology, site geology, geologic interpretation of the alteration and mineralization process, and faulting.

2.4.1 Regional Geology

The site is located along the eastern margin of the central Sierra Nevada. The Sierra Nevada geomorphic province is a northwest-trending mountain range approximately 400 miles long and 40 to 100 miles wide. The Sierra Nevada is bounded on the west by the Great Valley province, on the north by the Cascade Range, and on the east by the Basin and Range province. The Sierra Nevada geomorphic province is dominated by a westerly tilted fault block. Extensive uplift of the block on its eastern border created much steeper relief on the eastern side of the range than on the western side. Consequently, drainages on the eastern flank tend to be steeper and narrower than those on the western flank (Norris and Webb, 1990).

The extensive mountain range is the result of three major episodes of tectonics in the region. The rocks of the Sierra Nevada are divided into the subjacent and superjacent series. The subjacent series consist of the basement metasedimentary and igneous rocks. The bulk of the range came from the Sierra Nevada batholith, a magmatic intrusion beginning in the late Jurassic and continuing into the late Cretaceous. In the central Sierra Nevada, plutonic igneous rocks, mostly silicic (granite) form the multiple intrusions of the batholith and constitute 60 percent of the exposed rock. The major plutons range in composition from quartz diorite to granite. Sedimentary and volcanic rocks that overlie the basement, referred to as the superjacent series, are most prominent in the central and southern Sierra. The superjacent series includes Cretaceous marine sediments, Eocene Ione Formation, post-Eocene gravels and conglomerates, and Tertiary volcanics. Formation of the modern Sierra Nevada began about 50 million years ago when uplifting of the earth’s crust commenced, followed by periods of extensive weathering and glaciation forming the current topography and geologic features in the region.

According to Clark (1977), the region is predominantly underlain by granitic rocks of Mesozoic age in the western part of Alpine County and andesitic volcanic rocks of Tertiary age in the eastern part of Alpine County (Table 4). Present in smaller amounts are Mesozoic metamorphic rocks that occur as roof pendants surrounded by granitic rocks and Quaternary alluvium and glacial moraines in some of the valleys.

The oldest known rocks in Alpine County are metamorphosed rocks of pre-Cretaceous age (e.g., roof pendants). Although their exact age is unknown, some have been classified by Lindgren (1896) as possibly ranging from Triassic to Jurassic.

Volcanic rocks cover much of the eastern portion of Alpine County and along many of the high ridges and peaks in the western and southern portions. The most abundant volcanic rocks are andesitic breccias and tuffs of Pliocene age. The andesitic breccias and tuffs occur in beds as much as several thousand feet thick and overlie granitic and metamorphic rocks. These breccias consist of angular andesite fragments in a matrix of finer andesitic detritus. The fragments are up to several feet in diameter. Occasional granitic boulders are present in the andesitic breccias. The breccia is a rough-textured rock that is porous and ranges from green to dark gray. It is usually porphyritic with phenocryts of plagioclase and augite in a microcrystalline groundmass. Hornblende and hypersthene are also present. Massive andesite flows are present, especially in the vicinity of necks, domes, and plugs (Clark, 1977).

Other types of volcanic rocks occur in Alpine County but are much less extensive than the andesite. These include rhyolite and dacite tuffs and flows of Miocene age. In places, these rocks have been silicified. Also, a few small basalt flows of Pleistocene age cap several peaks in the eastern part of Alpine County. A stratigraphic column of the most common rock types in Alpine County is shown in Table 4.

2.4.2 Regional Structure, Regional Alteration, and Economic Geology

This section describes the regional structure, alteration patterns, and economic geology of Alpine County. The regional structural, alteration, and mineralization patterns surrounding the mine area form a background condition that should be used to place the site mineralization in proper context with regional mineralization. Information from this section may be useful during selection of background study areas for the RI/FS. A detailed discussion of alteration and mineralization at the site is presented in Section 2.4.4.

2.4.2.1 Regional Structure

The regional geologic structure in the eastern Alpine County area is apparent from the interpretation of aerial photographs. As shown on Figure 19, the regional structure is dominated by a circular pattern that appears to be approximately 9 to 10 miles in diameter, with Leviathan Mine located at the approximate center. Geologic interpretation of this structure is consistent with development of the Sierra Nevada batholith and intrusion of igneous magma into the earth's upper crust during pluton emplacement and potentially associated volcanism, both of which can cause circular deformation of the upper crust. Often the overlying material will collapse into the magma chamber in what is termed a cauldron collapse in the event of plutonism, or a collapsed caldera in the event of volcanism. Literature searches have not yielded any regional studies of sufficient detail to document the interpretation of this structure, only the more localized geology and mineralization.

2.4.2.2 Regional Alteration

The geology and large-scale areas of alteration and hot spring activity within Alpine County coincide with the circular structure observed in the aerial photographs and the geologic interpretation that this structure was formed by either plutonism or volcanism. During such events the heat of the underlying magma causes alteration of the outlying rocks. In addition, convecting mineral-laden hydrothermal solutions, the circulation of which is powered by magmatic heat, circulate upward and outward, causing hydrothermal alteration and forming mineral deposits. This interpretation is supported by the regional structure, mineralization, and alteration patterns observed:

- a collapsed cauldron or caldera structure, approximately 9 to 10 miles in diameter extending from the eastern side of the Sierra Nevada to the area of the Zaca Mine to the west;
- regional (older) copper porphyry-type alteration with copper, gold, and silver mineralization;
- higher-temperature copper mineralization toward the center (Leviathan) of the system and lower-temperature gold mineralization toward the perimeter (Zaca Mine); and
- younger hot springs mineralization likely occurred after the copper porphyry system, hot springs mineralization can be found in other areas outside of Leviathan near the East Fork of the Carson River.

Hydrothermal alteration has been observed at the site and throughout the region. Hydrothermal alteration is the change in the host rock mineralogy due to contact with hot fluids. The hot fluids carry solutions that are often rich in metals, sulfur, and salts from a magmatic source. As these fluids pass through various rock types, components are added, removed, and distributed often resulting in mineralized sections of sulfur and metal ore. Mines developed in Alpine County are primarily located in areas of hydrothermal alteration.

Altered rocks similar to those that have been mapped at the site have been mapped in the surrounding areas at the following locations (Figure 20):

- approximately 3 miles southwest of the site between Mogul Peak and Colorado Hill (Clark, 1977);
- approximately 13.5 miles southwest of the site at Ebbetts Pass located (Wilshire, 1957);
- approximately 6.5 miles north of the site near the confluence of Bryant Creek and the East Fork of the Carson River (beyond the California-Nevada border); and
- approximately 6 miles to the southeast along Nevada Highway 395.

Active hot springs are present along the banks of the East Fork of the Carson River, approximately 6 miles west of the site (1.5 miles northeast of Markleeville), and at Grover Hot Springs State Park, approximately 11 miles west of the site.

This information may be useful in selecting analog sites for use in developing background data.

2.4.2.3 Economic Geology

Mineral mining activities within Alpine County were primarily performed within the zones of alteration. The principal mineral commodities for Alpine County include sulfur, gold, silver, copper, tungsten, sand and gravel, and crushed stone. In addition, small amounts of lead, mercury, selenium, and zinc have been produced. Other mineral commodities known to occur in the Alpine County include antimony, arsenic, iron, limestone, manganese, and molybdenum.

The five mining districts in Alpine County include the Monitor-Mogul, Alpine, Raymond, Silver King, and Silver Mountain districts (Figure 21). The mining districts most pertinent to this investigation include the Monitor-Mogul district (the site is located in the northeastern part of this district) and the Silver Mountain District. These areas contain geology similar to the site and they may be investigated during the RI/FS for analog sites. The Monitor-Mogul District and the Silver Mountain District are described below.

Monitor-Mogul District

The Monitor-Mogul mining district is an area of alteration and metal mineralization that has been the main source of sulfur, gold, and silver in Alpine County. Copper, lead, zinc, mercury, antimony, arsenic, manganese, and tungsten are also known to have occurred within the district (Clark, 1977).

Leviathan Mine is located in the northeastern part of the Monitor-Mogul district, and has been the primary source of sulfur in the Alpine County. Sulfur has also been encountered in other parts of the Monitor-Mogul district but at quantities that are less than those encountered at the site. Copper-bearing minerals have historically been encountered at Leviathan Mine but not at economically obtainable quantities. A detailed discussion of the site geology is presented in Section 2.4.3.

Different types of sulfur-bearing minerals were used by Clark (1977) to identify distinct zones of alteration southwest of the site within the Monitor-Mogul District (Figures 20 and 21). One alteration zone surrounds the Morning Star Mine, which is located approximately 2 miles southwest of the site. The Morning Star Mine was reported to contain fairly abundant and usually fine- to medium-grained disseminated pyrite, chalcopyrite, and enargite and produced economic quantities of gold, silver, and copper. A separate zone of alteration surrounding the Zaca Mine is located at Colorado Hill approximately 4 miles southwest of the site. This zone of alteration was distinguished from the zone around Morning Star Mine based on the lesser quantities of enargite observed. The Zaca Mine was reported to produce economic quantities of gold, silver, copper, lead, zinc, tungsten, and antimony.

This information may be useful in selecting analog sites for use in developing background data.

Silver Mountain District

The Silver Mountain district is located in south-central Alpine County near Ebbetts Pass approximately 13 miles southwest of the site. Clark (1977) reported that the district contained extensive zones of silicified and altered volcanic rocks; however, no systematic studies had been conducted to determine the size and distribution of minerals of value. Significant mines within this district include the Exchequer, I.X.L., and Pennsylvania mines, which produced economic quantities of gold and silver. Sulfur-bearing minerals such as pyrite, galena, and chalcopyrite were identified in association with the silver and gold-bearing rocks. Hydrothermal alteration was identified in volcanic breccias within the areas throughout the Silver Mountain District (Wilshire, 1957).

Similar geologic features between the site and Silver Mine District suggests that potential background study areas may extend at least 13 miles southwest of the site and potentially in other areas of the Silver Mountain District.

2.4.3 Site Geology

The interpretation of site geology presented below in Section 2.4.3.1 is based on geologic information provided by Anaconda Company (Clark, 1977), surface mapping performed by Herbst and Sciacca (1982), borings advanced by the USGS (Hammermeister and Walmsley, 1985), and borings advanced by Atlantic Richfield (SRK, 1999). The various stratigraphic columns resulting from these investigations have been compiled in Table 5 for comparison. Section 2.4.3.2 presents and evaluation of the subsurface site geology based on information from the above referenced sources and interpretation of boring logs compiled during previous investigations. Consistent with the SMS for the RI/FS, the description of subsurface site geology is detailed by study area.

2.4.3.1 Surface Geology

This section describes the surface geology at the site according to documents by Clark (1977) and Herbst and Sciacca (1982).

The geology generally consists of hydrothermally altered volcanic and volcaniclastic sedimentary units of Quaternary and Tertiary age underlain by older granitic and metamorphic rock bedrock. The Quaternary age units are underlain by Tertiary-age units. Twenty-seven different rock units consisting of 7 Quaternary-age sediments and 20 Tertiary-age units have been mapped at the site. Nomenclature for the lithostratigraphic units exposed at the surface of the site was developed and a stratigraphic column of the site geology is shown in Table 5. A geologic map of the site and surrounding area is shown on Figure 22. Herbst and Sciacca and Brown and Caldwell (1983) utilized the information from the surface mapping to project the subsurface geologic conditions at the site. The trace of cross sections taken from Herbst and Sciacca and Brown and Caldwell is shown on Figure 23, and Figures 24 and 25 show the cross sections. Note these figures were originally prepared before the LRWQCB built the ponds and other structures at the site.

The Quaternary-age units identified include unconsolidated and recent deposits of gravel, sand, silt, clay, and rock fragments derived from recent landslides (Qls), debris flows (Qdf), alluvium (Qal), ponded sediment (Qps), and talus (Qt). The Quaternary-age units also include altered volcaniclastic sedimentary units that were recently disturbed by past mining activities, pollution abatement construction activities, and mass movements. These units include mine tailings or artificial fill (Qaf) and talus resulting from mining (Qtm).

Tertiary-age units generally include the in situ, native geologic material that existed at the site prior to mining activities or the LRWQCB construction activities. These units include altered and unaltered portions of the upper sedimentary sequence, a basalt flow, lower sedimentary sequence, and andesite bedrock.

The upper sedimentary sequence (Trs) includes agglomerate, sandstone, siltstone, latite and andesite. The upper sedimentary sequence is well graded with grain sizes that range from sandy clay to gravel to cobbles and include interbedded fine- to coarse-grained breccias and lahars. Ore has been observed in the andesite, tuff, and agglomerate. Sub-units include silicified breccia (Tsb), silicified iron-stained breccia (Tsib), quartz latite porphyry (Tqlp), sandstone (Trss), argillated altered sandstone (Trsa), argillated altered lahar (Trsab), lahar (Trsl), chloritized breccia (Trsb), ore rock (Tso), and ore rock with relict breccia texture (Tsob).

Mesozoic granitic rocks (Cretaceous-age) and metamorphic rocks (pre-Cretaceous) have been observed underlying Tertiary volcanic rocks in other areas of Alpine County; however, they have not been observed at the site. These Mesozoic rocks are considered the bedrock material that is likely to underlie the site.

2.4.3.2 Subsurface Geology

Subsurface geology at the site has been interpreted from data collected during previous investigations conducted by the USGS between 1982 and 1983 in borings PZ-1 through PZ-33 (Hammermeister and Walmsley, 1985) and by Atlantic Richfield between 1998 and 1999 in borings MW-1 through MW-12 (SRK, 1999; Figure 26).

Data from these investigations was evaluated to identify the lithology, develop cross sections, and identify the units in which each well was screened. Data evaluation included correlating lithologic descriptions from the available boring logs to the lithostratigraphic units developed by Herbst and Sciacca (1982). Due to the geologic complexity and the high degree of variability and ambiguity in the lithologic descriptions among the various boring logs recorded by multiple personnel, it was not feasible to classify the lithology as described in the logs into the 27 lithostratigraphic units defined by Herbst and Sciacca (1982). Instead, the lithology was simplified into 5 lithostratigraphic units:

Quaternary-age sediments

1. (Qls, Qdf, Qal, Qps, Qaf, Qt, and Qtm), or

Tertiary-age units, which include

2. upper sedimentary sequence (Trs) and ore rock (Tso),
3. basalt flow (Trb),
4 lower sedimentary sequence (Trc), and
5 andesite bedrock (Ta).

For the purpose of lithostratigraphic interpretation presented on cross sections (Figures 27 through 29), the Quaternary-age sediments were grouped with artificial fill, including overburden/spoils and mine waste rock, due to insufficient detail in the boring logs from the previous investigations to separate them into subgroupings, and they represent material that in one form or another was disturbed by mining activities and therefore may be a potential source of ARD. Tertiary-age units were grouped together as the “upper sedimentary sequence” because they represent native material which has not been disturbed by mining activities. Results of these groupings are presented on cross sections (Figures 27 through 29) and are described below.

Sitewide Stratigraphy

Stratigraphy at the Leviathan Mine site primarily consists of Quaternary-age artificial (Qaf) fill including mine waste rock and overburden overlying the Tertiary-age upper sedimentary sequence. Andesite (Ta) was observed at the base of some of the borings. The basalt flow (Trb) or lower sedimentary sequence (Trc) was not observed in any of the borings.

The thickest sections of mine waste were observed in the former mine waste rock dump area of the LCSA located beneath the location of Ponds 2N and 2S (Figure 29). In these areas waste rock is estimated to be between 80 and 115 ft. thick. The thickest section of upper sedimentary sequence (Trs) was observed up to a maximum thickness of 161 ft. in the borehole for piezometer (PZ) PZ-7 (in the LCSA). PZ-7 represents geologic information from the lowest elevation at the site with the bottom of the boring reaching 6,693 ft. above msl. Mineralized sulfur was interbedded within andesite of the upper sedimentary sequence (Trs; maximum of 23 ft. thick) in MW-5D (located in the southeast end of the pit) and mineralized agglomerate (approximately 11 ft. thick in monitoring well MW-10D located at the southern end of Pond 4; Figure 13).

Andesite was encountered at the base of some borings (PZ-1C and PZ-17A) but not in other nearby borings drilled to a lower elevation, suggesting that the andesite encountered was a local occurrence and not representative of bedrock.

Consistent with the SMS for the RI/FS, the description of site geology is detailed by study area below (Figure 4). Because borings have not been advanced in the DSA and BSA, the subsurface geology in these areas has not been evaluated and thus they are not discussed below.

Geology in the Pit Study Area (PSA)

Geologic information within the pit (Figure 6) was obtained from the lithologic logs generated from the boreholes for monitoring wells MW-3, MW-4, and MW-5D, and piezometers PZ-2A, PZ-17A, and PZ-33 (Figure 26). Cross sections of the PSA are shown on Figure 27.

Geology in the PSA includes mine waste rock and/or overburden material (used during regrading of the pit) in the center of the pit which is underlain by the upper sedimentary sequence (Trs) interbedded with sulfur ore. The maximum thickness of mine waste rock (Qaf) was observed in PZ-2A at approximately 21 ft. and appears to thin at the edges of the PSA. The maximum thickness of the upper sedimentary sequence (Trs) was observed at the edge of the PSA in PZ-33 at approximately 122 ft. (Figures 26 and 27).

Mineralized sulfur was observed in andesite with a thickness of 23 ft. near the top of the upper sedimentary sequence (Trs) in boring MW-5D in the southeastern portion of the pit (Figure 27). Mineralized sulfur ore was also observed in agglomerate at a thickness of 7 ft. within the upper sedimentary sequence (Trs) in boring PZ-17A also in the southeast corner of the pit. This was also the location where a boring was drilled into a collapsed section of a former mine tunnel at approximately 7,041 ft. above msl. Based on the borings elevation and location, it is likely that this boring encountered a collapsed section of Tunnel 5 (Figure 27).

Geology at Aspen Creek Study Area (ACSA)

Geologic information for the ACSA (Figure 5) was obtained from lithologic logs generated from the boreholes for piezometers PZ-3A, PZ-3B1/3B2, PZ-3C, and PZ-19A/19B (Figure 26). A cross section through the ACSA is shown on Figure 28.

All borings contained overburden (Qaf) underlain by the upper sedimentary sequence (Trs). The maximum thickness of material disturbed by mining activities was observed in PZ-3C at approximately 72 ft. Based on the limited amount of usable geologic information, additional information should be collected to delineate the lateral and vertical extent of overburden. The thickest section of the upper sedimentary sequence was observed in piezometer PZ-3A at 88 ft. (Figure 23).

Geology at Leviathan Creek Study Area (LCSA)

Geologic information for the LCSA (Figure 7) was obtained from lithologic logs generated from the boreholes for monitoring wells MW-1, MW-2S/2D, MW-6 through MW-12 and piezometers PZ-1A, PZ-1B, PZ-1C, PZ-7, PZ-9A (Figure 26). Cross sections in the LCSA are shown on Figure 29.

Mine waste rock and/or overburden were observed in all borings underlain by the upper sedimentary sequence. The thickest sections of mine waste rock at the entire site were observed in the former waste rock dump area located beneath the present-day Ponds 2N and 2S. This is supported by information from borings PZ-1B, MW-8, PZ-1A, and PZ-1C. In PZ-1B, mine waste rock was observed at a maximum thickness of 131 ft. This was before the construction of Ponds 2N and 2S, however, when some material was removed from the area (Brown and Caldwell, 1983). Based on the present-day surface elevation, it is estimated that 115 ft. of mine waste rock currently remains. This mine waste rock thins out toward Leviathan Creek to the south and west, to the north at MW-12, and to the east at MW-2D.

2.4.4 Alteration and Mineralization at the Site

Hydrothermal alteration has been well documented at the site and throughout the region. As described, the zones of alteration have been the primary location of mining activities. The sequence of geologic events that explained the possible origin for the deposition of sulfur at the site was proposed by Clark (1977) and is summarized below.

1. Volcanic and volcaniclastic units were deposited.
2. The volcanic and volcaniclastic deposits underwent faulting.
3. After faulting and the development of channel ways, the tuff was altered by ascending silica-rich solutions in part derived from an underground source, presumably an unexposed magma. It is not known what part, if any, heated groundwater may have played in mineralization.
4. Contemporaneously, and closely following silicification, iron-copper-bearing and hydrogen sulfide-charged fluids were channeled through fractures such as those once exposed in the underground workings.
5. Hydrogen sulfide gas was oxidized with deposition of sulfur and formation of water.
6. Tuff served as a sponge for fluids which spread laterally through the porous and permeable material.
7. Deposition of sulfur in the pores eventually caused the tuff to seal and resulted in more lateral and downward spreading of mineral-charged fluids. The last phase of

sulfur deposition consisted of fracture filling in the andesite and filling of the channels with sulfur.

8. Significance of silicified "cap rock" that was removed during pit development is undetermined but probably is related to the period of silicification. Many other silicified outcrops where sulfur is not known are found in the area;
9. Time of deposition was probably in the middle to late Tertiary period.
10. Oxidation of copper and iron sulfides produced the following hydrous sulfate minerals: chalcanthite, iron-chalcanthite, halotrichite, melanterite, and romerite. Gary (1939) identified all of these minerals in the underground workings. Some or perhaps all of these minerals are forming on the pit floor where ground or surface water is impounded.

The area of sulfur mineralization that Anaconda mining geologists were interested in (often referred to as the "ore body") occurred in the area of the open pit, approximately 200 to 300 ft. below the former ground surface. This sulfur ore body occurred as a relatively flat, elliptical lens, with dimensions of approximately 2,400 ft. in length, 700 ft. in width, with a maximum thickness of 90 ft. and an average thickness of 58 ft. (Evans, 1977). Sulfur mineralization has been observed within the tuff near the base of the upper sedimentary sequence and an underlying "andesite." Veins of pure sulfur, 1 to 2 ft. in thickness, were noted by Anaconda mining geologists within the tuff (Evans, 1977). Herbst and Sciacca (1982) reported that pyrite and marcasite are irregularly distributed through the ore-bearing interval, at concentrations up to 30 percent of the rock mass.

Marcasite, pyrite, arsenopyrite, and chalcopyrite occur within the strata above and below the ore body strata (Evans, 1977). These sulfide minerals are found throughout the silicified/altered overburden strata in the vicinity of the open pit. Jasperoid clasts within the silicified strata reportedly contain up to 15 percent disseminated sulfide minerals (Sciacca, 1984).

Smectite is the predominate clay mineral originating from alteration of the strata at the site. Sciacca (1984) reported that x-ray diffraction of samples from the spoil piles and waste rock dump, which are predominately altered strata of the upper sedimentary sequence, are predominately comprised of smectite. Lesser concentrations of kaolinite, chlorite, alunite, and illite were also reported using mineral analysis techniques (Hammermeister and Walmsley, 1985). Visible kaolinite may also be observed in portions of the open pit. Chloritized breccia has also been observed and noted in the nomenclature of Herbst and Sciacca (1982).

2.4.5 Faulting

The site is faulted, particularly in the area west and northwest of the open pit. Landslides, alluvial cover, and alteration obscure some of the faulting relationships. The following is summarized from Herbst and Sciacca (1982) and Sciacca (1984). Fault identification (A through G) is from nomenclature of Sciacca (1984). As discussed below, only the relative age of faulting has been interpreted based on offset and mineralization. All of the faults are shown on Figure 22.

At least three distinct periods of faulting are interpreted to be represented. Much of the faulting appears to predate the mineralization based on the alteration patterns. All faults are vertical or near vertical.

Fault A is a pair of normal faults that trend northeast-southwest. They pass on either side of a small sandstone knob on the west side of the pit. The northwest fault of the pair dips 83 degrees to the southeast. The northwestern block of the fault is upthrown.

Fault B trends east-west. It vertically offsets sandstone and basalt (south block upthrown); a portion of this fault may extend west into the biotite-pyroxene hornblende andesite.

Faults A and B are offset by Fault C, which is the most significant fault in the area. Fault C is visible in a road cut east of the landslide area. The fault passes through a swale between two hills on the northwest edge of the pit. No cap rock or sulfur mineralization has been noted north of Fault A or west of Fault C.

Fault D trends northwest-southeast with the northeast block upthrown. Because this fault offsets a silicified breccia-andesite contact, it appears to have a horizontal component of movement as well as a vertical component. At the southeast edge of the mapped fault trace there is a spring. The relationship of Fault D to Fault C is obscured by material in the pit.

Fault E is visible on the east side of the pit entrance. The fault extends along the headwall scarp of a large landslide east of the pit entrance. It offsets Faults A and B.

Fault F trends northeast-southwest near the south gate. The sense of movement on this fault is unclear.

Fault G is an east-west-trending fault that cuts the andesite, appears to vertically offset the basalt unit, and may be related to the Aspen Seep (AS) discharge. The relationship between this fault and Fault D is concealed by overburden and landslide debris. This fault passes through the horseshoe-shaped main scarp of the landslide in the mine tailings. Fault G offsets Fault E.

2.4.6 Joints and Fractures

Attitudes of joints and fractures vary widely within the study area. A common strike recorded during previous work is 70° to 80° east, in joints of jasperoid silicified rock, biotite pyroxene hornblende andesite, and quartz latite porphyry. A similar strike was noted in bedding in some unaltered and argillically altered sedimentary rock (Herbst and Sciacca, 1982). The dips accompanying these strikes are dissimilar, ranging from shallow dips to the south to steep northerly dips.

2.4.7 Landslide Activity

Slope stability issues have occurred in the northern part of the site at the Leviathan Creek basin landslide and in the Delta slope area (Figure 12).

Leviathan Creek Basin Landslide

The Leviathan Creek basin landslide is a large (180-acre) bedrock structure slide on the north end of site. It is our understanding that there is not a current program to monitor the movements in the landslide, but it is assumed to be active. Previous work indicated that there is likely a threshold phreatic surface within the slide mass that will cause movement. Although regrading has been performed since the time of that work, it is assumed that the potential for movement is still significant.

Delta Slope

The Delta slope is approximately 250 ft. long by 150 ft. wide and 80 ft. high and is composed of waste rock. The upper portion of the slope has been subject to rotational slope failures and the lower portion has been subject to debris flows. The Delta Seep (DS) is located at the toe of the Delta slope. The waste rock at the Delta slope was regraded after the 2004 slope failure. The current slope appears to be graded at about 3:1 (horizontal to vertical), with two relatively flat benches. Drainage trenches and surface water diversion features were installed in an attempt to reduce the infiltration of surface water into the slide mass and control potential erosion. There is a large catchment area above the slope that likely still allows surface water to flow toward the toe of the slope and DS.

2.5 HYDROGEOLOGY

This section describes the regional and site hydrogeology based on available hydrogeologic data collected by others during previous investigations. The following sections describe the regional hydrogeology and the site hydrogeology including hydrogeologic units, groundwater flow patterns and hydraulic gradients, and groundwater/surface water interactions.

2.5.1 Regional Hydrogeology

The site is located within the Markleeville Hydrologic Area within the larger East Fork Carson River Hydrologic Unit in the Lahontan Basin Plan (LRWQCB, 1995). This groundwater unit coincides with the California limits of the East Fork Carson River watershed (Figure 16). This diamond shaped area (approximately 300 square miles) is delineated by the Alpine County limits to the northeast, southeast, and southwest, and by the ridge that exists between East Fork Carson River and Indian Creek to the northwest.

Data Search

Hydrogeologic information at other properties within the East Fork Carson River Hydrologic Unit was obtained by searching regulatory databases (e.g., Department of Toxic Substances Control Envirostor database and the LRWQCB Geotracker database), performing an online literature search of nearby groundwater investigations conducted by the USGS, and performing a telephone interview with Mr. Doug Carey and Tom Gavigan of the LRWQCB on May 13, 2009.

The literature search revealed that no public hydrogeologic data has been developed in other areas of this hydrologic unit. During the LRWQCB telephone interview, Carey and Gavigan indicated that they could not recall of any significant aquifers within the Bryant Creek watershed and that the region primarily consisted of rock with poor permeability. Other than investigations performed at the site, little to no hydrogeologic investigations have been performed within the Bryant Creek watershed. The literature search and interview yielded no information on the regional hydrogeology.

In order to facilitate information on regional hydrogeology, an analysis was performed within the area delineated by the East Fork Carson River watershed (Figure 16). This analysis included using the regional topography and drainage (Section 2.1.2), surface water bodies, regional geology (Section 2.4.1), and hydrogeologic principles to develop the regional geology on a conceptual level. This analysis was based on the following assumptions:

- Groundwater flows downward and laterally beneath topographic high areas and upward and laterally beneath major stream valleys, lakes, and seeps.
- The shallow groundwater table mimics the shape of the surface topography.
- Groundwater divides coincide with the surface topography divide.

- Lakes, creeks, and seeps indicate the top of the shallow groundwater table.

Results

The geologic units identified on a regional level that may transmit groundwater include (1) Quaternary-age alluvium and glacial moraines in some of the valleys, (2) Tertiary-age altered volcanic sedimentary deposits, (3) Mesozoic-age metamorphic rock, and (4) Mesozoic granitic rock. Based on the regional geology described in Section 2.4.1, the alluvium and the altered volcanic sedimentary rocks are considered to be significantly more permeable than the well-consolidated metamorphic and granitic rocks.

Regional flow is expected to be to the northeast within the deep metamorphic and granitic bedrock units and flow along fractures and faults. The northwest-southeast-trending Sierra Nevada acts as a groundwater divide. Due to the presence of listric faults associated within the Basin and Range Province, deep regional groundwater flow is expected to be to the northeast toward the lowlands of the region.

An intermediate groundwater flow system is expected within the larger regional system. The groundwater divide that drives flow within the intermediate groundwater flow system includes the topographic highlands that encompass the Bryant Creek watershed and the larger East Fork Carson River watershed. Based on the orientation of the topographic highlands surrounding the Bryant Creek watershed, intermediate groundwater flow is likely to be to the north-northwest. However, at the confluence with the East Fork Carson River, groundwater flow is likely to the north-northeast into the Carson Valley. Intermediate groundwater flow likely occurs within the Tertiary-age volcanic and volcaniclastic units.

2.5.2 Local Hydrogeology

The local hydrogeology is based on information obtained from previous groundwater investigations performed at the site. Seventy-five wells or piezometers (many of which were clustered) were previously installed at the site consisting of 51 piezometers (PZ-1 through PZ-33; Hammermeister and Walmsley, 1985), 15 monitoring wells (MW-1 through MW-12; SRK, 1999), and 9 geotechnical wells (B-1 through B-9; Kleinfelder, 2001a, b; Figure 26). More than half of the wells, borings, or piezometers (43) were installed in the western-southwestern part of the site in the LCSA. The remaining wells were approximately equally distributed within the pit in the PSA (15) and the eastern part of the site in the ACSA (17).

2.5.2.1 Hydrostratigraphic Units

Four potential hydrostratigraphic units have been identified at the site. Based on an evaluation of data from previous investigations (boring logs generated from well and piezometer installation and aquifer test data), it appears that only two of the four potential hydrostratigraphic units have been encountered during previous site investigations. This section presents a discussion of the four potential hydrostratigraphic units at the site and an evaluation of the hydrostratigraphic units actually encountered during previous investigations.

Potential Hydrostratigraphic Units

Based on the site geology and evaluation of the permeability of the lithostratigraphic units at the site, Herbst and Sciacca (1982) identified four potential hydrostratigraphic units. However, at the time of their analysis there was no subsurface data from the site to substantiate or refute the existence of these units.

The four hydrostratigraphic units, in order of increasing depth, are as follows:

1. **Quaternary-age units—**poorly consolidated, altered, volcanic and volcaniclastic units. Includes mine waste rock, landslides, debris flows, alluvium, ponded sediments, artificial fill, talus, and mine talus. Contains primary and secondary permeability. The maximum thickness observed is between 80 and 115 ft.

2. **Tertiary-age upper sedimentary sequence—**moderately to well-consolidated, altered, volcanic and volcaniclastic units. Relatively undisturbed, native material. Contains primary and secondary porosity and permeability. Thickness unknown but estimated to be hundreds to over a thousand feet thick.

3. **Tertiary-age lower sedimentary sequence—**well-consolidated, altered, volcanic and volcaniclastic units. Same as the upper sedimentary sequence except that it is well indurated and separated by a layer of basalt. Due to the similarities, the lower sedimentary sequence may be considered as part of the upper sedimentary sequence.

4. **Mesozoic-age units—**well-consolidated granitic and metamorphic rocks. Bedrock material with poor primary permeability but significant secondary permeability along fracture planes and faults. Thickness unknown.

Herbst and Sciacca (1982) described two main types of permeability in the hydrogeologic units at the site: primary and secondary. Primary permeability occurs in the interstitial pores between grains and along bedding planes in geologic units. Primary permeability is generally highest in unconsolidated sedimentary and volcaniclastic units at the site.

Secondary permeability occurs along fractures, joints, or faults as a result of deformation and tectonic activity. Secondary porosity and permeability generally occur in well-consolidated units. Secondary porosity and permeability may also be present as a result of natural or artificial disturbances such as tunneling and landslides (along the plane of the landslide).

Evaluation of Hydrostratigraphic Units

To evaluate the different hydrostratigraphic units at the site, boring logs generated during the installation of the various wells and piezometers were reviewed to evaluate the hydrostratigraphic units in which each was screened. Well construction details are listed in Table 6. The results of this evaluation are shown in Table 7 and are summarized below:

- The wells screened within only the Quaternary-age units were the nine geotechnical wells (B-1 through B-9) and piezometers PZ-2A1, -2A2, -2C2, -3B2, -9B, -9C, -10B, -10C, -11B, -11C, -18A, -18B, -18C, and -19B.

- The wells that were partially screened in both the Quaternary-age units and the upper sedimentary sequence included piezometers PZ-1A, -1B, -1C, -14, -15, -16, and 17A and monitoring wells MW-7 and MW-11.

- The wells screened within only the Tertiary-age upper sedimentary sequence included piezometers PZ-2B1, -2C2, -3A, -3B1, -3C, -7, -9A, -10A, -11A, 17B, -17C, -19A, and -33 and monitoring wells MW-1 through MW-6, MW-8 through MW-10, and MW-12.

All other piezometers and monitoring wells could not be correlated to the geologic units at the site due to the poor legibility of the boring logs or due to the lack of information. No wells were screened within the Mesozoic granitic rocks or metamorphic rocks. Details of the previous well installation activities and hydrogeologic investigations are described in Section 3.

Following hydrostratigraphic unit classification of the wells, comparisons were made between the groundwater level elevations that exist between clustered wells that were screened within different geologic units. Clustered wells installed within the same geologic unit were excluded from the evaluation. The following comparisons are discussed below by study area.

In the PSA, only one pair of clustered wells, PZ-2C1/PZ-2C2, were screened in different geologic units. Groundwater level elevations collected in November 1982 and April 1983 (the most recent data) were between 3.56 and 4.25 ft. higher in the Quaternary-age units than in the Tertiary-age units (Table 7). This data suggests that the two geologic units in the PSA act as separate hydrostratigraphic units.

In the ACSA, clustered wells that were screened within different geologic units include PZ-3B1/PZ-3B2 and PZ-19A/PZ-19B. Groundwater level elevations collected in November 1982 and April 1983 (the most recent data) were between 3.40 and 7.23 ft. higher in the Quaternary-age units than the Tertiary-age units (Table 7). This data suggests that the two geologic units in the ACSA act as separate hydrostratigraphic units.

No clustered wells were found to be screened within different geologic units in the LCSA.

Across the site, information from the clustered wells indicate that the water table elevation between the Quaternary-age units can be between 3.40 and 7.23 ft. higher than the Tertiary-age units. This information supports the local hydrogeologic conceptual model that at least two hydrostratigraphic units exist at the site. However, additional information is needed from other locations and over a longer period of time to better support this observation.

2.5.2.2 Hydraulic Conductivity

Hydraulic conductivity values were measured using slug and/or aquifer test performed by Hammermeister and Walmsley (1985) and Prudic and Hammermeister (1962) within the Quaternary-age units and the Tertiary-age upper sedimentary sequence. No wells were identified as being screened within the Mesozoic-age hydrostratigraphic units and thus no hydraulic conductivity data exists for this unit.

Quaternary-Age Units

The hydraulic conductivity of the Quaternary-age units were measured to range from 2 to 27 feet per day (ft/day). This is based on the following information:

- Hammermeister and Walmsley (1985) measured the hydraulic conductivity in piezometers screened within the Quaternary-age units. These included piezometers PZ-2A1, -2A2, -3B2, -18A, -19B, which ranged in hydraulic conductivity from 2 to 26 ft/day.
- Hammermeister and Walmsley (1985) measured the hydraulic conductivity in piezometers screened within the Quaternary-age units and the upper sedimentary sequence. These included piezometers PZ-1A, -1C, -14, and -15, which ranged in hydraulic conductive from 0.4 to 2.0 ft/day.
- Prudic and Hammermeister (1962) estimated that the hydraulic conductivity of shallow groundwater flow beneath the mouth of the pit was 26.78 ft/day (31×10^{-5} feet per second [ft/sec]). The material at the mouth of the pit may is likely to represent the Quaternary-age units.

Upper Sedimentary Sequence

The hydraulic conductivity of the upper sedimentary sequence was measured to range from 0.1 to 6.2 ft/day. This is based on the following information:

- Hammermeister and Walmsley (1985) measured the hydraulic conductivity in numerous piezometers screened within the upper sedimentary sequence. These included piezometers PZ-2A2, PZ -2B1, PZ -2C1, PZ -2C2, PZ -3A, PZ -3B1, PZ -

3C, PZ -4, PZ -6 through PZ -11C, PZ -17A through PZ -19A, and PZ -20 through PZ -33. The measured hydraulic conductivity values ranged from 0.1 to 6.2 ft/day.

- Prudic and Hammermeister (1962) estimated that the hydraulic conductivity of material entering the pit ranged from 0.029 ft/day (3.4 x 10^{-6} ft/sec) to 0.037 ft/day (4.31 x 10^{-6} ft/sec). The material within the pit walls is likely to represent the upper sedimentary sequence.

2.5.2.3 Groundwater Flow Patterns and Hydraulic Gradients

Groundwater elevation data has been collected at the site between 1982 and 2009 (Tables 7 and 8). Potentiometric surface maps were adopted from groundwater elevation data collected in 1982 (Figure 30; Brown and Caldwell, 1983) and 1999 (Figure 31; SRK, 1999). Groundwater elevations collected in 1982 include wells from across the site. It should be noted that the 1982 map includes wells screened within various types of materials (overburden, alluvium, and bedrock) which may have different flow properties (and which will be evaluated during the RI/FS). The 1999 potentiometric surface map includes wells mostly in the PSA and LCSA. Most wells included in the 1999 map were screened within the Tertiary sedimentary geologic unit, except for MW-7 and MW-11, which were screened across Quaternary- and Tertiary-age geologic units. A potentiometric surface map has not been developed for the 2001 groundwater elevations because this data was only recorded for wells B-1 through B-9.

More current 2006 through 2008 groundwater elevation data has been collected at the site on a monthly basis generally between July and November of each year (Table 8). Wells included within the current groundwater elevation data were the same as the 1998 event but did not include data from monitoring well MW-12. Potentiometric surface maps prepared from data collected in August 2006, August 2007, and August 2008 are shown on Figures 32, 33, and 34, respectively.

Based on these maps, the potentiometric surface appears to follow the shape of the steep change in topography at the site. The northwest-southeast-trending ridge that crosses the site coincides with the groundwater divide that likely drives local groundwater flow. In the southern part of the site, groundwater flows from the ridge to the south into the pit and then to the west to Leviathan Creek. In the northwestern part of the site, groundwater flow from the ridge travels to the northwest toward Leviathan Creek. In the eastern-northeastern part of the site, groundwater flow is to the north toward Aspen Creek.

The overall direction of flow across the site is to the north-northwest with a gradient of approximately 0.125 vertical feet per horizontal foot (ft/ft) measured between PZ-24 and PZ-20. The localized groundwater flow toward the center of the pit has gradients that range between 0.08 and 0.6 ft/ft.

Influences That May Affect Groundwater Flow

According to Brown and Caldwell (1983), local irregularities occur in the potentiometric surface near the contact between the overburden/spoil pile and the landslide in the northwestern part of the site (Figure 30). Brown and Caldwell (1983) suggested that these irregularities in the potentiometric surface may be representative of differential recharge between the two areas, ponded water within the spoils, or a perched water table above the failure plane of the landslide. A number of other influences may affect the groundwater flow at this location and at other areas of the site:

- Historic surface topography. The historic surface topography which existed at the site in 1940 prior to open-pit mining is shown on Figure 14. Areas that have been buried and not excavated are likely to be a significant control on groundwater flow. Groundwater flow in areas that do not mimic the current surface topography may be influenced by historic surface drainage patterns.

- Faults, joints, and bedding. Herbst and Sciacca (1982) suggested that the faults, joints, and bedding may influence the movement of groundwater across the site. Depending on the weathering characteristics along the faults in the vicinity of the pit, such as mineralization, gouge, and fracturing. The dip of bedding and orientation of joints has been reported to vary widely across the site. Areas with an irregular potentiometric surface may be indicative of faults, joints, or irregular bedding.

- Collapsed tunnels and adits (Figures 17 and 18). Prudic and Hammermeister (1962), Brown and Caldwell (1983), and Herbst and Sciacca (1982) all concluded that Tunnel #5 is a significant discharge point for groundwater in the vicinity of the pit. The eastern segments of the adit, Tunnel #3, and Tunnel #5 may remain on the eastern side of the pit and may also act as groundwater conduits.

2.5.2.4 Groundwater/Surface Water Interactions

Groundwater/surface water interactions include the exchange of water and chemicals between surface water and groundwater sources. Often surface water and groundwater sources are treated as separate entities. However, depending on the permeability of the geologic material and direction of flow, surface water may be hydraulically connected with groundwater and alter the water quality of one another.

It is important to understand the interactions between groundwater and surface water at the site, as many of the key chemical sources may be comprised of waters derived from recharge due to precipitation at the surface, infiltration to the groundwater through natural or waste rock, and ultimately discharging from the groundwater to surface at various locations or as broader seeps. As such, the flow between the surface water and groundwater systems must be accounted for as both recharge to one system and discharge from another. At the site, these primarily consist of direct discharges and seeps from the groundwater system (accounted as both groundwater outflows and surface water inflows) and stream gains and losses within the creek beds (accounted as both surface water and groundwater inflows and outflows).

Groundwater discharges to the surface have been measured from the AS, DS, adit, PUD, and CUD. These waters are contained and treated on site before being discharged to the surface waters (Section 3.2). The measured flows are discussed with the water balance in Section 2.5.3.

No previous surface water–groundwater investigations have been performed at the site to evaluate the flux of surface water entering the groundwater system or the flux of groundwater entering the surface water bodies at the site. However, data suggests that there is a potential for gaining and losing conditions to occur at the following locations:

- At the site, the elevation of the groundwater table is significantly higher than Leviathan and Aspen creeks. In addition, the shape of the potentiometric surface "V's" upstream, which suggests that shallow groundwater may be discharging into the creeks.

- During construction of the Leviathan Creek Channel, the LRWQCB needed to install the CUD due to numerous groundwater seeps that were flowing into the area of excavation (Taxer et al., 1991). Coupled with the presence of seeps in the northern part of the site (DS, AS), this information suggests that shallow groundwater may be discharging into the creeks.

- Man-made surface water bodies and conveyance structures in the LCSA and at the ACSA may be "losing" or infiltrating into the groundwater system. No investigation has been performed to evaluate the extent of leakage through the pond liners or through the conveyance piping. However, a resolution adopted by the California State Water Resources Control Board on November 18, 2008 (No. 2008-0083) confirms that the pond liners were constructed in 1984 with a 20-year useful life, that the liners have exceeded their useful life, and that the liners are showing signs of failure. Water leaking through these systems, may be entering the groundwater system, come in contact with mine waste rock, and flow downgradient into the creeks.

2.5.3 Water Balance

Preliminary assessments of the water balance for the site have been developed within the DQO Report. This section presents a summary of existing data and preliminary assessments designed to provide a basic framework for understanding the components of the Water balance. The water balance will be reviewed and updated as additional data become available as part of the RI/FS.

In general, the water balance for the site consists of water flowing through the site in both the surface water and groundwater systems.

- Sources of surface water entering the site include upgradient streamflows, runoff from precipitation falling on the site, and discharge from groundwater to streams and pits on site. Surface water from these sources ultimately flows off-property in Leviathan Creek or evaporates from creeks and ponds on site.
- Sources of groundwater entering the site include inflows from upgradient and recharge from precipitation falling on site. Groundwater from these sources ultimately discharges either to the creeks on site, or as downgradient flow.

There is considerable interaction between the surface water and groundwater flow systems on site, as evidenced by the occurrence of various focused groundwater discharge locations (the adit, PUD, and CUD) and seeps (the DS and AS). As such, the water balance must account for the interactions between the surface water and groundwater systems.

A key consideration in developing a usable water balance is to understand component flows in terms that are useful to fulfilling project objectives. For the site, this means developing water balance components to support assessment of potential remediation and mitigation options. Water balance components must therefore be broken down into specific discharges and/or specific areas of the site that can be used to estimate distinct flows and chemical mass loadings, rather than being lumped into broader categories that may not be useful in specific remediation assessments. The following sections discuss previous water balance work and available data, the development of specific water balance components for the site, available methods to estimate flow rates for the various components, available data to assess each water balance component, and a preliminary estimate of the average annual water balance (including uncertainties) for the site.

2.5.3.1 Previous Studies

Previous studies conducted at Leviathan are described in detail in Section 3.1. Some of the studies contain data and assessments relevant to understanding the water balance, although none of the previous work organizes all relevant data into a comprehensive water balance encompassing both surface water and groundwater. Following is a summary of previous work relevant to the water balance:

- Brown and Caldwell (1983), *Design Report and Draft Environmental Impact Report*: This report includes regional climate and surface water flow data, and development of site-specific estimates of long-term average precipitation and streamflow based on comparisons with nearby data stations. It also develops monthly precipitation exceedance probabilities based on regional comparisons.

- Prudic and Hammermeister (1962), *Shallow Groundwater Flow in the Vicinity of the Open Pit at the Leviathan Mine*: This report presents estimates of groundwater flow rates into and upgradient of the mine pit. It also compares groundwater flow near the pit with potential infiltration from precipitation.

- Hammermeister and Walmsley, 1985, *Hydrologic Data for Leviathan Mine and Vicinity, Alpine County, California, 1981-83*: This report presents surface water flow and chemistry measurements collected from 1981 through 1983.

- USGS (1998 through 2008), periodic and daily streamflow data from continuous recording surface water flow gauging stations within the Leviathan Creek watershed.

- SRK (1998 and 1999), *Leviathan Mine 1998 Spring Stream Monitoring Program and 1998-1999 Data Summary Report*: These reports describe collection of surface water flow and chemistry data from selected sites within the Leviathan Creek watershed.

- MWH (2002b), *Draft Phase I RI/FS Work Plan:* This report presents and summarizes surface water flow hydrology based on flow measurements made by the USGS between 1998 and 2000. Flow measurements at the USGS stations are compared as percentages of total downstream flow. A direct comparison of surface water flows and groundwater discharges is presented.

- MWH (2001), *Site Management Plan*: This report includes updates to the surface water flow data.

The previous reports and data were reviewed in detail as part of the water balance development. Existing data and assessments from these sources will be used as part of RI/FS assessments where applicable. In addition, some of the assessments will be modified or updated as appropriate during development of the water balance as part of the RI/FS process.

2.5.3.2 Water Balance Components

Broad categories of the water balance include water derived from incident precipitation and upgradient flows, with discharges occurring to downgradient areas and to evaporation. While understanding the volume and timing of these sources and discharges is critical to the overall water balance, these categories must be broken down into specific discharges and/or specific areas of the site that can be used to estimate distinct flows and chemical mass loadings in support of overall remediation efforts. Water balance components must encompass and account for potential chemical source areas, variations in chemical mass loading across the site, and individual areas that may be subject to different remediation options. As such, the current water balance is focused on the PSA, ACSA, and LCSA (Figure 4). Waters flowing through these study areas can be segregated into individual components that encompass all potential chemical source areas.

Components of the water balance are outlined on Figure 35. As the RI/FS progresses, these components may be modified to include other distinct flows or areas, or they may be lumped into broader categories as necessary.

2.5.3.3 Flow Estimation

Estimation of the volumes and timing of flow for the water balance components described above may consist of both direct measurement and estimation from analytical methods based on indirect measurements of associated components. Flow estimation requires an understanding of broader categories such as precipitation, recharge, runoff, evaporation, streamflow, and groundwater system physical characteristics within the study areas. Estimates of the volumes and timing of detailed water balance flows can then be made based on the understanding of these broad categories. Available data has been reviewed and preliminary estimates of the water balance components have been developed where possible. These flow estimates are considered preliminary and subject to change as more data become available. The following sections describe the current understanding of various broad water balance categories.

Precipitation

An understanding of potential long-term average and short-term extreme precipitation at the site is important to assess potential infiltration and runoff flows from various portions of the site. Precipitation falling both within the watersheds above the site and directly on the site provides the source of all water flowing at the site. A meteorological station was developed on site and has been producing data since 2003. However, the data set is not complete in terms of daily precipitation totals, with data missing during many of the months for which data should be available. Because of the short period of record for on-property data and the significant amount of missing data within the period of record, other regional data sources and estimates were used to develop a preliminary estimate of potential precipitation at the site.

Brown and Caldwell (1983) used isohyets of precipitation measured at various regional meteorological stations to develop an estimate of approximately 14.4 inches for mean annual precipitation at the Leviathan Mine site. Monthly average precipitation was developed based on an assumed relationship between Leviathan and Woodford, California. MWH did not update this analysis, but noted that the state's meteorological station was in the process of installation.

Long-term precipitation estimates were based on records from available stations near the site. None of the long-term climate recording stations are considered to be reasonable analogs of the site based on differences in elevation, topography, aspect, etc. As such, there is no single site with a long-term record that is applicable for use in water balance development. Therefore, regional climate assessments were reviewed for potential application to the site.

A review of the map of mean annual precipitation for California developed by Rantz (1969), based on precipitation measured between 1900 and 1960, shows Leviathan Mine falling between the contours for 22.5 and 27.0 inches per year, suggesting a much higher mean annual precipitation than that estimated by Brown and Caldwell (1983).. This is likely due to the fact that simple interpolation methods such as the isohyetal method are not considered accurate for mountainous terrain because they do not account for the effects of topography or the angle or direction of various facing slopes on precipitation (e.g., higher elevations within the watershed may receive significantly more precipitation [Phillips et al., 1992]).

Techniques are available that attempt to account for variations in topography and other variables on climatic parameters. One widely used method is the PRISM climate mapping system, developed by Dr. Christopher Daly (http://prism.oregonstate.edu/). PRISM is a unique knowledge-based system that uses point measurements of precipitation, temperature, and other climatic factors to produce continuous, digital grid estimates of monthly, yearly, and event-based climatic parameters. The PRISM model is continuously updated to incorporate point data, a digital elevation model, and expert knowledge of complex climatic extremes, which includes rain shadows, coastal effects, and temperature inversions.

PRISM produced precipitation estimates are available for any location in the United States and come as data points on an 800-meter (30-arcsecond) grid of the United States.

Annual precipitation estimates developed using the PRISM model were downloaded for the site by entering the latitude and longitude of the current on-property meteorological station. Mean monthly and annual precipitation estimates based on data from 1971 through 2000 (e.g., 30-year normals) are presented in Table 9. Contours of PRISM-estimated mean annual precipitations within the broader watersheds are shown on Figure 36. As shown in Table 9, the majority of precipitation in the watershed occurs in winter months from October through March (25 inches or 79.4 percent of the average annual precipitation). Precipitation during these months falls as snow, producing significant snowpack that routinely restricts access to the site and then is followed by peak runoff periods in April and May.

The estimated long-term mean annual precipitation for Leviathan was estimated by the PRISM model at 31.5 inches per year. This is higher than the estimate by Rantz (1969) and more than double the estimate developed by Brown and Caldwell (1983). This illustrates the general uncertainty in understanding the actual amount of available water at the site and within the broader Leviathan Creek watershed.

With the limited available record at the site, it is difficult to evaluate whether site measurements are significantly more accurate than regional estimates based on climate modeling. Therefore, the higher (and potentially more conservative) PRISM estimates were used in the preliminary water balance assessment. The use of PRISM estimates is considered preliminary and may be modified during the RI/FS process.

Another important consideration in understanding precipitation in relation to ongoing site activities is the potential for short-term storm-related events and the impact on surface water flows and remediation options. While the majority of this type of precipitation is the result of snowmelt, large storm events can result in impacts to surface runoff.

The probable maximum precipitation (PMP) is the maximum depth of precipitation that is physically possible for a particular geographic region. The PMP has been estimated for the site based on procedures described in Hydrometeorological Report Nos. 58 and 59 (Atlantic Richfield, 2008). Based on the calculations presented in the DQO Report, the 24-hour all-season PMP for the site is estimated at approximately 12.6 inches in a day. This assessment may be revisited during RI/FS activities, as appropriate.

Streamflow

A key component of the water balance is surface water flow entering the site. The USGS established some short-term daily measurement stations in 1981 and 1982, and it established a number of permanent continuous monitoring stations in 1998. These stations are shown on Figures 2 and 37. Key stations near the site that have had generally continuous monitoring since 1998 include Station 1 (Leviathan Creek above the mine), Station 15 (Leviathan Creek above Aspen Creek), and Station 23 (Leviathan Creek above Mountaineer Creek). In addition, daily flow data has been collected at 4L Creek above Leviathan Creek and at Station 22 (Aspen Creek above the site) since October 2003. Monthly average flow rates measured at these stations are summarized in Table 10; monthly average streamflows are shown on Figure 38.

In addition to continuous monitoring stations at and near the site, several one-time or short-term streamflow measurements have been made at the site. This data is useful to provide a framework for assessing general site conditions, but generally cannot be used directly to develop water balance estimates.

While general average conditions may be estimated from the limited streamflow data set from continuous monitoring at the site, the period of record is not extensive enough to accurately estimate peak flow conditions. Peak streamflow and flood conditions are important to understand to support remedial design activities and to understand changes in the water balance during extreme events. Rough estimates of flood frequency flows from the gauged locations were developed using regression techniques outlined in *Nationwide Summary of U.S. Geological Survey Regional Regression Equations for Estimating Magnitude and Frequency of Floods for Ungaged Sites, 1993* (Jennings et al., 1994). The site falls within an area that has two different regression techniques: the Sierra region of the California statewide rural zones and the Eastern Sierra region of the southwestern United States zone (Jennings et al., 1994). Regression equations for various streamflow return periods are provided based on drainage area, elevation, and latitude. Both sets of regression equations were used to estimate potential peak discharge return period flows, as summarized in Table 11.

As shown in Table 11, peak discharge return flows estimated using regression equations from the Eastern Sierra region in the southwestern United States were generally smaller than those estimated using the equations for the Sierra region of rural California. Table 12 shows the peak discharges measured annually at stations with some period of record. As shown in Table 12, peak discharges are generally the same for the period of record (e.g., over a 7- to 9-year period) as those anticipated by the return flow estimates.

The maximum event for streamflow is referred to as the Probable Maximum Flood (PMF). There are many methods available for estimating the PMF (USACE, 2006). For simplicity's sake, we have used the 24-hour PMP, and assuming 100 percent runoff over the catchment area during the period (e.g., precipitation times catchment area), we have taken the average flow this would produce over the period. This method was chosen for use in the water balance assessment and may not be suitable for engineering design.

Estimates for the 24-hour PMF for the main site drainages are presented in Table 13. These flows are all higher than the estimated 100-year peak discharges and are considered conservative estimates of the peak sustained 24-hour flows at the site.

Flow Between Surface Water and Groundwater Sources

Groundwater discharges to the surface at the site occur from the AS, DS, and mine adit, as well as from the PUD and CUD. Flow data from these sources (except for the DS) has been collected since 1999 (Figure 39). Monthly average discharges from these sources are summarized in Table 14. As shown in the table, peak groundwater discharges occur during April and May, similar to peak surface water flows.

Groundwater System Flow and Physical Characteristics

The local hydrogeologic conceptual model identified at least four potential hydrostratigraphic units at the site (Section 2.5.2.1), of which two (Quaternary-age sediments and Tertiary-age upper sedimentary sequence) have been observed. The hydraulic conductivity of the Quaternary-age sediments was measured at between 2 and 27 ft/day and the hydraulic conductivity of the Tertiary-age upper sedimentary sequence was between 0.1 and 6.2 ft/day. The hydraulic conductivity of the Tertiary-age lower sedimentary sequence and Mesozoic-age hydrostratigraphic units has not been measured because this unit has not been encountered in wells located on site. As detailed information on the vertical and extent of these hydrostratigraphic units is obtained, the hydraulic conductivity values may be used to calculate the discharge or flow through the site.

For the purposes of the water balance, the flow through the groundwater system is estimated from infiltration rates, which are discussed later within this section.

Evaporation and Evapotranspiration

Previous water balance–related studies were generally focused on precipitation and streamflow conditions, and as such there have been no estimates developed for evaporation and evapotranspiration at the site. A variety of methods are available for estimating evaporation, ranging from watershed-scale comparisons of measured precipitation to measured streamflows and to development of site estimates from measured values from nearby climate stations. To develop a preliminary estimate of potential evaporation, data provided by the California Irrigation Management Information System (CIMIS) was reviewed. CIMIS provides estimates of total potential evapotranspiration that can be used as a reference to estimate water usage by various crop types. Monthly potential evapotranspiration estimates in inches were taken from graphics provided by CIMIS and were compared to PRISM estimates of monthly precipitation; these estimates are summarized in Table 15.

Monthly potential evapotranspiration estimates range from a low of 1.5 inches in December and January to a peak of 8.0 inches in July. Estimated annual average evapotranspiration for the site is approximately 53 inches per year, as compared to an estimated average annual precipitation of 31.5 inches per year. Comparing potential evaporation/evapotranspiration with precipitation is one method of estimating the total available water for infiltration and runoff on an annual basis, as discussed below. During the RI/FS, various alternative approaches may be reviewed for applicability to the site, and appropriate estimates of evaporation will be developed.

Infiltration and Runoff

Limited assessments have been performed related to estimating infiltration (recharge) and runoff at the site. Prudic and Hammermeister (1962) compared available precipitation and adit discharge data in the PSA to develop an estimate of potential infiltration in that area (~18 inches per year). No other estimates of infiltration or recharge are available. A variety of methods are available to estimate both infiltration and recharge, including comparisons of drainage area precipitation with streamflow and analytical and numerical modeling using site physical characteristics.

A total available water approach was used to develop preliminary estimates of runoff and recharge for the site. Precipitation in excess of potential evapotranspiration occurs only during the fall and winter (November through March). Over these months, an average annual total of 12.5 inches of excess water is available for runoff and infiltration.

To develop a preliminary estimate of runoff for the site, streamflow measurements were compared to drainage areas for the watershed above the stream measuring points. Stream flow is comprised of both base flow (i.e., flows derived primarily from groundwater inflows) and flows created by runoff from spring snowmelt or storm events. A review of monthly streamflow measurements indicates that the majority of runoff flows occur during March, April, and May (as a primary results of snowmelt), while winter flows (November through February) are generally comprised primarily of base flow (i.e., little runoff occurs during winter months).

To estimate runoff, spring flows measured at Station 1 and Station 15 were compared to the total drainage areas above the gauges. For Station 1, average annual spring streamflows represent approximately 1.4 inches of runoff from the entire watershed above the gauge. For Station 15, average annual spring flows represent approximately 1.2 inches of runoff. An average of these values, 1.3 inches, was used to assess potential runoff produced flows from ungauged areas of the site.

To estimate infiltration, winter flows measured at Stations 1 and 15 were compared to their respective drainage areas. For Station 1, average annual winter streamflows represent approximately 0.4 inch of infiltration over the entire upstream drainage area. For Station 15, average annual winter flows represent approximately 0.5 inch of infiltration over the upstream drainage area.

These estimates primarily represent runoff and infiltration from mostly undisturbed areas. Infiltration into areas that are comprised of fill or otherwise disturbed was estimated by comparing the disturbed area above the AS with the average annual flows measured at the seep. Assuming that flows measured at the seep are comprised of infiltration through the disturbed area above the seep, the average annual measured flows represent approximately 2.4 inches of infiltration.

The above estimates of runoff and infiltration were used to develop preliminary estimates of certain components of the water balance. During the RI/FS, alternative approaches may be reviewed for applicability to the site, and an appropriate method to estimate infiltration and runoff will be developed.

2.5.3.4 Preliminary Water Balance

Preliminary estimates of the average annual water balance are presented in Tables 16 and 17. Measured flows were used whenever available and appropriate. Where measured flows are not available, runoff and infiltration derived flows were developed based on the estimates presented in the previous section. A preliminary estimate of all water balance components other than groundwater inflows to the site and groundwater outflows were developed based on preliminary data. Groundwater inflows and outflows were not estimated because insufficient data is available to develop reasonable estimates. The water balance will be further developed and updated as necessary as part of ongoing RI/FS activities.

2.5.4 Overview of the Hydrogeologic Conceptual Site Model

As described in Section 2.2.2, the site can be divided into two primary groundwater watersheds divided by a topographic ridge trending from the southeast to the northwest across the center portion of the site. The area north and east of the ridge, which includes the overburden and landslide area, has relatively distinct hydrogeologic and alteration properties where the groundwater flows to the east and north. The area to the west of the topographic ridge flows primarily toward Leviathan Creek and includes the pit, which is believed to act as a localized groundwater sink, and the waste pile area. As described in Section 2.5.2, the hydrogeology of certain portions of the disturbed area has been studied by various parties beginning in the early 1980s. These previous studies largely focused on the area west of the topographic high, thus leaving the hydrogeology of the area north and east of the topographic high uninvestigated. A conceptual hydrogeologic model is presented on Figure 40.

Primary characteristics of the conceptual model of the site hydrogeology include the following:

- Groundwater flow generally mimics topography with flow from upland recharge areas to low-lying areas along Aspen and Leviathan creeks indicating that groundwater most likely discharges to surface water during most of the year.

- During the late summer months, Leviathan Creek is nearly dry near the disturbed portion of the site whereas there is flow further downstream suggesting that the stream is gaining downstream of the disturbed portion of the site. This demonstrates the importance of groundwater/surface water interactions.

- Although warranting further investigation; bedding planes, fractures, and other secondary permeability features do not appear to play a major role in influencing groundwater flow.

- Faulting does not appear to be a significant influence (as a groundwater divide or secondary permeability features) on groundwater flow, as fine-grained materials along fault zones are anticipated to have hydraulic characteristics similar to those of surrounding clay-altered bedrock.

- Four potential hydrostratigraphic units identified at the site consist of quaternary units including mine overburden and waste rock, a clay-altered Upper and Lower Tertiary sedimentary bedrock, and Mesozoic bedrock zone.

- In the northern overburden landslide area, the slide plane influences groundwater flow, there are small grabens in the slide area.

- Downward vertical gradients are observed in most of areas of the site where groundwater monitoring well pairs are present.

- The occurrence of seeps at the base of the overburden and waste rock piles suggests a potential water migration pathway along the interface of the overburden piles and the underlying bedrock. Anecdotal information suggests that the overburden and waste rock materials are more permeable than underlying bedrock thus allowing for the downward percolation of infiltrating precipitation and snowmelt with lateral flow along the interface between the overburden and the underlying bedrock where seeps “daylight” at elevations above Aspen and Leviathan creeks.

- The pit and underlying PUD and adit is a dominant feature influencing surface water infiltration and groundwater flow at the site. Discharges from the PUD and adit are assumed to originate from groundwater inflow, precipitation, snowmelt, and surface runoff from surrounding areas. The PUD and adit are both beneath the pit floor but it is unclear how much of the water introduced into the pit are not captured by the PUD and the adit and therefore have the potential to migrate outside of the pit toward Leviathan Creek.

3.0 INITIAL EVALUATIONS

This section first presents a summary of the previous investigations and data collected (Section 3.1), then a summary and analysis of previous and current removal actions conducted at the site (Section 3.2). The scoping evaluation conducted as part of the Data Quality Objectives Report (Atlantic Richfield, 2008) is presented in Section 3.3, and the CSM that was developed during the scoping and updated based on U.S. EPA and stakeholder comments is presented in Section 3.4. The CSM describes the potential migration and exposure pathways and the preliminary assessment of human health and ecological impacts.

3.1 PREVIOUS INVESTIGATIONS

A number of previous investigations have been performed at the site. Selected geochemical results of surface water, sediment, soil, and groundwater samples were extracted from the site investigation reports and are presented in Appendix B. The majority of the data collected from previous investigations is from surface water, sediment, and biota sampling. Although the historical data has been catalogued for purposes of this investigation, more current data better accounts for improvements in sediment and water quality attributable to the operation of treatments systems at the site since the later 1990s, and this data tends to be more valuable for assessing potential exposures and what actions might be necessary to assess that exposure under the RI/FS process.

In addition, more current, select data from the database has been tabulated, including the following:

- surface water data from samples collected and analyzed from 2005 through 2008 at each of the U.S. EPA surface water station locations (Tables 18 through 35; Figure 37);
- stream sediment data from samples collected from 6 U.S. EPA station locations (Table 36; Figure 37);
- soil sample pH data from samples collected and analyzed from 200 surface locations (Table 37; Figure 41);
- recent groundwater data from samples collected from 15 locations that were analyzed by a laboratory (Table 38; Figure 26); and
- recent groundwater field parameter data measured from 64 locations (Table 39; Figure 26).

Electronic surface water, sediment, soil and groundwater, and climate data obtained from other sources are included in the site database. The project database is discussed in Section 8.2.

3.1.1 Previous Investigations

A listing of the previous investigations reviewed for this Work Plan is provided below.

- Letter to the LRWQCB: Regarding Water Samples Collected from Aspen and Leviathan Creeks, Pre-Open Pit Mining (White, 1952)
- Nevada Division of Wildlife Stream Survey—Bryant Creek (NDCNR, 1955)
- Report Leviathan Creek Bioassay (Coli, 1958)
- Transmittal to the LRWQCB Leviathan Creek Water Quality Sample Results (Reinke, 1958)
- Report on Pollution of Leviathan Creek Caused by Leviathan Mine (LRWQCB, 1968)
- Letter: Transmit LRWQCB Meeting Minutes; Fish and Game Report (Leggett, 1969)
- Investigation of Soil and Irrigation Water Conditions on the Brooks Park—River Ranch (Nelson Laboratories, 1969)
- An Appraisal of the Effects of Contaminants in Irrigation Water Derived from Bryant Creek on the Agricultural Potential of River Ranch (Young, 1970)
- Report on Pollution of Leviathan Creek, Bryant Creek and the East Fork Carson River caused by the Leviathan Sulfur Mine (LRWQCB, 1975)
- The Revegetation Potential of the Leviathan Mine Spoils, master of science thesis, University Nevada, Reno (Butterfield, 1977)
- Leviathan Mine Pollution Abatement Project, Design Report and Draft Environmental Impact Report, April 1983 (Brown and Caldwell, 1983)
- Shallow Groundwater Flow in the Vicinity of the Open Pit at the Leviathan Mine (Prudic and Hammermeister, (1962)
- Hydrologic Data for Leviathan Mine and Vicinity Alpine County, California, 1981-83 (Hammermeister and Walmsley, 1985)
- Final Revised Analyses of Major and Trace Elements from Acid Mine Waters in the Leviathan Mine Drainage Basin, California and Nevada, October 1981 to October 1982 (Ball and Nordstrom, 1989)

- Partial Soil Remediation and Revegetation of the Leviathan Mine (Claassen and Hogan, 1977)

- Trace-Element Enrichment in Streambed Sediment and Crayfish, Carson and Truckee Rivers, Nevada and California, September 1992 (Lawrence, 1998)

- Leviathan Mine, Spring 1998 Monitoring Program (SRK, 1998)

- Data on Stream-Water and Bed-Sediment Quality in the Vicinity of Leviathan Mine, Alpine County, California, and Douglas County, Nevada; September 1998 (Thomas and Lico, 1998)

- 1998-1999 Data Summary Report, Administrative Order on Consent, Leviathan Mine, Alpine County, California (SRK, 1999)

- Data Report for the Leviathan Mine Study Area Water and Sediment Toxicity Testing and Benthic Community Data, September 1998 Assessment (ENSR, 1999)

- Assessments of Injuries to Aquatic Natural Resources near the Leviathan Mine, Alpine County, California. Phase 1 Data Report: Concentrations of Metals and Trace Elements in Aquatic Insects and Fish (Thompson and Welsh, 1999)

- Methylmercury in Water and Bottom Sediment along the Carson River System, Nevada and California, September 1998 (Hoffman and Thomas, 2000)

- Leviathan Mine Natural Resources Damage Assessment: Phase I Fisheries California Department of Fish and Game (Lehr, 2000)

- Operation and Monitoring of Bioreactors at the Leviathan Mine (Atlantic Richfield, 2001)

- Preliminary Assessment of Fish Community Dynamics and Trace-Element Exposures to Aquatic Invertebrates and Salmonids, Lower Bryant Creek and East Fork Carson River, Douglas County, Nevada, 2001 (Higgins, 2006)

- Geotechnical Investigation Report, Phase I Preliminary Slope Stability Evaluation, Leviathan Mine Delta Area Waste Pile, Alpine County, California (Kleinfelder, 2001a)

- Leviathan Mine 2001 Early Response Action, Channel Underdrain Treatment Completion Report (Brown and Caldwell, 2002)

- Geotechnical Investigation Report: Phase II Preliminary Slope Stability Evaluation, Leviathan Mine Delta Area Waste Pile, Alpine County, California. Report (Kleinfelder, 2001b)

- Influence of Natural Sources on Mercury in Water, Sediment and Aquatic Biota in Seven Tributary Streams of the East Fork of the Upper Carson River, California (Fischer and Gustin, 2002)

- Geotechnical Slope Stability Evaluation, Leviathan Mine Delta Area Waste Pile, Alpine County, California (Kleinfelder, 2003)

- Bioassessment Monitoring of Acid Mine Drainage Impacts in Streams of the Leviathan Mine Watershed: An Update for 2003 Surveys (Herbst, 2004)

- Water Quality Study Report for the Natural Resource Damage Assessment of Surface Water Below the Leviathan Mine, Alpine County, California and Douglas County, Nevada (Markin and Yee, 2006)

- Summary of Material Testing and Observation Services, Geotechnical Slope Stability, Leviathan Mine Delta Area Waste Pile, Alpine County, California (Kleinfelder, 2006)

- Precipitation data contained in the Draft Data Quality Objective Report: Remedial Investigation and Feasibility Study, Leviathan Mine, Alpine County (Atlantic Richfield, 2008)

3.1.2 Electronic Surface Water Data Obtained from Other Sources

In addition to the above documents, surface water data was collected during specific sample collection activities between 1998 and 2005. This data has been included in the document review and uploaded to the project database.

- The U.S. EPA continues to collect biota data each year from Aspen, Leviathan, and Bryant creeks.

- The USGS collected flow data from Stations 16 and 24 during 40 sampling events from October 1998 through August 2002.

- The USGS collected flow data from Station 26 during 5 events between February 1999 and June 2000.

- The LRWQCB collected surface water samples to evaluate the water quality from the Pond 4 Lime Treatment System (LTS). Data provided from June 2002 through September 2005.

- Atlantic Richfield collected ERA influent and effluent water quality data from the ASB from April 2003 through February 2005.

Electronic data from ongoing surface water investigations has also been included in the document review and is uploaded to the project database:

- Ongoing data from the LRWQCB includes (1) comprehensive surface water quality monitoring data (monthly and semiannual), and (2) influent and effluent water quality and sludge data from the biphasic treatment system of adit and PUD flows. Data provided since August 1984 (LRWQCB, ongoing EDT).

- Ongoing data from Atlantic Richfield includes (1) influent and effluent water quality and sludge data from the Pond 4 CUD/DS Treatment System and (2) influent and effluent water quality and sludge data from the ASB's treatment system. Data provided since September 13, 2001 (Atlantic Richfield, ongoing EDT).

- Ongoing data from the Nevada Department of Environmental Protection includes surface water sampling along the East Fork Carson River and Station 26. Data provided since January 1977 (Nevada Department of Environmental Protection, ongoing EDT).

- Ongoing data from the U.S. Army Corps of Engineers (USACE) and Burleson Consulting, Inc., includes measurements of pH, specific conductance, and temperature of surface water from 17 surface water stations. Data provided since June 2007 (USACE, 2007, and Burleson, 2008 to present).

In addition to the above documents, stream sediment data was collected by the LRWQCB between 2002 and 2005. The LRWQCB collected sediment samples to evaluate the efficiency of the Pond 4 LTS. Ongoing sediment data is currently being collected in the Pond 4 LTS. Both sources of electronic stream sediment data is periodically uploaded into the project database.

In addition to the above documents, ongoing groundwater quality data is being collected from MW-3 by the LRWQCB. This information is periodically uploaded to the project database.

In February of 2003, the LRWQCB began operating a weather station at the site at Pond 1. Measurements were collected on an hourly basis and included time, temperature, humidity, wind speed, wind direction, wind run, wind chill factor, heat index, barometer readings, precipitation, and evapotranspiration. This information is periodically uploaded to the project database (at the time of this document, the database includes information through December 31, 2008).

3.1.3 Project Database

The project database was first created by Burt Kilbourne of Atlantic Richfield on May 5, 1999. The database was initially managed by MWH in 2002. MWH updated the database into Microsoft Access and added additional historical data collected at the site. The database was then transferred to EMC^2 in the fall of 2002, and EMC^2 managed new incoming data until 2007. Since 2007, the database has been managed by AMEC.

The database includes data collected at the site between 1957 and the present. Detailed information from 36 sources has been incorporated into the database (32 previous investigations and 4 ongoing investigations). The type of data that has been included in the project database is shown on Figure 42. The number of data points from each of these sources has been organized by type and is presented in Table 40. Based on the current number of data points, the most information in the project database is surface water data (103,506), followed by stream sediment data (3,978), bioassessment data (2,910), groundwater data (2,786), soil data (1,776), and climate data (456). Additional data submitted to Atlantic Richfield has been updated in the database as appropriate.

3.1.4 Other Environmental Documents

Other environmental documents have contributed to the understanding of impacts at the site but did not include the collection of new data. The following documents have been reviewed in the development of this Work Plan:

- *Leviathan Mine Pollution Abatement Project, Design Report and Draft Environmental Impact Report, April 1983* (Brown and Caldwell, 1983);
- *A History of the Leviathan Mine Pollution Abatement Project, Alpine County, California* (Taxer et al., 1991);
- *Leviathan Mine 5-Year Workplan, Lahontan Regional Water Quality Control Board* (LRWQCB, 1995); and
- *Leviathan Mine Site, Phase I Remedial Investigation/Feasibility Study Work Plan Draft, April 2002* (MWH, 2002b).

3.2 SUMMARY AND ANALYSIS OF PREVIOUS MITIGATION AND RESPONSE ACTIONS

The U.S. EPA identified five flows or discharge areas that contribute the majority of ARD loading to surface water at the site. These include the adit, PUD, CUD, DS, and AS.

The above locations are shown on Figure 13. A number of mitigation and response actions (RAs) have been performed at the above locations and are briefly described in the following subsections. Within each section is a description of the efforts taken to mitigate or remediate ARD. If applicable, a brief description of the performance or effectiveness of the mitigation or response action is presented.

3.2.1 Previous RA

Over the history of the site, different parties have taken various actions to control the release of acidic water into Leviathan and Aspen creeks. These actions, implemented by Anaconda, Alpine Mining Enterprises, Mr. Brooks Park, and the LRWQCB, are described below.

3.2.1.1 Actions by Anaconda

Site reports include the following descriptions of Anaconda actions:

- In 1956, Anaconda constructed a bentonite-lined trench to divert the waters of Leviathan Creek in order to prevent creek water from coming in contact with mine waste. The trench was later destroyed during high spring flows (LRWQCB, 1968).
- Also in 1956, Anaconda constructed small and large retention ponds located near Leviathan Creek for the collection ARD. Acidic water was first conveyed to one or more larger ponds, then diverted to a smaller pond where lime was added to raise the pH and precipitate metals from the water before it was released to the creek. However, in 1959, breaching of the large pond dike released ARD to Leviathan Creek. The dike was rebuilt in the following year and the addition of lime to ponded water continued through 1961 (LRWQCB, 1968).
- In 1960 through 1961, Anaconda conducted a pilot test to evaluate the feasibility of using injection wells at the site to dispose of acidic water into the subsurface. Two injection wells were installed to the west-northwest of the pit. These efforts proved to be inefficient because of the small quantity of water that could be injected into the subsurface (LRWQCB, 1968). Brown and Caldwell suggested that failure was encountered because infiltration by gravity flow was used instead of pressure injection. In addition, infiltration rates were low because of clogging from precipitate buildup and because of low permeability of the subsurface material into which the wells were installed (Brown and Caldwell, 1983).
- In 1960, Leviathan Creek was lined with bentonite clay to limit the infiltration of surface water into groundwater. However, the bentonite clay lining was destroyed the following spring by high flows. Anaconda also tried spraying pond water on the roads as a dust abatement measure.
- In 1962, Anaconda constructed a concrete bulkhead near the portal of Adit No. 5 in an attempt to keep the acid water confined to the tunnel. According to an internal memo by the LRWQCB dated October 12, 1982, the bulkhead consisted of an eight-inch-thick gunite plug placed within the adit 40 ft. from the portal. Brown and Caldwell (1983) indicated this plug was ineffective, as evidenced each spring by the acidic flows from the portal outside and to the west of the mine pit.
- Also in 1962, Anaconda installed an eight-inch plastic pipe to divert Leviathan Creek around the waste rock. However, by 1963, high spring runoff washed out the headwall around the pipe (Brown and Caldwell, 1983).

3.2.1.2 Actions by Alpine Mining Enterprises

According to Brown and Caldwell (1983) Alpine Mining Enterprises constructed a dam in 1965 above the waste pile on Leviathan Creek, and another eight-inch pipe was installed to divert the creek water around the waste pile. This system was again destroyed during high spring flows. In addition to the dam project, drainage from Adit #5 was directed away from Leviathan

Creek (Brown and Caldwell, 1983). Despite these efforts, ARD was still being discharged to Leviathan Creek, and Alpine Mining Enterprises did not have funds available to continue trying to mitigate Leviathan Creek.

3.2.1.3 Actions by Mr. Brooks Park

Between 1975 and 1983, Mr. Brooks Park, a local Nevada rancher, used a backhoe every spring to reroute drainage from the pit and adit away from Leviathan Creek. This rerouting effort made no significant improvements to surface water quality (Brown and Caldwell, 1983).

3.2.1.4 Actions by LRWQCB

In 1971, the LRWQCB adopted a water quality control plan for the Bryant Creek basin, where corrective measures were recommended. In 1975, the LRWQCB worked with Anaconda to excavate a trench through the waste dump to reroute Leviathan Creek to its "original" and present course and to minimize contact with the waste rock (Brown and Caldwell, 1983).

No other funds were available for the corrective steps until 1979 when the California State Water Resources Control Board was awarded a grant of $3.76 million from the 1978 Clean Water and Water Conservation Bond Law for the restoration of the water quality downstream from the Leviathan site.

Using funds from the state Clean Water and Water Conservation Bond Law, the LRWQCB prepared an FS of the site (Skelly and Loy, 1979). This study, completed in 1979, identified the following five areas at the mine for further investigation and site characterization:

- open-pit and spoil areas,
- mine tunnels,
- waste dump,
- site drainage, and
- landslide areas.

Based on the recommendations presented in the FS, the LRWQCB contracted with the USGS to conduct a hydrologic study, including surface water and groundwater characterization. The California State Water Resources Control Board, Division of Technical Services conducted a geologic investigation and landslide evaluation during the summer and fall of 1982.

The following section discusses the construction work by the LRWQCB between 1983 and 1985.

The LRWQCB performed the following construction activities at the site beginning in 1983:

- regrading, compacting, and constructing storm water collection systems; these efforts were intended to reduce the movement of water through acid-generating soils, including improving drainage in the open pit so that limited water could enter the pit via overland flow;

- construction of five lined on-property ponds (15.1 acres in surface area ponds was recommended by Brown and Caldwell (1983), however approximately 11.54 acres in surface area were constructed) for the collection and evaporation of ARD;

- installation of an underdrain within the pit (PUD); the PUD was intended to intercept water infiltrating through the pit and divert it to the collection ponds for evaporation;

- installation of a diversion of drainage from the adit into the collection ponds for evaporation;

- construction of a concrete channel (approximately .5 mile long) to convey Leviathan Creek through the site to prevent erosion of mining waste and to prevent the creek flows from coming in contact with mine waste, thereby limiting the formation of ARD. The CUD was installed to dewater the area where the concrete channel was to be constructed. The concrete channel was built on top of the CUD and remains today;

- excavation and regrading of the overburden piles; this was intended to reduce erosion and water infiltration and subsurface drainage; and

- revegetation of disturbed areas, including the mine pit; this was intended to prevent erosion and increase evapotranspiration.

The LRWQCB continues to operate, maintain, and monitor these structures today.

Water quality monitoring and visual observations following construction confirmed that the impacts to Leviathan, Aspen, and Bryant creeks were partially reduced. However, the effectiveness of the LRWQCB's work was limited primarily by the three factors listed below (Taxer et al., 1991):

- Seeps and springs, particularly DS and AS, were not diverted into the evaporation ponds and continued to produce ARD that flows into Leviathan and Aspen creeks.

- ARD continued flowing at a rate of 15 to 45 gallons per minute (gpm) in the underdrain below the Leviathan Creek concrete channel (CUD), which was routed directly into Leviathan Creek.

- The evaporation ponds were under-sized; as a result, ARD overflowed from the Ponds into Leviathan Creek during periods of high flow each spring.

Subsequent to the construction work in the mid-1980's, LRWQCB investigated other ways to attempt to address pollution sources at Leviathan Mine. In 1995, the LRWQCB prepared a five-year work plan for the site, and in 1998 funds for implementing the 5-Year Work Plan became available. The Work Plan proposed numerous additional measures to address pollution sources:

- installation and operation and maintenance (O&M) of a biphasic neutralization LTS to treat ARD contained in the evaporation ponds as a means to prevent pond overflow.[1] The biphasic neutralization LTS, which has also been referred to as the pond water treatment facility, was used until relatively recently during the summer months to treat the ARD collected in the evaporation ponds;

- design, pilot testing, construction, and O&M of a semi-passive treatment system (bioreactor) constructed to treat ARD flow from AS. The ASB was designed, constructed, and pilot tested in 1996 through June 30, 2001 (the ASB RA and efficiencies are discussed in more detail in Section 3.2.2.1);

- installation, and O&M, of continuous flow recording devices at the adit, PUD, CUD, and AS, and locations along Leviathan, Aspen, Mountaineer, and Bryant creeks. Additionally gauge height of water levels at Ponds 1 and 4 (Figure 13) are continually recorded. The above activities are currently under contract with the USGS;

- revegetation efforts intended to establish and enhance vegetation and to provide slope stability to the mine waste while reducing the infiltration of water into the waste rock;

- monthly surface water quality monitoring (currently ongoing and collected by the LRWQCB); and

- site maintenance activities such as fence and gate repair, road resurfacing, and storm water ditch cleaning (currently ongoing by the LRWQCB).

The AAA requires that the LRWQCB continue to treat flows from the adit and PUD each year as well as the other measures listed above. Additionally, the conducted a geotechnical analysis of the stability of the mine wastes near the DS in 2001 and 2002, and in 2005, the LRWQCB performed work on the Delta slope in an attempt to stabilize unstable ground (described further in Section 3.2.2.2).

[1] Lime treatment was initially performed by the U.S. EPA in 1997 to reduce pond overflow during the peak flow season. The LRWQCB pilot tested a version of the biphasic neutralization lime treatment system in November 1998, and in the summer of 1999 the LRWQCB conducted a treatability study to evaluate a particular process for neutralizing the ARD held in the evaporation ponds.

3.2.2 Summary of Early Response Actions by Atlantic Richfield

As required by the 1998 AOC and the November 22, 2000, Administrative Order for Early Response Actions ("Administrative Order"), Atlantic Richfield has completed interim water treatment activities related to discharges from the CUD, DS, and AS that were not captured in the evaporation ponds. Removal actions completed by Atlantic Richfield in response to the 1998 AOC and the 2000 Administrative Order include:

- Operate and continue to improve the reliability of the ASB.
- Capture and treat flows from the CUD and DS.
- Construct and operate a high-density sludge (HDS) treatment system.
- Remove sludge from the ASB.

A description of each of these flows or discharges and a chronology and summary of treatability studies or removal actions conducted by Atlantic Richfield are discussed in the following sections. The information presented is excerpted from the *2008 Annual Completion Report: Channel Underdrain, Delta Seep, and Aspen Seep Water Treatment Activities* (Atlantic Richfield, 2009).

3.2.2.1 ASB

The ASB consists of the following features that initially (1996 through 2003) operated during the summer and early fall months. As of 2004, the ASB began year-round operations.

- **AS—**The AS (also referred to as the Overburden Seep) produces flows year-round at a rate ranging between 3 and 28 gpm from low points below overburden in the Aspen Creek drainage; and

- **ASB—**The ASB treats flows from the AS prior to discharge to Aspen Creek. The ASB utilizes sulfate-reducing bacteria, supported by ethanol as a carbon food source, to produce sulfide for removal of dissolved metals by metal sulfide precipitation. Sodium hydroxide (NaOH) is added for pH adjustment to produce a suitable pH environment for the sulfate-reducing bacteria and to encourage metal sulfide precipitation at neutral to slightly alkaline conditions. The ASB generally consists of a series of ponds, chemical feed systems, recirculation pumps, remote telemetry system, and a power source.

Following is a brief overview of past activities conducted to address discharges at the AS.

1996–2000—The original ASB was designed, constructed, and pilot tested by the LRWQCB in collaboration with the University of Nevada, Reno. The history and performance of the bioreactors through 2000 is presented in detail in the *Operation and Monitoring of Bioreactors at the Leviathan Mine* report (Atlantic Richfield, 2001).

2001—In 2001, efforts at the ASB included the installation of solar panels to drive peristaltic pumps that dosed NaOH to the system for pH adjustment to enhance the removal of iron as iron sulfide.

2002–2003—Using the previous year's bioreactor system, AS water was treated from January to August of 2002. After August 2002, construction began on a larger, gravity-operated bioreactor system that was designed with improved flow distribution, flushing, and sludge capture. Construction was completed in the spring of 2003. The newly constructed bioreactor treatment system consisted of a collection trench, five ponds (a pretreatment pond, two biocell ponds, and two settling ponds, denoted ASB Pond 3 and Pond 4), and an aeration channel. At this time evaluation and testing of four alternative alkaline additives to potentially replace NaOH were carried out. The evaluation concluded that NaOH was the most effective option for the application and it was used from this point forward.

2004—Starting in January 1, 2004, the AS was captured and the newly constructed ASB was operated as designed. A total of approximately 1.68 million gallons of AS water was treated and discharged to Aspen Creek between January 1 and May 11. On May 12, a "recirculation" mode of operation was initiated by directing influent AS water into the first settling pond and adding a submersible pump (powered by a diesel generator) to pump water to the pretreatment pond. The purpose of these changes was to reduce the amount of sludge that was produced and captured in the biocells by encouraging mixing of the metal-laden influent water with the sulfide-rich biocell effluent, and subsequent metal sulfide sludge formation, in the first settling pond rather than in the biocells. The recirculation provides water with low metals and high sulfate concentration to the biocells for sulfide production. For the remainder of 2004, the system was operated in the recirculation mode, treating approximately 2.83 million gallons.

2005—The bioreactors were operated for the year 2005. During this period, the flow from the AS was captured and treated using the recirculation mode of operation. Due to a relative increase in annual precipitation (mainly as snow), flows and metal concentrations were elevated, thereby necessitating increased reagent dosing rates compared to previous years. The total volume treated in 2005 was approximately 6.83 million gallons, an approximate 240 percent increase over the 2004 volume.

2006—The total volume treated for the year was approximately 7.94 million gallons. During this year, several engineering upgrades were accomplished, including the installation of two flow meters, one for the primary recirculation pipeline and one for the effluent pipeline. From July through early October, an experiment was conducted to use biodiesel waste, consisting mainly of glycerol and methanol, in place of ethanol as a carbon food source for the system. Ethanol use was resumed after the experiment, and storage tanks were purchased to allow greater on-property storage capacity for NaOH and ethanol.

2007—Year-round treatment, including capture and treatment of approximately 4 million gallons of water from the AS, occurred in 2007. Activities completed at the ASB during 2007 included operating and monitoring the bioreactor and sampling the influent and discharge water. Additionally, modifications and improvements to optimize the existing system components were completed, which included installation of propane tanks and a propane power generation system; installation of a container to house the generators, battery bank, and additional control equipment; installation of underground conduit and junction boxes to eliminate the aboveground use of electrical cords to power the treatment system components; upgrades to the NaOH and ethanol containment areas; upgrades to the NaOH and ethanol chemical feed systems; installation of a new backup recirculation pump; upgrade and reinstallation of a human-machine interface; upgrade and installation of a new telemetry system; installation of an emergency shelter; and removal of the miscellaneous waste materials from previous years' O&M and construction.

2008—Approximately 3 million gallons of water from the AS was continuously treated and discharged in 2008. Activities completed in 2008 at the ASB included upgrades to the propane power generation system. Other upgrades such as replacement of the conveyance lines, installation of a permanent sludge removal pipeline, installation of an overflow line for the AS and replacement of secondary containment liners were completed in the summer and fall of 2008.

3.2.2.2 Pond 4 Lime Treatment Systems, CUD, and DS

The Pond 4 treatment area has been used to treat CUD and DS flows during the summer months. The following features are important to treatment activities at the Pond 4 area:

- **CUD—**The CUD captures subsurface water year-round at a flow rate that can range from approximately 18 gpm to 45 gpm from beneath the concrete Leviathan Creek diversion channel.

- **DS—**The DS produces flows year-round ranging in rate between approximately 6 gpm and 25 gpm from the lowest topographic portion of the mine waste rock in the Leviathan Creek canyon, located approximately 600 ft. downstream from the end of the Leviathan Creek concrete diversion channel and the CUD. The DS includes an upper and lower seep.

* **Pond 4 Treatment Area—**During the summer months, the Pond 4 treatment area is where captured flows from the CUD and DS are treated and discharged into the Leviathan Creek diversion channel. The Pond 4 treatment area has generally consisted of the pond, varying types of treatment systems, discharge pumps, and a source of power.

The following activities have been conducted in past years to address flows from the CUD and DS at the Pond 4 area.

2001—In 2001, a short-term, continuous lime addition treatment system was implemented that was designed for metal hydroxide and metal oxy-hydroxide precipitation. The treatment system constructed in 2001 was referred to as the lagoon treatment facility (LTF), and it treated CUD waters between August 2 and October 1 at Pond 4. The LTF demonstrated the effectiveness of lime treatment: treated water metals concentrations were below the site discharge criteria.

2002—The LTF was reestablished to treat the CUD water as it did at the end of 2001. The LTF operated successfully between June and November. A total of approximately 3.17 million gallons of CUD water were treated during 2002. Changes made to the lime delivery system resulted in improved process control and fewer difficulties with the clogging of lime pumps. Water quality monitoring in Leviathan Creek during the LTF treatability study showed that compared to pretreatment, pH had increased and metals concentrations had been reduced downstream of the CUD discharge location during the time CUD water was being captured and treated.

Additionally, at the end of November 2002, a four-day study was conducted to determine the feasibility of combined flows from the CUD, DS, adit, and PUD. System additions to accomplish this study included a capture-and-pump system to transport the DS water to the location of the CUD collection tank; a pumping system to transport the combined CUD and DS waters to the LRWQCB pond water treatment facility (PWTF) located near Pond 1 (Figure 13); and plumbing modifications to the PWTF. The PWTF effectively treated the combined flow prior to discharge into Pond 4; however, it was reported that extended operation would be required to accurately determine the reliability of the process.

2003—The 2003 treatability activities focused on evaluating and optimizing the use of PWTF for combined flow treatment. While the PWTF was used for treatment of collected adit and PUD flows, the LTF was reassembled and used to treat the CUD and DS waters so that these flows continued to be diverted from Leviathan Creek. The LTF was operated between July 21 and August 20. During this period, approximately 1.46 million gallons of CUD and DS waters were treated and discharged to Leviathan Creek. Results of the LTF treatability study showed that the system was effective in reducing the concentrations of dissolved metals below effluent site discharge criteria.

2004—In 2004, the LTF was reassembled and initially used to treat the CUD and DS waters. Subsequently, the LTF was taken offline and a rotating cylinder treatment system (RCTS) was implemented and evaluated for treating the combined CUD and DS waters. The design concept of the RCTS departs from the deep tank designs of conventional LTSs in that it uses shallow troughs with rotating cylinders to oxygenate and agitate the mixture of impacted waters and lime. During the 2004 treatment period, approximately 4.9 million gallons of CUD and DS waters were treated and discharged to Leviathan Creek. The 2004 laboratory analytical results indicated that the majority of the treated discharge concentrations of dissolved metals were below effluent discharge criteria.

2005—In 2005, a pilot program to evaluate HDS treatment technology was conducted on CUD water. The HDS technology is based on the traditional lime neutralization method, but additionally involves recycling a portion of the treatment solids from a clarifier to further increase the density and reduce the volume of the sludge. From July 27 through September 30, approximately 2.9 million gallons of CUD waters were treated and discharged to Leviathan Creek. The sludge generated during the HDS treatment was filtered using a 25-cubic-yard (cy) dewatering bin and a disposable filter-cloth liner. The filtrate was pumped into a tank for use in the HDS process. Effluent water from the HDS treatment system was fed by gravity into Pond 4, where settling of remaining particles occurred prior to discharge. The 2005 laboratory analytical results indicated that the majority of the treated discharge concentrations of dissolved metals were below effluent discharge criteria.

The DS water was not collected and treated due to logistical and safety concerns related to the LRWQCB Delta slope stabilization activities that took place between June and October.[2] The Delta slope stabilization activities included installation of a drain intended to capture surface water runoff from the slope. This drain is called the Delta Slope Underdrain, and it is a discharge point for ARD adjacent to the DS. The location of the Delta slope is shown on Figure 13. The Delta Slope Underdrain flows were not collected for treatment until fall 2007, as discussed below.

[2] Surface water runoff from a thunderstorm on August 12, 2004, triggered a landslide that buried the DS capture system. Atlantic Richfield issued a no-entry into the DS area until slope stabilization and a geotechnical evaluation of the slope were completed.

2006—In 2006, the CUD was captured and treated using the same HDS technology as in the 2005 pilot program. Treatment of the CUD water began on July 19 and was temporarily discontinued on August 25 in preparation for the transition to another treatment system then under construction. During this time, approximately 1.91 million gallons were treated and discharged to Leviathan Creek. From September 2 through October 20, the CUD was captured and treated using an interim lime-neutralization treatment system or LTF system. The LTF system was similar to the 2004 LTF. During this period approximately 2.03 million gallons were treated and discharged to Leviathan Creek. The DS was not collected in 2006 for the reasons described above for 2005.

2007—In 2007, CUD water collection began on June 15, using a modified version of the existing 2006 collection system. Approximately 2.9 million gallons of CUD water were captured during the 2007 treatment season ending on October 10. The collection of the DS was initiated on June 29, following installation of a new temporary collection system. DS flow collection continued until October 10, except for a short suspension from September 14 through September 25 during the construction of the DS semipermanent collection and conveyance system. Approximately 660,000 gallons of DS water were captured during 2007.

The Pond 4 LTS was utilized to treat captured CUD and DS flows from June 19 to October 10, as well as approximately 400,000 gallons of water existing in Pond 4 at the beginning of the treatment season. The Pond 4 LTS treated the ARD by utilizing single-phase lime treatment for pH adjustment and metals removal, and RCTS units for mixing and aeration. Treated water was either placed into Pond 4 or pumped into filter bags that collected a portion of the sludge, and the filtered water was pumped to Pond 4 for final settling of suspended particles, testing, and eventual discharge to Leviathan Creek. All discharges of treated water from Pond 4, with minor exceptions, met effluent discharge criteria.

Approximately 56.7 tons of sludge generated from the 2006 LTF and approximately 45.2 tons of sludge generated from the 2007 LTS were removed during the summer and fall of 2007. Prior to disposal, the sludge was sampled for waste characterization and profiling. Sludge was transported under manifest[3] to U.S. Ecology in Beatty, Nevada.

[3] Sludge transported off site was classified as non–Resource Conservation Recovery Act (RCRA) California hazardous waste on the waste manifests; however, based on the 2007 and previous years' analytical results and in consideration of applicable federal and state regulations, Atlantic Richfield determined that the sludge was not a hazardous waste under state or federal regulations.

3.2.2.3 HDS Treatment from the Pond 4 Lime Treatment System

As discussed in the previous section, a pilot study using an HDS treatment system was conducted at Pond 4 in 2005 with demonstrated success. The HDS technology is meant to be used in conjunction with an LTS. It improves the efficiency of the LTS by recycling a portion of the treatment solids from the clarifier and further increasing the density while reducing the volume of the sludge. Less sludge produced requires less dewatering activity. It also provides a reliable control over lime dosage, which ultimately provides reliable treatment of impacted water.

In 2007, design plans were initiated for a semipermanent HDS treatment system to reliably treat discharges from the CUD and DS. The schedule for construction of the semipermanent HDS treatment system was such that a process building to house the HDS treatment system was designed, constructed, and erected in 2007. Additionally, the semipermanent collection and conveyance systems for the CUD and DS were designed, constructed, and completed in the fall of 2007. The construction of the DS semipermanent collection system included the collection of the upper and lower DS as well as collection of the Delta Slope Underdrain (constructed in 2005).

The semipermanent HDS treatment system was constructed at the Pond 4 LTS in 2008 and is expected to be in full operation beginning in late summer/early fall of 2009.

3.2.2.4 Sludge Removal from the ASB

Sludge is produced in all parts of the bioreactor system. The most significant production is in Pond 3, where the metal-rich incoming water mixes with the sulfide-rich water coming from the biocells and the NaOH for pH adjustment. Two water streams (the AS and the flow from biocell 2) and NaOH all are combined in manhole 6, where some physical mixing occurs. Pond 3 provides additional mixing by the recirculation pump, and also provides retention time for the reaction of the metals and the sulfide to produce metal sulfide precipitates (sludge), which happens at approximately neutral pH. Sludge settles out in Ponds 3 and 4. Pond 4 provides time for settling without disturbance; therefore, additional sludge accumulation is expected in Pond 4.

Additional sludge is produced by biomaterial forming in biocells 1 and 2 as part of the sulfide generation and metal precipitation process. Eventually this will cause clogging, so the biocells require changes in flow patterns and backflushing occasionally. The biomaterial with the associated metal precipitates will occasionally dislodge and end up in Ponds 3 and 4. A summary of the bioreactor performance and the 2007 plan for sludge removal and dewatering activities was presented in the *Technical Memorandum: Aspen Seep Bioreactor Sludge Removal* (Atlantic Richfield, 2007).

Sludge removal is necessary to maintain the efficiency of the treatment system by minimizing hydrologic changes within the bioreactor treatment cells and potential short-circuiting. Sludge removal efforts at the ASB are hampered by difficulties associated with the handling and dewatering of the high-water-content sludge. As a result, sludge accumulation in the two bioreactors as well as the two storage ponds has a negative impact on the efficiency of the ASB as a whole. The following paragraphs describe the procedures and effectiveness of sludge removal activities at the ASB to date.

In 2005, a minimal amount of sludge was removed from Pond 3 and from the two biocell ponds by pumping via trash pump into filter bags. The filter bags were stored on site through the winter and were removed in 2006.

During spring 2006, the volume of sludge accumulation in Pond 3 reached a level requiring removal. Consequently, Pond 3 sludge was either pumped into filter bags for dewatering, pumped into Pond 4 to await future removal, or pumped via trash pump and vacuum truck for off-property disposal. Approximately 27 cy of dewatered sludge was captured in filter bags, approximately 77.7 cy of non-dewatered sludge was removed from the pretreatment pond, and 228.1 cy of non-dewatered sludge from Pond 3 was removed and classified as nonhazardous waste solids and liquids by Resource Conservation and Recovery Act (RCRA) and California regulations. The sludge was disposed of off site at U.S. Ecology in Beatty, Nevada, between September 18 and October 25, 2006.

In 2007, two methods of sludge removal were pilot tested to evaluate the feasibility of sludge dewatering at the ASB. The first pilot test consisted of utilizing bags constructed of filter fabric and contained within roll-off-style filter bins (dewatering bins) and was commenced on June 24, 2007. The second pilot test employed a mobile belt filter press that dewaters sludge by applying pressure and physically squeezing water (filtrate water) from the sludge/slurry, reducing the moisture content of the sludge for more cost-efficient off-property disposal. Approximately 5.6 tons of sludge dewatered in the filter bags and approximately 59.3 tons of sludge dewatered in the belt filter press was removed from the ASB in 2007. The sludge was sampled prior to off-property disposal for waste characterization and profiling. The nonhazardous sludge was transported under manifest[4] to U.S. Ecology in Beatty, Nevada.

[4] Sludge transported off site was classified as non–Resource Conservation Recovery Act (RCRA) California hazardous waste on the waste manifests; however, based on the 2007 and previous years' analytical results and in consideration of applicable federal and state regulations, Atlantic Richfield determined that the sludge was not a hazardous waste.

In 2008, sludge removal and dewatering of sludge accumulation from the ASB was completed by utilizing the belt filter press similar to the 2007 pilot test. Approximately 58 tons of sludge was generated from the belt press operations and removed from the site under nonhazardous waste manifest to U.S. Ecology in Beatty, Nevada, for disposal.

3.3 RI/FS SCOPING PROCESS AND DQOS

Consistent with the SOW, a DQO report was prepared in 2008 (Atlantic Richfield, 2008). The DQOs were developed consistent with the RI/FS scoping process defined in the NCP, 40 CFR Section 300.430(b). The scoping process included identifying data needs to characterize the site, completing the CSM, better defining ARARs, and narrowing the range of the preliminary remedial alternatives identified. This data needs step is accomplished via the DQO process and then with the preparation of work plans. In general, the RI/FS must obtain data to define the source areas of contamination, the potential pathways of migration, and the potential receptors and associated exposure pathways to the extent necessary to evaluate whether or not and to what extent a threat to human health or the environment exists now or in the future, and then develop and evaluate remedial alternatives, including the No Action alternative (U.S. EPA, 1988).

The scoping process involves the following steps:

- evaluate existing data,
- develop a CSM,
- develop an SMS,
- develop remedial action objectives (RAOs) and initial remedial options,
- develop ARARs, and
- develop DQOs.

The DQO report was intended to be an initial step in the RI/FS scoping process and it was prepared in order to facilitate project planning, to assist in developing an RI/FS strategy and through the development of DQOs assist in the development of data gaps for the RI/FS. The data analysis and the DQOs presented in the DQO report were a definitive first step in the scoping process for the RI/FS, but due to the extended time frame and variable scope and quality of the previous data collection programs, this effort could not develop more specific data gaps.

The DQO report was submitted to the U.S. EPA on October 21, 2008. The DQO report was approved with comment on April 23, 2009 (U.S. EPA, 2009c). In general, the U.S. EPA indicated in its approval of the DQO report that additional data analysis and detail regarding the scope and prioritization of site investigation should be presented in the RI/FS PWP and in subsequent FRI work plans.

The scope and general results of the scoping presented in the DQO report are summarized below.

3.3.1 Scoping Data Evaluation

Consistent with the RI/FS process and the NCP, an evaluation of existing data was conducted in 2007 to form a basis for the development of the DQOs. As indicated above, the previous data collection activities had been conducted over a long period of time, and for a variety of reasons the data had never been reviewed in a comprehensive manner until this effort was conducted for the DQO report.

3.3.1.1 Database Upgrade

As part of the scoping evaluation, the site electronic database was reviewed for completeness and then was supplemented and upgraded for future use in the RI/FS process. An inventory of data from various environmental media was prepared and a general assessment of the data quality was conducted. This database update was last provided to the U.S. EPA and the stakeholders in June of 2008.

3.3.1.2 Evaluation of Hydrogeology

For purposes of the scoping data evaluation, the hydrogeology was reviewed. This review consisted of previous investigations, the regional geology, site-specific geology to date, and water levels. The hydrogeology review concluded with an initial working hydrogeologic model that could be used for the purpose of developing the DQOs. Characteristics of the model include the following:

- Groundwater flow mimics topography (with the exception of the pit area).
- Bedding does not play a major factor in groundwater flow.
- Faulting does not appear to play a major role (either as a groundwater divide or as secondary permeability features) in controlling groundwater flow; the clay in the faults acts similarly to surrounding clay-altered bedrock.
- Faulting likely occurred prior to sulfur mineralization.

- Although it varies locally, the groundwater system consists of a shallow waste rock or tailings/colluvial zone, a clay-altered bedrock zone, and possibly a weathered bedrock zone.

- In the northern overburden/landslide area, the slide plane influences groundwater flow; there are small grabens in the slide area.

- Where groundwater MW pairs are present, downward vertical gradients have been measured.

- Argillic alteration (smectite and illite) and replacement are widespread in the shallow bedrock, making hand identification of geologic units almost impossible. The primary groundwater transport zones are in the altered clay materials.

Based on the hydrogeological model and the data evaluation, investigation data gaps were developed for the RI/FS.

3.3.1.3 Evaluation of Geochemistry

A number of investigations pertaining to the geochemistry of the site were conducted and reviewed as part of the scoping evaluation. Soil data, groundwater chemistry, surface water and sediment data were reviewed. Based on the data review, a geochemistry CSM was developed that includes the following characteristics:

- Previous reports have listed five known sources of ARD discharge to Leviathan Creek: the PUD; adit drainage (Adit #5), CUD, DS, and AS.

- The pit and adit are significant sources where the reactions associated with ARD production are known to occur.

- Other known “sources,” the CUD, DS, and AS, represent point discharges to Leviathan Creek, while the actual source of contaminants is the weathering/oxidation of the fine-grained pyrite that is disseminated upgradient of the discharge point.

- The location and extent of the primary sources of ARD to the five point discharges noted above are not clearly defined, but may include small to large recharge basins, recharge through waste and overburden, flows emanating from the adit and/or pit, leakage from evaporation ponds, and leakage from transfer piping.

- Background water quality (surface and groundwater) is currently poorly defined.

- Significant mass loading of metals and total dissolved solids to Leviathan Creek occurs downstream of the site at Station 15. Metal loads are attenuated at various rates, which are primarily controlled by stream pH.

- Additional mass loading of some metals and sulfate from undefined sources occurs well downstream from the site.

- Groundwater is likely anoxic, and therefore, addition of alkalinity prior to surface discharge may provide an alternative, more passive approach to treatment.

- An increase in pH along the groundwater flow path in the eastern portion of the site suggests the possible neutralization of groundwater in contact with calcite-bearing rocks.

- Source control (e.g., inhibition of pyrite oxidation) requires that the contact of disseminated pyrite with water and/or oxygen be minimized.

3.3.1.4 Human Health and Ecological Risk Evaluation

As part of the scoping data evaluation, existing data collected in the vicinity of the site was assessed to identify chemicals of potential concern (COPCs) and evidence for potential impairment to human health and ecological receptions. The results of this evaluation are the CSMs described in Section 3.4.

3.3.1.5 Geotechnical Review

Review of existing data indicates that from a geotechnical standpoint, there are two significant material classifications at the site: waste rock and bedrock. Based on the preliminary evaluation of the available data and preliminary geotechnical aspects of the CSM, it was concluded that the design and construction of remedial measures at the site should account for the geotechnical considerations. Steep slopes may be subject to permanent deformation when groundwater is elevated or an earthquake occurs. Regrading of these slopes may be necessary. Treatment facilities on active landslides should be designed to accommodate deformation of the landslides. Ponds and other water retention structures should be located where they will not adversely impact the active landslides or potentially create other stability and seepage issues.

3.3.2 SMS

The purpose of developing an SMS is to tailor the RI and FS to site physical characteristics and impacts. Tailoring the RI/FS to the level of site complexity does not change the information requirements but it does involve identifying specific techniques that may be used to streamline the process to save time and costs while ensuring that information is sufficient in quantity and quality to select an appropriate remedy (U.S. EPA, 1988).

3.3.2.1 Identification of Study Areas

The SMS includes the definition of study areas that are used to develop the DQOs and to facilitate the implementation of further investigation:

- Aspen Creek study area (ACSA),

- pit study area (PSA),
- Leviathan Creek study area (LCSA), and
- off-property study area (OSA; now DSA, for downstream study area)

3.3.2.2 Continued Use of Interim Response Actions (IRMs)

As noted above, the current SMS includes the use of IRMs to capture and treat discharges from several areas.

3.3.2.3 Prioritization of Data Collection and Cleanup

Exposure pathways and the degree of risk to human health and the environment are significant criteria that can be used to prioritize the work to be conducted under the RI/FS. Based on the CSMs, the greatest current and future risk remaining to human health and the environment is from on-property source and discharge areas: Aspen, pit, CUD, DS, and ponds.

3.3.2.4 Background Data Collection

Background and/or pre-mining data collection are necessary as a high priority in the RI/FS. Investigation of the natural background condition can be used to establish or evaluate the feasibility of achieving cleanup goals. For the RI/FS it is anticipated that to collect background data for groundwater, surface water, sediment, and soil, and to develop biological reference data for the risk assessment, more than one background area or analog site will need to be selected.

3.3.2.5 Streamlining Techniques

Where possible, streamlining techniques will be used to expedite the RI/FS data collection and decision-making process. All of the approaches involve conducting a review of existing information on the site and stressing the importance of developing a comprehensive understanding of the probable site conditions, so that accurate predictions regarding contaminant source area, contamination distribution, and the presence of preferential migration and exposure pathways can be made.

3.3.3 RAOs and IRAs

Potential RAOs were identified and a preliminary range of RAs and associated technologies were identified. The purpose of identifying interim response actions (IRAs) now is not to conduct a detailed investigation of alternatives, but instead to provide a more general classification of potential RA based on the initially identified potential routes of exposure and associated receptors identified for the site. The identification of the IRAs at this stage will help ensure that data needed to conduct the technical evaluation can be collected as early as possible in the RI/FS process.

3.3.3.1 RAOs

RAOs are proposed goals for protecting human health and the environment. RAOs provide the framework for developing and evaluating remedial action alternatives. The RAOs for developing the initial list of the response actions are to do the following:

- prevent, mitigate, or reduce potential human health and environmental exposure;
- support long-term restoration of surface water and groundwater; and
- minimize threats to the environment, especially sensitive habitats and critical habitats of species protected under the Endangered Species Act.

3.3.3.2 Technology Descriptions

The general remedial action technologies currently under evaluation as potential response actions for the site are grouped into six categories:

1. no action,
2. administrative controls,
3. engineering controls,
4. removal actions,
5. physical/chemical treatment, and
6. biological treatment.

3.3.3.3. Remedial Technology Identification and Description by Study Area

A list of technologies was developed by study area for the purposes of the DQO Report to aid in identifying data needs.

3.3.4 Applicable or Relevant and Appropriate Requirements

The potential ARARs and "to be considered" criteria, or TBCs, identified for the site are those that could impact the selection of remedial action alternatives and the ultimate cleanup standards. The universe of ARARs and TBCs that may apply to the remedial alternatives under consideration at the site were listed to identify how the ARARs influence the feasibility of those alternatives at this point in the RI/FS scoping process. ARARs may also identify specific numerical cleanup objectives for the site or may require application of a certain approach to cleanup level development.

3.3.5 Data Quality Objectives

DQOs were developed for each of the study areas described as an interim step toward preparing the RI/FS Work Plan for the site. The seven steps U.S. EPA defines as the DQO process are presented below.

- **Step 1—Statement of the Problem.** Define the problem that necessitates the study; identify the planning team, examine budget, and schedule.
- **Step 2—Identify the Goal of the Study.** State how environmental data will be used in meeting objectives and solving the problem, identify study questions, and define alternative outcomes.
- **Step 3—Identify Information Inputs.** Identify data and information needed to answer study questions.
- **Step 4—Define the Boundaries of the Study.** Specify the target population and characteristics of interest; define special and temporal limits, and scale of interference.
- **Step 5—Develop an Analytic Approach.** Define the parameter of interest, specify the type of inference, and develop the logic for drawing conclusions from findings: decision making, hypothesis testing, estimation, and other analytical approaches.
- **Step 6—Specify Performance or Acceptance Criteria.** Specify probability limits for false rejection and false acceptance decision errors and develop performance criteria for new data being collected or acceptable criteria for existing data being considered for use.
- **Step 7—Develop the Plan for Obtaining Data.** Select the resource-effective SAP that meets the performance criteria.

The DQO process was followed for each of the four study areas. Beyond the DQOs the results of the analysis included an initial list of data gaps for each study area. The DQOs and the data needs are discussed in Sections 4 and 5.

3.4 CONCEPTUAL SITE MODEL

As described in U.S. EPA's *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (U.S. EPA, 1988), the purpose of a CSM is to describe what is known about chemical sources, migration pathways, exposure routes, and receptors at the site. The SOW in the UAO defines the "Leviathan Mine" as "the area within the mine property boundaries and adjacent areas outside the property boundary which have been disturbed by mining activities, such as mine wastes, excavations, landslides and runoff of surface water and groundwater." For the purpose of the csm, the Leviathan Mine Site is divided into two general areas: the disturbed area of the property where active mining occurred, referred to as "on-property," and the "off-property" areas, defined as all other areas of the site.

The CSM depicts the exposure pathways and the mechanisms by which a receptor may come into contact with COPCs in the environment. Using the U.S. EPA *Risk Assessment Guidance for Superfund* (U.S. EPA, 1989), potential exposure pathways applicable to the site have been identified and addressed. An exposure pathway is defined by four elements (U.S. EPA, 1989):

1. a source and mechanism of COPC release to the environment;
2. an environmental medium of concern (e.g., air, soil, water) or transport mechanism (e.g., volatilization) for the released COPC;
3. a point of potential contact with the medium of concern; and
4. an exposure route (e.g., ingestion) at the contact point.

An exposure pathway is considered "complete" if all four of these elements are present. Only complete or potentially complete exposure pathways need to be evaluated for the purposes of a risk assessment. Separate CSMs have been developed for human and ecological receptors (Figures 43 and 44). Elements (e.g., sources, fate and transport mechanisms) common to both CSMs are discussed further in this section. Subsequent sections discuss the specific receptors, exposure routes, and exposure pathways for human and ecological risk assessment. The past data sources reviewed for the risk assessments are shown in Tables 41 and 42.

3.4.1 Sources

The primary sources of chemicals at the site are overburden/waste rock and naturally occurring rock that are exposed to precipitation and generate ARD. Overburden refers to nonmineralized soils/rock that was removed to obtain access to the mineralized rock. Waste rock refers to mineralized rock that was discarded at the mine property and not shipped off-property for processing. The mine consists of an underground mine (with mine structures such as the adit) and an open-pit that exposes naturally occurring rock to oxygen and water. Reclamation activities and construction of ponds and other surface water management structures have altered the flow of surface water and groundwater through naturally occurring mineralized soil/rock and accumulated overburden and waste rock.

The high sulfur content of the waste rock and exposed rock results in acidic discharges (low pH of 2 to 3) as water percolates through the rock to groundwater or discharges to surface water. Groundwater and surface water with a low pH will result in the increased solubility of metals. Without treatment, the metals move with the surface water and can be deposited in sediments as pH increases. Specific discharge points of ARD at the site include underground sources as well as the CUD, AS, DS, PUD, and adit.

Waste rock and overburden exist at various locations on-property. Some of this material was reportedly used for dust control and stabilization on nearby access roads, although this has not been confirmed. An estimated 22 million tons of waste rock/overburden was distributed across the mine property (Brown and Caldwell, 1983).

3.4.2 Chemicals of Potential Concern

This section briefly summarizes the COPCs associated with the site. U.S. EPA's SOW (U.S. EPA, 2008a) identifies the following metals as potentially site related:

- aluminum
- arsenic
- beryllium
- cadmium
- chromium
- cobalt
- copper
- iron
- lead
- manganese
- mercury
- nickel
- selenium
- thallium
- vanadium
- zinc

In addition to pH, the following inorganic chemicals were also listed in the SOW:

- total sulfate
- ferric sulfate
- ferrous sulfate
- sulfuric acid

These four inorganic chemicals may be relevant for acid-base accounting and not for human health or ecological risk. These inorganic chemicals will not be analyzed for the purpose of evaluating potential human health or ecological risk. The U.S. EPA's selection of these COPCs was based on previous evaluations. This listing will serve as the basis for additional site characterization during the RI/FS.

Because these chemicals are present in nature, an assessment will be conducted to evaluate whether the concentrations measured represent natural background conditions. Concentrations will be compared with concentrations from reference sites to assess whether the chemicals should be classified as COPCs or as naturally occurring.

3.4.3 Fate and Transport

There are a number of mechanisms by which chemicals identified above can migrate to other areas or to other media. The U.S. EPA (1989c) has identified several of these mechanisms. Based on current information, the relevance of these mechanisms to the site is discussed below.

3.4.3.1 Fugitive Dust Generation

Fugitive dusts may be generated from the waste rock/overburden, including the upper portions of Leviathan Mine Road where this material was reportedly deposited. Further information is required to confirm where along the access roads that the material was deposited.

3.4.3.2 Volatilization

Mercury in its elemental state is considered semivolatile and may be volatilized from soil or surface water to ambient air. However, mercury at the site is anticipated to be primarily in an inorganic or organic form, which is significantly less volatile. Measurements of mercury concentrations in air at ground surface in mineralized areas indicate that mercury concentrations in air "did not pose a threat to human health" (Gustin et al., 2003). These measurements were conservative, as they did not adequately consider mixing with ambient air. Additionally, Leviathan Mine is not considered to be the source of mercury in streambed sediments (Bevans et al., 1998). As such, potential exposure to mercury via volatilization is not considered significant. Mercury present in inorganic or organic forms associated with airborne particulate matter will be evaluated via inhalation of fugitive dusts (see above).

3.4.3.3 Leaching (Infiltration)

Infiltration of precipitation, melted snowpack, and water stored or conveyed in man-made structures through the mine property to groundwater is a potential release mechanism for COPCs to groundwater. Precipitation and snowmelt in contact with the mine property may become ARD.

3.4.3.4 Groundwater Transport

Based on the conceptual hydrogeologic model for the site, the majority of groundwater from the mine property ultimately discharges to Leviathan and Aspen creeks. This assumption will be further evaluated in the water balance for the site.

3.4.3.5 Surface Water Runoff

Surface water runoff is created during precipitation events and can create ARD when it contacts the site soil or rock, waste rock, or overburden and then migrates to the local creeks. The low pH of ARD can result in dissolution of metals into water from rock and sediment. Increases in pH can result in deposition of metals transported by surface water to sediment.

3.4.3.6 Erosion

Site soil, overburden, and waste rock may be mobilized into runoff as sediment during higher-volume precipitation events, and may be deposited in creeks. Metals present in these materials may dissolve in surface water, depending on the pH of the runoff.

3.4.3.7 Deposition of Sediment

Sediment may be deposited along the banks of the creeks during high flow events and become accessible as soil.

3.4.3.8 Biotic Uptake

The chemicals identified in the SOW may be found in plants, aquatic organisms (including benthic invertebrates), and wildlife that come in contact with soil, surface water, and sediment affected by these chemicals.

3.4.4 Human Health Site Conceptual Exposure Model

The characterization of the potential exposure pathways at the site, based on existing information, is presented in the CSM (Figure 43). The remainder of this section identifies potential receptors, exposure routes, and potentially complete exposure pathways. Insignificant and incomplete pathways are also identified and discussed.

3.4.4.1 Potential Receptors

The identification of potential human receptors is based on the characteristics of the site, the surrounding land uses, and the probable future land uses. The on-property area, owned by the state, is secured with gates at the entrances from the access roads from the north and south (Leviathan Mine Road). During winter months potential access is further limited because of snowpack, such that a standard four-wheel-drive vehicle could not reach the mine property on the dirt access roads covered with snow. Access to the area, including the mine property, during the winter months requires use of snow cats, snowmobiles, or other alternative transportation.

The off-property areas surrounding the mine, through which creeks downstream of the mine property flow (e.g., Leviathan, Aspen, and Bryant creeks) and on which access roads to the mine property have been constructed, is administered by the USFS (Brown and Caldwell, 1983). There are no known physical or institutional controls limiting access to these areas such as fences or signs. The nearest private property are parcels near the southern mine entrance.

Future land use is not anticipated to change in the area surrounding the mine property. As such current receptors also are considered to be potential future receptors. The primary change in the future use would be potentially less restricted access to certain on-property areas following implementation of the final remedy and possible longer-term use of off-property areas by Washoe Tribe members.

The following receptors have been identified for the site and surrounding areas:

- **Current On-Property Trespasser—**Although access to the mine property is restricted by gates at the roadways, a trespasser could access the mine on foot since it is not always monitored or occupied. The trespasser would be anticipated to be at the mine for up to one week in a single year. The likelihood of this exposure scenario is limited by the restricted roadway access, remote location, periodic activity related to remediation, and unrestricted access to alternative areas outside the mine property.
- **Current Off-Property Recreational Visitor—**The off-property areas downstream of the mine property could be accessed by a recreational visitor for hiking, camping, hunting, fishing, and off-road vehicles. Based on previous assessments of a recreational visitor by the California Department of Health Services (CDHS, 2002) and Gradient Corporation (2002), these activities are limited to the summer months

when access to the area is not limited by snow. The current off-property recreational visitor is assumed to be present in the area for up to two weeks per year. We also anticipate that this scenario would address potential exposure for USFS personnel or a recreational cabin.

- **Current Off-Property Rancher—**During the agricultural growing season, water from Bryant Creek has been regularly diverted for irrigation purposes to the River Ranch. This diversion (River Ranch Irrigation Channel) is located immediately downstream of the Doud Springs inlet into Bryant Creek. The diversion is approximately 7.8 miles downstream from the mine property and is located on the western side of Bryant Creek. This diversion channel, which appears to be unlined and runs for approximately 2 to 3 miles before reaching the River Ranch, has been used for agricultural irrigation and livestock consumption on the River Ranch. Livestock pastured on the River Ranch might consume the irrigation water and feed on crops grown with the diversion water. There is another diversion from Bryant Creek located about 0.25 miles above the mouth of Bryant Creek as it enters the East Fork of the Carson River. This diversion is used to irrigate River Ranch pasture land to the north of Bryant Creek, along the Carson River East Fork (CDHS, 2002). During the site walk in June 2007, water was not being diverted from Bryant Creek or either pasture irrigation or livestock consumption. Based on observations by the USFS, water was being diverted in 2008 (USFS, 2008). Further information is required (e.g., when and how much water is diverted) to evaluate exposure pathways for this scenario.

- **Current Off-Property Resident—**Residences are located in the vicinity of Leviathan Mine Road where overburden and waste rock may have been used and could become airborne as dust from wind or road traffic. The potential for exposure is related to the portion of the Leviathan Mine Road nearest the residences and Route 395. Potential effects from the mine property or windblown dust from other portions of Leviathan Mine Road would be insignificant for this residential area.

- **Current Off-Property Washoe Tribe Member—**The Washoe Indian tribe of California and Nevada (Washoe tribe) historically has used the area in the vicinity of the site for hunting, fishing, and gathering (Walker, 2003). Although current practices by the tribe members are not documented, a current tribe member could access the area periodically for these purposes. However, tribal members are not likely to be using the resources at the site in a manner consistent with historical subsistence lifestyles (Walker, 2003).

- **Future Off-Property Washoe Tribe Member—**The Washoe tribe has developed a hypothetical reasonable maximum exposure (RME) scenario for future use of the land in the vicinity of the site (Harper, 2005a, b). The hypothetical RME scenario assumes that a tribal member lives a subsistence lifestyle with family in a house in a sparsely populated, riparian corridor near the site (Walker, 2003) throughout the year. The location of the residence is in the farthest upstream available allotment. The subsistence lifestyle includes a home garden, wood for fuel, no paved areas, and a groundwater well or surface water source of drinking water. Subject to legal restrictions on access, potential exposure would be driven by media-specific concentrations in this area for some exposure media (e.g., drinking water, plants), with periodic foraging to other areas nearer to the mine property (e.g., wildlife, aquatic organisms).

- **Future On-Property Recreational Visitor—** Future land use of some on-property areas may include open space within a national forest area. Based on discussions with stakeholders, we will assume that the mine property could be used for recreational vehicles in the future and will consider additional windblown dust raised by that activity. We also anticipate that this scenario would address potential exposure for USFS personnel or a recreational cabin.

3.4.4.2 Exposure Points and Routes

Based on the COPCs, affected media, and migration pathways discussed above, points of potential human contact with site-related COPCs include primary environmental media (soil, groundwater, surface water, and sediment) and secondary media (related to one or more primary media, including air, plants, aquatic organisms, wildlife, and cattle).

Soil: Potential exposure routes associated with COPCs in soil include direct and indirect exposure routes. Direct exposure routes include incidental ingestion, dermal contact, and inhalation of airborne particulates. Indirect exposure routes include ingestion of plants and wildlife where these media have been affected by COPCs in soil.

Groundwater: Potential exposure routes associated with use of on-property groundwater are based on designation of groundwater in the Markleeville Hydrologic Area as a potential municipal supply in the Lahontan Basin Plan (LRWQCB, 2005) and the fact that groundwater discharges to surface waters that are designated as drinking water sources. Although groundwater will be considered as a potential drinking water source, at this time, no exposure points are anticipated for this medium because all groundwater from on-property areas would not be accessed directly and is believed to discharge to the nearby creeks. Exposure routes related to its use as a drinking water source include ingestion and dermal contact. This conclusion will be re-evaluated based on results of site water balance.

Surface Water: Surface water exposure points may consist of several stream segments that are evaluated independently based on differences in concentrations, sample distribution, and confluences with additional streams. Potential exposure routes applicable to COPCs in surface water include direct and indirect exposure routes. Direct exposure routes include ingestion and dermal contact. Indirect exposure routes include ingestion of plants, aquatic organisms, wildlife, and cattle where these media have been exposed to COPCs in surface water.

Sediment: Similar to surface water, sediment exposure points may consist of several stream segments that are evaluated independently based on differences in concentrations, sample distribution and confluences with additional streams. Potential exposure routes applicable to COPCs in sediment include direct and indirect exposure routes. Direct exposure routes include incidental ingestion and dermal contact. Indirect exposure routes include ingestion of plants, aquatic organisms and wildlife where these media have been exposed to COPCs in sediment.

3.4.4.3 Exposure Pathways

Given the characteristics of the COPCs of interest and release processes discussed above, this section describes the potential exposure pathways for current and future land use.

Current On-Property Trespasser

A current on-property trespasser potentially could be exposed directly to on-property soil via incidental ingestion, dermal contact, and inhalation of resuspended particulates. The on-property trespasser may also consume plants, aquatic organisms, and wildlife exposed to on-property chemicals in soil. While off-property exposure pathways are also possible for this receptor, other receptors will address exposure to off-property media, and this receptor will be limited to on-property exposure.

Current Off-Property Recreational Visitor

A current off-property recreational visitor potentially could be exposed directly to COPCs in surface water and sediment via dermal contact and incidental ingestion. This receptor may ingest aquatic organisms, plants, and wildlife potentially affected by COPCs in surface water and sediment. This receptor potentially may be exposed directly to chemicals in off-property soil via ingestion, dermal contact, and inhalation of resuspended particulates as well as via ingestion of plants and wildlife exposed to off-property soil; off-property soil-related pathways, however, are considered only potentially complete until additional data is collected.

Current Off-Property Rancher

Water diverted from Bryant Creek has been used as a water supply for cattle and irrigation for pastures at the River Ranch. A rancher potentially could be exposed to COPCs that may bioaccumulate in the cattle, as well as to surface water itself and plants grown using the surface water for irrigation. Additionally, COPCs may accumulate in the soil over time, resulting in the potential for direct contact exposure and inhalation of resuspended particulates. This receptor was included to specifically address the potential for COPCs to be present at the ranch property. Other activities such as ingestion of off-property plants and wildlife are addressed by other receptors and are not included for this receptor. Additionally, this receptor is intended to address intermittent grazing of sheep in areas other than the River Ranch. Exposure for other grazing animals is assumed to be less frequent and over a shorter duration than for the cows at the River Ranch.

Current Off-Property Resident

Although it is unclear if related to Leviathan Mine, a current off-property resident may be exposed to windblown dust and dust from road traffic from the portion of Leviathan Mine Road if waste rock and overburden were used in these areas. If the windblown dust has deposited over time, the current off-property resident may be exposed via direct contact with soil and ingestion of homegrown produce. This receptor was included specifically to address exposures at an off-property residence; other exposure pathways, such as ingestion of wildlife, are addressed by other receptors.

Current Off-Property Washoe Tribe Member

A current off-property Washoe tribe member potentially may be exposed directly to COPCs in surface water and sediment via dermal contact and incidental ingestion during periodic visits to the site. The current tribe member also may ingest fish, plants, and wildlife potentially affected by COPCs in surface water, sediment, and soil. The current tribe member may potentially also be exposed directly to off-property soil via ingestion, dermal contact, and resuspension of particulates as well as via ingestion of plants and wildlife exposed to off-property soil. However, the off-property soil exposure pathways are considered only potentially complete until additional data is collected along roads and streambeds.

Future Off-Property Washoe Tribe Member

Based on the RME scenario, a future off-property Washoe tribe member potentially may be exposed directly to COPCs in surface water and sediment via dermal contact and ingestion. The future off-property tribe member also may ingest fish, plants, and wildlife potentially affected by COPCs in surface water, sediment, and soil. The future tribe member also may potentially be exposed directly to off-property soil via ingestion, dermal contact, and resuspension of particulates; however, the off-property soil exposure pathways only are considered potentially complete pending further evaluation.

Future On-Property Recreational Visitor

A future on-property recreational visitor potentially may be exposed directly to chemicals in on-property soil via ingestion, dermal contact, and inhalation of resuspended particulates as well as via ingestion of plants and wildlife exposed to on-property soil. To address stakeholder concerns, the possibility of exposure to airborne dust resulting from off-road vehicles being ridden across the mine property will be considered. An on-property groundwater supply well is not considered likely under future site use; thus ingestion of groundwater is not considered a complete exposure pathway.

3.4.5 Ecological Site Conceptual Model

The characterization of the potential ecological exposure pathways at the site, based on existing information, is presented in the CSM (Figure 44). This section identifies potential receptors, exposure routes, and complete pathways. Insignificant and incomplete pathways are also identified and discussed.

3.4.5.1 Potential Receptors

The identification of potential ecological receptors is based on the characteristics of the site, surrounding habitats, and general categories of organisms that would be expected to occur within aquatic, riparian, and upland habitats (Figure 45). The California Habitat Classification Scheme includes a description of 59 wildlife habitats for regularly occurring birds, mammals, reptiles, and amphibians in the state. Twenty-four of these habitats occur in the vicinity of Leviathan Mine. Based on a review of these habitats and the species that reside in these habitats, the following categories of receptors have been identified for the site and surrounding areas. A list of species for each habitat type and the species that will be selected to represent the following categories will be provided in the risk assessment work plan:

- benthic macroinvertebrates (aquatic insects)
- amphibians
- fish
- fish-eating mammals
- fish-eating birds
- aquatic plants
- riparian plants
- upland plants
- soil invertebrates
- herbivorous mammals
- omnivorous mammals

- carnivorous mammals
- herbivorous birds
- insectivorous birds
- raptors
- reptiles

With the exception of historical studies that have characterized benthic macroinvertebrates (ENSR, 1999; Thompson and Welsh, 1999; Herbst, 1995, 1997, 2000) and fish species (Lehr, 2000; LRWQCB, 1995) in the vicinity of the site, surveys to quantify the habitats and other categories of ecological receptors found within these habitats have not been conducted.

3.4.5.2 Exposure Points and Routes

Based on the COPCs, affected media, and migration pathways available for the site and surrounding areas, points of potential ecological receptor contact with COPCs include soil, surface water, sediment, air, plants, and aquatic and terrestrial wildlife.

- Potential exposure routes associated with COPCs in soil are ingestion, dermal contact, and inhalation of resuspended particulates. Additional exposure routes include ecological receptors that consume plants, soil invertebrates, or wildlife that accumulate COPCs from soil. Additional data is required to characterize soil COPC concentrations in on-property and surrounding area habitats utilized by ecological receptors.

- Potential exposure routes associated with COPCs in surface water are ingestion and dermal contact. The risk assessment will evaluate surface water exposure point concentrations (EPCs) of different streams and stream segments within the site and surrounding areas.

- Potential exposure routes associated with COPCs in sediment are ingestion, dermal contact. Additional exposure routes include ecological receptors that consume plants, benthic invertebrates, or aquatic wildlife that accumulate COPCs from sediment. The risk assessment will evaluate sediment EPCs of different streams and stream segments within the site and surrounding areas.

- Potential exposure routes associated with COPCs in air are inhalation of resuspended soil or dust generated from road traffic. Additional data is required to characterize the area potentially impacted by road-generated dust and the types of habitat that occur within this area.

- Potential exposure routes associated with aquatic and terrestrial plants are the uptake of COPCs from water, sediment, or soil and potential impacts to plants and organisms consuming plants.

- Potential exposure routes associated with aquatic and terrestrial wildlife are the uptake of COPCs from water, sediment, or soil and potential impacts to organisms consuming aquatic and terrestrial wildlife.

Contact with groundwater by ecological receptors is assumed to be incomplete, but groundwater discharges to surface water will be evaluated as part of the surface water exposure pathways.

3.4.5.3 Exposure Pathways

Figure 44 shows the exposure pathways identified for the ecological risk conceptual model. Exposure pathways for ecological receptors include ingestion, dermal contact, and inhalation. Complete exposure pathways for ecological receptors are denoted by a filled circle. At this time, the ecological risk of inhalation of dust generated from road traffic or inhalation of soil particles resuspended by wind or human activities is considered potentially complete. This issue will be further evaluated in the RI/FS, and once the areas receiving road dust have been determined along with the habitat and ecological receptors likely to utilize those habitats, this assumption will be reevaluated.

4.0 RI/FS RATIONALE

This section presents the rationale used to develop the RI/FS approach in Sections 5, 6, and 7. The RI/FS rationale is based on five factors as presented in Section 1:

1. DQOs,
2. Stakeholder comments to the DQOs,
3. CSMs as revised based on stakeholder comments,
4. SOW, and
5. NCP process.

4.1 DQOS

As described in Sections 1 and 3, and consistent with the SOW and the RI/FS guidance (U.S. EPA, 1988), preliminary DQOs for the RI/FS were presented in the DQO Report (Atlantic Richfield, 2008). The data needs presented in the DQO Report are summarized in Table 43 and will form an important part of the RI/FS rationale.

4.2 STAKEHOLDER COMMENTS TO DQOS

A number of the stakeholder comments received on the DQO Report pertained to revision of the DQO Report content. Because the DQO Report was approved by the U.S. EPA and the report will not be revised, these comments can only be addressed where sections on similar subject matter are presented in the RI/FS PWP or future FRI work plans. Stakeholder comments on the CSMs presented in the DQO Report have been addressed by revision of the CSMs as described in Section 4.3 below and in Sections 3.4 and 6. Comments from the stakeholders regarding the SOW are discussed in Section 4.4 below. Comments received from the stakeholders regarding RI/FS data gaps are summarized in Table 44, which includes a key to where in the RI approach presented in Section 5 the technical issue reflected in the comment is met. The comments form a basis for revision of the RI/FS DQOs and are used to develop the RI approach presented in Section 5.

4.3 REVISIONS TO THE CSMS

Stakeholder comments to the CSMs presented in the DQO report were addressed by revising the CSMs or modifying language describing the CSMs, or in some cases by developing additional data collection activities. The revised CSMs are presented in Section 3.4. The following changes were made to the Human Health CSM based on stakeholder comments:

1. The study areas for the site and specific terms such as “on-property” and “off-property” are discussed and these terms are explained in the CSM description.

2. The distinction between acid mine drainage (AMD) and ARD was clarified.

3. The distinction between waste rock and overburden was clarified.

4. Total sulfate, ferric sulfate, ferrous sulfate, and sulfuric acid were added as COPCs based on their listing in the SOW. However, the CSM clarifies that these inorganic constituents may be used for acid-base accounting, but will not be considered in the human health or ecological risk assessments.

5. A discussion of the potential volatilization of mercury was added.

6. The need to verify the assumption that on-property groundwater discharges to the creeks was documented.

7. The storage ponds were eliminated as a “source” of AMD/ARD (although they will still be evaluated for leakage).

8. The statement regarding the creation of surface water by AMD/ARD was reworded.

9. The surface water runoff transport mechanism was clarified.

10. Erosion was added as a transport mechanism.

11. Deposition of sediment was called out as a separate transport mechanism.

12. The duration that each receptor may be exposed at the site was added to the description of each receptor.

13. Exposure pathways for the recreational users (current and future) were expanded to include consumption of wildlife and fishing.

14. Additional information regarding the River Ranch diversion provided by the USFS was added.

15. The definition of the off-property resident is further clarified.

16. USFS employees are referred to as personnel rather than rangers.

17. The USFS’s role in administering federal lands (not owning them) was specified.

18. The discussion of exposure points and routes was revised to be clearer.

19. The CSM figure was revised to be consistent with the changes to the text.

The following changes were made to the Ecological CSM based on stakeholder comments:

1. Appropriate screening values for ingestion, inhalation, and dermal contact are being developed to aid in the determination of the appropriate data collection and future assessment work.

2. The data gaps for both the Human Health and Ecological CSMs are summarized in the risk assessment work plans and in the RI Approach in Section 5.

3. A separate sediment exposure pathway was added.

4. In order to evaluate the potential risk to all trophic levels, the following ecological receptors were added: amphibians, reptiles, aquatic insect-consuming birds (e.g., dipper), riparian plants, and omnivorous mammals. In addition, “upland birds other than raptors” were separated into both herbivorous and insectivorous birds.

5. Additional steps were added to identify a list of species known or likely to occur in the area (including special-status species) and representative species for each trophic level group.

6. Points of contact were included for invertebrates.

7. Consumption of soil invertebrates as an ingestion pathway associated with soil was added.

8. Consumption of benthic invertebrates as an ingestion pathway associated with sediment was added and will be evaluated for completeness.

9. Exposure of plants to groundwater is considered.

10. A quantitative, site-specific food-chain model will be used to evaluate potential risk to birds and mammals.

11. The collection of biota data will be considered to evaluate the ingestion pathways for birds and mammals.

4.4 SOW

The primary components of the SOW are discussed below as they are planned to be addressed in the RI/FS.

4.4.1 Environmental Setting and Pathway Characterization

Surface water and sediment are described in the SOW in terms of reference streams, erosion, and transport of mine waste to streams, and sediment at Ruhenstroth Dam (Table 1). The decision rules in the DQO Report focused on shallow groundwater as the primary transport and exposure pathway (for example, Leviathan Creek Study Area Decision Rules 3 and 4) as part of the working hypothesis and hydrogeologic model for the site. As part of a sitewide study in the RI and in support of the water balance, limited investigation of deeper groundwater may be needed to rule out transport in the next deeper groundwater unit.

Other items identified in the Hydrogeology section of the SOW include preparing a water balance, conducting groundwater monitoring, characterizing the hydrogeology, and assessing the potential for downgradient impacts. This data collection need will be met by the data gaps presented in the DQOs and described in Section 5. The work will focus on investigations necessary for remedy selection and the SOW goal of preventing or minimizing acid generation.

The SOW identifies the necessity for characterization of storm water, reference streams, and sediment, as appropriate. Reference streams will be assessed as part of the background study. Additional surface water monitoring will be necessary to support the water balance and the CSM needs. Initial studies of storm water runoff, including evaluation of erosion of sediments, will be evaluated as part of a sitewide study to determine the significance and potential exposure, although this pathway is considered limited due to the infrequent storms that occur at the site that can result in the erosion of sediments. The value of sample data near Ruhenstroth Dam, toward evaluating remedial decisions as part of the RI/FS will be made after other data is collected closer to the site.

4.4.2 Source Characterization

The SOW describes source characterization for mine wastes; describes the mine wastes as partially characterized; and notes that the volume, extent, and regulatory classification of the mine wastes are not well documented. The SOW also describes the disposal or release area characteristics as the location and distribution of waste types, design features, operating practices, period of operation, age of area, and general physical conditions.

The overburden or waste pile material should only need to be characterized if it is determined that this material is a source of contamination to Aspen or Leviathan Creek or to address other on-property exposure scenarios. The DQO Report identified decision rules or sampling and investigation programs necessary to address issues related to sources contributing ARD. It is only necessary to evaluate waste for chemical composition, chemical characteristics, or migration and dispersal if there is an exposure or release pathway that is relevant to remedial decision making. Where warranted based on the CSM, the sampling and investigation programs will measure COPC concentrations in soil and may include acid-base accounting.

4.4.3 Contamination Characterization

The SOW identifies the need to characterize contamination in groundwater, soil (including mine wastes), surface water, and sediment. It also identifies the need to characterize seasonal and annual mass flux of COPCs from the Leviathan Mine.

Groundwater—As discussed above, the working hypothesis in the DQOs limits groundwater investigations to shallow groundwater, although limited investigation of deeper groundwater may be necessary to evaluate determine the appropriate data needs to assess the sitewide hydrogeology. The distribution and concentration of COPCs will be evaluated in groundwater as necessary to evaluate exposure pathways and the need for remedial actions.

Soil—The term soil includes overburden and mine waste. Soil will be characterized as necessary to evaluate the exposure pathways identified in the CSMs.

Surface Water and Sediment—Significant data exists, but additional data will be collected as described above.

Seasonal and Annual Contaminant Mass Transport—Section 2.4.4.3 of the DQO Report addresses the SOW description of mass transport of COCs. The analytical and flow data necessary to relate specific locations (CUD, AS, DS) to loads is available and will be used to further develop the evaluation of mass transport. Specific data gaps will be identified based on evaluation of the existing data, and they will be filled during the course of the RI/FS.

Other key areas of the SOW include Receptor Identification and Risk Assessment, Geotechnical Engineering Evaluation, and FS. The scope of the risk assessments are detailed in the HHRA and ERA work plans and summarized in Section 6. The actual scope of the geotechnical studies will be determined later in the RI process as it becomes clear what data is necessary to support evaluation of remedies in the FS. The scope of the FS is presented in Section 7.

4.5 THE RI/FS GUIDANCE AND THE NCP

The RI/FS rationale will include continued use of the RI/FS process as defined in the guidance (U.S. EPA, 1988). The RI/FS process started with the scoping conducted in and presented in the DQO Report and will continue with the site characterization process as defined in Chapter 3 of the guidance. The following major components of the site characterization are described in the guidance:

- conducting field investigations as appropriate,
- analyzing field samples in the laboratory,
- evaluating results of the data analysis to characterize the site and develop a baseline risk assessment, and
- evaluating whether data is sufficient or of sufficient quality for developing and evaluating remedial alternatives.

Exposure pathways and the degree of risk to human health and the environment are significant criteria that can be used to prioritize the work to be conducted under the RI/FS. For example, the highest potential exposures are in the on-property source areas. These source areas should therefore be addressed first. Consistent with the NCP and the SMS developed in the DQO Report, site work that will be used as part of the RI/FS rationale is prioritized as follows:

High Priority

- high potential current or future exposure to human health or the environment; and
- data collection or response actions necessary to study or address other areas.

Moderate Priority

- moderate current or future potential exposure to human health or the environment;
- potential response actions could recontaminate areas located downstream, downwind or downgradient; and
- unusual complexity of problems that could require lengthy evaluation.

Low Priority

- low current or future potential for exposure to human health or the environment; and
- low risk of recontamination of other areas.

This prioritization will be used in Section 10 to plan and implement the RI work.

5.0 RI APPROACH

This section describes the development of an RI program that has been divided into two categories: 1) sitewide investigations; and 2) study area investigations.

The SOW requires that the RI program include investigations necessary to characterize actual or potential contaminant migration pathways and potential sources, identify actual or potential receptors, and conduct an assessment of risks posed to actual or potential receptors. The SOW includes a framework of specific requirements that are, in some instances, not applicable to the site or are unnecessary to satisfy the data gaps presented in the DQOs. Consistent with guidance, the DQOs are being used as the primary criteria for developing data needs.

Scope of PWP

As described in Section 1, this PWP is intended to meet the requirements of the UAO and data gap activities identified in the DQO Report and present a prioritization and general scope and schedule for upcoming RI/FS investigation activities. Data collection activities presented in the PWP are focused on supporting the upcoming risk assessments and remedial decision process for the site. As stated in the RI/Fs guidance (U.S. EPA 1988), the goal of the investigation is not to remove all uncertainty about site conditions. Rather, it is to gather sufficient information to support an informed risk management decision regarding which remedy appears to be most appropriate for the site. FRI work plans will describe specific details such as refined DQOs; the investigation locations; the number of soil borings and/or monitoring wells to be installed; the number of samples of soil, surface water, groundwater, biota and other applicable medium to be collected; the analytical program; and a schedule for implementation and reporting.

5.1 SITEWIDE INVESTIGATIONS

Certain data collection activities are better implemented on a sitewide basis given that they target elements or characteristics of the site (e.g., water balance studies) that are not focused on a particular study area or site feature but rather have a broader purpose. Sitewide investigations for the RI program are listed below and are described in more detail in Sections 5.1.1 through 5.1.7. Background studies are incorporated as a component of the sitewide investigations rather than a study area investigation as described in the DQO Report. The following data gaps were identified for sitewide investigations:

- water balance investigations,
- bioassessment investigations,

- hydrogeologic investigations,
- geotechnical investigations,
- storm water and snowmelt runoff investigations,
- surface water and sediment geochemical investigations, and
- background investigations.

Generalized data gaps identified in the DQOs for the sitewide investigations are as follows:

- Characterize mine features.
- Map topography of the site and identify structural geology based on surface expressions.
- Collect site-specific inflow-outflow data to construct a water balance (e.g., precipitation, evaporation, stream flow, temperature, wind speed, evaporation, evapotranspiration, identify springs).
- Analyze COPC concentrations in soil, groundwater, surface water, sediments and biota to support risk assessment/remedial evaluation.
- Assess potential uptake models for biota (e.g., fish and plants) to support risk assessment.
- Collect geotechnical data (e.g., grain size, soil properties, water levels) and evaluate the stability of existing and future structures.
- Collect data to determine the hydrologic properties of the aquifer to support plume delineation and fate and transport (e.g., water levels, aquifer tests, groundwater/surface water interactions, grain size analyses).
- Conduct geophysical surveys to identify subsurface conditions (e.g. structures and general permeability).

As indicated above, these generalized data needs are considered preliminary and will be refined with more specific DQOs during the development of FRI work plans and other project planning documents. Many of the data needs will also be addressed through the study area investigations described in Section 5.2.

5.1.1 Water Balance Studies

Sources of surface water entering the site include upgradient stream flows, runoff from precipitation falling on or near the site, and discharge from groundwater to streams and the ponds on site. Surface water from these and other sources ultimately flows downstream in

Leviathan or Aspen creeks and infiltrates or evaporates from creeks and ponds. Sources of groundwater include inflows from upgradient and recharge from precipitation falling on site. Groundwater from these sources ultimately discharges either to the creeks on site or as downgradient flow.

The data collection activities needed for refinement of the sitewide water balance for the RI program are outlined in the following tasks. The water balance will continue to be refined and updated as additional data becomes available throughout implementation of the RI/FS.

Task WB-1—Meteorological Monitoring

Direct measurements and calculations of precipitation, evaporation, temperature, wind speed, and evapotranspiration are necessary to better quantify various inflow and outflow components to the site water balance. A meteorological station was installed at the site and has been producing data since 2003. However, the data set from this station is not complete in terms of daily precipitation totals, with data missing during many months of the year. Consequently, the installation of a weather station is included in the scope of the RI to allow for the collection of meteorological data. This data will be utilized to develop better estimates of infiltration (recharge), evaporation/evapotranspiration, and runoff for the site. In addition, meteorological measurements at the site will be used in conjunction with data from the SNOTEL (snow telemetry) monitoring location at Monitor Pass to develop correlations between meteorological measurements at the site and Monitor Pass. These correlations may allow for the refinement of conservative estimates of long-term mean annual precipitation, estimated by the PRISM model at 31.5 inches per year, as described in Section 2.

Task WB-2—Streamflow Measurements

Streamflow measurements have been collected in the vicinity of the site on a relatively continuous basis since 1998. Key streamflow monitoring stations include Station 1 (Leviathan Creek above the mine), Station 15 (Leviathan Creek above Aspen Creek), and Station 23 (Leviathan Creek above Mountaineer Creek). In addition, daily flow data has been collected at 4L Creek above Leviathan Creek and Station 22 (Aspen Creek above the site) since October 2003. Although streamflow measurements are available in both Aspen and Leviathan creeks, in response to stakeholder comments and the SOW, additional streamflow measurements in stream reaches adjacent to the site will be collected to better characterize those segments that are gaining and losing under various conditions, including seasonal fluctuations.

Task WB-3—Measurement of Surface Water–Groundwater Interactions

In watershed-scale water balance studies, conventional streamflow measurement techniques allow for the calculation of gains or losses in a stream segment. However, for local, small-scale studies in which flow to or from surface water may be localized, tools such as seepage meters, mini-piezometers, and buried temperature probes may be most appropriate to measure stream gains or losses. Depending on the level of resolution obtained from the streamflow measurements described in Task WB-2 above, other techniques may be considered for measuring localized stream gains or losses, and to allow for the calculation of hydraulic gradients and the direction and flow rate between the surface-water body and the adjacent groundwater (e.g. tracers, synoptic sampling etc.).

5.1.2 Sitewide Bioassessment Investigations

Historical data on plant, fish, surface soil, sediment, and water in the vicinity of Leviathan Mine has been compiled in the project database. However, some historical data may not be usable to estimate exposure to human health and ecological receptors because the data was collected many years ago and does not represent current baseline conditions. Only data that includes sufficient quality assurance/quality control (QA/QC) procedures (U.S. EPA, 1992) to ensure data quality can be utilized. In order to evaluate the exposure pathways and receptors identified in the risk assessment, some additional sitewide bioassessment investigations will be needed. Exposure estimates will only be developed for complete exposure pathways identified in the CSMs (Section 3.4).

As described in Section 6, bioassessment investigations will be evaluated by first defining habitat types that are representative of conditions in the study areas potentially impacted by the mine, and in background areas consisting of undisturbed areas of the site and/or in off-property reference areas with similar habitat types. Habitat types may be identified using aerial imagery interpretation followed by field verification. Verification includes sampling between 10 and 30 percent of the habitat polygons in the study area to confirm habitat types. During field verification of the habitat, polygons, dominant, subdominant, and forage plant species will be identified. Habitat polygons selected for sampling will be based on ease of access, habitat type, polygon size, and polygons containing sites where soil, sediment, or water samples were previously collected. The exact number of samples will be determined based on an area-weighted criterion for each habitat type.

The scope of data collection and follow-up activities for sitewide bioassessment investigations that will be performed in support of the RI program is outlined in the following tasks.

Task BIO-1—Plant Sampling

During field verification of the habitat polygons, dominant, subdominant, and forage plant species will be identified. Plant specimens in each habitat type will be collected for COPC analysis. The plant specimens chosen for COPC analysis will be based on zone (on-property, downstream [roadside or floodplain], or background), abundance, human consumption potential and forage potential for the receptors identified in the CSM. Within each habitat type and zone, several plant species will be composited for analysis.

Task BIO-2—Habitat-Related Soil Sampling

Soil samples in each habitat type will be collected for COPC analysis. Because these soil samples will be collected in the same habitat types as the plant sampling described in the preceding task, these soil samples are designated as habitat related. Consistent with the plant samples, the soil sampling locations will be based on zones with similar physical characteristics and will be selected, when feasible, in areas or locations of previous soil sampling. Within each habitat type and zone, soils samples will be collected for analysis for COPCs. The exact number of samples will be determined based on an area-weighted criterion for each habitat type within each zone and will be detailed in a separate FRI work plan.

Soil and plant samples collected within the same area will be evaluated to determine if a correlation exists between metal concentrations in soil and plant tissue.

Task BIO-3—Fish Tissue Sampling

Fish species that are expected in the vicinity of the site include herbivores, insectivores, piscivores, and omnivores. Anecdotal information suggests that fish tissue analysis for COPCs has been conducted in the vicinity of the site by the U.S. Fish and Wildlife Service (USFWS). However, at the time of preparation of this Work Plan, no study plan or data was available for review. Tissue analysis of COPCs may need to occur if the data remains unavailable or, if after review of the data, the data is deemed insufficient.

Task BIO-4—Habitat-Related Sediment Sampling

Sediment samples will be collected for analysis of COPCs and for conducting sediment bioassays. These sediment samples will be designated as habitat-related sediment samples because they are being collected to evaluate potential impacts to aquatic habitats but can also be used for human exposure. Sediment bioassay testing and sediment pore water will be used to evaluate the potential for biological effects to benthic invertebrates from exposure to sediment samples following procedures described in *Methods for Measuring the Toxicity and Bioaccumulation of Sediment-Associated Contaminants with Freshwater Invertebrates* (U.S. EPA, 2000b). Sampling locations will be selected by considering historical sampling sites and will attempt to locate primarily depositional areas.

Task BIO-5—Habitat-Related Surface Water Sampling

Surface water samples will be collected at all sediment sampling locations and will be analyzed for COPCs and conventional parameters (e.g., alkalinity, hardness, pH, and dissolved oxygen). These surface water samples will be designated as habitat-related surface water samples because they are to be collected at the same locations as sediment samples described in the preceding task.

5.1.3 Sitewide Hydrogeologic Investigations

The sitewide hydrogeologic investigations will include better physical characterization (e.g., mine features, topography, structure, and stratigraphy) of source and recharge areas; additional in situ groundwater characterization data in source and discharge areas; water level monitoring of shallow groundwater flows and quality in selected areas; assessment of groundwater/surface water interactions in selected areas; identification and characterization of ponds and springs; characterization of aquifer parameters in selected areas; and development of background groundwater data.

The scope of data collection and follow-up activities for sitewide hydrogeologic investigations to be performed in support of the RI program is outlined in the following tasks.

Task HY-1—Well Reconnaissance, Redevelopment, and Sampling

The first activity included in the sitewide hydrogeologic investigation involves field reconnaissance to locate existing monitoring wells at the site to assess their condition and redevelop them to ensure that the wells will provide representative potentiometric and water quality data. Once the wells are located, developed, and secured a semiannual monitoring program will be initiated. This monitoring program will be modified once the hydrogeology of the site is better defined and additional monitoring wells are installed.

Task HY-2—Deep Exploratory Borings

Deep exploratory borings will be completed using mud rotary, air percussion, sonic drilling, or similar techniques at a number of locations across the site to develop a better understanding of the subsurface lithology, hydrostratigraphy, depth of overburden and/or waste rock materials, in situ groundwater quality, and other subsurface geologic characteristics that may influence groundwater flow and COPC migration (e.g., the presence of calcite-bearing rocks). Evaluation of geologic controls on groundwater flow will include, stratigraphy, faulting, bedding, and fracturing. Exploratory borings will be spatially distributed across the site to provide information on the aerial distribution and continuity of hydrostratigraphic units. Some of the borings will be drilled in upland areas to provide information on the thickness of overburden and/or waste rock overlying native bedrock materials. The exploratory borings will be drilled to a depth below the contact between overburden and/or waste rock materials to the underlying bedrock surface or to a depth where competent bedrock materials are encountered, whichever is deeper. Depending on the drilling method used, the borings may be logged using borehole geophysical methods, and coring may be conducted. Borehole geophysical methods to be considered include spontaneous potential, point and lateral resistivity, natural gamma, and acoustic televiewer logs.

Task HY-3—Monitoring Well Installation and Hydraulic Testing

Following completion of the deep exploratory borings described in Task HY-2, monitoring wells will be constructed in the boreholes using the well construction protocols described in the SOPs. The screened intervals of these wells will be determined based on the lithology and in situ water quality encountered in the borehole, likely to be in and close to the interface between the disturbed material and bedrock and/or in the erosional zone of the bedrock. Water levels measured in the resulting well pairs will provide information on vertical hydraulic gradients and the depth of groundwater impacted by COPCs.

After monitoring wells have been installed and appropriately developed, wells will be hydraulically tested with an appropriate method (e.g., using single-well slug or pressure-pulse tests) to estimate the hydraulic properties of the subsurface materials. Estimated hydraulic properties will be used to better quantify groundwater fluxes and flow velocities across the site.

Task HY-4—Groundwater Monitoring

Following well development and water level recovery, water levels will be measured on a regular schedule, and groundwater samples will be collected semiannually during the spring and fall seasons. This data will be used to assess potential temporal changes in groundwater levels, hydraulic gradients, groundwater flow directions, and groundwater quality.

5.1.4 Sitewide Geotechnical Investigations

As described in the DQO Report, a preliminary evaluation has been performed of the geotechnical conditions as they relate to future engineering alternatives for the site. Observations from this preliminary geotechnical evaluation are summarized as follows.

- Previous evaluations of the Leviathan Creek basin landslide on the north end of the site indicated that there is likely a threshold phreatic surface within the slide mass that will continue to cause slope movement. Although regrading has been performed since the time of this previous evaluation, it is assumed that the potential for slope movement is still significant.

- From a geotechnical engineering standpoint, the Leviathan Creek basin landslide is significant because the Aspen Seep is located within the slide mass. Structures built on the landslide and pipelines crossing the landslide mass are subject to deformations caused by the landslide. Because of the scale of the landslide, stabilization of the entire slide mass is likely not a feasible mitigation alternative.
- The upper portion of Delta slope has been subject to rotational slope failures and the lower portion has been subject to debris flows. Waste rock at the Delta slope was regraded after a 2004 slope failure and debris flow. The slope has remained relatively stable since the regrading and the installation of surface water diversion features and slope drains in 2005; however, the long-term stability of the slope has not been evaluated.
- The geotechnical design basis for the existing water storage ponds at the site is unknown. Therefore, the geotechnical stability of these ponds may require further evaluation to assess potential slope failure resulting from pond seepage or a seismic event.

The SOW suggests that geotechnical engineering assessment work should be performed as appropriate to evaluate the stability of the existing impoundment berms, storage ponds, mine waste slopes, and pit high walls, particularly during seismic events. As with other RI tasks, the geotechnical investigations will be conducted only to the extent necessary to support remedial decisions for the site.

Geotechnical considerations will play an important role in the evaluation of engineering alternatives in the FS. Steep slopes may be subject to permanent deformation when groundwater is elevated or during an earthquake. As a result, some regrading of these slopes may be necessary. Ponds and other water retention structures should be located where they will not adversely impact the active landslides or potentially create other stability and seepage issues.

The sitewide geotechnical investigations included in the RI program are described below.

Task GT-1—Visual Inspection and Evaluation

A visual inspection and assessment of existing man-made structures, overburden and waste rock piles, pit high walls, and landslide areas will be performed to identify potential problem areas and evaluate the need for further geotechnical investigations or mitigative measures. Features such as tension cracks and/or areas of existing or potential slope failures will be noted. Information on the design basis, engineering specifications, and/or as-built drawings for existing structures, including water storage ponds and surface water channels, should also be evaluated.

Task GT-2—Investigation for Storage Pond Expansion

Additional geotechnical work may be necessary to assess geotechnical considerations for raising impoundment berms or deepening the impoundments to increase winter storage capacity. Data is being evaluated to assess the effectiveness of the existing capacity and the need for expansion. If additional capacity is deemed necessary based on this analysis, evaluation of the stability of existing berms, assessment of the integrity of existing pond liners and collection of physical characterization data may be required to assess the design requirements for increasing the height of the berms or the depth of some of the ponds. This investigation would require deeper soil borings below selected ponds with the potential for increased capacity.

5.1.5 Sitewide Storm Water and Snowmelt Runoff Investigations

No storm water or snowmelt monitoring has been conducted at the site. However, anecdotal information, including observations during late spring 2009, suggests that storm water runoff at the site occurs during high-intensity rainfall events. Based on precipitation records and observations at the site, these high-intensity rainfall events occur infrequently, typically in the summer months associated with convective thunderstorm activity. Surface water runoff may also occur as a result of rapid snowmelt, although this is a less likely transport mechanism. The SOW suggests storm water monitoring is necessary to evaluate the interaction of seasonal snowmelt runoff with disturbed mine materials. In addition, an evaluation of sediment erosion by storm water and snowmelt runoff is required by the SOW.

Sitewide storm water and snowmelt runoff investigations are included in the RI program as described below. Investigations of sediment deposition in Leviathan and Aspen Creeks are described in Section 5.1.6.

Task SS-1—Reconnaissance Mapping of Erosional Features

Given the limited information on storm water and snowmelt runoff at the site, reconnaissance mapping of erosion features is included in the scope to identify areas where runoff may be occurring. This reconnaissance mapping will utilize topographic maps to identify drainage patterns and features where runoff is concentrated during a precipitation or rapid snowmelt event. The reconnaissance will also address the adequacy of existing storm water management and conveyance structures. These features will be considered as potential runoff water and suspended sediment sampling locations.

Task SS-2—Stormwater and Snowmelt Monitoring and Modeling

Following the reconnaissance and mapping of erosional features described above, preliminary modeling of surface water runoff and associated sediment transport will be performed to estimate the probable amount of rainfall and/or snowmelt that may result in surface runoff. This modeling assessment will also evaluate historical precipitation records to determine the probable frequency of such runoff events.

In addition, storm water sampling equipment will be procured and stored at the site to allow for the rapid mobilization of sampling crews should a high-intensity rainfall event occur while personnel are working at the site. Monitoring would consist of the collection of water and suspended sediment samples for laboratory analysis for COPCs.

5.1.6 Surface Water and Sediment Geochemical Investigations

The sediment investigation plan is intended to define the extent of contaminant transport, assess future mobility, and provide necessary input data for the risk assessments. Stream sediment data is available in the Leviathan database for samples collected primarily between 1998 and 2005 at several stream locations (USGS, ongoing EDR). Sources of metals loading to sediments are currently not fully understood, as unidentified sources not related to mining at the site may also contribute significantly to downstream loading.

Other data gaps include the following:

- background surface water quality is currently poorly defined;
- the mass and extent of site-derived sediments are not clearly delineated;
- significant mass loading of metals and total dissolved solids to Leviathan Creek may be occurring downstream of the site below Station 15;
- the current understanding of attenuative processes (e.g., adsorption/desorption, precipitation/dissolution, dilution, etc.) are not well understood; and
- the capacity of the system to continue to attenuate constituent transport and the stability of immobilized phases is not well defined.

Presented below are tasks that will be conducted to address the identified data gaps.

Task SW-1—Surface Water Delineation

Reconnaissance and mapping of streams, seeps, and ponds will be conducted to clearly delineate surface water bodies and surface water contributions to Leviathan Creek from upstream at Station 1 to the confluence of Leviathan and Barney Riley creeks. The reconnaissance and mapping will include a description of physical properties, including: location, elevation, width, depth, flow velocity, flow volume, and approximate areal extent for any identified ponds. The reconnaissance mapping will be conducted on multiple events, if needed to evaluate seasonal changes. This data will provide a more complete assessment of the surface water system in and adjacent to the Leviathan Mine site and will supplement the water balance analysis.

Task SW-2—Sediment Mapping

Concurrent with the physical mapping of surface water bodies, sediments will be evaluated and mapped. The fluvial geomorphology will be investigated by mapping the paleo-floodplains which extend laterally beyond the floodplain that exists immediately adjacent to the creeks. This information may be used during future investigations to evaluate the flooding tendencies of the Leviathan and Bryant Creeks. This information will be incorporated into a Geographic Information System (GIS) to gain an understanding and map the extent, form and nature of sediment deposition. This data can be used to evaluate the spatial and temporal variations in dominant channel formation and overbank sedimentation flow regimes in a debris flow channel (discriminating between deposits laid down by debris versus hyper-concentrated versus newtonian flow conditions in a flood).

If necessary 1- and 2-D modeling will be used to delineate areas of potential channel migration, sediment transport modeling, detailed terrain modeling of the channel to develop proxy estimates of bedload transport, and analysis of historical and contemporary information to assess potential for lateral channel migration. Additional information that will be collected during the mapping will include a description of other streams, elevation, flow, velocity, depth, width and apparent flooding tendencies and drainage patterns.

Task SW-3—Surface Water Geochemical Characterization

Due to the water treatment programs, flows and water quality in Leviathan Creek are expected to vary significantly during the year. Thus the surface water characterization task will, to the degree possible, attempt to account for these changing conditions.

An evaluation of chemical mass loading and transport will be conducted under different streamflow conditions, including before and after the onset of water treatment operations and related discharges. Surface water samples will be collected from historical sampling sites as well as at additional stations along Leviathan Creek and Bryant Creek.

Task SW-4—Sediment Geochemical Characterization

The sediment sampling will be conducted within Aspen, Leviathan, and Upper Bryant creeks. Sampling locations will be selected by considering historical sampling sites and will attempt to locate primary depositional areas. In addition, it is anticipated that sediment samples will be collected from sites identified for collection of surface water samples during synoptic sampling events.

5.1.7 Background Studies

Leviathan Mine is surrounded by historic mining activities for gold, silver, copper, lead, zinc, tungsten, and antimony, as evidenced by multiple historic mines in and around the area. These deposits were the result of regional hydrothermal alteration of the existing rock formations and volcanic activity. Hot springs are present in the area, most notably along the banks of the East Fork of the Carson River. The Leviathan, Aspen, and Mountaineer creeks are tributaries of the East Fork of the Carson River. Developing an understanding of the contribution of metals from these natural and anthropogenic sources to surface water features downgradient of the site and pre-mining soil and groundwater conditions at the site is a high priority in the RI/FS. Investigation of these background conditions will be critical in establishing and evaluating the feasibility of achieving appropriate response goals.

To date, limited background studies have been completed for the site. Currently, surface water sampling stations upstream from the site in Leviathan and Aspen creeks are used for comparison with downstream data. Groundwater monitoring wells 31 and 32, which are off-property, were used for background groundwater sample collection in the past, although these wells are not located or completed in geologic materials similar to those of the site.

The anticipated minimum background data needs for the RI program as described in the DQO Report, are as follows:

- **Analog creek site(s) for surface water, sediment, and biota—**The potential site(s) that would best be located near the site would represent similar rock types and alteration and preferably would not have been disturbed by mining. Areas along Mountaineer Creek and Monitor Creek have been reviewed as potential analog sites for surface water.

- **Background groundwater—**Groundwater monitoring wells used for background data collection should be installed in areas that have similar geologic alteration patterns but have not been disturbed by mining.

- **Background soil—**Soil samples will be collected from areas that have similar mineralization but have not been disturbed by mining.

- **Background seeps—**Samples will be collected from seeps present in background study areas to compare the chemistry to on-property seeps.

Reference areas sampling will be used to differentiate naturally occurring effects on groundwater, surface water, sediment and soil chemistry from mine effects. The reference areas may be located in a nearby creek (such as Mountaineer Creek) or near the site, or they may be located in a nearby watershed with similar characteristics. In selecting a reference area, anthropogenic contributors other than mining will also be considered. Locations that reflect obvious contributions of human activity may be judged inappropriate for background data collection.

A generalized summary of tasks associated with the background studies for groundwater, surface water, sediment, soil, and biological data is presented below.

Task BG-1—Groundwater Background

Background conditions in groundwater will be evaluated by collecting groundwater samples from monitoring wells located in areas not affected by mining but completed in geologic materials similar to those observed at the site. The location of background monitoring wells will be determined after conducting soil boring to characterize the sitewide hydrogeology and after installing monitoring wells; this will allow for the interpretation of hydrostratigraphy and groundwater flow directions before selecting background monitoring well locations. Groundwater samples from background monitoring wells will be monitored on a minimum semiannual basis for at least the spring and fall seasons to assess potential temporal changes in groundwater quality. Sufficient background groundwater samples will be collected to develop a statistically representative population of chemical data for each hydrostratigraphic unit.

Task BG-2—Soil Background

Background conditions in surface soils will be evaluated by collecting and analyzing soil samples in undisturbed portions of the site and/or in off-property areas with similar soil types. Soil sampling locations will be based on field reconnaissance and mapping of soil types along the perimeter of the site as well as on mapping of soil types to be conducted for the study area investigations described below. Sufficient background soil samples will be collected to develop a statistically representative population of chemical data for each primary soil type.

Task BG-3—Surface Water and Sediment Background

Background conditions in surface water and sediment will be evaluated by collecting co-located surface water and sediment samples in areas upgradient of the disturbed portion of the site and/or in analog watersheds with similar geologic characteristics. Surface water and sediment samples will be analyzed for COPCs to assess potential temporal changes in surface water and sediment concentrations. Sufficient background samples will be collected to develop a statistically representative population of chemical data for the Aspen and Leviathan Creek watersheds.

Task BG-4—Plant and Fish Tissue Background

Background conditions in biological media will be evaluated by first defining representative habitat types. As described above in the scope for the sitewide biological investigations, habitat types will be identified using aerial imagery interpretation followed by field verification. Fish tissue and plant samples collected outside of the impacted areas will be considered representative of background conditions.

5.2 STUDY AREA INVESTIGATIONS

The general rationale and scope of the RI activities for each of the study areas is presented in the following sections.

5.2.1 ACSA

Data needs identified in the DQO Report for the ACSA are summarized below:

- meteorological measurements and calculations (e.g., precipitation, evaporation, temperature, wind speed, and evapotranspiration);
- streamflow measurements and estimates of groundwater flux;
- concentrations and distribution of COPCs in surface soils and sediments;
- COPC concentrations in shallow groundwater;
- spatial extent of COPCs that have reached groundwater;
- hydraulic properties of unconfined (water table) aquifer;
- surface water quality; and
- soil physical (geotechnical) properties.

These data needs were updated in light of further evaluation of existing data, refinement of CSMs, and the review of stakeholder comments on the DQO Report. A number of the study area data needs will be addressed by the sitewide investigation presented above. Revised DQOs for specific data collection activities in the ACSA will be presented in future FRI work plans.

Based on the primary exposure media and potentially complete exposure pathways identified, the SOW, and the generalized data needs outlined in the DQO Report, the following RI activities are included in the scope of work for the ACSA.

Task ACSA-1—Soil Mapping, Sampling, and Chemical Analyses

The overburden piles in the ACSA are known to contain some areas with an increased percentage of pyrite. If water comes in contact with these areas, it could become impacted by COPCs. Where these areas exist at the ground surface they will need to be evaluated for human and ecological health exposure. The chemical characteristics of the overburden piles will also require investigation to assess the suitability of soils for potential future revegetation efforts as part of the alternatives analysis for remedy selection. The RI will include field reconnaissance and mapping of soil types on the overburden piles to identify areas with the greatest acid generation potential. Based on information gathered during this mapping effort, a soil sampling program for chemical analysis of COPCs will be implemented in selected portions of the overburden piles.

Task ACSA-2—Investigation of Mine Features

Mine features that warrant investigation in the ACSA consist primarily of overburden and waste rock piles. The extent of waste rock and overburden piles will be investigated during the performance of Task 1 described above. In addition, the effectiveness of surface geophysical techniques will be evaluated for assessing the thickness of the overburden and landslide materials, assessing increased sulfide mineralization, and identifying potential preferential groundwater flow pathways in overburden materials.

Task ACSA-3—Source Investigation of Aspen Seep

The occurrence of Aspen Seep at the base of the overburden piles at elevations well above Aspen Creek suggests a potential water migration pathway along the interface of the overburden piles and the underlying bedrock or historic topographic surface. The overburden materials are likely to be more permeable than underlying bedrock, thus allowing for the downward percolation of infiltrating precipitation and snowmelt with lateral flow along the interface between the overburden and the underlying bedrock where Aspen Seep "daylights" at its present location. Local structure such as failures within the overburden piles and paleo-channels in Aspen Creek may also be a factor. In addition, in the area above the Upper Aspen Seep there is a flat geographic area with higher sides that acts as a collection basin that may be a source of the water to both the Upper Aspen Seep and Aspen Seep (Figure 5). It is unknown where the water discharged at Aspen Seep becomes acidic or where the migration pathway of the water through the overburden piles is located; however, it is likely that the migration pathway is along the contact between the piles and the original ground surface. This migration pathway requires further investigation to evaluate the potential mitigation of discharges from Aspen Seep.

As a result, the RI program will include an investigation of the source of flow to and from (to assess pond leakage) the Aspen Seep by assessing the shallow groundwater flow system in the area upslope of and lateral to the present location of the Aspen Seep. If feasible, direct-push or similar technologies, including cone penetrometer testing, will be used to collect information on subsurface lithology and physical soil properties. Grab groundwater samples collected from direct-push or other types of borings will be tested for field parameters such as pH, temperature, and conductivity to map the area of shallow groundwater impacts that potentially contribute to Aspen Seep. Temporary well points or piezometers will also be installed to allow water level measurements and the mapping of the potentiometric surface in area the upgradient of Aspen Seep.

Task ACSA-4—Shallow Groundwater Investigation

Based on information gathered from Tasks 1 and 2 above, it is anticipated that a number of shallow groundwater monitoring wells will be installed near the interface between the overburden and underlying bedrock. The location of these wells will be selected to allow for water level and groundwater sampling to evaluate groundwater flow directions, to estimate hydraulic gradients, and to assess the nature and extent of groundwater impacts by COPCs. The screened intervals of these wells will be determined based on interpretations of sitewide hydrostratigraphy developed from exploratory borings drilled and logged during the sitewide hydrogeologic investigation described above or from more local borings installed for investigation in the ACSA. Information from the shallow monitoring wells installed in the ACSA will also be used to supplement interpretations developed from data gathered during the sitewide hydrogeologic investigations described above.

After monitoring wells have been installed and appropriately developed, wells will be hydraulically tested (e.g., using single-well slug or pressure-pulse tests) to estimate the hydraulic properties of the subsurface materials. Estimated hydraulic properties will be used to better quantify groundwater flow velocities across the site.

Task ACSA-5—Bioassessment Investigations

Biological investigations in the ACSA will be focused on potential exposure pathways to human and ecological receptors outlined in the CSMs described in Section 3.4. Biological investigations in the ACSA will be performed in association with the sitewide biological investigations described above.

Task ACSA-6—Surface Water and Sediment Sampling in Aspen Creek

Based on potential exposure pathways to human and ecological receptors outlined in the CSMs, surface water and sediment sampling will be performed for COPC analyses in Aspen

Creek. Surface water and sediment sampling activities in Aspen Seep will be performed as described in the sitewide program for surface water/sediment and biological investigations described above.

Task ACSA-7—Storm Water and Snowmelt Runoff Investigations

Storm water and snowmelt runoff investigations in the ACSA will be performed in association with the sitewide storm water investigations and will include the same reconnaissance and sampling activities as described above.

Task ACSA-8—Water Balance Studies

Inflow and outflow components to the water balance in the ACSA will be refined in association with the sitewide water balance studies described above. Water balance studies in the ACSA include the following.

- Meteorological measurements and calculations (e.g., precipitation, evaporation, temperature, wind speed, and evapotranspiration).
- Review and assess regional climate data and develop usable estimates of precipitation, evaporation/evapotranspiration, infiltration (recharge), and runoff for the ACSA.
- Perform site inspections and assessments of the current stream gauge locations and evaluate the need for new stations or upgrades to existing stations.
- Record additional stream flow measurements to better characterize bi annual fluctuations and gains and losses along the creeks through monthly synoptic sampling along key stretches of Aspen Creek, as feasible during periods of active flow.
- Integrate the results from groundwater assessments in the ACSA to develop estimates of groundwater flow and surface water/groundwater interactions.

5.2.2 PSA

Data needs identified in the DQO Report for the PSA are summarized below:

- meteorological measurements (e.g., precipitation, evaporation, temperature, wind speed, and evapotranspiration);
- estimates of groundwater flux;
- concentrations and distribution of COPCs in surface soils;
- COPC and major ion concentrations in shallow groundwater;

- spatial extent of COPCs that have reached groundwater;
- hydraulic properties of unconfined (water table) aquifer;
- soil physical (geotechnical) properties;
- geophysical surveys of underground workings and/or sub-pit features; and
- soil moisture measurements beneath/adjacent to pit clarifier.

These data needs have been updated in light of further evaluation of existing data, refinement of CSMs, and the review of stakeholder comments on the DQO Report. The potential exposure pathways for the PSA are different from other studies areas at the site in that there are no surface water features that allow for dermal contact or ingestion of surface water.

Based on the primary exposure media and potentially complete exposure pathways identified in Section 3.4, the SOW, and stakeholder comments to the generalized data needs outlined in the DQO Report, the following RI activities are included in the scope of work for the PSA.

Task PSA-1—Soil Mapping, Sampling, and Chemical Analyses

The results of previous surface soil sampling in the PSA show the highest concentrations of metals and other COPCs at the site. Similarly, data collected from the USGS piezometers and the SRK monitoring wells show the highest concentrations of metals and lowest pH in groundwater wells installed in the PSA. Consequently, surface soils and waste rock piles in the PSA are anticipated to be acid generating, potentially resulting in groundwater discharges to surface water features that are impacted by COPCs.

Where these areas exist at the ground surface they will need to be sampled to allow for assessments of human and ecological exposure. The chemical characteristics of surface soils and waste rock piles also require investigation to assess the suitability of soils for potential future revegetation efforts as part of the alternatives analysis for remedy selection. As a result, the scope of the RI for this area includes field reconnaissance and mapping of soil types on the overburden piles to identify areas with the greatest acid generation potential. Based on information gathered during this mapping effort, a soil sampling program for chemical analysis of COPCs will be implemented in selected portions of the waste rock piles and in surface soils in other parts of the PSA.

Task PSA-2—Investigation of Mine Features

Mine features that warrant investigation in the PSA include the waste rock and overburden piles, the pit, and Adit No. 5. The open-pit mining operation reportedly destroyed all the remnants of the underground operation (e.g., stopes, adits, raise, and shafts) with the exception of Adit No. 5, although it appears possible that there could be remnants of other underground workings in the pit walls. The remaining Adit No. 5 tunnel is reportedly nearly 1,000 ft. in length.

The extent of waste rock and overburden piles will be investigated during the performance of Task PSA-1 described above. In addition, the effectiveness of surface geophysical techniques will be evaluated for assessing the thickness of the waste rock and overburden materials, assessing sulfide mineralization, and identifying the extent of underground workings, including the extent of the Adit No. 5 tunnel. Similar to the ACSA, the effectiveness of geophysical methods will be evaluated for identification of potential preferential groundwater flow pathways in waste rock and overburden materials. Surface geophysical techniques to be evaluated will include, electromagnetic and direct current resistivity methods, and, if appropriate, seismic refraction methods.

Task PSA-3—Investigation of Sources to the Pit, PUD, and Adit

Assuming that groundwater mimics topography in the PSA, the pit acts as a large groundwater basin. Groundwater flow, precipitation, snowmelt, and runoff into the pit come in contact with in-place materials and regraded rock with sulfide mineralization. The PUD and Adit No. 5 are both beneath the pit floor, but it is unclear how much of the water introduced into the pit escapes capture by the PUD and Adit No. 5 and therefore has the potential to migrate outside of the pit. Another uncertainty relates to how much of Adit No. 5 flow originates as uncaptured water from the PUD and other infiltration through the pit floor as compared to groundwater flux into the adit tunnel. A certain amount of the water not captured by the PUD potentially infiltrates into unconsolidated material at the base of the pit and has the potential to migrate into groundwater. As a result, some shallow groundwater migrates beyond the pit boundary towards Leviathan Creek. Year-round discharges from Adit No. 5 ranging from 9 to 15 gpm suggest that the adit tunnel acts as a linear sink capturing groundwater flow. The acidic nature of the Adit No. 5 discharges suggests that groundwater entering the tunnel is being exposed to acid-generating conditions.

As a result of the uncertainties described above, the RI program will include an investigation of the source of flow to the pit, PUD, and adit, including an assessment of the shallow groundwater flow system in the vicinity of the adit and the floor of the pit. Shallow borings will be used to collect information on subsurface lithology and physical soil properties. Grab groundwater samples collected from the borings will be tested for field parameters such as pH, temperature, and conductivity to map the area of shallow groundwater impacts that potentially contribute flow to Adit No. 5. Temporary well points or piezometers may also be installed to allow water level measurements and the mapping of the potentiometric surface in the vicinity of the adit tunnel.

Task PSA-4—Shallow Groundwater Investigation

Based on information gathered from the tasks outlined above, it is anticipated that a number of shallow groundwater monitoring wells will be installed within the PSA and along its perimeter The location of these wells will be selected to allow for water level and groundwater sampling in support of an evaluation of groundwater flow directions, the estimation of hydraulic gradients and groundwater flow into the pit and the Adit No. 5 tunnel, and an assessment of the nature and extent of groundwater impacts by COPCs. The screened intervals of these wells will be determined based on interpretations of sitewide hydrostratigraphy developed from exploratory borings drilled and logged during the sitewide hydrogeologic investigations described above or from borings drilled in the PSA. Information from the shallow monitoring wells installed in the PSA will also be used to supplement interpretations developed from data gathered during the sitewide hydrogeologic investigations.

After monitoring wells have been installed and appropriately developed, wells will be hydraulically tested using single-well slug or pressure-pulse tests to estimate the hydraulic properties of the subsurface materials. Estimated hydraulic properties will be used to better quantify groundwater fluxes and flow velocities across the site.

Task PSA-5—Bioassessment Investigations

Biological investigations in the PSA will be focused on potential exposure media and pathways to human and ecological receptors outlined in the CSMs described in Section 3.4. Biological investigations in the PSA will be performed in association with the sitewide biological investigations described above.

Task PSA-6—Water Balance Studies

Inflow and outflow components to the water balance in the PSA will be refined in association with the sitewide water balance studies described above. Water balance studies in the PSA will include the following:

- Meteorological measurements and calculations (e.g., precipitation, evaporation, temperature, wind speed, and evapotranspiration).
- Review and assessment of regional climate data and develop usable estimates of precipitation, evaporation/evapotranspiration, infiltration (recharge), and runoff for the PSA.

- Integrate results from groundwater assessments in the PSA to develop estimates of groundwater flow into the pit, PUD, and Adit No. 5.

Task PSA-7—Storm Water and Snowmelt Runoff Investigations

Storm water and snowmelt runoff investigations in the PSA will be conducted in association with the sitewide investigations described above and will include the same reconnaissance and sampling activities as described above in Section 5.1.5.

5.2.3 LCSA

Data needs identified in the DQO Report for the LCSA as modified by stakeholder comments are summarized below:

- meteorological measurements (e.g., precipitation, evaporation, temperature, wind speed, and evapotranspiration);
- streamflow measurements and estimates of groundwater flux;
- concentrations and distribution of COPCs in surface soils;
- COPC and major ion concentrations in shallow groundwater;
- information on leakage from the storage ponds and other surface water conveyance structures;
- spatial extent of COPCs that have reached groundwater;
- hydraulic properties of unconfined (water table) aquifer;
- surface water quality; and
- soil physical (geotechnical) properties.

These data needs were outlined in the DQO Report and have been updated in light of further evaluation of existing data, refinement of CSMs, and the review of stakeholder comments on the DQO Report.

Based on the primary exposure media and potentially complete exposure pathways identified in Section 3.4, the requirements of the SOW, and the generalized data needs outlined in the DQO Report, the following RI activities will be conducted in the LCSA.

Task LCSA-1—Soil Mapping, Sampling, and Chemical Analyses

Based on prior sampling results, surface soils and waste rock piles in the LCSA are anticipated to be acid generating. Exposed mine materials will be sampled for assessments of human and ecological exposure and to assess the suitability of soils for potential future revegetation efforts. The scope of the RI includes field reconnaissance and mapping of soil characteristics of waste rock materials (including seeps) in the LCSA to identify areas with the greatest acid generation potential. Based on information gathered during this mapping effort, a soil sampling program for chemical analysis of COPCs will be implemented in selected portions of the waste rock piles and in surface soils in other parts of the LCSA.

Task LCSA-2—Investigation of Mine Features

Original mine features in the LCSA consist primarily of waste rock piles adjacent to Leviathan Creek in the disturbed portion of the site including the Delta slope. The extent of waste rock piles will be investigated during the performance of Task LCSA 1 described above. In addition, the effectiveness of surface geophysical techniques will be evaluated for assessing the thickness of the waste rock materials, identifying potential preferential groundwater flow pathways in waste rock materials, and assessing increased sulfide mineralization in the vicinity of the CUD and Delta slope. Surface geophysical techniques to be evaluated will include, electromagnetic and direct current resistivity methods, and, if appropriate, seismic refraction methods.

Task LCSA-3—Investigation of Sources to the CUD and DS

The LCSA has a relatively large water collection area that presumably drains mostly to the west and north towards Leviathan Creek. Water sources include precipitation, pond and channel leakage or water discharging through the pit. The presence of shallow groundwater is confirmed seasonally as water is intercepted in the waste piles near Pond 4 at shallow depths, even during the late summer months.

Similar to the overburden piles in the ACSA, it is likely that preferential flow paths for subsurface flows occur along the interface of the waste piles and the original bedrock surface, as well as along and around the piped/channelized Leviathan Creek. Pond and channel leakage could contribute to these flows seasonally. As described in the scope of investigations for the PSA, it is unclear if uncaptured subsurface flows from the pit could be contributing to the water found in the waste piles in the LCSA or discharges at the CUD.

There are several seeps discharging at slightly different elevations at the toe of the Delta slope the sources of which are uncertain. To address these uncertainties, the RI will include an assessment of the shallow groundwater flow system in the area upslope from the CUD and DS. If feasible, direct push technologies, including cone penetrometer testing, will be used to collect information on subsurface lithology and physical soil properties. Groundwater grab samples collected from direct-push borings will be tested for field parameters such as pH, temperature, and conductivity to map the area of shallow groundwater impacts that potentially contribute flow to the CUD and DS. Temporary well points or piezometers may also be installed to allow water level measurements and the mapping of the potentiometric surface in the area upgradient of the CUD and DS.

Task LCSA-4—Investigation of Ponding near Leviathan Creek

A small pond was observed adjacent to Leviathan Creek near the confluence with Aspen Creek in late summer 2008 and spring 2009. Water in this pond had a pH of 4 in late summer 2008 and a pH ranging from 5 to 5.5 in the spring of 2009. The source of the ponded water will be investigated as part of the RI program for the LCSA. An assessment of the shallow groundwater flow system surrounding the pond, including the area adjacent to Leviathan Creek, will be conducted using the same methods described previously for other areas.

Task LCSA-5—Shallow Groundwater Investigation

Based on information gathered from the above activities, it is anticipated that several shallow groundwater monitoring wells may be installed near the interface between the waste piles and underlying bedrock. The location of these wells will be selected to allow for water level and groundwater sampling in support of an evaluation of groundwater flow directions, the estimation of hydraulic gradients, and an assessment of the nature and extent of groundwater impacts by COPCs. The screened intervals of these wells will be determined based on interpretations of sitewide hydrostratigraphy developed from exploratory borings drilled and logged during the sitewide hydrogeologic investigation described above and soil boring conducted in the LCSA. Information from the shallow monitoring wells installed in the LCSA will also be used to supplement interpretations developed from data gathered during the sitewide hydrogeologic investigations. After monitoring wells have been installed and appropriately developed, wells will be hydraulically tested (e.g., using single-well slug or pressure-pulse tests) to estimate the hydraulic properties of the subsurface materials. Estimated hydraulic properties will be used to better quantify groundwater fluxes and flow velocities across the site.

Task LCSA-6—Surface Water and Sediment Sampling in Leviathan Creek

Based on potential exposure pathways to human and ecological receptors outlined in the CSMs described in Section 3.4, surface water and sediment sampling will be performed for COPC analyses in Leviathan Creek as described above for the sitewide program for surface water/sediment and biological investigations.

Task LCSA-7—Water Balance Studies

Inflow and outflow components to the water balance in the LCSA will be refined in association with the sitewide water balance studies described above. Water balance activities in the LCSA include the following:

- Meteorological measurements and calculations (e.g., precipitation, evaporation, temperature, wind speed, and evapotranspiration).
- Review and assess regional climate data and develop usable estimates of precipitation, evaporation/evapotranspiration, infiltration (recharge), and runoff for the LCSA.
- Perform site inspections and assessments of the current stream gauge locations and evaluate the need for new stations or upgrades to existing stations.
- Record additional stream flow measurements to better characterize bi-annual fluctuations and gains and losses along the creeks through synoptic sampling along key stretches of Leviathan Creek, as feasible during periods of active flow.
- Integrate results from groundwater assessments in the LCSA to develop estimates of groundwater flow and surface water/groundwater interactions.

Task LCSA-8—Bioassessment Investigations

Biological investigations in the LCSA will be focused on potential exposure pathways to human and ecological receptors outlined in the CSMs. Biological investigations in the LCSA will be performed in association with the sitewide biological investigations described above.

Task LCSA-9—Storm Water and Snowmelt Runoff Investigations

Storm water and snowmelt investigations in the LCSA will be conducted in association with the sitewide investigations described above. Investigations in this area will focus on surface water diversions installed to route flow from upland areas over or away from the Delta slope.

Stormwater-related activities will include:

- Conduct reconnaissance mapping of erosion features within the LCSA and identify potential locations for water and suspended sediment sampling for COPCs, including an evaluation of surface water diversion features constructed on the Delta slope.
- Perform preliminary modeling of surface water runoff and associated sediment transport to estimate the probable amount of rainfall and/or snowmelt that will result in surface runoff. Evaluate historical precipitation records to determine the probable frequency of such runoff events.

- Evaluate the effectiveness of existing stormwater management structures for controlling stormwater flows and mitigating erosion and sediment transport during high energy rainfall events.

- If surface runoff events occur during the performance of the RI activities, conduct sampling of storm water and snowmelt.

5.2.4 DSA

Data needs identified for the DSA include:

- streamflow measurements;

- concentrations and distribution of COPCs in surface water, soil, and sediments; and

- spatial extent of COPCs that have potentially reached groundwater.

Based on the primary exposure media and potentially complete exposure pathways identified, the SOW, and the generalized data needs outlined in the DQO Report, the following RI activities are included in the RI scope for the DSA.

Task DSA-1—Soil Mapping, Sampling, and Chemical Analyses

As described above, the DSA includes the floodplains of Leviathan, Aspen, and Upper Bryant creeks that may have been impacted by COPCs in surface water and sediment from the site. In addition, anecdotal information suggests that there are areas alongside the roads that may have been impacted because of the use of waste rock as road base material. Surface soil mapping, sampling, and chemical analyses for COPCs will be performed in the floodplains of Leviathan, Aspen, and Upper Bryant creeks and along portions of Leviathan Mine Road. This data will be used to assess potential impacts to human and ecological receptors and will be described in the HHRA and ERA work plans.

Task DSA-2—Surface Water and Sediment Sampling

The DSA consists of almost six miles of surface water with many tributaries and springs. Approximately 42 percent of the flow to Bryant Creek at its headwaters is from Leviathan Creek (MWH, 2002b). There are both losing and gaining reaches of the stream in the DSA. Concentrations of metals in surface water continually decrease downstream from the site, and the pH measured in Leviathan Creek in 2008 was neutral in all locations. The majority of dissolved iron previously measured in surface water is calculated to be removed before Station 25, which is at the confluence of Leviathan and Mountaineer creeks. Arsenic is also removed in the same distance. Nickel and zinc are removed more slowly. Several metals increase in concentration farther downstream in the DSA, including aluminum, arsenic, copper, and zinc believed to be from sources other than the mone.

Downstream surface water and sediment sampling in the DSA will be performed in association with the sitewide surface water and sediment investigations described above. In general, downstream surface water and sediment sampling activities in the DSA will consist of reconnaissance and mapping of surface water features and areas of sediment deposition areas, surface water sampling and sediment and sediment pore water samples collection. Sampling locations will be selected by considering historical sampling sites and primary depositional areas

Task DSA-3—Bioassessment Investigations

Biological investigations in the DSA will be focused on potential exposure pathways to human and ecological receptors outlined in the CSMs. Biological investigations in the DSA will be performed in association with the sitewide biological investigations described above.

6.0 RISK ASSESSMENT APPROACH

This section summarizes the approach for the baseline risk assessment to be completed as part of the RI/FS and required by the SOW and the UAO. The baseline risk assessment consists of two components, a HHRA and an ERA. The details of the HHRA and the ERA, including methods and assumptions, will be presented in the Draft HHRA Work Plan and the Draft ERA Work Plan submitted under separate cover.

6.1 HHRA APPROACH

The HHRA will provide a quantitative assessment of the potential for adverse health effects that may result from exposure to COPCs at the site. The objective of the HHRA will be to determine whether site COPCs pose a current or potential risk to human health and the environment in the absence of any future remedial action. It provides an analysis of baseline risks to determine the need for further study and a basis for comparing the potential health impacts of various remedial alternatives.

6.1.1 Regulatory Guidance

The HHRA will be performed in accordance with U.S. EPA guidance set forth in the following documents:

- *Risk Assessment Guidance for Superfund (RAGS), Volume I: Human Health Evaluation Manual, Part A* (U.S. EPA, 1989);
- *RAGS, Volume I: Human Health Evaluation Manual Supplement to Part A: Community Involvement in Superfund Risk Assessments* (U.S. EPA, 1999);
- *RAGS, Volume I: Human Health Evaluation Manual, Part D, Standardized Planning, Reporting, and Review of Superfund Risk Assessments* (U.S. EPA, 2001b);
- *RAGS, Volume I: Human Health Evaluation Manual, Part E, Supplemental Guidance for Dermal Risk Assessment* (U.S. EPA, 2004a);
- *RAGS, Volume I: Human Health Evaluation Manual, Part F, Supplemental Guidance for Inhalation Risk Assessment* (U.S. EPA, 2009b).
- *Calculating Upper Confidence Limits for Exposure Point Concentrations at Hazardous Waste Sites* (U.S. EPA, 2002a);
- *Human Health Evaluation Manual, Supplemental Guidance: Standard Default Exposure Factors* (U.S. EPA, 1991);
- *Exposure Factors Handbook* (U.S. EPA, 1997b);

- *Guidance for Data Usability in Risk Assessment* (U.S. EPA, 1992);
- *U.S. EPA Risk Characterization Program Memorandum* (U.S. EPA, 1995a)
- *Soil Screening Guidance: Users Guidance and Technical Background Document* (U.S. EPA, 1996, EPA/540/R-96/018 and EPA/540/R-96/128); and
- *Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites* (U.S. EPA, 2002c).

As directed by the SOW, the HHRA also will account for certain reasonable maximum exposure factors provided for members of the Washoe tribe (Walker, 2003; Harper, 2005a, b).

6.1.2 Data Evaluation and Management

The HHRA will consider both existing data and new data collected after publication of the HHRA Work Plan during the RI. Previous data will be reviewed to determine if it is of sufficient quality per U.S. EPA guidance (U.S. EPA, 1992) and applicability to current site conditions. New data will be subject to a data validation review consistent with the draft QAPP (AMEC, 2009b) and U.S. EPA guidance (U.S. EPA, 2004b) and will be reviewed for applicability to the HHRA prior to use.

6.1.3 Preliminary COPCs

U.S. EPA's SOW identified 16 metals as COPCs. Final COPCs for the risk assessment will be selected following comparison to selection criteria, which may include frequency of detection, identification as site-related, comparison to background concentrations, and comparison to risk-based screening criteria, as appropriate to each media.

6.1.4 Exposure Assessment

Exposure assessment involves the identification of the potential human exposure pathways at the site for present and potential future-use scenarios. Present conditions are as they exist today. Future conditions are based on reasonably likely land uses of the site. OSWER Directive 9355.7-4 on land use in the CERCLA remedy selection process states that RAOs developed during the RI/FS should reflect "reasonably anticipated future land use or uses." The Directive identifies key factors to be considered in the determination of a reasonably anticipated future land use, including current land use, zoning maps, population growth patterns, and historical development patterns.

The identification of potential human receptors is based on the characteristics of the site, the surrounding land uses, and the probable future land uses. On-property areas are owned primarily by the state and are currently fenced with gates at the entrances from the access roads to the north and south (Leviathan Mine Road); however, the remainder of the mine property is not surrounded by fencing. During winter months access currently is further limited because of snowpack, which prevents standard four-wheel-drive vehicles from reaching the mine property.

Future land use is not anticipated to change in the area surrounding the site. Therefore, current receptors also are considered to be potential future receptors. Future use of the off-property areas of the site would be consistent with the surrounding USFS land (e.g., recreational). The HHRA assumes longer-term use of off-property areas in the future by Washoe tribe members and potentially less restricted access to certain on-property areas for recreational use following a final remedy, revegetation, etc.

6.1.4.1 CSM for HHRA

Exposure pathways identified initially in the CSM (Section 3.4) will be finalized after assessing information gathered in the RI. Generally, an exposure pathway is considered complete if it consists of a source and mechanism of release; a transport medium; an exposure point (i.e., point of potential contact with a contaminated medium); and an exposure route (e.g., ingestion) at the exposure point.

Present and reasonably anticipated potential future-use scenarios will be evaluated; however, only some may be selected for quantitative analysis. Justifications will be provided for those exposure pathways retained and for those eliminated. Figure 43 presents the CSM for the site, and Table 45 summarizes exposure pathways in a tabular format based on U.S. EPA guidance (U.S. EPA, 2001b).

6.1.4.2 Exposure Quantification

The assumptions and approaches to be used will be consistent with a reasonable maximum exposure (RME) approach as defined by U.S. EPA (1989c). The RME scenario is defined by the U.S. EPA as the "highest exposure that is reasonably expected to occur at the site." For example, upperbound estimates of concentrations in environmental media will be used to assess potential exposure under the RME scenario. The equations for calculating Annual Average Daily Dose and Lifetime Average Daily Dose (AADD and LADD are those presented by the U.S. EPA in their RAGS guidance (U.S. EPA, 1989, 2004a, 2009a). Exposure assumptions used in daily intake calculations will be based on information contained in U.S. EPA guidance, site-specific information, and professional judgment. Exposure parameters will be selected from U.S. EPA (1989c; 1991a; 1997b, 2002a, 2004a) and Cal/EPA (1996) guidance, as appropriate, or will be based on site-specific factors when applicable (e.g., Washoe Tribe RME Scenario [Harper, 2005a, b]). A central tendency (CT) evaluation will be performed if the estimated cancer risks exceed the acceptable risk range of 1 x 10^{-6} to 1 x 10^{-4} and the hazard index (HI) is greater than 1.0.

6.1.5 Toxicity Assessment

Toxicological values and information regarding the potential for carcinogens and noncarcinogens to cause adverse health effects in humans will be obtained from a hierarchy of U.S. EPA sources beginning with the Integrated Risk Information System (IRIS) online database. The quantitative toxicity values and supporting explanations in IRIS have been reviewed and agreed upon by the U.S. EPA using available studies on a chemical. The complete hierarchy of sources to be reviewed is as follows:

- Tier 1—U.S. EPA's IRIS database (U.S. EPA, 2009c).
- Tier 2—U.S. EPA's Provisional Peer Reviewed Toxicity Values (PPRTVs).
- Tier 3—Other toxicity values. Tier 3 includes additional U.S. EPA and non-U.S. EPA sources of toxicity information. Additional U.S. EPA sources include the most current Health Effects Assessment Summary Tables (HEAST; U.S. EPA, 1997c) and information from the National Center for Environmental Assessment (NCEA). Non-U.S. EPA sources include the Agency for Toxic Substances and Disease Registry (ATSDR), the California Environmental Protection Agency (Cal/EPA), and Oak Ridge National Laboratory's Risk Assessment Information System.

For chemicals that do not have appropriate toxicity criteria from any of the above sources, where relevant and appropriate, we may request additional information from U.S. EPA's toxicologist or may use surrogate toxicity criteria based on similarities in chemical structure and toxicity. The use of surrogate criteria will be documented and submitted to the U.S. EPA for review and approval prior to the completion of the risk assessment. Those chemicals that cannot be quantitatively evaluated because of the absence of toxicity criteria will be more qualitatively evaluated.

6.1.6 Risk Characterization

The data evaluation, exposure assessment, and toxicity assessment will be integrated into quantitative and qualitative expressions of noncarcinogenic hazards and carcinogenic risks. The estimates of hazard and risk for individual chemicals and exposure pathways will be presented numerically in spreadsheets contained in an appendix to the HHRA. In general, the U.S. EPA recommends a target value or risk range (i.e., hazard index of 1 or risk range of 10^{-4} to 10^{-6}) as thresholds for evaluating potential human health impacts. Estimated risks and hazard indices will be combined for a given receptor across media, chemicals, exposure pathways, and age groups as appropriate. The results presented in the spreadsheet calculations will be compared to these target levels and discussed.

In any risk assessment, estimates of potential carcinogenic risk and noncarcinogenic health effects have numerous associated uncertainties. The primary areas of uncertainty and limitations will be discussed in the risk characterization.

6.2 ERA APPROACH

The ERA will characterize potential adverse effects to environmental receptors caused by exposure to site-related chemicals. The ERA will be conducted under U.S. EPA guidance (U.S. EPA, 1997a, 1998b) and will consist of three major components:

1. **Problem Formulation—**The information needed to focus the analysis phase of the ERA.
2. **Analysis—**The characterization of effects and characterization of exposure.
3. **Risk Characterization—**The calculation of risk estimates and discussion of uncertainties.

To evaluate ecological risks within the ERA study area (Figure 46), the following overall process has been established:

- Compile and review existing data and information about the Leviathan Mine site, including prior ecological risk assessment results for off-property areas (Gradient, 2002).
- Develop, using the problem formulation process, a CSM that identifies assessment endpoints and complete exposure pathways.
- Develop an analysis approach for assessing risks and identify data needed to assess risk.
- Evaluate data to identify data gaps and collect additional data to fill data gaps.
- Refine the CSM based on additional data.
- Prepare the baseline ERA report.

Data needs will be identified through an iterative process of data analysis and fieldwork. Existing ecological data is used to determine data needs for field sampling events through a problem formulation approach. Using this approach, representative species for the study area will be selected, and the data needed to further evaluate risks to these species will be identified.

6.2.1 Problem Formulation

Problem formulation defines assessment endpoints and examines historical and ecological information pertaining to the study area to develop a CSM. A CSM is a depiction of the pathways for transport of COPCs from sources to receptors. The CSM provides a framework for the ERA. The ERA CSM is described in Section 3.4.

6.2.1.2 Selection of Assessment and Measurement Endpoints

The assessment endpoints for the ERA were selected based on the following criteria (U.S. EPA, 1998b) and consistency with the SOW and the UAO:

- ecological relevance;
- political, societal, and cultural relevance;
- susceptibility to known or potential chemical stressors at the site;
- habitat viability and ecosystem function; and
- consistency with ecological management goals for the site.

Assessment endpoints will be evaluated at either the population or community levels. These levels are defined according to the values to be evaluated in the ERA (U.S. EPA, 1997a, 1998b).

Fish, birds, and mammals will be evaluated at the population level. Aquatic plants, amphibians, and reptiles will also be evaluated at the population level. However, because very little exposure and toxicity information is available that allows assessment of any single species of plant, amphibian, or reptile, the assessment may be performed collectively at the community level. Benthic invertebrates and aquatic plants are typically evaluated at the community level because many species are co-located in a localized "community" with little to no movement occurring within the habitat. A community-level assessment of benthic invertebrates will, therefore, be conducted in aquatic habitats associated with the Leviathan Mine site. A population-level assessment will also be conducted, as feasible. However, due to practical limitations and the available exposure and toxicity information, the population assessment for benthic invertebrates will likely be largely qualitative.

Assessment endpoints selected for the Leviathan Mine Baseline ERA are presented below. Target receptor species selected to meet the goals set by the assessment endpoints are identified below:

- Assessment Endpoint No. 1: Survival, Growth, and Reproduction of Aquatic, Riparian, and Terrestrial Plant Populations**;**
- Assessment Endpoint No. 2: Survival, Growth, and Reproduction of Benthic Invertebrate Populations;
- Assessment Endpoint No. 3: Survival, Growth, and Reproduction of Soil Invertebrate Populations;
- Assessment Endpoint No. 4: Survival, Growth, and Reproduction of Fish Populations;
- Assessment Endpoint No. 5: Survival, Growth, and Reproduction of Amphibian and Reptile Populations;
- Assessment Endpoint No. 6: Survival, Growth, and Reproduction of Bird Populations; and
- Assessment Endpoint No. 7: Survival, Growth, and Reproduction of Mammal Populations.

6.2.3 Analysis Approach

Exposure occurs when there is co-occurrence of the stressor and the receptor (U.S. EPA, 1998b). The stressors in the baseline ERA include concentrations of COPCs in soils, sediments, surface water, groundwater, and biota.

Ecological Effects

Measures of ecological effects on a population level will be performed by comparing response within the study area to both a Lowest Observed Adverse Effect Level (LOAEL) and a No Observable Adverse Effect Level (NOAEL). The level of biological organization being evaluated in the assessment endpoint will determine whether population- or community-level measures will be used.

Measures of Ecosystem and Receptor Characteristics

Measures of ecosystem and receptor characteristics that may adversely affect the ecological community or population will be identified and discussed qualitatively in the context of the chemical-specific risk estimates, the ultimate goal being to estimate those risks attributable to site-related COPCs. In addition, factors, such as the frequency and duration of exposure may modify exposure scenarios and are therefore important considerations in estimating risks.

The remainder of this section discusses the process of evaluating exposure by the identification of habitat types, ecological receptors, and exposure pathways.

6.2.3.1 Habitat Types Within the Leviathan Mine Site Study Area

The first step in delineating habitat types within the study area was accomplished by reviewing U.S. Department of Agriculture (USDA) Ecoregions information (Miles and Goudey, 1998) and querying the California Wildlife Habitat Relationships (CWHR) system database (CDFG, 2008) for the mine and surrounding area.

High-resolution color aerial imagery of the vicinity obtained from the USDA Geospatial Gateway (USDA, 2006) was used to delineate the different habitat types in the study area. Delineation of habitat types from aerial imagery was based on best professional judgment while viewing the imagery at a scale of 1:8,000. Although high-resolution imagery was used to delineate habitat types, it was not possible to delineate habitats at the same level of detail as the habitat types identified by the USDA (Miles and Goudey, 1998) or California Department of Fish and Game (CDFG; 2008). For example, it was not possible to differentiate lodgepole pine and Jeffery pine by observing the aerial image. Therefore, AMEC defined a simplified habitat classification scheme with the following categories:

- forest dominated;
- scrub-shrub dominated;
- grassland (including forbs) dominated;
- wetland;
- open water (includes ponds, lakes, and open-water wetlands);
- barren; and
- open mine.

Table 46 presents a comparison of the USDA, CWHR, and AMEC-defined habitat types occurring within the ERA study area. The AMEC-defined habitat types delineated within the study area are shown on Figures 45 and 46. Table 47 summarizes the areas of each habitat type delineated based on the high-resolution imagery.

The final step in delineating habitat types will be to verify delineation developed based on aerial imagery through field surveys. The delineation map on Figures 45 and 46 shows individual areas, or polygons, of habitat. Representative areas will be selected for verification surveys to confirm the habitat type. A detailed work plan for field verification will be developed separately.

During field verification of the habitat polygons, dominant, subdominant, and forage plant species will be identified. Depending on the time of year, forage species may be collected for analysis of COPCs. A detailed work plan for collecting and analyzing plant tissue samples for chemical analysis will be developed separately. Habitats identified included both terrestrial and aquatic habitats.

6.2.3.2 Identification of Ecological Receptors

The ERA will focus on wildlife species that are known to occur in the types of habitat within the study area. The CWHR database was queried to determine the wildlife species likely to be present in the types of habitat present in the study area. Table 48 provides a list of wildlife species that may potentially be present in the ERA study area.

During field verification of the habitat types and other fieldwork conducted as part of the ERA, incidental observations of wildlife use (e.g., visual observations of animals, scat, rubbings, or audio observations of wildlife calls) will be noted.

Target receptors for the Baseline ERA will include mammals, birds, reptiles, amphibians, fish, invertebrates, and plants. The following factors were considered in selecting representative species for each of these groups of target receptors:

- expected or known study area usage;
- feeding guild (e.g., carnivore, herbivore, piscivore);
- available information on toxicity reference values (TRVs) reviewed for the preparation of this ERA Work Plan (U.S. EPA, 1993; BLM, 2004);
- direct and indirect exposure routes;
- ability to bioaccumulate COPCs;
- sensitivity to COPCs; and
- societal and cultural significance.

For species without known TRVs, values from a surrogate species with a similar life history and body mass will be used.

The representative species selected for each group of target receptors are listed in Table 48.

Special status species are those species identified by federal and state governments as requiring special protection. Several species with special status are likely to use the study area. The special status of wildlife species potentially present in the ERA study area is shown in Table 48.

6.2.3.4 Potential Exposure Pathways

Representative species can be exposed to COPCs in soil, water, or sediment either directly through contact or ingestion of soil, sediments, or surface water, or indirectly through the food chain. The potential exposure pathways for target receptor groups are shown in the CSM (Figure 44). Table 49 presents exposure parameters for the vertebrate species selected for assessment.

6.2.4 Data Evaluation and Additional Sample Collection

Existing data will be reviewed to identify data appropriate for inclusion in the ERA. The objective will be to identify within each of the on property, off-property, and background areas, a minimum of three sampling stations in each habitat type (wetland, barren, forested, scrub-shrub, and grassland; Table 50). The exact number of samples will be determined based on an area-weighted protocol for each habitat type within each study area.

To the extent additional data is required, habitat polygons will be selected for sampling based on ease of access, habitat type, and polygon size, with preference for polygons containing sampling points where soil, sediment, or water samples have been previously collected. Detailed work plans for collecting and analyzing samples of plants, soils, sediment, and surface water will be developed separately.

6.2.5 Risk Estimation

The ERA Work Plan will present the general approach to exposure characterization, effects characterization, and risk estimation, and describes data needed to assess each endpoint using these methods. The exposure characterization describes what measures will be used to estimate exposure of receptors to COPCs in the study area from the complete pathways identified in the CSM (Figure 43). The effects characterization describes chemical-specific effects related to the assessment endpoints (e.g., through stressor-response profiles) and examines how the response changes with chemical concentration. The risk estimation will integrate information from the exposure and effects characterizations into an estimate of risk and the likelihood of adverse ecological effects.

Risk estimation is the process of integrating exposure and effects (U.S. EPA, 1998a). The hazard quotient (HQ) method, comparing the exposure estimate to a toxicity reference value (e.g., on a tissue residue, dietary dose, or media concentration-based value), will be used to estimate exposure through one or more pathways for all receptors except infaunal and epibenthic invertebrates, which are assessed using a sediment quality value approach (i.e., sediment bioassay testing, sediment chemistry and invertebrate sampling).

HQs that exceed 1.0 based on a no observed adverse effect level (NOAEL) suggest that adverse effects are possible at the individual level. In these cases, the estimated exposure exceeds the highest dose at which no statistically significant effects were observed. HQs based on a lowest observed adverse effect level (LOAEL) will also be calculated to examine potential population-level effects. HQs will be calculated in such a way as to distinguish the contribution of various media to the total HQ. HQs will be considered along with the associated uncertainty in the exposure and effects data to determine if a given COPC presents sufficient risk for a given measure of effect for each representative species.

6.2.6 Risk Characterization

Risk to target receptors will be characterized by weighing of the lines of evidence accumulated for the Baseline ERA. These include estimated chemical dose for different media; the quality, connectivity, and distribution of habitat types; analyses of plant and fish tissue; sediment bioassay testing; and benthic invertebrate community indices. Lines of evidence analysis will be based on relevance, exposure response, temporal slope, spatial scope, quality, and uncertainty (Suter et al., 2000).

7.0 FEASIBILITY STUDY APPROACH

The feasibility study (FS) includes the development and screening of alternatives and a detailed analysis of alternatives (Figure 47). The FS process is generally considered to be a dynamic and flexible process, in which presumptive remedial technologies are continually updated and modified with environmental, treatability, and Focused Feasibility Study (FFS) data. This process happens throughout all phases of the project, starting with the initial site investigation and ending with the implementation of the final remedial alternative. The results of this analysis culminate in the FS Report or FFS Report, which will use the site-specific data to evaluate the feasibility and effectiveness of implementing alternative remedial actions to address impacted media at the site and recommend a preferred remedial alternative. The conclusions of the FS and FFS will be used by the U.S. EPA to develop one or more Records of Decision (ROD) for the site.

Consistent with the RI/FS guidance (U.S. EPA, 1988) and other U.S. EPA guidance (*A Guide to Preparing Superfund Proposed Plans, Records of decision, and Other Remedy Selection Decision Documents,* OSWER 9200.1-23P, July 1999*; Early Action and Long-Term Action Under the Superfund Accelerated Cleanup Model (SACM) - Interim Guidance,* OSWER 9203.1-05I, 1992), at any point during the RI/FS process a remedy or a part of a remedy may be implemented as an early or interim remedial action. These early or interim remedies may be evaluated under a FFS. The FFS may be used to evaluate a more narrow range of remedial alternatives or a part of a remedial alternative if it provides early value to the cleanup process. For example, a FFS may be used to evaluate different winter storage options for containment of low pH drainage from the site. Additional characterization data, if necessary could be collected as pre-design data under the FFS or under a FRI as part of the greater RI/FS process. In this example, winter storage of this drainage may be implemented prior to completion of the RI/FS Report as long as sufficient documentation supporting the rationale for the action is available to fulfill the NCP's Administrative Record requirements. An interim action or early action ROD may be used to serve this purpose. The analysis in the FFS would also be used as part of the remedy evaluation process in the final FS.

The FS or FFS will be completed in accordance with the Federal National Oil and Hazardous Substances Pollution Contingency Plan; National Contingency Plan (NCP), and the *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (U.S. EPA, 1988). The primary objective of the FS is to ensure that appropriate remedial alternatives are developed and evaluated so that relevant information concerning the remedial action options can be presented to a decision-maker and an appropriate remedy selected (40 CFR 300.430). The process for developing the remedial action alternatives is shown on Figure 48.

The FS Report will include the results of the remedial investigation and the environmental and human health risk assessments. The first step in the FS process beyond site characterization and scoping involves establishing the RAOs based on the ARARs and other environmental policies. Impacted media to be remediated or controlled and physical hazards to be removed will then be identified based on environmental data collected during the remedial investigation. Site-specific remedial goals (quantitative media-specific goals that consider both the risks to human health and the environment, and compliance with ARARs) are then developed.

After the RAO and remedial goals have been established, general response actions (GRAs) for each medium of interest are then identified that could either independently or in combination satisfy the RAOs. Remedial technology types applicable to each general response action are then identified and screened to eliminate those that cannot technically be implemented at the site. Specific process options (subsets of each technology type) are further identified and evaluated based on their effectiveness, implementability, and relative cost (Figure 49). During this step, technology types and process options are either retained for further consideration or eliminated from consideration.

As noted above, evaluation of remedial technologies and process options will be an iterative process and occur throughout the RI/FS. If more information is required to fully evaluate a technology type or process option, treatability and pilot studies may be conducted (Figure 50). Focused feasibility studies may also be conducted during the RI/FS to address smaller more focused remediation issues. These FFS will follow guidelines similar to the sitewide FS. Data collected during the FFS will be used to the fullest extent possible during the sitewide FS, and the results of the FS may be incorporated into the final remedy for the site.

Finally, the remaining process options will then be assembled into remedial alternatives, each capable of satisfying the RAOs. The number and types of alternatives to be evaluated will take into account the characteristics and complexity of the wastes present at the site. The remedial alternatives will be evaluated individually and compared against one another based on nine criteria developed in the NCP (Figure 51). The criteria for the detailed analysis of alternatives are shown on Figure 52.

The components of the FS, starting with development of RAOs and remedial goals, are discussed in detail in the following subsections.

7.1 DEVELOPMENT OF REMEDIAL ACTION OBJECTIVES AND REMEDIAL GOALS

To develop the RAOs and remedial goals, the FS will identify and review ARARs and other environmental policies that pertain to site-specific concerns (defined as To Be Considered

[TBC] criteria). Media of concern and chemicals of potential concern at the site and the related health risk concerns are then identified to form the basis of the RAOs. Following the identification of RAOs, the calculated health risks and governing ARARs are considered, and remedial goals are established to define the objectives for the cleanup action.

The following subsections describe the identification of ARARs and TBCs, development of the RAOs, identification of media and volumes to be remediated and development of remedial goals.

7.1.1 Identification and Review of ARARs

CERCLA and its regulations (40 CFR 300 et seq., referred to as the NCP) provide an established and generally accepted framework for evaluating and remediating contaminated sites. Under the NCP, remedial actions must attain (or justify the waiver of) any federal or more stringent state environmental standards and facility siting laws that are "applicable or relevant and appropriate." These regulatory requirements are known as ARARs.

Identification of ARARs must be completed on a site-specific basis and involves a two-part analysis: first, a determination of whether a given requirement is applicable; then, if it is not applicable, a determination of whether it is nevertheless both relevant and appropriate. Federal, state, and local ARARs can be divided into chemical-specific, location-specific, and action-specific.

Chemical-Specific ARARs

Chemical-specific or ambient requirements include those laws and regulations that regulate the release to the environment of materials possessing certain chemical or physical characteristics or containing specified chemical compounds. These requirements generally set health- or risk-based concentration limits or discharge limitations for specific hazardous substances that may be found in, or discharged to, the ambient environment. Examples of these types of ARARs are federal and state drinking water standards.

Location-Specific ARARs

Location-specific ARARs are those requirements that relate to the geographical or physical position of the site, rather than the nature of the contaminants or the site remedial actions. These requirements may limit the type of remedial action that can be implemented, and may impose additional constraints on the remedial action. To the extent that a remedial action will affect historical resources, streams, flood plains, wetlands, or other location-specific features, the NCP requires that the potential remedial alternatives comply with location-specific requirements. Examples of these types of ARARs are cultural resource reviews or stream alteration requirements.

Action-Specific ARARs

Action-specific ARARs consist of requirements that define acceptable handling, treatment, and disposal procedures for hazardous substances. These ARARs generally set performance, design, or other similar action-specific controls or restrictions on particular kinds of activities related to management of hazardous substances or pollutants. These requirements are triggered by the particular technologies and remedial alternatives selected to accomplish the remedial action. RCRA regulations for hazardous waste generation, handling, transportation, storage, treatment, and disposal are an example of an action-specific ARAR.

Definition of TBCs

A requirement may not meet the definition of ARAR, but may still be useful in guiding decision makers regarding whether to take action at a site or to what degree action is necessary. Such requirements are called TBC criteria. The TBC are generally nonpromulgated advisories or guidance issued by federal, state, or local government that are not legally binding, but may provide useful information or recommend procedures for remedial action. Although TBCs do not have the status of ARARs, they are considered along with ARARs as part of the site FS in establishing the required level of cleanup for protection of health or the environment.

Waivers

Section 121 in CERCLA and the NCP at 40 CFR Par 300.430(F)(ii)(C) provide that, under certain circumstances, an otherwise ARAR may be waived. These waivers apply only to the attainment of the ARAR; other statutory requirements, involving remedies that are protective of human health and the environment, cannot be waived. The types of waivers provided by CERCLA Section 121(d)(4) are listed below:

- **Interim Remedy—**The remedial action selected is only part of a total remedial action that will attain such a level or standard of control when completed.
- **Greater Risk to Human Health or the Environment—**Compliance with the requirement at the site will result in greater risk to human health and the environment than alternative options.
- **Technical Impracticability—**Compliance with the requirement is technically impracticable from an engineering perspective.
- **Equivalent Standard of Performance—**The remedial action selected will attain a standard of performance that is equivalent to that required under the otherwise

applicable standard, requirement, criterion, or limitation through use of another method or approach.

- **Inconsistent Application of State Requirements—**With respect to a state standard, requirement, criterion, or limitation, the state has not consistently applied (or demonstrated the intention to apply consistently) the standard, requirement, criterion, or limitation in similar circumstances at other remedial actions.

- **Fund Balancing—**In the case of a remedial action to be undertaken solely under Section 104 of CERCLA using the fund, selection of a remedial action that attains the level or standard of control in the requirement will not provide a balance between, on the one hand, the need for protection of public health and welfare and the environment at the site under consideration, and, on the other hand, the availability of amounts from the fund to respond to other sites that present or may present a threat to public health or welfare or the environment, taking into consideration the relative immediacy of such threats. The fund-balancing waiver is not applicable to the site because proposed remedial actions at the site are not fund actions.

ARAR waivers will be considered, and highlighted if applicable, throughout the ARAR identification process.

7.1.2 Development of RAOs

As discussed above, RAOs are proposed goals for protecting human health and the environment. RAOs provide the framework for developing and evaluating remedial action alternatives and will be developed based on information gathered during the RI and the risk assessment. ARARs and TBCs, as described above, will also be considered during development of the RAOs. Most of the RAOs will be based on human health and environmental protection and will likely include the following:

- Prevent, mitigate or reduce potential human health and environmental exposure.

- Support long-term restoration of surface water.

- Minimize threats to the environment, especially sensitive habitats and critical habitats of species protected under the Endangered Species Act.

7.1.3 Identification of Remedial Goals and Volumes and Area of Media

The final remedial goals for the site (acceptable exposure levels) will be based on the results of the environmental and human health risk assessments and compliance with ARARs. The final remedial goals will be site-specific and media-specific, and quantitative goals will be developed for each affected media and chemical of concern.

Specific media types at the site that will be evaluated include groundwater, soil (including mine wastes), surface water, and sediments. The FS will determine the area and volume of each of these media to which GRA (discussed below) will be applied.

7.2 DEVELOPMENT OF REMEDIAL ALTERNATIVES

Remedial alternatives will be developed in a three-step process:

1. identifying GRAs;
2. identifying, screening, and evaluating technology types and process option; and
3. combining retained technology types into remedial alternatives, each capable of satisfying the RAOs.

These steps are likely to be iterative and may include treatability, pilot, and/or focused feasibility studies to full evaluate remedial technologies and develop remedial alternatives. This process is discussed further in the following subsections.

7.2.1 GRAs

The CERCLA guidance requires identification of GRAs (medium-specific) that, when implemented, will meet the RAOs for the site. GRAs are refined throughout the FS process to develop appropriate remedial action alternatives for the site. Combinations of GRAs may be used to meet the RAOs. The following GRAs will be considered in the FS:

- **No action—**no additional action is taken to remediate the site (NCP required alternative).
- **Institutional controls—**enforceable land use restrictions and local ordinances that may limit the use and development of a property, and prevent certain actions at the property (e.g., groundwater use or soil excavation). This can also include site access control such as fencing and security patrols.
- **Natural attenuation—**reliance on natural attenuation processes (including biodegradation, dispersion, sorption, chemical transformation) to reduce the concentration of target compounds. No active human intervention is involved, although monitoring is commonly required.
- **Physical containment—**technologies that employ barriers to restrict human or environmental (e.g., wind and rain) access to chemicals of concern, or which restrict the movement of chemicals of concern without changing their inherent nature. This includes both physical barriers and hydraulic containment measures.

- **In situ treatment and/or removal of contaminants—**technologies that destroy contaminants in the ground, or transform or degrade the contaminants into harmless substances.

- **Removal, ex situ treatment, replacement, and/or off-property disposal—** technologies that remove affected media and treat the contaminants in aboveground reactors or dispose of the media off site.

7.2.2 Identification, Screening, and Evaluation of Remedial Technologies and Process Options

The CERCLA guidance defines technology types as "general categories of technologies (pumping, biological treatment, etc.…)" and process options as "specific processes within each technology type." Technology types and process options are first identified using a variety of sources including references developed for application to Superfund sites and other standard engineering texts. Technology types and process options that are not considered "technically implementable" will be screened out of the evaluation. The remaining technology types and process options will be evaluated further based on effectiveness, implementability (institutional aspects), and cost. This evaluation will draw upon data collected during treatability, pilot, and focused feasibility studies. Technology types that will be considered in the FS Report are as follows:

- **Capping—**Examples of capping include surface armoring, placing a cover over waste, soil enhancement, geosynthetic or asphalt cover system, concrete, or soil to eliminate contact.

- **Hydraulic Control—**Controlling groundwater can be accomplished by a range of engineering practices: French drains provide a preferential pathway for groundwater to flow in an area; automated well fields are used at sites with complex hydrologic conditions.

- **Storm Water Controls—**Storm water controls include waddles, straw bales, and diversion ditches used to redirect the water. Materials such as straw and geo-textile matting are spread over large, sloped areas to aid erosion control. Reseeding an exposed area is another way to control erosion. Generally, these practices are used in conjunction with each other.

- **Erosion Controls/Diversion—**Erosion control and diversion measures generally involve more construction equipment to implement and possibly the placement of armoring in the diversion ditch bottoms to control erosion. This is usually used at the perimeter of large sites in an effect to divert all flow entering the site.

- **Grading/Surface Water Diversion—**Grading and surface water diversion generally describes on-property surface water control, collection, and containment.

- **Containment—**Containment is used to prevent one media from contacting another. The use of cutoff walls, ponds, and retention basins are examples of containment.

- **Excavation—**Excavation is the process of physically removing a media and moving or disposing of it in a different location.

- **Groundwater Extraction—**Groundwater extraction is the process of removing groundwater from the subsurface usually through pumping and treating or discharging the water after extraction.

- **Interceptor Trenches—**Interceptor trenches are engineered subsurface structures that provide preferential pathways for groundwater to flow. They capture and divert the water prior to reaching another point.

- **Reinjection/infiltration—**Reinjection and infiltration are means of reintroducing water to the subsurface. Reinjection uses mechanical means to pump the water into the ground and infiltration refers to gravity being used.

- **Chemical Treatment—**Primarily lime treatment and variations on this technology. Lime treatment of ARD is a relatively simple chemical process where low pH ARD is neutralized using lime to precipitate dissolved metals. Chemical precipitation and other metal treatment options could be considered here.

- **Bioreactor—**A treatment technology that uses large quantities of biologic cultures to reduce the toxic effects of waste stream being treated.

- **In situ Treatment—**In situ treatment can include in situ chemical reduction of metals or stimulating biological reduction.

- **Revegetation—**Revegetation uses grass and plants to take up rainwater with their roots and help prevent it from soaking into the soil below. Revegetation also mitigates erosion.

- **Biologic Treatment—**Biologic treatment utilizes organic carbon and crushed limestone to enhance the conditions for sulfur reducing bacteria. These bacteria along with the limestone neutralize the pH and reduce the dissolved metal concentrations in ARD.

- **Wetland Treatment—**Constructing wetlands has been demonstrated to be a technologically feasible method of treating dissolved metal-laden water. Wetlands provide an organic rich environment that is typically anaerobic. The two mechanisms that remove metals are absorption by the organic rich substrate and sulfate reduction.

- **Phytoremediation—**Phytoremediation suggests the use of plants and their associated microbiota, soil amendments and agronomic techniques to remove, contain, or render harmless environmental contaminates.

As required by the NCP, remedial technologies are evaluated based on their effectiveness, implementability, and cost. Each of these criteria is described in detail below.

7.2.2.1 Effectiveness

Effectiveness is evaluated based on how well a technology satisfies the RAOs for a specific medium; protects human health and the environment in the short and long term; attains federal and state ARARs; and permanently reduces the toxicity, mobility, or volume of hazardous constituents through treatment.

7.2.2.2 Implementability

Implementability is evaluated based on the technical feasibility of implementation, and the availability of the technology. Implementability should also consider the technical and institutional ability to monitor, maintain, and replace a technology, and the administrative feasibility of implementing the technology.

7.2.2.3 Cost

During the technology screening process, cost should be evaluated on a relative basis. A high level of accuracy in estimating costs is not required, although the relative costs of competing technologies should be reasonably well defined. Cost estimates for technologies that are retained and incorporated into remedial alternative(s) will be more accurately estimated during the remedial alternative analysis.

7.2.3 Assemble Remedial Alternatives

As part of the FS, a range of potential remedial alternatives are developed using the technologies carried forward from the technology screening process described above. Technologies are combined to form alternatives that will satisfy the RAOs, manage site risk, and address the media that have been identified as requiring remediation. Conceptual designs are developed for each remedial alternative, and a preliminary cost estimate is presented for each alternative. The number and types of alternatives to be evaluated shall take into account the characteristics and complexity of the wastes present at the site.

7.3 EVALUATION OF REMEDIAL ALTERNATIVES

After the remedial alternatives are developed, each are then evaluated individually and compared against one another. The NCP and CERCLA RI/FS guidance specify threshold, balancing, and modifying criteria (a total of nine criteria) by which remedial alternatives must be evaluated. Each of the evaluation criteria are discussed in detail below.

7.3.1 Threshold Criteria

Threshold criteria relate to statutory requirements that each alternative must satisfy in order to be eligible for selection. These criteria include the overall protection of human health and the environment and compliance with ARARs.

7.3.1.1 Overall Protection of Human Health and the Environment

This criterion summarizes the protectiveness of an alternative, discussing how the alternative provides human health and environmental protection.

7.3.1.2 Compliance with ARARs

Compliance with ARARs assesses whether an alternative is consistent with regulations applicable to the site and, if not, the basis for the inconsistency.

7.3.2 Balancing Criteria

The balancing criteria are the technical criteria upon which the detailed analysis is primarily based. These criteria include long-term effectiveness and permanence; reduction of toxicity, mobility, and volume through treatment; short-term effectiveness; implementability; and costs.

7.3.2.1 Long-Term Effectiveness and Permanence

Long-term effectiveness addresses the protection of human health and the environment after the RAOs have been met. In evaluating alternatives for their long-term effectiveness, the analysis considers: the ability to perform intended functions such as containment or removal; the adequacy and reliability of long-term engineering or institutional controls; and long-term performance, operation, and maintenance requirements.

7.3.2.2 Reduction of Toxicity, Mobility, and Volume Through Treatment

This criterion evaluates an alternative's ability to meet the statutory preference for treatment as a principal element of remediation. For each alternative, reduction of the toxicity, mobility, and volume of impacted material achieved through treatment are discussed. This criterion includes the permanence of the remedy and the nature of residuals remaining after treatment.

7.3.2.3 Short-Term Effectiveness

Short-term effectiveness evaluates the alternative during construction and implementation until RAOs are achieved. Specific considerations include potential exposures to the community, environment, and on-property workers during construction and the relative duration of the alternative to achieve RAOs.

7.3.2.4 Implementability

Implementability addresses the ability to implement an alternative, as well as both technical factors involved in implementation and administrative issues. Considerations include the relative ease of installation (constructability) and technical feasibility of implementing the selected technologies at the site (including compatibility with site features, site constraints and limitations, and accessibility of the area), administrative feasibility of coordinating implementation of the alternative among various state and federal agencies, acquiring required permits and approvals, and the availability of the technologies services, equipment, and materials necessary for implementation.

7.3.2.5 Cost

This criterion considers the costs associated with implementing an alternative. The cost discussion includes a breakdown of capital costs and annual operations, maintenance, and monitoring costs. Cost estimates are based on conceptual designs of the remedial alternatives. Labor and material costs are estimated from published unit costs and experience on similar projects; contractor and vendor bids generally are not obtained. CERCLA guidance indicates that an accuracy of +50 percent to -30 percent is acceptable for the estimated costs. Actual project costs may vary depending on the final design of the remedial system, site conditions, additional evaluations, regulatory and community requirements, and availability of labor and materials at the time of implementation. A net present value cost will be developed for each alternative using an appropriate discount rate. For systems that are anticipated to be operated in perpetuity, cost estimates are based on a maximum duration of 30 years, consistent with CERCLA guidance.

7.3.3 Modifying Criteria

There are two modifying criteria: state support/agency acceptance and community acceptance. Assessment of these criteria are generally not completed until after public comment on the Draft RI/FS Report.

7.4 SELECTION OF A PREFERRED ALTERNATIVE

After each of the potential remedial alternatives has been evaluated based on the nine NCP-required evaluation criteria, and a preferred alternative is identified, the preferred alternative is selected. After finalization of the FS, a more detailed remedy design will be completed and presented in the Remedial Action Plan (RAP) and Remedial Design (RD) reports. The level of detail provided in the FS for each design should be adequate to support decision making regarding the identification of a preferred remedial alternative. The RAP and

RD reports will provide the more detailed design and planning required for implementation of the selected remedial alternative.

8.0 DATA MANAGEMENT PLAN (DMP)

This section provides the DMP for project data records generated during the RI/FS. The primary purpose of the DMP is to communicate to users and decision makers how the RI project data will be handled both in the field and in the office. This DMP establishes standardized procedures and formats for nonprivileged documents and environmental data (field and laboratory) generated during the RI/FS. The DMP includes guidance for:

- obtaining project data records,
- storing data in the project database,
- reporting project data, and
- maintaining project files.

The project database is designed to maintain the organization of complex environmental information using a relational structure of data tables. This structure enables both historical and new data to be effectively stored so that specific descriptive facts (field sampling, geographical location, analytical data, etc.) are contained in separate tables but remain related to one another by key information fields. Consequently, queries for tracking and securing technical data records about a study area, treatment system operation, sampling location, or monitoring station, from sample collection through receipt of analytical results and data validation records, can be completed effectively and can draw together meaningful information to address project objectives.

8.1 PROJECT DATA RECORDS

Effective data management is essential to provide consistent, accurate, and defensible documentation of data quality. Project data records will include identifying descriptive information, geographical information, and results of field and laboratory measurements associated with air, water, soil, sediment, and biota sample collection. Project data records will also include meteorological data corresponding to sample collection activities.

Environmental data obtained during the RI will be documented using one of three methods. Primary data documentation consists of raw data gathered directly during field activities. Secondary data documentation consists of transcribing the raw data into a usable and computer accessible format. Tertiary data documentation is data that has been appropriately reviewed and can be used for technical decisions during the RI/FS. Together, these data is considered part of the permanent data record.

8.1.1 Field Data Management

Field data will consist mainly of manual transcription of records, measurements, and observations recorded directly into field data logbooks, or using field data sheets, or electronic field notebooks. These field documentation methods will be used to record events that occur during a particular field activity, as well as measurement readings and other pertinent information such as soil boring logs or monitoring well construction forms. The chain-of-custody (COC) forms will be used to document the collection, transport, and receipt of samples from the field to the laboratory. Standardized field forms have been developed and are included in the SAP (Appendix C). Within the SAP, a FSP, QAPP, and the SOPs are provided. Further details regarding field records and COC procedures are outlined in the FSP, QAPP, and SOPs.

To avoid alteration, damage, or loss of field data during the RI/FS, it will be the responsibility of the field task manager to ensure that at the conclusion of any field activity, all field data (i.e., logs, field sheets, photographs, etc.) will remain in the project field office until documents can be placed into the permanent project file.

8.1.2 Receipt of Project Data

Newly generated field and laboratory data will be transcribed to electronic data formats consistent with the requirements for the project database. To enable efficient and accurate documentation, tracking, retrieval, use, and presentation of the project data, these electronic deliverables will be uploaded into the primary project database.

Electronic copies of analytical reports will be provided by the subcontract laboratory. These reports will contain all analytical results and supporting QC documentation. Laboratory reporting requirements are specified in the QAPP. Any written documents and forms presented in the analytical reports will be reviewed as described in the QAPP and maintained in the project files.

8.1.3 Sample Tracking

Knowledge of the status of samples and analytical data reports produced during the RI/FS will be the primary goal of data tracking. The Database Manager is responsible for this tracking. Knowledge of field activities, sample collection events, and laboratory processes is critical to sample tracking.

To track samples, the Database Manager will perform the following tasks:

- Review FSPs.

- Readily retrieve COC information.
- Receive field records from the project field office.
- Receive Electronic Data Deliverables and copies of the analytical report from the lab.

To assist the Database Manager, the Project Quality Assurance (QA) Manager will perform the following tasks:

- Check the completeness of the analytical report.
- Manage the validation of the analytical data.
- Resolve any discrepancies with the laboratory.
- Compile data validation reports for the project file.

The Database Manager will work closely with the Project QA Manager to ensure that the information in the project database correlates to the records on the hardcopy analytical report and respective data validation reports.

8.1.4 Data Validation Records

The accuracy and precision of the data values will be compared to set QC criteria as described in detail in the QAPP. Figure 13 of the SAP depicts the plan for managing the validation of laboratory data during the RI. The Project QA Manager is responsible for managing all data reviews and ensuring that all records become part of the permanent project file.

8.2 PROJECT DATABASE

The database software to be utilized is Microsoft Access. The Access database system will be used to archive, manage, access, and tabulate sample data collected at the site. Once received, all electronic data will be compiled in the project database. The project database will serve as a comprehensive management tool for compilation of historical and ongoing investigations. Computerized data records will be archived to secondary back up computer media to ensure integrity of the data in the event of failure of the primary computer storage media.

8.2.1 Types of Data

The project database is comprised of site-related data collected since the 1950s.

All data in the project database have been categorized based on data type as follows:

- surface water chemistry,
- surface water flow and water levels,
- sediment chemistry,
- soil chemistry and physical properties,
- groundwater monitoring well details,
- groundwater chemistry and water levels,
- water treatment data,
- biota data, and
- climate data.

Ongoing data collection efforts conducted by different entities provide site-related information used to populate the project database. The entities providing this ongoing data are as follows:

- **Lahontan Regional Water Quality Control Board (LRWQCB)—**Provides surface water quality monitoring data, influent and effluent water quality and sludge data from the LRWQCB Treatment System of Adit No. 5 and PUD water, and climate data from an on-property meteorological station.
- **Nevada Division of Environmental Protection (NDEP)—**Provides surface water quality data for selected monitoring sites in the Carson River Basin.
- **U.S. Geological Survey (USGS)—**Provides provisional and published streamflow and stream level data from automatic gauging stations corresponding to several LRWQCB surface water monitoring stations; and
- **U.S. EPA Region 9—**Provides additional site-related data from multiple sources such as benthic macroinvertebrate and sediment data.

8.2.2 Electronic File Deliverables (EDDs)

The analytical laboratories will provide EDDs by e-mail. These EDDs will contain only final data (no preliminary data). The Database Manager will keep a replicate copy of all EDDs so as to not alter the original field. All changes, revisions, or other edits to the original EDD will supersede any previous versions of the EDD.

The database manager will verify that the EDD file was received. Any analytical data provided by the laboratories that cannot be formatted into an EDD will be manually entered into an electronic file for upload into the project database. All manually entered data will receive an independent quality check by the Database Manager. The Database Manager will document this quality check in an appropriate manner (i.e., initialing the original deliverable used for transcription purposes).

Prior to loading data into the project database, the EDD will be checked for error and inconsistencies to ensure its accuracy and correctness. Any errors will be corrected prior to loading the final data set. The Database Manager will be responsible for evaluating the accuracy of the following prior to data loading:

- field sample identification numbers,
- duplicate project sample identification numbers,
- parameter names and synonyms, and
- sample collection date.

The Database Manager will be supported by the Project QA Manager to assess the accuracy of the information in the incoming EDD file. The EDD will be included in the data validation process and loaded into the project database after verification is completed and any associated data validation qualifiers have been added to the sample results. The process for data validation and the definitions for data validation qualifier codes are described in the QAPP.

8.2.3 Data Access

The permanent project record will include final reports and database downloads available on the Internet with World Wide Web access, file transfer protocol, and e-mail. Local storage of data sets and programs are described below.

- **World Wide Web Access—**The project Web site or FTP site will have a copy of the project database and data sets stored on other sites such as LRWQCB and USGS. Authorized users are able to create queries based on specific criteria, such as location, date/time, matrix type, and a range of values contained within the data set. In addition, U.S. EPA Region 9 is responsible for maintaining a Superfund Web site (www.epa.gov/region09/superfund/superfundsites.html) for access to site-related documents.

- **File Transfer Protocol (FTP)—**Establishment of FTP capabilities will enable easy transfer of documents and files between Internet users.

- **E-mail—**E-mail capability will permit the convenient exchange of information among users who will be able to interface with the Web site.

- **Geographical Information System (GIS) —**Project data will be presented in a GIS format.

- **Community Access—**There are four repositories to allow public access to project documents and data, as follows:

  Alpine County Library
  270 Laramie Street
  Markleeville, California 96120
  (530) 694-2121

  Douglas County Library
  1625 Library Lane
  Minden, Nevada 89423
  (775) 782-9841

  Nevada State Library and Archives
  100 North Stewart Street
  Carson City, Nevada 89701
  (775) 687-5160

  Superfund Records Center
  95 Hawthorne Street, Room 403
  San Francisco, California 94105
  (415) 536-2000

In accordance with the RI/FS SOW, all data records will be retained in the project file for a period of 10 years.

8.2.4 Data Maintenance

Maintenance of components that make up the data infrastructure (systems that store, back up, archive, etc.) and network systems will be monitored on a monthly basis to ensure that ongoing data storage and access needs are efficiently managed. Data will be protected from system failure, accidental damage, catastrophic failures, and intrusion. State and federal guidelines for data management will be observed to ensure data remains retrievable in the future.

The project database resides on a network server which is also stored on redundant, mirrored hard drives to protect against data loss in case of hard-drive failure. These drives are mounted in a custom file server protected by an uninterruptible power supply.

8.3 DATA REPORTING

After the completion of focused field programs and at the conclusion of the RI/FS, illustrations, charts, tables, and other visual displays will be used to organize, evaluate, and present the RI/FS data for reporting purposes. A formal review and approval process will be conducted by Atlantic Richfield before any report is submitted to the U.S. EPA. Draft and final documents will be distributed as prescribed in the UAO. Reports will also be posted to the project server. All presentation materials and reports will be archived along with field and laboratory data.

8.3.1 Data Presentation

Investigation data will be extracted from the project database and presented using tables, figures, and Geographic Information Systems (GIS) tools, as appropriate for reporting purposes. The project database has been reviewed to address project objectives, data, and application needs of the RI/FS. A common schematic has been established for the project database to facilitate use by the various stakeholders. Specific activities associated with this effort include establishment of a controlled vocabulary (e.g., chemical names, sample locations, units of measure), utilization of vertical and horizontal information, and a process to tie together key historical data sets into the project database. The project database will provide spatial referencing that can be used by AutoCAD programs or GIS programs such as ArcInfo and ArcView, so that data can be used as effectively as possible.

8.3.2 Reporting Data to the U.S. EPA

To comply with the SOW, newly generated data will be provided to the U.S. EPA in an electronic format compatible with U.S. EPA data management systems, including global positioning system (GPS) information, using the established FTP site. The copy of the project database provided on the FTP site is a standardized data management, evaluation, and reporting system that serves as the mechanism for data sharing among project participants.

Data will be submitted to the U.S. EPA periodically with semiannual progress reports, as well as upon request by the U.S. EPA during periods of increased data collection activities.

8.4 MANAGEMENT OF PROJECT FILES

The project files will contain an accurate record of all activities conducted and information generated during the RI/FS.

8.4.1 Hard-Copy Files

Hard-copy files will be generated for project plans, activities, and results for the RI/FS. Hard-copy files may be in paper format or as PDFs stored on electronic media (i.e., CD-ROM or DVD).

8.4.2 Electronic Files

Electronic files will be obtained for environmental data generated for the RI/FS. Electronic files are posted to the project server and can be accessed by anyone who is an approved user.

8.4.3 Document Control

Document controls are established to ensure that documents are accurately inventoried and maintained in the project files. Document control numbers will be assigned to each deliverable document produced during the RI/FS. Documents are labeled with the appropriate control number, placed in the project files, and listed on the master project file log for ease of access and reference. Documents that are privileged (e.g., attorney work product or attorney-client privileged) will be maintained separately and are not addressed under this DMP or by the aforementioned procedures.

9.0 PROJECT MANAGEMENT PLAN

The RI/FS is an integral part of the overall Leviathan Mine Site Remediation Project. As such, this activity will be managed/controlled in accordance with the RI/FS Program Work Plan and Project Management Plan in compliance with the UAO.

9.1 PROJECT ORGANIZATION

This section presents the organization of the project and provides a brief description of the responsibilities of key Atlantic Richfield personnel and contractors associated with the RI/FS. The organization of the RI/FS project team is also shown on Figure 1 of the QAPP, which is presented in Appendix B of the SAP (Appendix C of this Work Plan). Certain RI/FS tasks may be performed by other entities, including the LRWQCB. Those tasks and entities are not included in the following discussion.

To the extent required under the UAO and consistent with work plans submitted to and approved by the U.S. EPA, Atlantic Richfield will be responsible for the following activities:

- Prepare planning documents.
- Perform RI and FS investigations (some activities will be shared with the USGS and LRWQCB).
- Prepare reports documenting the completed work with an interpretation of the results.
- Distribute the RI/FS work plans, data reports, and technical memorandums.
- Distribute progress reports on a quarterly basis.
- Distribute database/GIS updates (with information from LRWQCB, USGS, and others, as appropriate).
- Participate in stakeholder, agency, community relations, and Technical Advisory Committee (TAC) meetings, as requested by the U.S. EPA.
- Coordinate planning meetings and teleconferences.
- Coordinate on-property kick-off meetings prior to initiating new on-property activities.
- Approve QAPP and appropriate Quality Assurance (QA) corrective actions, as necessary.

The following roles and responsibilities are identified for the RI/FS.

RI/FS Project Manager

- Oversees UAO activities and communication.
- Provides strategy development, budget control, and schedule updates.
- Responsible for resource management.
- Reviews and provides technical quality to work plans and reports.
- Administers tasks upon U.S. EPA approval of the RI/FS and FRI work plans.
- Responsible for interacting with the U.S. EPA and Atlantic Richfield.
- Oversees RI field activities, procedures, activities, and project schedule.
- Assigns technical responsibilities to project staff and subcontractors.
- Assures delivery of data and project deliverables to Atlantic Richfield and the U.S. EPA.
- Implements necessary action, and as appropriate changes orders, for activities to accomplish project objectives.
- Checks field procedures.

RI/FS Project Coordinator

The RI/FS Project Coordinator will coordinate with the Atlantic Richfield Health and Safety Oversight, and coordinate activities of the Technical Managers, and will provide a liaison between them and the Project Manager. The Project Coordinator will also have the following responsibilities:

- Schedules, commits, and coordinates appropriate and subcontractor resources.
- Provides project leadership and direction.
- Monitors meeting schedule and budgetary goals.
- Ensures acceptability and timely submission of project deliverables.
- Assures implementation of QAPP requirements.

RI/FS Technical Managers

The RI/FS Technical Managers will be responsible for assisting the Project Manager and the Project Coordinator in coordination of the RI/FS activities. They will also be responsible for the daily operations of the project, including the following:

- Manage the technical personnel.
- Report progress to the Project Manager.
- Conduct field activities.
- Comply with the HASP and Quality Assurance/Quality Control (QA/QC) Plan procedures.

RI/FS Health and Safety Officer

The RI/FS Health and Safety Officer will be responsible for overseeing the health and safety aspects of the field activities associated with the RI/FS activities. This responsibility will include implementing the Site Health, Safety, Security, and Environment (HSSE) Program Document as well as the Task-Specific HASP RI/FS activities. The Health and Safety officer will coordinate with the Project Manager and Project Coordinator.

RI/FS Quality Assurance Manager

The RI/FS Quality Assurance Manager will be responsible for overseeing field, office, and laboratory activities associated with this project, in accordance with the QAPP prepared for this Work Plan. The Quality Assurance Manager will also be responsible for coordinating the periodic Performance Audits and System Audits specified in the QAPP to assess whether the data meets QA/QC requirements. Nonconforming activities will be documented in writing and corrective actions will be instituted, as necessary. The Quality Assurance Manager will report directly to the Project Manager and will be independent from the technical staff. The Quality Assurance Manager will confer on a regular basis with the Project Coordinator to assess upcoming project activities and schedule surveillances and audits.

In addition to the above, the following positions will make up the technical management and staff:

- Feasibility Study Manager
- Risk Assessment Manager
- Field Staff

- Data Review Chemists
- Technical Subcontractors
- Analytical Laboratories

The Field Coordinator and Field Study Manager will lead the daily activities of the remedial investigation and data collection. The Quality Assurance Manager will be responsible for implementing the appropriate quality assurance procedures as described in Appendix B of the SAP. The QA/QC personnel will operate independently of the technical staff. Coordination between the QA/QC staff and technical staff will be the responsibility of the RI/FS Project Manager. In addition, the RI/FS Project Manager will be responsible for providing the Health and Safety Officer and the QA/QC personnel.

9.2 AGENCY ROLES AND RESPONSIBILITIES

After Atlantic Richfield has been authorized to carry out the RI/FS activities in accordance with the CERCLA requirements and U.S. EPA procedures, the U.S. EPA will be responsible for the following:

- Review, provide stakeholder comments on, and respond to all work plans, scopes of work, reports, and determine the most appropriate RD or other remedial action (RA), as necessary.
- Maintain the U.S. EPA System of Registries.
- Schedule and coordinate stakeholder, agency, community relations, and TAC meetings.
- Implement the CIP, maintain the project Web site for the community, and prepare fact sheets.
- Determine a ROD upon completion of the RI/FS investigation.

This Work Plan and subsequent FRI work plans will describe detailed procedures and criteria by which the RI/FS will be performed and developed by Atlantic Richfield. After approval by the U.S. EPA, the Work Plan and FRI work plans shall also be incorporated by reference into the UAO. It is the responsibility of the U.S. EPA to ensure the quality of the effort of Atlantic Richfield conducting the RI/FS. Therefore, the U.S. EPA will establish oversight procedures and project controls to ensure that the response actions are consistent with CERCLA and the NCP. The U.S. EPA will determine contractor and staff resources required for oversight and initiate planning the necessary oversight requirements.

The contact for the U.S. EPA, also known as the Remedial Project Manager (RPM), and alternate are listed below.

Kevin Mayer, Primary RPM
75 Hawthorne Street SFD 7-2
San Francisco, CA 94105
Office: (415) 972-3176
Fax: (415) 947-3526
E-mail: mayer.kevin@epa.gov

Gary Riley, Alternate RPM
75 Hawthorne Street SFD 7-2
San Francisco, CA 94105
Office: (415) 972-3003
Fax: (415) 947-3528
E-mail: riley.gary@epa.gov

9.3 Reporting Requirements

Atlantic Richfield will follow the reporting requirements set forth in the UAO and SOW. Those reporting requirements are listed in the paragraphs below.

Atlantic Richfield shall make presentations at and participate in meetings at the request of the U.S. EPA during the initiation, conduct, and completion of the RI/FS. In addition to discussion of the technical aspects of the RI/FS, topics will include anticipated problems or new issues. Meetings will be scheduled at the U.S. EPA's discretion.

As required by the UAO, Atlantic Richfield shall provide to U.S. EPA quarterly progress reports by the 10th of January, April, July, and October. Upon request from Atlantic Richfield, U.S. EPA may alter the due dates for these progress reports or allow their incorporation into reports submitted by Atlantic Richfield pursuant to any administrative settlement agreement for implementation of removal actions at the site. At a minimum, with respect to the period since the last report, these progress reports shall:

- describe the actions that have been taken to comply with the UAO;
- describe work planned for the next quarter with schedules relating such work to the overall project schedule for the work; and
- describe all problems encountered and any anticipated problems, any actual or anticipated delays, and solutions developed and implemented to address any actual or anticipated problems or delays.

These reports shall not be considered a substitute for notification to U.S. EPA in the event of an occurrence requiring emergency response. In addition, more frequent progress reports may be required during performance of certain work activities.

All results of sampling, tests, modeling, or other data (including raw data) generated by Atlantic Richfield, or on Atlantic Richfield's behalf, during implementation of the UAO, and not previously submitted to U.S. EPA or the database, shall be submitted to U.S. EPA in an annual database update or, if the RPM so directs, in the subsequent quarterly progress report as described in Section XII of the UAO.

9.4 HEALTH AND SAFETY CONSIDERATIONS

The site Health, Safety, Security, and Environment (HSSE) Program Document and the Task Specific HASP RI/FS activities were developed for this project based on past investigative activities at the Leviathan Mine site and in accordance with the guidelines set forth by Atlantic Richfield. The HASP has been prepared in compliance with the Occupational Safety and Health Administration (OSHA) and the Hazardous Waste Operations and Emergency Response Standard (29 CFR 1910.120). The purpose of the site HSSE Program Document is to:

- provide a description of the Atlantic Richfield Remediation Management safe work procedures;
- identify the general potential physical and chemical hazards that may be encountered;
- outline emergency response procedures; and
- specify the requirements for the contractor specific HASPs.

The purpose of the Task Specific HASP for RI/FS activities is to:

- identify the potential physical and chemical hazards that may be encountered while working at the site;
- outline company specific emergency response procedures;
- provide health and safety control measures to be followed during implementation of RI/FS activities;
- identify health and safety supervisory personnel and their responsibilities, medical surveillance and training requirements, personal protective equipment (PPE), required air monitoring, and decontamination protocols;

- provide ongoing site monitoring to verify and validate safety requirements are being complied with and revise specific protection levels as required; and
- protect the general public and the environment.

The level of protection required for personnel working on the project during the majority of the field work is expected to be Level D with the addition of either work-type gloves or nitrile gloves when collecting samples. Health and Safety monitoring during field activities will be conducted. The level of protection may be modified at any time in accordance with new data acquired during the course of the project. Key elements of the requirements established have been included in the Task Specific HASP, RI/FS activities (Appendix D).

9.5 CONTRACTOR, LABOR, AND EQUIPMENT AVAILABILITY CONCERNS

The concerns regarding availability of contractors, labor, and equipment are related to the basic concern of performance with the project schedule. The availability of qualified contractors with an adequately skilled and trained labor pool is a factor critical to timely and competent performance of the RI.

The site is located in a remote area and the nearest contractors specializing in drilling, earthwork, and remote sensing are located at least two hours from the site (near either Reno, Nevada, or Sacramento, California). Currently, Atlantic Richfield uses contractors from Reno and Sacramento. It is not anticipated that major problems such as schedule delays will occur with regard to contractor or labor availability during the project; however, because of the remoteness of the site, the following two strategies will be pursued to minimize any potential delays to the schedule due to the availability of materials and equipment.

- procuring subcontractors and equipment early on in the process, and
- identifying and soliciting backup sources of materials and equipment at the time of selecting primary suppliers.

9.6 STRATEGY TO IMPLEMENT

A QAPP has been prepared for work involving the RI/FS activities. This QAPP has been prepared in general accordance with U.S. EPA Requirements for Quality Assurance Project Plans (QA/R-5; U.S. EPA, 2001a), and “Guidance for Quality Assurance Project Plans” (QA/G-5; U.S. EPA, 2002b). The QAPP is presented in Appendix B of the SAP (Appendix C of PWP).

This RI/FS Work Plan and QAPP will be considered the project controlling documents. Work on the project will be conducted according to the methods described in the most current version of these documents. The technical staff and the QA staff will receive controlled copies of work plans and revisions. The QA staff will be responsible for issuing work plans and revisions and for preparing and issuing controlled copies of the QAPP. It will be the responsibility of each individual in the technical and QA staff to incorporate revisions to the Work Plan and QAPP in a timely manner.

The QA staff is independent, and will not have technical responsibility on the project. The Coordinator of Quality Assurance (CQA), reports directly to the RI/FS Project QA Manager and indirectly to the RI/FS Project Coordinator. The CQA has the authority and responsibility to stop work if the QA objectives are not met.

To assess that data quality is known, documented, and satisfies the DQOs specified in the QAPP, surveillances will be scheduled and performed for selected tasks. These surveillances will be conducted by the QA staff, or qualified individual, with no project responsibility and who reports to the CQA. The purpose of these surveillances will be to document that the performance of the selected tasks is in compliance with the Work Plan and QAPP. These surveillances are specified in the QAPP. In addition, audits will be performed on the project by a certified Lead Auditor. The number of audits performed is presented in the QAPP. The audits are intended to evaluate the effectiveness of the QA program and to verify compliance with the stated QA objectives.

10.0 RI/FS PRIORITIZATION AND SCHEDULE

This section provides a prioritization and general schedule for upcoming RI/FS activities as required by the UAO/SOW and as requested in the April 23, 2009, letter from U.S. EPA approving the DQO Report and directing Atlantic Richfield to prepare this PWP (U.S. EPA, 2009d). The April 23, 2009, U.S. EPA letter directed Atlantic Richfield to submit the FRI work plans for subsurface monitoring and for mapping of the downstream watershed in order to facilitate work in 2009 and by this direction these FRI work plans became the first prioritization for the RI/FS program. U.S. EPA April 23, 2009, letter also indicated that upon review of the PWP, U.S. EPA will direct submittal dates for subsequent FRI work plans to ensure that all RI/FS objectives will be addressed effectively and in a timely manner.

10.1 PRIORITIZATION

As described in the RI/FS guidance and in Sections 1 and 4 of this PWP, the major objectives of the RI/FS site characterization are to:

- define source areas of contamination;
- evaluate potential pathways to the extent necessary to evaluate whether or not and to what extent a threat to human health or the environment exist now or in the future; and
- evaluate remedial alternatives.

These objectives will be met by performing the tasks described in Section 5 and in the FRIs according to the priority tiers described in Section 4.5.

High Priority

- high potential current or future exposure to human health or the environment; and
- data collection or response actions necessary to study or address other areas.

Moderate Priority

- moderate current or future potential exposure to human health or the environment;
- potential response actions could recontaminate areas located downstream, downwind or downgradient; and
- unusual complexity of problems that could require lengthy evaluation.

Low Priority

- low current or future potential for exposure to human health or the environment; and
- low risk of recontamination of other areas.

This prioritization will be used in Section 10 to plan and implement the RI work.

Strictly following the guidance, on-property work would take precedent over off-property work because these areas represent the greatest current or future potential exposure to human health and the environment and are most relevant to the selection of the final remedy. However, the guidance also provides the direction to consider schedule and to collect data to characterize the site and develop a baseline risk assessment. In order to accomplish this objective, an integrated schedule for collection of risk assessment data needs to be developed so that data is available at the appropriate time in the RI/FS process.

Some of the RI tasks may require more than one year of study to collect the data necessary to complete the analysis. Groundwater monitoring is a good example of one of these tasks. Some tasks need to be completed in sequential order to develop the information necessary to complete the subsequent task properly (e.g., hydrogeologic characterization prior to monitoring well installation). In these cases the up front data necessary to complete the later study needs to be prioritized. In general, the overall prioritization objective will be to have most of the data collection on somewhat concurrent timelines so that the RI and the risk assessments will come to fruition at a coordinated time in the future.

The following subsections include a description of the Tier 1, Tier 2, and Tier 3 priorities and a list of the tasks included within each category. The tasks are identified either by the site-wide tasks or by study area specific tasks. The site-wide tasks include water balance studies (WB), bioassessment investigations (BIO), hydrogeologic investigations (HY), geotechnical investigations (GT), stormwater and snowmelt runoff investigations (SS), surface water and sediment geochemical investigations (SW), and background studies (BG). Study area specific tasks include the PSA, ACSA, LCSA, and DSA. For example, HY-5 indicates the fifth task in the site-wide hydrogeologic investigation. For more complete task descriptions, refer to Section 5 or Table 51.

10.1.1 Tier 1 Priority

Based on the rationale presented above, the following RI tasks are considered a Tier 1 priority. These activities include initiation of the background study, investigation, and confirmation of mine features and reconnaissance and mapping activities necessary as prerequisites to more intrusive investigations to follow.

- Task BG-1—Groundwater Background
- Task BG-2—Soil Background
- Task BG-3—Surface Water and Sediment Background
- Task WB-1—Meteorological Monitoring
- Task HY-1—Well Reconnaissance, Redevelopment, and Sampling
- Task HY-2—Deep Exploratory Borings
- Task SW-1—Surface Water Delineation
- Task SW-2—Sediment Mapping
- Task SS-1—Reconnaissance Mapping of Erosional Features
- Task ACSA-1—Soil Mapping, Sampling, and Chemical Analyses
- Task ACSA-2—Investigation of Mine Features
- Task ACSA-3—Source Investigation of Aspen Seep
- Task PSA-1—Soil Mapping, Sampling, and Chemical Analyses
- Task PSA-2—Investigation of Mine Features
- Task PSA-3—Investigation of Sources to the Pit, PUD, and Adit
- Task LCSA-1—Soil Mapping, Sampling, and Chemical Analyses
- Task LCSA-2—Investigation of Mine Features
- Task LCSA-3—Investigation of Sources to the CUD and DS
- Task DSA-1—Soil Mapping, Sampling, and Chemical Analyses

10.1.2 Tier 2 Priority

Consistent with the logic presented for Tier 1 activities, Tier 2 activities include second-phase and more intrusive investigation work based in most cases on the results of work conducted in Tier 1. Water balance data collection, storm water sampling, source investigation work, and installation of the groundwater monitoring system are Tier 2 activities.

- Task WB-2—Streamflow Measurements
- Task WB-3—Measurement of Surface Water–Groundwater Interactions
- Task BIO-1—Plant Sampling
- Task BIO-2—Habitat-Related Soil Sampling
- Task HY-3—Monitoring Well Installation and Hydraulic Testing
- Task SS-2—Storm Water and Snowmelt Monitoring
- Task ACSA-4—Shallow Groundwater Investigation
- Task ACSA-7—Storm Water and Snowmelt Runoff Investigations
- Task ACSA-8—Water Balance Studies
- Task BG-4—Plant and Fish Tissue Background
- Task PSA-4—Shallow Groundwater Investigation
- Task PSA-6—Water Balance Studies
- Task PSA-7—Storm Water and Snowmelt Runoff Investigations
- Task LCSA-5—Shallow Groundwater Investigation
- Task LCSA-7—Water Balance Studies
- Task LCSA-9—Storm Water and Snowmelt Runoff Investigations

10.1.3 Tier 3 Priority

Tier 3 activities consist of bioassessments and surface water and sediment investigations and investigation of any remaining sources. This would be the point in the process to assure that all of the data requirements of the RI and the risk assessment have been met. In the later part of Tier 3 as necessary to begin to assess ARARs, geotechnical investigations may be conducted.

- Task BIO-3—Fish Tissue Sampling
- Task BIO-4—Habitat-Related Sediment Sampling
- Task BIO-5—Habitat-Related Surface Water Sampling
- Task HY-4—Groundwater Monitoring

- Task SW-3—Surface Water Geochemical Characterization
- Task SW-4—Sediment Geochemical Characterization
- Task ACSA-5—Biological Investigations
- Task ACSA-6—Surface Water and Sediment Sampling in Aspen Creek
- Task PSA-5—Biological Investigations
- Task LCSA-4—Investigation of Ponding near Leviathan Creek
- Task LCSA-6—Surface Water and Sediment Sampling in Leviathan Creek
- Task LCSA-8—Biological Investigations
- Task DSA-2—Surface Water and Sediment Sampling
- Task DSA-3—Biological Investigations
- Task GT-1—Visual Inspection and Evaluation
- Task GT-2—Investigation for Storage Pond Expansion

10.2 SCHEDULE

The schedule for implementation of the RI/FS is highly dependent on the timeline for U.S. EPA review and approval of this PWP. The schedule also will depend on the extent to which RI/FS activities are assigned to and performed by other entities, including the LRWQCB. After comments to the PWP are received, there is typically a comment resolution process and the document will need to be revised and submitted as final, as required by the UAO. Atlantic Richfield will work cooperatively with U.S. EPA to facilitate this process in the most expedient time frame; however, it is difficult to estimate how long it will be before individual FRI work plans can be developed to facilitate additional work under the PWP. FRI work plans containing the detail for the work presented will need to be reviewed and approved in a time frame that allows implementation during the limited access and field season available for completing work at the site. As indicated above, U.S. EPA has indicated that it will direct submittal dates for subsequent focused work plans after reviewing this PWP.

With the considerations cited above, U.S. EPA has indicated that it would like to have the RI/FS complete within an approximate five-year time frame assumed to start from approval of the final PWP. The risk assessment work plans are being prepared and these plans will be submitted to U.S. EPA shortly after the PWP. Using this framework and the tiered data collection scheme presented above, the RI work presented would need to be completed within three to four years so that the draft RI and risk assessment reports could be completed in or around the end of the fourth year. The FS would follow approval of the RI and the risk assessments.

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