SAMPLING AND ANALYSIS PLAN

Remedial Investigation/Feasibility Study Program

Leviathan Mine Site

Alpine County, California

Prepared for:

Atlantic Richfield Company
La Palma, CA

Prepared by:

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July 10, 2009

Project 13091

AMEC Geomatrix

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LIST OF ABBREVIATIONS AND ACRONYMS

%R	percent recovery
ACSA	Aspen Creek Study Area
ADQ	audit of data quality
AMEC	AMEC Geomatrix, Inc.
ANSI/ASQC	American National Standards Institute/American Society for Quality Control
AO	Administrative Order
ARD	acid rock drainage
AS	Aspen Seep
BSA	Background Study Area
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
COC	chain-of-custody
COPC	chemical of potential concern
CPAR	Corrective and Preventive Action Request
CUD	Channel Underdrain
DFG	Department of Fish and Game
DMP	Data Management Plan
DQA	Data Quality Assessment
DQI	Data Quality Indicator
DQO	Data Quality Objective
DS	Delta Seep
DSA	Downstream Study Area
EDD	electronic data deliverable
FCR	field change request
FFS	Focused Feasibility Study
FRI	Focused Remedial Investigation
FSP	Field Sampling Plan
ft.	feet
ft/ft	vertical feet per horizontal feet
GIS	Geographic Information System
gpm	gallons per minute
GW	groundwater
HASP	Health and Safety Plan
HAZWOPER	Hazardous Waste Operations and Emergency Response
HSSE	Health, Safety, Security, and Environment
IS	invertebrate sample
LaMP	Laboratory Management Program
LCS	Laboratory Control Sample
LCSA	Leviathan Creek Study Area
LCSD	laboratory control sample duplicate
LD	laboratory duplicate
MSD	matrix spike duplicate
msl	mean sea level
MWH	Montgomery Watson Harza

LIST OF ABBREVIATIONS AND ACRONYMS
(continued)

PARCCS	precision, accuracy, representativeness, comparability, completeness, and sensitivity
PPE	personal protective equipment
PS	plant sample
PSA	Pit Study Area
PUD	Pit Underdrain
PWP	Program Work Plan
QA/QC	quality assurance/quality control
QAPP	Quality Assurance Project Plan
RI	Remedial Investigation
RI/FS	Remedial Investigation/Feasibility Study
RPD	relative percent difference
RPM	Remedial Project Manager
RWQCB	Regional Water Quality Control Board
SAP	Sampling and Analysis Plan
SB	soil boring
SMS	Site Management Strategy
SOP	standard operating procedure
SOW	statement of work
SS	stream sediment
SW	surface water
U.S. EPA	U.S. Environmental Protection Agency
U.S.	United States
UAO	Unilateral Administrative Order
USGS	U.S. Geological Survey
WS	waste sample

REMEDIAL INVESTIGATION AND FEASIBILITY STUDY SAMPLING AND ANALYSIS PLAN

Leviathan Mine Site
Alpine County, California

1.0 INTRODUCTION

This Remedial Investigation/Feasibility Study (RI/FS) Sampling and Analysis Plan (SAP) has been prepared by AMEC Geomatrix, Inc. (AMEC), on behalf of Atlantic Richfield Company (Atlantic Richfield). This SAP 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 ("site") (Figures 1 and 2). This SAP provides guidance for fieldwork activities and ensures that the sampling and data collection activities will meet the objectives of the RI/FS while being comparable to and compatible with previous investigations. It outlines the field procedures, sampling and data collection activities, and analytical procedures to complete the RI/FS tasks. This document has been prepared in accordance with the Guidance for Conducting Remedial Investigations and Feasibility Studies under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA; U.S. EPA, 1988).

This SAP represents Appendix C of the RI/FS Program Work Plan (PWP). This SAP consists of three components:

1. RI/FS Field Sampling Plan (FSP),
2. RI/FS Quality Assurance Project Plan (QAPP), and
3. RI/FS Standard Operating Procedures (SOPs).

The FSP provides guidance for the fieldwork that will be used to complete the tasks defined within the PWP (Appendix A). The QAPP establishes the policy, organization, functional activities, and quality assurance and quality control (QA/QC) protocols needed to achieve the laboratory Data Quality Objectives (DQOs; Appendix B). The SOPs establish the procedures, equipment, and documentation that will be used during the field investigations (Appendix C).

To the extent necessary, updates to the sampling and analysis procedures will be presented in the Focused Remedial Investigation (FRI) work plans.

1.1 LEVIATHAN MINE AND RI/FS STUDY AREAS

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.

The site is located near the eastern margin of the Sierra Nevada, approximately four miles west of the California/Nevada border. The regional topography consists of rugged mountains and high meadowlands that slope gradually towards the north.

As part of the Site Management Strategy (SMS) described in the DQO Report (Atlantic Richfield, 2008), the site has been divided into five study areas (Figure 4):

1. **Pit Study Area (PSA).** This area includes the entire pit area (reclaimed and not reclaimed portions), and the adit, Pit Underdrain (PUD), and clarifier areas (Figure 5).

2. **Aspen Creek Study Area (ACSA).** This area includes the overburden piles, the reach of Aspen Creek that passes by the eastern side of the site, and the historic landslide area (Figure 6).

3. **Leviathan Creek Study Area (LCSA).** This area includes the area west and north of the pit, as well as the storage ponds, diversion channel and Channel Underdrain (CUD), other surface water diversion structures, Delta Seep, and length of Leviathan Creek from above the site to the confluence of Leviathan and Aspen creeks (Figure 7).

4. **Downstream Study Area (DSA).** The DSA starts at the confluence of Leviathan and Aspen creeks and continues into the upper portion of Bryant Creek to the extent that impacts from the site that are above background concentrations are recorded (Figure 8).

5. **Background Study Area (BSA).** The BSA(s) will include areas with characteristics similar to those of the site where analog sites can be established to conduct background studies. These areas have not yet been defined.

The location and boundaries, physical description, results of previous studies, and conceptual model for each study area are presented in Section 3 of the PWP. 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.

1.2 PROBLEM STATEMENT

According to Paragraph 8 of the UAO, there are several sources of acid rock drainage (ARD) at the Site which may impact Leviathan Creek. When a release from the site occurs, it may flow into the Leviathan-Bryant Creek watershed. Unless treated, releases contain low pH and elevated concentrations of metals and metalloids, most notably arsenic, as well as iron, aluminum, chromium, cobalt, copper, nickel, and zinc.

A number of investigations have previously been performed at the site to identify and mitigate the impacts from ARD. However, much of the previous data has not been collected under sampling plans or QA/QC procedures that formally meet the requirements of the CERCLA Guidance (U.S. EPA, 1988). Therefore, these data may not be useable to characterize the nature and extent of contamination, assess risk, or evaluate potential remedial alternatives at the site.

1.3 PURPOSE

The purpose of this SAP is to ensure that sampling and data collection activities will be comparable to and compatible with previous data collection activities while providing a mechanism for planning and approving field activities. It describes the sampling equipment, field procedures, data and sample collection activities, and analytical activities that will be performed for the RI/FS.

1.4 SAP APPROACH

The SAP is designed to be a program document that provides guidance for the RI/FS field applications. Collectively, the SAP and FRI work plans establish the minimum requirements for sample and data collection activities for the RI/FS.

1.5 HEALTH, SAFETY, SECURITY, AND ENVIRONMENTAL (HSSE) EXPECTATIONS

The activities described in this document will be performed in accordance with the policies and procedures outlined in the Leviathan Mine Site HSSE Program Document (HSSE Program Document; ENSR, 2008) and the RI/FS Task Specific Health and Safety Plan (RI/FS HASP; AMEC, 2009). These documents are provided within Appendix D of the PWP.

2.0 BACKGROUND

This section includes a brief discussion of the Leviathan and Bryant Creek watersheds and the geology and hydrogeology at the site. Refer to Section 2.0 of the PWP for a more detailed discussion of the site history, background and physical characteristics.

2.1 THE LEVIATHAN AND BRYANT CREEK WATERSHED

Leviathan Mine lies adjacent to Leviathan and Aspen creeks, both of which are tributaries of the 31.5-square-mile Bryant Creek watershed (Figure 2). The 10.5-square-mile Leviathan Creek watershed ranges in elevation from 8,963 ft. msl at Leviathan Peak and flows north down to 6,400 ft. msl at the confluence of Leviathan and Mountaineer creeks, where it becomes Bryant Creek. Bryant Creek continues to flow to the north approximately 4 miles to the California-Nevada border and then an additional 3.5 miles to its confluence with the East Fork of the Carson River in Nevada.

2.2 GEOLOGY AND HYDROGEOLOGY

The following is a brief description of the site geology and hydrogeology. A detailed description of the site geology and hydrogeology is provided in Sections 2.4 and 2.5 of the PWP, respectively.

2.2.1 Geology

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 1; Clark, 1977). 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 geology at the site primarily consists of hydrothermally altered volcanic and volcaniclastic material, which is heterogeneously mixed with grain sizes that range between clay-sized and boulder-sized materials. A total of 27 geologic units have been identified at the site (Table 2). However, based on information obtained during drilling activities, the stratigraphy at the Leviathan Mine primarily consists of Quaternary-age artificial fill, including mine waste rock and overburden overlying the Tertiary-age upper sedimentary sequence (Table 2). A detailed description of the rock units at the site is provided in Section 2.4 of the PWP.

The site is tectonically active with known faults and mass movements. The site is faulted with many orientations, particularly in the area west and northwest of the open pit. Landslides, alluvial cover, and alteration obscure some of the faulting relationships. The largest landslides

include the Leviathan Creek basin landslide and the Delta Slope. The Leviathan Creek basin is a large (180-acre) bedrock structure slide on the north end of site (in the LCSA). The Delta slope is approximately 250 ft. long by 150 ft. wide and 80 ft. high and is located in the western part of the site (in the LCSA). Both slides are assumed to be active. Details of the tectonic activity at the site are provided in Section 2.4 of the PWP.

2.2.2 Hydrogeology

Four potential hydrostratigraphic units have been identified at the site. In order of increasing depth, these include:

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. thick.

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. Similar to 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 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.

Due to the topographic changes, the depth to groundwater is highly variable across the site and within each study area. 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). The localized groundwater flow toward the center of the pit has gradients that range between 0.08 to 0.6 ft/ft.

Additional details of the site hydrogeology, including evaluations of hydraulic conductivity and recent potentiometric surface maps, are provided in Section 5 of the PWP.

3.0 OBJECTIVES AND SCOPE

The following subsections describe the objectives and scope of this SAP.

3.1 OBJECTIVES

The objectives of this SAP are as follows:

- Provide guidance for RI/FS field and laboratory activities, data collection activities, and sample analysis activities so that the results will meet the objectives and tasks of the RI/FS.
- Ensure that sampling and data collection activities will be comparable to and compatible with previous data collection activities.
- Provide a mechanism for planning and approving field activities.

The objectives of the RI/FS are described in Section 1.2 of the PWP. Specific DQOs for the data collection and sampling activities will be provided in the FRI and Focused Feasibility Study (FFS) work plans.

The tasks developed in the PWP to meet the RI/FS objectives were divided between site wide or study area specific investigations. The site-wide investigations and tasks to be performed during the RI/FS are described in Section 5.1 of the RI/FS PWP. Study area-specific investigations and tasks to be performed during the RI/FS are described in Section 5.2 of the RI/FS PWP.

3.2 SCOPE

The scope of the SAP has been designed to fulfill the objectives and tasks presented above. It includes developing an FSP, QAPP, and SOPs for the planned investigations..

4.0 RI/FS FIELD SAMPLING PLAN

The FSP provides guidance for the fieldwork that will be performed to complete the tasks and objectives defined in the PWP. Refer to Appendix A for the FSP.

5.0 RI/FS QUALITY ASSURANCE PROJECT PLAN

The QAPP establishes the policy, organization, functional activities, and QA/QC protocols needed to achieve the laboratory DQOs. Refer to Appendix B for the QAPP.

6.0 RI/FS STANDARD OPERATING PROCEDURES

The SOPs establish the procedures, equipment, and documentation that will be used during the RI/FS. Refer to Appendix C for the SOPs.

7.0 REFERENCES

AMEC Geomatrix (AMEC), 2009, Task Specific Health and Safety Plan, Remedial Investigation/Feasibility Study Activities, Leviathan Mine Site, Alpine County, California, April.

Atlantic Richfield, 2008, Draft Data Quality Objectives Report: Remedial Investigations and Feasibility Study, Leviathan Mine, Alpine County: Prepared by AMEC Geomatrix, Inc., October.

Clark, W., 1977, Mines and Mineral Resources of Alpine County, California: California Division of Mines and Geology, County Report No. 8.

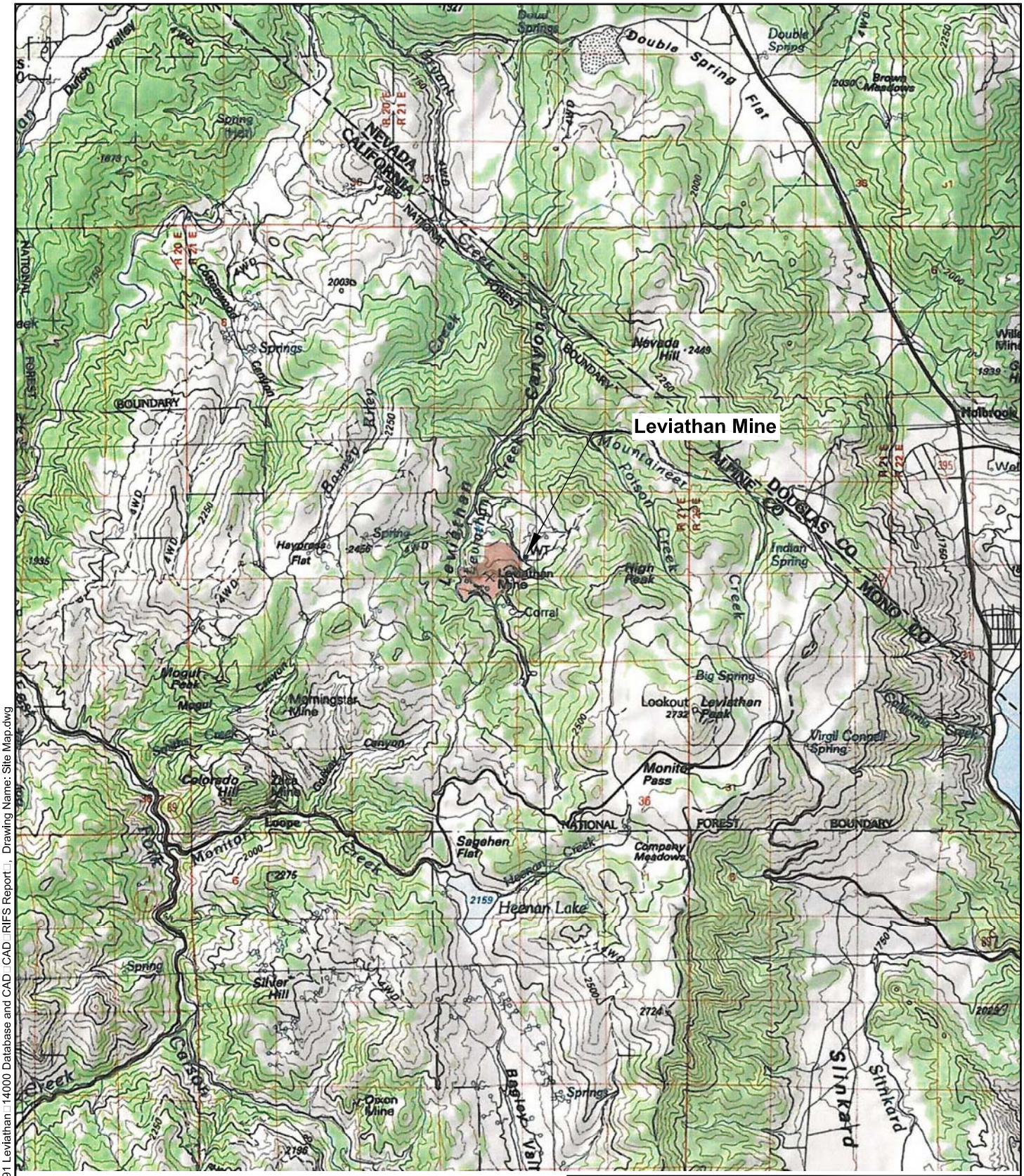
ENSR, 1999, Data Report for the Leviathan Mine Study Area Water and Sediment Toxicity Testing and Benthic Community Data: September 1998 Assessment.

ENSR, 2008, Leviathan Mine Site Health and Safety, Security, and Environmental Program Document: Prepared for Atlantic Richfield, May 27.

U.S. Environmental Protection Agency (U.S. EPA), 1988, Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA. Interim Final: OSWER Directive 9335.3-01, EPA/540/G-89/004, October.

U.S. EPA, 2009, Approval with Comments for Leviathan Mine Data Quality Objectives Report submitted October 2008, and Direction to Prepare Remedial Investigation and Feasibility Study Work Plan Pursuant to Administrative Order for Remedial Investigation and Feasibility Study, Leviathan Mine, Alpine County, California: CERCLA Docket No. 2008-18, April 23

FIGURES



Source: National Geographic USGS Topographic Maps (California)

SITE LOCATION MAP
Leviathan Mine Site
Alpine County, California

By: dpv	Date: 6/01/09	Project No. 13091A.109
AMEC Geomatrix		Figure 1

Plot Date: 06/30/09 - 9:44am, Plotted by: donna.valasek
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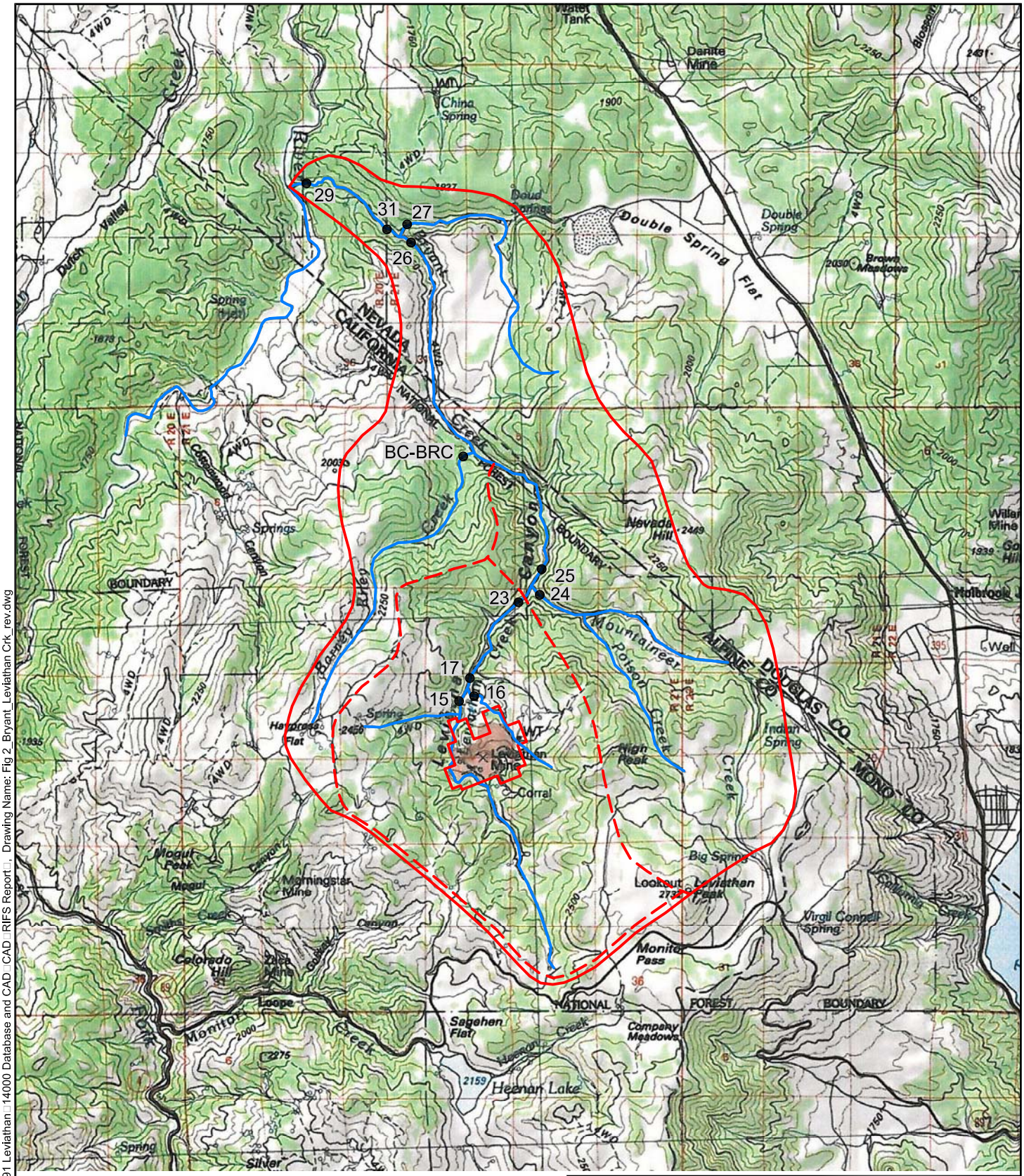

Explanation

- Leviathan Creek Watershed
- Bryant Creek Watershed
- ● 25 Surface Water Monitoring Location and Designation

N

APPROXIMATE SCALE IN FEET

0 8,000

Source: National Geographic USGS Topographic Maps (California)

BRYANT AND LEVIATHAN CREEK WATERSHEDS
Leviathan Mine Site
Alpine County, California

By: dpv	Date: 6/01/09	Project No. 13091A.109
AMEC Geomatrix		Figure 2

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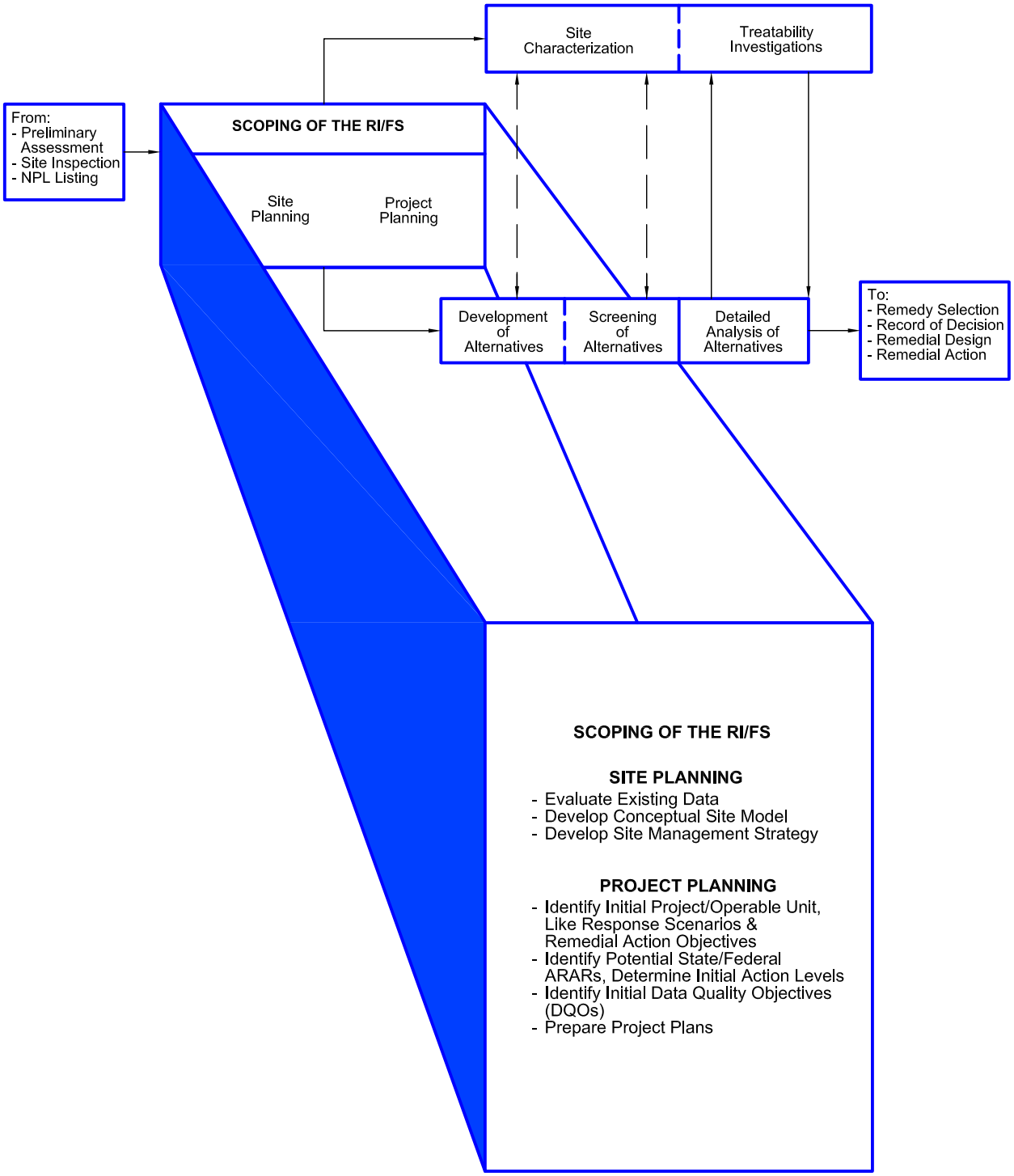

SCOPING OF THE RI/FS
Leviathan Mine Site
Alpine County, California

By: dpv	Date: 6/1/09	Project No. 13091A.109
AMEC Geomatrix		Figure 3

Reference: OSWER Directive 9335.3-01

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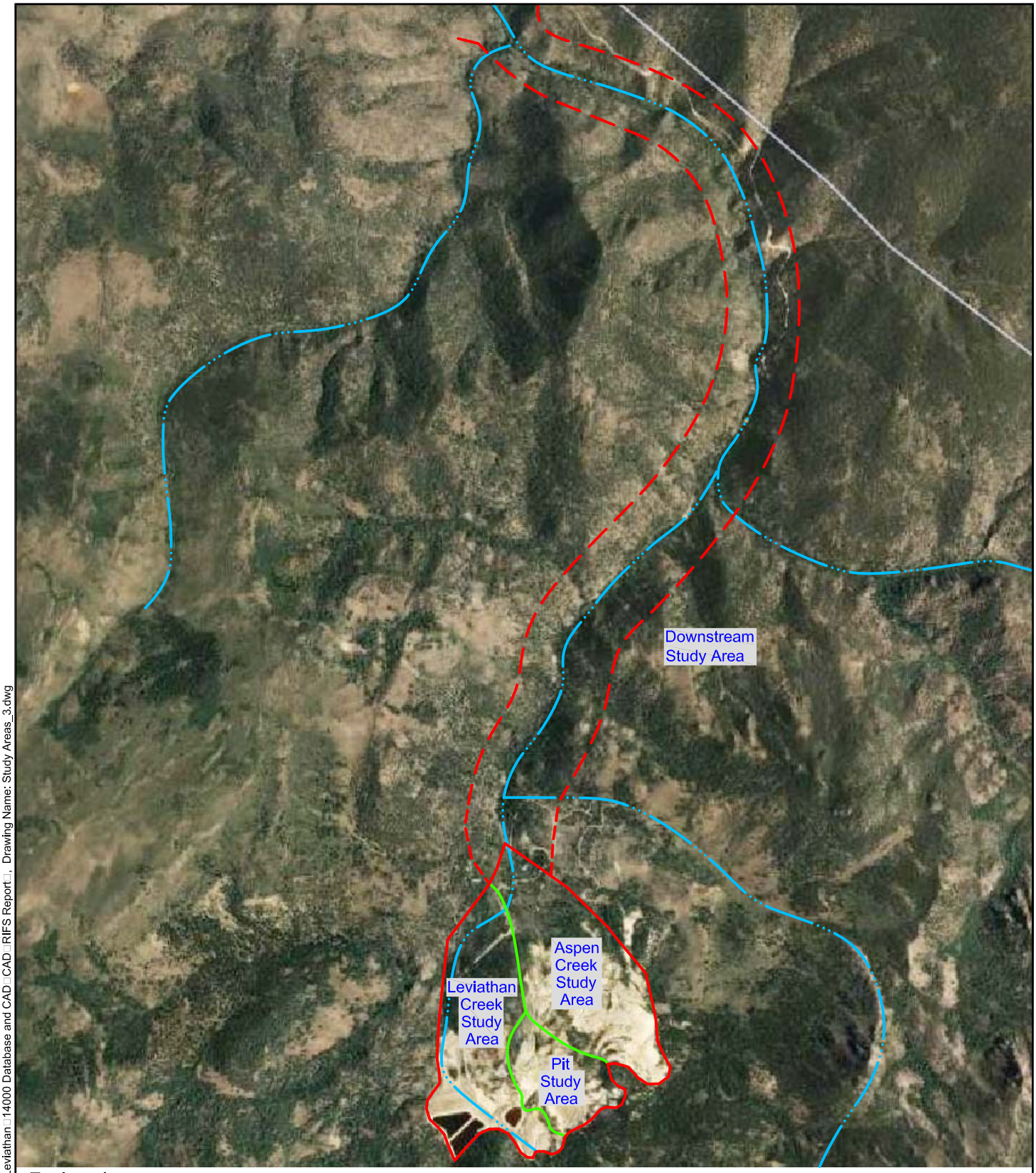

Explanation

- Downstream Study Area Boundary
- Study Area Boundary
- Limits of the Site
- Creek

Note

Background area will be identified in the future.

N

APPROXIMATE SCALE IN FEET
0 1,500

Source: 2008 Google Earth Pro

STUDY AREAS
Leviathan Mine Site
Alpine County, California

By: dpv	Date: 6/01/09	Project No. 13091A.109
AMEC Geomatrix		Figure 4

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Explanation

- Adit Tunnel
- Boundary of Study Area
- Approximate Location of PUD Features

Source: Summit Engineering, October 2, 2007

N

APPROXIMATE SCALE IN FEET
0 450

PIT STUDY AREA
Leviathan Mine Site
Alpine County, California

By: dpv	Date: 6/01/09	Project No. 13091A.109
AMEC Geomatrix		Figure 5

Plot Date: 07/02/09 - 4:36pm, Plotted by: donna.valasek
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Explanation

- Boundary of Study Area
- Creek
- Leviathan Creek Basin Landslide
- Discharge Point

Note

Aspen Creek Area extends off map to confluence of Leviathan Creek and Aspen Creek.

Source: Summit Engineering, October 2, 2007

N

APPROXIMATE SCALE IN FEET
0 700

ASPEN CREEK STUDY AREA
Leviathan Mine Site
Alpine County, California

By: dpv	Date: 6/01/09	Project No. 13091A.109
AMEC Geomatrix		Figure 6

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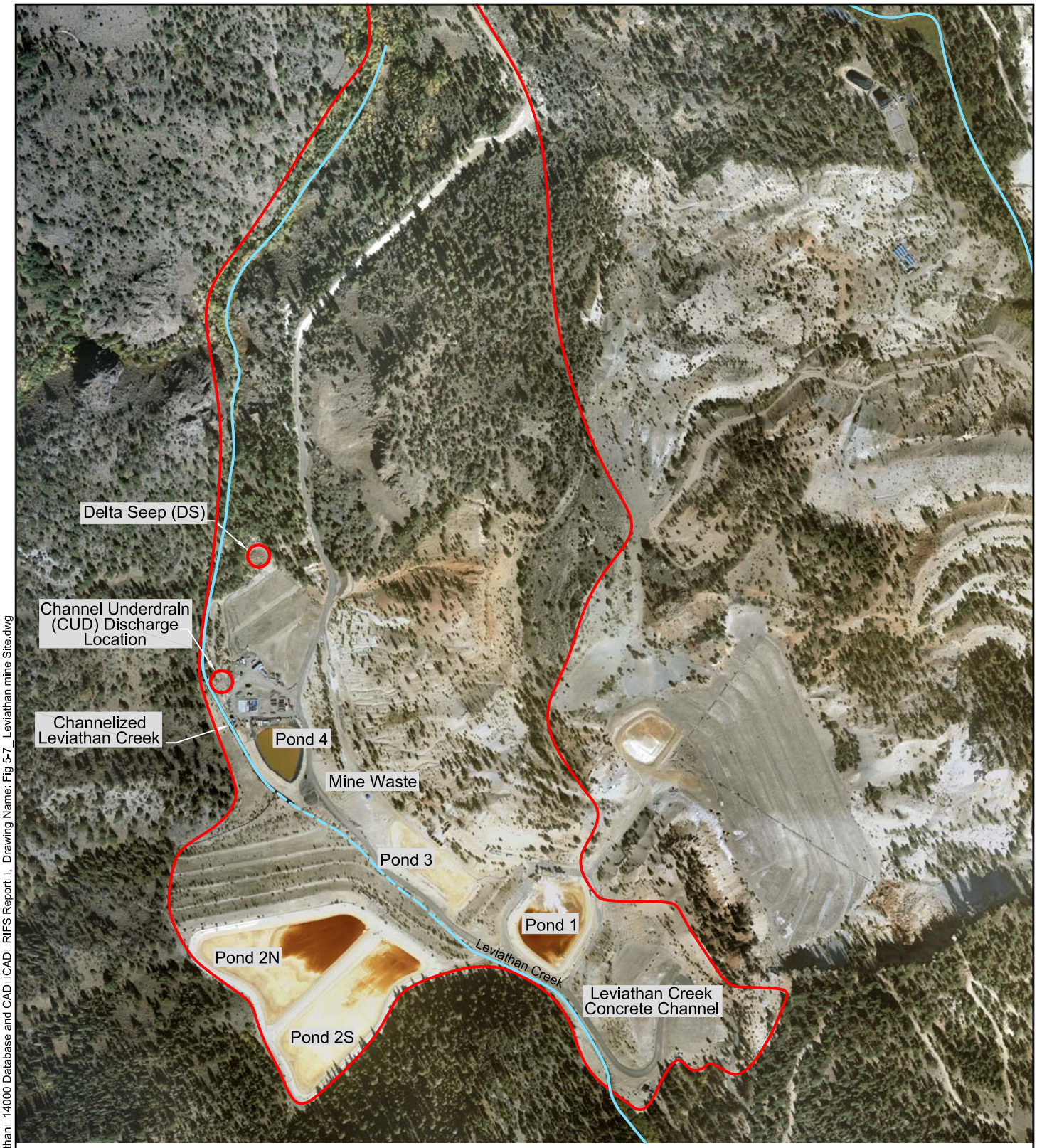

Explanation

- Discharge Point
- Boundary of Study Area
- Creek
- Pond 2S — Study Area Features

Note

LCSA extends off map to confluence of Leviathan Creek and Aspen Creek.

Source: Summit Engineering, October 2, 2007

N

APPROXIMATE SCALE IN FEET
0 700

LEVIATHAN CREEK STUDY AREA
Leviathan Mine Site
Alpine County, California

By: dpv	Date: 6/01/09	Project No. 13091A.109
AMEC Geomatrix		Figure 7

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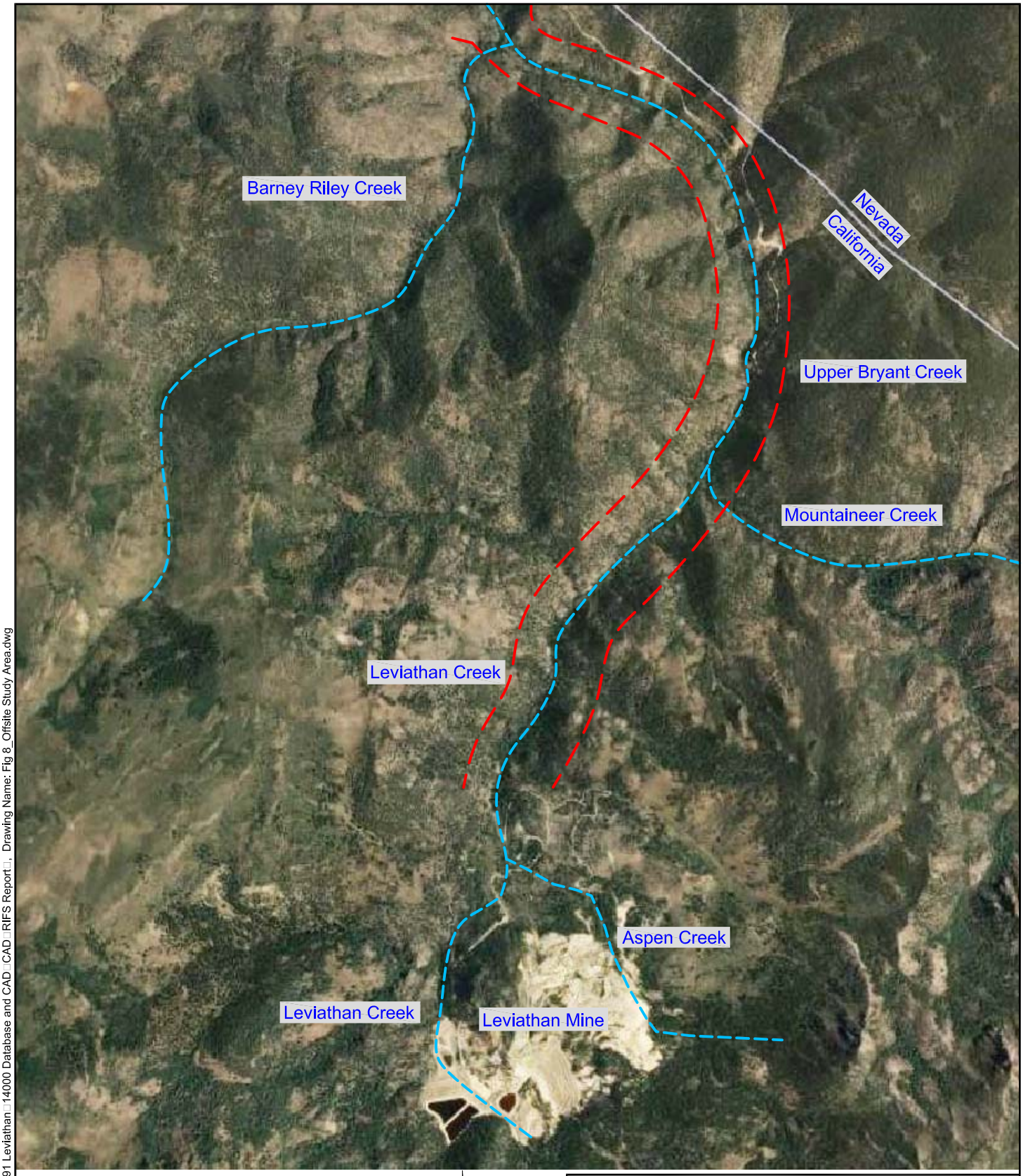

Explanation

Creeks

Off-site Study Area

N

APPROXIMATE SCALE IN FEET
0 1,500

2008 Google Earth

DOWNSTREAM STUDY AREA
Leviathan Mine Site
Alpine County, California

By: dpv	Date: 6/01/09	Project No. 13091A.109
AMEC Geomatrix		Figure 8

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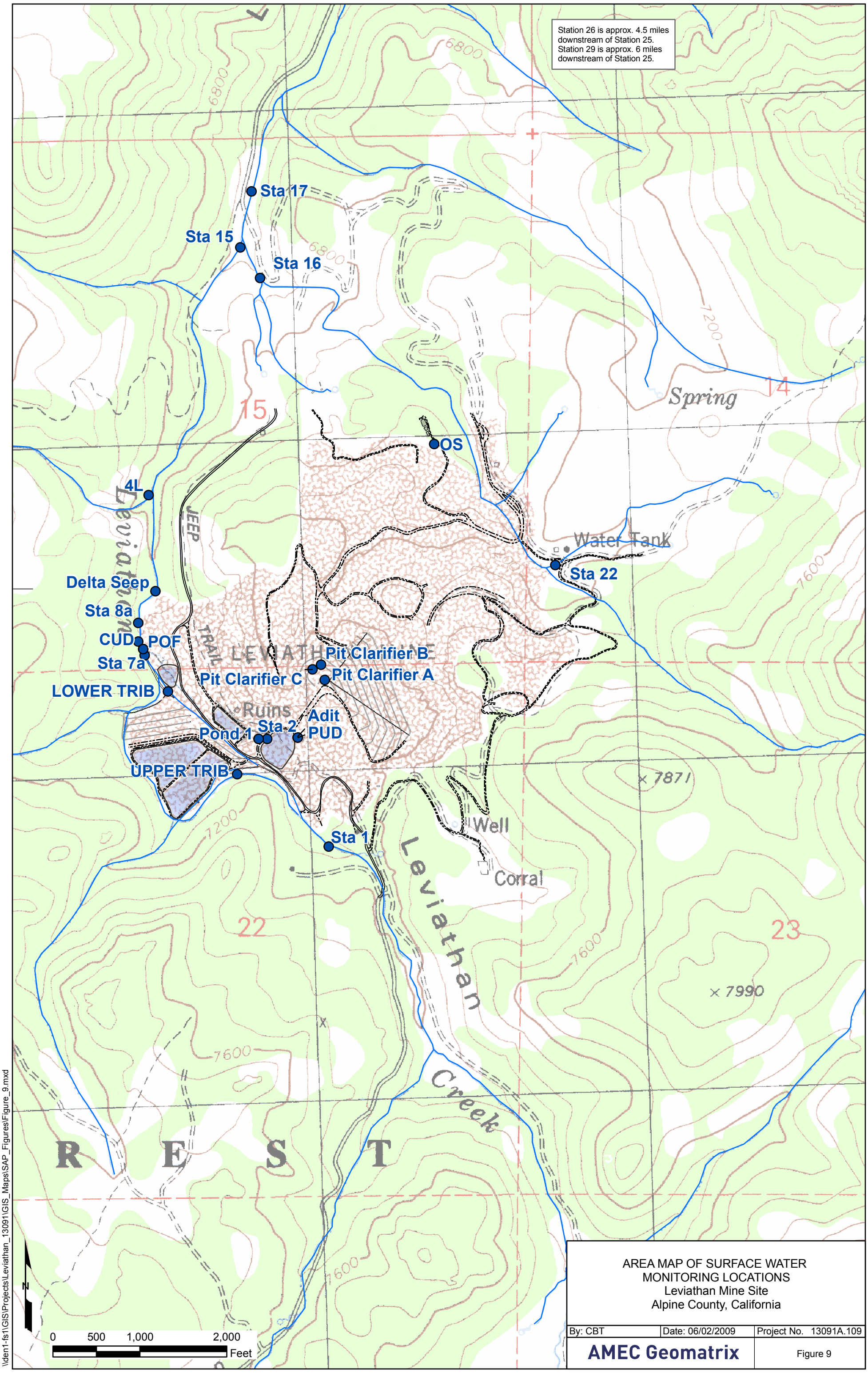

AREA MAP OF SURFACE WATER MONITORING LOCATIONS
Leviathan Mine Site
Alpine County, California

By: CBT	Date: 06/02/2009	Project No. 13091A.109
AMEC Geomatrix		Figure 9

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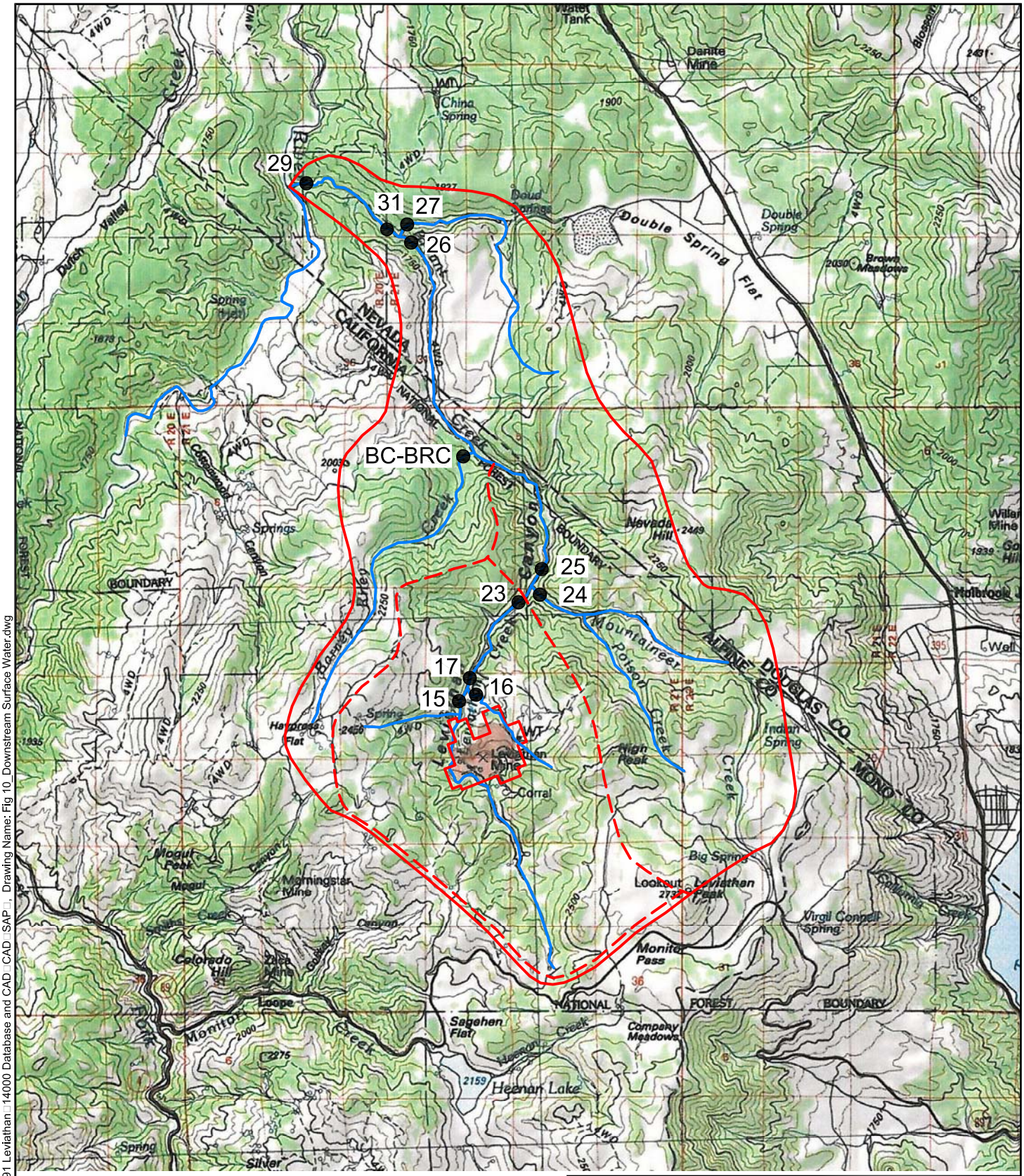

Explanation

- Leviathan Creek Watershed
- Bryant Creek Watershed
- 25 Surface Water Monitoring Location and Designation

APPROXIMATE SCALE IN FEET

0 8,000

Source: USGS National Geographic

DOWNSTREAM SURFACE WATER AND SEDIMENT MONITORING STATIONS
Leviathan Mine Site
Alpine County, California

By: dpv	Date: 6/01/09	Project No. 13091A.109
AMEC Geomatrix		Figure 10

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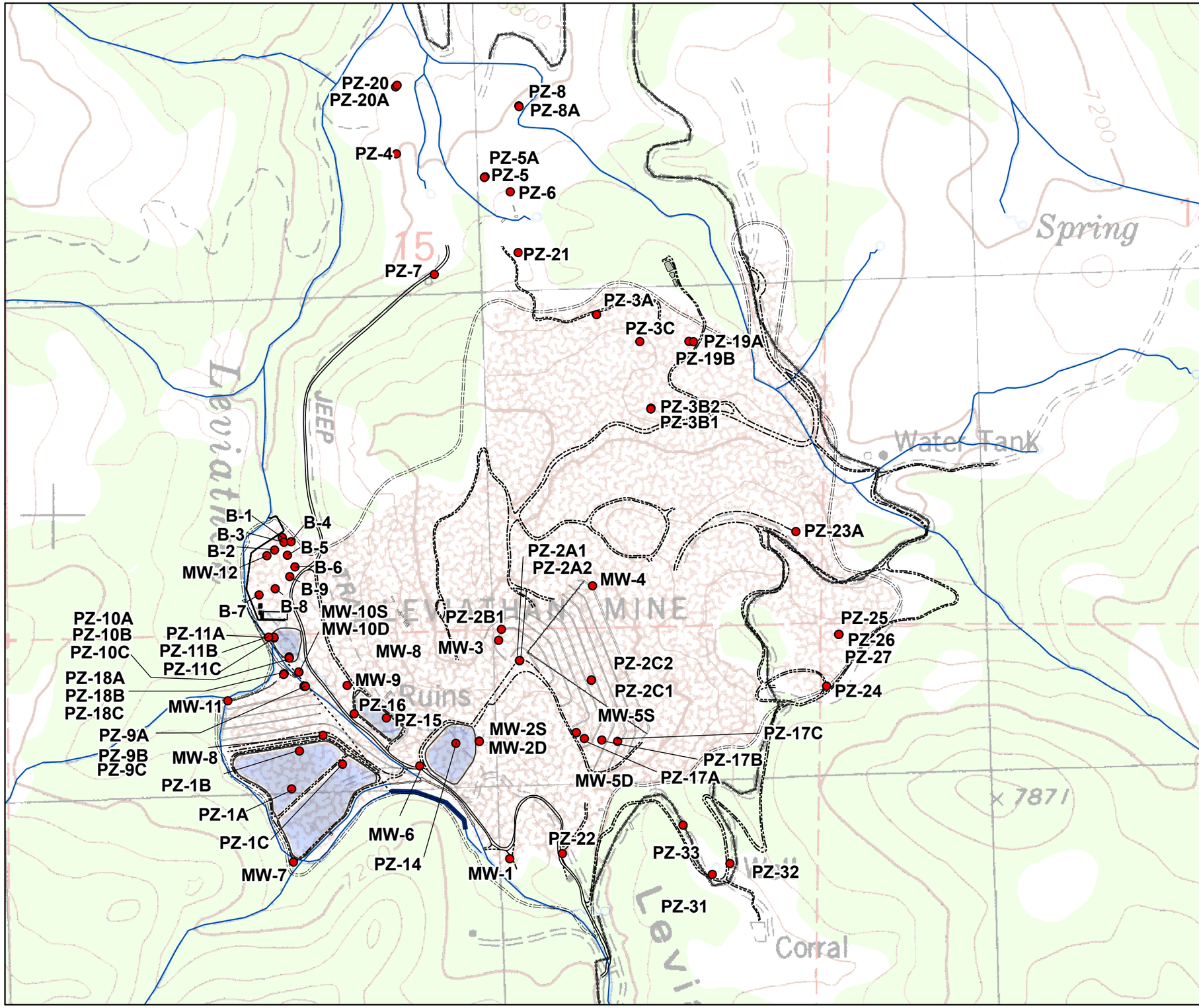

PREVIOUS BORINGS, MONITORING WELLS, AND PIEZOMETERS
Leviathan Mine Site
Alpine County, California

By: CBT	Date: 5/1/2009	Project No. 13091A.109
AMEC Geomatrix		Figure 11

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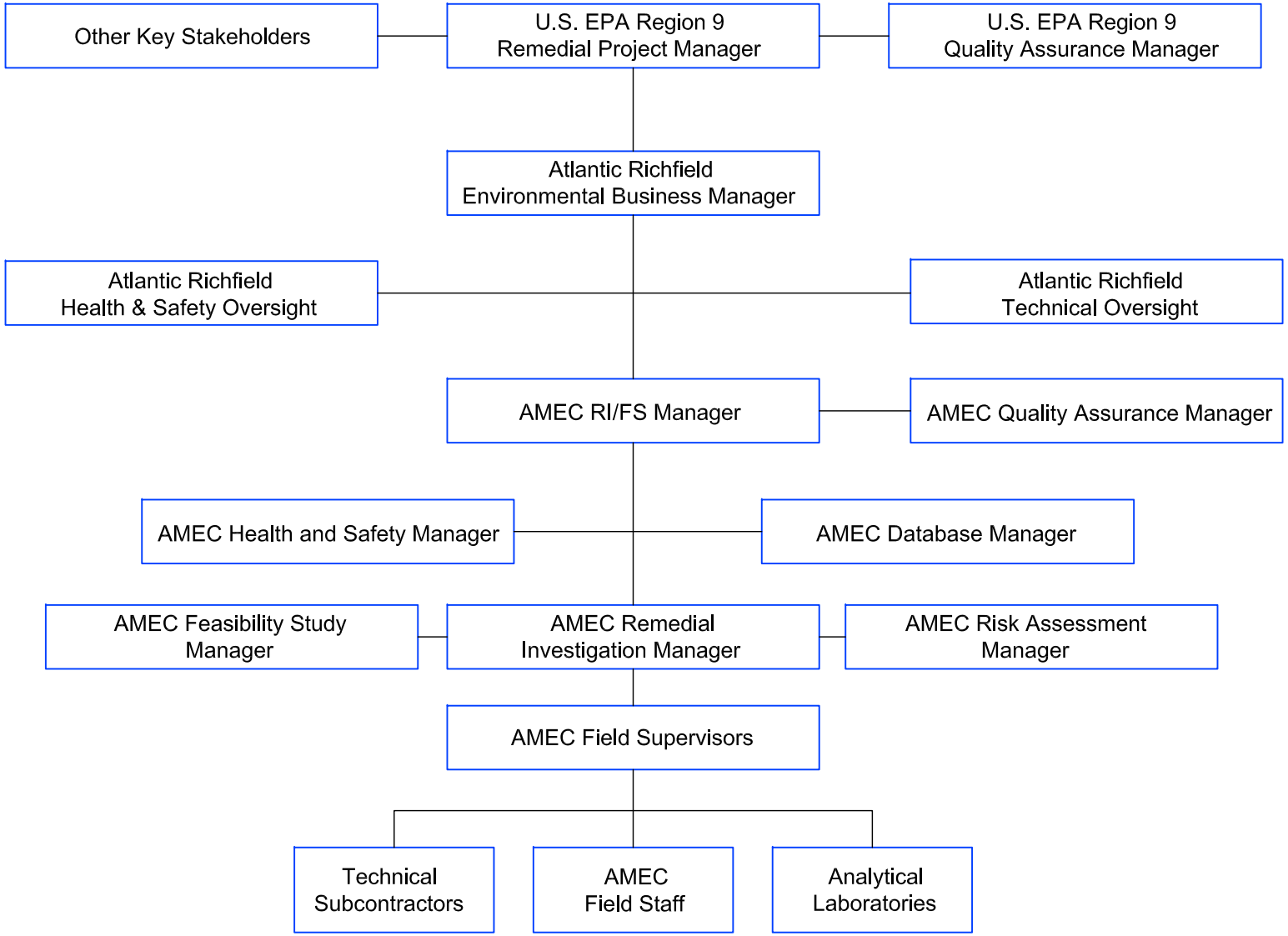

RI/FS ORGANIZATION CHART
Leviathan Mine Site
Alpine County, California

By: dpv	Date: 07/07/09	Project No. 13091A.109
AMEC Geomatrix		Figure 12

Plot Date: 07/07/09 - 9:56am, Plotted by: donna.valasek
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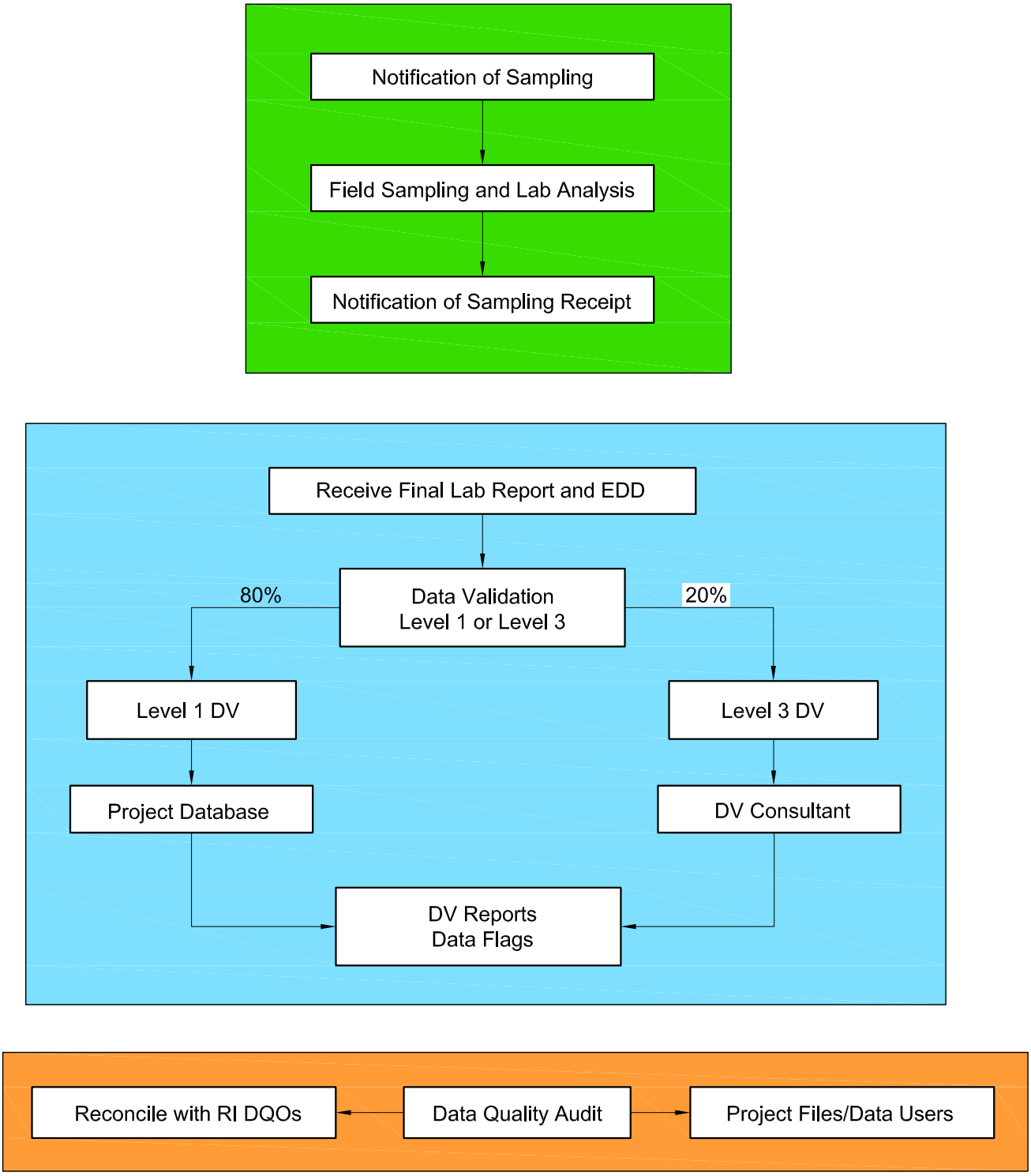


Explanation

DQO Data quality objective

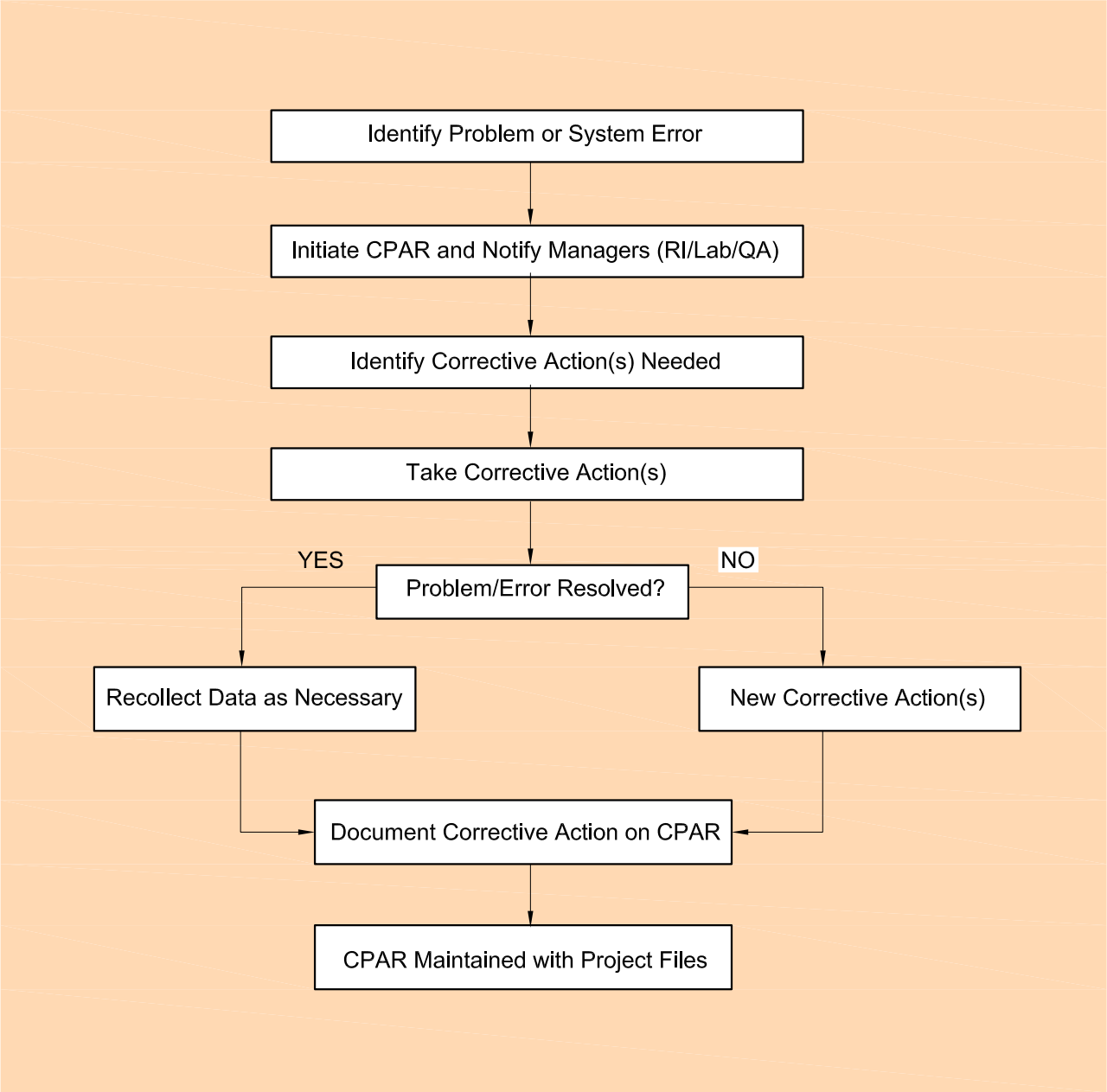
DV Data validation

EDD Electronic data deliverable

FLOW CHART OF THE LABORATORY DATA MANAGEMENT PROCESS
Leviathan Mine Site
Alpine County, California

By: dpv	Date: 6/01/09	Project No. 13091A.109
AMEC Geomatrix		Figure 13

Plot Date: 07/07/09 - 1:28pm, Plotted by: donna.valasek
Drawing Path: P:□Project□13000s□13091 Leviathan□14000 Database and CAD□CAD□SAP□, Drawing Name: Fig 13_Flow Chart.dwg



Explanation

CPAR Corrective and Preventative Action Request

CRITICAL PATH FOR CORRECTIVE AND PREVENTIVE ACTION
Leviathan Mine Site
Alpine County, California

By: dpv	Date: 6/01/09	Project No. 13091A.109
AMEC Geomatrix		Figure 14

Plot Date: 07/07/09 - 10:02am, Plotted by: donna.valasek
Drawing Path: P:□Project□13000s□13091 Leviathan□14000 Database and CAD□CAD□SAP□, Drawing Name: Fig 14_Critical Path.dwg

TABLES

TABLE 1
STRATIGRAPHY OF COMMON ROCK TYPES FOUND IN ALPINE COUNTY
Leviathan Mine Site
Alpine County, California

Geologic Age			Rock Units	Rock Types	Mineral Deposits
Cenozoic	Quaternary	Holocene	Alluvium	Silt, sand, gravel	Sand and gravel, placer gold
		Pleistocene	Glacial moraines	Sand and gravel	Sand and gravel, placer gold
	Tertiary (primarily Miocene)		Volcanic rocks	Andesite tuff, breccia and flows; rhyolite, dacite	Sulfur, gold silver, copper, lead, zinc, mercury, antimony, arsenic, mineral specimens, stone
Mesozoic	Cretaceous		Granitic rocks	Granite, quartz monzonite, granodiorite, quartz diorite	Stone, gold, silver
	Pre-Cretaceous		Metamorphic rocks	Mica schist, quartzite, hornfels, tactite, crystalline limestone	Tungsten, gold, silver, mineral specimens, limestone

Source: Clark, W., 1977, Mines and Mineral Resources of Alpine County, California: California Division of Mines and Geology, County Report 8.

TABLE 2
SITE STRATIGRAPHY
Leviathan Mine Site
Alpine County, California

Prior to Open-Pit Mining (Clark, 1977)[a]	After Open-Pit Mining. Based on surface mapping (Herbst and Sciacca, 1982)[b]							After Open-Pit Mining. Based on boring logs (USGS, 1985)[c]	After Open-Pit Mining. Based on boring logs (SRK, 1999)[d]	
	Artificial Fill (Qaf)	Talus from mining activities (Qtm)	Debris Flows (Qdf)	Landslides (Qls)	Ponded Sediment (Qps)	Alluvium (Qal)		Mine Waste or Artificial Fill. Various colors. Mix of altered volcanic tuff, breccia, and agglomerate. Clay with cobble, gravel and sand. (Qaf-Qal) Maximum 115 feet thick observed in PZ-1B	Mine Waste or Artificial Fill. Various colors. Mix of acid leach tuff, conglomerate, andesite, agglomerate. Sandy to gravelly clay. (Qaf-Qal) Maximum 82 feet thick observed in MW-8	
		Talus (Qt)								
Silicified Cap Rock (maximum 160 feet thick)	Upper Sedimentary Sequence (Trs)	Quartz latite porphery (Tqlp)	Silicified iron-stained breccia (Tsib)	Silicified breccia (Tsb)			Ore Rock with Relict Breccia Texture (Tsob)	Upper Sedimentary Sequence. Grey, brown, green, blue. Agglomerate, altered volcanic tuff, breccia, lahar, sandstone, siltstone, and andesite. Gravelly to sandy clay. (Trs) Maximum of 161 feet observed in PZ-7	Upper Sedimentary Sequence (Trs) maximum of 70 feet observed in MW-2D	Sulfur Ore in Andesite (Tso) Maximum of 23 feet thick observed in MW-5D
Tuff - Massive (maximum 100 feet thick)			Chloritized Breccia (Trsb)		Argillated Altered Lahar (Trsab)	Lahar (Trsl)	Ore rock (Tso)			Interbedded grey, green, purple andesite, white, yellow, orange acid leached tuff and agglomerate. Clay with cobbles and angular gravel, sands, and silt.
Agglomerate (maximum 120 feet thick)			Argillated Altered Sandstone (Trsa)	Sandstone (Trss)						
Tuff - Massive, locally bedded (unknown thickness)										
Sulfur Ore (maximum 90 feet thick, 2400 feet wide)										Sulfur Ore in agglomerate (Tso) Maximum of 11 feet thick observed in MW-10D
										Interbedded grey, green, purple andesite, white, yellow, orange acid leached tuff and agglomerate. Clay with cobbles and angular gravel, sands, and silt.
			Basalt (Trb)							
			Autobrecciated Basalt (Trba)							
	Lower Sedimentary Sequence (Trc)		Sandstone Sequence (Trcs)							
			Lahar (Trcl)							
Andesite Bedrock (unknown thickness)		Hornblende pyroxene andesite (Tra)	Biotite Pyroxene Hornblende Andesite (Ta)	Leviathan Peak Andesite (Tlpa)	Altered Leviathan Peak Andesite (Tlpaa)					

Notes

[a] From accounts by Anaconda Mining Company geologists in Clark, W., 1977,*Mines and Mineral Resources of Alpine County, California*: California Division of Mines and Geology, County Report 8

[b] Interpreted from surface mapping information in Herbst, C.M., and Sciacca, J.E., 1982*Geology of the Leviathan Sulfur Mine and Vicinity, California.*

[c] Interpreted from selected boring logs in Hammermeister, D.P. and Walmsley, S.J. (USGS), 1985*Hydrologic Data for Leviathan Mine and Vicinity, Alpine County, California.* Selected boring logs include information from piezometers PZ-1A, PZ-1B, PZ-1C, PZ-2A, PZ-3A, clustered PZ-3B1 and PZ-3B2, PZ-3C, PZ-7, PZ-9A, PZ-10A, PZ-17A, clustered PZ-19A and PZ-19B, and PZ-33. Other borings not included due to lack of information or poor legibili

[d] Interpreted from all boring logs MW-1 to MW-12 in SRK, 1999,*1998-1999 Data Summary Report, Administrative Order on Consent, Leviathan Mine, Alpine County, California*: Prepared for Atlantic Richfield

TABLE 3
QUALITY CRITERIA FOR METALS MEASUREMENT DATA
Leviathan Mine Site
Alpine County, California

Laboratory Quality Control	Frequency of Analysis	Measurement Quality Objective
Calibration Standard	Per analytical method or manufacturer's specifications	Per analytical method or manufacturer's specifications
Continuing Calibration Verification	Per 10 samples analyzed	90-110% recovery
Laboratory Blank	Per 20 samples or per analytical batch, whichever is more frequent	<RL for target analyte
Reference Material	Per 20 samples or per analytical batch, whichever is more frequent	75-125% recovery
Matrix Spike	Per 20 samples or per analytical batch, whichever is more frequent	75-125% recovery
Matrix Spike Duplicate	Per 20 samples or per analytical batch, whichever is more frequent	75-125% recovery; RPD<25%
Laboratory Duplicate	Per 20 samples or per analytical batch, whichever is more frequent	RPD<25% (if sample concentration is >5XRL)
Internal Standard	Per sample (including QC samples) when method appropriate	60-125% recovery
Field Quality Control	**Frequency of Analysis**	**Measurement Quality Objective**
Field Duplicate	10% of total project sample count	RPD<25%(water); RPD<50%(soil) (if sample concentration is >5XRL)
Field Blank, Equipment Blank	Per 10 samples collected	Blanks<RL for target analyte

TABLE 4
QUALITY CRITERIA FOR GENERAL CHEMISTRY MEASUREMENT DATA
Leviathan Mine Site
Alpine County, California

Laboratory Quality Control	Frequency of Analysis	Measurement Quality Objective
Calibration Standard	Per analytical method or manufacturer's specifications	Per analytical method or manufacturer's specifications
Continuing Calibration Verification	Per 10 samples analyzed	80-120% recovery (90-110% for anions)
Laboratory Blank	Per 20 samples or per analytical batch, whichever is more frequent	<RL for target analyte
Reference Material	Per 20 samples or per analytical batch, whichever is more frequent	80-120% recovery
Matrix Spike	Per 20 samples or per analytical batch, whichever is more frequent	75-125% recovery
Matrix Spike Duplicate	Per 20 samples or per analytical batch, whichever is more frequent	75-125% recovery; RPD<25% for duplicates
Laboratory Duplicate	Per 20 samples or per analytical batch, whichever is more frequent	RPD<25% (if sample concentration is >5XRL
Field Quality Control	**Frequency of Analysis**	**Measurement Quality Objective**
Field Duplicate	10% of total project sample count	RPD<25% (if sample concentration is >5XRL)
Field Blank, Equipment Blank	Per 10 samples collected	<RL for target analyte

TABLE 5
TARGET LIMITS FOR GROUNDWATER/SURFACE WATER SAMPLE ANALYSES
Leviathan Mine Site
Alpine County, California

Parameter	Method Reference[1]	Expected Detection Limit	Target Limits[2]
pH	Field SOP YSI or similar)	0.1 unit	NA
Conductivity	Field SOP (YSI or similar)	0.1 mS/cm	NA
Temperature	Field SOP (YSI or similar)	0.15°C	NA
Oxidation Reduction Potential	Field SOP (YSI or similar)	0.1 mV	NA
Dissolved Oxygen	Field SOP (YSI or similar)	0.2 mg/L	NA
Ferrous Iron/Ferric Iron	Field SOP (HACH or similar)	0.02 mg/L	NA
Dissolved Sulfide	Field SOP (HACH or similar)	0.01 mg/L	NA
Flow Rate	Field SOP (Flow meter)	feet/second	NA
Metals:			
Aluminum	EPA 6010B/6020/200.7	0.05 mg/L	0.10 mg/L
Arsenic		0.001 mg/L	0.01 mg/L
Beryllium		0.0005 mg/L	0.004 mg/L
Cadmium		0.001 mg/L	0.005 mg/L
Chromium		0.005 mg/L	0.050 mg/L
Cobalt		0.005 mg/L	0.011 mg/L
Copper		0.005 mg/L	0.038 mg/L
Iron		0.1 mg/L	0.3 mg/L
Lead		0.001 mg/L	0.015 mg/L
Manganese		0.005 mg/L	0.05 mg/L
Nickel		0.02 mg/L	0.1 mg/L
Selenium		0.002 mg/L	0.02 mg/L
Thallium		0.001 mg/L	0.0017 mg/L
Vanadium		0.010 mg/L	0.09 mg/L
Zinc		0.020 mg/L	0.3 mg/L
Mercury	EPA 7470A/245.1	0.0002 mg/L	0.00077 mg/L
Total Dissolved Solids	SM 2540C	10 mg/L	NA
Total Suspended Solids	SM 2540D	10 mg/L	NA
Acidity	SM 2310B	10 mg/L	NA
Alkalinity (as $CaCO_3$)	SM 2320B	5 mg/L	NA
Hardness (as $CaCO_3$)	SM 2340B	1 mg/L	NA
Sulfate	EPA 300.0	5 mg/L	NA
Chloride	EPA 300.0	5 mg/L	NA
Sulfide	SM 4500-S	0.02 mg/L	NA

Notes
1 Where applicable, sample preparation procedures outlined in the referenced method will be performed prior to analysis.
2 Target limits evaluated based on the lowest screening level for the regional CTR, MCL, and Basin Plan limits for applicable parameters. All others represent projected benchmarks for evaluating human health or ecological risks for the site. (Should additional requirements become known during the RI/FS, an evaluation of the appropriateness of these proposed methods will be conducted.)

Abbreviations
mg/L = milligrams per liter
mS/cm = microsiemens per centimeter
mV = millivolt
NA = not applicable

TABLE 6
TARGET LIMITS FOR METALS IN SOIL/SEDIMENT/TISSUE ANALYSES
Leviathan Mine Site
Alpine County, California

Analyte	Method Reference[1]	Expected Detection Limit	TARGET LIMITS[2]		
			Soil	Sediment	Tissue
Aluminum	EPA 6010B/6020	5 mg/kg	5 mg/kg	NA	NA
Arsenic		0.5 mg/kg	0.07 mg/kg	5 mg/kg	15 mg/kg
Beryllium		1 mg/kg	100 mg/kg	NA	20 mg/kg
Cadmium		0.5 mg/kg	10 mg/kg	0.6 mg/kg	0.4 mg/kg
Chromium		1 mg/kg	10 mg/kg	20 mg/kg	20 mg/kg
Cobalt		1 mg/kg	10 mg/kg	50 mg/kg	10 mg/kg
Copper		1 mg/kg	100 mg/kg	15 mg/kg	20 mg/kg
Iron		2 mg/kg	NA	NA	NA
Lead		0.5 mg/kg	0.15 mg/kg	30 mg/kg	10 mg/kg
Manganese		0.5 mg/kg	NA	NA	NA
Nickel		1 mg/kg	100 mg/kg	15 mg/kg	30 mg/kg
Selenium		1 mg/kg	100 mg/kg	NA	0.5 mg/kg
Thallium		1 mg/kg	5 mg/kg	1 mg/kg	1 mg/kg
Vanadium		1 mg/kg	100 mg/kg	NA	NA
Zinc		10 mg/kg	100 mg/kg	120 mg/kg	40 mg/kg
Mercury	EPA 7470A	0.02 mg/kg	10 mg/kg	0.1 mg/kg	0.1 mg/kg
Moisture Content	ASTM 2450B	0.1%	NA	NA	NA
Density	ASTM E1109	0.1 g/cc	NA	NA	NA
TCLP Metals[3]	EPA 1311/6010B/7470A	10× EDL_{water}	[3]	[3]	NA
TTLC Metals[4]	EPA 6010B/7471A	10× EDL_{water}	[4]	[4]	NA
STLC Metals[5]	WET/EPA 6010B/7470A	10× EDL_{water}	[5]	[5]	NA

Notes
1 Where applicable, sample preparation procedures outlined in the referenced method will be performed prior to analysis.
2 Target limits evaluated based on the lowest screening level for the regional CHHSL or PRG for applicable parameters. All others represent projected benchmarks for evaluating human health or ecological risks for the site. (Should additional requirements become known during the RI/FS, an evaluation of the appropriateness of these proposed methods will be conducted.)
3 RCRA Toxicity Characteristic Leaching Procedure (40CFR261.24)
4 California Total Threshold Limit Concentration (CCR Title 22, chapter 11)
5 California Soluble Threshold Limit Concentration (CCR Title 22, chapter 11)

Abbreviations
EDL = expected detection limit
g/cc = grams per cubic centimeter
mg/kg = milligrams per kilogram
NA = not applicable

TABLE 7
ANALYTICAL METHODS, HOLDING TIMES AND PRESERVATION REQUIREMENTS
Leviathan Mine Site
Alpine County, California

Parameter	Method Reference	Container	Suggested Volume[1]	Preservation[2]	Maximum Holding Time
Water Samples					
Metals[3]	EPA 6010B/6020/7471A	P	500 mL	HNO_3 to pH<2	28 days for Hg; 6 months for others
Acidity	SM 2310B	P	250 mL	None	14 days
Alkalinity	SM 2320 B	P	250 mL	None	14 days
Hardness (as $CaCO_3$)	SM 2340B	P	500 mL	HNO_3 to pH<2	6 months
Sulfate	EPA 300.0	P	250 mL	Field filtered; none	28 days
Sulfide	SM 4500-S	AG	1 L	Field filtered; NaOH to pH>10	7 days
Soil/Sediment Samples					
Metals[3]	EPA 6010B/6020/7470A	WMG	20 g	None	28 days for Hg; 6 months for others
Acid Base Accounting	EPA 600/2-78-054	WMG	50 g	None	28 days
Paste pH	MSA (Page et al.)	WMG	50 g	None	7 days
Sulfate	EPA 300.0M	WMG	50 g	None	28 days
Moisture Content	ASTM 2450B	WMG	50g	None	7 days
Density	ASTM E1109	Ziploc Bag	50g	None	28 days
Tissue Samples					
Metals[3]	EPA 6010B/6020/7470A	Ziploc Bag	100g	Note[4]	Note[4]
Moisture Content	ASTM 2450B	Ziploc Bag	50g	Note[4]	Note[4]

Notes
1 Additional volume (3×) must be provided for selected matrix QC samples (MS, MSD, LD).
2 Samples should be stored at a temperature ranging from 0°C to 6°C.
3 Metals: Al, As, Be, Cd, Cr, Co, Cu, Fe, Hg, Pb, Mn, Ni, Se, Tl, V, Zn
4 There are no regulated preservation requirements or holding times for the respective matrices.

Abbreviations
P Polyethylene
AG = amber glass with Teflon-lined cap
WMG = wide-mouth glass jar with Teflon-lined cap

TABLE 8
DATA VALIDATION QUALIFIERS
(Based on the U.S. EPA National Functional Guidelines)
Leviathan Mine Site
Alpine County, California

U	The analyte was analyzed for, but was not detected above, the sample quantitation limit, or it may be detected, but due to contamination from an outside source such as laboratory or field equipment, the sample quantitation limit has been adjusted.
J	The analyte was positively identified but the associated numerical value may not represent the actual concentration of the analyte in the sample due to analytical bias in precision or accuracy, or because the resulting trace concentration is below the respective quantitation limit.
UJ	The analyte was not detected above the reported sample quantitation limit. However, the reported quantitation limit is approximate and may or may not represent the actual limit of quantitation necessary to accurately and precisely measure the analyte in the sample.
R	The sample results are rejected due to serious deficiencies in the ability to analyze the sample and meet quality control criteria. The presence or absence of the analyte cannot be verified.
+	The result is biased high.
–	The result is biased low.

APPENDIX A

RI/FS Field Sampling Plan

APPENDIX A

FIELD SAMPLING PLAN

Remedial Investigation/Feasibility Study Program

Leviathan Mine Site

Alpine County, California

Prepared for:

Atlantic Richfield Company
La Palma, CA

Prepared by:

AMEC Geomatrix, Inc.,
Rancho Cordova, CA

June 10, 2009

_____	_____
RI/FS PROGRAM MANAGER	**RI/FS QA PROJECT MANAGER**

AMEC Geomatrix

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LIST OF ABBREVIATIONS AND ACRONYMS

ACSA	Aspen Creek Study Area
AMEC	AMEC Geomatrix, Inc.
ARAR	applicable and/or relevant and appropriate requirement
ARD	acid rock drainage
AS	Aspen Seep
BSA	Background Study Area
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
COPC	chemical of potential concern
CSM	conceptual site model
CUD	Channel Underdrain
DFG	Department of Fish and Game
DQO	Data Quality Objective
DS	Delta Seep
DSA	Downstream Study Area
FFS	Focused Feasibility Study
FRI	Focused Remedial Investigation
FSP	Field Sampling Plan
ft.	feet
ft/ft	feet per horizontal foot
LCSA	Leviathan Creek Study Area
msl	mean sea level
PSA	Pit Study Area
PUD	Pit Underdrain
PWP	Program Work Plan
QA/QC	Quality Assurance/ Quality Control
QAPP	Quality Assurance Project Plan
QC	Quality Control
RI	Remedial Investigation
RI/FS	Remedial Investigation Feasibility Study
RWQCB	Regional Water Quality Control Board
SAP	Sampling and Analysis Plan
SOW	statement of work
SOP	Standard Operating Procedure
UAO	Unilateral Administrative Order
U.S.	United States
U.S. EPA	U.S. Environmental Protection Agency

REMEDIAL INVESTIGATION AND FEASIBILITY STUDY
FIELD SAMPLING PLAN

Leviathan Mine Site
Alpine County, California

A1.0 INTRODUCTION

This Remedial Investigation/Feasibility Study (RI/FS) Field Sampling Plan (FSP) has been prepared by AMEC Geomatrix, Inc. (AMEC), on behalf of Atlantic Richfield Company (Atlantic Richfield). This FSP fulfills a requirement of the Administrative Order for Remedial Investigation and Feasibility Study (Unilateral Administrative Order or UAO) issued to Atlantic Richfield on June 23, 2008, by the United States (U.S.) Environmental Protection Agency (EPA) for the Leviathan Mine site ("site"; Figures 1 and 2). The FSP is included in the Sampling and Analysis Plan (SAP), which is a part of the larger RI/FS Program Work Plan (PWP). This FSP has been prepared in accordance with the Guidance for Conducting Remedial Investigations and Feasibility Studies under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA; U.S. EPA, 1988).

This document has been designed to present the activities that will be performed during the RI/FS. Additional details (e.g., sample designation, location, frequency) will be provided within the Focused Remedial Investigation (FRI) work plans and the Focused Feasibility Study (FFS) work plan. This approach was granted by the U.S. EPA in response to Atlantic Richfield's December 15, 2008, proposal for producing the RI/FS Work Plan in stages (U.S. EPA, 2009).

Other components of the SAP include the RI/FS Quality Assurance Project Plan (QAPP) (Appendix B of the SAP) and the RI/FS Standard Operating Procedures (SOPs; Appendix C of the SAP). The QAPP describes the policy, organization, functional activities, and quality assurance and quality control (QA/QC) protocols needed to achieve the laboratory Data Quality Objectives (DQOs). The SOPs describe the procedures, equipment, and documentation that may be used during the course of the Remedial Investigation (RI). Collectively, the three components of the SAP (i.e., this FSP, the QAPP, and the SOPs) establish the minimum requirements for the RI/FS field activities.

Section A1.0 of this document presents the introduction, purpose, FSP approach, and the study areas. Section A2.0 includes a brief discussion of the site background. A detailed discussion of the background is provided in the PWP. Section A3.0 describes the objectives and scope of this FSP. Section A4.0 describes the sample location and frequency. Section A5.0 describes the sample designation requirements. Section A6.0 describes the sampling

equipment and procedures. Section A7.0 describes the sample handling and analysis requirements as they pertain to the field activities (the laboratory-related sample handling and analysis requirements are discussed in the QAPP). Section A8.0 lists the references cited in the FSP.

A1.1 LEVIATHAN MINE AND RI/FS STUDY AREAS

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 quadrangles (Figure 1).

The Leviathan Mine site is located near the eastern margin of the Sierra Nevada, approximately four miles west of the California/Nevada border. The regional topography consists of rugged mountains and high meadowlands that slope gradually towards the north.

To efficiently manage the RI/FS field activities, the site has been divided into five study areas (Figure 4):

1. **Pit Study Area (PSA).** This area includes the entire pit area (reclaimed and not reclaimed portions), and the adit, Pit Underdrain (PUD), and clarifier areas (Figure 5).

2. **Aspen Creek Study Area (ACSA).** This area includes the overburden piles, the reach of Aspen Creek that passes by the eastern side of the site and the historic landslide area (Figure 6).

3. **Leviathan Creek Study Area (LCSA).** This area includes the area west and north of the pit, the storage ponds, the diversion channel and Channel Underdrain (CUD), other surface water diversion structures, the Delta Seep (DS), and the length of Leviathan Creek from above the site to the confluence of Leviathan and Aspen creeks (Figure 7).

4. **Downstream Study Area (DSA).** The downstream study 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).

5. **Background Study Area (BSA).** The background study area(s) will include areas with characteristics similar to those of the site where analog sites can be established to conduct background studies.

The location and boundaries, physical description, results of previous studies and conceptual model for each study area are presented in Sections 2 and 3 of the PWP. 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.

A1.2 PROBLEM STATEMENT

Previous mining activities at the site included tunnel mining (1863–1951) and open-pit mining (1952–1963). Open-pit mining was conducted in the center of the site and included the excavation of material (overburden) which was placed to the side of the pit, extraction of copper and sulfur from heavily mineralized sections of the material (processing), and placement of the processed spoils along Leviathan Creek (waste dump). Combined with the remaining mine tunnels, these activities have increased the exposure of sulfide mineralization in the overburden material to water and air. The combination of sulfides, water, and air has resulted in the formation and outflow of acidic waters that drain from mine features; this is referred to as acid rock drainage (ARD) in the SAP.

A number of investigations have previously been performed at the site to identify and mitigate the impacts from ARD. However, much of the previous data has not been collected under sampling plans or QA/QC procedures that formally meet the requirements of the CERCLA guidance (U.S. EPA, 1988). Therefore, these data may not be usable to characterize the nature and extent of contamination, assess risk, or evaluate potential remedial alternatives at the site.

A1.3 PURPOSE

The purpose of the FSP is to provide guidance for the field work to be performed for the PWP. It is designed so that a field sampling team unfamiliar with the site would be able to gather the samples and field information required to complete each task identified within the PWP.

A1.4 FSP

The FSP represents a program document designed to describe the field activities for the RI/FS. It is to be used in conjunction with the other components of the SAP (i.e., the QAPP and SOPs) and with the FRI work plans which will be prepared at a future date. The FRI and FFS work plans will provide the specific details of each investigation (e.g., sample location, designation, frequency).

A2.0 BACKGROUND

Background information applicable to the QAPP and FSP is summarized in Section 2 of the SAP. Additional background information is summarized in Section 2 and 3 of the PWP.

A3.0 OBJECTIVES AND SCOPE

The objectives and scope of the RI/FS are presented in PWP Sections 4, 5, 6, and 7 and summarized in the SAP.

A4.0 SAMPLE LOCATION AND FREQUENCY

The sample location and frequency of sampling that will be performed during the RI/FS will be specified in the future FRI work plans. The focused work plans will include information on the sample matrix to be collected (e.g., soil, groundwater, air) and the constituents to be analyzed. Where appropriate, a table will be used to clearly identify the number of samples to be collected along with the appropriate number of replicates and blanks. Where appropriate, a figure will be used to show the locations of the existing and proposed sampling points.

A5.0 SAMPLE DESIGNATION

The sample designations to be used during the RI/FS field activities will be defined in the future FRI and FFS work plans and will adhere to the designation requirements stated in the QAPP (Appendix B of the SAP). The following sample designation requirements have been excerpted from Section B3.2.1 of the QAPP. Any revisions to the QAPP after the preparation of this document will supersede the designation requirements presented below.

Samples will be labeled with self-adhesive labels, with all necessary information filled out using waterproof ink. At a minimum, each sample label will contain the following information:

- project name;
- site location;
- sample identification code;
- date and time of sample collection, with sampler’s initials;
- analyses required;
- method of preservation, if used; and
- sampler's initials.

Each sample will be assigned a unique identification code according to sample location and date. This ID will consist of three parts, which will not be separated by any symbols, characters, or spaces. The components of the sample ID are as follows:

1. sample type—Groundwater (GW), surface water (SW), stream sediment (SS), soil boring (SB), plant sample (PS), fish sample (FS), invertebrate sample (IS), and waste sample (WS);

2. study area designation—AS Study Area (A), Leviathan Creek Study Area (A), Pit Study Area (P), Downstream Study Area (D), or Background (B); and

3. date—Expressed as a two-digit month, date, and year (MM/DD/YY).

Continuous sequence number for each day of sampling in each of the designated sampling areas. Sequential numbering will restart at 01 on a given sampling day, in a given sampling area. For example, if the 99th sample is taken for a groundwater sample in the Leviathan Creek Study Area on February 5, 2010, the sample ID will be "*GWL02051099.*" Waste characterization samples will be designated by respective study area. For example, if investigative-derived waste (soils or water) from the PSA is collected on January 1, 2010, the sample ID will be "*WSP0101100.1*" Refer to Section B3.4.2 of the QAPP for a discussion of handling and labeling laboratory quality control samples.

Field blanks and duplicates will be labeled so as not to indicate the identity of the sample to the lab and will follow the labeling convention (using the appropriate number sequence) in place of calling the sample "blank" or "Dup." The identity of field quality control (QC) samples will be traceable through appropriate documentation as described in the respective SOPs.

A6.0 SAMPLING EQUIPMENT AND PROCEDURES

The sampling equipment and procedures that will be used to fulfill the objectives and scope of this document (Section A3.0) are provided in the SOPs. SOPs include a detailed description of field procedures, sampling equipment, and forms that will be needed during the field investigation. The SOPs are provided within Appendix C of the SAP and include the following:

- SOP 1.0—General Preparation and Mobilization Requirements
- SOP 2.0—Basic Health and Safety For Field Operations
- SOP 3.0—Field Documentation and Sample Handling
- SOP 4.0—Sample Collection Techniques and Data Collection Strategies
- SOP 5.0—Surface Geophysical Surveys

- SOP 6.0—Field Measurements—Water
- SOP 7.0—Equipment Decontamination
- SOP 8.0—Surface Water Sampling and Streamflow Measurement
- SOP 9.0—Soil, Water, and Waste Disposal
- SOP 10.0—Sediment Sampling
- SOP 11.0—Soil Logging
- SOP 12.0—Test Pit Excavation
- SOP 13.0—Drilling
- SOP 14.0—Soil Sampling
- SOP 15.0—Borehole Geophysical Surveys
- SOP 16.0—Installation and Construction of Groundwater Monitoring Wells and Piezometers
- SOP 17.0—Groundwater Sampling
- SOP 18.0—Cone Penetrometer Test
- SOP 19.0—Aquifer Testing
- SOP 20.0—Seepage Meter
- SOP 21.0—Bubble-Water Manometer
- SOP 22.0—Tracer Study
- SOP 23.0—Field Density Tests
- SOP 24.0—Dust Monitoring
- SOP 25.0—Mini-Piezometer Installation
- SOP 26.0—Lysimeter
- SOP 27.0—Tensiometer
- SOP 28.0—Electrofishing

A7.0 SAMPLE HANDLING AND ANALYSIS

The sample handling and analysis procedures are described in the various sections of the QAPP (Appendix B of the SAP). It includes tables that identify the sample preservation methods, types of sampling jars, packing and shipping requirements, sample designation requirements for the project database, documentation requirements, and holding times. Examples of paperwork include chain-of-custody forms, sample logs, and sample labels.

SOP 3.0—Field Documentation and Sample Handling has summarized the aspects that are most likely to be used in the field. This SOP is subordinate to the QAPP; therefore, if any revisions are made to the QAPP, they will supersede those activities described in SOP 3.0.

A8.0 REFERENCES

Atlantic Richfield, 2008, Draft Data Quality Objectives Report: Remedial Investigations and Feasibility Study, Leviathan Mine, Alpine County: Prepared by AMEC Geomatrix, Inc., October.

Clark, W., 1977, Mines and Mineral Resources of Alpine County, California: California Division of Mines and Geology, County Report No. 8.

Department of Fish and Game (DFG), 1954, Inter-departmental communication letter to the Lahonton Regional Water Quality Control Board, Subject: Leviathan Creek, Alpine County, August 27.

Hammermeister, D.P., and Waimsley, S.J., 1985, Hydrologic Data for Leviathan Mine and Vicinity, Alpine County, California, 1981-1983: U.S. Geological Survey Open-File Report 85-160, 161 pp.

Herbst, C.M., and Sciacca, J.E., 1982, Geology of the Leviathan Sulfur Mine and Vicinity: In Brown and Caldwell, Leviathan Mine Pollution Abatement Project, Design Report and Draft Environmental Impact Report: State Water Resources Control Board, Lahontan Region, 20 pp.

Regional Water Quality Control Board (RWQCB), 1968, Report on Pollution of Leviathan Creek Caused by Leviathan Mine: State of California, Regional Water Quality Control Board, Lahontan Region, January.

RWQCB, 1995, Leviathan Mine 5-Year Workplan, Lahonton Regional Water Quality Control Board: Prepared by C. Schoen, B. Warden, and D. Henrioulle-Henry, July.

U.S. Environmental Protection Agency (U.S. EPA), 1988, Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA. Interim Final: OSWER Directive 9335.3-01, EPA/540/G-89/004, October.

U.S. EPA, 1992, Guidance for Data Usability in Risk Assessment (Part A): Office of Emergency and Remedial Response, Publication 9285.7-09A, Washington D.C.

U.S. EPA, 2008, Administrative Order For Remedial Investigation and Feasibility Study, Leviathan Mine, Alpine County, California, U.S. EPA Region IX: CERCLA Docket No. 2008-18, June 23.

U.S. EPA, 2009, Approval with Comments for Leviathan Mine Data Quality Objectives Report submitted October 2008, and Direction to Prepare Remedial Investigation and Feasibility Study work plan pursuant to Administrative Order for Remedial Investigation and Feasibility Study, Leviathan Mine, Alpine County, California: CERCLA Docket No. 2008-18, April 23.

APPENDIX B

RI/FS Quality Assurance Project Plan

APPENDIX B

QUALITY ASSURANCE PROJECT PLAN

Remedial Investigation/Feasibility Study Program

Leviathan Mine Site

Alpine County, California

Prepared for:

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June 10, 2009

Approvals:

_____	_____
RI/FS PROGRAM MANAGER	**RI/FS QA PROJECT MANAGER**
_____	_____
U.S. EPA PROGRAM MANAGER	**U.S. EPA QA PROJECT MANAGER**

AMEC Geomatrix

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REMEDIAL INVESTIGATION/FEASIBILITY STUDY
QUALITY ASSURANCE PROJECT PLAN

Leviathan Mine Site
Alpine County, California

B1.0 INTRODUCTION AND PURPOSE

This Remedial Investigation/Feasibility Study (RI/FS) Quality Assurance Project Plan (QAPP) has been prepared by AMEC Geomatrix, Inc. (AMEC), on behalf of Atlantic Richfield Company (Atlantic Richfield) for the Leviathan Mine site ("site") in Alpine County, California (Figures 1 and 2). It has been developed in conjunction with the RI/FS Program Work Plan (PWP) as required by the *Administrative Settlement Agreement and Order for Remedial Investigation and Feasibility Study Issued by the United States Region IX Environmental Protection Agency (CERCLA Docket No. 2008-18*; U.S. Environmental Protection Agency [U.S. EPA], 2008), also referred to as the Unilateral Administrative Order (UAO). The UAO includes a Statement of Work (SOW) for conducting the RI/FS at the site, including completion of a RI/FS QAPP.

The QAPP represents Appendix B of the RI/FS Sampling and Analysis Plan (SAP). The purpose of this document is to summarize the policy, organization, and functional activities necessary to achieve the data quality objectives (DQOs) presented in the *Draft Data Quality Objectives Report* (Atlantic Richfield, 2008) as refined and summarized in Section 5 of the RI/FS PWP. This document defines the general quality assurance (QA) and quality control (QC) measures that will be employed during any sampling and analysis to ensure that these activities are conducted in accordance with U.S. EPA requirements (U.S. EPA, 1990). It also includes the anticipated analytical methodologies and describes specific laboratory and field requirements that will ensure that the environmental data collected is of sufficient technical quality to support the characterization of potential contaminants of concern, assess the potential for human health and ecological risks and aid in the development of future response actions. This QAPP has been prepared in general accordance with the *Leviathan Mine Site-wide Quality Assurance Project Plan* (Montgomery Watson Harza [MWH], 2002) and in accordance with *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, 2002).

Other components of the SAP include the RI/FS Field Sampling Plan (FSP) (Appendix A of the SAP), and the RI/FS Standard Operating Procedures (SOPs) (Appendix C of the SAP). Collectively, the three components of the SAP (i.e., this QAPP, the FSP, and the SOPs) establish the minimum requirements to address future Focused Remedial Investigation (FRI)

and Focused Feasibility Study (FFS) work plans for specific investigations and sampling activities. As explained in Section 1.4 of the RI/FS PWP, the FRI and FFS work plans will include detailed descriptions of investigation work for each task or study area, including the location, number of samples, and analytical parameters necessary to address environmental data needs or SOW requirements, and will effectively become part of the RI/FS PWP.

B1.1 QUALITY ASSURANCE PROJECT PLAN MANAGEMENT

This QAPP is an integral part of the PWP and as such, its purpose is to provide a standard reference for all RI/FS activities, which will be detailed in additional FRI and FFS work plans. For each planned field investigation and data collection effort, an FRI and FFS work plan will be prepared to address specific project objectives, field activities, and data use. The procedures outlined in this QAPP govern the acquisition of environmental samples and the reporting of data, sample handling and chain-of-custody (COC) protocols, laboratory and field analyses, data handling and data management, field documentation, data reporting, quality auditing, corrective/preventive action processes, and management of records in support of a final RI report for evaluating sources of contamination, supporting risk assessment, and selecting long-term remedial actions.

Section B1.0 presents the introduction, purpose, and management of this document. Section B2.0 identifies the key project personnel involved in completion of the RI/FS and provides the general project description. Section B3.0 describes the methods for sample collection and analysis. Section B4.0 addresses the requirements for assessing data quality and the overall effectiveness of the QAPP. Section B5.0 provides requirements for the validation and reporting of RI data. References cited in this QAPP are provided in Section B6.0.

B1.2 APPROVAL OF QAPP

This QAPP may not be sufficient to address every aspect of future environmental sampling programs required for completion of the RI/FS, and it may require additional QA planning or updating as specific sampling and data collection efforts are more clearly defined in future FRI and FFS work plans. Changes or revisions to the procedures described in this QAPP will be documented as described in Section B2.7.5 and incorporated into the respective FRI and FFS work plans as appropriate for future investigations at the site for approval by the U.S. EPA.

B1.3 DISTRIBUTION OF QAPP

Distribution of any related work plans that specify data collection in support of the RI/FS will incorporate this QAPP in its entirety. Any subsequent revisions to this RI/FS QAPP will be formally distributed to the parties receiving the respective work plans or as directed by the U.S. EPA.

B2.0 GENERAL PROJECT DESCRIPTION AND KEY ORGANIZATION

This section presents a general project description and describes the responsibilities of key personnel associated with the environmental sampling planned at the site.

B2.1 PROJECT TEAM ORGANIZATION

The organization of the RI/FS project team is shown on Figure 12 (RI/FS Organization Chart).

The key positions and associated responsibilities are described below.

U.S. EPA Remedial Project Manager (RPM):

- Provide oversight of Administrative Order (AO) activities.
- Approve QAPP.
- Review monthly reports.
- Review and approve AO deliverables.

Atlantic Richfield Environmental Business Manager and Project Coordinator:

- Maintain responsibility for AO activities.
- Review QA needs, problems, and requests.
- Approve QAPP and appropriate QA corrective actions, as needed.
- Responsible for regulatory correspondence.

AMEC RI/FS Program Manager:

- Oversee AO activities.
- Provide strategy development and budget control.
- Responsible for resource management.
- Review work plans and reports.

AMEC RI Project Manager:

- Oversee RI activities and project schedule.
- Assign technical responsibilities to project staff and subcontractors.
- Ensure delivery of data and project deliverables to Atlantic Richfield.
- Implement necessary action, and as appropriate change orders, for activities to accomplish project objectives.
- Check field procedures.
- Review work plans and reports.

AMEC RI/FS Field Operations Supervisors and Health & Safety Personnel:

- Coordinate field activities in accordance with FRI and FFS work plans.
- Implementation of Health and Safety Plan (HASP).
- Coordinate with subcontractors.

AMEC RI/FS Project Quality Assurance (QA) Manager:

- Ensure QA procedures are followed during sample collection.
- Report difficulties/complications in sample collection.
- Ensure COC forms and field sampling sheets are filled out properly.
- Ensure that the appropriate field QC samples are collected per standard operating procedures.
- Receive laboratory deliverables and pertinent field data.
- Ensure appropriate validation activities for data.
- Evaluate qualified data.
- Coordinate schedule and progress of data deliverables.
- Track and file laboratory deliverables.
- Coordinate database management activities and maintain final project QA files.

Data Review Chemists:

- Conduct data verification and data validation at the direction of the Project QA Manager.
- Coordinate with laboratory to obtain additional information necessary to complete reviews.
- Report results of the verification/validation to the Project QA Manager.
- Notify Project QA Manager upon identification of nonconformance in the laboratory procedures.

Analytical Laboratories:

- Perform off-site analyses of samples.
- Ensure timely delivery of analytical results.
- Perform calibration and maintenance of equipment.
- Conduct internal QA/QC procedures.
- Notify Project QA Manager when problems occur.
- Ensure data and required data deliverables are reported correctly.
- Ensure all custody records are properly completed and handled.

B2.2 PROBLEM STATEMENT AND BACKGROUND

Historical mining activities at the Site have resulted in wastes and underground conduits that resulted in acid rock drainage (ARD). The ARD is currently being treated for low pH and high metals content to reduce impacts to associated surface water bodies (Aspen Creek and Leviathan Creek). The UAO issued by the U.S. EPA to Atlantic Richfield on June 23, 2008 (U.S. EPA, 2008), requires the RI/FS to quantify potential contaminants of concern in groundwater, surface water, sediment, soils, and mine wastes. Collectively, these data will define the extent, origin, direction, and rate of movement of contaminants at the site. 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 to develop and evaluate remedial alternatives.

B2.3 PROJECT DESCRIPTION AND SCHEDULE

The robust RI program for the site is divided into two investigation categories: (1) sitewide investigations and (2) study area investigations. As described in the SAP, the site has been subdivided into four study areas (Figure 4) for the purpose of implementing the RI/FS in an efficient manner:

1. Pit Study Area (PSA) (Figure 5),
2. Aspen Creek Study Area (ACSA) (Figure 6),
3. Leviathan Creek Study Area (LCSA) (Figure 7), and
4. Downstream Study Area (DSA) (Figure 8).

Historical data will be used as appropriate in the development of future FRI and FFS work plans to address data gaps as part of the sitewide investigations and in conjunction with data needs for each of the defined study areas. Additional details with respect to specific field investigations will be presented in the separate FRI and FFS work plans, of which this QAPP will be incorporated by reference. Once necessary work has been completed, the valid environmental data will be presented in the RI Report and evaluated with respect to the risk assessment for human health and ecological concerns, a feasibility study to address long-term cleanup.

B2.4 DATA QUALITY OBJECTIVES

DQOs specify the quality, quantity, and analytical level of data required to make decisions relative to site objectives. The DQOs will ensure that the data collected under the specified work plans are of sufficient quantity and quality for the “intended use” of the data. The DQOs for expected data collection tasks and evaluation of the chemicals of potential concern

(COPCs) to be completed as part of the RI/FS Program for the site were developed according to the U.S. EPA seven-step process (U.S. EPA, 1988); they are presented in the DQO Report and summarized in Section 5 of the RI/FS PWP. Some DQOs have been refined to incorporate comments from stakeholders regarding RI/FS data gaps, as discussed in the RI/FS PWP.

B2.5 CRITERIA FOR MEASUREMENT DATA

Data quality indicators (DQIs) include the elements precision, accuracy, representativeness, comparability, completeness, and sensitivity (PARCCS). The laboratory procedures will follow the most current of the minimum DQIs recommended by U.S. EPA Region 9 available on its Web site (http://www.epa.gov/region09/qa/datatables.html). The basis for assessing the elements of data quality is discussed in the following subsections. The site-specific criteria provided in this section and summarized in Tables 3 and 4 will be used to evaluate the quality of the data for the intended use.

B2.5.1 Precision

Precision measures the reproducibility of repetitive measurements. It is strictly defined as the degree of mutual agreement among independent measurements as the result of repeated application of the sample process under similar conditions.

Analytical precision is a measurement of the variability associated with duplicate or replicate analyses of the same sample in the laboratory, and it is determined by analysis of laboratory QC samples, such as laboratory control sample duplicates (LCSD), matrix spike duplicates (MSD), and laboratory duplicates (LD). If the measurement of analytes in the specified control samples are comparable within established control limits, then precision is within limits.

Total precision is a measurement of the variability associated with the entire sampling and analytical process. It is determined by analysis of duplicate or replicate field samples, and measures variability introduced by both the laboratory and field operations. Field duplicate samples are analyzed to assess field and analytical precision.

Duplicate results are assessed using the relative percent difference (RPD) between duplicate measurements. If the RPD for laboratory QC samples exceeds the limits specified in Table 3 or Table 4, any bias in the respective data will be evaluated as part of the validation process and the data will be qualified as necessary. If the RPD between primary and duplicate field samples exceeds 25 percent for water or 50 percent for other matrices, any bias in the data will be evaluated as part of the validation process and the data qualified as necessary. When

both results are within five times the reporting limit, the calculated precision is not considered to be significant. The RPD is expressed as a percentage and will be calculated as follows:

$$\text{RPD (\%)} = 100 \times \frac{|X_1 - X_2|}{(X_2 + X_1)/2}$$

where X_1 is the larger of the two observed values, and X_2 is the smaller of the two observed values.

B2.5.2 Accuracy

Accuracy is a statistical measurement of correctness and includes components of random error (variability due to imprecision) and systematic error. It reflects the total error associated with a measurement. A measurement is accurate when the value reported does not differ from the true value or known concentration of the spike or standard.

Accuracy of laboratory analyses will be assessed by laboratory control samples, surrogate standards, matrix spikes, and initial and continuing calibrations of instruments. Laboratory accuracy is expressed as the percent recovery (%R). Acceptance limits for laboratory control standards and matrix spikes are statistically derived by the laboratory and will be reported along with the laboratory data. At a minimum, the accuracy limits specified in Table 3 (Metals Analyses) or Table 4 (General Chemistry Parameters) will be met for the respective analytes. If the percent recovery is determined to be outside of acceptance criteria, any bias in the data will be evaluated as part of the validation process and the data qualified as necessary. The calculation of percent recovery is provided below:

$$\text{\% R} = 100 \times \frac{X_S - X}{T}$$

where X_s is the measured value of the spiked sample, X is the measured value of the unspiked sample, and T is the true value of the spike solution added.

Field accuracy will be assessed through the analysis of field blanks. Analysis of blanks will monitor errors associated with the sampling process, field contamination, sample preservation, and sample handling. The DQO for field blanks is that all values are less than the reporting limit for each target constituent. If contamination is reported in the field blanks, any associated bias in the data will be evaluated in accordance with validation procedures and qualified as necessary.

B2.5.3 Representativeness

Representativeness is the degree to which data accurately and precisely represents selected characteristics of the media sampled. Representativeness of data collection is addressed by careful preparation of sampling and analysis programs. In general, the RI/FS PWP provides a plan for the types and general location of sampling expected for the site. Sampling plans detailing the specific activities to be conducted in each of the study areas will be presented in future FRI and FFS work plans.

Together, the FRI and FFS work plans, the RI/FS PWP, FSP, SOPs, and this QAPP will address representativeness by including the following:

- specifying sufficient and proper numbers and locations of samples,
- incorporating appropriate sampling methodologies,
- specifying proper sample collection techniques and decontamination procedures,
- selecting appropriate laboratory methods to prepare and analyze environmental samples, and
- establishing proper field and laboratory QA/QC procedures.

B2.5.4 Completeness

Completeness is the amount of valid data obtained compared to the amount that was expected under ideal conditions. The number of valid results (i.e., not rejected results) divided by the number of possible results, expressed as a percentage, determines the completeness of the data set. The objective for completeness is to recover at least 90 percent of the planned data to support field efforts. The formula for calculation of completeness is presented as follows:

$$\% \text{ Completeness} = 100 \times \frac{\textit{number of valid results}}{\textit{number of expected results}}$$

B2.5.5 Comparability

Comparability is an expression of confidence with which one data set can be compared to another. The objective of comparability is to ensure that data collected during the RI/FS activities is comparable to the site knowledge, adequately addresses applicable criteria or standards established by the U.S. EPA, and will support the site-specific risk assessment. This QAPP addresses comparability by specifying laboratory methods and units of measure that are consistent with the current standards of practice as approved by the U.S. EPA and California Department of Health Services. Field methods are discussed in the site-specific SOPs (Appendix C of the SAP) and are herein incorporated by reference.

B2.5.6 Sensitivity

Sensitivity will be established through adequate laboratory detection limits that will achieve the benchmark criteria or other regulatory limits, such as hazardous waste classifications referenced in the California Code of Regulations Title 22 (CCR, 2007). These detection limits are shown in Table 5 for aqueous samples and Table 6 for solid samples. The adequacy of any selected analytical methodology will be determined based on the necessary sensitivity required for the anticipated use of the data and the rationale provided in the respective FRI and FFS work plans.

B2.6 TRAINING REQUIREMENTS

All personnel performing non-emergency work at the site on behalf of Atlantic Richfield in exclusion zones as defined in the *Leviathan Mine Health, Safety, Security and Environmental* [HSSE] *Program Document* (Atlantic Richfield, 2009) will have current 24 or 40-hour Hazardous Waste Operations and Emergency Response (HAZWOPER) certification and 8-hour refresher HAZWOPER certification per 29 CFR 1910.120 (www.osha.gov). Additional training requirements are specified in the HSSE and individual contractors' task-specific HSSE plans. In addition, personnel responsible for operating mechanical equipment, including pumps, generators, and mixing equipment, will receive the necessary operating instructions on that equipment. Sampling personnel will be trained in the use of industry-standard practices and those practices specified in the SOPs (Appendix C of the SAP). Sampling oversight will be provided by a qualified geologist, scientist, or engineer.

All personnel involved in field activities will be familiar with the requirements of the project QAPP. One hard copy of the current approved version of the FRI and FFS work plans and the SAP (including this QAPP) will be maintained in the Leviathan Field Office for ready reference.

B2.7 DOCUMENTATION AND RECORDS

This section presents the methods for generation, compilation, reporting, and archiving of data as part of the overall data management process. The project records will be organized, filed, and maintained under the direction of Atlantic Richfield.

B2.7.1 Field Documentation

Data measured by field instruments will be recorded in field notebooks and/or on required field data sheets. Examples of field data sheets are included with the SOPs (Appendix C of the SAP). Sample collection activities will be documented on field data sheets and placed in a three-ring binder assigned to the respective sampling event. All entries will be made in indelible ink; errors will be corrected by one single line through the text being revised and all

such corrections will be initialed and dated. Field notebooks are maintained in the project field office for accessibility by the sampling personnel.

Field data sheets will be used to record the following information:

- name of sample collection personnel;
- sample date, time, types, numbers, and quantities;
- sample container preservation steps performed;
- sample locations (ID number or code);
- sampling equipment used;
- decontamination steps performed;
- calibration and maintenance actions;
- information identifying other field equipment by equipment identification number; model/manufacturer, serial number, or other unique identifier; and
- confirmation that COC forms (see Section B2.7.2) were properly completed and sample custody transferred as required by this QAPP.

In addition, other ancillary information should be recorded, as follows:

- summary of daily activities;
- any deviations from the associated FRI and FFS work plans, FSP, QAPP, or SOP;
- time of arrivals/departures of sampling personnel and/or other visitors to the sampling site(s);
- weather conditions; and
- any unusual events.

The field notebooks will be kept up to date on a daily basis; backup copies of each day's entries will be made at least weekly and forwarded separately to the project office files, as noted in Section B2.7.4.

B2.7.2 Chain-of-Custody Records

During sampling activities, a "paper trail" of sample custody must be maintained from the time the samples are collected until laboratory data is issued. Initial information concerning sample collection will be recorded in the field notebook as described in Section B2.7.1. Information on the custody, transfer, handling, and shipping of samples will be recorded by the sampling personnel on an Atlantic Richfield COC form (provided in SOP 6.0), or equivalent form

provided by the destination laboratory. A COC form will be completed for each set of samples collected daily. At a minimum, every COC will contain the following information:

- sampling personnel's signature;
- project name;
- date and time of collection;
- sample identification number and matrix;
- analyses requested;
- number of containers;
- signatures of persons relinquishing custody, dates, and times;
- signatures of persons accepting custody, dates, and times;
- method of shipment; and
- shipping papers/waybill identification number (as appropriate).

Additionally, COCs for samples shipped to an Atlantic Richfield contract laboratory will contain the following information:

- name of the lead regulatory agency,
- name and contact information of the environmental business manager,
- name and contact information of the consultant and project manager,
- ENFOS proposal number and the stage and activity level of the project, and
- level of data package requested.

A copy of each COC form will be retained in the project files in accordance with Section B2.7.4.

B2.7.3 Analytical Laboratory Records

The selected laboratories will be responsible for preparing analytical laboratory reports and electronic data deliverables (EDDs) in accordance with Atlantic Richfield's technical requirements. The EDDs will be obtained for all analytical results. An automated laboratory information management system must be used to produce the EDD. The results presented in the EDD will correspond exactly to the analytical results presented in the hard copy report.

B2.7.4 Sampling Program Record Files

Sampling program records are defined as completed, legible documents that furnish objective evidence of the quality and completeness of the data acquired pursuant to the requirements of

the project activities. These records will be organized, filed, and maintained under the direction of the RI Project Manager and at a minimum will include the following:

- original copies of all field sampling data sheets;
- field copies and original (laboratory) copies of all COC forms;
- personnel training records;
- incoming and outgoing correspondence related to the project activity (e.g., letters, telephone conversation records, faxes, and hard copies of e-mail messages);
- copies of all laboratory agreements and amendments thereto;
- as-received laboratory reports and data packages;
- all approved Field Change Request (FCR) forms (see Section B2.7.5);
- draft and final versions of all reports and any associated laboratory data packages;
- corrective and Preventive Action Request (CPAR) Forms (see Section B4.4);
- assessment and/or technical review reports;
- data validation reports; and
- final versions of this QAPP and its appendices.

B2.7.5 Field Change Request Forms

Due to the conditions associated with field sampling activities, unexpected situations may occur that will require deviations or modifications to the requirements of the QAPP (and/or SOPs). Other changes may be required by the U.S. EPA and Atlantic Richfield during the course of the monitoring program. When changes are necessary, the Project QA Manager may authorize the field personnel to undertake modifications to the QAPP or its appendices, provided that the scope of such modifications is discussed with the Project QA Manager and approved beforehand and then documented on a FCR form as shown in Attachment 1. Each FCR form will be uniquely numbered and will identify the affected sections of the QAPP or its supporting appendices, the scope of the requested variation, and the justification for its acceptance.

B3.0 DATA GENERATION AND ACQUISITION

This section of the QAPP generally describes how the samples will be collected, shipped, and analyzed.

B 3.1 SAMPLING PROCESS DESIGN

The number of samples that should be collected and analyzed depends on the objective of the investigation. There are three basic sampling strategies: random, systematic, and judgmental sampling.

1. **Random sampling** involves collection of samples in a nonsystematic fashion from the entire site or a specific portion of a site.
2. **Systematic sampling** involves the collection of samples based on a grid or a pattern which has been previously established.
3. **Judgmental sampling** involves the collection of samples only from the portion of the site most likely to be contaminated.

A combination of these strategies is the best approach, depending on the type of the suspected/known contamination, the uniformity and size of the site, and the level/type of information desired.

Collection of environmental samples of high integrity is important to the quality of chemical data to be generated. To this end, strict field procedures have been developed that will be employed at various locations during phases of the field investigation. These field procedures are detailed in the SOPs (Appendix C of the SAP). Field monitoring and sampling will be conducted to support the collection of environmental data outlined in the RI/FS PWP and detailed in the respective FRI and FFS work plans.

B3.1.1 Sample Collection and Preparation

Two basic types of sample collection techniques will be used: grab and composite samples.

- **A grab sample** is defined as a discrete aliquot representative of a specific location at a given point in time. The sample is collected all at once at one particular point in the sample medium. The representativeness of such samples is defined by the nature of the materials being sampled. In general, as sources vary over time and distance, the representativeness of grab samples will decrease.
- **A composite sample** is a non-discrete sample composed of more than one specific aliquot collected at various sampling locations and/or different points in time. Analysis of this type of sample produces an average value and can in certain instances be used as an alternative to analyzing a number of individual grab samples and calculating an average value. It should be noted, however, that compositing can mask problems by diluting isolated concentrations of some hazardous compounds below detection limits.

For sampling situations involving potential hazardous wastes, grab sampling techniques are generally preferred for the following reasons:

- The amount of time sampling personnel must be in contact with the wastes is minimized.
- The risks associated with compositing unknowns are reduced.
- The chemical changes that might occur due to compositing are eliminated.

As specified by the receiving laboratory, field preparation activities may need to be performed during the sample collection process to ensure that a representative sample is properly collected and transported. Such activities may include specific sampling methods, sample containers, and field preservation. Consult the laboratory for special sample collection and preparation activities that may need to be performed in the field in order to meet the needs of the planned laboratory analytical method.

General field procedures for collecting samples are described in the SOPs included as Appendix C of the SAP. Details of the sample collection and preparation activities will be defined in the FRI and FFS work plans. Additional guidance for specialized sampling such as fish, insects, and invertebrates will be detailed as necessary in the respective FRI and FFS work plans since these specific habitats have yet to be identified.

B3.1.2 Sampling Locations

The rationale for selection of sampling locations will be to fulfill the DQOs and requirements of the SOW that are described in Sections 4 and 5 of the RI/FS PWP. Specific sampling locations are not yet defined. Sampling locations related to the collection of environmental data for the sitewide investigations, as well as for each of the study areas, will be detailed in the respective FRI and FFS work plans. The sampling locations, frequency of sampling, and analyses to be conducted will also be presented in the respective FRI and FFS work plans.

B3.1.3 Sample Preservation Requirements

Table 7 presents sample holding times, storage conditions, and preservation requirements for sample collection. Additional guidance for specialized test methods such as biological samples, mineralogy, and sediment toxicity will be detailed in future FRI and FFS work plans since compilation of data from other sitewide investigations will provide a more definitive scope for these efforts.

B3.1.4 Decontamination Procedures

Nondedicated sampling equipment will be triple-rinsed prior to taking each sample. All rinsate will be disposed of on site. Field personnel will handle field equipment and containers carefully to minimize the potential for cross-contamination. Containers will be handled in such a manner as to prevent direct contact with internal surfaces, and the sampling personnel will avoid wearing items or clothing that may interfere with dexterity or create a route for cross-contamination.

B3.2 SAMPLE HANDLING AND CUSTODY REQUIREMENTS

General sample identification, labeling, handling, and custody requirements are discussed in this section. COC procedures will be strictly adhered to during sample collection, transportation, and laboratory handling to ensure the identity of the samples. Improper sample and data handling and inadequate COC procedures affect the credibility and acceptability of analytical results, regardless of their accuracy or precision. COC documentation will document the processing of the sample from the time of collection to the time of analysis.

B3.2.1 Sample Labeling and Handling

Sample containers with the necessary preservatives will be provided by the contract laboratories, in accordance with Section B3.1.3. After collection, samples will be labeled with self-adhesive labels with all necessary information filled out using waterproof ink. At a minimum, each sample label will contain the following information:

- project name;
- site location;
- sample identification code;
- date and time of sample collection, with sampler's initials;
- analyses required;
- method of preservation, if used; and
- sampler's initials.

Each sample will be assigned a unique identification code according to sample location and date. This ID will consist of three parts:

1. Sample Type—groundwater (GW), surface water (SW), stream sediment (SS), soil boring (SB), plant sample (PS), fish sample (FS), invertebrate sample (IS), and waste sample (WS);

2. Study Area Designation—Aspen Creek Study Area (A), Leviathan Creek Study Area (L), Pit Study Area (P), Downstream Study Area (D), or Background (B);

3. Date—expressed as a two-digit month, day, and year (MM/DD/YY); and

4. A continuous sequence number will be used for each day of sampling in each of the designated sampling areas. Sequential numbering will restart at 01 on a given sampling day, in a given sampling area.

The four parts of the ID will not be separated by any symbols, characters, or spaces. For example, if the 48th sample is taken for a groundwater sample in the Leviathan Creek Study Area on February 5, 2010, the sample ID will be *"GWL02051048."* If the next sample collected on February 5, 2010 is taken from a soil boring in the Aspen Creek Study Area, (and this is the first sample collected in this study area for the day) the sample ID will be *"SBA02051001."* Waste characterization samples will be designated by respective Study Area. For example, if investigative-derived waste (soils or water) from the Pit Study Area is collected on January 1, 2010, the sample ID will be *"WSP01011001,"* Refer to Section B3.4.2 for discussion on handling and labeling laboratory QC samples.

Field blanks and duplicates shall be labeled so as not to indicate the identity of the sample to the laboratory and will follow the labeling convention (using the appropriate number sequence) in place of calling the sample "blank" or "Dup." The identity of field QC samples will be traceable through appropriate documentation as described in the respective SOPs.

Sample containers will be sealed in sealable plastic bags and immediately placed on ice in an insulated cooler and chilled. Insulated coolers will be provided by the contract laboratories. Samples will be placed right side up in a cooler with ice for delivery to the laboratory.

B3.2.2 Chain-of-Custody Procedures

The sampling personnel responsible for the collection of samples will sign and retain a copy of the COC form, as described in Section B3.7.2, document the method of shipment, and send the original with the samples. The original signed COC form will be sealed in a watertight plastic envelope and attached to the inside lid of the cooler. Coolers will be secured with strapping tape and a container custody seal applied that is overstrapped with clear strapping tape. All sample shipment coolers will be transferred from the field directly to the analytical laboratory. In cases where direct delivery to the analytical laboratory is not possible, samples will be stored in a refrigerator at no more than 6°C, but above freezing. Access to the refrigerator will be restricted to the Field Operation Supervisors and sampling personnel.

The COC form will be shipped with the cooler to confirm transfer; the carrier waybill number will be recorded on the original COC. Commercial carriers are not required to sign the COCs. Copies of the COCs and waybills will be forwarded by the Field Operation Supervisors to the Project Manager for incorporation into the project files, in accordance with Section B3.7.4.

Sample shipment will be scheduled to prevent exceeding any required holding period. Failure to conduct analyses within the required holding times may potentially require the qualification of associated analytical results and will prompt appropriate corrective and preventive action measures as discussed in Section B4.4.

B3.2.3 Laboratory Operations

Atlantic Richfield sponsors the Laboratory Management Program (LaMP). The LaMP was implemented to ensure that the analytical testing and services needs of Atlantic Richfield on environmental/remediation projects were consistently met. The LaMP provides and ensures sources of high-quality analytical data for Atlantic Richfield that are legally defensible, and it minimizes the total cost of ownership. The LaMP consists of a network of approved contract laboratories that supply analytical testing services for Atlantic Richfield's environmental and remediation programs.

The LaMP addresses QA policies and QC procedures required by these contract laboratories consistent with U.S. EPA recommendations for laboratories set by the American National Standards Institute (ANSI/ASQC, 1995). Any selected laboratory will be a licensed testing facility in the state of California and certified pursuant to the California Health and Safety Code Section 25198. Laboratory selection will be based on qualifications, proven performance, and costs.

The respective laboratory's project manager will report to the Project QA Manager on all aspects of sample analysis. In addition, Atlantic Richfield will be advised on any matters related to data quality that may affect laboratory performance. Laboratory analyses will be managed in accordance with the approved laboratory QA plans and manuals, this QAPP, and the requirements described in the LaMP. In the event conflicts may exist between this QAPP, the LaMP, and any of the laboratory QA plans, the more stringent requirements will apply.

B3.2.3.1 Sample Receipt

When samples arrive at each laboratory, the designated laboratory custodian receiving the sample cooler will inspect the cooler and sample containers for damage. The custodian will sign the shipping COC and attach the carrier billing. The shipping COC and waybill will be archived in the laboratory's project file, and a copy of the shipping COC and waybill will be

forwarded to Atlantic Richfield for filing in the monitoring program records in accordance Section B3.7.4. The laboratory custodian will then open the cooler to inspect the samples for integrity and compare the number of containers and label information with the COC form attached to the inside of the cooler lid. Cooler temperatures will be checked and documented on the COC form. Broken or damaged sample containers, sample labeling discrepancies between container labels and the COC form, and analytical request discrepancies will be noted on the COC form. The Project QA Manager or Field Operations Supervisor will be notified of any such problems for the appropriate action.

Once any discrepancies are resolved, the laboratory custodian will enter the samples into an analytical custody log and will assign each sample a unique identification number that is cross-referenced to the sample number assigned in the field. The identification number will be used by the laboratory in its internal tracking system, and the status of any given sample can be checked at any time by referring to the laboratory numbers on the COC form and in the laboratory logbooks. Both the laboratory and sample numbers will be cited in the final laboratory report. The laboratory custodian will then sign the COC form. The original COC will be routed to the laboratory's data management group. Copies of the COC forms documenting custody changes and documentation will be received and kept in the laboratory's project files. The original COC forms will remain with the samples until final disposition of the samples by the laboratory. Samples, extracts, or digestates will not be sent to another laboratory without the written authorization of the Project QA Manager.

B3.2.3.2 Sample Storage and Security

While in the laboratory, the samples and aliquots that require storage at no more than 6°C, but above freezing, will be kept in a locked refrigerator prior to analysis. Other sample types requiring storage at freezing temperatures will be placed appropriately in secured freezers at the laboratory. At a minimum, the following procedures will be applied:

- Samples and extracts will be stored in a secure area controlled by the laboratory's designated sample custodian.
- Samples will be removed from the shipping container and stored in their original containers unless damaged; damaged samples will be disposed of in an appropriate manner.
- Samples will be disposed of not less than 30 days after final laboratory reports are issued and documented.
- Whenever samples are removed from storage, removal will be documented.
- Sample transfers will be documented on internal COC records.

- Samples and extracts will be stored after completion of analyses in accordance with contractual requirements, or until instructed otherwise by the Project QA Manager.
- Samples will not be stored with standards or sample extracts.

B3.2.3.3 Sample Tracking

Laboratory personnel will use COC records or databases to generate backlist reports of any unanalyzed samples. The reports will include the collection times along with the laboratory sample number, and will include a reference to the project title, field sample identifications, and sample matrix. Sample analyses will be scheduled on the basis of holding time considerations. Analytical assignments will be reviewed on a daily basis to ensure that holding times are not exceeded. If holding times are exceeded during laboratory custody, the Project QA Manager or Field Operations Supervisor will be notified immediately for the appropriate action.

B3.2.3.4 Sample Custody Records

Minimum requirements for laboratory sample COC controls are as follows:

- Samples will be stored in a secured area.
- Access to the laboratory will be through a monitored area; other outside access doors to the laboratory will be kept locked in accordance with local fire requirements.
- A visitors' log will be maintained and visitors will be escorted while in the laboratory.
- Refrigerators, freezers, and other sample storage areas will be securely locked or maintained in a secured area.
- Only authorized personnel will have keys to locked sample storage area(s).
- Samples will remain in secure sample storage until removed for preparation or analysis.
- Sample transfers into and out of storage will be documented.
- Custody records will be maintained by the laboratory's sample management group.

To ensure that any potential analytical problems can be properly addressed, samples, extracts, and digestates will be retained at the laboratory for at least 30 days after the laboratory's final analytical data report has been submitted to Atlantic Richfield. The samples, extracts, and digestates may then be discarded in an approved and environmentally safe manner unless otherwise directed by the Project QA Manager.

B3.3 ANALYTICAL METHOD REQUIREMENTS

The primary laboratory for all off-site sample analyses will be Test America, Inc., unless project constraints or specialized testing requirements dictate otherwise. The laboratory and its staff have the responsibility to process all samples submitted according to the specific protocols for sample custody, holding times, analysis, and associated laboratory QA. Designated laboratory personnel will maintain contact with the Project QA Manager to ensure that laboratory DQIs are achieved as described in Section B2.5. Laboratory DQIs are defined in terms of accuracy and precision.

B3.3.1 Sample Preparation Methods

Sample preparations will be in accordance with standard laboratory practices and the governing analytical methods as defined in Table 7. Subsamples will be obtained for matrix spikes prior to sample preparation and analysis. A subsample will consist of a proportion of a homogenized sample that is at least equal to the minimum size requirement for the analytical test.

B3.3.2 Analytical Methods

Table 7 summarizes the extended analytical list for sample testing. Analytical methodologies and detection limits are also presented. Not all parameters identified in Table 7 will be analyzed for in every sample. Also, additional analytical methods may be necessary for specialized sample testing. The specific analytical tests required for individual samples will be defined in the future FRI and FFS work plans.

B3.4 QUALITY CONTROL CONSIDERATIONS

QC samples will be employed and monitored as part of the overall program. Results of QC samples will be evaluated with respect to the DQIs. Laboratory QC samples are initiated and monitored by the laboratory as part of the testing procedures. Field QC samples should be collected in the field and used to evaluate the quality of the field sampling activities. Each project-specific work plan will address the specific field QC sampling requirements in the associated QAPP. These samples will be handled and analyzed using the same procedures as the primary samples

B3.4.1 Field Quality Control Samples

Field QC samples may consist of field duplicate samples, field method blanks, and/or field equipment rinsate blanks.

B3.4.1.1 Field Duplicate Samples

Field duplicate samples may be collected to assess the precision and overall quality of the sampling and analytical procedures. Field duplicate samples are collected at the same time and from the same source as the original sample. Duplicate samples will be collected, numbered, packaged, and sealed in the same manner as other samples and submitted blind to the laboratory for identical analyses as the original sample. Field duplicates will be collected and analyzed at a frequency of 10 percent of the overall project samples. Certain sample types (e.g., plants, fish, invertebrates) do not lend themselves to this type of sampling. In lieu of field duplicate samples for these specialized biota samples, the laboratory will be instructed to homogenize the sample and perform appropriate laboratory duplicate analysis to ensure adequate precision data is obtained.

B3.4.1.2 Field Method Blank Samples

Field method blanks consist of contaminant-free water (often commercially distilled water or laboratory-prepared deionized water, depending on the specific QC requirements) that is placed into the sampling containers at the same time and location of a field sample. The field blank sample is handled in the same manner as other samples and submitted blind to the laboratory for analysis identical to that of the other samples. Field blanks are used to evaluate any contamination present during sampling and/or laboratory contamination. Field method blanks will be collected and analyzed after every 10 samples, where applicable to the sampling method employed. The collection of field blank samples will be discussed in the respective FRI and FFS work plans.

B3.4.1.3 Field Equipment Rinsate Blank Samples

Field equipment rinsate blanks consist of contaminant-free water that is placed into the sampling containers at the same time and location of a field sample. The equipment rinsate blank sample is collected in the same manner as other samples, utilizing any nondedicated, decontaminated sampling equipment (sample tubing, filters, shovels, etc.). These samples are submitted blind to the laboratory for analyses identical to the other samples'. Field equipment rinsate blanks are used to evaluate decontamination procedures of sampling equipment. Field equipment rinsate blank samples apply only to nondedicated field equipment. Field equipment rinsate blank samples will be collected and analyzed every 10 samples, where applicable to the sampling method employed. The collection of field equipment blank samples will be discussed in the respective FRI and FFS work plans.

B3.4.2 Laboratory Quality Control Samples

Laboratory QC samples will be introduced into the measurement process to evaluate laboratory performance and sample measurement bias, as defined by the governing analytical methods. Control samples may be prepared from environmental samples or generated from standard materials in the laboratory. Categories of laboratory QC samples that may be required by each analytical method are summarized in Tables 3 and 4.

B3.4.2.1 Method Blanks

Method blanks will be used for the laboratory processes, as defined by the governing method. A method blank is a volume of deionized water that is carried through the entire sample preparation and analysis procedure. The method blank volume or weight will be approximately equal to the sample volumes or sample weights being processed. Method blanks are used to monitor interference caused by constituents in solvents and reagents and on glassware and other sampling equipment. A method blank is prepared and analyzed with each analytical batch of 20 or fewer samples prepared.

B3.4.2.2 Matrix Spikes

A spike is a sample to which is added a known amount of analyte(s) before analysis. From the concentrations of the analyte in the spiked and unspiked samples, a percent recovery is calculated. Many samples show matrix effects in which other sample components interfere with the determination of the analyte. The value of the percent recovery indicates the extent of the interference. A matrix spike is prepared by adding an analyte to a sub-sample of a field sample before sample preparation and analysis. For multi-analyte methods, a representative suite containing all of the analytes is used in the matrix spike. If matrix spikes are spiked at too low a concentration (i.e., less than three to five times the native concentration), they will be repeated at a higher spike concentration. An analytical spike is prepared by adding analyte to an aliquot of a processed sample prior to analysis, and it is used to determine whether the analysis system provides results that are representative of the sample when a matrix spike is outside its limits.

B3.4.2.3 Laboratory Control Samples (Verification Solutions)

A laboratory control sample (LCS), or a blank spike, is an aqueous or solid control sample of known composition that is analyzed using the same sample preparation, reagents, and analytical methods employed for the monitoring program samples. An LCS is obtained from an outside source or is prepared in the laboratory by spiking reagent water or a clean solid matrix for a stock solution that is different than that used for the calibration standards. The LCS is the primary indicator of process control used to demonstrate whether the sample preparation and

analytical steps are in control, apart from sample matrix effects. LCSs contain the target analytes identified in the method.

B3.4.2.4 Laboratory Duplicate Samples

Duplicate samples are samples that have been divided into two portions at some step in the measurement process. Laboratory duplicates are prepared by taking two aliquots of a process sample and analyzing them in the same manner. Duplicate samples provide information on the precision of the operations involved. Analytical duplicates are a pair of sub-samples from a field sample that are taken through the entire preparation and analysis procedure; any difference between the results indicates the precision of the entire method in the given matrix. Analytical duplicates are also accomplished by duplicating the matrix spike to provide a matrix spike duplicate. Both matrix and analytical spike duplicates are used to monitor the precision of the analytical process. For water samples, the laboratory will analyze one laboratory duplicate sample per sample delivery group. A sample delivery group is defined as a group of up to 20 samples received within a 14-day period.

B3.5 INSTRUMENT/EQUIPMENT CALIBRATION AND MAINTENANCE REQUIREMENTS

Field Operation Supervisors are responsible for the field-related testing equipment used to collect measurement data. The laboratory chemist is responsible for conducting the calibration and maintenance of all laboratory-related equipment. This section outlines these responsibilities.

B3.5.1 Calibration of Field Measurement Equipment

For water sampling, instrumentation and equipment used will generally be limited to field meters and analyte-specific field testing kits. The field measurement equipment will be used and maintained in accordance with the manufacturer's instructions. Field meters and field test kits will be calibrated following the manufacturer's instructions for each analyte of interest and at least once per sampling event. Scheduled maintenance will be performed by trained personnel. Procedures specific to the calibration, use, and maintenance of field equipment are presented in the SOPs (Appendix C of the SAP).

B3.5.2 Calibration of Laboratory Equipment

This section presents the calibration methods for testing equipment that will be performed and checked at the onset of laboratory analysis.

B3.5.2.1 Instrumentation Requiring Calibration

All analytical measurement instruments and equipment used by the laboratories will be controlled by a formal calibration and preventive maintenance program. At a minimum, each

laboratory will require that equipment be of the proper type, range, accuracy, and precision to provide data compatible with specified requirements. All instruments and equipment that measure a quantity or whose performance is expected at a stated level are subject to calibration. In addition, each laboratory's preventive maintenance program will include the following, at a minimum:

- a listing of the instruments and equipment that will be used;
- the frequency of maintenance, considering manufacturer's recommendations and previous experience with the equipment; and
- a file for each instrument, containing a list of spare parts maintained, external contracts, and a list of items to be checked or serviced during maintenance.

B3.5.2.2 Calibration Methods

Physical and chemical calibrations will be performed within each laboratory as described in the governing methods, laboratory SOPs, and the additional LaMP requirements that are summarized in this subsection. Physical calibration refers to physical measurements that are made on equipment to verify or provide corrections to the observed data. Physical calibrations will be documented on data sheets that are designed for each specific application. At a minimum, the information record will include the date, analyst, instrument identification, identification of reference standard, expected values, measured values, and correction factors, if applicable.

Chemical calibration or standardization refers to operations in which instrument response is related to analyzed concentration. The minimum requirements for chemical calibration will be as specified in the applicable method. Chemical calibrations consist of initial and continuing calibrations, which are documented in several ways depending on the type of instrument. For noncomputerized data systems such as strip chart recorders and meter readouts, the instrument responses will be transcribed, along with other pertinent information, onto data sheets for each specific analysis. When computerized data systems are used, the data will be collected and stored in computer files, as well as on hardcopy printouts, which may be either included with the data package or kept in a central record. With computerized data systems, the run logs provide a cross-reference to the calibration runs. At a minimum, the information recorded for the calibrations will include the data, analyst, instrument identification, standard identification and concentrations, raw instrument responses, file descriptor, and calibration parameters such as regression coefficients, correlation coefficients, or response and calibration factors.

Initial calibration consists of the establishment of a calibration or standard curve, which associates instrument response and analyzed concentration. The curve is constructed by measuring the responses of a series of standard solutions containing the analytes of interest at known concentrations. As stated in the LaMP, the lowest nonzero standard will be equal to the laboratory detection limit. This initial calibration will be verified each working day by measurement of one or more calibration standards.

B3.5.2.3 Calibration Standards

Primary standards will be obtained as either neat materials to be used to prepare stock standard solutions, or as prepared solutions to be used as stock standards. Records will be maintained on primary standards that include date of receipt, source, purity, composition, storage conditions, and expiration dates. Primary standards will be traceable to National Institute of Standards and Technology standards or will be vendor certified. The preparation of stock, intermediate, and working standard solutions will be documented in the standards preparation logbooks. Each stock, intermediate, and working standard will be assigned a number to permit traceability of preparation from stock to working standards and to reference the analysis of the standards. Logbooks will be completed by the appropriate analysts as they prepare standards and will be subject to supervisory review. At a minimum, working standards will be labeled with preparation data as well as with the number or designation of the logbook where information on the standard is recorded. Measurements made during standards preparation will also be recorded.

B3.5.2.4 Calibration Frequency

The frequency of instrument calibration will be according to the manufacturer's instructions or the SOPs for each laboratory.

B3.6 INSPECTION AND ACCEPTANCE OF SUPPLIES AND CONSUMABLES

All purchased supplies and consumables that support field monitoring and sampling activities or that have a direct relationship to sample quality (e.g., sample containers, decontamination supplies, distilled/deionized water) will be inspected upon receipt. At a minimum this inspection will check the following:

- Part number/physical description matches requisition.
- Supplies are intact and undamaged.
- All required components/documentation is included.
- Any nonconforming items will be documented and returned to the supplier for replacement, rework, or other action as necessary.

B3.7 DATA ACQUISITION REQUIREMENTS

This section describes the overall process of monitoring sample acquisition and associated analytical, data management, and reporting processes. The quality of the field and analytical data from any given sampling round will be further evaluated using the acceptance criteria described below.

B3.7.1 Acquisition of Non-Direct Measurement Data

To supplement the data collection activities conducted in support of the RI/FS, other potential "external" data sources will be included in the project database as appropriate. These sources include, but are not limited to, the Regional Water Quality Control Board (RWQCB), the U.S. Geological Survey (USGS), the California Department of Fish and Game (DFG), and the U.S. EPA. The primary use of this external data will be to help focus the RI/FS data collection efforts, address data gaps for completing the RI/FS, and provide a cohesive approach to future decisions. Acceptance criteria for non-direct measurement data will address the following:

- **Representativeness.** Were data collected from a population that is sufficiently similar to the population of interest and the population boundaries? How will confounding effects (such as season, time of year, and sampling method) be addressed?
- **Bias.** Are there characteristics of the data set that would shift conclusions? Is there sufficient information to estimate and correct bias?
- **Precision.** How is the spread in the results estimated? Does the estimate of variability indicate that it is sufficiently small to meet the objectives of the project as stated in Section 2.5.1, Data Quality Objectives?
- **Qualifiers** Are the data evaluated in a manner that permits logical decisions on whether or not the data are applicable to the current project? Is the system of qualifying or flagging data adequately documented to allow the combination of data sets?
- **Summarization.** Is the data summarization process clear and sufficiently consistent with the goals of this project?

Further examination of the non-direct measurement data will be conducted to verify that the data are of sufficient quality to meet the needs of the project decisions (e.g., risk assessment). The data will be reviewed to verify the following:

- The sample locations are adequately surveyed and from the same general vicinity as known collected data.
- The sample collection methods are well documented.

- The QA/QC information associated with the sample analysis is available and has been adequately evaluated.
- The data provide the necessary information to support a robust project database.

If the data is of insufficient or unknown quality, limitations will be placed on its use in supporting project decisions.

B3.7.2 Data Management

This section discusses how the newly generated data will be managed and incorporated into the Atlantic Richfield central data management system.

B3.7.2.1 Field Data Verification/Reporting

Field data will be recorded on field data sheets as the measurements are taken. Integrity of daily field instrument calibrations will be checked by the field staff according to the instrument calibration procedures provided by the equipment manufacturer. The field instrument QC measurements will be reviewed to ensure the accuracy and precision of the field screening measurements. As a standard QC procedure, the field staff will verify field data calculations and documentation entries. Prior to entry into the database, field data will be screened to ensure that no transcription errors occurred.

B3.7.2.2 Laboratory Data Generation

Any anomalies or limitations for the use of the data identified during sample analysis will be documented as part of the laboratory's analytical data packages. The laboratories will establish calibration curves and calculation of sample concentrations from instrument responses in accordance with the method protocols, the technical requirements of the LaMP, and the laboratory SOPs. Raw laboratory data will be converted to sample concentrations using formulas defined by applicable laboratory SOPs. The calculations will be performed by computerized data systems interfaced to the instruments, by calculators, or through programs installed on stand-alone computers. Laboratory analysts will be responsible for the reduction of the raw data that they generate. At a minimum, such activities will include the following:

- reduction of raw data generated to reportable values;
- initial review of analytical and QC data;
- performance of manual calculations and transfer of data onto forms, laboratory reports, and laboratory databases;
- preparation of computer files for instrumental calculations;
- generation of data forms for the analytical reports;

- copying of relevant forms and logs for inclusion in the laboratory reports;
- submittal of the laboratory report to a supervisor for a QA/QC review; and
- resolution of discrepancies noted during the QA/QC review.

For non-instrument methods and for methods using instruments without computerized data systems that require manual calculations, the responsible analyst will enter bench-generated data into bound laboratory workbooks with form-specific instrument responses, standard and spike concentrations, sample numbers, and other pertinent information. For instruments that are directly coupled to computerized data systems, raw data consist of instrument responses in the form of printer output or computer-generated data files. Printer outputs will be filed by sample batch and the data files archived on appropriate media. Computer data files will be identified by unique, sequential descriptors cross-referenced in the run logs to the analysis sequence. At a minimum, strip chart recordings will be labeled with the following information:

- sample identification number,
- date and time of analysis,
- instrument identification,
- name(s) of analyst(s),
- applicable operational parameters,
- data file identification, and
- positively identified elements or compounds.

For the purpose of this project, laboratory reports will meet the defined BP Level I data deliverables described in the LaMP technical requirements for all samples reported. In addition, BP Level III data deliverables will be required for a minimum of 20 percent of the overall samples collected for the purpose of completing data validation. Completed laboratory reports (PDF versions and EDDs) for each sampling round will be routed to the Project QA Manager for verification, validation, evaluation, and reporting. Prior to release, the laboratory will ensure that data packages are complete and do not contain any obvious entry errors; any observed problems will be referred to the affected laboratory for resolution.

At a minimum, the laboratory screening process will verify the following:

- COC forms are properly maintained from the field, to the laboratory, and through all analytical procedures.
- Laboratory reports are complete and contain no transcription errors or omissions.
- Holding time requirements are met.

- Method blanks meet method requirements.
- Laboratory QC samples meet acceptance limits.
- Laboratory detection limits do not exceed expected target limits.

B3.7.2.3 Data Storage and Retrieval

Atlantic Richfield maintains a central electronic data management system (database) using Access software. The purpose of the database is to provide the efficient management of, and access to, normalized Leviathan Mine site-related environmental data. The database is structured to be compatible with U.S. EPA data systems and Geographic Information Systems (GIS). A Data Management Plan (DMP) has been developed as part of the overall RI/FS program and is presented in Section 8.0 of the RI/FS PWP.

AMEC is responsible for maintaining and updating the project database with the RI/FS data, water quality results, and flow data collected as part of the site removal actions, climate data, and any site-related water quality data provided by the RWQCB. Periodic data updates will continue throughout the RI/FS program. Information collected in the project database will be made available upon request.

AMEC will retain records of all sampling information, including all sampling logs and field notes, all calibration and maintenance records and all original strip chart recordings for continuous monitoring instrumentation, copies of all reports, a copy of this QAPP, and any amendments for a period of at least five years from the date of the sample, measurement, report, or application. All records will be maintained as part of the monitoring program records in accordance with Section B2.7.4.

AMEC is responsible for its own data quality evaluation and data entry. Data will be formatted in accordance with the electronic template provided by Atlantic Richfield. After AMEC has performed the appropriate data quality evaluation and data entry, the data will be made available to Atlantic Richfield electronically. Atlantic Richfield will then incorporate the new data into the central project database. Appropriate field records and documentation (including sampling logs, field notes, calibration records, etc.) will also be forwarded to Atlantic Richfield upon request.

B4.0 ASSESSMENT/OVERSIGHT

This section describes how the data collection activities will be checked to ensure that they are completed correctly and according to procedures outlined in this QAPP.

B4.1 FIELD AND LABORATORY ASSESSMENTS

At the discretion of the Project QA Manager, on-site assessments of sampling practices or analytical laboratory activities may be performed periodically over the course of the monitoring program. Any nonconformances observed will be documented and resolved as discussed in Section B4.4. Additional systems audits or surveillance may be conducted at the request of the Atlantic Richfield Environmental Business Manager, or if specifically requested, by the U.S. EPA. One field assessment will be conducted during this project.

For a given project, options for assessments include the following:

Readiness Review—A technical check to determine if all components of the project are in place before work can commence on a specific phase of field work. The readiness review is often referred to as a “kickoff meeting.”

Project Surveillance—Continual or frequent monitoring of project status and analysis of project records to ensure that the specific requirements of the QAPP and associated project planning documents are being fulfilled.

Technical Systems Audit—A thorough and systematic on-site qualitative audit of facilities, equipment, personnel, training, procedures, and record keeping examined for conformance to the QAPP. If deemed necessary, the audit should be conducted in the early stages of a new project phase to identify and correct any nonconformances as early as possible.

Performance Evaluation—An audit of an analytical laboratory where performance evaluation samples are submitted and compared with routinely obtained samples. If a performance evaluation is conducted, the following information will be provided:

- constituents to be measured;
- target concentration ranges, timing/schedule for performance evaluation sample analysis; and
- aspect of measurement quality to be assessed (e.g., bias, precision, and detection limit).

Audit of Data Quality (ADQ)—An audit that uses data verification methodology to examine how data were handled, what judgments were made, and whether any uncorrected mistakes were made. If an ADQ is planned, it should be performed prior to the production of a final report in order to correct any systematic data reduction errors. This step is in addition to standard minimum data verification or data validation (see Section B5.2).

B4.2 INDEPENDENT TECHNICAL REVIEW

An independent technical review of all deliverable reports will be coordinated by the RI Project Manager, Project QA Manager, or designee, and all comments resolved prior to final submittal. Any comments received from these reviews will be resolved and any revised reports re-reviewed prior to resubmittal. Copies of all final reports and associated correspondence will be retained as RI program records. The following methodologies are options for review:

Peer Review—The review should assess the assumptions, calculations, extrapolations, alternative interpretations, methods, acceptance criteria, and conclusions documented in the project report. The name, title, and position of any peer reviewer should be included and any comments appended to the final report.

Data Quality Assessment (DQA)—DQA involves the use of statistical tools to determine if the data meet the assumptions that the DQOs and data collection design were developed under, and whether the total error in the data is tolerable.

DQA is performed to determine whether the project-specific DQOs have been satisfied. DQA consists of five steps that relate the quality of the results to the intended use of the data:

- **Step 1:** Review DQOs and sampling design.
- **Step 2:** Conduct preliminary data review.
- **Step 3:** Select statistical test(s), as appropriate, to evaluate data quality.
- **Step 4:** Verify assumptions.
- **Step 5:** Draw conclusions about the quality of the data (data report will not include interpretation of results, but will state conclusions regarding the quality of the results).

If, as a result of the DQA process, it is determined that data do not satisfy all DQOs, then corrective action(s) should be recommended. Corrective actions include, but are not limited to, revision of the DQOs based on the results of the investigation, or collection of more information or data. It may be determined that corrective actions are not required, or the decision process may continue with the existing data, with recognition of the limitations of the data.

B4.3 DOCUMENTATION OF ASSESSMENTS

The field assessment and independent technical review will be documented, reported to management, and retained as project records. Checklists may be developed to assist the reviewer during certain assessments.

B4.4 CORRECTIVE AND PREVENTIVE ACTION

Corrective action and preventive action is required in response to a nonconformance. A nonconformance is defined as a potential or existing condition that may have an adverse impact on data quality. A nonconformance may be observed during routine project work or during any assessment process. Corrective and preventive action is applicable to both the field and laboratory procedures. In general, any member of the project team who identifies a nonconformance can initiate a corrective and preventive action.

The corrective and preventive action process is designed to identify, correct, and prevent or reduce the likelihood of recurrence of any nonconformance. The process consists of the following steps, corresponding to the Corrective and Preventive Action Request (CPAR) form in Attachment 2:

- Identify the problem constituting the potential nonconformance.
- Communicate the problem to the Project QA Manager by initiating a CPAR identifying the source of the quality requirement that has not been followed (e.g., analytical method reference, applicable SOP, laboratory QA/QC procedure, applicable section of QAPP) as well as a description of the nonconformance.
- Project QA Manager assigns control number to CPAR.
- Project personnel assist in identifying the root cause of the nonconformance and identifying appropriate corrective actions as well as preventive actions.
- Project QA Manager and/or RI Manager approve proposed corrective and preventive actions and ensure that they are assigned to appropriate personnel with achievable deadlines.
- Assigned personnel (or external laboratory staff) implement actions and confirm completion.
- The Project QA Manager verifies completion and verifies that the actions taken were effective.
- Any impact on data quality that was unable to be corrected must be noted in the “comments” section on the CPAR form.

The resolution of all quality issues will be documented under the direction of the Project QA Manager and retained in the project records.

B5.0 DATA VALIDATION AND USABILITY

Implementation of data review and validation helps to ensure that the project data are evaluated in a consistent and objective manner. These requirements are defined for field sampling and field measurement activities, as well as for data generated by the off-site laboratory in a manner consistent with U.S. EPA Region 9 guidelines (U.S. EPA, 2001b), which provides a graded approach to data review based on the intended use of the data collected for Superfund.

B5.1 REVIEW OF FIELD MONITORING DATA

Field monitoring provides time critical measurements of environmental samples for site management and operation decisions. Data measured by field instruments will be recorded on Daily Field Records (DFRs), laptops, and/or on required field forms. Examples of field documentation forms are included in the sampling SOPs (Appendix C of the SAP). Units of measure for field monitoring equipment are provided in Table 5. Field data will be reviewed by the Field Operations Supervisor to evaluate completeness of the field records and appropriateness of the field methods employed.

Field data to be input into the project database includes general water quality parameters, surface water flow readings, sampling coordinates, and weather station data. All field records will be retained in the project files.

B5.2 DATA VERIFICATION AND VALIDATION REQUIREMENTS FOR LABORATORY DATA

Data verification refers not only to the routine checks the Project QA Manager conducts to ensure that the SAP is followed, but also to the QC procedures of the analytical laboratory. The laboratory will provide analytical results and supporting laboratory QA results in both electronic and PDF formats. The laboratory will provide additional documentation as requested by the Project QA Manager.

At a minimum, data verification will include evaluation of sampling documentation, data representativeness, technical holding time, field and laboratory blank sample analyses, method QC sample results, field duplicates, and the presence of any elevated detection limits. The output of data verification includes the verified data package from the laboratory with any applicable laboratory qualifiers.

Selected data will be independently validated using guidance from the National Functional Guidelines (U.S. EPA, 1994). Independent validation will include assessment of the data relative to method QC protocols, QC criteria in this QAPP, and professional judgment. At the

direction of the Project QA Manager, data validation (including raw data evaluation) will be completed for a minimum of 20 percent of the total data set.

B5.3 DATA VALIDATION REPORTS

Procedures for performing data validation for the types of analyses to be performed for this investigation are consistent with the principles documented in the National Functional Guidelines (U.S. EPA, 1994). Data validation will be documented in a manner consistent with the functional guidelines. The results of the data validation will be summarized in a written report, including any calculations and pertinent laboratory records and accompanied by a tabular summary of the qualified data formatted for the project database. Data validation reports will be provided in final project reports.

B5.4 DATA REPORTING QUALIFIERS

The data validation procedures are designed to review each data set and identify biases inherent to the data and determine its usefulness. Data validation flags are applied to those sample results that fall outside of specified tolerance limits. Data validation flags will indicate if results are considered anomalous, estimated, or rejected. Only rejected data are considered unusable for decision-making purposes; however, other qualified data may require further verification. Qualifiers to be applied during data validation are based on those defined in the National Functional Guidelines and are provided in Table 8.

B5.5 RECONCILIATION WITH DATA QUALITY OBJECTIVES

All data quality issues concerning field sampling efforts, laboratory analysis, data validation, and data reporting will be reviewed by the Project QA Manager. A DQA (see Section B4.2) will be performed to determine whether data generated are consistent with the investigation objectives. Specific issues to be reviewed include conformance with data quality requirements and overall data completeness. Also, if data are found to deviate significantly (by several orders of magnitude) from previous analyses or surrounding conditions upon which the sampling program was based, the data may be qualified based on the validation's assessment of the usability of the data for the intended end uses.

B6.0 REFERENCES

ANSI/ASQC, 1995, American National Standards Institute/American Society for Quality Control: Specifications and Guidelines for Quality Systems for Environmental Data Collection and Environmental Technology Programs (E4-1994), American National Standard.

Atlantic Richfield, 2008, Draft Data Quality Objectives Report: Remedial Investigations and Feasibility Study, Leviathan Mine, Alpine County: Prepared by AMEC Geomatrix, Inc., October.

Atlantic Richfield, 2009, Leviathan Mine Site Health, Safety, Security, and Environmental Program Document: Prepared by AECOM, March and subsequent revisions.

CCR, 2007, California Code of Regulations: OEARA Regulations Title 22, Chapter 11.

Montgomery Watson Harza (MWH), 2002, Leviathan Mine Site-wide Quality Assurance Project Plan, April.

U.S. Environmental Protection Agency (U.S. EPA), Data Quality Indicators, www.epa.gov/region09/qa/datatables.html.

U.S. EPA, 1988, Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA, Interim Final: Office of Emergency and Remedial Response, OSWER Directive 9355.3-01, October.

U.S. EPA, 1990, Quality Assurance/Quality Control Guidance for Removal Activities: OSWER Directive No. 9360.4-01, April.

U.S. EPA, 1994, Contract Laboratory Program National Functional Guidelines for Inorganic Data Review, EPA-540/R-94/013, February.

U.S. EPA, 2001a, EPA Requirements for Quality Assurance Project Plans: Office of Environmental Information, U.S. EPA QA/R-5, EPA/240/B-01/003, March.

U.S. EPA, 2001b, Region 9 Superfund Data Evaluation/Validation Guidance, Draft: R9QA/006.1, December.

U.S. EPA, 2002, Guidance for Quality Assurance Project Plans: Office of Environmental Information, EPA QA/G-5, EPA/240/R-02/009, December.

U.S. EPA, 2008, Administrative Order for Remedial Investigation and Feasibility Study, Leviathan Mine, Alpine County, California: U.S. EPA Region IX, CERCLA Docket No. 2008-18, June 23.

ATTACHMENTS

FIELD CHANGE REQUEST	
Job/Task No:	**FCR No.:**
Task description:	
Affected plan or procedures:	
Requested variation(s):	
Justification:	
Requested by:	**Date:**
Field change authorized by:	**Date:**
Approved by:	**Date:**
Approved by:	**Date:**
Comments:	

CORRECTIVE/ PREVENTIVE ACTION REQUEST (CPAR)	
Job/Task No:	**CPAR No.:**
Description of Nonconformance:	
Affected plan or procedures:	
Root Cause(s):	
Corrective Action(s):	
Preventive Measure(s):	
Requested by:	**Date:**
Approved by:	**Date:**
Approved by:	**Date:**
Verified by:	**Date:**
Comments:	

APPENDIX C

RI/FS Standard Operating Procedures

APPENDIX C

STANDARD OPERATING PROCEDURES
Remedial Investigation/Feasibility Study Program

Leviathan Mine Site

Alpine County, California

Prepared for:

Atlantic Richfield Company
La Palma, CA 90623

Prepared by:

AMEC Geomatrix, Inc.,
Rancho Cordova, CA

July 10, 2009

AMEC Geomatrix

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STANDARD OPERATING PROCEDURES
REMEDIAL INVESTIGATION AND FEASIBILITY STUDY
Leviathan Mine Site
Alpine County, California

INTRODUCTION

This Remedial Investigation/Feasibility Study (RI/FS) Standard Operating Procedures (SOP) document represents Appendix C of the RI/FS Sampling and Analysis Plan (SAP). It has been prepared on behalf of Atlantic Richfield Company (Atlantic Richfield) for the Leviathan Mine Site in Alpine County, California (site) (Figures 1 and 2 of the SAP). The RI/FS SOP document has been prepared in response to the Administrative Order for Remedial Investigation and Feasibility Study (Unilateral Administrative Order or UAO) issued to Atlantic Richfield on June 23, 2008, by the United States (U.S.) Environmental Protection Agency (EPA) for the site.

This RI/FS SOP document includes a collection of 28 SOPs designed to standardize the field procedures that will be performed for the RI/FS. Each SOP describes the purpose, equipment needs, proper field documentation forms, and methodology for a general field task. The SOPs developed within this document will be included within the Focused Remedial Investigation (FRI) work plans (as appropriate). The FRI work plans are future work plans that will be focused within smaller study areas of the site.

Other components of the SAP include the RI/FS Field Sampling Plan (FSP) (Appendix A of the SAP and the RI/FS Quality Assurance Project Plan (QAPP) (Appendix B of the SAP). The RI/FS FSP describes the field activities that will be performed for the RI/FS. The RI/FS QAPP describes the policy, organization, functional activities, and quality assurance and quality control (QA/QC) protocols needed to achieve the laboratory Data Quality Objectives (DQO's). Collectively, this RI/FS SOP document, the RI/FS FSP, and the RI/FS QAPP establish the minimum requirements for the future FRI work plans.

The following sections describe the following 28 SOPs:

- SOP 1.0 – General Preparation and Mobilization Requirements
- SOP 2.0 – Basic Health and Safety For Field Operations
- SOP 3.0 – Field Documentation and Sample Handling

- SOP 4.0 – Sample Collection Techniques and Data Collection Strategies
- SOP 5.0 – Surface Geophysical Surveys
- SOP 6.0 – Field Measurements – Water
- SOP 7.0 – Equipment Decontamination
- SOP 8.0 – Surface Water Sampling and Stream Flow Measurement
- SOP 9.0 – Investigation Derived Waste Disposal
- SOP 10.0 – Sediment Sampling
- SOP 11.0 – Soil and/or Rock Logging
- SOP 12.0 – Test Pit Excavation
- SOP 13.0 – Drilling
- SOP 14.0 – Soil Sampling
- SOP 15.0 – Borehole Geophysical Surveys
- SOP 16.0 – Installation and Construction of Groundwater Monitoring Wells and Piezometers
- SOP 17.0 – Groundwater Sampling
- SOP 18.0 – Cone Penetrometer Test
- SOP 19.0 – Aquifer Testing
- SOP 20.0 – Seepage Meter
- SOP 21.0 – Bubble-Water Manometer
- SOP 22.0 – Tracer Study
- SOP 23.0 – Field Density Tests
- SOP 24.0 – Dust Monitoring
- SOP 25.0 – Mini-Piezometer Installation
- SOP 26.0 – Lysimeter
- SOP 27.0 – Tensiometer

If the SOPs described within this document are to be revised in order to meet the needs of an individual investigation, it should be specified within each FRI work plan(s). If a global change to an SOP is needed, a field change request form must be filled out and approved by the Project Quality Assurance Manager according to Section B2.7.5 of the QAPP.

Forms or other attachments have been included in the appropriate SOPs. The forms and attachments described in this document are listed below (with the locations shown in parentheses):

- Before You Go – Site Access Overview 2009 (SOP 1.0)
- Journey Hazard Assessment (JHA) Card (SOP 1.0)
- First page of the United States Department of Agriculture USDA Forest Service Road Use Permit (SOP 1.0)
- Authorization to Work (ATW) Form (SOP 2.0)
- Job Safety Analysis (JSA) Worksheet (SOP 2.0)
- Daily Field Record (DFR) (SOP 3.0)
- Sample Control Log (SOP 3.0)
- Atlantic Richfield Chain-of-Custody (COC) Record (SOP 3.0)
- Water Level Monitoring Record (SOP 6.0)
- Field Instrumentation Calibration Sheet (SOP 6.0)
- Well Sampling and/or Development Record (SOP 6.0)
- Stream Flow (Discharge) Measurement Form (SOP 8.0)
- Waste Tracking Log (SOP 9.0)
- Soil Boring Log (SOP 11.0)
- Rock Boring Lob (SOP 11.0)
- Stratigraphic Column of the Geologic Units Identified by Herbst and Sciacca (1982) (SOP 11.0)
- Geologic Units, Leviathan Sulfur Mine and Vicinity – Excerpted pages from Appendix A of the “Leviathan Mine Pollution Abatement Project” by Brown and Caldwell dated April 1983. (SOP 11.0)

- Field Test Pit Sample Log (SOP 12.0)
- Field Test Pit Log (SOP 12.0)
- Field Well Construction Summary (SOP 16.0), which includes:
  - Well Casing Installation
  - Annular Materials Volume Calculations Worksheet
  - Grouting Form
  - Surface Completion Details for Wells
- Well Sampling and/or Development Record (SOP 16.0)
- Aquifer Test Data Form (SOP 19.0)
- ASTM Designation D2922-91 – Standard Test Methods for Density of Soil and Soil-Aggregate in Place by Nuclear Methods (Shallow Depth) (SOP 23.0)
- ASTM Designation D1556-90 – Standard Test Method of Density and Unit Weight of Soil In Place by the Sand Cone Method (SOP 23.0)
- Airborne Dust Monitoring Form (SOP 24.0)
- Personal Airborne Dust Exposure Monitoring Form (SOP 24.0)

C1.0 – GENERAL PREPARATION AND MOBILIZATION REQUIREMENTS

Purpose and Scope: The purpose of this document is to present procedures that must be followed prior to all field operations. It includes a discussion of general preparation activities, mobilization, and site-specific training.

Equipment: The following items are needed in order to mobilize to the site:
4-wheel-drive truck or sport utility vehicle with all terrain tires;
Full size spare tire and car jack/tire changing tools;
Fire extinguisher and fist aid kit;
Level D personal protective equipment including long sleeve shirt, long pants, steel toe boots, hard hat, safety glasses, high visibility vest (or a high visibility long sleeve shirt), and heavy work gloves.

Documentation: Before You Go - Site Access Overview Document (attached);
Journey Hazard Assessment (JHA) (attached);
Hands on defensive driver course/commercial driver's license;
First page of the U.S. Department of Agriculture Forest Service Road Use Permit (attached);
Fit for duty annual physical; and
40-hour Hazardous Waste and Operations training or 8-hour annual refresher training.

This Standard Operating Procedure (SOP) is to be used in conjunction with the Sampling and Analysis Plan (SAP) and future Focused Remedial Investigation (FRI) work plans. In addition to the SAP, the following SOPs should be consulted:

- SOP 2.0 – Basic Health and Safety for Field Operations

Also refer to the Leviathan Mine Site Health, Safety, Security and Environmental (HSSE) Program Document by ENSR dated May 27, 2008, the Task Specific Health and Safety Plan by AMEC Geomatrix dated June 2009, and the Job Safety Analysis for the planned scope of work.

C1.1 GENERAL PREPARATION

Prior to the start of an investigation, the following general preparation activities should be performed:

- Obtain all appropriate Federal, State, and Local permits for the proposed work (if needed);
- If driving to the site, obtain a "Hands on defensive driver course" or a commercial driver's license and fill out a JHA form (attached);

- Review documents (Section C1.1.1);
- Perform notifications (Sections C1.1.2 and C1.1.3); and
- Obtain field equipment and documentation (Section C1.1.4);
- If subcontractors will be accessing the site, they may also be required to perform the above activities. Copies of insurance certificates, OSHA 40 hour hazwoper training certificates, and fit for duty documents must be obtained from subcontractors.

C1.1.1 Document Review

Prior to mobilizing to the site, the following documents should be reviewed:

- "Before You Go – Site Access" handout (attached);
- Leviathan Mine Site HSSE Program Document by ENSR dated May 27, 2008;
- RI\FS Task Specific Health and Safety Plan by AMEC Geomatrix dated June 2009;
- Documentation showing verification of Defensive Driver Training;
- The United States Forest Service Annual Operating Plan, including the Traffic Management Plan; and
- Applicable SOPs provided in the RI\FS FSP.

C1.1.2 Site Notification

Scheduling should begin a minimum of two weeks prior to initiation of each new field investigation by notifying U.S. EPA Remedial Project Manager, the AMEC Geomatrix RI/FS Manager, the AMEC Geomatrix Site Coordinator, and where applicable, the Lahontan Regional Water Quality Control Board (LRWQCB) Coordinator:

- U.S. EPA Remedial Project Manager – Mr. Kevin Mayer
  75 Hawthorne Street SFD-7-2
  San Francisco, CA 94105
  Office: 415-972-3176
  Fax: 415-947-3526
  mayer.kevin@epa.gov

- AMEC Geomatrix RI/FS Manager – Mr. Joe Niland, PG
  10670 White Rock Road, Suite 100

Rancho Cordova, CA 95670
Office: 916-853-8900
Fax: 916-636-3208
joe.niland@amec.com

- LRWQCB Coordinator – Mr. Chein Kao, PE
  California Regional Water Quality Control Board
  Lahontan Region
  2501 Lake Tahoe Boulevard
  South Lake Tahoe, CA 96150
  Office: 530-542-5461
  Fax: 530-542-5470
  ckao@waterboards.ca.gov

- AMEC Geomatrix Site Coordinator – Britt Jones or Michelle Souza

Britt Jones	Michelle Souza
Cell: 916-612-6237	Site phone: 530-554-2599
britt.jones@amec.com	michelle.souza@amec.com

Notifications to the Site Coordinators must include the following information:

- Anticipated date and time of anticipated arrival;
- Access road in which you plan on using;
- Anticipated types and sizes of vehicles that will access the site;
- Anticipated duration of site access;
- Names and purpose for each personnel accessing the site; and
- A copy of the approved work plan, including associated maps, tables and attachments.

In addition, the Site Coordinator MUST be contacted 48 hours prior to mobilizing to the site to verify anticipated site conditions. If any of the above information changes after you have initially notified the Site Coordinator, you must notify the Site Coordinator by e-mail or by calling 530-554-2599 (Do NOT call the Site Coordinator while driving).

C1.1.3 Laboratory Notification and Sample Container Request

The laboratory must be notified of the anticipated sampling schedule which includes:

- anticipated soil or water sampling dates;
- anticipated quantity of samples; and
- anticipated soil or water sampling test methods;
- if applicable, anticipated rapid turn around times for soil or water samples.

The analytical laboratory must be contacted to request the appropriate number of sample containers and sample coolers. Upon receipt of the shipment from the laboratory, the sample containers must be inspected. The laboratory must be notified of any missing, broken, or leaking containers which will be replaced as soon as possible.

C1.1.4 Field Equipment

Field equipment and/or meters required by the work plan will either be purchased or rented. Upon receipt, equipment and/or meters, it will be inspected and calibrated to appropriate standards, batteries will be charged, and replacement batteries will be purchased. Refer to each SOP for specific equipment to be used. The operation of equipment shall always follow the manufacturer's recommendations.

C1.1.5 Field Documentation

General field documentation procedures are described in SOP 3.0 – Field Documentation and Sample Handling. Additional field documents may be required depending on the type of investigation. These are discussed in the individual SOPs.

C1.2 MOBILIZATION

This section discusses the procedures to follow when mobilizing to the site. It includes driving directions and worker, visitor, and truck driver access restrictions.

C1.2.1 Driving Directions

Site Access via Hwy 89 or Monitor Pass (California Entrance): From HWY 89, turn on Leviathan Mine Road and drive approximately 3 miles on a dirt road until you come to a silver locked gate. This access is limited to vehicles and vehicles with trailers less than 30 feet total length. Do **NOT** attempt to access the site via this route with any vehicle longer than 30 feet or truck and trailer longer than 30 feet.

Site Access via HWY 395 (Nevada Entrance): From HWY 395, turn on Leviathan Mine Road and drive approximately 10 miles on a dirt road until you come to a green cattle gate. Go through the cattle gate and proceed until you arrive at a silver locked gate. This access is for all vehicles including Semi-trucks hauling trailers more than 30 feet total length.

Note: When two vehicles meet on a steep road where neither can pass, the vehicle facing downhill must yield the right of way by backing up until the vehicle going uphill can pass. The vehicle facing downhill has the greater amount of control when backing. When a large truck and a smaller vehicle meet on a narrow road where neither can pass, the smaller vehicle will back up to the nearest wide spot.

C1.2.2 Worker, Visitor, and Truck Driver Access

The following is a list of guidelines and rules for accessing the site:

- There is no access to the site prior to 6:30 AM. The current code for all the gates is 1301. It is always a good idea to confirm the current gate code prior to accessing the site as it changes several times throughout the year.
- Unless actively passing through the gate, the gates must remain closed and locked at all times (no dummy locking). The **ONLY** exception is when there is traffic control personnel posted at the gate.
- If you encounter a gate that is open and no one is around, then it is your responsibility to close and lock the gate. The only exception to this is the green cattle gate at the Nevada Entrance which is usually left open. If you find the green gate closed then please close it behind you.
- Outside the gates, the roads are open to the public. The roads can be very busy and the public doesn't always follow the signs on the road or the direction of the traffic control personnel.
- Workers, delivery drivers, or visitors shall **NOT** talk on their cell phone while driving to and on the site.
- Travel with lights turned on.
- Ensure that all passengers are wearing seatbelts at all times.
- Watch and follow traffic signs and signals from traffic control personnel (**STOP or SLOW**).
- Just because traffic control is present, it does not mean that there is no on coming traffic.

- Travel only as fast as conditions allow and go slow around blind corners.
- Drive at a speed that will keep dust to a minimum. However, speeds must not exceed the recommended posted speed limit outside the gates or 15 mph inside the gates of the mine.
- Once entering the site, proceed directly to the Pond 4 area.
- Parking for small cars, trucks, and SUVs is available on the south side of Pond 4.
- When parking, always back into your spot and use a spotter if possible while backing. Always set the parking break.
- Trucks delivering materials and/or equipment must stop at the sign that says (all trucks stop here) and set the parking break.
- After parking your vehicle or truck, follow the signs and walk directly to the main office stationed at the entrance to Pond 4. This is where you will sign in and get further instructions.
- When entering the Pond 4 area by vehicle or foot, be aware of truck traffic and heavy equipment operations.
- When you are ready to move your vehicle, do a walk around to make sure your path of travel is clear.
- Vehicles will not be left at the site overnight.
- **Before leaving each day, remember to sign out at the Main office. This is very important!!!!!!**

If you are scheduled to access the site during times of inclement weather, you will be notified by the Site Coordinator of the status of site access. The Inclement Weather Plan is presented in the Leviathan Mine Site HSSE Program Document.

C1.3 SITE SPECIFIC TRAINING

Once onsite, visitors, and new workers must attend a site orientation training session. This training presentation is required once each year and covers the following:

- Site Overview;
- Site Documentation;
- Emergency Evacuation;

- General Site Requirements;
- Site Specific Hazards; and
- BP Specific Requirements.

If necessary, hydrogen sulfide training will be provided to visitors and new workers at this time.

Upon completion of these training presentations, workers and visitors will be allowed to begin site access or site work.

ATTACHMENTS

- Before You Go – Site Access Overview 2009
- Journey Hazard Assessment (JHA) Card
- First page of the USDA Forest Service Road Use Permit

Leviathan Mine Site
Before You Go – Site Access Overview
2009

This document should be reviewed prior to accessing the Site for the first time. Once you have reviewed this material, please sign the acceptance form on the last page and provide to your contracting company's project manager.

Before accessing the Site, remember to wear long sleeves, long pants, steel toe boots and remember to bring hard hat, safety glasses, an orange shirt or orange vest, and heavy work gloves.

Plan your trip ahead of time. Prior to mobilization to the Site, notify the Site Coordinator by calling (530) 554-2599 or by sending an e-mail to: britt.jones@amec.com and michelle.souza@amec.com with the following information:

- Date and time of anticipated arrival;
- Access road in which you plan on using;
- Types and sizes of vehicles that are anticipated on accessing the Site;
- Duration of anticipated Site access;
- Names and basis for each personnel accessing the Site; and

If any of the above information changes after you have initially notified the Site, you must notify the Site by using either e-mail or calling the Site at (530) 554-2599 (Do NOT call the Site while driving).

All drivers must complete a Journey Hazard Assessment Card for every trip to the site prior to driving to the site. This is intended to assess risk and ensure that you have completed the necessary safety checks. The Journey Hazard Assessment Card can be found on page 4 and 5 of this document.

All drivers must complete hands-on driver training prior to accessing the site. If you have a DOT license, additional training is not required.

All drivers must carry a copy of the first page of the U.S. Department of Agriculture Forest Service Road Use Permit. The Road Use Permit can be found on page 6 of this document.

Visitor and Truck Driver Access

There is no access to the Site prior to 6:30 AM or after 5:30 PM. The current code for all the gates is **1301**. It is always a good idea to confirm the current gate code prior to accessing the Site as it can change several times throughout the year. There may be other locks attached to the gates, please make sure you incorporate the other locks when locking the gates so that other parties do not get locked out.

Unless actively passing through the gate, the gates must remain closed and locked (no dummy locking) at all times. The **ONLY** exception is when there is traffic control personnel posted at the gate.

If you encounter a gate that is open and no one is around, then it is your responsibility to close and lock the gate. The only exception to this is the green cattle gate at the Nevada Entrance which does not have a lock and is occasionally left open during the work hours of 6:30 AM to 5 PM, Monday through Friday. If the green cattle gate is open prior to or after these times then please close the gate.

Leviathan Mine Site
Before You Go – Site Access Overview
2009

Outside the gates, the roads are open to the public. The roads can be very busy and the public doesn't always follow the signs on the road or the direction of the traffic control personnel.

If you are scheduled to access the Site during times of inclement weather, you will be notified of the status of Site access as soon as possible by your contractor's HSSE Supervisor.

All vehicles entering the Site MUST…

- Workers, delivery drivers or visitors shall NOT talk on their cell phone while driving to and onto the Site.
- Travel with lights turned on.
- Ensure that all passengers are wearing seatbelts at all times.
- Watch and follow traffic signs and signals from traffic control personnel (STOP or SLOW).
- Just because traffic control is present, it does not mean that there is no on coming traffic.
- Travel only as fast as conditions allow and go slow around blind corners.
- Drive at a speed that will keep dust to a minimum. However, speeds must not exceed 25 mph outside of the gates or 15 mph inside the gates of the mine.
- Once entering the Site, proceed directly to the Pond 4 area.
- Parking for small cars, trucks, and SUVs is available on the south side of Pond 4.
- When parking, always back into your spot and use a spotter if possible while backing. Always set the parking break.
- Trucks delivering materials and/or equipment must stop at the sign that says (all trucks stop here) and set the parking break.
- After parking your vehicle or truck, walk directly to the main office stationed at the entrance to Pond 4. This is where you will sign in and get further instructions.
- When entering the Pond 4 area by vehicle or foot, be aware of truck traffic and heavy equipment operations.
- When you are ready to move your vehicle, do a walk around to make sure your path of travel is clear.
- Vehicles will not be left at the Site overnight.
- Before leaving, remember to sign out. This is very important!!!!!!
- Once off Site, call the representative for your contract company so they know that you are off the Site safely.

Site Access via HWY 89 or Monitor Pass (California Entrance)

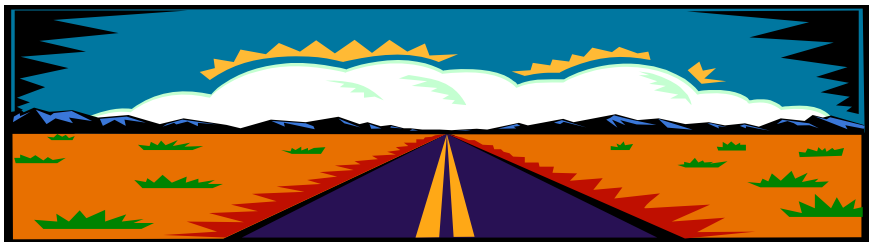
From HWY 89 you will turn on Leviathan Mine Road and drive approximately 3 miles on a dirt road until you come to the silver locked gate. This access is limited to vehicles and vehicles with trailers less than 30 feet total length. Do **NOT** attempt to access the site via this route with a truck or truck and trailer longer than 30 feet.

Site Access via HWY 395 (Nevada Entrance)

From HWY 395 you will turn on Leviathan Mine Road and drive approximately 10 miles on a dirt road until you come to a green cattle gate. Go through the cattle gate and you will arrive at the silver locked gate. This access is for all vehicles and Semi-trucks hauling trailers more than 30 feet total length.

Note: When two vehicles meet on a steep road where neither can pass, the vehicle facing downhill must yield the right of way by backing up until the vehicle going uphill can pass. The vehicle facing downhill has the greater amount of control when backing. When a large truck and a smaller vehicle meet on a narrow road where neither can pass, the smaller vehicle will back up to the nearest wide spot.

REMEDIATION MANAGEMENT
JOURNEY HAZARD ASSESSMENT CARD



STOP! THINK! GO!

Name _____ **Date** _____

STOP
Do I need to make this journey? ❑ **Yes** ❑ **No**

STOP
Where am I traveling? How long will I be driving? And do I have an ETA with a contact person and have communicated area hazards and safest mode of transport?

_____

_____

THINK
How can I ensure that I have a safe journey?

_____

_____

THINK
Am I well rested an alert for the journey? ❑ **Yes** ❑ **No**

THINK
Have I done a vehicle walk around and ensured that the vehicle is safe and ready for travel? ❑ **Yes** ❑ **No**

HAVE A SAFE TRIP!

DRIVING IS RISKY BUSINESS!

ELEMENTS OF THE DRIVING STANDARD

- **Has vehicle been inspected?** ❑ **Yes** ❑ **No**
- **Will passengers be transported?** ❑ **Yes** ❑ **No**
- **Has cargo been secured?** ❑ **Yes** ❑ **No**
- **Driver's License is current?** ❑ **Yes** ❑ **No**
- **Appropriately rested and alert?** ❑ **Yes** ❑ **No**
- **Journey risks have been identified?** ❑ **Yes** ❑ **No**
- **Seatbelts are in working order?** ❑ **Yes** ❑ **No**
- **Medically fit for driving?** ❑ **Yes** ❑ **No**
- **ATV Helmet is correct?** ❑ **Yes** ❑ **No**

GO

COMMENTS

_____

_____

_____

_____

_____

DRIVE TO THE BP DRIVING STANDARD!

DRIVE SAFELY!

Leviathan Mine Site
Before You Go – Site Access Overview
2009

Acceptance Form

I have reviewed the presentation and handout of the Before You Go – Site Access Overview prepared for the Leviathan Mine Site. I have read and understood its contents and I agree that I will abide by its requirements.

Name: _____

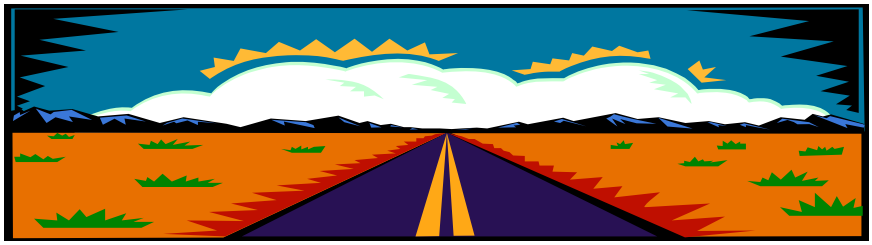
Signature:_____

Date:_____

Company: _____

Provide the signed acceptance form to your contracting company's project manager.

REMEDIATION MANAGEMENT
JOURNEY HAZARD ASSESSMENT CARD



STOP! THINK! GO!

Name _____ **Date** _____

STOP
Do I need to make this journey? ❑ **Yes** ❑ **No**

STOP
Where am I traveling? How long will I be driving? And do I have an ETA with a contact person and have communicated area hazards and safest mode of transport?

_____

_____

THINK
How can I ensure that I have a safe journey?

_____

_____

THINK
Am I well rested an alert for the journey? ❑ **Yes** ❑ **No**

THINK
Have I done a vehicle walk around and ensured that the vehicle is safe and ready for travel? ❑ **Yes** ❑ **No**

HAVE A SAFE TRIP!

DRIVING IS RISKY BUSINESS!

ELEMENTS OF THE DRIVING STANDARD

- Has vehicle been inspected? ❑ Yes ❑ No
- Will passengers be transported? ❑ Yes ❑ No
- Has cargo been secured? ❑ Yes ❑ No
- Driver's License is current? ❑ Yes ❑ No
- Appropriately rested and alert? ❑ Yes ❑ No
- Journey risks have been identified? ❑ Yes ❑ No
- Seatbelts are in working order? ❑ Yes ❑ No
- Medically fit for driving? ❑ Yes ❑ No
- ATV Helmet is correct? ❑ Yes ❑ No

GO

COMMENTS

_____

_____

_____

_____

_____

DRIVE TO THE BP DRIVING STANDARD!

DRIVE SAFELY!

USDA United States Department of Agriculture | Forest Service | Humboldt-Toiyabe National Forest | 1200 Franklin Way
Sparks, NV 89431-6432
(775) 331-6444 Fax (775) 355-5399

File Code: 2160/7730-4
Date: MAY 2 _ 2008

Anthony Brown
Environmental Manager
Atlantic Richfield Company
4 Centerpointe Drive, LPR 4-435
La Palma, CA 90623-1066

RECEIVED
MAY 5 2008
Remediation Management

Dear Mr. Brown:

The USDA Forest Service received two signed copies of the Road Use Permit guaranteeing Atlantic Richfield Company use of the Leviathan Mine Road (aka FS road 10052) and other related road segments for commercial hauling and personnel transport at the Leviathan Mine site through December 31, 2013. ARCO had previously provided the FS a copy of the 2008 annual operating plan for road use and projected maintenance and approved its content and application. The FS reminds ARCO to provide proof of insurance and a $10,000 bond (in one of the various forms outlined in the permit document) in a timely fashion to the Carson Ranger District to complete its fiduciary obligation under terms of the permit. At that time, the permit will be fully executed. The Carson Ranger Station address is: 1536 S. Carson Street, Carson City, NV 89701

The FS complements ARCO for the manner in which special requests to perform maintenance prior to full execution of the permit have occurred. On this note, we approve the road grading request made for next week and remind ARCO to apply best management practices related to fire and dust suppression during this operation. The FS anticipates a successful operating season in 2008 and will assist ARCO in the cooperative effort required to continually upgrade and improve the mine road for future years.

Sincerely,

Kevin Wilmot

for EDWARD C. MONNIG
Forest Supervisor

ENCLOSURE: SIGNED ROAD USE PERMIT

cc: Edward DeCarlo, Ken Maas, Genny E Wilson, Kevin Wilmot

+

FS-7700-41(12/06)
OMB 0596-0016

U.S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE

ROAD USE PERMIT

AUTHORITY:

Section 4 and Section 6 of the National Forest Roads and Trails Act
16 U.S.C. 535 and 537

Atlantic Richfield Company (4 Centerpointe Drive, La Palma, CA 90623) is hereby guaranteed use of the following roads or road segments and related transportation facilities (hereinafter "roads") on the Carson Ranger District, Humboldt-Toiyabe National Forest, for commercial hauling (transportation of goods and supplies), subject to the terms and conditions of this permit:

Leviathan Mine Road aka FS Road 10052; extending approximately 9 miles between Highway 395 and the Leviathan Mine site (Site) to the east and approximately 5 miles from the Site to Highway 89 on the west. This permit includes the portion of the 10052 road extending east past the 10348 road, to the Aspen Seep bioreactor. The roads are shown on the attached Appendix C.

APPENDICES

A – Annual Operating Plan
B – Maintenance Requirements
C – Map

TERMS AND CONDITIONS

I. GENERAL TERMS

A. AUTHORITY. This permit is issued pursuant to the National Forest Roads and Trails Act, 16 U.S.C. 535 and 537, and 36 CFR Part 212, Subpart A, as amended, and is subject to their provisions.

B. RESPONSIBLE OFFICIAL. The responsible official is the Forest Supervisor, Humboldt-Toiyabe National Forest, pursuant to Forest Service Handbook 7709.59.20.42.

C. TERM. This permit shall expire at midnight on December 31, 2013, approximately five years from the date of issuance. Expiration of this permit shall not require notice, a decision document, or any environmental analysis or other documentation.

D. RENEWAL. This permit is not renewable. Prior to expiration of this permit, the holder may apply for a new permit that would renew the use authorized by this permit. Renewal of the use shall be at the sole discretion of the responsible official.

E. AMENDMENT. This permit may be amended in whole or in part by the Forest Service when, at the discretion of the responsible official, this action is deemed necessary or desirable to incorporate new terms that may be required by law, regulation, directive, the applicable land management plan, or projects and activities implementing a land management plan pursuant to 36 CFR part 215.

F. COMPLIANCE WITH LAWS, REGULATIONS, AND OTHER LEGAL REQUIREMENTS. In exercising the rights and privileges granted by this permit, the holder shall comply with all present and future federal laws and regulations and all present and future state, county, and municipal laws, regulations, and other legal requirements, including state traffic laws, that apply to the permit area, to the extent they do not conflict with

3. Temporary traffic control signs, flagging, and warning devices for operation or maintenance conducted under this permit shall comply with Part 6 of the MUTCD.

4. The holder shall not operate vehicles or equipment with cleats or other tracks that will injure the road surface.

E. REQUIREMENT TO CARRY A COPY OF THE PERMIT. Drivers of all vehicles operating under this permit shall have a copy of the first sheet of this permit in their vehicle. The copy will be presented, on request, to any Forest Service officer.

III. PERFORMANCE

A. MAINTENANCE REQUIRED TO ACCOMMODATE USE. The holders shall perform road maintenance required to accommodate the holder's use under this permit.

B. SCHEDULE, PLANS, AND SPECIFICATIONS. To accommodate the authorized use, the holder shall perform the road maintenance to specifications described in Appendix B, in accordance with the annual operating plan and schedule provided in Appendix A. A road log has been completed by the Forest Service that identifies drainage features, drain dips, super-elevations, low points, and other pertinent features by milepost that may be affected by maintenance procedures specified in this permit and appendix B.

C. COMMENSURATE SHARE BETWEEN PARTIES

1. The holder shall perform maintenance commensurate with the holder's use of the roads authorized by this permit (the holder's commensurate share), as described in each user's annual operating plan and measured by vehicle units or miles of road used most frequently. The holder shall be entirely responsible for maintenance that is necessitated by the holder's use, i.e., maintenance which would not be necessary if the holder's use did not occur. In addition, the holder is authorized to perform, and if the holder chooses to perform shall be proportionately responsible with other users of the roads authorized by this permit or similar instrument for maintenance not necessitated by traffic, but needed for safe access to the site, i.e., maintenance that is necessary due to natural causes such as rain, wind, rock fall, and growth of brush. Maintenance that could be required by this clause includes, at a minimum, work addressed in section IV of this permit.

2. Commensurate shares, as defined in this section, will be allocated between the Atlantic Richfield Company and the California Regional Water Quality Control Board, based on the annual operating plans provided.

This proportionate use applies to: **Leviathan Mine Road aka FS Road 10052; extending approximately 9 miles between Highway 395 and the Leviathan Mine site (Site) to the east and approximately 5 miles from the Site to Highway 89 on the west, except that ARCO is 100% responsible for maintenance of the 10052 road extending east past the 10348 road, to the Aspen Seep bioreactor.**

D. PERFORMANCE BOND FOR ROAD MAINTENANCE. As a further guarantee of the holder's commensurate share obligation, the responsible official may require the holder to furnish a surety bond or other security.

1. As a further guarantee of compliance with the holder's commensurate share obligation, ARCO shall deliver and maintain a surety bond or other acceptable security, such as cash deposited and maintained in a federal depository or negotiable securities of the United States, in the amount of $10,000. The responsible official may periodically evaluate the adequacy of the bond or other security and increase or decrease the amount as appropriate. If the bond or other security becomes unsatisfactory to the responsible official, the holder shall within 30 days of demand furnish a new bond or other security issued by a surety that is solvent and satisfactory to the responsible official. If the holder fails to meet any of the requirements secured under this clause, money deposited pursuant to this clause shall be retained by the United States to the extent necessary to satisfy the obligations secured under this clause, without prejudice to any other rights and remedies of the United States.

2. The bond shall be held for the length of the permit.

2. The holder shall be liable for all injury, loss, or damage incurred by the United States, including fire suppression, or other costs in connection with rehabilitation or restoration of natural resources caused by the use authorized by this permit. Compensation shall include but not be limited to the value of resources damaged or destroyed, the costs of restoration, cleanup, or other mitigation, fire suppression or other types of abatement costs, and all administrative, legal (including attorney's fees), and other costs. Such costs may be deducted from a performance bond required under clause III D.1.

3. The holder shall be liable for damage caused by use of the holder or the holder's heirs, assigns, agents, employees, contractors, or lessees to all roads and trails of the United States to the same extent as provided under clause V.E.1.

F. **HEALTH, SAFETY, AND ENVIRONMENTAL PROTECTION.** The holder shall promptly abate as completely as possible and in compliance with all applicable laws and regulations any activity or condition arising out of or relating to use of the roads authorized by this permit that causes or threatens to cause a hazard to public health or the safety of the holder's employees or agents or harm to the environment (including areas of vegetation or timber, fish or other wildlife populations, their habitats, or any other natural resources). The holder shall immediately notify the responsible official of all traffic accidents and any other serious accidents that occur in connection with the authorized use. The responsibility to protect the health and safety of all persons affected by use of the roads authorized by this permit is solely that of the holder. The Forest Service has no duty under the terms of this permit to inspect the roads authorized by this permit or authorized activities of the holder for hazardous conditions or compliance with health and safety standards.

G. **COMPLIANCE WITH ENVIRONMENTAL LAWS.** The holder shall in connection with use of the roads authorized by this permit comply with all applicable federal, state, and local environmental laws and regulations, including but not limited to those established pursuant to the Resource Conservation and Recovery Act, as amended, 42 U.S.C. 6901 *et seq.*, the Federal Water Pollution Control Act, as amended, 33 U.S.C. 1251 *et seq.*, the Oil Pollution Act, as amended, 33 U.S.C. 2701 *et seq.*, the Clean Air Act, as amended, 42 U.S.C. 7401 *et seq.*, the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), as amended, 42 U.S.C. 9601 *et seq.*, the Toxic Substances Control Act, as amended, 15 U.S.C. 2601 *et seq.*, the Federal Insecticide, Fungicide, and Rodenticide Act, as amended, 7 U.S.C. 136 *et seq.*, and the Safe Drinking Water Act, as amended, 42 U.S.C. 300f *et seq.*

H. **INDEMNIFICATION OF THE UNITED STATES.** The holder shall indemnify, defend, and hold harmless the United States for any costs, damages, claims, liabilities, and judgments arising from the acts or omissions of the holder or the holder's employees, contractors, or subcontractors in connection with use of the roads authorized by this permit. This indemnification provision includes but is not limited to acts and omissions of the holder or the holder's heirs, assigns, agents, employees, or contractors in connection with use of the roads authorized by this permit which result in (1) violations of any laws and regulations which are now or which may in the future become applicable, and including but not limited to those environmental laws listed in clause V.G of this permit; (2) judgments, claims, demands, penalties, or fees assessed against the United States;
(3) costs, expenses, and damages incurred by the United States; or (4) the release or threatened release of any solid waste, hazardous waste, hazardous substance, pollutant, contaminant, oil in any form, or petroleum product into the environment. The responsible official may prescribe terms that allow the holder to replace, repair, restore, or otherwise undertake necessary curative actions to mitigate damages in addition to or as an alternative to monetary indemnification.

I. **INSURANCE**

1. The holder or the holder's employees, contractors, or subcontractors shall have in force automobile insurance covering losses associated with the use authorized by this permit in at least the amount of $300,000 for injury or death to one person, $500,000 for injury or death to two or more persons, and $100,000 for property damage. Minimum amounts of coverage and other insurance requirements are subject to change at the sole discretion of the responsible official on the anniversary date of this permit.

2. Any insurance policies obtained by the holder pursuant to this clause shall name the United States and Alpine County as additional insured parties. The additional insured provision shall provide for insurance coverage for the United States and Alpine County as required under clause V.I (1). The policies also shall

ACCEPTED:

ANTHONY R. BROWN Anthony R. Brown 4/23/08

NAME AND TITLE ENVIRONMENTAL MANAGER SIGNATURE DATE
SIGNING ON BEHALF OF ATLANTIC RICHFIELD COMPANY

APPROVED:

Edward Manning Edward Manning 4/28/08

Forest Supervisor, RESPONSIBLE OFFICIAL SIGNATURE DATE

According to the Paperwork Reduction Act of 1995, an agency may not conduct or sponsor, and a person is not required to respond to, a collection of information unless it displays a valid OMB control number. The valid OMB control number for this information collection is 0596-0016. The time required to complete this information collection is estimated to average one-quarter hour for the application and eight hours for the annual operating plan, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information.

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C2.0 – BASIC HEALTH AND SAFETY FOR FIELD OPERATIONS

Purpose and Scope: The purpose of this document is to outline basic safety requirements that must be followed during all field sampling operations. It describes basic procedures, the Authorization To Work (ATW) form, Job Safety Analysis (JSA) form, British Petroleum (BP) Permitting requirements, and safety meetings.

Equipment: Minimum Site Personal Protective Equipment as defined in the Task Specific Health and Safety Plan (HASP) by AMEC Geomatrix;
Hydrogen sulfide monitors and/or escape respirators for some areas of the site; and
Personal flotation devices during work around water.

Documentation: Authorization-to-work (ATW) Form (attached); and
Job Safety Analysis (JSA) Form (attached).

This Standard Operating Procedure (SOP) is to be used in conjunction with the Sampling and Analysis Plan (SAP) and future Focused Remedial Investigation (FRI) work plans.

C2.1 BASIC PROCEDURES

Prior to conducting sampling activities, the following documents should be reviewed:

- SOP 1.0 – General Preparation and Mobilization Requirements;

Also refer to the Leviathan Mine Site Health, Safety, Security and Environmental (HSSE) Program Document by ENSR dated May 27, 2008, the Task Specific Health and Safety Plan by AMEC Geomatrix dated June 2009, and the Job Safety Analysis for the planned scope of work.

During this review, special attention should be paid to BP policies and site specific procedures, with attention to hazards associated with the work, personal protective equipment (PPE), air monitoring, and emergency response.

C2.2 AUTHORIZATION TO WORK, JOB SAFETY ANALYSIS, AND BP PERMITS

An ATW is a form required by Atlantic Richfield that reviews the pre-task hazards associated with a planned investigation, required procedures, and required permits for the planned investigation. It must be filled out by trained personnel that will be onsite during the investigation with an intimate knowledge of the activities that will be performed at the site. <u>An ATW must be filled out prior to the start of each day of field work</u>.

The ATW must include a JSA worksheet that describes the activities, hazards, risk control measures, responsible person, and stop work triggers for the anticipated activities at the site. Regardless of the task, the JSA should specifiy the following:

- PPE requirements;
- Air monitoring requirements;
- Hydrogen sulfide monitoring requirements;
- The location of rally points in case of emergency

The completed JSA must be reviewed by onsite staff at the start of each day of investigation and signatures of each employee performing the work must be obtained.

BP permits may be required prior to starting an investigation. The four BP permits include:

- Hot Work Permit;
- Confined Space Entry Permit;
- Ground Disturbance Permit (ground penetration >1 foot); and
- Working at Heights (> 6 feet) Permit.

If there is any question as to whether the planned investigation will require one of the above BP permits, contact the Site Coordinator by sending an email to: britt.jones@amec.com. Please allow a minimum of a week for a response. If a permit is required, it must be filled out and approved by an authorized permit writer.

Determine if chemicals are to be used during the scheduled task. If so, ensure that appropriate material safety data sheets (MSDSs) are available and all personnel are trained on the specific hazards of the chemical they will be using. Bring copies of the appropriate MSDS sheets and include them with the ATW forms.

C2.3 SAFETY MEETING

Conduct a safety briefing with all personnel before starting work on a daily basis or as a new scope of work begins. The meeting must include discussion of the planned scope of work, the JSA, permits, and potential dangers that may be encountered during the course of the field investigation (i.e., hazards, MSDS sheets). If potential hazards exist, discuss potential engineering, administrative, or PPE controls that will be implemented to ensure the safety of

all individuals. Ensure that subcontractors involved with the work are engaged in the safety meeting. Collect the appropriate PPE and verify that personnel are trained on its use. Discuss procedures to be performed in the event of an emergency.

C2.4 PERFORMING THE WORK

Perform the work using the correct tools for the job and watching out for unforeseen hazards. Conduct air monitoring as necessary and know what the limits are of the contaminants of concern.

If the work changes, new hazards emerge or an emergency situation develops: **Stop Work**. Take necessary actions, revise the JSA prior to reentering the work area, and go over the changes with the work crew.

Once the work is completed, clean the jobsite up, put the safety equipment away and discuss with the crew any improvements from a safety standpoint that could be implemented the next time the work is performed.

ATTACHMENTS

- Authorization to Work (ATW) Form
- Job Safety Analysis (JSA) Worksheet

REMEDIATION MANAGEMENT - AUTHORIZATION TO WORK

PRE-TASK HAZARD REVIEW

TASK	EQUIPMENT
1.	1.
2.	2.
3.	3.
4.	4.
5.	5.
6.	6.

Chemical / Products / Material

1. ☐ Hydrogen Sulfide	2. ☐ Benzene	3. ☐ Diesel	4. ☐ Hydrocarbon	5. ☐ Acid	6. ☐ Lead
7. ☐ Carbon Monoxide	8. ☐ Asbestos	9. ☐ Caustic	10. ☐ Gasoline	11. ☐ Heavy Metals	
12. ☐ NORMS	13. ☐ Other:				

Hazardous Energy

19. ☐ Radiation	20. ☐ Electric	21. ☐ Pneumatic	22. ☐ Thermal-Steam
23. ☐ Hydraulic	24. ☐ Pressure	25. ☐ Mechanical	26. ☐ Fluids & Gases
27. ☐ Gravitational		28. ☐ Other:	

Other Potential Hazards

34. ☐ Walking / Working Surfaces		35. ☐ Traffic	36. ☐ Working at Heights	37. ☐ Pinch Points
38. ☐ Weather	39. ☐ Noise	40. ☐ Grinding	41. ☐ Heavy equipment	42. ☐ Sharp Edges
43. ☐ Hot Work	44. ☐ Security	45. ☐ Congested Area		46. ☐ Overhead Work
47. ☐ Body Position	48. ☐ Static Posture	49. ☐ Wind	50. ☐ Rotating Equipment	51. ☐ Lifting
52. ☐ Housekeeping	53. ☐ Spills	54. ☐ Underground Utility		55. ☐ Slopes and Terrain
56. ☐ Confined Space	57. ☐ Vibration	58. ☐ Ground Disturbance		59. ☐ Rigging
60. ☐ Vehicle Safety – Driving		61. ☐ Repetitive Motion		62. ☐ Container/Drum Labels
63. ☐ Waste	64. ☐ Heat/Cold Stress	65. ☐ Hand & Power Tools		66. ☐ Fitness to Work
67. ☐ Open Pipe	68. ☐ Boom Swing	69. ☐ Lighting	70. ☐ Exposure to poisonous plants / animals / bugs	
71. ☐ Overhead Electrical		72. ☐ Auger/Drill Stem		73. ☐ Other:

Required Safety Precautions

79. ☐ Safety Glasses	80. ☐ Goggles	81. ☐ Face Shield	82. ☐ Ear Plugs	83. ☐ High Visibility Clothing
84. ☐ Hard Hat	85. ☐ Escape Pak	86. ☐ Steel Toe Shoes	87. ☐ Ear Muffs	88. ☐ Respirator:
89. ☐ FRC	90. ☐ Supplied Air	91. ☐ Topical Creams / Repellents		92. ☐ Gloves:
93. ☐ Fire Watch	94. ☐ Drip Pans	95. ☐ Plastic Sheeting	96. ☐ Vac Truck	97. ☐ Fall Protection
98. ☐ Barricade	99. ☐ Fire Blanket	100. ☐ Upwind Areas Checked		101. ☐ Warning Signs
102. ☐ Flag Off Area	103. ☐ Life Lines	104. ☐ Fire Extinguisher at Jobsite		105. ☐ Sampling Prohibited
106. ☐ Seal Manholes, Sewers, and Catch Basins		107. ☐ Communication Method		108. ☐ Welding Shields
109. ☐ Continuous Monitoring		110. ☐ Wet Down Area		111. ☐ Ladder Tie Off
112. ☐ Tag Lines		113. ☐ Active Site Hazard Communication		114. ☐ Fence Off Area
115. ☐ No Cell Phone		116. ☐ Long Sleeve Shirt	117. ☐ No Smoking	118. ☐ Other:

REQUIRED PROCEDURES

☐ Drilling	☐ MOC	☐ Traffic Control	☐ LO/TO/Blinding
☐ Hoist/Lifting	☐ Journey Hazard Assessment		☐ Ground Disturbance

REQUIRED PERMITS

☐ Hot Work	☐ Trenching/Excavation	☐ Confined Space	☐ Working from Heights	☐ None

Contractor(s) / Employee(s) Signatures: I have reviewed and understand the conditions of this permit, and its attachments. I will report hazardous conditions or acts identified on this job site to my supervisor and / or BP representative so they can be corrected as necessary.		1.	2.
		3	4.
5.	6.	7.	8.
9.	10.	11.	12.

Onsite Manager: (Print Name)	Date:	Location of Site Work:
Site	Date/Time Issued: am/pm	Date/Time Expires: am/pm
☐ Is HASP onsite?	☐ Is ERP onsite?	☐ Is JSA onsite?
Authorization Signature:		
Exceptions/Comments		

Revision 001, Date: 08/01/05

Job Safety Analysis Worksheet

Contractor:	Geomatrix	Date:		JSA No.:	
Coordinator/Supervisor:		PPE Required: Level D		Field Team:	Name / Name
Location of worksite:	Leviathan Mine				
Description of work:					

Activity List the tasks required to perform the activity in the sequence they are carried out.	Hazards Against each task list the hazards that could cause injury when the task is performed.	Risk control measures List the control measures required to eliminate or minimize the risk of injury arising from the identified hazard.	Who is responsible? Write the name of the person responsible (supervisor or above) to implement the control measure identified.	Stop Work Triggers Identify what will cause you to stop work during this task.

1 – Target number of job steps: six to ten

2 – Codes for Potential Hazards:

Caught Between (CBT)	Contacted By (CB)	Caught On (CO)	Fall To Below (FB)	Overexertion (O)	Struck Against (SA)
Caught In (CI)	Contact With (CW)	Exposure (E)	Fall - Same Level (FS)	Release To (R)	Struck By (SB)

3 – Types of Critical Actions: Administrative Controls, Engineering Controls, PPE, and/or Safe Work Practice / SOP

Job Safety Analysis Worksheet

Contractor:	Geomatrix	Date:		JSA No.:	
Coordinator/Supervisor:		PPE Required: Level D		Field Team:	Name / Name
Location of worksite:	Leviathan Mine				
Description of work:					

1 – Target number of job steps: six to ten

2 – Codes for Potential Hazards:

Caught Between (CBT)	Contacted By (CB)	Caught On (CO)	Fall To Below (FB)	Overexertion (O)	Struck Against (SA)
Caught In (CI)	Contact With (CW)	Exposure (E)	Fall - Same Level (FS)	Release To (R)	Struck By (SB)

3 – Types of Critical Actions: Administrative Controls, Engineering Controls, PPE, and/or Safe Work Practice / SOP

Job Safety Analysis Worksheet

Contractor:	Geomatrix	Date:		JSA No.:	
Coordinator/Supervisor:		PPE Required: Level D		Field Team:	Name / Name
Location of worksite:	Leviathan Mine				
Description of work:					

Reviewed By: Print Name	Signature	Company	Reviewed Date	Reviewed By: Print Name	Signature	Company	Reviewed Date

1 – Target number of job steps: six to ten

2 – Codes for Potential Hazards:

Caught Between (CBT)	Contacted By (CB)	Caught On (CO)	Fall To Below (FB)	Overexertion (O)	Struck Against (SA)
Caught In (CI)	Contact With (CW)	Exposure (E)	Fall - Same Level (FS)	Release To (R)	Struck By (SB)

3 – Types of Critical Actions: Administrative Controls, Engineering Controls, PPE, and/or Safe Work Practice / SOP

C3.0 – FIELD DOCUMENTATION AND SAMPLE HANDLING

Purpose and Scope: The purpose of this document is to present procedures for field documentation and sample handling. It includes a description of how to fill out a Daily Field Record (DFR), Sample Control Log, and Chain-of-Custody (COC). It also describes procedures for sample labeling, handling, preservation, packaging, and shipping.

Equipment: The following equipment will be needed depending on specific task and will be used, as appropriate, when packing or shipping samples:
Sample Bottles;
Sample Labels;
Custody Seals;
Fine Tipped Permanent Markers;
Nitrile gloves or other appropriate gloves;
Sealable storage bags;
Bubble wrap or appropriate packing materials;
Blue ice or double bagged ice;
Coolers suitable for sample shipment and holding ice;
Strapping/packaging tape and shipping labels, if needed; and
Camera with spare memory chip and batteries.

Documentation: DFR (attached);
Sample Control Log (attached);
Atlantic Richfield COC Document (attached) or laboratory equivalent;
Maps/plot plan; and
Camera.

This Standard Operating Procedure (SOP) is to be used in conjunction with the Sampling and Analysis Plan (SAP) and future Focused Remedial Investigation (FRI) work plans. In addition, the following SOPs should be consulted:

- SOP 1.0 – General Preparation and Mobilization Requirements; and
- SOP 2.0 – Basic Health and Safety for Field Operations.
- SOP 7.0 – Equipment Decontamination

Also refer to the Leviathan Mine Site Health, Safety, Security and Environmental (HSSE) Program Document by ENSR dated May 27, 2008, the Task Specific Health and Safety Plan by AMEC Geomatrix dated June 2009, and the Job Safety Analysis for the planned scope of work.

C3.1 FIELD AND SAMPLE DOCUMENTATION

Documentation of the conditions and procedures used to collect, treat, and handle samples and field data is one of the most important aspects of any monitoring program. Proper documentation provides sources to determine the integrity and applicability of the data. Carefully document all field activities in a field logbook or on data sheets. Field logbooks shall be bound with consecutively numbered pages and shall be written in with permanent black ink. Field activities shall be recorded in sufficient detail so that field activities can later be reconstructed from the notes. Any changes to the notes in the field logbook shall be made by drawing a single line through the incorrect material and initialing and dating the mark-out.

C3.1.1 Daily Field Record (DFR)

Documentation of observations and data acquired in the field provide information on sample acquisition, field conditions at the time of sampling, and a permanent record of field activities. Record field observations and data collected during the investigation with waterproof ink on DFR sheets (Attached). A new DFR should be completed for each day or when a separate phase of work is initiated.

The DFRs will include the following information, as appropriate.

- Project and Task Number;
- Project Name;
- Location of sample (if samples are collected);
- Date;
- Time;
- Field Activity;
- Weather Conditions;
- Personnel Onsite, Company Name, and Time Onsite;
- Personal Safety Checklist;
- Drum Identification (if drums are used); and
- Description of Work Performed.

Information written within the area delineated “Description of Work Performed” should include the following:

- Sample identification number(s);

- Description of sample;
- Sample depth;
- Number and volume of samples;
- Sample methods used, or reference to the appropriate SOP;
- Sample handling, including filtration and preservation, as appropriate, for separate sample aliquots;
- Field observations;
- Photo documentation;
- Results of any field measurements, such as depth to water, pH, temperature, electrical conductivity, and discharge; or
- Decontamination procedures.

Photographs should be taken of pertinent activities that occur during the investigation. These should include capturing images that clearly demonstrate that the goals of the project are being met. They should also be taken of any changes in procedures or unexpected findings that occur in the field. Items of scale should be included in the view of the photograph (i.e., ruler, clipboard, etc.). A running log of the photographs with a description of each photograph should be included on a photo log attached to the DFR.

Strike out changes or deletions in the field book or on the data sheets with a single strike mark and be sure that the original information remains legible. Each page should be completely filled without any blank lines, if necessary write “Not Applicable” or “NA” on blank lines. The field logbook or field data sheets should be signed daily by the author of the entries.

C3.1.2 Sample Control Log

If samples are collected during the field investigation, a sample control log must be filled out documenting the sampler name, date, time, COC number, analyses requested, duplicates collected and naming designation, additional notes, the date that the samples were sent to the laboratory, and the expected date that the results are due.

C3.1.3 Chain Of Custody (COC)

During sampling activities, a “paper trail” of sample custody must be maintained from the time the samples are collected until laboratory data are issued. Information on the custody, transfer, handling, and shipping of samples should be recorded by the sampling personnel on an Atlantic Richfield COC form. If an Atlantic Richfield COC form is not available, an equivalent form provided by the destination laboratory can be used instead. A COC form will

be completed for each set of samples collected daily. At a minimum, every COC will contain the following information:

- Sampling Personnel's name and signature;
- Project name;
- Date and time of collection;
- Sample identification number and matrix;
- Analyses requested;
- Number of containers;
- Signature of persons relinquishing custody, dates, and times;
- Signature of persons accepting custody, dates, and times;
- Method of shipment; and
- Shipping papers/waybill identification number (as appropriate).

Atlantic Richfield sponsors the Laboratory Management Program (LaMP). The LaMP consists of a network of approved contract laboratories that supply analytical testing services for Atlantic Richfield's environmental and remediation programs. The LaMP was implemented to ensure that the analytical testing and services needs of Atlantic Richfield Company are consistently met on environmental/remediation projects. The LaMP provides and assures sources of high quality analytical data for Atlantic Richfield that are legally defensible and minimizes the total cost of ownership. COCs for samples shipped to an Atlantic Richfield contract laboratory will contain the following information:

- The name of the lead regulatory agency;
- The name and contact information of the environmental business manager;
- The name and contact information of the consultant and Project Manager;
- The Enfos proposal number and the stage and activity level of the project; and
- The level of data package requested.

An example COC is provided as an attachment and should be strictly followed as it is important that COCs are completed with consistent information. A copy of each COC form will be retained in the project files in accordance with Section B2.7.4 of the RI/FS QAPP.

C3.2 SAMPLE LABELING

After sample collection, the samples will be labeled with self-adhesive labels with all necessary information added using waterproof ink. Make sure the labels are completed so that the information is legible and consistent. At a minimum, each sample label will contain the following information:

- Project name (Leviathan);
- Study Area;
- Sample identification code;
- Date (mm/dd/yy) and military time (tt:tt) of sample collection;
- Analyses required;
- Method of preservation, if used; and
- Sampler's initials.

The information on the sample label should match the COC.

Each sample, including quality assurance/quality control samples, will be assigned a unique identification code according to sample location and date for use in the project database. Each sample will be assigned a unique identification code according to sample location and date. This ID will consist of three parts. The three parts of the ID will not be separated by any symbols, characters, or spaces. The components of the sample ID are:

- Sample Type – Groundwater (GW), surface water (SW), stream sediment (SS), soil boring (SB), plant sample (PS), fish sample (FS), invertebrate sample (IS), and waste sample (WS);
- Study Area Designation – Aspen Creek Study Area (A), Leviathan Creek Study Area (L), Pit Study Area (P), Downstream Study Area (D),or Background (B);
- Date – Expressed as a two-digit month, day, and year (MM/DD/YY); and
- Continuous sequence number for each day of sampling in each of the designated sampling areas. Sequential numbering will restart at 01 on a given sampling day, in a given sampling area.

For example, if the 99th sample taken for a groundwater sample in the Leviathan Creek Study Area on February 5, 2010, the sample ID will be *"GWL02051099"*. Waste characterization samples will be designated by respective Study Area. For example, if investigative derived waste (soils or water) from the Pit Study Area is collected on January 1, 2010, the sample ID will be *"WSP01011001"*. Refer to Section B3.4.2 for discussion on handling and labeling laboratory quality control samples.

Field blanks and duplicates shall be labeled so as not to indicate the identity of the sample to the lab and will follow the labeling convention (using the appropriate number sequence) in place of calling the sample “blank” or “Dup". The identity of field QC samples will be traceable through appropriate documentation as described in the respective SOPs.

Sample containers will be sealed in sealable plastic bags and immediately placed on ice in an insulated cooler and chilled. Insulated coolers will be provided by the contract laboratories. Samples will be placed right side up in a cooler with blue or double bagged ice for delivery to the laboratory.

C3.3 SAMPLE HANDLING

General sample handling procedures shall include the following:

- Always make field measurements on a separate sub-sample, not on the sample that is sent to the laboratory for analysis. Discard the sub-sample after the measurements have been made.
- Do not use containers that have been used in the laboratory to store concentrated reagents or have been previously used as sample containers. Use only new containers that are certified clean by the manufacturer or laboratory for sample collection.
- For water samples, do not allow the inner portion of sample containers and caps to come into contact with bare hands, gloves, or other objects.
- Keep sample containers in a clean environment away from dust, dirt, and fumes. Field personnel shall wear disposable nitrile gloves when collecting water samples. Gloves must be changed out between each water sample collected.
- Do not let any samples, including water, vegetation, or invertebrate samples, stand in the sun. Store all samples in coolers with blue or double bagged ice;
- COC procedures will be strictly adhered to during sample collection, transportation, and laboratory handling to assure the identity of the samples. Improper sample and data handling and inadequate COC procedures affect the credibility and

acceptability of analytical results, regardless of their accuracy or precision. COC documentation will document processing of the sample from the time of collection to the time of analysis.

If overnight storage of collected water samples is required prior to shipment to a laboratory, the samples will be stored in accordance to procedures described in Section C3.6.

C3.4 SAMPLE PRESERVATION

Sample preservation will depend on the analytical method to be performed and the sample matrix. Preservation methods and preservatives for each analytical method and matrix will be presented in the FRI work plans. The planned sample preservation activities, sample container size and type, and analytical methods should be confirmed with the laboratory well in advance of collecting samples.

For all water samples, the laboratory will supply clean, unused, and pre-preserved sample containers as appropriate. If containers are preserved, the type of preservative should be clearly labeled on each bottle. Do not rinse out sample containers. The preservative will be documented on the sample labels, COC, and in the project DFRs. For soil samples, the laboratory does not typically provide the sample containers (e.g. stainless steel sample tubes, acetate liners, etc.). Sample containers used for soil samples will be decontaminated prior to use in accordance to procedures described in Section C7.1.1.

C3.5 SAMPLE PACKAGING AND SHIPPING

If samples are required by the laboratory to be chilled, they will be stored during the day in ice-cooled containers. Samples collected during the morning may be temporarily stored in a refrigerator (if available) until shipment in the afternoon. All samples stored in the coolers or the refrigerator will be documented on the sample tracking form. When samples are being packaged for shipment, the procedures listed below will be followed.

1. Field personnel will visually screen each sample in the cooler for loose surface contamination, and confirm that each sample is listed on the sample tracking form and the COC.

2. Samples will be packed with abundant packaging material to minimize the potential for damage during shipment. Samples will be packaged with either double bagged "wet" ice or "blue-ice," as necessary, to maintain an appropriate temperature within the cooler.

3. The completed COC will be signed and placed in a plastic sealable storage bag which will be taped to the inside cover of the cooler. The COC form will be shipped

with the cooler to confirm transfer; the carrier waybill number will be recorded on the original COC. Commercial carriers are not required to sign the COCs.

4. If samples are to be transported overnight via Federal Express or United Parcel Service, all ice must be double bagged to prevent leakage. The lid of the cooler must be taped shut with custody seals and labeled with stickers indicating "Fragile" and arrows pointing to the lid. The cooler will then be taped shut using clear shipping tape. Failure to seal all potential leaks may result in rejection of delivery by the courier. If samples are shipped on a Friday then Saturday delivery stickers must be attached to the coolers on all four sides as well as the top. Make sure to check the overnight delivery space on the shipping papers. Affix the label on the top or side of the cooler.

5. Samples will typically be shipped to the laboratory daily. Copies of the completed COC will be kept in the field office by the field manager.

6. Sample shipment will be scheduled to prevent exceeding any required holding period. Failure to conduct analyses within the required holding times may potentially require the qualification of associated analytical results and will prompt appropriate corrective and preventive action measures.

C3.6 OVERNIGHT STORAGE

Samples stored overnight require storage at no more than 4°C or 39°F, but above freezing. Samples will be kept in a locked and secured cooler or refrigerator and shipped the following day.

ATTACHMENTS

- Daily Field Record (DFR)
- Sample Control Log
- Atlantic Richfield Chain-of-Custody (COC) Record

DAILY FIELD RECORD

Project and Task Number:	Date:
Project Name:	Field Activity:
Location:	Weather:

PERSONNEL: Name	Company	Time In	Time Out

PERSONAL SAFETY CHECKLIST

X	Steel-toed Boots		Hard Hat		Tyvek Coveralls
	Rubber Gloves		Safety Goggles		1/2-Face Respirator

DRUM I.D.	DESCRIPTION OF CONTENTS AND QUANTITY	LOCATION

TIME	DESCRIPTION OF WORK PERFORMED

DAILY FIELD RECORD (continued)

Page ____ of ____

Project and Task Number:	Date:

TIME	DESCRIPTION OF WORK PERFORMED

AMEC Geomatrix

SAMPLE CONTROL LOG

Project Name: _____

Project and Task No.: _____

Laboratory: _____

Page __ of __ .

Sampling Date	Sampling Time	Sample ID	COC Number	Analyses Requested	ADDITIONAL NOTES: Turnaround Time, Sample Location, Handling Notes, Chain-of-Custody Remarks, Duplicate/Bland info, etc.	Date Sent to Lab	Date Results Due

Atlantic Richfield Company
A BP affiliated company

Laboratory Management Program LaMP Chain of Custody Record

Page _____ of _____

BP/ARC Project Name: _____ **Req Due Date (mm/dd/yy):** _____ **Rush TAT:** Yes ____ No ____

BP/ARC Facility No: _____ **Lab Work Order Number:** _____

Lab Name:	BP/ARC Facility Address:	Consultant/Contractor:
Lab Address:	City, State, ZIP Code:	Consultant/Contractor Project No:
Lab PM:	Lead Regulatory Agency:	Address:
Lab Phone:	California Global ID No.:	Consultant/Contractor PM:
Lab Shipping Accnt:	Enfos Proposal No:	Phone:
Lab Bottle Order No:	Accounting Mode: Provision ____ OOC-BU ____ OOC-RM ____	Email EDD To:
Other Info:	Stage: Activity:	Invoice To: BP/ARC ____ Contractor ____

BP/ARC EBM:

EBM Phone:

EBM Email:

Report Type & QC Level

Standard ____

Full Data Package ____

Lab No.	Sample Description	Date	Time	Matrix: Soil / Solid	Matrix: Water / Liquid	Matrix: Air / Vapor		No. Containers / Preservative: Total Number of Containers	Unpreserved	H_2SO_4	HNO_3	HCl	Methanol		Requested Analyses										Comments

Comments

Note: If sample not collected, indicate "No Sample" in comments and single-strike out and initial any preprinted sample description.

Sampler's Name:	Relinquished By / Affiliation	Date	Time	Accepted By / Affiliation	Date	Time
Sampler's Company:						
Shipment Method: Ship Date:						
Shipment Tracking No:						

Special Instructions:

THIS LINE - LAB USE ONLY: Custody Seals In Place: Yes / No | Temp Blank: Yes / No | Cooler Temp on Receipt: _____°F/C | Trip Blank: Yes / No | MS/MSD Sample Submitted: Yes / No

C4.0 – SAMPLE COLLECTION TECHNIQUES AND DATA COLLECTION STRATEGIES

Purpose and Scope: The purpose of this document is to describe general sampling techniques and data collection strategies.

Equipment:
Nitrile gloves or other appropriate gloves;
Measuring Wheel or Tape Measure;
Flag markers;
Camera;
Marking flags; and
Marking paint.

Documentation:
Daily Field Record (DFR);
Photo Log; and
Maps.

This Standard Operating Procedure (SOP) is to be used in conjunction with the Sampling and Analysis Plan (SAP) and future Focused Remedial Investigation (FRI) work plans. Specific sample techniques, strategies, locations and frequency will be presented in the FRI work plans. However, in the event that the FRI work plans require that sample collection techniques and data collection strategies must be determined in the field (e.g. pre-investigation planning, mapping, waste sampling), the procedures within this SOP should be followed.

In addition, the following SOPs should be consulted:

- SOP 1.0 – General Preparation and Mobilization Requirements
- SOP 2.0 – Basic Health and Safety for Field Operations

Also refer to the Leviathan Mine Site Health, Safety, Security and Environmental (HSSE) Program Document by ENSR dated May 27, 2008, the Task Specific Health and Safety Plan by AMEC Geomatrix dated June 2009, and the Job Safety Analysis for the planned scope of work.

C4.1 SAMPLE COLLECTION TECHNIQUES

Two basic types of sample collection techniques will be used: Grab and Composite Samples. These techniques are described below:

- A grab sample is defined as a discrete sample representative of a specific location at a given point in time. The sample is collected all at once at one particular point

in the sample medium. The representativeness of such samples is defined by the nature of the materials being sampled. In general, as sources vary over time and distance, the representativeness of grab samples will decrease.

- A composite sample is a non-discrete sample composed of more than one sample collected at various sampling locations and/or different points in time. Analysis of this type of sample produces an average value and can in certain instances be used as an alternative to analyzing a number of individual grab samples and calculating an average value. It should be noted, however, that compositing can mask problems by diluting isolated concentrations of some hazardous compounds below detection limits.

C4.2 DATA COLLECTION STRATEGIES

The number of samples that should be collected and analyzed depends on the objective of the investigation. There are three basic sampling strategies: random, systematic, and judgmental sampling. Each of the strategies is explained in the following:

- Random sampling involves collection of samples in a nonsystematic fashion from the entire site or a specific portion of a site.
- Systematic sampling involves collection of samples based on a grid or a pattern which has been previously established.
- Judgmental Sampling involves collection of samples only from the portion of the site most likely to be contaminated.

A combination of these strategies is the best approach depending on the type of the suspected/known contamination, the uniformity and size of the site, and the level/type of information desired.

C4.3 SAMPLE LOCATION DOCUMENTATION

Once a sample location is chosen and the sample has been collected, the location will be temporarily staked or marked until it has been surveyed. Additionally, 3 to 4 photos of the location should be taken so the location is well documented. The photos should be documented on a photo log (SOP 3.0 – Field Documentation and Sample Handling).

Wooden steaks or pin flags with the name of the location written in permanent marker can be driven into the ground to show the location. It is not recommended that spray paint be used to mark locations as it may get washed off or brushed over by dirt and rocks. Spray paint may be used as a temporary location marker, however the spray paint marker should either be surveyed or replaced as soon as possible so the location is not lost.

It is expected that survey activities will be subcontracted to a third party that has a current California survey license. The surveyor will obtain accurate coordinates and elevations of the sample locations within several weeks after the location has been abandoned so that the sample location can be relocated in the future if necessary.

A global positioning system (GPS) type device may be used in place of a surveyor to obtain coordinates of sample locations, however, elevation data is not as accurate if it is provided by a GPS type device..

C5.0 – SURFACE GEOPHYSICAL SURVEYS

Purpose and Scope: The purpose of this document is to describe general methodology for conducting a surface geophysical investigation. It includes a discussion of the setup procedures and a description of the following surface geophysical technologies: magnetics, electromagnetics (EM), ground penetrating radar (GPR) and transient electromagnetics (TEM).

Equipment:
Ground Penetrating Radar;
Electromagnetic Instrument;
Transient Electromagnetic Instrument;
Magnetometer;
Laptop computer;
Nylon rope for grid;
General tools (wrenches, screwdrivers, etc.);
Safety Equipment;
Marking paint; and
Marking flags;

Documentation:
Daily Field Record (DFR);
Maps/plot plan; and
Camera.

Surface geophysical surveys measure the subsurface geological properties with minimal disturbance to the underlying material. They may be conducted during the reconnaissance phase investigations to provide preliminary information so that more detailed investigations can be adequately planned. Depending on the conditions, they may be used to identify buried hazards (e.g., tunnels, explosives, drums, etc.) and distinguish between layers of sand and clay, alluvium and bedrock, saturated and unsaturated soil, and contaminated and uncontaminated soil.

This Standard Operating Procedure (SOP) describes setup procedures that will be performed by the field geologist or engineer while observing the surface geophysical survey performed by others. This SOP does not include procedures for conducting a surface geophysical survey. It is expected that the surface geophysical survey will be subcontracted to a third party that is appropriately qualified and specializes in such investigations. In addition to the setup procedures, this SOP includes a discussion of various surface geophysical technologies that may be used during the course of the RI to provide background information for the observing field personnel. The surface geophysical technologies discussed in this SOP include magnetics, electromagnetics (EM), ground penetrating radar (GPR), and transient electromagnetics (TEM). Other surface geophysical technologies which are not discussed in this SOP may also be used.

This SOP is to be used in conjunction with the Sampling and Analysis Plan (SAP) and future Focused Remedial Investigation (FRI) work plans. In addition to the SAP, the following SOPs should be consulted:

- SOP 1.0 – General Preparation and Mobilization Requirements
- SOP 2.0 – Basic Health and Safety for Field Operations
- SOP 3.0 – Field Documentation and Sample Handling
- SOP 4.0 – Sample Collection Techniques and Data Collection Strategies

Also refer to the Leviathan Mine Site Health, Safety, Security and Environmental (HSSE) Program Document by ENSR dated May 27, 2008, the Task Specific Health and Safety Plan by AMEC Geomatrix dated June 2009, and the Job Safety Analysis for the planned scope of work.

C5.1 SET-UP

Set-up and execution of the geophysical survey will be conducted under the supervision of a geologist or engineer. Prior to conducting a survey, the following tasks will be completed:

- Identify and visit locations to be surveyed noting the presence of nearby buildings, structures, overhead, or buried power lines, etc., that may interfere with data collection;
- Evaluate the geophysical methodologies best suited for the investigation objectives and the site conditions;
- Confirm survey locations and methods with Project Manager;
- Procure necessary equipment or subcontractors needed to collect the desired data. If warranted, test equipment to ensure it is in proper working condition; and
- Notify the proper onsite personnel of survey schedule. If necessary, mark or secure the area a day in advance to be sure there are no obstructions (e.g., parked cars) to collecting data.

Prior to collecting magnetic, EM, or GPR data, a data collection grid will be set up across the area to be surveyed. The exact grid spacing will be based on the estimated size of objects or subsurface features to be located.

C5.2 METHODS

This section describes the background and general procedures for collecting data using magnetics, EM, GPR, and TEM methods. The method used will depend on the type of feature to be located and the nature of the terrain.

C5.2.1 Magnetics

Magnetometer surveys consist of measuring variations in the earth's magnetic field. This may include measuring its total intensity and/or its vertical gradient. Vertical gradient measurements can be used to accurately locate buried ferrous objects such as tanks, pipes, and other metallic debris.

Magnetic data is collected by carrying a hand held magnetometer across the survey area. Individual readings are collected at evenly spaced points within a grid. Each magnetic measurement will be transmitted to a data logger. Magnetic measurements will be retrieved from that data logger and contoured using a personal computer. Contour maps will be used to identify areas of anomalous magnetization. These identified areas will be marked on the ground surface following identification using marking paint and marking flags.

C5.2.2 Electromagnetics (EM)

Electromagnetic methods are used to measure earth conductivity values at specified points. The measured EM values, referred to as terrain conductivity, are obtained through electromagnetic induction as the instrument is carried 3 feet above the ground surface. The basic EM instrument consists of two coils and an electronics module. A specified distance separates the transmitter coil from the receiver coil. When energized, the transmitter coil induces circular eddy current that loops into the earth. The magnitude of each current loop is a function of subsurface conditions. In turn, each of these current loops generates a secondary magnetic field proportional to the value of the current flowing within the loop. A portion of this secondary magnetic field is intercepted by the receiver coil and results in an output voltage that is amplified by the instrument. The magnitude of this voltage is linearly related to the terrain (ground) conductivity. EM methods are used where shallow penetration is required to qualitatively map lateral variations in ground conditions. Depth or thickness determinations cannot be made solely by this method.

EM data is collected by carrying a hand held electromagnetic instrument across the survey area. Individual terrain conductivity measurements are collected at evenly spaced points over a grid. Each terrain conductivity measurement is digitally recorded using a data logger. The

terrain conductivity data will be downloaded from the data logger to a personal computer. Contour maps of terrain conductivity will be produced using a personal computer. Areas of anomalous conductivity will be identified and marked on the ground surface using marking paint and flags.

C5.2.3 Ground Penetrating Radar (GPR)

The GPR system most frequently used in hazardous waste site investigations is an impulse system that radiates short-duration electromagnetic pulses into the ground from an antenna near the surface. These pulses are reflected from various interfaces within the earth and are picked up by the receiver section of the antenna and returned to the control unit for processing and display. These reflections occur at different soil horizons, soil/rock interfaces, rock/air interfaces (voids), manmade objects, or at any interface which creates a contrast in complex dielectric properties. For example, digging a trench and filling it again can create a difference between the dielectric properties of the disturbed earth and those of the undisturbed material that can be sensed by the GPR.

For presentation of data, GPR signals are processed and displayed by a graphic recorder. As the antenna is moved along the surface, the graphic display results in a picture-like record showing a continuous profile along a traverse.

The penetration depth of radar penetration is very site-specific. Generally, depths of 10 to 30 feet can be attained. The depth is reduced by the presence of groundwater, increases in electrical conductivity, and high concentrations of fine-grained materials (silts or clays). For example, high concentrations of salts or montmorillonite clay are highly attenuative of the radar pulse and penetration may not exceed three feet.

GPR data is collected by moving an antenna along the ground surface. GPR signals are processed and analog records are displayed on a strip recorder in real time. The resulting record is a continuous profile along the traverse. Records will be used to identify potential trench locations and buried debris. Suspected locations will be marked on the ground surface using marking paint and flags.

C5.2.4 Transient Electromagnetic (TEM)

The TEM method can provide subsurface information similar to other electrical methods; however, it provides increased depths of investigation with significantly greater resolution.

A square wave signal is transmitted into a rectangular coil placed on the ground surface. When the current in the coil is rapidly terminated, the flow of electrical current is induced at the surface of the earth; this generates a secondary current signal. The resulting secondary field is detected by a second coil and is measured over a period of time as the induced current diffuses into the earth and the secondary signal decays. This provides an indication of the change in resistivity/conductivity with depth. The depth of penetration is dependent on the area and number of turns of the transmitting coil, the current transmitted in the coil, and the repetition rate of the transmitted current.

TEM can be used to perform vertical electric soundings (VES) or to measure subsurface variations along profiles. For vertical electric soundings, the two coils remain stationary, while signals are recorded using different repetition rates. For profiling, a variation of this method is used. Both coils are moved from station to station along a profile, and a single signal sweep is used at each location. This will provide information regarding the vertical distribution of resistivity at each station.

TEM profiling will be used to evaluate stratigraphy of the site. Station spacing and location will be determined in the field.

C6.0 – FIELD MEASUREMENTS - WATER

Purpose and Scope: The purpose of this document is to provide procedures for measuring the water levels from wells and collecting field parameters in surface water and groundwater. It includes instructions on the setup, field procedures, and how to fill out the associated field forms.

Equipment:
pH Meter and electrode;
Electrical Conductivity (EC) Meter;
Dissolved Oxygen (DO) Meter;
Oxygen Reduction Potential (ORP) (Eh) Meter;
Thermometer;
Turbidity Meter;
Water Level Indicator;
Distilled or deionized Water;
Spray water bottle;
Sample cup or beaker;
Calibration standards for each meter;
Miscellaneous Field Tools;
Extra batteries; and
Safety Equipment.

Documentation:
Daily Field Record (DFR);
Water Level Monitoring Record (attached);
Well Sampling and/or Development Record (attached)
Field Instrument Calibration Sheet (attached).

This Standard Operating Procedure (SOP) describes the general methodology for water level measurement from wells and measuring field parameters in water. Field parameters include pH, electric conductivity (EC), turbidity, oxidation-reduction potential (ORP), temperature, and dissolved oxygen (DO). Refer to the manufacturers recommendations for specific operational procedures and calibration requirements for each type of meter described in this SOP.

This SOP is to be used in conjunction with the Sampling and Analysis Plan (SAP) and future Focused Remedial Investigation (FRI) work plans. In addition, the following SOPs should be consulted:

- SOP 1.0 – General Preparation and Mobilization Requirements
- SOP 2.0 – Basic Health and Safety for Field Operations
- SOP 3.0 – Field Documentation and Sample Handling
- SOP 4.0 – Sample Collection Techniques and Data Collection Strategies

- SOP 7.0 – Equipment Decontamination

Also refer to the Leviathan Mine Site Health, Safety, Security and Environmental (HSSE) Program Document by ENSR dated May 27, 2008, the Task Specific Health and Safety Plan by AMEC Geomatrix dated June 2009, and the Job Safety Analysis for the planned scope of work.

C6.1 SET-UP

Prior to taking any field measurements, sampling personnel will assemble all necessary equipment and check all instruments to be used to ensure they are in proper working condition. Each meter will then be calibrated as often as recommended by the manufacturer. Calibration data will be recorded on a Field Instrument Calibration Sheet.

C6.2 WATER LEVEL MEASUREMENT

This SOP focuses on taking water level measurements from wells. Open the well by removing the lid on the well box and remove the well cap. When opening the well box and removing the cap, be sure to keep your head away from the top of the open casing to avoid inhaling any fumes that may reside within the well.

Decontaminate all water level measurement equipment as described in SOP 7.0 – Equipment Decontamination prior to inserting any instruments into the well.

Water level measurements will be referenced to a known elevation datum. The measuring point at the top of the well casing (generally the north side of the casing) will be permanently marked and surveyed. Measurements will be consistently taken from the same marked point. Water levels will be measured with an electrical sounding device, a hydrocarbon interface measuring device, or equivalent device. A hydrocarbon interface measuring device may be used as the primary instrument if the presence of light non-aqueous phase liquids (LNAPLs) or dense non-aqueous phase liquids (DNAPLs) is suspected.

The static water level will be measured in each monitoring well or supply well using an electronic water level indicator. Measurements will be made by recording the depth-to-water (DTW) and repeating the measurement until at least two consecutive depth readings within 0.01-foot are measured. The final water level measurement for each well will be recorded in the field on a Water Level Monitoring Record.

When attempting to collect a DTW measurement, if a vacuum or a pressure buildup is detected upon opening the airtight well cap, an initial depth to water level will be obtained and the well will be allowed to equilibrate for approximately 20-minutes. After the field geologist or engineer has used good judgment to determine that the water table is stable, another DTW measurement within the well and determined will be obtained. Additional measurements will be obtained at 20-minute intervals until at least two consecutive depth readings are within 0.01-foot.

The field geologist or engineer may also measure the depth-to-bottom (DTB), or the depth to the bottom of the well by lowering a measuring device (e.g., sounding device) to the bottom of the well.

At the completion of the DTW and possible DTB measurements, the field geologist or engineer will wipe down the down-hole equipment with a new paper towel to remove excess water or debris from the tool and decontaminate, as appropriate.

C6.3 FIELD PARAMETERS

The following describes measuring field parameters of pH, EC, temperature, turbidity, ORP, and DO.

C6.3.1 pH

The general procedures for the operation, calibration, and maintenance of the field pH meter and its accessories are included in the instruction manual provided with the equipment. In addition, the instruction manual provides information regarding specific calibration requirements and user recommendations. Manufacturer's specifications and recommendations should be followed when using the pH meter.

Prior to use each day, the pH meter should be examined for cleanliness, for defects, and for any possible need of repair. The examination should include the battery and electrode. Once the pH meter is noted to be in correct operating condition, it should be calibrated according to the manufacturer’s recommendations. All calibration notes must be recorded on a Field Instrumentation Calibration Sheet (attached).

C6.3.2 Electrical Conductivity

The general operation, calibration, and maintenance for use of the conductivity meter are included in the instruction manual provided with the equipment. In addition, the instruction manual provides information regarding specific calibration requirements and user

recommendations. Manufacturer's specifications and recommendations should be followed when using the conductivity meter.

Prior to use each day, the conductivity meter should be examined for cleanliness, for defects, and for any possible need of repair. The examination should include the battery and the probe. Once the conductivity meter is noted to be in correct operating condition, it should be calibrated according to the manufacturer's recommendations. All calibration notes must be recorded on a Field Instrumentation Calibration Sheet.

C6.3.3 Temperature

The operation, calibration, and maintenance of the thermometer and its accessories for use in the field are included in the instruction manual provided with the equipment. In addition, the instruction manual provides information regarding specific calibration requirements and user recommendations.

Prior to use each day, examine the thermometer for cleanliness, defects, and any possible need of repair. The examination should include the battery and probe. Once the temperature meter is noted to be in correct operating condition, it should be calibrated according to the manufacturer's recommendations. All calibration notes must be recorded on a Field Instrumentation Calibration Sheet.

C6.3.4 Turbidity

The general procedures for the operation, calibration, and maintenance of a field turbidity meter are included in the instruction manual provided with the equipment. In addition, the instruction manual provides information regarding specific calibration requirements and user recommendations.

Prior to use each day, the turbidity meter should be examined for cleanliness, for defects, and for any possible need of repair. The examination should include the battery. Once the turbidity meter is noted to be in correct operating condition, it should be calibrated according to the manufacturer's recommendations. All calibration notes must be recorded on a Field Instrumentation Calibration Sheet.

C6.3.5 Oxidation-Reduction Potential

The general procedures for the operation, calibration, and maintenance of the field ORP are included in the instruction manual provided with the equipment. In addition, the instruction

manual provides information regarding specific calibration requirements and user recommendations.

Prior to use, examine the ORP meter for cleanliness, defects, and any possible need of repair. The examination should include the battery and probe. Once the ORP meter is noted to be in correct operating condition, it should be calibrated according to the manufacturer's recommendations. All calibration notes must be recorded on a Field Instrumentation Calibration Sheet.

C6.3.6 Dissolved Oxygen

The general procedures for the operation, calibration, and maintenance of a field DO meter are included in the instruction manual provided with the equipment. In addition, the instruction manual provides information regarding specific calibration requirements and user recommendations.

Prior to use, examine the DO meter for cleanliness, defects, and any possible need of repair. The examination should include the battery and probe. Once the DO meter is noted to be in correct operating condition, it should be calibrated according to the manufacturer's recommendations. All calibration notes must be recorded on a Field Instrumentation Calibration Sheet.

ATTACHMENTS

- Water Level Monitoring Record
- Well Sampling and/or Development Record
- Field Instrumentation Calibration Sheet

WATER LEVEL MONITORING RECORD

Project Name: _____ Project and Task Number: _____

Date: _____ Measured by: _____ Instrument Used: _____

Note: For you convenience, the following abbreviations may be used.

P = Pumping I = Inaccessible D = Dedicated Pump
ST = Steel Tape ES = Electric Sounder MP = Measuring Point WL = Water Level

Well No.	Time	MP Elevation (feet)	Water Level Below MP (feet)	Water Level Elevation (feet)	Previous Water Level Below MP	Remarks

WELL SAMPLING AND/OR DEVELOPMENT RECORD

Well ID: _____

Sample ID: _____ **Duplicate ID:** _____

Sample Depth: _____

Project and Task No.: _____

Project Name: _____

Date: _____

Sampled By: _____

Method of Purging: _____

Method of Sampling: _____

Initial Depth to Water:

Depth to Water after Sampling: _____

Total Depth to Well: _____

Well Diameter: _____

1 Casing/Borehole Volume: _____
(Circle one)

3 Casing/Borehole Volumes: _____
(Circle one)

Total Casing/Borehole Volumes Removed: _____

Time	Intake Depth	Rate (gpm)	Cum. Vol. (gal.)	Temp. (°C)	pH (units)	Specific Electrical Conductance (µS/cm)	Remarks (color, turbidity, and sediment)

pH CALIBRATION (choose two)				
Buffer Solution	**pH 4.0**	**pH 7.0**	**pH 10.0**	
Temperature C				
Instrument Reading				

Model or Unit No.:

SPECIFIC ELECTRICAL CONDUCTANCE – CALIBRATION			
KCL Solution (µS/cm=µmhos/cm)			
Temperature C			
Instrument Reading			

Model or Unit No.:

Notes:

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FIELD INSTRUMENT CALIBRATION SHEET

Project Name: _____ **Project Number:** _____

Date: _____

Equipment Type: _____

Manufacturer: _____

Model Number: _____ **Serial Number:** _____

Calibration (as necessary, minimum twice per day):

Calibration #1 **Time:** _____

Calibration Standard: _____

Instrument Reading: _____

Calibration #2 **Time:** _____

Calibration Standard: _____

Instrument Reading: _____

Calibration #3 **Time:** _____

Calibration Standard: _____

Instrument Reading: _____

Calibration #4 **Time:** _____

Calibration Standard: _____

Instrument Reading: _____

Date of Last Calibration: _____ Date(s) Instrument Used: _____

Name of person(s) who calibrated instruments: _____

Calibration Standards Used:

(1) _____

(2) _____

(3) _____

(4) _____

Source of Calibration Standards: _____

Misc. Comments:

_____

Calibrated by:

C7.0 – EQUIPMENT DECONTAMINATION

Purpose and Scope: The purpose of this document is to describe procedures for equipment decontamination. It includes a discussion on decontaminating sampling equipment, drilling and excavation equipment, and collecting equipment blanks to verify that the decontamination procedures were adequately performed.

Equipment:
Steam Cleaner;
Four 5-gallon buckets;
Bottle brushes;
Distilled water;
Potable water;
Non-Phosphate Cleaning Solution (Liquinox); and
4-ml plastic sheeting.

Documentation:
Daily Field Record (DFR); and
Atlantic Richfield Chain-of-Custody (COC) Form.

This Standard Operating Procedure (SOP) is to be used in conjunction with the Sampling and Analysis Plan (SAP) and future Focused Remedial Investigation (FRI) work plans. In addition, the following SOPs should be consulted:

- SOP 1.0 – General Preparation and Mobilization Requirements
- SOP 2.0 – Basic Health and Safety for Field Operations
- SOP 3.0 – Field Documentation and Sample Handling
- SOP 9.0 – Investigation Derived Waste Disposal

Also refer to the Leviathan Mine Site Health, Safety, Security and Environmental (HSSE) Program Document by ENSR dated May 27, 2008, the Task Specific Health and Safety Plan by AMEC Geomatrix dated June 2009, and the Job Safety Analysis for the planned scope of work.

C7.1 DECONTAMINATION PROCEDURES

Decontamination procedures described in this section are applicable to non-dedicated, non-disposable equipment. Dedicated and disposable equipment will be disposed according to procedures described in SOP 9.0 – Investigation Derived Waste Disposal.

C7.1.1 Sampling Equipment

Prior to use and after each sample is collected, all soil and water sampling equipment will be decontaminated either using a steam cleaner or washed using a three step system. The steam cleaner will be supplied by a subcontractor and used according to the manufacturer's recommendations (described below in C7.1.2). The three step decontamination system will include washing the sampling equipment: (1) in soapy water using a non-phosphate (Liquinox) solution, (2) rinsed with potable water and (3) rinsed again with distilled water. Equipment will be washed in a row of three buckets. Hard bristle bottle brushes may be used to remove mud and debris prior to the three step system with an optional fourth bucket. Sample equipment should be allowed to drain dry after the final distilled water rise. Decontamination water will be disposed of according to procedures described in SOP 9.0 – Investigation Derived Waste Disposal.

C7.1.2 Drilling and Excavation Equipment

Drilling and excavating equipment, including backhoe buckets, drill bits, casing, augers, and tools or other equipment that have come in contact with potentially impacted soils or water will be steam cleaned between each location, as appropriate. The steam cleaner will be capable of generating a working pressure of approximately 2,000 pounds per square inch (psi), a discharge rate of 5 gallons per minute (gpm), and an operating temperature of at least 130 degrees Fahrenheit (˚F).

Drilling and excavation equipment will be decontaminated using a portable decontamination station provided by the drilling or excavation subcontractor or a decontamination area constructed onsite. If constructed, the onsite decontamination area will be lined and bermed with two layers of 10 mil visqueen to contain rinsate from steam cleaning operations. If appropriate, the decontamination area will be designed to allow a backhoe, drilling rig, and support vehicles to drive onto the visqueen. After completion of each boring, drill casing or augers, drill bits and drill rods will be transported by truck to the steam cleaning area, as appropriate. Drill casing from the monitoring well drilling procedures will be cleaned while on the support truck. Hollow-stem augers (if used) will be placed on lumber in the decontamination area for cleaning. Rinsate collected in the decontamination area will be collected as appropriate and disposed of according to SOP 9.0 – Investigation Derived Waste Disposal.

In addition to the drilling equipment, if not already pre-cleaned, all monitoring-well casing, well screen, and centralizers will be steam cleaned prior to installation. Cleaned well materials will be covered with 4 mil visqueen, and transported to the well location.

C7.1.3 Submersible Pumps

If a non-dedicated submersible pump is necessary to properly evacuate a well, it will be cleaned prior to use and between sampling locations using a three step wash. First, the pump intake device will be submersed into non-phosphate cleaning solution and run until the bucket is empty. Second, the pump will be submersed into a bucket containing potable water and run until the bucket is empty. The second step can be repeated twice in order to sufficiently rinse the pump. The third step involves rinsing the pump with distilled water using the same method as Steps 1 and 2.

C7.1.4 Equipment Blanks

As appropriate, equipment blanks will be collected after decontamination of the sampling equipment during soil sampling activities to provide an additional check on possible sources of contamination related to field sampling instruments. To collect an equipment blank, laboratory supplied distilled or deionized water is passed through or over clean sampling equipment and collected directly into empty sample containers for analysis. Equipment blanks will be handled and transported in the same manner as the samples acquired that day. Equipment blanks will be analyzed according to all water analytical methods. Equipment blanks for each investigation activity will be collected at intervals defined in the Quality Assurance Project Plan (QAPP).

Equipment blanks will be labeled and handled as described in the QAPP and SOP 3.0 – Field Documentation and Sample Handling.

C8.0 – STREAM FLOW MEASUREMENT AND SURFACE WATER SAMPLING

Purpose and Scope: The purpose of this document is to provide a general outline for developing site specific procedures for collection of representative surface water samples and surface water volumetric flow measurements in small streams, small rivers or ponds and lakes.

Potential Equipment: Surface Water Sample Collection Devices:
- Dip sampler;
- Discrete depth sampler and associated equipment
  - Kenmmerer
  - Van Dorn;
- Peristaltic pump, power supply and associated equipment;

Directional Compass;
25-foot Steel Tape and 100-foot Flexible Tape Measure;
Survey stakes, flagging, hammer;
Marking Buoys, pre-stretched line and anchors;
Boat or Raft (deep River or Pond/Lake Sampling);
- Appropriate Line;
- USCG Approved Type III Life Vests;

Depth/Velocity Appropriate Flow meters
- Pygmy
- Price AA
- Electronic Direct Reading Current Meter

Wading Rod for Flow meter;
Vertical Staff Gauge;
3-inch, schedule 40 PVC Pipe, length to be determined
Electronic Depth Gauge;
Volumetric Flow Measuring Structure (Weir)
- V-Notch
- Flume

Sample containers (cleaned and provided by the laboratory);
Ice chests and blue or double bagged ice;
Tarps;
Miscellaneous tools;
Safety Equipment, and
Hip Boots and Knee-high water tight boots.

Documentation: Daily Field Record (DFR);
Maps;
Digital Camera and Photo Log;
Sample Control Log;
Atlantic Richfield Chain-of-Custody (COC) form or laboratory equivalent;
Field Instrument Calibration Sheet; and
Stream Flow (Discharge) Measurement Form (attached).

This SOP is to be used in conjunction with the Sampling and Analysis Plan (SAP) and future Focused Remedial Investigation (FRI) work plans. In addition to the SAP, the following SOPs should be consulted:

- SOP 1.0 – General Preparation and Mobilization Requirements
- SOP 2.0 – Basic Health and Safety for Field Operations
- SOP 3.0 – Field Documentation and Sample Handling
- SOP 4.0 – Sample Collection Techniques and Data Collection Strategies
- SOP 6.0 – Field Measurements - Water
- SOP 7.0 – Equipment Decontamination
- SOP 9.0 – Investigation Derived Waste Disposal

Also refer to the Leviathan Mine Site Health, Safety, Security and Environmental (HSSE) Program Document by ENSR dated May 27, 2008, the Task Specific Health and Safety Plan by AMEC Geomatrix dated June 2009, and the Job Safety Analysis for the planned scope of work.

C8.1 STREAM FLOW MEASUREMENT

Small stream and river volumetric flow can be calculated with measurements of the stream cross-sectional area and the velocity of flow through that area using the following formula.

$$Q = V \times A$$

Where,

Q = Discharge (in cubic feet per second)

V = Velocity (in feet per second)

A = Area (in square feet)

The area of the cross-section through which water is flowing will be determined by one or more techniques based on the overall general size of the stream (width and depth) and water velocity. A staff gauge (graduated into feet and tenths of feet (meters and centimeters) can be used to directly measure depths of shallow streams and rivers at select points perpendicular to the stream flow. If the bottom profile of the stream or river is undulating or complicated in some manner, the sum of the volumetric flows of the individual areas making up the cross-section can determine the overall volumetric flow rate. This will require calculating the individual areas and determination of corresponding velocities in those areas. For relatively simple geometries, a simple depth measurement and velocity determination can be directly made. For complicated geometries and deep water (greater than approximately 2.5 feet) multiple velocity readings, using one of a number of velocity specific and calibrated electronic or magnetic flow meters will be required.

An alternative method for directly reading stream or river volumetric flows, at locations that require repeated sampling, may be to install a permanent Weir or Flume that can be used to channel flow and read volumetric flows directly. If this method is utilized it will require plans and specifications for the design and construction of the structure.

The proper collection of representative surface water samples will also be dependent on the geometry and depths of the surface water to be sampled and the contaminant of concern. Surface water can be sampled through direct filling of contaminant specific sample containers or through collection of the sample in a pre-defined sample collection device where the sample is then transferred to the sample container. Generally, sampling of surface water from ponds and lakes do not require volumetric flows but will require knowledge of the total depth of the pond or lake and a predetermined knowledge of the depths from which samples are to be collected.

The choice of the proper location to collect a surface water sample, the method to measure areas and velocities and the proper choice of the materials of construction and type of flow meter and sample collection device is site and contaminant-specific and shall be defined in the FRI work plans.

All work performed determining areas, velocities and collection of representative samples should be thoroughly documented on a DFR using diagrams. Photographs and a photo log will also be used to document the methods used for measuring flow.

C8.1.1 Choosing a Transect Location

Stream flow measurements are performed along a transect of the stream. The transect location should include an area of moving water that can be waded and in an area of channelized flow. Hip boots or Knee-high water tight boots will be used for wading in streams. The transect location should be chosen based on a variety of general criteria ranging from point-source outfalls of concern, stream morphology, accessibility, safety concerns, and the location of pre-established sample locations. Once chosen, a transect location should be documented to provide a basis for repetition and comparison with previous or future sample events.

Stream specific criteria for selecting a transect location include looking for particular characteristics such as:

- a well defined and stable stream bank;
- few obstructions in the channel; and
- no eddies or still water.

Conversely, turbulent water should also be avoided, if possible. The stream should be free flowing and unrestricted by obstructions upstream or downstream, which might cause flow diversion or flow backup. A smooth streambed profile, one of relatively consistent depth across its width, is optimal. The depth of the stream must be adequate for the determination of a flow velocity and subsequent collection of the surface water sample without disturbing the stream bottom sediment.

For purposes of reproducibility, any likely movable objects within the stream bed, which may interfere with the reproducibility with subsequent sample collection events should be removed, if possible and allowable. Removal of channel obstructions, (i.e., woody debris, rocks, or other obstructions), should be performed to allowed sufficient time for stream flow re-stabilization before flow measurements are recorded.

C8.1.2 Setup

Once a transect location is selected, the stream flow equipment should be laid out as close to the transect as safety allows.

- Lay out tarps near the area where readings are to be performed, one for equipment, and one for staff seating and miscellaneous supplies.
- Unload equipment and setup the workstation, allowing for easy access to needed materials.
- If contaminants are expected (such as pathogens), establish a decontamination area with another tarp where staff will be exiting the stream. Place decontamination supplies (sprayer bottles with bleach solution and distilled rinse water) in this area.
- If the banks of the stream are steep, place a ladder against the bank for safe ingress and egress.

C8.1.3 Setting up the Transect

If the stream to be sampled is more than a few (five) feet across and the bottom profile of the stream is geometrically complicated, a transect for defining the area of the stream (by defined small sub-areas of depth) will be defined and measured in the field. The following procedures describe the process for setting up the transect.

- Setup the transect endpoints by driving a stake into the ground on each side of the stream. The resulting transect should be at right angles to the stream flow.
- Stretch a line (polyester pre-stretched line) across the stream and fasten to each stake, ensuring the line remains taut and as near the surface of the water as possible.
- Facing upstream, align the zero increment of the tape measure with the left edge of water and mark the line or secure the measuring tape to the line across the width of the stream using zip ties. If available, fasten the side of the tape measure marked in tenth of foot increments face-up. It may be convenient to fasten the tape measure to the line at the specific locations where measurements will be taken.
- Measure the total width of the stream.
- Determine the spacing of the stream velocity readings to be collected based on the width of the stream. The reading locations should be whole feet; equal distances apart, with 20 to 30 readings for streams wider than 20 feet, and at one-foot intervals for streams less than 20 feet wide. For example, if a stream is 46 feet wide, a spacing of 2 feet (24 readings including both edges) would be preferred to a

spacing of 1½ feet (30 readings). The first and last reading locations for each transect should fall at or outside the left and right edges of the water and will have zero velocity and zero depth.

If a boat or raft will be used to take the readings because the stream cannot be safely waded, the boat or raft must be stabilized against movement at each transect station but allowed to be moved across the stream as measurements dictate. A line (preferably polyester pre-stretch) tied to existing secure objects such as trees, guardrails, or other stationary objects (one on either side of the stream) should be attached to the boat through cleats, cams or eyelets on the boat or raft (and secured by appropriate knots (such as a bowline)) to enable the line to be untied. The objects should be as far upstream of the transect as the width of the stream. The lines must be independently adjustable on the boat to allow for freedom of movement along the transect yet allowing stability from downstream or lateral drift. If stationary objects are not available, vehicles, securely driven stakes, or two secure anchors on each stream bank may be necessary. Motors, if used, should not be used during actual velocity readings or sample collection.

C8.1.4 Measurement of Stream Depth

The depth of the stream should be measured at each point of the transect using equipment specific to the approximate depth encountered. For depths less than 5-feet, a staff gauge or steel measuring tape, in a vertical position, can be used to measure depth directly in feet and tenths of feet. If the velocity of the stream is too great, the turbulence around the gauge may make accurate and reproducible readings difficult. In this case, a PVC pipe, longer than the stream is deep and perforated near the bottom to allow communication with the stream flow, can be used to minimize the turbulence around the staff gauge while measuring the depth. The tube should be placed in the location of the measurement, the water level in the tube allowed to come to equilibrium and then the staff gauge used through the tube. Care should be taken to not disturb the sediment or organisms on the bottom of the stream bed.

For greater depths, a graduated measuring, and weighted, line may be used or an electronic depth meter for situations such as lakes and deep ponds.

For relatively small width and geometrically simple streams, a single depth measurement may be sufficient for the area calculation. This determination will be made in the FRI work plan when determining the sampling specific locations.

C8.1.5 Measurement of Stream Velocity

There are a number of velocity measuring methods/devices that can be used for determination of the stream velocity at each sampling location or at each point of a transect. The methods for velocity determination will be defined in the FRI work plan with the prior knowledge of each sample collection point location. The procedures for the proper calibration and use of velocity meters are well defined by the US Geological Survey and other State and Federal agencies as well as manufacturers of the meters. The measurements should follow these procedures and be made by staff with experience with the meters to be used.

For small streams with simple geometry and steady laminar flow, a simple method for velocity determination is to measure the rate of travel of a float on the surface of the water using a defined distance along the axis of the stream an accurate stop watch. If this method is used, at least 10 repetitions of the measurement should be made and an average of the 10 velocities used in the subsequent volumetric flow determination.

For most stream flow situations that may be encountered, where the stream can be safely waded, a velocity reading should be collected at each transect location using a calibrated velocity meter such as a Pygmy meter, Price AA meter or electronic direct reading meter. For each of these, a vertical profile of the stream velocity, at each transect whole foot location (see above) shall be measured as follows:

- Depths ≤ 2.5 Feet: One measurement should be taken at 60% of the depth at each measurement location.

- Depths >2.5 Feet: Two measurements should be taken: at 20% and 80% of the total depth at each measurement location.

The use of these in-stream measuring devices usually includes the use of a Wading Rod, which is a tool that is designed and constructed to easily set and hold the flow meter at the desired location and the desired depth (20%, 60% or 80%) using a defined set of gradations on the Rod and instructions that accompany the meters.

C8.1.6 Measurement of Flow Velocities

For all velocity readings, the Wading Rod should be kept vertical and the meter perpendicular to the flow. For those streams with multiple measurements across a transect, measure and record the velocity, move to the next location along the transect, and repeat the procedure until reaching the opposite bank. At least one measurement should be made at each pre-

determined measurement point along the transect, however additional measurements along the transect can be used to help average the flow if the site conditions suggest that this is appropriate.

C8.1.7 Calculating Stream Flow

Once the velocity and depth of the points along the transect have been determined, the midsection method can be used for determining the stream flow. Compute the volumetric flow in each transect increment by multiplying the averaged velocity, or single velocity in streams less than 2.5 feet deep, in each increment by the area determined for that transect increment (depth times width). Note that the first and last increments are located at the edge of the stream and have a depth and velocity of zero. Sum the volumetric flow for each increment to compute total stream flow. Record all measurements and the resulting flow in cubic feet (or cubic meters) per second on the appropriate field forms.

C8.2 SURFACE WATER SAMPLING

Preparation and execution of surface water sampling will be conducted under the supervision of a licensed geologist, hydrologist, or engineer. Surface water sampling preparation and surface water sampling techniques will be defined in the FRI work plan and general requirements are discussed below.

C8.2.1 Preparation

Prior to performing the sampling, the following tasks will be completed:

- Determine the extent of the sampling effort, the sampling methods to be employed, and which specific equipment and supplies are needed (these will be defined by the stream, lake or pond characteristics and the contaminants of concern).
- Obtain necessary sampling and monitoring equipment.
- Decontaminate all sampling equipment and ensure that it is in working order.
- Prepare scheduling and coordinate with staff, clients, and regulatory agency, if appropriate.
- Scout proposed locations to ensure accessibility and sampling feasibility.
- Use stakes, flags, or buoys to identify and mark all planned sampling locations. If required, the proposed locations may be adjusted based on site access, property, boundaries, and obstructions.

Things to consider before sampling include:

- Will the sample be collected from the shore or from a boat on the impoundment?
- What is the desired depth at which the sample is to be collected?
- What is the overall depth and flow direction of a river or stream?
- What is the chemical nature of the analyte(s) of concern? Do they float on the water surface (collect by skimming the surface) or are the miscible (soluble) and are more likely to be present at depths (collect sub-surface)?

These considerations will help to dictate the sample equipment to be used during the sample collection.

8.2.2 Surface Water Sampling Techniques

Sampling of both aqueous and non-aqueous liquids is generally accomplished through the use of one of the following samplers or techniques:

- Dip Sampler;
- Direct Method;
- Discrete Depth Samplers;
- Peristaltic Pumps.

Sampling situations vary widely and other techniques may be available, however these sampling techniques will allow for collection of representative samples from the majority of streams, rivers, lakes and ponds.

Sample collection devices must be of a proper composition based upon the analyses to be performed. For example, devices which are free of metal surfaces should be used for collecting samples for metal analyses. The FRI work plan will define the materials of construction that can come into contact with the water to be sampled as well as the laboratory prepared sample containers and preservatives (if any) to be used for the water samples.

C8.2.2.1 Dip Sampler

A dip sampler is useful for situations where a sample is to be recovered from an outfall pipe or along a stream, lake or pond where direct access is limited. Generally a Dip sampler is a

sample collection container (either open of capable of closing upon sample collection) mounted on a long pole that may be telescoping. The long handle on such a device allows access from a discrete location. Sampling procedures are as follows:

1. Assemble the device in accordance with the manufacturer's instructions.
2. Extend the device to the sample location and collect the sample.
3. Retrieve the sampler and transfer the sample to the appropriate sample container.

C8.2.2.2 Direct Method

For streams, rivers, lakes, and other surface waters, the direct method may be utilized to collect water samples from the water surface. This method is typically not used for sampling lagoons, impoundments, or ponds where significant concentrations of contaminants are present.

Use adequate protective clothing and gain access to the sampling station by appropriate means. For shallow stream stations, the sampler should face upstream and collect the sample upstream from where the sample personnel are standing and without disturbing sediment. Surface water samples should always be collected prior to a sediment sample at the same location. Submerge the closed sample container, open the bottle to collect the sample, and then cap the bottle while it remains under water.

When using the direct method, do not use pre-preserved sample bottles as the collection method may dilute the concentration of preservative necessary for proper sample preservation.

C8.2.2.3 Discrete Depth Samplers

When samples are to be collected from discreet depths of a stream, river, lake or pond, the predetermined depths and contaminants of concern will define what specific sample collection devices should be used. There are sample collection devices that can be used to collect samples from shallow water (less than 2.5 feet) which are generally horizontal tubes (Kemmerer sampler) or deeper depths which generally use the same principal of sample collection (Van Dorn Sampler). Both samplers are lowered to the desired sampling depth and allowed to come to equilibrium with the flowing or steady water. The line which holds the sample device is connected to a spring loaded mechanism which allows the ends of the sample tube to close. The sampler is closed by sending a "messenger", typically a metal

weight, down the line to the sampler where then the weight trips the spring and the sampler is closed. The following criteria should be followed:

1. Using a properly decontaminated sampler, set the sampling device so that the sampling end pieces are pulled away from the sampling tube, allowing water to pass through the tube.

2. Lower the pre-set sampling device to the predetermined depth. This requires knowledge of the total depth at the sample location. Avoid bottom/sediment disturbance. The line holding the sampler may need to be pre-marked to ensure that the proper depth is being sampled.

3. When the discrete sampler bottle is at the required depth, send down the messenger to close the sampling device.

4. Retrieve the sampler and discharge the first 10 to 20 milliliter (mL) to clear any potential contamination of the valve. Transfer the water sample to the appropriate sample container in accordance with SOP 3.0 – Field Documentation and Sample Handling and SOP 6.0 – Field Measurements - Water.

5. Be sure to use special attachments available on some discrete samplers to distribute small volumes at low flow rates, when appropriate.

C8.2.2.4. Peristaltic Pump Samplers

A peristaltic pump can be used to collect a sample from the water column at most depths of interest in a stream or river. Tubing (the composition of which will be defined in the FRI work plan is lowered to the desired sample depth (using weights to ensure that the tubing is placed to the correct depth) and connected at the surface to the peristaltic pump.

Typically peristaltic pumps work to a depth of approximately 25 feet below ground surface. Because of the overlying water, deeper depths can be sampled but may not be efficient due to the low pumping rates of peristaltic pumps and the sample volume that may be needed for sample analysis. Commercially available pumps vary in size and capability, with some being designed specifically for the simultaneous collection of multiple water samples. Due to the various pumps available no universal sampling procedure is available and the sampler should follow the procedures provided in the instruction manual for the pump.

ATTACHMENTS

- Stream Flow (Discharge) Measurement Form

Stream Flow (Discharge) Measurement Form

Stream _____ Time Begin _____
Site Description _____ Time Ended _____
Date _____ Section Width (ft.) _____
Meter Type _____ Stream Width[1] (ft.) _____
Personnel _____

Observations _____

Section Midpoint (ft.)	Section Depth (ft.)	Observational Depth[2] (ft.)	Velocity		Area - WxD ($ft.^2$)	Flow (Q) - VxA ($ft.^3$)
			At Point (ft./s)	Average (ft./s)		
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
					Total Discharge - ΣQ ($ft.^3/s$)	

Notes
1. Make minimum of 10 measurements. When the total width is >5.0 ft., 20 measurements is preferred.
2. Measure at 60% of depth from surface where <2.5 ft. deep. Measure at 20% and 80% of depth in waters >2.5 ft. deep.

AMEC Geomatrix

C9.0 – INVESTIGATION DERIVED WASTE DISPOSAL

Purpose and Scope: The purpose of this document is to present procedures for containment and disposal of investigation derived waste such as soil, water, and materials.

Equipment: Buckets, containers with covers for soil and water (e.g., 55-gallon drums, 20-yard roll-off bins, Baker Tanks™, etc.);
Waste disposal labels;
Appropriate sample containers and sampling equipment;
Miscellaneous tools; and
Safety Equipment.

Documentation: Daily Field Record (DFR)
Waste Tracking Log (attached)
Maps/plot plan; and
Camera.

This Standard Operating Procedure (SOP) is to be used in conjunction with the Sampling and analysis Plan (SAP) and future Focused Remedial Investigation (FRI) work plans. In addition, the following SOPs should be consulted:

- SOP 1.0 – General Preparation and Mobilization Requirements
- SOP 2.0 – Basic Health and Safety for Field Operations
- SOP 3.0 – Field Documentation and Sample Handling
- SOP 14.0 – Soil Sampling

Also refer to the Leviathan Mine Site Health, Safety, Security and Environmental (HSSE) Program Document by ENSR dated May 27, 2008, the Task Specific Health and Safety Plan by AMEC Geomatrix dated June 2009, and the Job Safety Analysis for the planned scope of work.

The procedures below are to be followed for investigation derived waste consisting of water, soil, or materials such as personal protective equipment (PPE) or disposal sampling equipment. Investigation derived groundwater will be generated from well development and purging activities. Investigation derived soil will be generated from soil borings. The following sections describe the process for disposal of investigation derived waste.

All containers containing waste will be kept closed and sealed at all times unless actively adding waste. Each container must have a visible and legible label present. Labels will be constructed of weather-resistant vinyl and waterproof ink markers will be used to add information in the field. All empty containers must have a label that indicates that the container is empty. Prior to filling any waste containers, the sampler will replace the empty label with a label that describes the source of the waste (well or boring ID), the contents (soil or water), date accumulation started, date accumulation finished, and a name and contact information of the RI/FS Coordinator.

The location of the waste generated will be documented on a waste tracking log (attached).

C9.1 GROUNDWATER DISPOSAL PROCEDURES

Groundwater produced during the well rehabilitation, purging and development activities will be discharged to the ground surface near the well for evaporation and infiltration. Water will be discharged in a manner to prevent pooling or erosion. If surface discharge is not practical, development water may be containerized and transported to the onsite treatment systems at Pond 4 or the ASB.

All surface discharge activities will be performed in a manner that prevents migration to a surface water body and in accordance with the HSSE Program document and the Task Specific HASP.

It is not anticipated that investigation derived waste water will be transported offsite. However, if necessary the waste water disposal activities will be performed in accordance with Section C9.3.

C9.2 SOIL DISPOSAL PROCEDURES

It is anticipated that most soil investigations will be performed in areas that have unconsolidated material at the surface that was left behind from previous site activities (i.e., mining, construction, landslides). Any soil or mud developed during the drilling or excavation activities are expected to have similar characteristics as the disturbed material that exists in the vicinity of the investigation. Therefore, if disturbed material already exists at the surface, any soil or mud developed during the investigation will be spread evenly in the immediate vicinity. The material will be spread in a manner that has a low profile as to prevent wind blown dust from occurring. These soil disposal activities will be performed in a manner that

prevents migration to a surface water body and in accordance with the HSSE Program document and the Task Specific HASP.

If soil and mud produced during the investigation is suspected to contain other contaminants (e.g., petroleum odors, ethanol odor), the field Engineer or Geologist will contact the Project Manager for guidance. Exceptions to the above soil disposal procedures will be addressed on a case-by-case basis.

C9.3 MATERIAL DISPOSAL PROCEDURES

All disposable equipment, including PPE and items such as rope and sampling devices, will be disposed in the onsite municipal solid waste trash receptacle. The exception is for the disposal of equipment that has come in contact with contaminants that are suspected to be non-native to the area or those that are known to be hazardous (e.g., ethanol, diesel fuel, etc.). If this situation exists, the field engineer or geologist will contact the Project Manager for guidance.

C9.4 OFFSITE FACILITY DISPOSAL PROCEDURES

Offsite disposal of investigation derived waste is not expected. However in the event that it is needed, the location and quantity of the waste that is generated will be documented on a map and Waste Tracking Log (attached).

Offsite disposal of waste will be performed in accordance with appropriate Federal, State, and Local Regulations. A sample of the waste to be disposed of at an offsite facility will be collected and submitted to a laboratory for analysis. Analytical results of the sample will then be sent to the disposal facility where a waste profile will be generated. The profile will be reviewed and signed by a designated Atlantic Richfield representative. The U.S. EPA will then be notified of all types and quantities of waste prior to its shipment offsite.

Upon approval of the waste profile, an appropriate manifest (Hazardous or Non-Hazardous) will be completed. All waste manifests will be reviewed and signed by a designated Atlantic Richfield representative. The truck driver transporting the waste will also sign and keep the manifest in his presence at all times while transporting the container to the disposal facility. The truck driver will be responsible for adhering to all Department of Transport (DOT) rules and regulations for the transport of waste on public roads.

ATTACHMENT

- Waste Tracking Log

Waste Tracking Log
Leviathan Mine Site
Alpine County, California

Date	Waste Type and Volume	Source Location	Container Type and Volume	Number of Containers	Storage Location

AMEC Geomatrix

C10.0 – SEDIMENT SAMPLING

Purpose and Scope: The purpose of this document is to provide procedures for collecting representative sediment samples for chemical, biological, or physical analysis. It includes preparation, sample collection, and health and safety.

Equipment:

Bailer - teflon, PVC, or disposable polyethylene;
Dip sampler;
Discrete depth sampler;
Peristaltic pumps;
Line and messengers;
Safety Equipment;
Compass;
Tape Measure;
Survey stakes, flags, or buoys and anchors;
Stainless steel, plastic, or other appropriate composition bucket;
Sample containers (cleaned and provided by laboratory);
Ziploc plastic bags;
Spade or shovel;
Spatula;
Scoop;
Trowel;
Bucket Auger;
Thin-walled Auger;
Thin-wall tube auger;
Thin-wall tube sampler;
Tube sampler;
Slide hammer;
Extension rods;
T-handle;
Ponar dredge;
Eckman dredge;
Nylon rope;
Ice chests;
Blue or double bagged ice;
Miscellaneous field equipment; and
Safety equipment.

Documentation: Daily Field Record;
Maps/plot plan;
Logbook;
Camera;
Sample Labels;
Sample Control Log; and
Atlantic Richfield Chain-of-Custody form (COC) or laboratory equivalent.

This Standard Operating Procedure (SOP) is to be used in conjunction with the Sampling and Analysis Plan (SAP) and future Focused Remedial Investigation (FRI) work plans. In addition to the SAP, the following SOPs should be consulted:

- SOP 1.0 – General Preparation and Mobilization Requirements
- SOP 2.0 – Basic Health and Safety for Field Operations
- SOP 3.0 – Field Documentation and Sample Handling
- SOP 4.0 – Sample Collection Techniques and Data Collection Strategies
- SOP 7.0 – Equipment Decontamination
- SOP 9.0 – Investigation Derived Waste Disposal

Also refer to the Leviathan Mine Site Health, Safety, Security and Environmental (HSSE) Program Document by ENSR dated May 27, 2008, the Task Specific Health and Safety Plan by AMEC Geomatrix dated June 2009, and the Job Safety Analysis for the planned scope of work.

C10.1 PREPARATION

Set-up and execution of the sediment sampling will be conducted under the supervision of a California licensed Professional Geologist or Professional Engineer. Prior to conducting the sampling, the following tasks will be completed:

1. Determine the extent of the sampling effort, the sampling methods to be employed, and required equipment and supplies.
2. Obtain necessary sampling and monitoring equipment.
3. Decontaminate or pre-clean equipment and ensure that it is in working order.

4. Prepare schedules and coordinate with staff, client, and regulatory agencies, if appropriate.

5. Scout proposed locations to ensure accessibility and sampling feasibility.

6. Use stakes, flags, or buoys to identify and mark all sampling locations. If required, the proposed locations may be adjusted based onsite access, property boundaries, and obstructions.

C10.2 SAMPLE COLLECTION

Sediment samples may be recovered using a variety of methods and equipment, depending on the depth of the aqueous later, the portion of the sediment required (surface versus subsurface), the type of sample required (disturbed versus undisturbed), and the sediment type. All sampling equipment must be decontaminated prior to collecting a sample at each location as described in SOP 7.0 – Equipment Decontamination. The following sections describe techniques that may be used during sediment sampling.

C10.2.1 Sediment Sampling with a Trowel or Scoop

This method is typically used when sampling beneath a shallow aqueous layer (less than 8 ft deep). A stainless steel, plastic spoon, or lab spoon will be sufficient in most applications. Metal plated devices should be avoided. If the surface water body is wadeable, wade into the surface water body and while facing upstream (into the current), scoop the sampler along the bottom of the surface water body in the upstream direction. In surface water bodies that are too deep to wade but less than eight feet deep, a stainless steel scoop or spoon attached to a piece of conduit can be used either from the banks or from a boat. The following procedures should be followed when collecting samples with a scoop or trowel:

1. Use a pre-cleaned stainless steel scoop or trowel to remove the desired thickness of sediment from the sampling area.

2. Transfer the sample into an appropriate sample or homogenization container.

C10.2.2 Surface Sediment Sampling with a Thin-Wall Tube Auger

This method is typically used when sampling beneath a shallow aqueous layer and when sampling surface sediments. This system consists of an auger, a series of extension rods, and a “T” handle. The auger is driven into the sediment and used to extract a core. A sample of the core is taken from the appropriate depth.

Use the following procedure to collect sediment samples with a thin-walled auger:

1. Insert the auger into the material to be sampled at a 0° to 45° angle from vertical. This orientation minimizes spillage of the sample from the sampler. Extraction of samples may require tilting of the sampler.

2. Rotate the auger once or twice to cut a core of material.

3. Slowly withdraw the auger, making sure that the slot is facing upward.

4. An acetate core may be inserted into the auger prior to sampling, if characteristics of the sediments or body of water warrant. By using this technique, an intact core can be extracted.

5. Transfer the sample into an appropriate sample or homogenization container.

C10.2.3 Deep Sediment Sampling with Augers and Thin-Wall Tube Samplers

This method is typically used when sampling beneath a shallow aqueous layer and when sampling deep sediments. This system uses an auger, a series of extension rods, "T" handle, and a thin-wall tube sampler. The auger bores a hole to a desired sampling depth and then is withdrawn. The auger tip is then replaced with a tube core sampler, lowered down the borehole, and driven into the sediment at the completion depth. The core is then withdrawn and sample collected.

Follow these procedures to collect sediment samples with a hand auger:

1. Attach the auger bit to a drill extension rod, and then attach the "T" handle to the drill extension rod.

2. Clear the area to be sampled of any surface debris.

3. Begin auguring, periodically removing any accumulated sediment from the auger bucket.

4. After reaching the desired depth, slowly and carefully remove the auger from boring.

5. Remove auger tip from drill rods and replace with a pre-cleaned thin –wall tube sampler. Install the proper cutting tip.

6. Carefully lower the tube sampler down the borehole. Gradually force the tube sampler into the sediment. Care should be taken to avoid scraping the borehole sides. Also avoid hammering of the drill rods to facilitate coring, since the vibrations may cause the boring walls to collapse.

7. Remove the tube sampler and unscrew the drill rods.

8. Remove the cutting tip and remove the core from the device.

9. Discard the top of the core (approximately 1 inch), as this represents the material collected by the tube sampler before penetration of the layer of concern.

10. Transfer the sample into an appropriate sample or homogenization container.

Several augers are available which include bucket and posthole augers. Selection of a sampling device should take into consideration both the depth of water at the sampling location and the physical characteristics of the medium to be sampled.

C10.2.4 Sediment Sampling with an Eckman or Ponar Dredge

This method is typically used when sampling beneath a deep aqueous layer and when sampling surface sediments. Three types of dredges (the Eckman, Ponar, and "mini" Ponar dredges) are commonly used and are described below.

C10.2.4.1 Eckman Dredge

The Eckman dredge is limited to sampling material which is unusually soft, such as organic sludge or light mud. It is unsuitable for sampling sandy, rocky, and hard bottoms and is too light for use in streams with high velocities.

Follow these procedures for collecting sediment with an Eckman Dredge:

1. Thread a study nylon or stainless steel cable through the bracket, or secure the extended handle to the bracket with machine bolts.

2. Attach springs to both sides. Arrange the Ekman dredge sampler so that the jaws are in the open position and trip cables are positioned over the release studs.

3. Lower the sampler to a point just above the sediment surface.

4. Drop the sampler sharply onto the sediment.

5. Trigger the jaw release mechanism by lowering a messenger down the line, or by depressing the button on the upper end of the extended handle.

6. Raise the sampler and slowly decant any free liquid through the top of the sampler. Be careful to retain fine sediments.

7. Open the dredge and transfer the sediment into a stainless steel or plastic bucket. Continue to collect additional sediment until sufficient material has been secured.

Thoroughly mix sediment to obtain a homogeneous sample and then transfer to the appropriate sample container.

C10.2.4.2 Ponar and "Mini" Ponar Dredge

The Ponar dredge is similar to the Eckman dredge, however, it has been modified by the addition of side plates and a screen on the top of the sample compartment. The screen over the sample compartment permits water to pass through the sampler as it descends thus reducing turbulence around the dredge. The Ponar dredge is one of the most effective samplers for general use on all types of substrates.

The "mini" Ponar dredge is a smaller, lighter version of the Ponar dredge. It is a good device to use when collecting smaller sample volumes and when collecting sludge and sediment containing hazardous constituents.

Follow these procedures when using a Ponar or "mini" Ponar dredge:

1. Attach a sturdy nylon or steel cable to the hook provided on top of the dredge.
2. Arrange the Ponar dredge sampler in the open position, setting the trip bar so the sampler remains open when lifted from the top.
3. Slowly lower the sampler to a point just above the sediment.
4. Drop the sampler sharply into the sediment, then pull sharply up on the line, thus releasing the trip bar and closing the dredge.
5. Raise the sampler to the surface and slowly decant any free liquid through the screens on the top of the dredge. Be careful to retain fine sediments.
6. Open the dredge and transfer the sediment to a stainless steel or plastic bucket. Continue to collect additional sediment until sufficient material has been collected. Thoroughly mix sediment to obtain a homogeneous sample, and then transfer to the appropriate sample container.

C10.2.5 Sediment Sampling with a Sample Coring Device

Core samplers are used to sample vertical columns of sediment. Many types of coring devices have been developed depending on the depth of water from which the sample is to be obtained, the nature of the bottom material, and the length of core to be collected. Core samples vary from hand push tubes to weight- or gravity- driven devices.

Follow these procedures when using a sample coring device to collect subsurface sediments:

1. Assemble the coring device by inserting the acetate core into the sampling tube.

2. Insert the “eggshell” check valve mechanisms into the tip of the sampling tube with the convex surface positioned inside the acetate core.

3. Screw the coring point onto the tip of the sampling tube.

4. Screw the handle onto the upper end of the sampling tube and add extension rods as needed.

5. Place the sampler in a perpendicular position on the material to be sampled.

6. This sampler may be used with either a drive hammer for firm consolidated sediments, or a “T” handle for soft sediments. If the “T” handle is used, place downward pressure on the device until the desired depth is reached. Rotate the sample to shear off the core, retrieve the device and proceed to Step 15.

7. If the drive hammer is selected, insert the tapered handle (drive head) of the drive hammer through the drive head.

8. With left hand holding the tube, drive the sampler into the material to the desired depth. Do not drive the tube further than the tip of the hammer’s guide.

9. Record the length of the tube that penetrated the sample material, and the number of blows required to obtain this depth.

10. Remove the drive hammer and fit the keyhole-like opening on the flat side of the hammer onto the drive head. In this position, the hammer serves as a handle for the sampler.

11. Rotate the sampler at least two revolutions to shear off the core..

12. Lower the sampler handle (hammer) until it just clears the two ear-like protrusions on the drive head, and rotate about 90°.

13. Withdraw the sampler by pulling the handle (hammer) upwards and dislodging the hammer from the sampler.

14. Unscrew the coring point and remove the “eggshell” check valve.

15. Slide the acetate core out of the sampler tube. The acetate core may be capped at both ends. The sample may be used in this fashion, or the contents transferred to a stainless steel or plastic bucket and mixed thoroughly to obtain a homogeneous sample representative of the entire sampling interval.

C11.0 – SOIL AND/OR ROCK LOGGING

Purpose and Scope: The purpose of this document is to describe procedures for soil and/or rock logging. It describes the required equipment and forms, the information necessary to complete a boring log, and methods for describing drill cuttings and soil cores.

Equipment:
Hand Lens;
Dilute hydrochloric acid (HCl);
Soil Knife;
Water level indicator;
Rock Hammer;
Measuring Tape;
Compass; and
Plastic Bags.

Documentation:
Daily Field Record;
Soil Boring Log (attached); and
Rock Boring Log (attached).

This Standard Operating Procedure (SOP) is to be used in conjunction with the Sampling and Analysis Plan (SAP) and future Focused Remedial Investigation (FRI) work plans. In addition to the SAP, the following SOPs should be consulted:

- SOP 1.0 – General Preparation and Mobilization Requirements
- SOP 2.0 – Basic Health and Safety for Field Operations
- SOP 3.0 – Field Documentation and Sample Handling
- SOP 4.0 – Sample Collection Techniques and Data Collection Strategies

Also refer to the Leviathan Mine Site Health, Safety, Security and Environmental (HSSE) Program Document by ENSR dated May 27, 2008, the Task Specific Health and Safety Plan by AMEC Geomatrix dated June 2009, and the Job Safety Analysis for the planned scope of work.

All logging activities must be performed by appropriately trained field staff under the guidance of a licensed Professional Engineer or Professional Geologist.

C11.1 BORING LOG PREPARATION

On the first page of the log for each boring, the sampler will record the following information:

- Project information including Job Number (13091), Client Name (Atlantic Richfield); Location (Leviathan Mine Site and Study Area);
- Borehole identifier;
- Drilling subcontractor;
- Date started and date finished;
- Drilling method;
- Drilling equipment including rig model, sampling equipment, and rig number, if more than one on site;
- Sampling method including hammer weight in pounds and drop height in feet;
- Name of Person Conducting the Logging and the responsible geologist or engineer;
- Elevation and location datum; and
- Complete and accurate location sketch with dimensions to landmarks. Significant and relatively permanent features such as road intersections, corners of large buildings, or other man-made structures are best used. The sketch must include a north arrow.

Each succeeding page of the boring log should contain at a minimum:

- Job Number;
- Client Name;
- Borehole identifier;
- Any water level measurements; and
- Page numbers (marked as page x of x)

On the DFR for the day, the following details must be recorded: Water levels will be recorded each day prior to drilling start-up and as appropriate. Maps indicating the location of the boring log should be attached to the DFR. The casing depth must be noted for each water level reading. Drilling mud use must be noted, if applicable. Water levels will be referenced to

ground surface, unless otherwise noted. At the conclusion of drilling, a final static water level will be measured. The field personnel will note on the log any remarks relative to the measurement, such as relatively rapid fluctuations. When more than one boring is drilled, the elevations of the water levels will be tabulated and the measurements will be compared to evaluate the consistency of readings between boreholes.

Surface conditions will be noted, including vegetation or ground cover and land use, general topography (rolling, level, etc.), and physical features (hillside, river bottom, etc.). The time and date of the commencement and conclusion of the drilling, down time, and the end and start of each shift should also be noted on the log.

Upon completion of each boring, a standard completion note will be placed at the bottom of the last page of the boring log. The note will include:

- Boring completed at (depth) feet on (date);
- Casing used to a depth of (depth) feet on (date);
- Ground water level recorded at (depth) feet on (date);
- Hole backfilled to ground surface on (date); and
- Casing diameter and length will be recorded.

All depths will be recorded in decimals, not fractions.

C11.2 GENERAL LOGGING PROCEDURES

The left side of the boring log will be filled out accurately and completely for each boring and sampling attempt. The following information will be included:

- In the depth column each hash mark will represent a 0.5' interval.
- In the sample number column, write the sample number in sequential whole numbers for each boring (i.e., 1, 2, 3). Restart the numbering for each boring.
- In the sample column, indicate the interval that the sample was collected and the sampler type. The abbreviations for sampler types are TW for thin-wall, P for piston, ST for Shelby Tube, SS for standard split spoon, CC for continuous core, and GS for grab samples. These abbreviations, or notations as to other sampler types, will be used in the sampler type column. Other types of sampler types may

be used depending on the type of drilling equipment used and will be noted on the boring logs (as appropriate).

- Depending on the type of investigation, blow counts may be recorded. If recorded, the blow count for each 6-inch interval will be recorded opposite the appropriate interval on the depth scale. This will be used to later calculate the number of blows to advance the sampler tube one foot.

- Record the depth of casing for each sample attempt, if applicable.

- Record the sample number and depth. The sample depth is always measured to the top of the sample. A sample attempt where no sample is recovered will not be numbered, but the attempt must be noted.

- Mark the sampling attempts in the depth in feet column.

Record a detailed description of the soil or rock strata encountered and all pertinent information regarding drilling operations and estimated soil, rock, and groundwater properties. The description will include the geologic and/or geotechnical descriptions.

- The geologic description includes classifying the soil or rock units to the site-specific geologic nomenclature developed by Herbst and Sciacca (1982). References by Hebrst and Sciacca and Brown and Caldwell are attached to this SOP. These documents provide detailed descriptions of the geologic units identified at the Site.

- The geotechnical description includes classifying the soil or rock units to the soil or rock classification systems as described in Section C11.3 and C11.4, respectively. The key terms used to describe soil and rock are presented on Tables C11-1 and C11-2, respectively.

    - Table C11-1 presents the key terms to describe the geotechnical physical properties of soil. This table was adapted from the *AMEC Geotechnical Manual for Employees of AMEC Earth and Environmental* dated June 6, 2008 and the Unified Soil Classification System (USCS) as described in ASTM D2487-06.

    - Table C11-2 presents the key terms to describe the geotechnical physical properties of rock. This table was also adapted from *AMEC Geotechnical Manual for Employees of AMEC Earth and Environmental* dated Juen 6, 2008, U.S. Bureau of Reclamation, 1998, Engineering Geology Field Manual, Volume 1 (second edition), and Standard Test Method for Determining Rock Quality Designation (RQD) of Rock Core as described in ASTM D6032-08.

- Mark abrupt soil or rock changes by a solid horizontal line at the appropriate depth in the soil or rock graph column. Mark gradational by a dashed line. Do not use diagonal lines.
- Note any changes in hydrogeologic conditions (i.e., dry, saturated).
- Abbreviations may be used to save space for editing purposes; where used, a list of abbreviations must be provided.

Comments or remarks are extremely important and should be included. Some important aspects of the drilling operation that will be recorded are as follows:

- The organic content of the soil and the depth of topsoil and roots;
- Any sudden change in the speed, sound, or penetration rate of the drill rig;
- Whether continuous samples or drill cuttings have been used log the boring; and
- Whether a sample is suspected of having been disturbed, contaminated, or chemically or physically altered during the drilling process.

Field personnel will make specific arrangements for scanning and sending completed boring logs to the Project Manager, or someone designated by the Project Manager. Field personnel will retain one copy of the boring log in the field for reference throughout the job.

C11.3 SAMPLING AND DESCRIPTION OF SOIL

This section presents the descriptive term and general procedures that will be used to classify soil sampled in exploratory borings, test pits or trenches, and the general format for presenting the soil data that are recorded in the field. The classification terms for soil descriptions are presented in Table C11-1.

The following data are considered to be the minimum information that should be recorded in the field when logging soil. An example of AMEC soil boring log is attached to this SOP. The various components of the soil sample are listed below:

Geologic Unit Name

Indicate the geologic unit name in accordance with the nomenclature developed by Herbst and Sciacca (1982). 27 different geologic units were identified at the site and are attached to this SOP along with a stratigraphic column.

USCS Classification Group Name or Symbol[1]

Indicate the soil type (gravel, sand, silt, or clay), grading (well or poor), and grain size (coarse or fine).

Moisture Content[1]

Indicate the moisture in the sample

Relative Density/Consistency[1]

Indicate if the soil is loose, soft dense, or hard.

Cementation[1]

Indicate if the soil is cemented.

Grain Size[1]

Indicate the size of the grains in the soil.

Maximum Particle Size[1]

Indicate the larges observed particle size.

Odor (if present)

Indicate if an odor is present.

Lithologic Descriptions (which are to include the following):

1. First Line: ALL CAPITAL LETTERS
   a) Geologic Unit Type and Soil Type [and Formation name if known]

2. Second Line, Third Line, etc. (in the following order): all lower case letters
   a) Color. Use the Munsell Color Chart for rock color descriptions. Describe color when the rock is moist or wet. The Munsell number is recorded after the color. The color of mottling or conspicuous zones of weathering or alteration also should be noted.
   b) Moisture Content
   c) Relative Density/Consistency
   d) Cementation
   e) Grain size
   f) Maximum particle size
   e) odor
   g) Any other distinctive geologic features that will aid in correlation or interpretation of the geologic conditions (e.g., the type and size of voids, fossils, cementation, reaction to HCl, etc).

Graphic Log

Depicts the core as sketched in the field.

[1] Values and definitions are listed in Table C11-1 of this Section.

TABLE C11-1
TERMS USED TO DESCRIBE THE GEOTECHNICAL PHYSICAL PROPERTIES OF SOIL

USCS Soil Classification System For Coarse-Grained Soils (<50% passes #200 sieve)

GW	Well Graded gravels, gravel-sand mixtures, little or no fines
GP	Poorly-Graded gravels, gravel-sand mixtures. Little or no fines
GM	Silty gravels, poorly-graded gravel-sand-silt mixtures
GC	Clayey gravels, poorly-graded gravel-sand-silt mixtures
SW	Well-graded sands, gravelly sands, little or no fines
SP	Poorly-graded sands, gravelly sands, little or no fines
SM	Silty sands, poorly-graded sand-gravel-silt mixtures
SC	Clayey sands, poorly-graded sand-gravel-clay mixtures

USCS Soil Classification System for Fine-Grained Soils (>50% passes #200 sieve)

ML	Inorganic silts &very fine sands, silty or clayey fine sands, clayey silts with slight plasticity
CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
OL	Organic silts & clays of medium-to-high plasticity
MH	Inorganic silts, micaceous or diatomaceous fine sand or silt
CH	Inorganic clays of high plasticity, fat clays
OH	Organic silts & clays of medium-to-high plasticity
PT	Peat, humus, swamp soils with high organic content

COLOR

Use the Munsell Color Chart for soil color descriptions. Describe color if the soil is moist or wet. The Munsell number is recorded after the color. The color of mottling or conspicuous zones of weathering or alteration also should be noted.

MOISTURE CONTENT

Dry	Absence of moisture, dusty, dry to touch
Moist	Damp but no visable water
Wet	Visible free water, usually soil is below water table

APPARENT/RELATIVE DENSITY – COARSE-GRAINED SOIL

Very loose	Easily penetrated with ½-inch reinforcing rod pushed by hand.
Loose	Difficult to penetrate with½-inch reinforcing rod pushed by hand
Medium Dense	Easily penetrated a foot with ½-inch reinforcing rod driven with 5-lb. hammer
Dense	Difficult to penetrate a foot with ½-inch reinforcing rod driven with 5-lb. hammer
Very Dense	Penetrated only a few inches with ½-inch reinforcing rod driven with 5-lb. hammer

CONSISTENCY – FINE-GRAINED SOIL

Very soft	Easily penetrated several inches by thumb. Excludes between thumb and fingers when squeezed in hand
Soft	Easily penetrated 1-inch by thumb. Molded by light finger pressure
Medium Stiff	Penetrated over ½-inch by thumb with moderate effort.
Stiff	Indented about ½-inch by thumb but penetrated only with great effort.
Very Stiff	Readily indented by thumbnail
Hard	Indented with difficulty by thumbnail

CEMENTATION

Weakly – Crumbles or breaks with handling or slight finger pressure
Moderately – Crumbles or breaks with considerable finger pressure
Strongly – Will not crumble or break with finger pressure

GRAIN SIZE

Boulders	Larger than basketball-sized
Cobbles	Fist-sized to basketball-sized
Coarse Gravel	Thumb-sized to fist-sized
Fine Gravel	Pea-sized to thumb-sized
Coarse Sand	Rock salt-sized to pea-sized
Medium Sand	sugar-sized to rock salt-sized
Fine Sand	Flour-sized to sugar-sized
Fines	Flour sized and smaller

C11.4 SAMPLING AND DESCRIPTION OF ROCK

This section presents the descriptive terms and general procedures that will be used to classify rock core sampled in exploratory borings, test pits or trenches, and the general format for presenting the rock core in the field. The classification terms for rock descriptions are presented in Tables C11-1 and C11-2.

The following data are considered to be the minimum information that should be recorded in the field when logging rock core. An example of AMEC field boring (rock core) log is attached to this SOP. The various components (columns) of the field log are described below, in order from left to right as they appear on the log:

Core Run
Indicate the run number, or sampling interval.

Core Recoverey
Indicate the percent core recovery for a specific run. Recovery can be expressed as a ratio and/or a percentage.

Rock Quality Designation (RQD)
Indicate summation of run (i.e. fresh to only moderately weathered) core pieces over 4 inches in length (measured along the axis of the core) divided by the total length of the core run. RQD can be expressed as a ratio and/or a percentage.

Fracturing[2]
Indicate the fracture spacing within a run.

Hardness[2]
Indicate the hardness of the core within a run.

Strength[2]
Indicate the strength of the core within a run.

Weathering[2]
Indicate the degree of weathering of the core within the run.

Geologic Unit Name
Indicate the geologic unit name in accordance with the nomenclature developed by Herbst and Sciacca (1982). 27 different geologic units were identified at the site and are attached to this SOP along with a stratigraphic column.

Lithologic Descriptions (which are to include the following):

[2] Values and definitions are listed in Table C11-2 of this Section.

1. First Line: ALL CAPITAL LETTERS
   a) Geologic Unit Name and Rock Type

2. Second Line, Third Line, etc. (in the following order): all lower case letters
   a) Color. Use the Munsell Color Chart for rock color descriptions. Describe color when the rock is moist or wet. The Munsell number is recorded after the color. The color of mottling or conspicuous zones of weathering or alteration also should be noted.
   b) Grain size and texture. Note grain roundness, shape, and sorting.
   c) Lithology. Predominant minerals identifiable in hand specimen should be noted.
   d) Bedding/Foliation/Flow Texture. Note attitude(s) and describe any depositional features or structures (e.g., planar or cross bedding, laminated bedding, etc.).
   e) Contacts. Contacts should be identified and their nature described.
   f) Any other distinctive geologic features that will aid in correlation or interpretation of the geologic conditions (e.g., the type and size of voids, fossils, cementation, reaction to HCl, etc).

Examples:

SANDSTONE
dark gray (10 YR 5/2) with yellowish brown mottling (10YR 5/4), medium to coarse subangular sand, well sorted, mostly quartz and lithics, no bedding apparent, contacts not exposed, has local veinlets of quartz.

CLAYSTONE
Grayish brown (7.5 YR 3/3), has thin (< 1 inch thick) sand stringers and fossiliferous beds (up to 1 foot thick), exposed contacts appear depositional.

Graphic Log
Depicts the core as sketched in the field.

Discontinuity Descriptions[3] (which are to include the following in order):

1. Discontinuity type (i.e., bedding plane, joint, foliation, shear/fault, mechanical break, or vein) and dip angle.

2. Aperture (i.e., tight, open, filled, or healed). Note presence and type of staining or coatings on fracture surfaces, fracture surface moisture conditions, amount of separation/filling, and type and hardness of filling.

3. Surface shape (i.e., irregular, planar, and wavy or undulating)

[3] See Table C11-3 for additional information.

4. Roughness (i.e., stepped, rough, moderately rough, slightly rough, smooth, polished). Note the presence of slickensides or striations.

Remarks

Records information pertaining to the drilling operation. Some of the information that may be recorded includes:

Drilling methods	Samples and sampling methods
Drilling rate	Drilling difficulties
Loss of circulation	Color of return water
Casing used and reasons	Cement or drilling mud used
Driller's comments	Water pressure test intervals

Core box numbers and boundaries between boxes will be noted in this column.

The reason for stopping the hole is recorded at the bottom of the column, using the following terms:

Terminated hole: hole stopped by geologist because sufficient information and depth was attained.

Abandoned hole: stopped hole because of coring difficulties.

Refusal: stopped by rock too hard for drilling equipment.

TABLE C11-2

TERMS USED TO DESCRIBE THE GEOTECHNICAL PHYSICAL CONDITION OF ROCKS[4]

FRACTURING
- (VC) Very closely spaced (crushed)
- (Cl) Closely spaced
- (Mo) Moderately spaced
- (Wi) Widely spaced
- (VW) Very widely spaced
- (Ex) Extremely wide

SPACING (True spacing)
- Less than 0.1 ft (< 30 mm)
- 0.1 ft to 0.3 ft (30 to 100 mm)
- 0.3 ft to 1.0 ft (100 to 300 mm)
- 1.0 ft to 3.0 ft (300 mm to 1 m)
- 3.0 ft to 10.0 ft (1 to 3 m)
- Greater than 10 ft (> 3 m)

BEDDING OR FLOW TEXTURE
- (La) Laminated
- (VTn) Very thinly
- (Tn) Thinly
- (Mo) Moderately
- (Tk) Thickly
- (VTk) Very thickly
- (Ma) Massive

THICKNESS/SPACING
- Less than 0.03 ft (3/8 in) (< 10 mm)
- 0.03 (3/8 in) to 0.1 ft (10 to 30 mm)
- 0.1 to 0.3 ft (30 to 100 mm)
- 0.3 to 1 ft (100 to 300 mm)
- 1.0 to 3.0 ft (300 mm to 1 m)
- 3.0 to 10.0 ft (1 to 3 m)
- Greater than 10 ft (> 3 m)

HARDNESS - a measure of the resistance of a rock surface to scratching/abrasion.
- (So) Soft – can be grooved or gouged easily with a knife, can be scratched with fingernail
- (Lo) Low Hardness - can be grooved 1/16 inch (2 mm) deep with a knife with moderate or heavy pressure
- (Mo) Moderately Hard - can be scratched with a knife with light or moderate pressure
- (Ha) Hard - can be scratched with a knife with difficulty
- (VH) Very Hard - cannot be scratched with a knife

STRENGTH - a measure of crushing resistance of rock.
- (Fr) Friable – breaks with light to moderate manual pressure
- (We) Weak – core or fragment breaks with light hammer blow or heavy manual pressure
- (Mo) Moderately Strong – core or fragment breaks with moderate hammer blow
- (St) Strong – heavy hammer blow required to break specimen
- (VS) Very Strong – core or fragment breaks only with repeated heavy hammer blows
- (Ex) Extremely Strong – core or fragment can only be chipped with repeated heavy hammer blows

WEATHERING - a measure of the physical and chemical alteration of a rock from its original "fresh" condition.

	DECOMPOSITION	DISCOLORATION	FRACTURES
(Fr) Fresh	Unaltered; cleavage surfaces glistening	No discoloration	No stains or coatings
(Sl) Slight	No megascopic alteration of minerals; no grain separations	Slight and localized	Few stains on fracture surfaces
(Mo) Moderate	Slight alternation of minerals; cleavage surfaces lusterless/stained; partial separation of grains visible	Moderate discoloration, usually throughout	Thin coatings or stains
(Se) Severe	Moderate to complete alteration of minerals; feldspars to clay, etc.; rock is friable	Discolored throughout	Extensively coated with oxides, carbonates, or clay

[4] Based on US Bureau of Reclamation, 1998, Engineering Geology Field Manual, Second Edition, Vol.1.

TABLE C11-3

KEY TO TERMS USED TO DESCRIBE DISCONTINUITES IN ROCK[5]

DISCONTINUITY TYPE (and dip angle)

(Be) Bedding plane
(Fo) Foliation
(Me) Mechanical break (dip angle not recorded)
(Jo) Joint
(Sh) Shear or Fault
(Ve) Vein

APERTURE

(Ti) Tight – No visible separation
(Op) Open – (Note amount of separation; note staining or coatings on fracture surfaces; note fracture surface moisture conditions)
(He) Healed – (Note degree of healing, i.e., partial or complete, thickness and mineralogy/hardness)
(Fi) Filled – (Note degree of filling, i.e., partial or complete, thickness and type of filling)

SURFACE SHAPE

(Ir) Irregular
(Pl) Planar
(Wa) Wavy or undulating

ROUGHNESS (note presence of slickensides or striations)

(St) Stepped – Near normal steps and ridges occur on fracture surface
(Ro) Rough – Large, angular asperities can be seen
(Mo) Moderately rough – Asperities are clearly visible and fracture surface feels abrasive
(Sl) Slightly rough – Small asperities on the fracture surface visible and can be felt
(Sm) Smooth – No asperities, smooth to touch
(Po) Polished – Extremely smooth and shiny

Where appropriate during field mapping, the following discontinuity characteristics also should be noted:

Discontinuity orientations (strike and dip)
Prominent joint sets, cleavages, foliations, etc.
Fracture continuity
Fracture cross-cutting relationships
Moisture/seepage conditions

[5] Based on US Bureau of Reclamation, 1998, Engineering Geology Field Manual, Second Edition, Vol. 1.

C11.5 ROCK CORE COLLECTION

If rock is encountered during drilling, the geologist should record the time required for each core run, drill gauge readings for rotation and down-feed pressure, and drill fluid and rock cutting recovery and conditions. Where deemed appropriate by the geologist, soft or highly deformed rock can be sampled using a modified California sampler without sleeves, Shelby or Pitcher tubes, or 94 mm core. If specified by the FRI work plan, all recovered core may be stored in core boxes supplied by the drilling company. When core is sensitive to changes in moisture content, the core may be wrapped in plastic or shrink wrap to protect the core. Rock cores may be photographed in the core boxes. Movement and transportation of core boxes should be minimized to reduce disturbance of the core. Rock core shall be described in the field according to Field Logging and Classification of Rock.

Marking Core Boxes - Core shall be placed in the box beginning in the upper left corner (hinge side), continuing to the right. The front edge of the lower half of the box shall be marked in accordance with the sample drawing attached. Wooden divider blocks should be put between the core from different runs, with the depth of the runs marked on the blocks. Blocks also will be placed to mark intervals where there is no recovery for a specific run. The core may have to be broken to store it. Unless someone is studying the core, the lid of the core box should be fastened into place.

Core Left in the Hole - Core sometimes is left in the hole when a run is pulled. This core is referred to as “stick up” and should be recovered during the next run. The procedure is to log the entire core in a given run. Thus, if 1.5 m (5 feet) are drilled and 300 mm (1 foot) is left in the hole (not ground up), the run is considered a 1.5-meter run, and all logging, percent of core recovery, etc., are computed on that basis. The next run may recover the 300 mm (1 foot) previously drilled, but this 300 mm (1 foot) properly belongs with the previous run.

This procedure may seem to be a minor item, but unless properly handled it can cause serious confusion. For example, suppose a 1.5 m (5 foot) core barrel is being used and the run begins at a depth of 15.2 m (50 feet). At 16.8 m (55 feet), the barrel is removed from the hole, and instead of 1.5 m (5 feet) of core, only 1.2 m (4 feet) of core is in the barrel. Drilling starts again at 16.8 m (55 feet) and the coring is stopped at 17.1 (56 feet). The barrel contains 610 mm (2 feet) of core when the run is pulled. If properly recorded there is 100 percent recovery for this 300 mm (1 foot) run and for the previous 1.5 m (5 foot) run.

There are other techniques for determining “stick up”. The stick up typically can be distinguished by excessive “tool marks” where the core barrel fit over the stick up. Care should be taken to ensure that the driller isn’t “washing away” core at the tip.

Core Photographs – Prior to wrapping cores for testing, cores can be photographed using a high resolution digital camera. Core photographs will be cropped and placed in a Microsoft Word template showing 5 feet (one core run) per page. Photos will be documented as documented in SOP 3.0 – Field Documentation and Sample Handling.

ATTACHMENTS

- Soil Boring Log
- Rock Boring Log
- Stratigraphic Column of the Geologic Units Identified by Herbst and Sciacca (1982)
- Geologic Units, Leviathan Sulfur Mine and Vicinity – Excerpted pages from Appendix A of the "Leviathan Mine Pollution Abatement Project" by Brown and Caldwell dated April 1983.

SOIL BORING LOG

FRI PROJECT NAME:	Log of Boring No.	
BORING LOCATION (Study Area and GPS Coordinates):	APPROXIMATE SURFACE ELEVATION AND DATUM:	
DRILLING CONTRACTOR:	DATE STARTED:	DATE FINISHED:
DRILLING METHOD:	TOTAL DEPTH:	MEASURING POINT:
DRILLING EQUIPMENT:	DEPTH TO WATER:	
SAMPLING METHOD:	LOGGED BY:	
HAMMER WEIGHT: DROP DISTANCE	REVIEWED BY:	

DEPTH (feet)	SAMPLES			Geologic Unit Symbol	USCS Symbol	DESCRIPTION	REMARKS
	Sample No.	Sample Interval	Blows/ Foot			NAME (Geologic Unit Name and USCS Soil Type) Color, moisture, grain size, angularity, minerals and alteration, % distribution, density or consistency, grading, cementation, plasticity, odors, native or recently disturbed material.	

AMEC Geomatrix

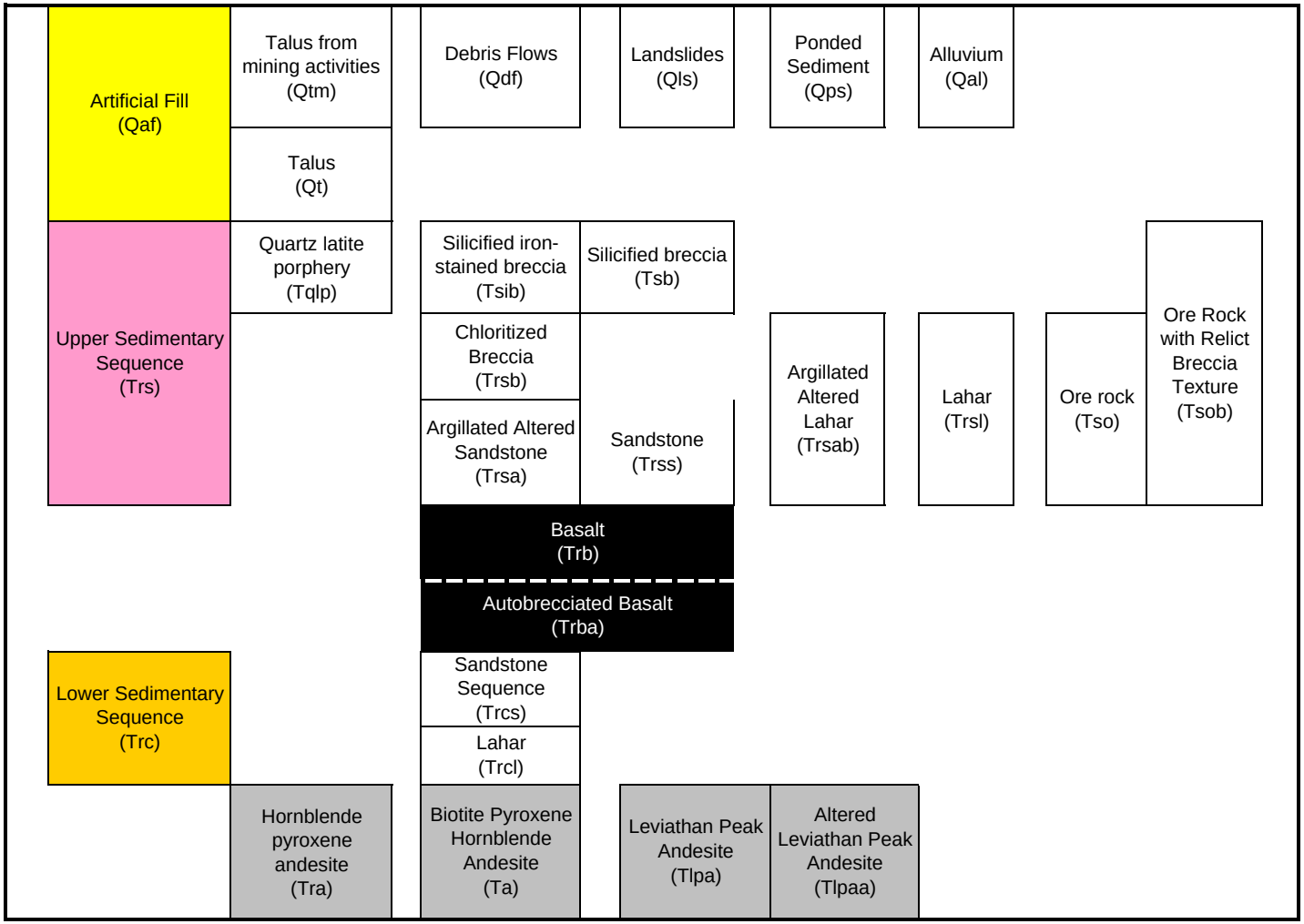
ROCK BORING LOG

FRI PROJECT NAME:	Log of Boring No.	
BORING LOCATION (Study Area and GPS Coordinates):	APPROXIMATE SURFACE ELEVATION AND DATUM:	
DRILLING CONTRACTOR:	DATE STARTED:	DATE FINISHED:
DRILLING METHOD:	TOTAL DEPTH:	MEASURING POINT:
DRILLING EQUIPMENT:	DEPTH TO WATER:	
SAMPLING METHOD:	LOGGED BY:	
HAMMER WEIGHT: DROP DISTANCE	REVIEWED BY:	

DEPTH (feet)	Core Run	Core Recov.	RQD	Fracturing	Hardness	Strength	Weathering	Geologic Unit Symbol	Rock Type Symbol	DESCRIPTION NAME (Geologic Unit Name and Rock Type) Color, minerals and alteration, grain size, % distribution, structure, cementation, reaction with HCl	GRAPHIC LOG	DISCONTINUITY DESCRIPTION	REMARKS

AMEC Geomatrix

Stratigraphic Column of the Geologic Units Identified by Herbst and Sciacca (1982)
Leviathan Mine Site
Alpine County, California



Herbst and Sciacca, (1982) = *Geology of the Leviathan Sulfur Mine and Vicinity, State Water Resources Control Board, Division of Technical Services. October 1982.*

A detailed description of the geologic units are presented in Appendix A of the *Leviathan Mine Pollution Abatement Project* by Brown and Caldwell dated April 1983.

The following information was excerpted from "Leviathan Mine Pollution Abatement Project" by Brown and Caldwell, dated April 1983.

APPENDIX A

GEOLOGIC UNITS
LEVIATHAN SULPHUR MINE AND VICINITY

QUATERNARY UNITS

LANDSLIDES (Qls) and DEBRIS FLOW (Qdf)--

Landslides and debris flow in pit area are post-mining, on oversteepened slopes cut during the mining process. Landslides in pit appear stabilized; fresh ground cracks visible in slope above ore rock on northeast side of pit and in sandstone on west rim of pit. Debris flow in pit is active. Large landslides immediately north of pit in tailings and downslope are active. Both Qls and Qdf are composed of loose material and are probably permeable.

ALLUVIUM (Qal) and PONDED SEDIMENT (Qps)--

Alluvium composed of native material or reworked mine tailings. Ponded sediment has formed as a result of mining activities. Permeability may be high depending on sediment composition.

ARTIFICIAL FILL (Qaf)--

Generally composed of mine tailings but may include disturbed native materials in roadbeds. On wet day, several inches of standing water noted on Qaf near old Isabel Construction Company site; unit may not have high surface permeability.

TALUS (Qt) and TALUS RESULTING FROM MINING (Qtm)--

Naturally-occurring talus present on slopes outside the pit and artificial fill areas. Talus formed on oversteepened mined slopes mantles slopes within pit. Sand-sized talus on west side of pit may be highly permeable; appears to have high storage capacity.

TERTIARY UNITS

QUARTZ LATITE PORPHYRY (Tqlp)--

Well-indurated dark to white-grey weathering light blue-grey groundmass of very fine-grained plagioclase and quartz (70%) containing 2 to 5 millimeter plagioclase phenocrysts (20-25%) altering to clay ; euhedral biotite (5%) present along with prismatic hornblende phenocrysts with some slight flow alignment (1%); mafics altering. Tqlp may intrude Tlpa, but within study area, Tqlp is always in contact with Tsib/Tsb and never seen in contact with Tlpa, so exact relationship unknown. Unit well-jointed; may have some fracture permeability.

Excerpted pages include pages 14-20.

SILICIFIED BRECCIA (Tsb) and SILICIFIED IRON-STAINED BRECCIA (Tsib)--

Tsb is grey to white on fresh and weathered surfaces with streaky blue relict breccia texture; jasperoid appearance; locally contains kaolinite bodies; generally lacks sulfur and sulfide mineralization. Tsib is dark rust brown on weathered surfaces, red to blue-black on fresh surfaces; often jasperoid apperance; is more resistant rock, forming cornices; pervasively fractured. Free sulphur and abundant sulfides present in Tsib which is dark blue on fresh surfaces (within pit); locally contains blue-green copper mineral (chrysocolla); appearance varies--some examples:

Tsib on north side of pit: silicified iron-stained breccia and argillically altered silicified breccia (lahar?); argillically altered rock weathers peach. Both rock types show breccia texture, local flow banding on some light-colored sialic clasts. Breccia clasts average 1 to 20 cm, are subangular to rounded; matrix and clasts are of different compositions; clasts appear to be volcanic, range from andesite with relict texture to jasperoid; can be mineralized with sulfur, some sulfides (10-15%) (pyrite, marcasite, arsenopyrite) present, particularly in dark colored clasts.

Tsib west of Leviathan Creek: iron-stained, silicified breccia-type relict texture, clasts weather yellow-white, as compared to matrix, which weathers dark red; clasts angular to subrounded, 3 to 15 cm in size, relict andesitic texture in some clasts. May contain minor arsenopyrite. Also, some non iron-stained, more argillically altered breccia in same location. Calcite deposits present where water moves through fractures. No sulfur.

Age of Tsb/Tsib uncertain; Tsb in contact with altered Tlpa, Tsib or Tsb surrounds Tqlp whenever Tqlp present in study area. Units highly fractured but without persistant joint orientation. Most float rounded. No primary permeability but may have fracture permeability. Relict textures suggest unit origionally lahar, conglomerate, or sedimentary breccia, silicified and locally mineralized.

LEVIATHAN PEAK ANDESITE (Tlpa, Tlpaa)--

Porphyritic hornblende andesite with well-indurated red and light grey weathering red and grey glassy groundmass (40-50%) containing fine-grained and porphyritic plagioclase (45-50%), porphyritic hornblende (5-7%) and possible biotite (1%) phenocrysts. Seen only as angular float in study area; may have some fracture permeability. Locally argillically altered with relict hornblende phenocrysts, copper sulfide stains (bormite?) where in contact with Tsb (noted as Tlpaa on geologic map).

Excerpted pages include pages 14-20.

BIOTITE PYROXENE HORNBLENDE ANDESITE (Ta)--

Well-indurated red-brown weathering black glassy groundmass (60-65%) containing 20-30% flow-aligned tabular 1 to 3mm plagioclase phenocrysts with some iron-staining, twinning, and zoning, and hornblende (5-8%), pyroxene (5%), and biotite (1%) phenocrysts; groundmass shows some alteration to clay and may contain minor very fine grained dark grey opaque minerals; plagioclase locally altering to clay with extensive calcite replacement; pyroxenes replaced by chlorite. In some areas , calcite crystals present as vug linings with quartz crystals inside vugs. Locally copper sulfate stained (light blue-green). Locally flow banded. Slightly propylitized. Unit only seen in contact with sediments and, locally, underlying Trb. Locally jointed and/or fractured; may have fracture permeability.

UPPER SEDIMENTARY SEQUENCE (Trs)--

Interbedded fine- to coarse grained sandstones, pebbly sandstones, breccias, and lahars. Unit includes leached and bleached sandstone and kaolinite beds visible in pit. Also includes sandstones and breccias permeated with sulfur that comprise principal ore body.

Sandstone (Trss)--

Best exposed on west rim of pit: very fine to fine-grained poorly indurated lithic wacke, matrix poorly to moderately sorted, subangular, propylitically altered to green minerals; pebble conglomerates and granule beds with finer particles, contains 2 m by 7 m sized lenses of fine sandstone; fractures iron-stained with calcite rinds on pebbles, especially near fault. Sandstone at northwest edge of pit even less indurated; many fault scarps and incipient arcuate fractures present which have created or could create catchment basins for precipitation. Poor induration of this unit is a main contributor to landsliding in the pit area as most slides seem to originate in this unit or its altered equivalents. Unit unconformably overlies Trb and Trba on west side of pit with basal scour channel. Basal conglomerate consists of basalt (Trb) chunks (60%, angular to subangular) in iron-cemented matrix of fine to medium sand- sized rock fragments (40%). Possible primary permeability.

Lahar (Trsl)--

Angular to subrounded 5 to 25 cm clasts in tan ashy matrix. Matrix comprises 85-90% of rock (matrix supported). Clasts include Tra. In area east of pit, clasts average 2-15 cm with most 2-3 cm, angular to subangular. Locally slightly silicified, locally graded bedding, locally conglomeratic with more sandy matrix. Laterally discontinuous; only seen nonconformably overlying Tra. Possible matrix permeability.

Excerpted pages include pages 14-20.

Argillically Altered Sandstone (Trsa, Trsab)--
White to peach (iron-stained) argillically altered sandstone and breccia; locally shows conchoidal fracture, locally appears porous and may be permeable. Relict siltstone texture and possible fining-upward sequence immediately west of pit. Above is rock (clast?) with fluidal outline, relict andesitic texture (relict plagioclase phenocrysts) in punky white matrix. Permeability questionable because of high clay content. May have breccia texture (Trsab).

Chloritized Breccia (Trsb)--
Only found underlying Tsib. Matrix brown to green, waxy to greasy luster, soft, some slickensides, massive with no discernable grains. Some black, round, very fine grained opaque minerals. Representative clast altered to chlorite, clays, talc?; some minerals with fresher cores; only visible relict textures are volcanic with relict phenocrysts 1/2 to 2mm long and tabular to prismatic habit. Some minerals altered entirely to epidote with indistinct outlines. Minor iron staining along outside of clasts; clasts up to size in Tsib (1 to 20 cm); may be correlative to Tsib, differing in alteration and lacking flow banding. Permeability probably low because of high clay content.

Ore Rock (Tso)--
Consists of mineralized breccia (Tsob) and sandstone; may include mineralized tuff. Breccia is at least 20-30% sulfur (pervasive replacement); most clasts less than or equal to 6cm; unit contains very fine to fine-grained grey, brassy, and silver sulfides (up to 30%) (oxidized and unoxidized pyrite, disseminated and in very fine grained irregular masses, and arsenopyrite (?) in aggregates). Sandstone contains a maximum of 20% disseminated sulfur; sulfur also as fracture coatings. Sandstone generally contains fewer sulfides than breccia. Possible fracture permeability in both sandstone and breccia. Largest concentrations of sulfides in Tso are east of pit entrance in dark blue brecciated ore rock and west and opposite of pit entrance (fine grained, locally oxidized pyrite in patchesand seams).

Excerpted pages include pages 14-20.

HORNBLENDE PYROXENE ANDESITE (Tra)--

Strong flow banding, flow alignment of plagioclase and hornblende phenocrysts. Red to tan weathering, purplish-grey groundmass (60-70%) containing: 1-2 mm plagioclase phenocrysts (andesine) with weathering rinds and some albite twinning and zoning (25- 35%), orthopyroxene (10%), and minor hornblende (1-3%), and very minor, slightly altered biotite (1%). Most mafics have altered cores. Only scattered outcrops; usually present as angular float. May have fracture permeability. Locally altered to punky buff-colored rock with dark opalescent copper sulfide staining (no native sulfur) east of pit near silicified iron-stained breccia.

BASALT (Trb)--

Fine grained igneous rock, olive green to black on weathered surface, grey black on fresh surface; fine-grained plagioclase (labradorite) (45-50%) and clinopyroxene (5-7%) phenocrysts in glassy groundmass (40-50%). Pyroxenes replaced by chlorite, rimmed by magnetite. Calcite filling fractures; no sulfur mineralization; manganese oxide (dendritic) staining; locally autobrecciated with calcite cement on or in breccia fractures. Contact between autobreccia and basalt appears sheared with foliation subparallel to joints in basalt. Locally minor light turquoise-colored powdery copper minerals (chrysocolla ?), some hornblende altering to blue green mineral. Some pyroxene phenocrysts from 1-7mm long dispersed in rock. Forms cliffs and hills; locally is massive flow with wavy, blocky fracture and pervasive jointing; salt stains on joints indicate water flow through fractures. On west end of pit, unit is poorly indurated and grey-colored with 0.5-1 mm long altered plagioclase phenocrysts.

AUTOBRECCIATED BASALT (Trba)--

As above with autobreccia texture, spheroidal weathering.

LOWER SEDIMENTARY SEQUENCE (Trc)--

Interbedded very fine- to coarse-grained sandstone with pebbly sandstone and laminar siltstone interbeds, and lahars. Propylitically altered.

Sandstone Sequence (Trcs)--

Ridge west-southwest of pit entrance: poorly-sorted sequence of fine to very fine grained-sandstone with pebbly sandstone interbeds and laminar siltstone interbeds. Rock is moderately- to well-indurated, subangular to subrounded, green brown on fresh and weathered surfaces, with calcite underlying siltstone.

Excerpted pages include pages 14-20.

crystal lithic sandstone: medium to coarse grained volcanic lithic fragments with some quartz, plagioclase, hornblende, and pyroxene crystals; silica cemented; contains other fine to very fine grained beds, medium scale low angle crossbeds in sets up to 8 cm, outcrop principally laminar sandstone. Also laminar bedded red-brown to yellow-tan fine to very fine-grained sandstone in 2-5 cm thick beds with good parting, highly fractured.

pebble interbeds: comprise 10 to 20% of rock; interbeds up to 6 cm thick with subangular to subrounded pebbles up to 3 cm (isolated pebbles up to 8 cm), pebble lines and lenses laterally discontinuous.

shale interbeds: purple fresh and weathered surfaces with some iron stains, ripple marks, recumbant folds (soft sediment deformation) up to 7 cm thick.

hydrology: little primary permeability present in rock itself, but water movement possible along fractures and bedding planes. Rock appear similar to sandstone in pit except more indurated; variation could be result of propylitic alteration of stratigraphically different but lithologically similar sandstone.

Waterfall near waste dump: shale, weathering hard and blocky; sandstone, especiallypebblysandstone, weathering spheroidally, friable with hand.

pebbly sandstone: large, sub-rounded (60 cm by 30 cm) volcanic clast. In clast, all mafics altered to light green clay, contains fresh plagioclase phenocrysts (1 to 2 mm), with only minor saussuritization of plagioclase. Near top of the unit, sandstone and pebble conglomerate well indurated, indicating "baked" zone near contact with basalt, matrix green. May be equivalent of Trl. Overall induration of this unit much less than igneous units; tends to form topographic lows, appears to underlie large landslides north of pit. May have some primary permeability.

Lahar (Trcl)--

Near crusher building: Unsilicified breccia, 40% clasts, 60% matrix; clasts 3 to 25 cm; approximatly 95% volcanic; types noted: medium to light grey porphyritic hornblende andesite with phenocrysts up to 2 mm, averaging 1 1/2 to 2 mm; red silicified rock, angular to subrounded; andesite basalt clast, 6 cm, subrounded; two poorly indurated light grey very fine to fine grained sandstone clasts, 10 cm, angular to subangular, and 25 to 30 cm, angular to sub angular; some weathered rinds present on clasts; matrix fine grained light grey to white, may be amorphous and green, with

Excerpted pages include pages 14-20.

hornblende/pyroxene and biotite crystals. Matrix may be reddish on fresh surface, weathers spheroidally. Euhedral biotite alters to brown or brown green (chloritized). Also quartz, sericite, muscovite, with ashey matrix that alter to clay or zeolite. No fresh plagioclase. Rock is matrix supported with matrix and clasts of similar hardness but matrix is more fractured. May have some low matrix permeability.

Basal mudflow unit along waterfall near waste dump: 90% green ashy matrix composed of 60-65% glass with phenocrysts of plagioclase (30%), quartz (3-5%), biotite (1%), green amphibole (1%), and pyroxene (1%). Rock contains 10% volcanic clasts. Alteration includes rhodochrosite? (salmon veinlets), alteration of mafics (hornblende and pyroxene most altered), some alteration of plagioclase to clay, calcite replacement.

Induration of the above units can vary throughout the study area. Lower sedimentary sequence poorly exposed in vicinity of landslide north of pit. Where visible, is friable wacke with few pebble and gravel interbeds.

Excerpted pages include pages 14-20.

C12.0 – TEST PIT EXCAVATION

Purpose and Scope: The purpose of this document is to provide procedures for excavating a test pit. The resulting test pits can be used for shallow stratigraphic description and physical and chemical sampling.

Equipment:
Backhoe;
Steam cleaner;
Soil hand sampling equipment;
Shovel;
Camera;
Dust Meters
Miscellaneous tools; and
Safety Equipment.

Documentation:
Daily Field Record;
Field Test Pit Sample Log (attached); and
Field Test Pit Log (attached).

This Standard Operating Procedure (SOP) describes setup procedures that will be performed by the field geologist or engineer while observing the test pit excavation activities being performed by others. This SOP does not include procedures for operating heavy equipment. It is expected that the test pit excavation activities will be subcontracted to a third party that is appropriately qualified and specializes in such investigations.

This SOP is to be used in conjunction with the Sampling and Analysis Plan (SAP) and future Focused Remedial Investigation (FRI) work plans. In addition to the SAP, the following SOPs should be consulted:

- SOP 1.0 – General Preparation and Mobilization Requirements
- SOP 2.0 – Basic Health and Safety for Field Operations
- SOP 3.0 – Field Documentation and Sample Handling
- SOP 4.0 – Sample Collection Techniques and Data Collection Strategies
- SOP 7.0 – Equipment Decontamination
- SOP 11.0 – Soil and/or Rock Logging
- SOP 14.0 – Soil Sampling

- SOP 24.0 – Dust Monitoring

Also refer to the Leviathan Mine Site Health, Safety, Security and Environmental (HSSE) Program Document by ENSR dated May 27, 2008, the Task Specific Health and Safety Plan by AMEC Geomatrix dated June 2009, and the Job Safety Analysis for the planned scope of work.

This SOP describes pre-excavation activities, test pit excavation procedures, and the test pit logging activities. It is expected that all excavation activities will be subcontracted to a third party that has a current California contractor's license. All pre-excavation activities and test pit excavations must be performed by appropriately trained field staff under the guidance of a California licensed Professional Engineer or Professional Geologist.

C12.1 TEST PIT PREPARATION PROCEDURES

The following activities must be performed prior to the start of any excavation activities:

- Provide subcontractors with the applicable scope documents and necessary access information.
- Prepare schedules and coordinate with staff, client, and regulatory agencies, if appropriate.
- Obtain an approved British Petroleum (BP) ground disturbance permit and all appropriate permits according to Federal, State, and local regulations.
- Confirm the test pit location with the Project Manager and pre-mark the locations with white spray paint. Additional markings with flags, wooden stakes, or other methods may be used to ensure that the locations can be easily found.
- While pre-marking the test pit locations, perform a preliminary review of potential overhead or underground utilities and hazards that may interfere with the test pit location.
- Obtaining proper clearance for potential above- and below-ground hazards in process areas. These activities may include:
    - reviewing As-Built Utility diagrams; and
    - contracting a private utility locator to locate potential subsurface obstructions
    - using an air knife or hand digging the top 5 feet

- Verify that equipment has been decontaminated and is in good working order prior to its arrival onsite.

- If relocation is necessary due to the presence of a utility line, the new location must be at least 2 feet away from the outermost edge of the obstruction. Confirm any relocated borings with the Project Manager;

- Unexploded ordnances (UXO) may exist within buried sections of tunnels or other unknown areas at the site. If any suspected UXO are encountered, the area must be marked as a zone of exclusion and the Project Manager must be notified. No work shall be performed within the study area if a UXO is suspected.

C12.2 TEST PIT EXCAVATION

The following activities must be performed prior to excavation:

- Perform a Health and Safety tailgate meeting with all personnel performing the excavation activities. Secure the work zone with traffic cones and barricade tape. Verify that the appropriate Personal Protective Equipment (PPE) is worn within the work zone. Setup dust monitoring devices in accordance with SOP 24.0 – Dust Monitoring.

- Decontaminate the excavation bucket and all sampling tools. Setup a decontamination station for sampling equipment. Decontamination of sampling equipment is described in SOP 7.0 – Equipment Decontamination.

- Set up a soil logging and note taking area.

All excavation activities will be performed in accordance with OSHA regulations and all appropriate Federal, State, and Local regulations. Test pit procedures described below adhere to guidelines and requirements of Title 8 CCR, Article 6, Sections 1541 and 1542.

Once the test pit location is selected and approved by the Project Manager, all surface debris including branches, pine needles and boulders shall be removed and set aside. After the surface is cleared, the test pit will be excavated using a backhoe or other types of excavation equipment. If necessary, engineering controls, such as water spray, will be implemented to minimize generation of dust. Air monitoring for dust may be needed during excavation activities.

If possible, test pits greater than four feet in depth will not be entered by field personnel. If soil samples are required from greater than four feet, soil will be obtained from the sampling location using the backhoe bucket. Soil sample collection methods are described in SOP 14.0

– Soil Sampling. Observations for logging purposes will be made from the surface, if possible. If detailed logging is required at depths greater than four feet and entry is required to perform the logging, the test pit will be appropriately shored in accordance with Title 8 CCR, Article 6, Section 1541. No confined space entry work will be conducted.

A series of photographs will be taken of each test pit to document the location and features within the test pit. The first photographs for each location will be taken prior to excavation to document the features of the ground surface prior to disturbance. An object with a known size (usually a small ruler) will be added to each photograph so features in the test pit can be sized appropriately.

If groundwater is encountered while excavating, the depth of the water within the excavation will be noted and the excavation will not continue.

Excavated soil will be stockpiled on plastic sheeting. Each stockpile will be labeled with a wooden stake indicating the location where the soil was excavated. The excavated soil will be covered with plastic sheeting weighted with sand bags or similar weighting devices when not actively being worked. When all documentation is complete, the stockpile will be uncovered and the test pit will be backfilled using the backhoe. Backfilling will typically be performed in one-foot lifts and compaction will be completed for each lift using the backhoe bucket and by driving the backhoe over the backfilled test pit after the final lift of backfilling is completed. Backfilling details will be described in the FRI work plans and will be specific to each investigation area.

Important details that should be recorded on the daily field record (DFR) include:

- surface conditions including vegetation or ground cover;
- general topography or physical features (rolling, level, drainage area, etc.); and
- the time of the commencement and conclusion of excavation down time.

C12.3 TEST PIT LOGGING PROCEDURES

There are two forms for test pit logging. The Field Test Pit Log (attached) is a form that will be completed to document the type of soil encountered within the test pit and to provide a sketch of the excavation location. The Field Test Pit Sample Log is a form that will be completed to

document any samples collected within the test pit. These forms are discussed further in the sections below.

C12.3.1 Field Test Pit Log

The following information will be included on the field test pit log:

- project number;
- test pit number;
- project name (Leviathan Mine Site);
- client name (Atlantic Richfield);
- test pit location (study area);
- start and finish date;
- start and finish time;
- excavator type including model;
- elevation and location datum;
- name of person conducting the logging the test pit; and
- observed groundwater level (if water is encountered),

On the back of the Field Test Pit Log, a complete and accurate location sketch including dimensions to landmarks will be drawn. Important features such as road intersections, corners of large buildings, or other man-made structures should be documented so the location of the test pit can be located in the future. A north arrow will be included in the sketch.

The left side of the test pit log will be filled out accurately and completely for each test pit. The following information will be included:

- In the depth column each hash mark will represent a 0.5' interval.
- If a sample is collected for laboratory analysis, write the sample number at the appropriate depth.
- The sample number and depth. The sample depth is always measured to the top of the sample.

The soil description area of the log will contain a detailed description of the soil stratigraphy encountered and all pertinent information regarding excavation operations and estimated soil and ground water properties. Refer to SOP 11.0 - Soil and/or Rock Logging.

Comments on the test pit log are extremely important. Some important aspects of the excavation operation that will be recorded include:

- The organic content of the soil and the depth of topsoil and roots;
- The presence of large boulders or buried trees; and
- The presence of man made objects.

Field personnel will make specific arrangements for scanning and sending completed test pit logs to the Project Manager, or someone designated by the Project Manager. Field personnel will retain one copy of the test pit log in the field for reference throughout the job.

C12.3.2 Field Test Pit Sample Log

The following information will be completed at the top of the field test pit sample log:

- project number;
- test pit number;
- client name (Atlantic Richfield);
- test pit location (study area);
- date;
- the name of the contractor performing the excavation;
- the length, width, and total depth of the test pit; and
- the name of person conducting the sample logging and the name of the responsible geologist or engineer.

The field test pit sample log will include the sample time, sample depth, sample type (grab or composite), the moisture level (dry, moist, or saturated), sample volume, and a description of the soil or materials in the sample (color, consistency or density, texture, structure, shape and surface condition of grains, odor, etc.).

ATTACHMENTS

- Field Test Pit Sample Log
- Field Test Pit Log

FIELD TEST PIT SAMPLE LOG
Levithan Mine Site
Alpine County, California

Project Number:	Client:	Date:
Test Pit Depth:	Test Pit Location:	Contractor:
Depth to Groundwater:	Test Pit Length:	Test Pit Width:
Responsible Geologist or Engineer:	Sampler:	Surface Elevation:
		Sampling Method:

Sample Details						**Soil / Materials Description**
Time	Depth (ft)	Sample ID	Type (grab or composite)	Moisture Level	Volume and Sample Container	(Color, consistency or density, texture, structure, shape and surface condition or grains, odor, etc.)

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FIELD TEST PIT LOG
Leviathan Mine Site
Alpine County, California

Project Number:	Test Pit Number:	Start Date:
Project:	Test Pit Location:	Finish Date:
Client:	Total Depth of Test Pit:	Start Time:
Survey Datum:	Depth to Groundwater:	Finish Time:
Excavator Type:	Ground Elevation:	Backfill Date:

Depth (ft)	Elevation (ft)	Sample ID	Soil Description
0			
0.5			
1			
1.5			
2			
2.5			
3			
3.5			
4			
4.5			
5			
5.5			
6			

Depth (ft)	Elevation (ft)	Sample #	Test Pit Sketch
0			
0.5			
1			
1.5			
2			
2.5			
3			
3.5			
4			
4.5			
5			
5.5			
6			

AMEC Geomatrix

C13.0 – DRILLING

Purpose and Scope: The purpose of this document is to describe procedures for drilling soil borings. It describes the required equipment and forms, the set-up procedures, drilling procedures, various types of drilling technologies, and borehole abandonment procedures.

Equipment:
Drill rig, drilling tools, and support truck with clean water storage tanks;
Steam cleaner;
Grout pump and tremie pipe;
Portland cement, Types I through V;
Powdered bentonite;
Plastic mheeting;
Dust meters
Miscellaneous tools; and
Safety equipment.

Documentation:
Daily Field Record;
Soil Boring Log;
Maps/plot plan; and
Camera.

This Standard Operating Procedure (SOP) describes setup procedures that will be performed by the field geologist or engineer while observing the drilling activities performed by others. This SOP does not include procedures for operating the drilling equipment. It is expected that the drilling operations will be subcontracted to a third party that is appropriately qualified and specializes in such investigations.

This SOP is to be used in conjunction with the Sampling and Analysis Plan (SAP) and future Focused Remedial Investigation (FRI) work plans. In addition to the SAP, the following SOPs should be consulted:

- SOP 1.0 – General Preparation and Mobilization Requirements
- SOP 2.0 – Basic Health and Safety for Field Operations
- SOP 3.0 – Field Documentation and Sample Handling
- SOP 4.0 – Sample Collection Techniques and Data Collection Strategies
- SOP 7.0 – Equipment Decontamination
- SOP 9.0 – Investigation Derived Waste Disposal

- SOP 11.0 – Soil and/or Rock Logging
- SOP 18.0 – Cone Penetrometer Test
- SOP 24.0 – Dust Monitoring

Also refer to the Leviathan Mine Site Health, Safety, Security and Environmental (HSSE) Program Document by ENSR dated May 27, 2008, the Task Specific Health and Safety Plan by AMEC Geomatrix dated June 2009, and the Job Safety Analysis for the planned scope of work.

All drilling activities will be subcontracted to a third party that has a current California drilling license. All drilling activities must be conducted under the oversight of a California licensed Professional Engineer or Professional Geologist.

C13.1 PRE-DRILLING ACTIVITIES

The following activities must be performed prior to the start of any drilling activities:

- Provide subcontractors with the applicable scope and necessary access information.
- Prepare schedules and coordinate with the staff, client, and regulatory agencies.
- Obtain an approved British Petroleum (BP) ground disturbance permit and all appropriate permits according to Federal, State, and local regulations.
- Confirm the drilling locations with the Project Manager and mark the locations with white spray paint. Additional markings with flags, wooden stakes, or other methods may be used to ensure that the locations can be easily found at the time of drilling.
- While marking the drilling locations, perform a preliminary review of potential overhead or underground utilities and hazards that may interfere with the drilling program.
- Obtaining proper clearance for potential above- and below-ground hazards. This may include some or all of the following:
    - reviewing As-Built Utility diagrams;
    - notifying Underground Services Alert,
    - subcontracting to a utility clearance specialist; and

- o physically verifying that utilities do not exist by hand digging or using an "air knife" to vacuum out surface sediments.

- If relocation is necessary due to the presence of a utility line, then new location must be at least 2 feet away from the outermost edge of the obstruction. Confirm any relocated borings with the Project Manager.

- Verify that equipment has been decontaminated and is in good working order prior to its arrival onsite.

- Unexploded ordnances (UXO) may exist within buried sections of tunnels or other unknown areas at the site. If any suspected UXO are encountered, the area must be marked as a zone of exclusion and the Project Manager must be notified. No work shall be performed within the study area if a UXO is suspected.

C13.2 DRILLING PROCEDURES

The following activities must be performed on the day of drilling:

- Perform a Health and Safety tailgate meeting with all personnel performing the drilling activities. Secure the work zone with traffic cones and barricade tape. Verify that the appropriate Personal Protective Equipment (PPE) is worn within the work zone. Set up dust monitoring devices in accordance with SOP 24.0 – Dust Monitoring.

- Decontaminate all down-hole drilling and sampling tools. Set up a decontamination station for sampling equipment.

- Set up a soil logging and note taking area.

- If the location is near utilities (all utilities at the site are near the Pit, Ponds, and Aspen Seep Bioreactor), then an air knife or hand digging equipment will be used to excavate the first 6.5 feet of material. Observe for potential backfill material that might accompany a buried utility line. In some cases, utility lines can be buried at depths greater than 6.5 feet deep. If such a case is suspected, continue excavating to the appropriate depth before drilling.

- Perform drilling and sampling activities. Drilling methods are described in Section C13.3 of this SOP. Refer to SOP 14.0 – Soil Sampling for procedures on how to collect soil samples.

- Perform the appropriate air monitoring for health and safety during drilling. This may include the use of a photoionization detector (PID), flame ionization detector (FID), or personal air monitoring devices.

- Document the drilling activities. SOP 3.0 – Field Documentation and Sample Handling, presents field documentation and sample handling procedures and SOP 11.0 – Soil and/or Rock Logging, presents procedures for logging soil and or rock and completing a boring log. Soil cores will be classified and stored. Note any drill rig chatter, or a change in down-hole drilling rate on the boring log.

- Once all drilling activities are completed at a location, the boring may be surveyed with borehole geophysical equipment, converted into a monitoring well or piezometer, or abandoned. Refer to SOP 15.0 – Borehole Geophysical Surveys for procedures on conducting a borehole geophysical survey. Refer to SOP 16.0 – Installation and Construction of Groundwater Monitoring Wells and Piezometers for procedures on how to install monitoring wells and piezometers. Refer to Section C13.4 of this SOP for procedures on how to abandon a borehole.

- Decontaminate all equipment prior to moving to the next boring location. Properly containerize, label, and document the location of all waste such as soil cuttings and decontamination water. Refer to SOP 9.0 – Investigation Derived Waste Disposal for procedures on how to dispose of soil, water, and waste.

C13.3 TYPES OF DRILLING METHODS

This section provides a brief description of the drilling methods that may be used at the site, including dual tube percussion and casing hammer, hollow-stem auger, rotary, direct push, and sonic. The method actually used will depend on the use and anticipated depth of the boring, and the material anticipated to be encountered.

C13.3.1 Dual Tube Percussion and Casing Hammer Methods

The dual tube percussion and air rotary casing hammer methods are used in cases where boreholes penetrate unconsolidated material containing intervals of cobbles or boulders.

Where dual tube percussion methods are specified, ten-foot-long dual flush-threaded casing sections fitted with O-rings will be used. The outer diameter is approximately 10-inches, the inner diameter is approximately 9-inches. Compressed air is used to circulate drill cuttings up the inner tube. Water-level measurements and drive samples can be collected from within the inner tube.

Where casing hammer methods are specified, ten-foot-long flush threaded drive casing sections fitted with hollow drill rod will be used. The outer diameter of the drive casing is approximately 10-inches. Compressed air is forced down the drill stem and out the drill bit to circulate drill cuttings up the annulus. Drill cuttings will be collected at least every five feet and stored in plastic bags. Water level measurements may be collected with the drill rods in place;

however, depth discrete “drive samples” can be collected only after the drill bit and rod have been removed from the borehole. A boring log based upon drive samples and observed cuttings must be prepared.

C13.3.2 Hollow-stem Auger Method

The hollow-stem auger method is used in cases where shallow boreholes will penetrate unconsolidated sediment.

Where hollow-stem auger drilling methods are specified, hollow-stem augers, with lock bolt jointed 5-foot sections, and drill rod, plug, and bit assembly will be used. The auger diameter will be selected based upon auger availability, drilling rig capacity, anticipated boring depth, sampler type, and intended boring use.

Drilling fluids may be used with hollow-stem augers only in cases where flowing sands require maintenance of a positive hydraulic potential between the inside and outside of the augers. In such cases, potable water will be pumped directly to the inside of the augers. If the drill rod assembly within the auger should become bound by flowing sands, potable water will be pumped to the top of the drill rod assembly and the assembly will be raised and lowered through the augers until the assembly becomes unbound. The source, time, duration of use,rate of flow of drilling water, as well as justification for water use, will be recorded on the boring log.

C13.3.3 Rotary Drilling Methods

Rotary drilling methods using drilling fluids other than air are used in cases where deep penetrative work is to be conducted in unconsolidated sediments or shallow penetrative work is to be conducted in soft rock and other deposits containing boulders.

Where rotary drilling methods are specified, a drill pipe fitted with a roller, drag bit, or drive shoe will be used. The type and diameter of the bit or shoe will be specified based upon availability, formation characteristics, drilling rig capacity, anticipated boring depth, sampler type, and intended boring use.

Temporary surface casing may be installed to prevent migration of ground water through the borehole. Sealing of the surface casing will be specified based upon site geology and aquifer characteristics.

Potable water mixed with bentonite may be used as a drilling fluid. In such cases, a portable, steel, two-stage drilling mud pit with steel gate will be used. The mud pit base will be fitted with a rubber, bentonite, or cloth gasket to prevent circulation loss at the ground surface. Make-up drilling water will be added directly to the mud pit. Settled fines will be removed periodically from the first stage of the pit. The rate and volume of necessary drilling water make-up will be recorded on the boring log.

C13.3.4 Direct Push Method

The direct push methodis used for shallow penetrative work in unconsolidated sediments where it is beneficial to minimize the volume of cuttings. Continuous core, discrete soil drive samples, soil vapor or groundwater samples can be collected with this method. Only small diameter monitoring wells or piezometers can be installed with the direct push method.

The push rig advances steel casing hydraulically to reach the desired termination depth. Samples are collected as the drilling tool advances. Cone penetrometer testing (CPT) is a type of direct push method that is used to estimate soil stratigraphy, density, strength and hydrogeologic information by measuring sleeve friction, cone bearing and pore water pressure. The tool can be modified to measure soil resistivity or detect the presence and concentration of aromatic hydrocarbons.

Hydropunch™ tools have an inlet screen that can be exposed at a desired depth to sample groundwater in direct push borings. Refer to SOP 18.0 – CPT for procedures on using CPT, and refer to SOP 17.0 – Groundwater Sampling for procedures on Hydropunch™ sampling.

C13.3.5 Sonic Drilling (Sonic Coring)

The sonic method of drilling is used where it is beneficial to collect continuous cores; use no air, mud, water, or other medium for penetration; drill through most types of formation; drill at any angle from horizontal to vertical; and yield no cuttings (other than core) in the drilling process. The sonic drill head is a hydraulically-activated unit that imparts high frequency sinusoidal wave vibrations into a drill string to effectuate a cutting action at the bit face. The resultant cutting action forces a circular continuous core of the formation up into the drill string. Due to the high forces developed by the resonant head and the external flush nature of the specialized drill string, excess formation material generated by the cutting face of the bit is forced into the borehole wall thus resulting in the generation of no cuttings in the drilling process.

C13.4 BOREHOLE ABANDONMENT

All soil borings will be permanently sealed to prevent vertical migration of contaminants. Soil borings shall be destroyed by backfilling, from bottom to the surface, with Holeplug™, Enviroplug™, Volclay™, or a cement-bentonite grout slurry (cement grout), and in accordance with appropriate Federal, State, and local regulations. Boreholes that extend below the water table will be backfilled by tremie method. For boreholes that do not penetrate the water table the grout material may be poured from the surface.

Holeplug™ and Enviroplug™ bentonite do not require mixing but are poured into the borehole dry and charged with clean water.

Volclay™ and cement-bentonite grout (herein termed cement grout) require mixing with clean, potable water. The cement-bentonite mix should not contain more than 5 percent bentonite.

Approximately 24 hours after initial grouting, the borehole shall be checked for settlement. If a settlement depression has formed, the depression shall be filled with grout and checked again 24 hours later. This process shall be repeated until grout remains at the ground surface.

C14.0 – SOIL SAMPLING

Purpose and Scope: The purpose of this document is to provide procedures for collecting soil samples. It includes a discussion of general procedures, various sampler devices, surface soil sampling, bulk soil sampling, and soil sample compositing.

Equipment:
Stainless steel spatulas;
Stainless steel spades;
Stainless steel hand auger buckets and hand auger accessories;
Power auger/drilling rig;
Split spoon samplers;
Continuous core samplers;
Shelby tubes;
Teflon sheets;
Plastic sheeting;
Stainless steel sampling rings;
Plastic ring caps;
Stainless steel measuring cup;
Stainless steel trowel;
Hand bucket auger;
Driver sampler;
Cleaning and decontamination equipment;
Sample labels;
Ice chest;
"Blue" or double bagged “wet” ice;
Sealable plastic storage bags;
Miscellaneous tools; and
Safety equipment.

Documentation:
Daily Field Record (DFR);
Soil Boring Log;
Atlantic Richfield Chain-of-Custody form (COC) or laboratory supplied equivalent;
Maps/plot plan; and
Camera.

This Standard Operating Procedure (SOP) is to be used in conjunction with the Sampling and Analysis Plan (SAP) and future Focused Remedial Investigation (FRI) work plans. In addition to the SAP, the following SOPs should be consulted:

- SOP 1.0 – General Preparation and Mobilization Requirements
- SOP 2.0 – Basic Health and Safety for Field Operations

- SOP 3.0 – Field Documentation and Sample Handling
- SOP 4.0– Sample Collection Techniques and Data Collection Strategies
- SOP 7.0 – Equipment Decontamination
- SOP 11.0 – Soil and/or Rock Logging
- SOP 12.0 – Test Pit Excavation
- SOP 13.0 – Drilling
- SOP 18.0 – Cone Penetrometer Test

Also refer to the Leviathan Mine Site Health, Safety, Security and Environmental (HSSE) Program Document by ENSR dated May 27, 2008, the Task Specific Health and Safety Plan by AMEC Geomatrix dated June 2009, and the Job Safety Analysis for the planned scope of work.

C14.1 GENERAL PROCEDURES

All soil sampling activities must be performed by appropriately trained field staff under the guidance of a California licensed Professional Engineer or Professional Geologist.

The following is a list of general procedures that should be adhered to during soil sampling:

- Record relevant data on a Daily Field Record prior to sampling (SOP 3.0 – Field Documentation and Sampling Handling);
- Decontaminate all sampling equipment prior to sampling (SOP 7.0 – Equipment Decontamination);
- Clear surface vegetation, rocks, and other material not designated for sampling from the sampling point;
- Reach the desired sampling depth by excavating a test pit (SOP 12.0 – Test Pit Excavation) or by drilling a soil boring (SOP 13.0 - Drilling);
- Collect the soil sample and transfer it to the appropriate container;
- Record the soil sample lithology (SOP 11.0 – Soil and/or Rock Logging);
- Affix an appropriate label to the sample container, being sure to provide required information. Place the properly labeled sample container in an appropriate carrying

container and maintain the sample at the required temperature. Add information pertaining to the sample to the COC, Daily Field Record, and Field Record of Soil Sampling forms. Package and ship samples at end of the day to the appropriate laboratory following the sample handling procedures described in SOP 3.0 – Field Documentation and Sample Handling; and

- Either discard or decontaminate all items which contact the sample such as trowel, split-spoon sampler, and gloves before proceeding to the next sampling location.

Specific procedures for the various methods that may be used to collect soil samples are described in the following sections.

C14.2 SAMPLER DEVICES AND METHODS

Several drilling methods may be used to reach desired depths for soil sampling. When the desired sampling depth has been reached and the borehole has been prepared, the following sampler devices and methods may be used to collect samples:

- Penetration Test and Split-Barrel Sampler (split-spoon);
- Thin Wall Sampler;
- Continuous Sampling System;
- Collection of Cuttings; and
- Shelby Tube.

C14.2.1 Penetration Test and Split-Barrel Sampling

Penetration test and split-barrel sampling are methods used to collect representative disturbed soil samples. Samples collected by these methods will be used for description and identification, chemical analysis, and in some cases physical analysis. A split-barrel sampler consists of a section of pipe that splits into two pieces along its axis. A driving shoe and waste barrel screwed to the ends hold the split section together during driving. Aids for sample retention may also be incorporated into the split-barrel sampler. These include catchers, spring or gravity traps (in the lower end), and check valves (in the top end). The standard sampler has an outside diameter of 2-inches and an inside diameter of 1-3/8 inches.

The penetration test samplers have been used to develop an empirical relationship between driving resistance and the relative density of soil. The procedure for determining and interpreting penetration resistance or relative density is the Standard Penetration Test (SPT), which is described as follows:

- After the boring has been advanced to the desired sampling depth and extracted drill cuttings have been suitably removed, a split-barrel sampler attached to drill rods is lowered to the bottom of the cleaned-out borehole.

- Once the sampler is on the bottom of the borehole, three 6-inch increments are marked on the drill rods above a convenient fixed datum.

- The sampler is driven by a 140-pound hammer free falling a distance of 30-inches onto a collar or drive head attached to the top of the drill rods. The sampler is driven a total of 18-inches into the undisturbed soil, and the number of blows required to advance each 6-inch increment is recorded.

- The standard penetration test should be terminated if one of the following occurs:

    - A total of 50 blows has been applied during any one of the three 6-inch increments;

    - A total of 100 blows has been applied;

    - There is no observed advance of the sampler during the application of 10 successive blows of the hammer.

- After the total penetration of the sampler has been achieved, the sampler is retrieved to the surface and opened.

The sample is logged and removed from the sampler, the sampler is decontaminated and then re-assembled. If the samples are to be retained for future reference, they will be placed in sealable plastic bags and labeled as to depth and location according to standard procedures. Typically, samples are taken at each lithologic change and at intervals not greater than 5 feet (unless otherwise stipulated by the field engineer or geologist).

Where relatively undisturbed samples are to be collected, soil samples are obtained with a "California" or similar split-barrel (split-spoon) sampler fitted with dry decontaminated 2.5-inch diameter, 3 or 4-inch long stainless steel rings. Procedures for sampling with the "California" sampler are similar to procedures described for the standard penetration test. Soil samples will be collected by driving the split-barrel sampler 18-inches (or until refusal) into undisturbed soil at the bottom of the borehole. The drill rig is equipped with a 140-pound hammer to drive the sampler. Hammer blows required to drive the sampler in 6-inch increments will be recorded on the Boring Log.

Upon retrieval from the borehole, the sampler will be dismantled, and the sample tubes removed and placed on clean plastic. These tubes will be separated with a clean steel knife,

then logged by the field geologist. After logging, the exposed ends of the rings will be covered with 2-mil Teflon sheets, and plastic end caps. Sample labels will be affixed to the end caps and will contain the following information: boring number; sample location; sample number; sample depth; date of sampling; time of sampling; sample collector's name; soil type; and name of client or facility owner. Depending on the length of each tube, three to six tubes will be retained from each sample interval.

C14.2.2 Thin Walled Sampler

A thin wall sampler is a one-piece metal tube, of thing gauge, which is forcefully driven into the soil to collect an undisturbed sample. The tube is the sample container and cannot be reused. Thin walled samplers cannot be used in extremely hard soil. Thin wall sampling tube methods are used where undisturbed samples of fine-grained materials are to be obtained for chemical analysis, saturated vertical hydraulic conductivity testing or other geotechnical analysis. Other larger diameter samples (3- to 6-inches in diameter) are helpful in sampling gravel deposits and retrieving samples of sufficient volume to perform compaction tests. The size of the sampler should be documented on all penetration records.

The thin wall sampling method is conducted by attaching a sampling tube to the nose-end of the “California” sampler and pushing the tube, in one continuous motion, into the material to be sampled. Once the tube is retrieved, slough material will be removed from the tube and the actual sample length will be measured. If the sample is to be retained for future reference or analysis, it will be trimmed, logged, capped, sealed, and labeled.

C14.2.3 Continuous Core Sampling System Methods

Continuous core sampling system methods may be specified where continuous soil cores are to be recovered by hollow-stem auger, direct push, or sonic drilling methods. The continuous sampling system utilizes a core barrel, which recovers a soil core from the interval drilled. The core barrel is recovered after each interval is drilled.

Soil samples may be cut directly from continuous cores of soil cores or transferred into laboratory supplied containers. In some cases, the entire length of the soil cores will be placed in lined core boxes so that the logged conditions can be confirmed by a geologist tasked with the responsibility of review.

C14.2.4 Cuttings Collection Methods

Cuttings brought to the surface during drilling activities may be collected as grab samples for laboratory or physical analysis. Cuttings will be collected at a minimum of every five feet and at changes in lithology. Samples will be placed in a container marked with a unique designation that includes the borehole identification and the sample depth..

C14.3 SURFACE SOIL SAMPLING

Methods to be used for collection of surface soil samples include taking a grab sample with either a scoop or trowel, hand bucket auger, or the hand drive sample method. The scoop or trowel samplers are used to collect shallow soil samples, up to 6-inches in depth. The sampler will transfer the sample into a laboratory-supplied glass jar or pre-cleaned stainless steel tube and seal the end(s). In the case of the hand drive-sampler method, samples will be collected directly into stainless steel tubes. If collecting a sample in a stainless steel tube, the sampler will seal the ends with a sheet of Teflon and a cap on both ends of the tube. The sampler will document the soil type on a boring log and label the sample container with sample number, depth, date, time, and study area.

C14.4 BULK SOIL SAMPLING

Bulk soil samples for some physical and mineralogical tests will be collected from test pits and soil borings. Samples will be collected from test pits less than 5-feet deep from the wall of the pit with a stainless steel trowel. In test pits deeper than 5-feet, samples will be collected out of the backhoe bucket. Bulk samples from soil borings will be collected from the cuttings produced during drilling or retrieved from a sampler.

Samples of sand, silt, and clay-size material will be collected into gallon-sized plastic bags or in sample sleeves. Coarse-grained gravels will be collected into 5-gallon buckets. In general, the size of the bulk sample will be at least 10 times greater than the size of the largest class or material. Samples will be labeled with the sample number, date, time, location, depth, and test pit or borehole.

C14.5 SOIL SAMPLE COMPOSITING

Soil sample compositing is used to combine soil from two or more samples so that the composite that is submitted for analysis is representative of the entire mass of soil sampled. Soil samples can be composited in the laboratory or in the field.

Individual samples to be composited will be identified on their labels by their own sample identification and by the sample identification for the composite sample. Samples to be composited also will be identified clearly on the COC and on the Field Record of Soil Sampling by both identifications. In the case of bulk samples, mineralogical samples, or any other soil samples to be composited for archiving or non-chemical analysis, the procedure is described below. In general, compositing consists of the following steps:

- Take an approximately equal in weight sub-sample from each sample to be composited;
- Combine and homogenize the sub-samples; and
- Take a sample of homogenized soil for analysis.

Grab samples are disturbed samples obtained by shovel, hand trowel, bucket auger, or similar means. A grab sample can be sub-sampled by taking a smaller grab sample if the material is relatively homogeneous or if the grab sub-sample will contain the various types of materials in approximately the proportions present the larger sample. Otherwise, the material should be homogenized and subdivided as described below.

Split-spoon and similar samples may be more easily subdivided by splitting the sample lengthwise with a spatula into halves or smaller fractions. Another approach is to cut a v-shaped channel from the side of the sample and use the material from the channel for compositing.

Sub-samples should be the same volume. A measuring cup is satisfactory for determining size. The size of each sub-sample should be chosen in advance on the basis of the final sample volume and the amount of material available. Make the size of the sub-sample after quartering or splitting larger than the desired volume, then mix the sub-sample thoroughly in the measuring cup with a spatula and discard the excess. Combine the sub-samples on a tray covered with aluminum foil or plastic sheeting. Chop cohesive materials into pieces considerably smaller than the final sample size with a trowel or spatula. Mix the composite sample until it appears homogeneous. If the composite sample is too large, subdivide it as follows: Pile the soil in a cone. Flatten the cone to a uniform thickness. Draw two lines across the pile, dividing it into quarters. Discard two opposite quarters re-mix the remaining quarters, and repeat the process until the sample is slightly larger than the sample container. Fill the container and discard the excess. Label the container and document the sample as described in SOP 3.0 – Field Documentation and Sample Handling. The sampler must identify the

sample as a composite and to identify the number and locations of samples that were composited.

C15.0 – BOREHOLE GEOPHYSICAL SURVEYS

Purpose and Scope: This document describes procedures for conducting a borehole geophysical survey. It discusses the set-up and various borehole geophysical methods.

Equipment:
Electrical resistance probe ("single-point" resistance);
Standard resistivity probe (both long and short normal);
Natural gamma tool;
Spontaneous potential probe (SP);
Caliper tool (three-arm);
Mechanical wench (if applicable);
Video camera;
Geophysical logging unit;
Miscellaneous tools; and
Safety equipment.

Documentation:
Daily Field Record (DFR);
Soil Boring Log;
Maps/plot plan; and
Camera.

Borehole geophysical measurements are obtained from geophysical logging tools suspended in uncased boreholes or cased wells. These tools measure a variety of physical properties of geologic materials penetrated by the borehole, including:

- Formation electrical resistivity of conductivity;
- Formation electrochemical contrasts between the borehole and *in situ* fluids;
- Formation of natural gamma ray emissions; and
- Borehole diameter.

Measurements are made as the tool is pulled up the borehole at a constant rate on a multi-conductor armored cable (or wireline) using a power supply at the surface. Measurement depth is controlled by passing the cable over a calibrated sheave. Downhole data are transmitted via the cable to a computer at the surface where the data is stored and processed. Geophysical logs are paper copy records of borehole measurements plotted with amplitude on the horizontal axis and depth on the vertical axis.

This Standard Operating Procedure (SOP) describes setup procedures that will be performed by the field geologist or engineer that will observe the surface geophysical survey. This SOP does not include procedures for conducting a surface geophysical survey. It is expected that the surface geophysical survey will be subcontracted to a third party that is appropriately qualified and specializes in such investigations. In addition to the setup procedures, this SOP includes a discussion of various surface geophysical technologies that may be used during the course of the RI to provide background information for the observing field personnel.

This Standard Operating Procedure (SOP) is to be used in conjunction with the Sampling and Analysis Plan (SAP) and future Focused Remedial Investigation (FRI) work plans. In addition to the SAP, the following SOPs should be consulted:

- SOP 1.0 – General Preparation and Mobilization Requirements
- SOP 2.0 – Basic Health and Safety for Field Operations
- SOP 3.0 – Field Documentation and Sample Handling
- SOP 4.0 – Sample Collection Techniques and Data Collection Strategies
- SOP 7.0 – Equipment Decontamination

Also refer to the Leviathan Mine Site Health, Safety, Security and Environmental (HSSE) Program Document by ENSR dated May 27, 2008, the Task Specific Health and Safety Plan by AMEC Geomatrix dated June 2009, and the Job Safety Analysis for the planned scope of work.

C15.1 SET-UP

The following activities must be performed prior to the start of any borehole geophysical survey activities:

- Provide subcontractors with the applicable scope and necessary access information.
- Prepare schedules and coordinate with staff, client, and regulatory agencies if appropriate.

Borehole geophysical logging will be performed by a qualified subcontractor. A Professional Geologist shall oversee all geophysical logging activities and perform the following steps prior to logging:

- Obtain and evaluate available logs from wells in close proximity to the test boring;
- Select appropriate probes or tools required to provide meaningful data; and
- Ensure that equipment and/or tool calibrations are performed in accordance with the manufacturer recommendations prior to logging. A copy of the calibration log will be obtained from the subcontractor and kept with the borehole geophysical log; and
- Ensure that all down hole equipment has been decontaminated and is in good working order prior to its use onsite.

The field procedures used for borehole geophysical surveys will be controlled by the specific type of survey equipment used. Boreholes will be logged while lowering and raising the wire line probes to evaluate instrument response and data reproducibility.

Document all the borehole geophysical survey activities on a DFR. Include information such as start time, stop time, logging speed, subcontractor's name and company, total depth of survey, and method used.

C15.2 METHODS

Physical properties that may be measured in soil borings onsite include natural radiation, electrical conductivity, electrical resistance, the electrical potential of a fixed surface electrode (or spontaneous potential), temperature changes, and borehole size. Typical applications include stratigraphic correlation, identification of lithology, formation thicknesses, definition of aquifer boundaries, limited water quality determination, and identification of borehole temperature gradients. The following subsections provide brief descriptions of possible methods that may be used.

C15.2.1 Natural Gamma Log (NGL)

NGL tools detect gamma radiation emitted by radionuclides in the formation. The most common natural gamma ray emitting radionuclides are Potassium (40K) and Uranium and Thorium-series daughter products (214Pb and 214Bi). NGL are commonly used to characterize stratigraphy and make correlations between wells. They can also be used to infer quantitative estimates of effective porosity and hydraulic conductivity of the materials penetrated by the borehole. This log is widely used because it can be run in air or fluid-filled conditions, drill pipe, and cased or uncased holes. NGLs record gamma radiation emitted from the formation in counts per second (cps).

C15.2.2 Electromagnetic Induction Log (IL)

Induction tools operate on the principle of electromagnetic induction. An electrical current is induced in the formation by generating a radio frequency (20–40 kHz), alternating current in the transmitting coil of the IL tool. The induced current is proportional to the formation electrical conductivity and is measured by a receiver coil spaced 1.5 to 2.0 ft from the transmitter. IL tools can be run in air-filled or fluid-filled conditions, and uncased boreholes or wells that are cased with non-electrically conductive material. ILs are ideal for characterizing stratigraphy and making correlations between wells. They are also useful for inferring formation porosity. The IL is recorded in electrical conductivity units of millisiemens/meter (mS/m).

C15.2.3 Galvanic Resistivity (Electric Log)

Electric Log tools measure apparent formation resistivity directly. An electrical current is passed between a current source electrode on the logging tool and a current return electrode at the surface. Electrical potential differences are measured between electrodes on the surface and at depth. The resulting ratios are converted to apparent resistivities, using algorithms based upon the electrode array geometries and potential theory. Because these electrical tools are galvanically coupled directly to the earth with their electrodes, the techniques are called galvanic resistivity methods. Galvanic resistivity logs are ideal for characterizing stratigraphy and making correlations between wells. They are also useful for inferring formation porosity. Galvanic resistivities are recorded in units of ohm-meter (ohm-m).

C15.2.4 Spontaneous Potential Log (SP)

SP is an electrochemical phenomena resulting from salinity differences between the mud filtrate and *in situ* waters and the passage of saline waters through clays. High clay mineral content zones act as cation selective membranes, allowing cations to pass but repelling anions. This selectivity will result in a cation deficiency on the more saline side of the membrane and a cation surplus on the low salinity side. If the *in situ* waters are more saline than the mud filtrate, the electrical potential (with respect to some distant reference point) opposite clay zones will be positive with respect to that opposite sands and gravels. If the mud filtrate is more saline than the *in situ* waters, the opposite will occur. The SP curve is a relative measurement and is presented in units of millivolts (mv).

C15.2.5 Borehole Video Log (BVL)

BVL cameras are used to view uncased boreholes and cased wells. Best results are obtained in air-filled or clear fluid-filled conditions. Both black and white and color cameras are used to evaluate fractured bedrock, inspect borehole “washouts,” and inspect casing conditions. It is

often important to allow sufficient time for the BVL camera to equilibrate with downhole temperature and humidity conditions to ensure that the camera lens does not fog up.

C15.2.7 Three-Arm Caliper Log

Three-arm calipers are used to measure borehole diameter as a function of depth. Caliper Logs consist of three to four arm sensors. Caliper logs are usually run first when conducting uncased borehole logging operations. In order to assess the integrity of the borehole prior to using more expensive tools that may be lost in a rough borehole.

C15.2.7 Additional Geophysical Logs

The suite of logs presented above is not all inclusive of downhole geophysical tools that may be used at the site. The intent is to provide a geophysical characterization that compliments the geologic log and addresses questions and ambiguities in the geologic interpretation. The use of additional or alternative geophysical logging tools may be required to adequately characterize the site.

C16.0 – INSTALLATION AND CONSTRUCTION OF GROUNDWATER MONITORING WELLS AND PIEZOMETERS

Purpose and Scope: The purpose of this document is to describe procedures for constructing, installing, and developing groundwater monitoring wells, extraction wells, recharge wells, and piezometers. This document includes a discussion on well design, well installation, well surface completion, well development, and well construction summary diagrams..

Equipment: Drilling rig, drilling tools, and support truck with water tanks;
Steam cleaner;
Grout plant and tremie pipe;
Portland cement, Types I through V;
Powdered bentonite;
Well casing and screen, cap and bottom plug (screen slot size based upon target geologic formation);
Stainless steel centralizers;
Bentonite pellets;
Washed, graded sand (grain size based on formation and screen slot size utilized);
Protective well box or monument and padlock;
Concrete mix;
Plastic sheeting; and
Safety Equipment.

Documentation: Daily Field Record (DFR);
Soil Boring Log;
Field Well Construction Summary (attached) which includes:
- Well Casing Installation
- Annular Materials Volume Calculations Worksheet
- Grouting Form
- Surface Completion Details for Wells

Well Sampling and/or Development Record (attached)
Maps/plot plan; and
Camera.

This Standard Operating Procedure (SOP) describes setup procedures that may be performed by the field geologist or engineer that will observe the well installation activities performed by others. This SOP does not include procedures for conducting a well installation. It is expected that the well installation activities will be subcontracted to a third party that is appropriately qualified and specializes in such investigations.

This SOP is to be used in conjunction with the Sampling and Analysis Plan (SAP) and future Focused Remedial Investigation (FRI) work plans. In addition to the SAP, the following SOPs should be consulted:

- SOP 1.0 – General Preparation and Mobilization Requirements
- SOP 2.0 – Basic Health and Safety for Field Operations
- SOP 3.0 – Field Documentation and Sample Handling
- SOP 6.0 – Field Measurements – Water
- SOP 7.0 – Equipment Decontamination

Also refer to the Leviathan Mine Site Health, Safety, Security and Environmental (HSSE) Program Document by ENSR dated May 27, 2008, the Task Specific Health and Safety Plan by AMEC Geomatrix dated June 2009, and the Job Safety Analysis for the planned scope of work.

C16.1 PREPARATION AND SET-UP

All necessary drilling/well permits and utility clearances shall be obtained prior to the start of drilling operations. A geologist experienced in design and construction of monitoring wells will be present to supervise the well construction and will be overseen by a California licensed Professional Geologist. Unless otherwise arranged, well construction supplies and equipment will be supplied by the drilling subcontractor. Prior to drilling and well construction, all drilling equipment, tools, and well materials (unless new) to be used in well construction will be cleaned thoroughly with a portable steam cleaning system supplied by the drilling subcontractor. Between well installations, drilling equipment and tools will be cleaned at the designated contaminant reduction zone.

C16.2 MONITORING WELL DESIGN

During advancement of the soil boring, the geologist will prepare a boring log and keep a time log of significant events during each working day. Logs will indicate field classification of soils, sampling depths, first encountered and static groundwater levels, progress of drilling, final completion depth, and the nature and resolution of any problems encountered. Based on data gathered from the borehole, the desired purpose of the well, and previously collected information from other boreholes and monitoring wells, the geologist and Project Manager will determine the well specifications. Well specifications include the following:

- Total depth of well;
- Screened interval placement;
- Screen slot size;
- Location of centralizers;
- Filter pack size;
- Filter pack interval;
- Thickness and placement of bentonite seal; and
- Grouting method.

Wells in unconsolidated material

Wells installed in unconsolidated material (e.g., gravels, sands, silts, clays) will typically be constructed of either 2 or 4-inch Schedule 40 PVC blank and screen. In the case of wells deeper than 150 feet, 2 or 4-inch Schedule 80 PVC will be used to minimize the potential for casing blistering when the grout cures. The diameter of the screen and casing will be a minimum of 4-inches less than the diameter of the borehole. Stainless steel centralizers will be placed at the top and bottom of the screen and every 40 feet along the blank casing. The bottom of each well will consist of a slip cap mounted with stainless steel screws to a flush-threaded end cap. Holes of 1/16-inch diameter will be drilled through both caps prior to installation to prevent water from sitting in the bottom of the well if the static water level drops below the bottom of the well. A locking cap will be used to secure the top of the well.

Wells in consolidated material

Procedures for installing wells within consolidated material (e.g., rock) will be presented in future FRI work plans.

C16.3 WELL INSTALLATION

This section describes the well installation procedures for unconsolidated material. Procedures for wells to be installed in consolidated material will be presented in the future FRI work plans.

Once the desired depth of the borehole has been reached, the borehole will be prepared for installation of the well casing. The well casing/screen assembly will be inserted into the borehole. The casing/screen assembly will be installed as follows:

- The well casing, including the bottom cap and screen, will be suspended in the borehole at the desired depth.

- The primary filter pack, consisting of washed, graded sand that is appropriate for the formation and slot size of the screen, will be poured from the surface or placed by tremie method to the bottom of the annulus between the well casing and the borehole. The filter pack will extend at least 2 feet above the top of the screen. The level of filter pack in the annulus will be verified by tag-line measurement during emplacement. The volume of sand will be compared to the calculated annular volume to verify proper placement of the filter pack.

- When the primary filter pack is installed to the desired depth, the screened interval will be surged to settle the sand around the well screen (preliminary development). During surging, the well casing will be secured at the surface to prevent settling of the casing. Surging will continue until the filter pack stops settling. Upon completion, sand will be added to bring the filter pack up to the desired depth.

- A bentonite seal at least three feet thick will be placed immediately above the primary filter pack. If bentonite is to be placed below standing water, a high-solids bentonite grout will be pumped by tremie method. The level of the top of the bentonite seal will be verified by tag-line measurement. If pellets are used, adequate time for hydration (at least 30 minutes) of the pellets will be allowed before grouting the remaining annulus.

- Boring cuttings will not be used as backfill. The borehole annulus will be grouted with a cement-bentonite grout mix, which will extend to within approximately 2 feet of the ground surface. The grout must be tremied if there is standing water above the bentonite seal.

- The top 2 feet will be filled with a concrete mix used to make the concrete pad and secure the protective well box or monument.

- The grout will then be allowed to settle. If significant settlement of grout occurs, additional grout will be added to the prescribed depth of approximately 2 feet below ground surface prior to the installation of the protective casing and the concrete pad.

C16.4 WELL SURFACE COMPLETION

For wells completed above ground surface, steel security pipe with a hinged, lockable cover will be installed in the grout to a depth of 1 to 2 feet and equipped with a padlock. For flush-mount wells a steel protector and cover with watertight seal will be installed in the concrete pad. The integrity of the well will be protected with a lockable sanitary sealing well cap with an expandable O-ring, which forms an airtight seal. All locks will be keyed alike.

For wells completed above ground surface, the drilling subcontractor will construct a concrete apron generally (3ft x 3ft x 0.5ft) around each well. Concrete aprons will be crowned to provide positive runoff away from the well. Concrete pads may be constructed within 3 days after wells have been installed. If necessary, steel guard posts 2-inches in diameter and filled with concrete will be installed around the pads. Posts will be five feet long and will have a stickup of 2.5 feet above ground surface and 2.5 feet below ground surface. For flush mounts, the space around the protective casing will be filled with concrete and rounded to provide positive runoff away from the well.

C16.6 WELL CONSTRUCTION SUMMARY DIAGRAMS

Upon completion of well construction and development, a standard Field Well Construction Summary and Well Casing Installation Form (Attached) will be completed. The following information will be included:

- Project name and number;
- Job location or study area;
- Well ID;
- Permit number (if applicable);
- Land-surface elevation and datum;
- Date of installation;
- Drilling method (i.e., hollow-stem auger, air hammer, air rotary, or mud-rotary);
- Drilling contractor;
- Drilling fluids (where applicable);
- Amount of fluids lost during drilling;
- Well construction details, such as: Type of well (i.e., flush-mount or stick-up); borehole diameter; well casing diameter, material, and amount; final well depth; depth and type of filter pack; depth of bentonite seal; and depth and type of grout mixture; and
- Well purpose (i.e., monitoring, production, or recovery).

C16.5 WELL DEVELOPMENT

Well development consists of preliminary and final development. Preliminary well development will be conducted after installation for the well screen, casing, and primary filter pack, but prior to installation of seals and grout. Additional filter pack will be added, as needed, after completion of preliminary well development to bring the filter pack up to the desired depth.

Final well development will begin no earlier than 24 hours after the grout has been placed. Typically, well development will be performed using one more of these methods: surging, over-pumping, or bailing. The method to be used will be selected based on specific hydrogeologic conditions at the site but will generally consist of a sequence of bailing, surging, bailing, and then pumping. Approximately ten casing volumes of water will be removed. Water exiting the well will be collected and properly disposed of as described in SOP 9.0 – Investigation Derived Waste Disposal. Well development will continue until the water is relatively free of sand, fines, and the turbidity is reduced. Generally, development will continue until turbidity values are less than 5 NTU. Measurements of pH, specific conductance, and temperature will also be collected every 5 minutes during pumping. When these parameters have stabilized, the well is considered developed and the water in the well is considered to be representative of the groundwater for that location. (See SOP 6.0-Field Measurements - Water).

Measurement of development parameters will be recorded on the Well Development Form (Attached) and will include the time of each measurement, approximate volume of water removed prior to each measurement, and the time intervals during which development is conducted.

- Well development method;
- Date of well development;
- Amount of water removed during development;
- Static depth to water;
- Pumping depth to water;
- Duration of pumping;
- Yield;

- Specific capacity; and

C16.7 EXTRACTION AND RECHARGE WELL CONSTRUCTION AND INSTALLATION

Recharge wells to be installed during remedial activities will be constructed according to the procedures outlined for Monitoring Well Installation and Construction with the following exceptions. Boreholes for recharge wells will be at least 16-inches in diameter and will be drilled by either casing hammer or tri-tube (similar to dual tube) methods. Well casing will be between 8- and 10-inches in diameter. Casing material, diameter and thickness, screen slot sizes, and filter pack design will be determined based on design criteria and on material encountered during drilling. In addition, extraction and recharge wells may have yield criteria that require specifications for well development that are designed specifically for the well.

C16.8 PIEZOMETER INSTALLATION

Piezometers installed during investigation or remedial activities will be constructed according to procedures outlined for Monitoring Well Installation and Construction, with the following exceptions:

- Boreholes for piezometers may be as small as 8-inches in diameter;
- well piezometer casing will generally be 2-inches in diameter; and
- Piezometer screen may be constructed of either PVC or stainless steel.

Exact specifications for each piezometer, including screen material, casing diameter, screen slot size and filter pack design will be based on material encountered during drilling.

ATTACHMENTS

- Field Well Construction Summary, includes:
  - Well Casing Installation
  - Annular Materials Volume Calculations Worksheet
  - Grouting Form
  - Surface Completion Details for Wells
- Well Sampling and/or Development Record

FIELD WELL CONSTRUCTION SUMMARY

Well ID: _____ **Project Name:** _____

Project/Task No.: _____ **Location:** _____

Geomatrix Personnel: _____

DRILLING SUMMARY

Drilling Contractor: _____ Driller: _____

Drilling Method: _____ Drill Rig: _____

Drilling Fluid: _____ Drill Bit(s): _____

BORING AND WELL CASING DEPTH MEASUREMENTS

Pilot Boring: Depth Interval BGS _____ Diameter _____ Depth Interval BGS _____ Diameter _____

Reamed Boring: Depth Interval BGS _____ Diameter _____ Depth Interval BGS _____ Diameter _____

Total Depth BGS of Well Casing: _____ Depth of Perforated Interval BGS: _____

Total Depth of Well Below TOC: _____ Depth of Perforated Interval Below TOC: _____

WELL DESIGN Geologic Log ☐ Geophysical Log ☐ Sieve Analysis ☐

Codes: B = Bentonite Seal C = Casing CC = Conductor Casing
CL = Centralizer EC = End Cap F = Filter G = Grout
N = Native Fill S = Screen TS = Transition Seal

Casing/Screen			Annular Materials		
Feet	– BGS	Code	Feet	– BGS	Code
	–			–	
	–			–	
	–			–	
	–			–	
	–			–	
	–			–	
	–			–	
	–			–	
	–			–	
	–			–	
	–			–	

Filter Material: _____

Seal (B/TS): _____

Grout: _____

Native Material:

Surface Finish:

Centralizers:

Other: _____

CONSTRUCTION TIME LOG

Task	Start Date	Start Time	Finish Date	Finish Time
Drilling				
Conductor				
Casing				
Geophys.				
Casing				
Filter				
Seal (B/TS)				
Grout				
Other				

Well Casing: _____
C1

C2

Well Screen: _____
S1

S2

Conductor CC1 _____
Casing: CC2

Project No. **Figure No.**

FIELD WELL CONSTRUCTION SUMMARY
WELL CASING INSTALLATION

Well ID: _____ Project/Task No.: _____

I. Section Measurements: (to 0.01 of an inch)

Well casing sections (A)

_____ _____ _____ _____ _____ _____ _____ _____

_____ _____ _____ _____ _____ _____ _____ _____

_____ _____ _____ _____ _____ _____ _____ _____

Total = _____ (1)

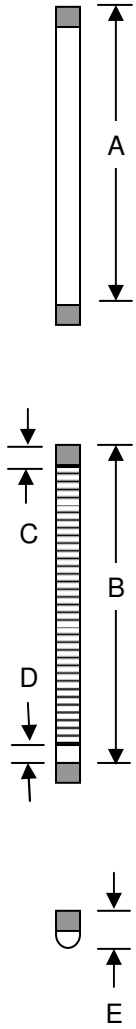
Well screen sections (B)

_____ _____ _____ _____ _____ Total = _____ (2)

Length from top of screen section to top perforation (C) = _____ (3)

Length from bottom of screen section to bottom perforation (D) = _____ (4)

Length of bottom endcap + tailpipe (measured inside of cap) (E) = _____ (5)



II. Total Measurements Referenced to GS: (to 0.01 of an inch)

Total length of well casing (1+2+5) = _____ (6)

Total length of perforated interval (2-3-4) = _____ (7)

Temporary height/depth of top of casing AGS (+) / BGS (–)

(1) Desired depth to top of screen interval _____ (8a) (1+3-8a) = _____ (9a)

or (2) Desired depth to bottom of screen interval _____ (8b) (1+3+7-8b) = _____ (9b)

Total depth of well (BGS) (to 0.10 of an inch) (6-9a or 6-9b) = _____ (10)

Depth of perforated interval (BGS) (to 0.10 of an inch) Bottom (10-5-4) = _____ (11)

Top (11-7) = _____

III. Surface Completion: (to 0.10 of an inch)

Top of casing adjustments: Casing removed (–) / added (+)

_____ _____ _____ _____ Total = _____ (12)

Final TOC: AGS (+) / BGS (–) (9a-12 or 9b-12) = _____ (13)

Total Depth of Well below TOC (to 0.10 of an inch) (6-12) = _____ (14)

Depth of Perforated Interval below (TOC) (to 0.10 of an inch) Bottom (14-5-4) = _____ (15)

Top (15-7) = _____

Note: All measurements of well casing and screen sections to be to the nearest 0.01 ft. All final measurements referenced to ground surface and top of casing are to be to the nearest 0.10 ft.

GS = ground surface AGS = above ground surface BGS = below ground surface TOC = top of casing

FIELD WELL CONSTRUCTION SUMMARY
ANNULAR MATERIALS VOLUME CALCULATIONS WORKSHEET

Project: _____ **Date:** _____

Location: _____ **Project/Task No:** _____

Well I.D.: _____

Filter Pack Volume Calculations (Filter Pack and Transition Seal)

Filter Pack/Granular Transition Seal Description (Brand and Gradation)	Bottom Depth (feet)	Top Depth (feet)	Total Length of Filter Pack Interval (feet)	Borehole Diameter (inches)	Casing Diameter (inches)	Lbs. of Sand per Linear Foot of Annulus	Total Volume of Filter Pack (cubic feet)	Calculated Number of 100 lb. Bags of Sand Required	Number of 100 lb. Bags of Sand Used

Annular Seal Volume Calculations (Bentonite Seal)

Bentonite Seal Description	Bottom Depth (feet)	Top Depth (feet)	Length of Bentonite Seal Interval (feet)	Borehole Diameter (inches)	Casing Diameter (inches)	Lbs. of Bentonite Chips/Pellets per Linear Foot of Annulus	Total Volume of Bentonite Seal (cubic feet)	Calculated Number of 50 lb. Bags/Pails of Bentonite Required	Number of 50 lb. Bags/Pails of Bentonite Used

Annular Seal Volume Calculations (cement/bentonite grout, neat cement grout, bentonite grout, sand-cement grout, etc.)
See attached **GROUTING FORM** for detailed grout slurry data.

Annular Seal Description (Include Cement Type -- e.g., I, II, V)	Bottom Depth (feet)	Top Depth (feet)	Length of Annular Seal Interval (feet)	Borehole Diameter (inches)	Casing Diameter (inches)	Calculated Total Volume of Grout for Annular Seal (gallons or ft^3 or yd^3 -- circle one)	Total Volume of Grout Used in Annular Seal (gallons or ft^3 or yd^3 -- circle one)

Miscellaneous Data and Conversions

1 gallon water = 8.34 pounds
1 cubic foot water = 62.4 pounds
1 cubic foot water = 7.48 gallons water
1 sack of sand = 1 cubic foot and approximately 100 pounds
1 sack of cement (wet) = 0.5 cubic foot = 3.75 gallons
1 pail of bentonite pellets = approximately 50 pounds
1 sack of cement (dry) = 1 cubic foot and approximately 96 pounds

FIELD WELL CONSTRUCTION SUMMARY
GROUTING FORM

amec

Project Name: _____ **Project/Task Number:** _____

Site Name: _____ **Date:** _____

Location: _____ **Well/Boring ID:** _____

	TIME			BATCH MIXTURE					BATCH VOLUME		CUMULATIVE VOLUME				
Batch Number	Begin Mixing	End Mixing	End Pumping	# Sacks Cement	Water (gallons)	Bentonite (lbs)	Sand (lbs)	Grout Weight (lbs/gal)	cu. ft.	gallons	cu. ft.	gallons	Calculated Grout Level (ft bgs)	Measured Grout Level (ft bgs)	Tremie Pipe Depth (ft bgs)

SURFACE COMPLETION DETAILS FOR WELLS

Well ID: _____ Project/Task No.: _____

Surface Flush Mount Completion (to 0.10 of an inch)

Well Box Manufacturer: _____ Model No. _____

Well Box: Diameter: _____ Length _____ Bolt Type: Diameter _____ (fractions of an inch, e.g., 5/8) # Bolts: _____

Well Vault: Dimensions: Length _____ x Width _____ x Height _____

Bolt Type: Diameter _____ (fractions of an inch, e.g., 5/8) # Bolts: _____

Notes:

Above Grade Surface Completion (to 0.10 of an inch)

Steel Protective Cover: Length _____ Diameter or Width _____ (circle one) Height AGS _____ Depth BGS _____

Cap Type (check one): Locking Hinged _____ Locking Slip Cap _____

Annular Space (check appropriate): Mortar Collar ____ Sand ____ Other _____ Drainage Hole ____ Height AGS _____

Concrete Pad Dimensions: Length _____ x Width _____ x Thickness _____

Steel Protective Bollards: # of _____ Length _____ Diameter or Width _____ (circle one) Height AGS _____ Depth BGS _____

Radial Distance of Steel Protective Bollard from Well _____

AGS = above ground surface

BGS = below ground surface

Notes:

FIELD WELL CONSTRUCTION SUMMARY NOTES

WELL SAMPLING AND/OR DEVELOPMENT RECORD

amec

Well ID: _____

Sample ID: _____ Duplicate ID: _____

Sample Depth: _____

Project and Task No.: _____

Project Name: _____

Date: _____

Sampled By: _____

Method of Purging: _____

Method of Sampling: _____

Initial Depth to Water:

Depth to Water after Sampling: _____

Total Depth to Well: _____

Well Diameter: _____

1 Casing/Borehole Volume: _____
(Circle one)

3 Casing/Borehole Volumes: _____
(Circle one)

Total Casing/Borehole Volumes Removed: _____

Time	Intake Depth	Rate (gpm)	Cum. Vol. (gal.)	Temp. (°C)	pH (units)	Specific Electrical Conductance (µS/cm)	Remarks (color, turbidity, and sediment)

pH CALIBRATION (choose two)				
Buffer Solution	pH 4.0	pH 7.0	pH 10.0	
Temperature C				
Instrument Reading				

Model or Unit No.:

SPECIFIC ELECTRICAL CONDUCTANCE – CALIBRATION			
KCL Solution (µS/cm=µmhos/cm)			
Temperature C			
Instrument Reading			

Model or Unit No.:

Notes:

C17.0 – GROUNDWATER SAMPLING

Purpose and Scope: The purpose of this document is to present procedures for collecting a groundwater sample for chemical analysis. It includes a discussion on sampling preparations, field procedures, piezometer sampling, and grab groundwater sampling.

Equipment:
Bailer (Teflon, Polyvinyl Chloride (PVC), polyethylene, or equivalent);
Bailer reel with twine;
A tarp or plastic sheet;
Water level indicator;
pH meter;
Electrical Conductivity (EC) meter;
Thermometer;
Oxygen-reduction potential (ORP) (Eh) meter;
Dissolved oxygen (DO) meter;
Turbidity meter;
Sample containers (laboratory cleaned and provided);
Electric generator;
Electric submersible pump control box;
Oil-less compressor;
Groundwater pump (e.g., submersible pump, peristaltic pump, bladder pump, etc.);
Filter equipment;
Tubing (Teflon, PVC, polyethylene, or equivalent);
Ice chests;
Blue or double bagged “wet” ice;
5-gallon buckets;
Miscellaneous tools; and
Safety Equipment.

Documentation:
Daily Field Record (DFR);
Sample Control Log;
Atlantic Richfield Chain-of-Custody (COC) form;
Field Instrument Calibration Sheet;
Well Sampling and/or Development Record;
Maps/plot plan; and
Camera.

Water sampling activities generally are performed after water table elevations have been measured and stagnant water within the wells has been purged. This Standard Operating Procedure (SOP) describes the purging and groundwater sampling procedures to be performed in monitoring wells, piezometers and open boreholes.

This SOP is to be used in conjunction with the Sampling and Analysis Plan (SAP) and future Focused Remedial Investigation (FRI) work plans. In addition to the SAP, the following SOPs should be consulted:

- SOP 1.0 – General Preparation and Mobilization Requirements
- SOP 2.0 – Basic Health and Safety for Field Operations
- SOP 3.0 – Field Documentation and Sample Handling
- SOP 4.0 – Sample Collection Techniques and Data Collection Strategies
- SOP 6.0 – Field Measurements – Water
- SOP 7.0 – Equipment Decontamination
- SOP 9.0 – Investigation Derived Waste Disposal

Also refer to the Leviathan Mine Site Health, Safety, Security and Environmental (HSSE) Program Document by ENSR dated May 27, 2008, the Task Specific Health and Safety Plan by AMEC Geomatrix dated June 2009, and the Job Safety Analysis for the planned scope of work.

C17.1 PREPARATION AND SET-UP

Preparation and set-up for water sampling will include the following:

- Review the above listed SOPs and obtain, prepare, and maintain all applicable field forms;
- Review the scope of work and take note of the proposed sample locations, number of samples, and list of analytes to be collected. Verify the proposed samples with the Project Manager.
- Plan the sampling order when using non-dedicated equipment. The order of sampling is based on the results of the previous sampling event, where sampling proceeds from the lowest to highest detectable concentrations.
- Notify the laboratory 2-3 weeks in advance of sampling of the number of samples and types of analyses. Confirm preservation and handling requirements with the laboratory. Arrange for the laboratory to ship appropriate containers and sample coolers to the office prior to mobilization to the site, and upon receipt, inspect sample containers, and notify laboratory of any missing or damaged containers

- Coordinate and provide notification of the sampling schedule to the Project Manager and other affected individuals, and clear access to wells and/or surface water sampling locations.

- Calibrate in accordance with manufacturer's instructions the , pH, EC, temperature, ORP, DO, and turbidity meters to ensure the meters are in good working condition and providing accurate measurements. Document the results of each calibration on a Field Instrument Calibration Sheet (SOP 6.0 – Field Measurements - Water).

- Assemble all other required equipment and check that it is in proper working condition.

- Ensure all sampling equipment has been decontaminated (SOP 7.0 – Equipment Decontamination). If dedicated or disposable sampling equipment is used, decontamination activities will not be needed.

C17.2 PROCEDURE

Document general field activities on a Daily Field Record (SOP 3.0 – Field Documentation and Sampling Handling).

Prior to purging, the field technician will visually check the well for damage and begin to prepare the Well Sampling Record (attached).

The static water level and depth-to-bottom will then be measured according to the procedures outlined in SOP 6.0 – Field Measurements - Water. Depth-to-water measurements will be recorded to the nearest 0.01-foot and recorded on the Water Level Monitoring Record and Well Sampling Record. Monitoring well construction logs, along with available water level data, will be reviewed to determine the volume of water to be purged.

Each well will then be purged to allow collection of a representative sample. Monitoring wells will be purged using bailers or submersible pumps. If a submersible pump is used the purge rate will be determined for the well by the purge volume and as approved by the Project Manager. The purge method may be dependent on the chemical of potential concern, physical constraints, and available equipment. Extracted purged water will be properly contained and managed in accordance with SOP 9.0 – Investigation Derived Waste Disposal. Purging of each monitoring well will continue until the following two minimum conditions are met:

- Three casing volumes are removed from the well or piezometer.

- The field pH, specific conductivity, temperature, ORP, DO, and turbidity measurements of the discharged water have stabilized to consecutive readings that are within 10% of the previous readings.

Wells that are pumped or bailed dry prior to removing three casing volumes of water will be allowed to recover and then pumped or bailed dry a second time. Field measurements of temperature, pH, specific conductivity, ORP, DO, and turbidity will then be collected as the well fills again. If any of the field measurements are suspect, instruments will be re-calibrated as outlined in the Quality Assurance Project Plan (QAPP). Calibration information will be recorded on the Instrument Calibration Form and noted on Daily Field Records. Samples will be collected when the well has recharged a minimum of 80% of the pre-purge volume, as verified by measuring the depth to water.

Prior to collecting any samples, the field technician will put on new gloves. Water will then be pumped or bailed, filtered (if necessary), and decanted into laboratory supplied containers. Typical flow rates for collecting samples range from approximately 200 milliliters per minute (ml/minute) to 2 gallons a minute (gpm). A dedicated sample pump or a disposable bailer will be used to obtain the samples from the well. When using a bailer for sample collection, the bailer will be lowered with minimum splash to just below the water surface. If multiple types of analyses will be performed, the sample containers will be filled in the following order:

- Metals; and
- Other Chemical Constituents.

Samples collected for metals and other inorganic analysis will be filtered and preserved in the field according to laboratory instruction. Sample preservative requirements are provided in the FRI work plan. Samples that require filtering will be filtered using a disposable filter with a filter screen size of 0.45 micrometers (µm) (micron filter). A description of the odor or physical appearance of the sample including color, clarity, suspended solids, etc. will be reported on the Well Sampling Record.

Labels will be affixed to each sample bottle recording the sample identification number, date, time (military time), analysis required, preservative used, and collector's initials. An Atlantic Richfield COC or laboratory equivalent will accompany each sample to establish the required documentation necessary to trace sample possession. All collected samples, including any duplicates and blanks, will be recorded on a Sample Control Log. Refer to SOP 3.0 – Field Documentation and Sample Handling for details.

Non-dedicated and non-disposable bailers, pumps, meters, reels, water levels meters, and Teflon tubing will be decontaminated prior to first use and upon completion of sampling (SOP 7.0 – Equipment Decontamination). Soil, water, and waste disposal is discussed in SOP 9.0 – Investigation Derived Waste Disposal.

C17.3 PIEZOMETER SAMPLING

Piezometers are a permanent or temporary well that may be designed and constructed without the surface sealing or sand filter pack requirements of a monitoring well. This type of well is primarily used to collect water-level elevation data to aid in determining the direction of groundwater flow.

Piezometers may be sampled periodically to evaluate water quality, in which case, piezometers will be sampled according to procedures outlined above for the sampling of monitoring wells.

C17.4 GRAB GROUNDWATER SAMPLING

Grab groundwater samples may be collected during or immediately after drilling if water from the formation is freely flowing into an open boring.

Grab groundwater samples will be collected according to the procedures outlined above for sampling of monitoring wells with the exception that purging and monitoring of field parameters may not be performed prior to sample collection.

C17.5 HYDROPUNCH™ GROUNDWATER SAMPLING

A Hydropunch™ (HP) sampler is a grab groundwater sampling device is screened over a short interval (generally less than two feet) that can be used to collect a water sample at a relatively discrete interval when compared to traditional wells. If the depths of potential groundwater bearing zones are identified, a HP sampler may be lowered into the open borehole and driven into undisturbed soil by a hammer or direct push (described in SOP 13.0 - Drilling). Once the HP sampler is driven into soil, the outer shell of the sampler is retracted to expose a screen. If groundwater is present it will flow into the sampler through the screen. T

If a discrete water sample is desired at a depth already reached by the boring, an adjacent borehole can be installed with a HP sampler to collect groundwater samples at the desired sample depth.

Groundwater samples will be collected from the HP in the same manner as discussed in Section C17.1 with the exception that no purging or monitoring of field parameters will be performed prior to sample collection.

C18.0 – CONE PENETROMETER TEST

Purpose and Scope: The purpose of this document is to describe procedures for collecting Cone Penetrometer Test (CPT) data.

Equipment:
CPT rig;
Support Truck with grout mixer/pump;
Steam Cleaner;
Sample collection tools;
Miscellaneous Tools; and
Safety Equipment.

Documentation:
Daily Field Record (DFR);
Sample Control Log;
Atlantic Richfield Chain-of-Custody (COC) form;
Maps/plot plan; and
Camera.

A CPT consists of continuously pushing a cylindrical rod with a cone at the base slowly into the subsurface while measuring the pressure on the tip, the friction on the sidewalls, and the pore-water pressure. The relationship between these three measurements are recorded as a function of depth and compared to standards to characterize the soil behavior or to infer changes in lithology. The CPT can also be used to infer the pore-water pressure and may be used to identify potential groundwater bearing zones. When used in combination with a Hydropunch™ tool, grab groundwater samples can be collected from the identified groundwater bearing zone(s).

This Standard Operating Procedure (SOP) describes setup procedures that may be performed by the field geologist or engineer that will observe the CPT performed by others. This SOP does not include procedures for operating a CPT drilling rig. It is expected that the CPT will be subcontracted to a third party that is appropriately qualified and specializes in such investigations.

This SOP is to be used in conjunction with the Sampling and Analysis Plan (SAP) and future Focused Remedial Investigation (FRI) work plans. In addition to the SAP, the following SOPs should be consulted:

- SOP 1.0 – General Preparation and Mobilization Requirements
- SOP 2.0 – Basic Health and Safety for Field Operations

- SOP 3.0 – Field Documentation and Sample Handling
- SOP 4.0 – Sample Collection Techniques and Data Collection Strategies
- SOP 6.0 – Field Measurements – Water
- SOP 7.0 – Equipment Decontamination
- SOP 9.0 – Investigation Derived Waste Disposal
- SOP 13.0 – Drilling
- SOP 14.0 – Soil Sampling
- SOP 17.0 – Groundwater Sampling

Also refer to the Leviathan Mine Site Health, Safety, Security and Environmental (HSSE) Program Document by ENSR dated May 27, 2008, the Task Specific Health and Safety Plan by AMEC Geomatrix dated June 2009, and the Job Safety Analysis for the planned scope of work.

C18.1 GENERAL CONE PENETRATION TEST PROCEDURES

CPT is considered to be a direct push drilling method. Therefore, pre-drilling and general drilling procedures are similar to those discussed in SOP 13.0 - Drilling, except soil/rock logging cannot be performed by CPT. Where possible, CPT should be performed in the vicinity where soil logging has been performed previously so that the CPT data can be compared to site-physical soil data. It is expected that CPT activities will be subcontracted to a third party that has a current California drilling license. All CPT activities must be conducted under the oversight of appropriately trained field staff under the guidance of a California licensed Professional Geologist.

C18.1.1 Pre-drilling activities

The following activities must be performed prior to the start of any drilling activities:

- Provide subcontractors with the applicable scope documents and necessary access information.
- Prepare schedules and coordinate with staff, the client, and regulatory agencies if appropriate.

- Obtain an approved British Petroleum (BP) ground disturbance permit and all appropriate permits according to Federal, State, and local regulations.

- Confirm the drilling location with the Project Manager and pre-mark the locations with white spray paint. Additional markings with flags, wooden stakes, or other methods may be used to ensure that the locations can be easily accessed.

- While pre-marking the drilling locations, perform a preliminary review of potential overhead or underground utilities and hazards that may interfere with the drilling program.

- Obtaining proper clearance for potential above- and below-ground hazards. This may include some or all of the following:

  - reviewing as-built utility diagrams;

  - notifying Underground Services Alert; and

  - physically verify that utilities do not exist by hand digging or using an "air knife" to vacuum out surface sediments on the day of excavation.

- Verify that equipment has been decontaminated and is in good working order prior to its arrival onsite.

- If a location must be relocated due to the presence of a utility line, it must be at least 2 feet away from the outermost edge of the obstruction. Confirm any relocated borings with the Project Manager.

- Unexploded Ordinances (UXO) may exist within buried sections of tunnels, or other unknown areas at the site. If any suspected UXO are encountered, the area must be marked as a zone of exclusion and the Project Manager must be notified. <u>No work shall be performed within the study area if a UXO is suspected</u>.

C18.1.2 General CPT Procedures

The CPT consists of a 1.5-inch diameter metal cone that is hydraulically pushed into the ground at a constant rate of loading. The maximum reaction load for the CPT used is 20 tons. Instrumentation in the cone measures resistance at the tip, side friction along a sleeve just above the tip, and pore-water pressure. Continuous plots of sleeve friction and tip resistance are obtained from the device and presented as tons/square foot. The ratio of sleeve friction to tip resistance is also produced on the data printout as percent. Refusal occurs when tip resistance exceeds about 400 tons/square foot.

The most common method of obtaining CPT-derived stratigraphic information is by a correlation between soil type and the measured cone tip and sleeve friction resistance. The

resistance to the continuous penetration encountered by the cone tip and sleeve is transmitted via electronic cable through hollow push rods and into analog and digital recorders at ground surface. The resulting data is used to develop a detailed evaluation of subsurface site stratigraphy. In addition, site-specific correlation is typically developed through comparison with the lithology on nearby boring logs.

No waste soil or fluid is expected when the CPT is retracted. Upon completion of each test hole, a tremie pipe will be placed to the termination depth and the test hole will be grouted by pumping grout under pressure by the tremie method. The surface of each hole is finished with road surface material or a non-shrinking, high-strength concrete, as appropriate**.**

The following activities must be performed on the day of CPT:

- Perform a Health and Safety tailgate meeting with all personnel performing the drilling activities. Secure the work zone with traffic cones and barricade tape. Verify that the appropriate Personal Protective Equipment (PPE) is worn within the work zone.
- Decontaminate all down-hole drilling and sampling tools. Setup a decontamination station for sampling equipment.
- Set up a soil logging and note taking area.
- If the location is near utilities (all utilities at the site are near the Pit, Ponds, and Aspen Seep Bioreactor), then an air knife or hand digging equipment will be used to excavate the first 6.5 feet of material. Observe for potential backfill material that might accompany a buried utility line. In some cases, utility lines can be buried at depths greater than 6.5 feet deep. If such a case is suspected, continue excavating to the appropriate depth before proceeding with CPT.
- Perform drilling activities. Refer to SOP 13.0 - Drilling.
- If necessary, perform the appropriate air monitoring for health and safety during drilling. This may include the use of a photoionization detector (PID), flame ionization detector (FID), or personal air monitoring devices.
- Document the CPT activities, SOP 3.0 – Field Documentation and Sampling Handling presents field documentation procedures.
- Once all CPT activities are completed at a location, print out the CPT results. Determine the top and bottom depths of potential groundwater bearing zones and contact the Project Manager. This information will be used by the Project Manager

to determine potential groundwater sampling depth(s). Document all discussions and decisions made.

- Grouting through a tremie pipe will be completed after the CPT equipment is retracted. Refer to SOP 13.0 – Drilling for procedures on how to abandon a borehole.

- Decontaminate all equipment prior to moving to the next location. Properly containerize, label, and document the location of all waste such as decontamination water in the appropriate containers. Refer to SOP 9.0 – Investigation Derived Waste Disposal for procedures on how to dispose of soil, water, and waste.

C18.2 CPT PROCEDURES FOR SOIL SAMPLING

If desired, soil samples may be collected from a predetermined interval using a special tool that is pushed into the subsurface by the hydraulic rams in a CPT drill rig. The special tool is often called a piston style sampler.

A new location will be drilled for soil sampling as it is not recommended that the soil sample be collected from a CPT borehole. The 1.5-inch cone and metal rods are swapped out for the piston style sampler and hollow rods. Typically 2 - 1 ¼-inch by 6-inch stainless steel rings are placed in the sample tool to capture the soil samples. The tip of the sampler is pushed to the top of the desired sample depth. Once the depth is reached, the sampler and rods are retracted until the bearings on the sample tool lock in place. The sample tool is then advanced to collect a 1 foot sample.

Additionally, soil samples also may be collected by the use of a continuous core sampler. The cores may include liners that can be cut, capped, and submitted for laboratory analysis at the desired sample interval. Refer to SOP 14.0 for procedures on soil sampling.

C18.3 HYDROPUNCH™ IN-SITU GROUNDWATER SAMPLING

Hydropunch™ in-situ sampling is designed to obtain a representative formation water sample. The tool body consists of a stainless steel outer tube, an inner sample chamber, sample chamber Teflon check valves, and a drive point on the bottom, all of which can be dismantled for cleaning. The outside diameter of the tool is typically 1.66-inches and the length is typically 63.25-inches.

At each sample location, a solid (dummy) cone will be advanced to a few feet above the shallow sampling interval. Then, the Hydropunch™ will be advanced to the desired sample

depth and a sample obtained. The Hydropunch™ will then be retracted and replaced with a clean Hydropunch™ and pushed to the next desired depth, if warranted, and a sample obtained. This sampling technique provides depth-discrete chemical samples while minimizing the potential for cross contamination. When collecting water samples in silt or clay, it may be necessary to leave the Hydropunch™ in the ground for an extended time (possibly overnight) in order to allow the sampler to fill.

At each sampling interval, once the target depth is reached with the sampling device, an upward pull opens the inlet section of the tool to allow groundwater to flow into the sample chamber. Teflon check valves seal the sample chamber when the inlet is closed, which allows the groundwater sample to be brought to ground surface. The sample then will be transferred from the sample chamber through a Teflon tube to the appropriate sample container.

The following activities must be performed on the day of sampling:

- Reposition the drill rig a few feet from the CPT borehole.
- Advance the sampling tool to the predetermined depth and collect a grab groundwater sample. Refer to SOP 17.0 – Groundwater Sampling for procedures on collecting a grab groundwater sample.
- Document the sampling activities. SOP 3.0 – Field Documentation and Sample Handling presents field documentation and sample handling procedures.
- Decontaminate all equipment prior to moving to the next sample location (SOP 7.0 – Equipment Decontamination).

C19.0 – AQUIFER TESTING

Purpose and Scope: The purpose of this document is to present procedures for conducting an aquifer test. It describes the procedures to be followed for conducting step-drawdown, constant discharge, and slug aquifer tests and specific capacity tests.

Equipment:
Tape measure (subdivided into tenths of feet);
Water pressure transducer;
Electric water level indicator;
Weighted tape measures;
Steel tape measure (subdivided into tenths of feet);
21X micrologger;
Electronic data-logger (if transducer method;
is used)
Stainless steel slug of a known volume;
Watch or stopwatch with second hand;
Semi-log graph paper (if required);
Waterproof ink pen and logbook;
Thermometer;
Appropriate references and calculator;
Electrical tape;
Compact portable computer or equivalent
with grapher installed on the hard disk;
Generator;
Graduated Container;
A barometer or recording barograph (for tests
conducted in confined aquifers);
Electrical tape;
Flashlights;
pH meter;
Conductivity meter;
Discharge pipe;
Flow meter;
Miscellaneous tools; and
Safety equipment.

Documentation
Daily Field Record (DFR);
Aquifer Test Data Form (attached);
Maps/plot plan; and
Camera.

This Standard Operating Procedure (SOP) is to be used in conjunction with the Sampling and Analysis Plan (SAP) and future Focused Remedial Investigation (FRI) work plans. In addition to the SAP, the following SOPs should be consulted:

- SOP 1.0 – General Preparation and Mobilization Requirements
- SOP 2.0 – Basic Health and Safety for Field Operations
- SOP 3.0 – Field Documentation and Sample Handling
- SOP 4.0 – Sample Collection Techniques and Data Collection Strategies
- SOP 6.0 – Field Measurements - Water
- SOP 7.0 – Equipment Decontamination
- SOP 9.0 – Investigation Derived Waste Disposal

Also refer to the Leviathan Mine Site Health, Safety, Security and Environmental (HSSE) Program Document by ENSR dated May 27, 2008, the Task Specific Health and Safety Plan by AMEC Geomatrix dated June 2009, and the Job Safety Analysis for the planned scope of work.

All aquifer tests procedures must be performed by appropriately trained field staff under the guidance of a licensed Professional Engineer or Professional Geologist.

C19.1 GENERAL PROCEDURES

The following general procedures should be performed prior to the start of an aquifer test:

- Provide subcontractors with the applicable scope documents and necessary access information.
- Prepare schedules and coordinate with staff, client and regulatory agencies.
- Obtain approval of all appropriate British Petroleum (BP) permits and all appropriate permits according to Federal, State, and local regulations
- Prepare, calibrate, and test any pressure transducers or data loggers that may be used during the aquifer test, in accordance with manufacturer's directions.
- Prepare, calibrate, if necessary, and test meters, totalizers, or other equipment to measure the discharge.
- Confirm the aquifer test locations with the Project Manager.

The following activities must be performed on the day of the aquifer test:

- Document all events and decisions on a DFR (SOP 3.0 – Field Documentation and Sample Handling).

- Perform a health and safety tailgate meeting with all personnel performing the drilling activities (SOP 2.0 – Basic Health and Safety for Field Operations). Secure the work zone with traffic cones and barricade tape. Verify that the appropriate Personal Protective Equipment (PPE) is worn within the work zone.

- Setup a decontamination station. Decontaminate all down-hole tools. Refer to SOP 7.0 – Equipment Decontamination.

- Set up a note taking area.

- Set up a water storage area. Water may be stored in 55-gallon drums, Baker tanks, or other appropriate containers that can be sealed and transported. If the well is located in an area of uneven terrain, the container should be placed directly on top of the transport vehicle (e.g., flat bed truck). The water storage area should have secondary containment, such as bermed plastic sheeting.

- Measure the depth to water in the pumping well and observation wells. Record the values as pre-test elevations on appropriate forms. Refer to SOP 6.0 – Field Measurements - Water.

- Set up data loggers and pressure transducers in observation wells to record the change in water levels during the aquifer test. Refer to the manufacturer's recommendations for proper operation. Set the start times.

- Perform the aquifer test at the pre-determined start time. Change the discharge rate as specified in the work plan. Aquifer tests are generally performed over a few days.

- Measure drawdown over time within the designated observation wells. This may be performed by hand (Refer to SOP 6.0 – Field Measurements - Water) or by using data loggers and pressure transducers. Where dataloggers are used, water levels should be checked by hand to confirm the accuracy of the data loggers and pressure transducers. Report suspect data to the Project Manager.

- At the completion of the aquifer test, shut down and remove all equipment as appropriate.

- Decontaminate all equipment prior to moving to the next planned well location. Refer to SOP 7.0 – Equipment Decontamination for equipment decontamination procedures.

- Properly containerize, label, and store all purged groundwater, decontamination water, and waste. Refer to SOP 9.0 – Investigation Derived Waste Disposal for procedures on how to dispose of soil, water, and waste.

- Download the data to a designated data storage devise and repeat the above steps as necessary.

C19.2 METHODS OF AQUIFER TESTING

This section provides a brief description of the drilling methods that may be used. The method actually used will depend on previously collected data.

C19.2.1 Step-Drawdown Test

The step-drawdown aquifer test is performed to estimate a maximum sustainable discharge rate for the pumping well. The pretest phase, conducted prior to the aquifer test, will consist of water level measurements taken in the pumped well and observation wells that are to be monitored throughout the duration of the test. The water level measurements will be collected using electric sounders or pressure transducers and a data logger. All data will be recorded for the designated wells.

The pumping phase of the step-drawdown test will consist of the following:

- Pumping the well at successively higher pumping rates (steps) specified by the responsible professional, with an approximate duration of two to four hours per step;

- Periodically and at similar times measuring the water levels in the pumped well and observation wells during each step;

- Measuring the instantaneous and cumulative discharge from the pumped well using a flow meter or other appropriate means; and

- Recording the time at which all measurements were taken.

The pumping rate for each step will be maintained relatively constant. The rate will be checked periodically (at least hourly) and adjusted if necessary. The accuracy of the flow meter will be checked using a graduated container and a stopwatch, or similar method.

The recovery phase of the step-drawdown test begins immediately after the pump is shut off at the completion of the final step of the pumping phase. Recovery water-level measurements

will be made periodically in the pumped well and observation wells. Water level measurements will conclude when one of the following is satisfied:

- The water level in the pumped well has recovered to pre-test level;
- The water level in the pumped well has remained constant for at least 2 hours; or
- 24 hours have elapsed since the time of pump shut-off.

C19.2.2 CONSTANT DISCHARGE TEST

Prior to the constant discharge test, water level measurements will be taken in the pumped well and all observation wells that are to be monitored throughout the duration of the test. Water level measurements will be taken with electric sounders, pressure transducers with a data-logger, or a steel tape. All pretest water level measurements for the pumping well and observation wells will be recorded for the designated well.

The pumping phase of the aquifer test will consist of the following:

- Pumping the well at a constant designated rate;
- Periodically and at similar times measuring the water levels in the pumped well and observation wells during each step;
- Measuring the instantaneous and cumulative discharge from the pumped well using a flow meter or other appropriate means; and
- Recording the time at which all measurements were taken.

The duration of the pumping phase will be established prior to the start of the aquifer test. Time-drawdown curves for the observation wells may be plotted in the field on semi-logarithmic graph paper during the pumping phase to evaluate the progress of the test. If the plots indicate steady-state conditions in the aquifer, the test may be ended before its planned conclusion if approval is given by the responsible professional. Likewise, the pumping phase of the test may be extended at the discretion of the responsible professional.

The water levels in the pumped well and the observation wells will be measured simultaneously on a pre-determined time schedule. An example time schedule is outlined below.

Time Since	Time Intervals Between

Pump Started (min.)		Measurements (min.)
0-2		0.25
2-5		0.50
5-15		1
15-60		5
60-240	**(EXAMPLE)**	30
240-Conclusion		60

Discharge from the pumped well will be measured using a flow meter and a stopwatch or other appropriate methods. Discharge will be maintained at a relatively constant rate. The discharge rate will be checked and adjusted (if necessary, at 10-minute intervals during the first hour of pumping and 1-hour intervals thereafter). The accuracy of the flow meter will be checked using a graduated container and a stopwatch or similar method. Rate of discharge, cumulative gallons discharged, and time of measurement will be recorded.

If pumping should stop (due to mechanical breakdown of generator, pump, etc.) for a period greater than 2 percent of the elapsed pumping time, the test should be postponed. The pumping phase of the test may be resumed when one of the following conditions has been reached:

- The water level in the pumped well has recharged to within 5 percent of the pretest water level; or
- The well has not been pumped for a period at least equal to the elapsed pumping time of the test before postponement.

Upon completion of the pumping phase of the test, the pump will be shut off. Water level measurements will be taken simultaneously in the pumped well and the observation wells immediately following pump shut-off according to a predetermined schedule. An example time schedule is presented below.

Time Since Pump Stopped (min.)		Time Intervals Between Measurements (min.)
0-2		0.25
2-5		0.50
5-15		1
15-60		5
60-240	**(EXAMPLE)**	30
240-Conclusion		60

Water level measurements will be concluded when one of the following conditions applies:

- The water level in the pumped well has recovered to the pretest water level;
- The water level in the pumped well has remained constant for at least 2 hours; or
- 24 hours have elapsed from the time the pump was shut off.

C19.2.3 Slug Tests

Slug tests involve a single well in which the response to an "instantaneous" raising or lowering of the water level is measured. Slug tests are generally of short duration, usually less than 5 minutes, with the first 30 seconds being most important. As such, measurement of water levels during the test should be measured using a pressure transducer and data logger. If the formation is relatively low yielding, the test period may be longer and manual measurement methods may be used.

During the pretest phase, the static water level is measured. At the beginning of the slug test, a known volume of water is either bailed from or added to the well, or a weighted slug of known volume is lowered into or raised from the well. The water level is measured immediately after the slug or water is added or removed, and then the change in water level with time is measured in pre-determined increments. The water level measurements and time at which the measurements were collected will be recorded.

C19.2.4 Specific Capacity Tests

A specific capacity test is a constant discharge-constant drawdown pumping test. The purpose of specific capacity testing is to determine the specific capacity (SC) of the pumping well and to estimate transmissivity (T) by using an established empirical relationship between SC and T. These estimates can be used as a check on hydraulic parameters collected during long-term pumping tests or as a preliminary estimate of T when long-term pumping tests have not been performed.

The practical requirement of the field method is to achieve a stabilized drawdown in the pumping well at a constant pumping rate. The pumping rate should be low enough for the results to be indicative of aquifer properties and not overly influenced by losses due to well efficiency. The stabilized drawdown condition should be achieved at a constant pumping rate for a duration of at least 30 minutes. Water levels are measured to the nearest 0.01 foot using an electric sounder or pressure transducer. The pumping rate is measured with a flow meter

or using a graduated container and a stopwatch. The cumulative volume pumped is recorded at the time water level measurements are taken. Time is measured in seconds with a stopwatch. Static and pumping water levels, pumping rate and/or cumulative gallons removed, and time at which measurements were taken will be recorded.

ATTACHMENTS

- Aquifer Test Data Form

amec

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AQUIFER TEST DATA

Owner _____ Address _____ County _____ State _____

Date _____ Company performing test _____ Measured by _____

Well No. _____ Distance from pumping well _____ Type of test _____ Test No. _____

Measuring equipment _____

Time Data	Water Level Data	Discharge Data	Comments on factors affecting test data
Pump on: Date _____ Time _____ (t_{i_n}) Pump off: Date _____ Time _____ (t'_{i_n}) Duration of aquifer test: Pumping _____ Recovery _____	Static water level _____ Measuring point _____ Elevation of measuring point _____	How Q measured _____ Depth of pump/air line _____ Previous pumping? Yes ____ No ____ Duration _____ End _____	

Date	Clock time	Time since pump started t	Time since pump stopped t'	t/t'		Water level measurement	Correction or Conversion	Water level	Water level change s or s'		Discharge measurement	Rate		

AMEC Geomatrix

C20.0 – SEEPAGE METER

Purpose and Scope: The purpose of this document is to describe procedures for measuring the seepage flux between surface water and groundwater sources using a seepage meter. It includes a discussion of general procedures, construction, installation, and operation of seepage meters.

Equipment: a 5-gallon, cylindrical plastic bucket cut in half (2.5 gallon capacity);
1 liter Tedlar® bag or larger bag with an inlet that can be easily attached to a tube;
Current Damper (e.g., Coffee can);
Drill;
Drill bits, ¼", ⅜", and ½" diameter;
Plastic tube with barbed fittings on both ends, ¼" inside diameter (i.d.), ⅜" outside diameter (o.d), at least 2" long;
Polyethylene tubing, ¼" inside diameter (i.d.), ⅜" outside diameter (o.d.);
Polyethylene tubing, ⅛" i.d., ¼" o.d.;
Teflon® tubing, ¼" i.d., ⅜" o.d.;
½-inch rubber stopper (2)
½-inch glass tube (2)
Flow Measurement Equipment;
Weight scale;
Global Positioning System (GPS) device;
Boat or Raft;
Rope;
Miscellaneous tools;
Life Vests and floatation devices; and
Safety Equipment.

Documentation: Daily Field Record (DFR);
Sample Control Log;
Maps/plot plan; and
Camera.

The seepage flux between surface water and groundwater can be measured directly with a seepage meter. A seepage meter consists of an open-bottomed container pushed into a streambed and used to measure the time it takes for a volume of water to flow into or out of a bag connected to the container.

This Standard Operating Procedure (SOP) describes the procedures for constructing, installing, and operating a seepage meter. Results of the seepage meter will result in a discharge value (volume/time) or Q which can be used with Darcy's law to calculate the

seepage flux. The following procedures are based on work by D.R. Lee and J.A. Cherry titled, *A field exercise on groundwater flow using seepage meters and mini-piezometers* which was published in the Journal of Geological Education in 1978.

This SOP is to be used in conjunction with the Sampling and Analysis Plan (SAP) and future Focused Remedial Investigation (FRI) work plans. In addition to the SAP, the following SOPs should be consulted:

- SOP 1.0 – General Preparation and Mobilization Requirements
- SOP 2.0 – Basic Health and Safety for Field Operations
- SOP 3.0 – Field Documentation and Sample Handling
- SOP 4.0 – Sample Collection Techniques and Data Collection Strategies
- SOP 6.0 – Field Measurements – Water
- SOP 7.0 – Equipment Decontamination
- SOP 8.0 – Surface Water Sampling and Stream Flow Measurement
- SOP 9.0 – Investigation Derived Waste Disposal

Also refer to the Leviathan Mine Site Health, Safety, Security and Environmental (HSSE) Program Document by ENSR dated May 27, 2008, the Task Specific Health and Safety Plan by AMEC Geomatrix dated June 2009, and the Job Safety Analysis for the planned scope of work.

C20.1 GENERAL PROCEDURES

If a seepage meter has already been purchased, or if such activities are subcontracted to a third party, the following general procedures should be followed prior to the start of a seepage meter test. If the seepage meter must be constructed, refer to Section C20.2:

- If subcontractors are to be used then they must be provided with the applicable scope documents and necessary access information.
- Obtain approval of all British Petroleum (BP) permits and all permits according to Federal, State, and local regulations.

- Prepare schedules and coordinate with staff, client, and regulatory agencies if appropriate.
- Obtain all equipment;
- Confirm the seepage meter location(s) with the Project Manager.
- Perform a reconnaissance of the investigation area for potential hazards such as rapids, steep slopes, wadeability, slips, trips, and falls that may affect the study. Any potential concerns should be discussed with the Project Manager. Appropriate changes to the project design will be made if the test location presents a health and safety hazard.

The following activities must be performed on the day of the seepage meter test:

- Document all general field events on a Daily Field Record. Refer to SOP 3.0 – Field Documentation and Sample Handling.
- Perform a health and safety tailgate meeting with all personnel performing the drilling activities. Secure the work zone with traffic cones and barricade tape. Verify that the appropriate Personal Protective Equipment (PPE) and safety equipment is worn within the work zone.
- Prior to taking field measurements, the sampling personnel will assemble all necessary equipment and check all instruments to be used to ensure they are in proper working condition.
- Measure the surface water flow and record the measurements at the proposed seepage meter location. Refer to SOP 8.0 – Stream Flow Measurement and Surface Water Sampling.

C20.2 SEEPAGE METER CONSTRUCTION

A seepage meter may be constructed in a number of ways with various sizes depending on the natural conditions. Therefore, the following construction details may be subject to change.

1. Construct the container (i.e., 5-gallon bucket cut in half) and flip it over with the bottom side facing up (Figure 20.1).
2. Drill a ½-inch diameter vent hole in the base of the container. The hole should be placed off-center, near the edge of the container (Figure 20.1).
3. Insert a glass tube through a one-hole stopper. Put the stopper and glass tube in the hole at the top of the container. This is the vent tube.

4. Drill a ½" diameter hole on the side of the container. The hole should be located on the same side that the vent hole was placed about halfway up the side of the container (Figure 20.1).

5. Insert a glass tube or other tubing through a one-hole stopper. Put the stopper and glass tube in the side of the container. This section will be later attached to tubing and the collection bag.

6. If the seepage meter is placed in a stream with current, make a current damper with a coffee can. Poke a small hole (⅛" o.d) through the center of plastic coffee can lid. Feed ⅛" i.d., ¼" o.d., polyethylene tubing through the hole. The tube should fit snuggly.

7. Place a Tedlar® bag into the coffee can and connect to Teflon® tubing (⅛" i.d., ¼" o.d) as shown on Figure 20.2.

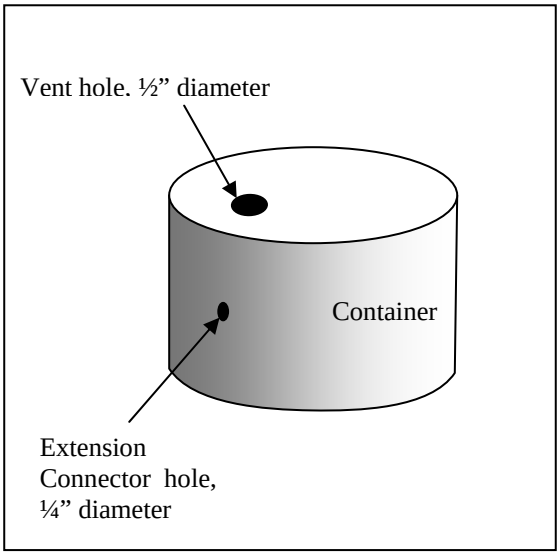

Figure 20.1 – Seepage meter construction Steps 1-4. Oblique view.

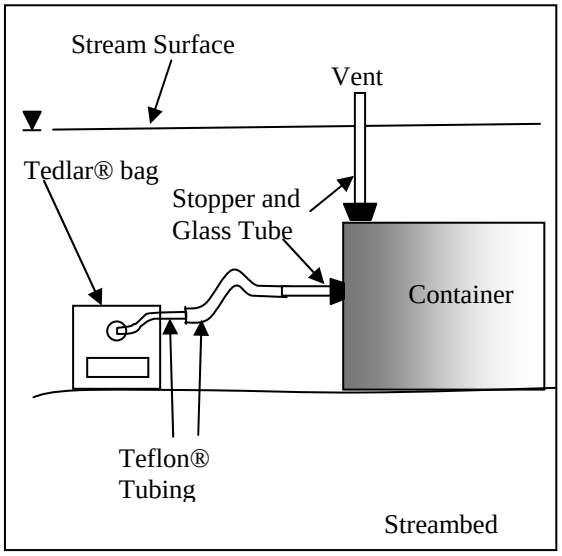

Figure 20.2 – Seepage meter construction Steps 6-7. Side view. Surface water flow is from right to left.

C20.3 SEEPAGE METER INSTALLATION

Seepage meters should be installed in low velocity areas (e.g., lakes, backwater areas) that do not have a gravel or rocky bottom. Where possible, the meter and collection bag should be installed in stagnant water to avoid differences in pressure caused by moving water (i.e., Bernoulli Effects). If a seepage meter must be installed in moving waters, the collection bag

must be housed within a container (e.g., coffee can) to dampen the flow of water which might affect the seepage rate. The following procedures describe installation of the seepage meter.

1. Completely submerge the seepage meter into the stream with the vent hole facing upward.

2. Tilt the seepage meter from side to side to remove all bubbles from the container. Once all bubbles have been removed, push the walls of the seepage meter into the streambed sediments. Put the side of the container with the vent hole on the downstream side and tilt that side up. The upstream side of the container should be tilted downward.

3. Attach a pre-weighed bag (explained in Section 20.4) to the tubing and cover the bag with coffee can or other housing container to block the flow of water along the bag. Bubbles should be removed from the can to prevent the bag from drifting away.

4. Place a rock or other weighted device to keep the can and bag in place, thereby limiting movement and damage to the bag.

A schematic of an installed seepage meter is shown in Figure 20.3.

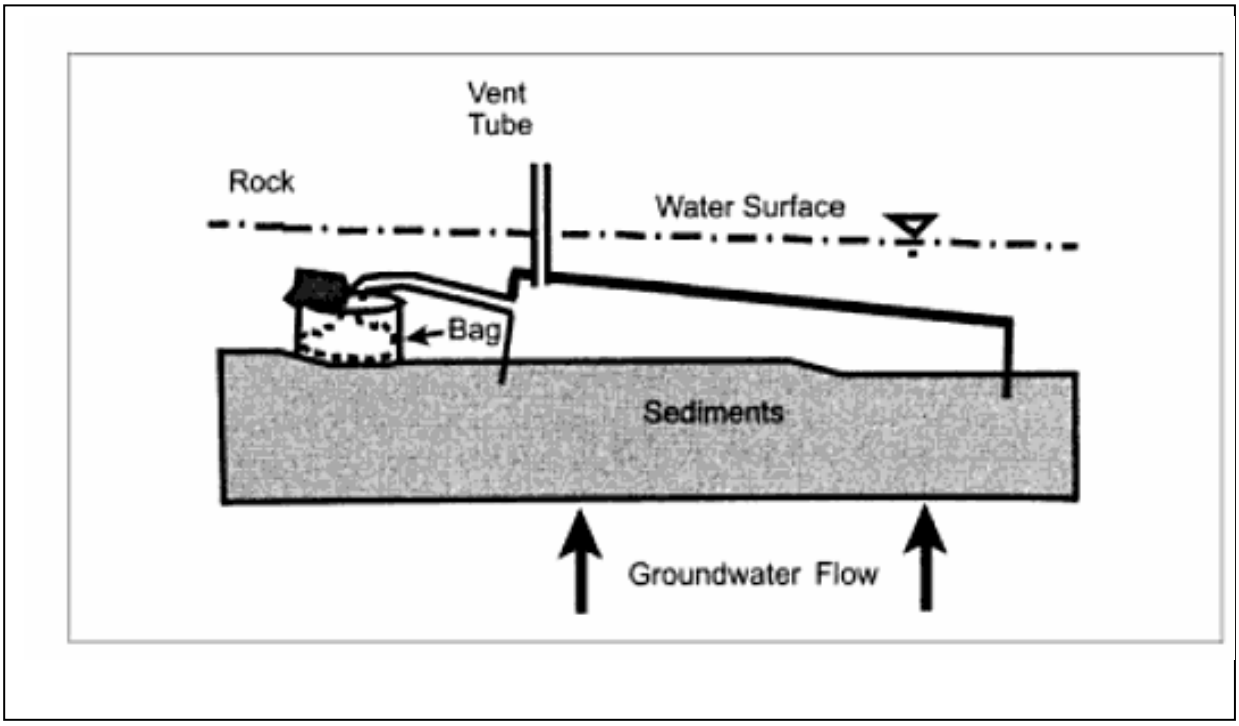

Figure 20.3 – Side view schematic of an installed seepage meter. Surface water flow is from right to left. The Tedlar® bag is placed in a coffee can and weighted with a rock to eliminate the disturbance caused by moving surface water.

C20.4 OPERATION

The following describes the procedures for conducting a test to collect data that will be used to determine the seepage flux across the surface water-groundwater interface.

1. Perform a site reconnaissance of the anticipated investigation area. Identify low velocity areas with a flow meter and areas that do not have gravel or rocky bottoms. Measure the surface water flow and record the pretest value.

2. If this is the first test, partially fill the bag with water, remove air bubbles, and close the inlet valve. Weigh the bag and record the pretest weight of the bag.

   Losing Conditions: If this is a subsequent test and it is known that the location is a losing section of the stream, fill the bag with water, remove the air bubbles, and close the inlet valve. Weigh the bag and record the pretest weight of the bag.

   Gaining Conditions: If this is a subsequent test and it is known that the location is a

gaining section of the stream, then remove all contents of the bag and close the inlet valve. Weigh the bag and record the pretest weight of the bag.

3. Install the seepage meter as described in Section 20.3. Secure and appropriately label the submerged seepage meter so that the meter can be relocated and all Health and Safety protocols are adhered to.

4. Record the location on a hard copy of a map and with a GPS device (only for the first test).

5. Open the valve to the bag and record the start time. The duration of the test will depend on the seepage flux encountered. The test should be conducted during a period that does not allow the bag to be completely emptied (in a losing condition) or filled (gaining condition). A number of short tests may need to be performed to determine the appropriate duration.

6. At the completion of the test, close the valve, record the time, detach the bag, weigh the bag, and record the value. Leave the seepage meter in place if multiple tests are to be performed.

C21.0 – BUBBLE-WATER MANOMETER

Purpose and Scope: The purpose of this document is to describe operation of a bubble-water manometer to measure relative differences in pressure between the stream and a groundwater source. It describes set-up, operation, and removal of the bubble-water manometer.

Equipment: Bubble-water manometer installed on a board with a level;
In-stream piezometer;
Hand pump or Peristaltic pump;
Fully charged car battery (if peristaltic pump is used);
Current damper (e.g., coffee can);
Polyethylene tubing, size dimensions depend on the manometer board connections;
Teflon® tubing, size dimensions depend on manometer board connections;
Flow measurement equipment;
Global Positioning System (GPS) device;
Stream waders, wet suit, river boots; and
Safety Equipment.

Documentation: Daily Field Record (DFR);
Maps/plot plan; and
Camera.

This SOP is to be used in conjunction with the Sampling and Analysis Plan (SAP) and future Focused Remedial Investigation (FRI) work plans. In addition to the SAP, the following SOPs should be consulted:

- SOP 1.0 – General Preparation and Mobilization Requirements
- SOP 2.0 – Basic Health and Safety for Field Operations
- SOP 3.0 – Field Documentation and Sample Handling
- SOP 4.0 – Sample Collection Techniques and Data Collection Strategies
- SOP 7.0 – Equipment Decontamination
- SOP 8.0 – Surface Water Sampling and Stream Flow Measurement
- SOP 25.0 – Mini-piezometer Installation

Also refer to the Leviathan Mine Site Health, Safety, Security and Environmental (HSSE) Program Document by ENSR dated May 27, 2008, the Task Specific Health and Safety Plan

by AMEC Geomatrix dated June 2009, and the Job Safety Analysis for the planned scope of work.

C21.1 BUBBLE-WATER MANOMETER BOARD

A bubble-water manometer measures the pressure head differences between a stream and a groundwater source to infer the direction of flow.

A bubble-water manometer typically consists of an inverted U-tube made of plastic tubing with three valve connections. One valve is connected to groundwater, another valve is connected to surface water, and a third valve is located near the top of the inverted U-tube and leads to a pump or ambient air. A simplified manometer bubble-water manometer attached to a board is shown on Figure 21.1.

C21.2 SET-UP

Prior to taking field measurements, the sampling personnel will assemble all necessary equipment and check all instruments to be used to ensure they are in proper working condition.

C21.3 OPERATION

- Mini-piezometers may need to be installed into the streambed. Refer to SOP 25.0 – Mini-Piezometer Installation for the installation of mini-piezometers. Measure the depth of the *center of the screened interval* to the top of the streambed surface. This is the difference in length between the groundwater source and stream source (ΔLength or dl) (Figure 21.1). Record this value.

- Attach the manometer to the mini-piezometer, stream, and pump. In most cases, surface water in a stream is moving which can affect the pressure measurement. To eliminate the "Bernoulli Effect" caused by moving water, the stream inlet should be housed within a box that acts as a current damper. A current damper may consist of a perforated chamber that rests on the streambed surface. Figure 21.1 shows the attachment of a bubble-water manometer board to groundwater through an in-stream piezometer, to the stream through a current damper, and to a peristaltic pump.

- Open the three valves leading to the mini-piezometer, stream, and pump. Pump water from the manometer and remove all air bubbles. The manometer may need to be shaken to remove all bubbles. Once all air bubbles have been removed, close the valve that leads to the pump and then shut off the pump.

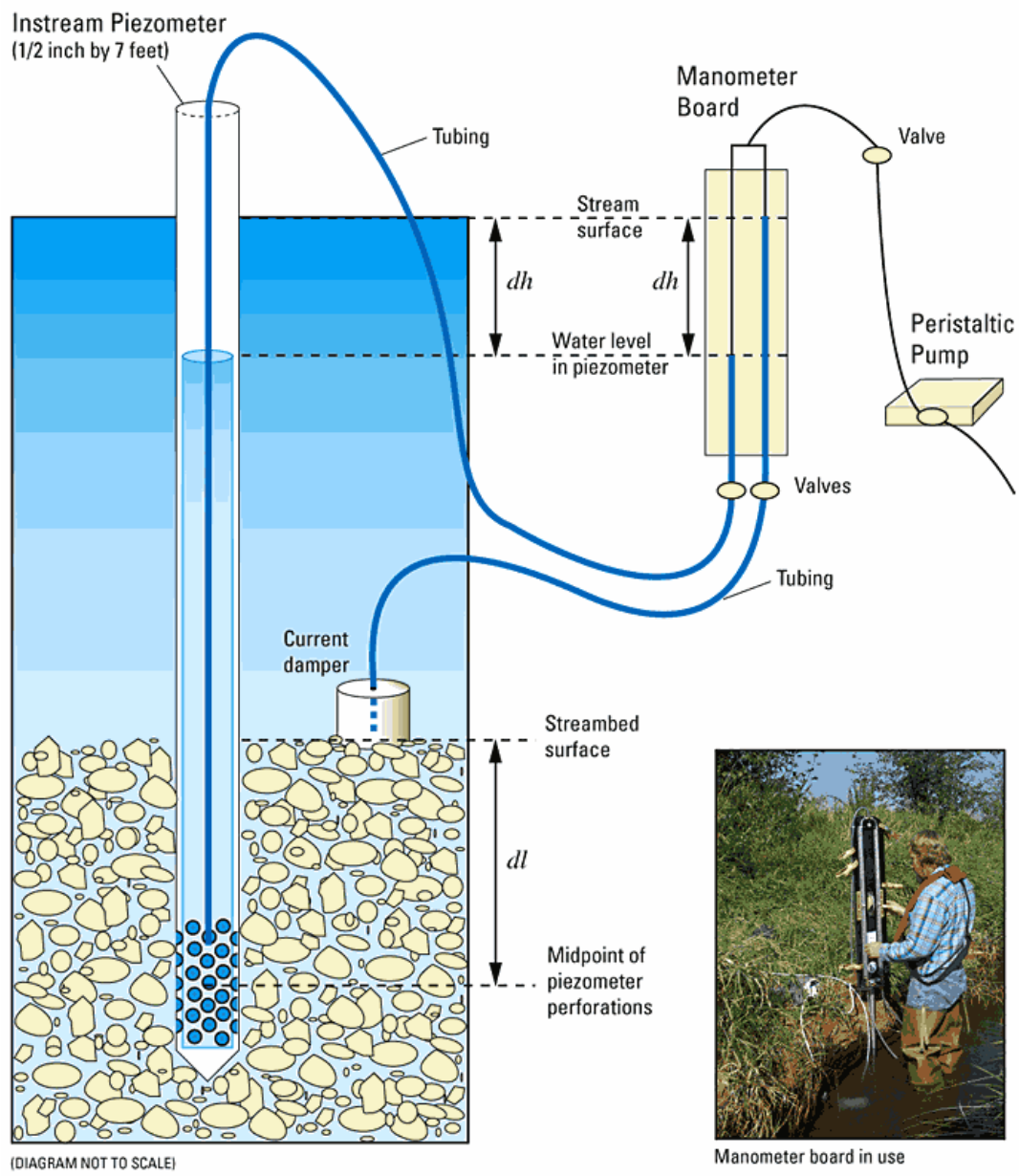

Figure 21.1 – How a manometer board is used to directly measure hydraulic head differences across a streambed and compute vertical hydraulic gradients. *dh* is the difference in head (water level) between surface water and ground water. *dl* is depth below the streambed to the midpoint of piezometer perforations. Vertical hydraulic gradient is determined by dividing *dh* by *dl*. Figure from "Ground and Surface Water Interactions and Quality of Discharging Ground Water, Lower Nooksack River Basin, WA" by the U.S. Geological Survey (Scientific Investigations Report 2005-5255).

- Unhook the manometer tubing from pump. The top end of the manometer now extends to a closed valve.

- Quickly open and close the valve that leads to ambient air so that a large, single bubble enters the manometer. There should only be one bubble within the manometer that extends to both sides of the inverted U. If multiple bubbles are present, gently shake the manometer to combine all of the bubbles near the top of the tubing just below the top valve which leads to ambient air. As a reminder, the valves leading to the stream and groundwater should both be open while the valve on the top of the manometer board should be closed.

- Level the manometer board so that the board is vertical.

- Measure the difference in pressure head (i.e., hydraulic head) that exists between the stream and groundwater (ΔHead or dh) (Figure 22.1). Measurements should be made at the bottom of each meniscus. Record this length.

- Repeat steps 3-9 to verify the reading and evaluate the precision of the measurements.

- Measure the stream flow (SOP 8.0 – Stream Flow Measurement and Surface Water Sampling) at or immediately up-stream of the mini-piezometer. Record the flow.

- Document the location of the mini-piezometer on a map using a map and compass or a GPS device.

C21.4 REMOVAL

Unhook the manometer tubing from the piezometers and seal the valves leading to the piezometer. Refer to SOP 25.0 – Mini-Piezometer Installation for details on the removal of piezometers.

C22.0 – TRACER STUDY

Purpose and Scope: The purpose of this document is to present various types of tracers and general procedures for conducting a tracer test.

Equipment:
Tracer (varies, dye or solute);
Monitoring devices (varies, fluorometers, conductivity meters, etc);
Data loggers (optional);
5-gallon plastic buckets (2);
Stream flow meter ;
Down-hole pumps;
Miscellaneous tools; and
Safety Equipment.

Documentation:
Daily Field Record (DFR);
Field Instrumentation Calibration Sheet;
Maps/plot plan; and
Camera.

Tracers are used to determine the path of surface water or groundwater flow. Tracers are dissolved in water at concentrations that do not significantly change the aqueous density. Conservative tracers do not lose mass through reaction or partitioning into differing phases (vapor, solids). These type of tracers are used to determine the advection and dispersion properties of a surface water or groundwater system.

This SOP is to be used in conjunction with the Sampling and Analysis Plan (SAP) and future Focused Remedial Investigation (FRI) work plans. In addition to the SAP, the following SOPs should be consulted:

- SOP 1.0 – General Preparation and Mobilization Requirements
- SOP 2.0 – Basic Health and Safety for Field Operations
- SOP 3.0 – Field Documentation and Sample Handling
- SOP 4.0 – Sample Collection Techniques and Data Collection Strategies
- SOP 6.0 – Field Measurements - Water

Also refer to the Leviathan Mine Site Health, Safety, Security and Environmental (HSSE) Program Document by ENSR dated May 27, 2008, the Task Specific Health and Safety Plan by AMEC Geomatrix dated June 2009, and the Job Safety Analysis for the planned scope of work.

C22.1 PLANNING

The following general procedures should be performed prior to the start of a tracer test:

- Identify a tracer to be used for the tracer test. Refer to Sections C22.1.1 and C22.1.2.
- Model the flow of the tracer from the planned injection well so that the observation wells can be placed at appropriate locations. Refer to Section C22.1.3.
- Provide subcontractors with the applicable scope documents and necessary access information.
- Obtain approval of all appropriate British Petroleum (BP) permits and all permits according to Federal, State, and local regulations.
- Prepare schedules and coordinate with staff, client, and regulatory agencies if appropriate.
- Perform notifications in addition to those described in SOP 1.0 – General Preparation and Mobilization Requirements. These are discussed Section C22.1.4.
- If the tracer has not been pre-mixed by the manufacturer, mix the tracer in a wind-free area, away from sunlight, with all workers in direct contact with the mixing process wearing appropriate Health and Safety protection. Record the properties of the tracer (e.g., field meter reading, density, color).
- Prepare, calibrate, and test any meters or data loggers that may be used during the tracer test.
- Confirm the tracer test design with the Project Manager.

C22.1.1 Types of Tracers

Common tracers used in surface water and groundwater studies include:

- Dye Tracers - fluorescein and rhodamine-WT; and
- Solute Tracers – potassium, chloride, and lithium.

Fluorescent dyes that are readily detected at low concentrations (parts per million) and pose little environmental risk can effectively trace ground-water flow paths but may degrade in sunlight or under low pH conditions. Dye-tracer studies can be used to determine the time-of-travel for ground water to move to and into surface water, as well as hydraulic properties of

aquifer systems. Depending on the objectives, dye tracers can be detected by visual observation, fluorometric analysis of discrete water samples, and by in-situ continuous-flow fluorometry.

Solute tracers can be detected at low levels but may pose an environmental risk to plants depending on the solute introduced and the concentration. If a known concentration of a solute is injected into the subsurface and measured downstream over time, the seepage velocity can be calculated. In addition, the amount of dilution at the down-gradient receptors may be used to calculate the discharge. Depending on the objectives, many solute tracers may be measured with a conductivity meter as an electrical charge (e.g., millisiemens). The concentration of the solute can be calculated by creating a calibration curve that relates the electrical charge to known standard concentrations.

C22.1.2 Selecting a Tracer

The most conservative tracer for the site should be selected. This may be determined by consulting tracer manufacturers or by performing a bench scale test.

Contact Tracer Manufacturers

One way to select a tracer is to consult tracer manufacturers to determine if the product can be used with the conditions at the site. Depending on the chemical characteristics of the natural water (e.g., pH, temperature, turbidity, etc.), a tracer may be highly reactive and may degrade quickly yielding false or inconclusive results. Any available water quality data should be provided to a manufacturer to determine the most conservative tracer to be used at the site. The manufacturer should provide information on the equipment required to track the tracer.

Perform a Bench-Scale Test

Another way to identify the most conservative tracer for the site is to perform a bench-scale test. Site-specific water samples could be mixed with various tracers to determine rate of degradation and identify the most conservative tracer for the site.

C22.1.3 Modeling Tracer Movement

Tracer migration should be modeled to estimate the direction of groundwater flow so that an appropriate network of observation points can be placed near the injection well. Modeling may include development of a flow net, analytical model, or numerical model. These models can be used to estimate the direction of flow, advection (i.e., velocity), and dispersion of the tracer to determine the most likely areas where the tracer plume may be identified after injection.

C22.1.4 Notifications

Notifications should be made to the community and downstream communities of any tracer tests to be performed within or near a surface water body. Signs should be placed along the stream which the tracer study is being performed. This is especially the case if dye tracer tests are to be performed. Dye tracer tests will discolor the water (fluorescent yellow or red) and may be alarming to the public.

C22.2 OPERATION

The following activities must be performed during a tracer study:

- Document general events on a Daily Field Record (SOP 3.0 – Field Documentation and Sample Handling).
- Perform a health and safety tailgate meeting with all personnel performing the drilling activities (SOP 2.0 – Basic Health and Safety for Field Operations). Secure the work zone with traffic cones and barricade tape. Verify that the appropriate Personal Protective Equipment (PPE) is worn within the work zone.
- Setup a decontamination station. Decontaminate all down-hole tools. Refer to SOP 7.0 – Equipment Decontamination.
- Set up a note taking area.
- Set up the down-gradient/downstream monitoring devices – If data loggers are to be used, program the start time, frequency of sample measurement, and end time. The start time for all monitoring devices should be chronologically set to begin simultaneously. Document the location of each monitoring point on a map.
- Measure and record the stream flow (for tracer studies conducted in surface waters only).
- Inject the tracer and record the time. The tracer should be introduced as a “plug” or a single injection. If injected into surface water, the tracer may be directly poured from the container or a bucket into a well-mixed section of the stream. If injected into a borehole, the tracer may be pressure injected or allowed to infiltrate with gravity.
- Use an appropriate meter to measure the tracer. Record the time and change in concentration at each observation point during the test. The method of tracking the tracer will depend on the objectives of the tracer test and the type of tracer used. Dye tracers may be visually observed with the first arrival times recorded, fluorometric analysis of discrete water samples, or by in-situ continuous-flow

fluorometry. Solute tracers may be measured with a conductivity meter as an electrical charge and later converted to concentration values.

- Stop the test when the plume of tracer has traveled past all monitoring points.
- Upon completion of the tracer test, containerize, seal, and label any unused or waste materials. Decontaminate all equipment that has come in contact with the tracer chemicals. Containerize, secure, label, and store all waste generated during the course of the tracer study.

C23.0 – FIELD DENSITY TESTS

Purpose and Scope: The purpose of this document is to present procedures for conducting field density tests. It includes a discussion of the sand cone method and nuclear gauge method.

Equipment: Sand Cone Apparatus (includes sand cone, sand, balances or scales, and drying equipment);
Nuclear Gauge Apparatus (includes nuclear gauge, reference standard, site preparation device, drive pin, and drive pin extractor);
Miscellaneous tools (wrenches, etc.); and
Safety Equipment.

Documentation: Daily Field Record (DFR);
Field Instrumentation Calibration Sheet;
ASTM D2922-91 (attached);
ASTM D1556-90 (attached);
Maps/plot plan; and
Camera.

Field density tests are used to determine the degree of compaction in fill. The two most common testing methods used to determine in-place density of compacted fill are the sand cone method and the nuclear gauge method. The results of the in-place density tests are compared to laboratory maximum dry density to determine relative compaction.

This Standard Operating Procedure (SOP) discusses procedures for conducting density tests using the sand cone method and the nuclear gauge method.

This SOP is to be used in conjunction with the Sampling and Analysis Plan (SAP) and future Focused Remedial Investigation (FRI) work plans. In addition to the SAP, the following SOPs should be consulted:

- SOP 1.0 – General Preparation and Mobilization Requirements
- SOP 2.0 – Basic Health and Safety for Field Operations
- SOP 3.0 – Field Documentation and Sample Handling
- SOP 4.0 – Sample Collection Techniques and Data Collection Strategies

Also refer to the Leviathan Mine Site Health, Safety, Security and Environmental (HSSE) Program Document by ENSR dated May 27, 2008, the Task Specific Health and Safety Plan

by AMEC Geomatrix dated June 2009, and the Job Safety Analysis for the planned scope of work.

C23.2 GENERAL PROCEDURES FOR DENSITY TESTING

If density testing is subcontracted to a third party, the following general procedures should be followed prior to the start of test.

- Provide subcontractors with the applicable scope documents and necessary access information.
- Obtain approval of all British Petroleum (BP) permits and all permits according to Federal, State, and local regulations.
- Prepare schedules and coordinate with staff, client, and regulatory agencies if appropriate.
- Obtain all equipment;
- Confirm the density test location(s) with the Project Manager.
- Confirm that all heavy equipment operations for the test location have been completed.

The following activities must be performed on the day of the density test:

- Document all general field events on a Daily Field Record. Refer to SOP 3.0 – Field Documentation and Sample Handling.
- Perform a health and safety tailgate meeting with all personnel performing the testing activities Verify that the appropriate Personal Protective Equipment (PPE) and safety equipment is worn within the work zone.
- Prior to taking field measurements, the sampling personnel will assemble all necessary equipment and check all instruments to be used to ensure they are in proper working condition.

C23.2 DENSITY TESTING METHODS

The sand cone method and the nuclear gauge method are described in this SOP. Each type is explained in the sections below.

C23.2.1 Sand Cone Method

The sand cone method consists of excavating a test hole by hand in the soil. The soil removed from the ground is saved in a container. The test hole is filled with free flowing sand through the Sand Cone Apparatus of a known density and the volume is determined. The in-place wet density of the soil is determined by dividing the wet mass of the removed material by the volume of the test hole. The water content of the material from the test hole is determined and the dry mass and in-place dry density of the material are calculated using the wet mass of the soil, the water content, and the volume of the test hole.

All procedures for conducting the sand cone method will be performed in accordance to ASTM Standard D1556-90 (Attached). All measurements must be performed by field personnel properly trained in performing such activities.

C23.2.2 Nuclear Gauge Method

The nuclear gauge method determines the total or wet density of soil and soil-rock mixtures by the attenuation of gamma radiation where the source and detector(s) remain on the surface (Backscatter Method) or the source or detector is placed at a known depth (e.g., 12 inches) while the detector(s) or source remains on the surface (Direct Transmission Method). The density in mass per unit volume of the material being tested is determined by comparing the detected rate of gamma radiation with previously established calibration data.

All procedures for conducting the nuclear gauge method will be performed in accordance to ASTM Standard D2922-91 (Attached). All measurements must be performed by a field personnel trained and certified in performing such activities.

C23.3 FAILING TESTS

Field personnel should provide density testing results directly to the Contractor in the field. If any test results do not meet project specifications, field personnel should inform the General Contractor that the compaction requirements are not being achieved and describe the extent of fill that needs to be corrected. Possible causes for failing tests might include:

- Low water content (below optimum);
- High water content causing pumping;
- Wrong type of equipment for soil type;

- Lifts are too thick; or
- Not enough compaction.

Field personnel should refrain from telling the Contractor how to improve compaction. It is the Contractor's responsibility to meet the required compaction specifications.

C23.4 PASSING TESTS

The Contractor should be verbally informed of the exact percentage of the passing test. Written reports should be provided to the Contractor only with the approval of the Project Engineer and the Client.

ATTACHMENTS

- ASTM Designation D2922-91 – Standard Test Methods for Density of Soil and Soil-Aggregate in Place by Nuclear Methods (Shallow Depth)
- ASTM Designation D1556-90 – Standard Test Method of Density and Unit Weight of Soil In Place by the Sand Cone Method

Standard Test Methods for Density of Soil and Soil-Aggregate in Place by Nuclear Methods (Shallow Depth)[1]

This standard is issued under the fixed designation D 2922; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

These methods have been approved for use by agencies of the Department of Defense. Consult the DoD Index of Specifications and Standards for the specific year of issue which has been adopted by the Department of Defense.

1. Scope

1.1 This test method covers the determination of the total or wet density of soil and soil-rock mixtures by the attenuation of gamma radiation where the source and detector(s) remain on the surface (Backscatter Method) or the source or detector is placed at a known depth up to 300 mm (12 in.) while the detector(s) or source remains on the surface (Direct Transmission Method).

1.2 The density in mass per unit volume of the material under test is determined by comparing the detected rate of gamma radiation with previously established calibration data.

1.3 The values tested in SI units are to be regarded as the standard. The inch-pound equivalents may be approximate.

1.4 It is common practice in the engineering profession to concurrently use pounds to represent both a unit of mass (lbm) and a unit of force (lbf). This implicitly combines two separate systems of units; that is, the absolute system and the gravitational system. It is scientifically undesirable to combine the use of two separate sets of inch-pound units within a single standard. This standard has been written using the gravitational system of units when dealing with the inch-pound system. In this system the pound (lbf) represents a unit of force (weight). However, the use of balances or scales recording pounds of mass (lbm), or the recording of density in lbm/ft^3 should not be regarded as nonconformance with this standard.

1.5 *This standard does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* For specific Hazard statements, see Section 6.

2. Referenced Documents

2.1 *ASTM Standards:*

D 698 Test Method for Moisture-Density Relations of Soil and Soil-Aggregate Mixtures Using 5.5-lb (2.49-kg) Rammer and 12-in. (305-mm) Drop[2]

D 1556 Test Method for Density of Soil In-Place by the Sand-Cone Method[2]

D 1557 Test Method for Moisture-Density Relations of Soil and Soil-Aggregate Mixtures Using 10-lb (4.54-kg) Rammer and 18-in. (457-mm) Drop[2]

D 2167 Test Method for Density of Soil In-Place by the Rubber-Balloon Method[2]

D 2216 Method for Laboratory Determination of Water (Moisture) Content of Soil, Rock, and Soil-Aggregate Mixtures[2]

D 2937 Test Method for Density of Soil In-Place by the Drive-Cylinder Method[2]

D 3017 Test Method for Water Content of Soil and Rock In-Place by Nuclear Methods (Shallow Depth)[2]

D 4253 Test Method for Maximum Index Density and Unit Weight of Soils Using a Vibratory Table[2]

D 4643 Method for Determination of Water Content by the Microwave Oven Method[2]

D 4718 Practice for Correction of Unit Weight and Water Content for Soils Containing Oversize Particles[2]

D 4944 Test Method for Field Determination of Water (Moisture) Content of Soil by the Calcium Carbide Gas Pressure Tester Method[3]

D 4959 Test Method for Determination of Water (Moisture) Content by Direct Heating Method[3]

3. Significance and Use

3.1 The test method described is useful as a rapid, nondestructive technique for the in-place determination of density of soil and rock.

3.2 The test method is suitable for quality control and acceptance testing for construction and for research and development applications.

3.3 The nondestructive nature of the test allows repetitive measurements to be made at a single test location.

4. Interferences

4.1 The chemical composition of the sample may affect the measurement, and adjustments may be necessary.

4.2 The test method exhibits spatial bias in that the instrument is more sensitive to the density of the material in close proximity to the surface (Backscatter Method only).

NOTE 1—The nuclear gauge density measurements are somewhat biased to the surface layers of the soil being tested. This bias has largely been corrected out of the direct transmission method and any remaining bias is insignificant. The backscatter method is still more sensitive to the material within the first several inches from the surface.

[1] These test methods are under the jurisdiction of ASTM Committee D-18 on Soil and Rock and are the direct responsibility of Subcommittee D18.08 on Special and Construction Control Tests.

Current edition approved Dec. 23, 1991. Published January 1992. Originally published as D 2922 – 71. Last previous edition D 2922 – 78 (1990).

[2] *Annual Book of ASTM Standards*, Vol 04.08.

[3] *Annual Book of ASTM Standards*, Vol 04.09.

4.3 Oversize rocks or large voids in the source-detector path may cause higher or lower density determination. Where lack of uniformity in the soil due to layering, rock or voids is suspected, the test volume site should be dug up and visually examined to determine if the test material is representative of the full material in general and if rock correction (see 9.6) is required.

4.4 The sample volume is approximately 0.0028 m^3 (0.10 ft^3) for the Backscatter Method and 0.0057 m^3 (0.20 ft^3) for the Direct Transmission Method when the test depth is 15 cm (6 in.). The actual sample volume is indeterminate and varies with the apparatus and the density of the material. In general, the higher the density the smaller the volume.

5. Apparatus

5.1 *Nuclear Gauge*—An electronic counting instrument, capable of being seated on the surface of the material under test, and which contains:

5.1.1 A sealed source of high energy gamma radiation such as cesium or radium.

5.1.2 *Gamma Detector*—Any type of gamma detector such as a Geiger-Mueller tube(s).

5.2 *Reference Standard*—A block of material used for checking instrument operation and to establish conditions for a reproducible reference count rate.

5.3 *Site Preparation Device*—A plate, straightedge, or other suitable leveling tool which may be used for planning the test site to the required smoothness, and in the Direct Transmission Method, guiding the drive pin to prepare a perpendicular hole.

5.4 *Drive Pin*—A pin of slightly larger diameter than the rod in the Direct Transmission Instrument, used to prepare a hole in the material under test for inserting the rod.

5.5 *Drive Pin Extractor*—A tool that may be used to remove the drive pin in a vertical direction so that the pin will not distort the hole in the extraction process.

5.5.1 A slide hammer, with a drive pin attached, may also be used both to prepare a hole in the material to be tested and to extract the pin without distortion to the hole.

6. Hazards

6.1 This equipment utilizes radioactive materials that may be hazardous to the health of the users unless proper precautions are taken. Users of this equipment must become familiar with applicable safety procedures and government regulations.

6.2 Effective user instructions together with routine safety procedures, such as source leak tests, recording and evaluation of film badge data, etc., are a recommended part of the operation and storage of this instrument.

7. Calibration

7.1 Calibration of the instrument will be in accordance with Annex A1.

8. Standardization and Reference Check

8.1 Nuclear gauges are subject to long-term aging of the radioactive source, detectors, and electronic systems, which may change the relationship between count rate and material density. To offset this aging, the gauge may be calibrated as the ratio of the measured count rate to a count rate made on a reference standard or to an air-gap count (for the backscatter air-gap technique, see 9.5.1.3). The reference count rate should be of the same order of magnitude as the measured count rate over the useful density range of the instrument.

8.2 Standardization of the gauge shall be performed at the start of each day's work, and a permanent record of these data shall be retained. Perform the standardization with the gauge located at least 8 m (25 ft) away from other sources of radioactive material, and clear of large masses or other items which may affect the reference count rate.

8.2.1 If recommended by the instrument manufacturer to provide more stable and consistent results: (1) turn on the gauge prior to use to allow it to stabilize, (2) leave the power on during the use of the gauge for that day.

8.2.2 Using the reference standard, take at least four repetitive readings at the normal measurement period and determine the mean. If available on the gauge, one measurement period of four or more times the normal period is acceptable. This constitutes one standardization check.

8.2.3 If the value obtained above is within the limits stated below, the gauge is considered to be in satisfactory condition, and the value may be used to determine the count ratios for the day of use. If the value is outside these limits, allow additional time for the gauge to stabilize, make sure the area is clear of sources of interference, and then conduct another standardization check. If the second standardization check is within the limits, the gauge may be used, but if it also fails the test, the gauge shall be adjusted or repaired as recommended by the manufacturer. The limits are as follows:

$$|N_s - N_o| \leq 2.0 \sqrt{N_o/F}$$

where:

N_s = value of current standardization count,

N_o = average of the past four values of N_s taken for prior usage, and

F = value of prescale. [The prescale value (F) is a divisor which reduces the actual value for the purpose of display. The manufactor will supply this value if other than 1.0.] Some instruments may have provisions to compute and display these values.

8.2.3.1 If the instrument standardization has not been checked within the previous three months, perform at least four new standardization checks, and use the mean as the value for N_o.

8.3 Use the value of N_s to determine the count ratios for the current day's use of the instrument. If for any reason the measured density becomes suspect during the day's use, perform another standardization check.

9. Procedure for Field Use

9.1 Standardize the gauge. (See Section 8.)

9.2 Select a test location. If the gauge will be closer than 250 mm (10 in.) to any vertical mass that might influence the result, such as in a trench or alongside a pipe, follow the manufacturer's correction procedure.

9.3 Remove all loose and disturbed material. Remove additional material as necessary to reach the material that represents a valid sample of the zone or stratum to be tested. Surface drying and spatial bias should be considered in

determining the depth of material to be removed.

9.4 Plane or scrape a smooth horizontal surface so as to obtain maximum contact between the gauge and the material being tested. The placement of the gauge on the surface of the material to be tested is always important, but is especially critical to the successful determination of density when using the *backscatter* method. The optimum condition in all cases, is total contact between the bottom surface of the gauge and the surface of the material being tested. To correct for surface irregularities, use of native fines or fine sand as a filler may be necessary. The depth of the filler should not exceed approximately 3 mm (⅛ in.) and the total area filled should not exceed 10 % of the bottom area of the instrument. The maximum depth of any void beneath the gauge that can be tolerated without filling shall not exceed approximately 3 mm (⅛ in.). Several trial seatings may be required to achieve these conditions.

9.5 Proceed with the test in the following manner:

9.5.1 *Backscatter Procedure:*

9.5.1.1 Seat the gauge firmly on the prepared test site.

9.5.1.2 Keep all other radioactive sources away from the gauge to avoid affecting the measurement so as not to affect the readings.

9.5.1.3 Secure and record one or more readings for the normal measurement period in the backscatter position.

NOTE 2—When using the backscatter air-gap procedure, follow the instrument manufacturers instructions regarding apparatus set up. Take the same number of readings for the normal measurement period in the air-gap position as in the standard backscatter position. Determine the air-gap ratio by dividing counts per minute obtained in the air-gap position by counts per minute obtained in standard backscatter position.

9.5.1.4 Determine the ratio of the reading to the standard count or to the air gap count. From this count ratio and the appropriate calibration and adjustment data, determine the in-place wet density.

9.5.2 *Direct Transmission Procedure:*

9.5.2.1 Make a hole perpendicular to the prepared surface using the guide and the hole-forming device 5.4, or by drilling if necessary. The hole shall be of such depth and alignment that insertion of the probe will not cause the gauge to tilt from the plane of the prepared area. The depth of the hole must be deeper than the depth to which the probe will be placed. The guide shall be the same size as the base of the gauge, with the hole in the same location on the guide as the probe on the gauge. The corners of the guide are marked by scoring the surface of the soil. The guide plate is then removed and any necessary repairs are made to the prepared surface.

9.5.2.2 Proceed with testing in the following manner:

9.5.2.3 Set the gauge on the soil surface, carefully aligning it with the marks on the soil so that the probe will be directly over the pre-formed hole.

9.5.2.4 Insert the probe in the hole.

9.5.2.5 Seat the gauge firmly by rotating it about the probe with a back and forth motion.

9.5.2.6 Pull gently on the gauge in the direction that will bring the side of the probe against the side of the hole that is closest to the detector (or source) location in the gauge housing.

9.5.2.7 Keep all other radioactive sources away from the gauge to avoid affecting the measurement.

9.5.2.8 Secure and record one or more readings for the normal measurement period.

9.5.2.9 Determine the ratio of the reading to the standard count. From this count ratio and the appropriate calibration and adjustment data, determine the in-place wet density.

NOTE 3—Some instruments have built-in provisions to compute the ratio, wet density, and to enter an adjustment bias. Additionally some instruments may have provisions to measure and compute moisture content, and dry density.

9.6 If the volume tested as defined in 4.4 has excess oversize material with respect to the limitations in the appropriate Test Methods D 698, D 1557 or D 4253, then a correction for wet density (unit weight) and water content must be applied. This correction will be done in accordance with Practice D 4718. This test method requires sampling from the actual test volume.

9.6.1 If samples of the measure material are to be taken for purposes of correlation with other test methods or rock correction, the volume measured can be approximated by a 200 mm (8 in.) diameter cylinder located directly under the center line of the radioactive source and detector(s). The height of the cylinder to be excavated will be the depth setting of the source rod when using the Direct Transmission method or approximately 75 mm (3 in.) when using the Backscatter Method.

9.6.2 An alternative to the correction for oversize particles, that can be used with mass density methods or minimal oversize situations, involves multiple tests. Tests may be taken at adjacent locations and the results averaged to get a representative value. Comparisons need to be made to evaluate whether the presence of a single large rock or void in the soil is producing unrepresentative values of density. Whenever values obtained are questionable, the test volume site should be dug up and visually examined.

10. Calculation of Results

10.1 The in-place wet density is determined as outlined in 9.5. If dry density is required, the in-place water content shall be determined using either gravimetric samples and laboratory determination of water content (Test Methods D 2216, D 4643, D 4959, D 4944), or an instrument which determines water content by neutron thermalization (Test Method D 3017).

10.1.1 If the water content is determined by nuclear methods, Test Method D 3017, subtract the kg/m^3 (lbf/ft^3) of moisture from the kg/m^3 (lbf/ft^3) of wet density, and obtain dry density in kg/m^3 (lbf/ft^3).

10.1.2 If the water content is determined by other methods, and is in the form of percent, proceed as follows:

$$\rho_d = \frac{100\rho_m}{100 + W}$$

where:

ρ_d = dry density in kg/m^3 (lbf/ft^3),
ρ_m = wet density in kg/m^3 (lbf/ft^3), and
W = water as a percent of the dry mass.

11. Report

11.1 The report shall include the following:

11.1.1 Standardization and adjustment data for the date of the tests.

11.1.2 Make, model and serial number of the test instrument.

11.1.3 Name of the operator(s).

11.1.4 Test site identification.

11.1.5 Visual description of material tested.

11.1.6 Test mode (backscatter or direct transmission) and test depth (if applicable).

11.1.7 Wet and dry densities in kg/m^3 or unit weights in lb/ft^3.

11.1.8 Water content in percent of dry mass or dry unit weight.

12. Precision and Bias

12.1 *Precision:*

12.1.1 Data are being evaluated to determine the precision of this test method. In addition, Subcommittee D18.08 is seeking pertinent data from users of the test method.

12.1.2 An instrument count precision of 8 kg/m^3 (0.5 lbf/ft^3) for the Backscatter Method and 4 kg/m^3 (0.25 lbf/ft^3) Direct Transmission Method are typical on a material of approximately 2000 kg/m^3 (125 lbf/ft^3) density, with a measurement time of one minute.

12.1.2.1 Instrument count precision is defined as the change in density that occurs corresponding to a one standard deviation change in the count due to the random decay of the radioactive source. The density of the material and the time period of the count must be stated. It may be determined from a series of 20 or more counts taken without moving the instrument, or alternately from the calibration data using the assumption that σ is equal to the $\sqrt{\text{count}}$ at that density. The count must be the true instrument count corrected for any pre-scaling (see 8.2.3).

$$P = \frac{\sigma}{S}$$

where:

P = instrument precision in density (kg/m^3 or lbf/ft^3)

σ = one standard deviation of the count

S = the slope of the calibration curve at the defined density value.

12.2 *Bias:*

12.2.1 There is no accepted reference value for this test method, therefore, bias cannot be determined.

13. Keywords

13.1 density; field density; nuclear methods

ANNEX

(Mandatory Information)

A1. CALIBRATION

A1.1 Verify or re-establish calibration curves, tables, or equation coefficients at least once every 12–18 months and after all major repairs which may affect the instrument geometry.

A1.2 The instrument shall be calibrated in such a way as to produce a calibration response within ± 16 kg/m^3 (± 1.0 lbf/ft^3) on blocks of materials (standards) of established densities. (This calibration may be done by the manufacturer, the user, or an independent vendor.) Nuclear instrument response is influenced by the chemical composition of measured material. This response must be taken into account in establishing the assigned standard block density. The densities of materials used to establish or verify the calibration should extend through a range representative of the density of the materials to be tested. The density of these material standards shall be determined to an accuracy of ± 0.2 %.

A1.3 Sufficient data shall be taken on each density standard to ensure an instrument count precision of at least one-half the instrument count precision required for field use. The data may be presented in the form of a graph, table, equation coefficients, or stored in the gauge, to allow covering the count rate data to material density.

A1.4 The method and test procedures used in establishing the calibration count rate data shall be the same as those used for obtaining the field count rate data.

A1.5 The material type, actual density and assigned standard block density of each calibration standard used to establish or verify the instrument calibration shall be stated as part of the calibration data.

A1.6 The standards shall be of sufficient size to not change the count rate if enlarged in any dimension. Minimum surface dimensions of approximately 610 mm long by 430 mm wide (24 × 17 in.) have proven satisfactory. For the Backscatter Method a minimum depth of 230 mm (9 inches) is adequate; for the Direct Transmission Method the depth shall be at least 50 mm (2 in.) deeper than the deepest rod depth. A larger surface area may be required for the Backscatter Air-Gap technique. Minimum surface dimensions may be reduced slightly if the standards are adjacent to a dense material.

A1.7 The most successful standards that have been established for accurate calibration have been made of aluminum, magnesium, aluminum/magnesium, granite and limestone. These standards have been used in combination with each other and with historical curve information to produce accurate and reliable calibration.

A1.7.1 Standards of soil, rock, and concrete that have the characteristics of reproducible uniformity are difficult to prepare. These standards may be of use for some special calibration or field calibration where local site material chemistry or background situation require special adaptation.

The American Society for Testing and Materials takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.

This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, 1916 Race St., Philadelphia, PA 19103.

Standard Test Method for Density and Unit Weight of Soil in Place by the Sand-Cone Method[1]

This standard is issued under the fixed designation D 1556; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

[ε1] NOTE—The title was corrected editorially in November 1991.
[ε2] NOTE—Editorial changes were made November 1993.

1. Scope

1.1 This test method may be used to determine the in-place density and unit weight of soils using a sand cone apparatus.

1.2 This test method is applicable for soils without appreciable amounts of rock or coarse materials in excess of 1½ in. (38 mm) in diameter.

1.3 This test method may also be used for the determination of the in-place density and unit weight of undisturbed or *in situ* soils, provided the natural void or pore openings in the soil are small enough to prevent the sand used in the test from entering the voids. The soil or other material being tested should have sufficient cohesion or particle attraction to maintain stable sides on a small hole or excavation, and be firm enough to withstand the minor pressures exerted in digging the hole and placing the apparatus over it, without deforming or sloughing.

1.4 This test method is not suitable for organic, saturated, or highly plastic soils that would deform or compress during the excavation of the test hole. This test method may not be suitable for soils consisting of unbound granular materials that will not maintain stable sides in the test hole, soils containing appreciable amounts of coarse material larger than 1½ in. (38 mm), and granular soils having high void ratios.

1.5 When materials to be tested contain appreciable amounts of particles larger than 1½ in. (38 mm), or when test hole volumes larger than 0.1 ft^3 (2830 cm^3) are required, Test Method D 4914 or D 5030 are applicable.

1.6 It is common practice in the engineering profession to concurrently use pounds to represent both a unit of mass (lbm) and a unit of force (lbf). This implicitly combines two separate systems of units, that is, the absolute system and the gravitational system. It is scientifically undesirable to combine the use of two separate sets of inch-pound units within a single standard. This test method has been written using the gravitational system of units when dealing with the inch-pound system. In this system the pound (lbf) represents a unit of force (weight). However, the use of balances or scales recording pounds of mass (lbm), or the recording of density in lbm/ft^3 should not be regarded as non-conformance with this test method.

1.7 *This standard does not purport to address the safety problems associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

D 653 Terms and Symbols Relating to Soil and Rock[2]
D 698 Test Methods for Moisture-Density Relations of Soils and Soil-Aggregate Mixtures Using 5.5-lb (2.49-kg) Rammer and 12-in. (304.8-mm) Drop[2]
D 1557 Test Methods for Moisture-Density Relations of Soils and Soil-Aggregate Mixtures Using 10-lb (4.54-kg) Rammer and 18-in. (457-mm) Drop[2]
D 2216 Method for Laboratory Determination of Water (Moisture) Content of Soil, Rock, and Soil-Aggregate Mixtures[2]
D 3584 Practice for Indexing Papers and Reports on Soil and Rock for Engineering Purposes[2]
D 4253 Test Method for Maximum Index Density of Soils Using a Vibratory Table[2]
D 4254 Test Method for Minimum Index Density of Soils and Calculation of Relative Density[2]
D 4643 Method for Determination of Water (Moisture) Content of Soil by the Microwave Oven Method[2]
D 4718 Practice for Correction of Unit Weight and Water Content for Soils Containing Oversize Particles[2]
D 4753 Specification for Evaluating, Selecting, and Specifying Balances and Scales for Use in Soil and Rock Testing[2]
D 4914 Test Method for Density and Unit Weight of Soil and Rock in Place by the Sand Replacement Method[2]
D 4944 Test Method for Field Determination of Water (Moisture) Content of Soil by the Calcium Carbide Gas Pressure Tester Method[3]
D 4959 Test Method for Determination of Water (Moisture) Content of Soil by Direct Heating Method[3]
D 5030 Test Methods for Density and Unit Weight of Soil and Rock in Place by the Water Replacement Method[3]

[1] This test method is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.08 on Special and Construction Control Tests.

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[2] *Annual Book of ASTM Standards*, Vol 04.08.
[3] *Annual Book of ASTM Standards*, Vol 04.09.

3. Terminology

3.1 *Definitions*—All definitions are in accordance with Terminology D 653.

4. Summary of Test Method

4.1 A test hole is hand excavated in the soil to be tested and all the material from the hole is saved in a container. The hole is filled with free flowing sand of a known density, and the volume is determined. The in-place wet density of the soil is determined by dividing the wet mass of the removed material by the volume of the hole. The water content of the material from the hole is determined and the dry mass of the material and the in-place dry density are calculated using the wet mass of the soil, the water content, and the volume of the hole.

5. Significance and Use

5.1 This test method is used to determine the density of compacted soils placed during the construction of earth embankments, road fill, and structural backfill. If often is used as a basis of acceptance for soils compacted to a specified density or percentage of a maximum density determined by a test method, such as Test Methods D 698 or D 1557.

5.2 This test method can be used to determine the in-place density of natural soil deposits, aggregates, soil mixtures, or other similar material.

5.3 The use of this test method is generally limited to soil in an unsaturated condition. This test method is not recommended for soils that are soft or friable (crumble easily) or in a moisture condition such that water seeps into the hand excavated hole. The accuracy of the test may be affected for soils that deform easily or that may undergo a volume change in the excavated hole from vibration, or from standing or walking near the hole during the test (see Note 1).

NOTE 1—When testing in soft conditions or in soils near saturation, volume changes may occur in the excavated hole as a result of surface loading, personnel performing the test, and the like. This can sometimes be avoided by the use of a platform that is supported some distance from the hole. As it is not always possible to detect when a volume change has taken place, test results should always be compared to the theoretical saturation density, or the zero air voids line on the dry density versus water content plot. Any in-place density test on compacted soils that calculates to be more than 95 % saturation is suspect and an error has probably occurred, or the volume of the hole has changed during testing.

6. Apparatus

6.1 *Sand-Cone Density Apparatus*, consisting of the following:

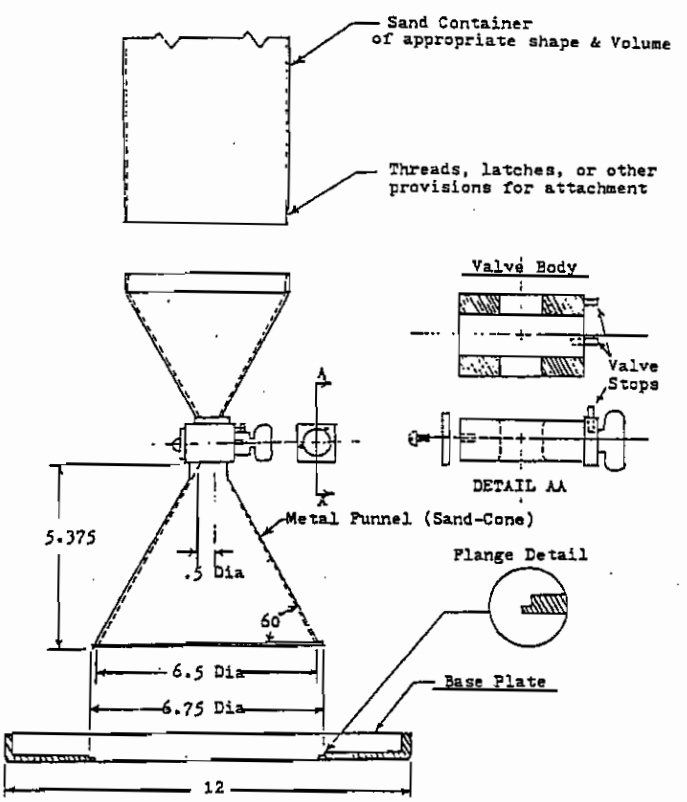
6.1.1 An attachable jar or other sand container having a volume capacity in excess of that required to fill the test hole and apparatus during the test.

6.1.2 A detachable appliance consisting of a cylindrical valve with an orifice approximately ½ in. (13 mm) in diameter, attached to a metal funnel and sand container on one end, and a large metal funnel (sand-cone) on the other end. The valve will have stops to prevent rotating past the completely open or completely closed positions. The appliance will be constructed of metal sufficiently rigid to prevent distortion or volume changes in the cone. The walls of the cone will form an angle of approximately 60 % with the base to allow uniform filling with sand.

6.1.3 A metal base plate or template with a flanged center hole cast or machined to receive the large funnel (cone) of the appliance described in 6.1.2. The base plate may be round or square and will be a minimum of 3 in. (75 mm) larger than the funnel (sand-cone). The plate will be flat on the bottom and have sufficient thickness or stiffness to be rigid. Plates with raised edges, ridges, ribs, or other stiffners of approximately ⅜ to ½ in. (10 to 13 mm) high may be used.

6.1.4 The mass of the sand required to fill the apparatus and base plate will be determined in accordance with the instructions in Annex A1 prior to use.

6.1.5 The details for the apparatus shown in Fig. 1 represents the minimum acceptable dimensions suitable for testing soils having maximum particle sizes of approximately 1½ in. (37.5 mm) and test hole volumes of approximately 0.1 ft³ (2830 cm³). When the material being tested contains a small amount of oversize and isolated larger particles are encountered, the test should be moved to a new location. Larger apparatus and test hole volumes are needed when particles larger than 1½ in. (37.5 mm) are prevalent. The apparatus described here represents a design that has proven satisfactory. Larger apparatus, or other designs of similar proportions may be used as long as the basic principles of the sand volume determination are observed. When test hole volumes larger than 0.1 ft³ (5660 cm³) are required Test



Metric Equivlents	
in.	mm
.5	12.5
5.375	136.5
6.5	165.1
6.75	171.5
12	304.8

FIG. 1 Density Apparatus

Method D 4914 should be utilized.

6.2 *Sand*—Sand must be clean, dry, uniform in density and grading, uncemented, durable, and free-flowing. Any gradation may be used that has a uniformity coefficient ($C_u = D_{60}/D_{10}$) less than 2.0, a maximum particle size smaller than 2.0 mm (No. 10 sieve), and less than 3 % by weight passing 250 µm (No. 60 sieve). Uniformly graded sand is needed to prevent segregation during handling, storage, and use. Sand free of fines and fine sand particles is required to prevent significant bulk-density changes with normal daily changes in atmospheric humidity. Sand comprised of durable, natural subrounded, or rounded particles is desirable. Crushed sand or sand having angular particles may not be free-flowing, a condition that can cause bridging resulting in inaccurate density determinations (see Note 2). In selecting a sand from a potential source, a gradation and five separate bulk-density determinations in accordance with the procedure in Annex A2 should be made on each container or bag of sand. To be an acceptable sand, the bulk-density variation between any one determination shall not be greater than 1 % of the average. Before using sand in density determinations, it shall be dried, then allowed to reach an air-dried state in the general location where it is to be used (see Note 3). Sand shall not be re-used without removing any contaminating soil, checking the gradation, drying and redetermining the bulk-density (see Note 4). Bulk-density tests of the sand will be made at time intervals not exceeding 14 days, always after any significant changes in atmospheric humidity, before reusing, and before use of a new batch from a previously approved supplier (see Note 5).

NOTE 2—Some manufactured (crushed) sands such as blasting sand have been successfully used with good reproducibility. The reproducibility of test results using angular sand should be checked under laboratory controlled testing situations before selecting an angular sand for use.

NOTE 3—Many organizations have found it beneficial to store sands in moisture resistant containers. Sand should be stored in dry areas protected from weather. The use of a lighted bulb or other heat source in, or adjacent to the storage containers has also been found to be beneficial in areas of high humidity.

NOTE 4—As a general rule, reclaiming sand after testing is not desirable.

NOTE 5—Most sands have a tendency to absorb moisture from the atmosphere. A very small amount of absorbed moisture can make a substantial change in bulk-density. In areas of high humidity, or where the humidity changes frequently, the bulk-density may need to be determined more often than the 14 day maximum interval indicated. The need for more frequent checks can be determined by comparing the results of different bulk-density tests on the same sand made in the same conditions of use over a period of time.

6.3 *Balances or Scales*—Meeting Specification D 4753, with 5.0 g readability, or better, to determine the mass of sand and excavated soils. A balance or scale having a minimum capacity of 20 kg and 5.0 g readability is suitable for determining the mass of the sand and the excavated soil when apparatus with the dimensions shown in Fig. 1 is used.

6.4 *Drying Equipment*—Equipment corresponding to the method used for determining water content as specified in Test Methods D 2216, D 4643, D 4959, or D 4944.

6.5 *Miscellaneous Equipment*—Knife, small pick, chisel, small trowel, screwdriver, or spoons for digging test holes, large nails or spikes for securing the base plate; buckets with lids, plastic-lined cloth sacks, or other suitable containers for retaining the density samples, moisture sample, and density sand respectively; small paint brush, calculator, notebook or test forms, etc.

7. Procedure

7.1 Select a location/elevation that is representative of the area to be tested, and determine the density of the soil in-place as follows:

7.1.1 Inspect the cone apparatus for damage, free rotation of the valve, and properly matched baseplate. Fill the cone container with conditioned sand for which the bulk-density has been determined in accordance with Annex A2, and determine the total mass.

7.1.2 Prepare the surface of the location to be tested so that it is a level plane. The base plate may be used as a tool for striking off the surface to a smooth level plane.

7.1.3 Seat the base plate on the plane surface, making sure there is contact with the ground surface around the edge of the flanged center hole. Mark the outline of the base plate to check for movement during the test, and if needed, secure the plate against movement using nails pushed into the soil adjacent to the edge of the plate, or by other means, without disturbing the soil to be tested.

7.1.4 In soils where leveling is not successful, or surface voids remain, the volume horizontally bounded by the funnel, plate and ground surface must be determined by a preliminary test. Fill the space with sand from the apparatus, determine the mass of sand used to fill the space, refill the apparatus, and determine a new initial mass of apparatus and sand before proceeding with the test. After this measurement is completed, carefully brush the sand from the prepared surface (see Note 6).

NOTE 6—A second calibrated apparatus may be taken to the field when this condition is anticipated (instead of refilling and making a second determination). The procedure in 7.1.4 may be used for each test when the best possible accuracy is desired, however, it is usually not needed for most production testing where a relatively smooth surface is obtainable.

7.1.5 Dig the test hole through the center hole in the base plate, being careful to avoid disturbing or deforming the soil that will bound the hole. Test hole volumes are to be as large as practical to minimize errors and will in no case be smaller than the volumes indicated in Table 1 for the maximum size of soil particle removed from the test hole. The sides of the hole should slope slightly inward and the bottom should be reasonably flat or concave. The hole should be kept as free as possible of pockets, overhangs, and sharp obtrusions since these affect the accuracy of the test. Soils that are essentially granular require extreme care and may require digging a conical-shaped test hole. Place all excavated soil, and any soil loosened during digging, in a moisture tight container that is marked to identify the test number. Take care to avoid losing any materials. Protect this material from any loss of moisture

TABLE 1 Minimum Test Hole Volumes Based on Maximum Size of Included Particle

Maximum Particle Size		Minimum Test Hole Volumes	
in.	(mm)	cm^3	ft^3
½	(12.5)	1420	0.05
1	(25.0)	2120	0.075
2	(50)	2830	0.1

until the mass has been determined and a specimen has been obtained for a water content determination.

7.1.6 Clean the flange of the base plate hole, invert the sand-cone apparatus and seat the sand-cone funnel into the flanged hole at the same position as marked during calibration (see Annex A1). Eliminate or minimize vibrations in the test area due to personnel or equipment. Open the valve and allow the sand to fill the hole, funnel, and base plate. Take care to avoid jarring or vibrating the apparatus while the sand is running. When the sand stops flowing, close the valve.

7.1.7 Determine the mass of the apparatus with the remaining sand, record, and calculate the mass of sand used.

7.1.8 Determine and record the mass of the moist material that was removed from the test hole. When oversized material corrections are required, determine the mass of the oversized material on the appropriate sieve and record, taking care to avoid moisture losses. When required, make appropriate corrections for the oversized material using Practice D 4718.

7.1.9 Mix the material thoroughly, and either obtain a representative specimen for water content determination, or use the entire sample.

7.1.10 Determine the water content in accordance with Test Method D 2216, D 4643, D 4944, or D 4959. Correlations to Method D 2216 will be performed when required by other test methods.

7.2 Water content specimens must be large enough and selected in such a way that they represent all the material obtained from the test hole. The minimum mass of the water content specimens is that required to provide water content values accurate to 1.0 %.

8. Calculation

8.1 Calculations shown are for mass in grams and volumes in cubic centimetres. Other units are permissible provided the appropriate conversion factors are used to maintain consistency of units throughout the calculations. See 1.6 for additional comments on the usage of inch-pound units.

8.2 Calculate the volume of the test hole as follows:

$$V = (M_1 - M_2)/\rho_1$$

where:

V = volume of the test hole, cm³,
M_1 = mass of the sand used to fill the test hole, funnel and base plate, g (from 7.1.7),
M_2 = mass of the sand used to fill the funnel and base plate (from Annex A1.2.2.6), g, and
ρ_1 = bulk density of the sand (from Annex A2.3.5), g/cm³.

8.3 Calculate the dry mass of material removed from the test hole as follows:

$$M_4 = 100\ M_3/(w + 100)$$

where:

w = water content of the material removed from test hole, %, (from 7.1.10),
M = moist mass of the material from test hole, g, (from 7.1.8), and
M = dry mass of material from test hole, g, or multiply by 0.002205 for lb.

8.4 Calculate the in-place wet and dry density of the material tested as follows:

$$\rho_m = M_3/V$$
$$\rho_d = M_4/V$$

where:

V = volume of the test hole, cm³ (from 8.2),
M_3 = moist mass of the material from the test hole, g, (from 7.1.8),
M_4 = dry mass of the material from the test hole, g, (from 8.3),
ρ_m = wet density of the tested material g/cm³ or its wet unit weight, y_m in lb/ft³ where $y_m = \rho_m \times 62.43$, and
ρ_d = dry density of the tested material, g/cm³ or its dry unit weight, γ_d in lb/ft³ where $\gamma_d = \rho_d \times 62.43$.

8.5 It may be desired to express the in-place density as a percentage of some other density, for example, the laboratory densities determined in accordance with Test Method D 698, D 1557, D 4253 or D 4254. This relation can be determined by dividing the in-place density by the laboratory density and multiplying by 100. Calculations for determining relative density are provided in Test Method D 4254. Corrections for oversize material, if required, should be performed in accordance with Practice D 4718.

9. Report

9.1 Report, as a minimum, the following information:

9.1.1 Test location, elevation, thickness of layer tested, or other pertinent data to locate or identify the test.

9.1.2 Test hole volume, cm³ or ft³.

9.1.3 In-place wet density, g/cm³ or lb/ft³.

9.1.4 In-place dry density, ρ_d, g/cm³.

9.1.5 In-place dry unit weight, KN/m³ ($\rho_d \times 9.807$), or lb/ft³ ($\rho_d \times 62.43$), expressed to the nearest .1 KN/m³, or 1.0 for lb/ft³.

9.1.6 In-place water content of the soil expressed as a percentage of dry mass, and the test method used.

9.1.7 Test apparatus identity and calibrated volume.

9.1.8 Bulk density of the sand used, g/cm³, or lb/ft³.

9.1.9 Visual description of the soil or material designation.

9.1.10 Mass and percentage of oversized particles and the size sieve used, if performed.

9.1.11 Comments on the test, as applicable.

9.1.12 If the in-place dry density or unit weight is expressed as a percentage of another value, include the following:

9.1.12.1 The laboratory test method used.

9.1.12.2 The comparative dry density or unit weight value and water content used.

9.1.12.3 Correction for oversized material and details, if applicable.

9.1.12.4 The comparative percentage of the in-place material to the comparison value.

9.1.13 If the in-place density, unit weight, or water content are to be used for acceptance, include the acceptance criteria applicable to the test.

10. Precision and Bias

10.1 *Statement of Precision*—Due to the nature of the soil or rock materials tested by the method it is either not feasible or too costly at this time to produce multiple specimens that

have uniform physical properties. Any variation observed in the data is just as likely to be due to specimen variation as to operator or laboratory testing variation. Subcommittee D18.08 welcomes proposals that would allow for development of a valid precision statement.

10.2 *Statement of Bias*—There is no accepted reference value for this test method, therefore, bias cannot be determined.

10.3 While no formal round-robin testing has been completed, it is estimated by Subcommittee D18.08 from available data that the results of two properly conducted tests performed by a skilled operator on the same material at a given time and location should not differ by more than approximately 2 lb/ft^3 (3.2 Kg/m^3). Tests performed by unskilled operators on the same material would be expected to yield substantially greater differences.

11. Keywords

11.1 The following keywords are applicable to this test method in accordance with Practice D 3584: acceptance tests; compaction tests; degree of compaction; density tests; earthfill; embankments; field control density; field tests; inplace density; inplace dry density; *in situ* density; relative density; sand cone; soil compaction; soil tests; unit weight.

ANNEXES

(Mandatory Information)

A1. CALIBRATION OF SAND CONE APPARATUS

A1.1 Scope

A1.1.1 This annex describes the procedure for determining the mass of sand contained in the funnel and base plate of the sand-cone apparatus.

A1.1.2 The mass of sand contained in the apparatus and base plate is dependent on the bulk-density of the sand. Consequently, this procedure must be performed for each apparatus whenever there are changes in the sand bulk-densities.

A1.2 Calibration Procedure

A1.2.1 Calibration of the apparatus can be accomplished by either of two methods:

A1.2.1.1 *Method A*—By determining the mass of calibrated sand that can be contained in each funnel and base plate set, or

A1.2.1.2 *Method B*—By determining the volume of sand needed to fill each funnel and base plate set and applying this volume constant whenever new sand bulk-densities are calculated.

A1.2.1.3 Since the mass of sand contained in the apparatus funnel and base plate is dependent on the bulk density of the sand, if Method A is used, it must be repeated whenever the bulk-density of the sand changes.

A1.2.2 All determinations of mass are to be made to the nearest 5 g.

A1.2.3 *Method A:*

A1.2.3.1 Fill the apparatus with sand that is dried and conditioned to the same state anticipated during use in testing.

A1.2.3.2 Determine the mass of the apparatus filled with sand, g.

A1.2.3.3 Place the base plate on a clean, level, plane surface. Invert the container/apparatus and seat the funnel in the flanged center hole in the base plate. Mark and identify the apparatus and base plate so that the same apparatus and plate can be matched and reseated in the same position during testing.

A1.2.3.4 Open the valve fully until the sand flow stops, making sure the apparatus, base plate, or plane surface are not jarred or vibrated before the valve is closed.

A1.2.3.5 Close the valve sharply, remove the apparatus and determine the mass of the apparatus and remaining sand. Calculate the mass of sand used to fill the funnel and base plate as the difference between the initial and final mass.

A1.2.3.6 Repeat the procedure a minimum of three times. The maximum variation between any one determination and the average will not exceed 1 %. Use the average of the three determinations for this value in the test calculations.

A1.2.4 *Method B (Optional):*

A1.2.4.1 When large numbers of tests and batches of sand are anticipated, it may be advantageous to determine the volume of each apparatus and base plate. Baring damage to the apparatus or mismatching of the base plates, this volume will remain constant, and will eliminate the need to repeat Method A when the sand bulk-density changes (see Note A1.1). If this alternative is chosen, the calculations in the field test must be altered to determine the total volume of the sand in the field test hole and apparatus. The volume of the apparatus is then subtracted to determine the volume of the test hole.

A1.2.4.2 Determine the mass of sand required to fill the apparatus funnel and base plate in accordance with A1.2.3, following steps A1.2.3.1 through A1.2.3.6 for each batch of sand.

A1.2.4.3 Calculate the volume of the funnel and base plate by dividing the bulk-density of the sand (as determined in Annex A2) by the mass of sand found in A1.2.3.6. Perform a minimum of three determinations and calculate an average value. The maximum volume variation between any one determination and the average will not exceed 1 %. Use the average of the values when performing test calculations.

NOTE A1.1—The sand-cone apparatus should be routinely inspected for damage that may affect the volume of the cone. Dings, out-of-round, or other damage will affect the volume and will necessitate a redetermination of the volume (if repairable).

A2. CALIBRATION OF DENSITY SAND

A2.1 Scope

A2.1.1 This annex is used for determining the bulk-density (calibration) of the sand for use in this test method.

A2.1.2 The calibration determines an average density of the sand for use in calculating the volume of the test hole.

A2.2 Equipment Required

A2.2.1 *Container*—Select a container of known volume that is approximately the same size and allows the sand to fall approximately the same distance as the hole excavated during a field test. The 1/30 ft^3 (944 cm^3) and 1/13.33 ft^3 (2124 cm^3) molds specified in Test Methods D 698, or the 0.1 ft^3 (2830 cm^3) mold specified in Test Method D 4253 are recommended. Alternatively, cast duplicates of actual test holes may be used. This is accomplished by forming plaster of paris negatives in actual test holes over a range of test volumes, and using these as forms for portland cement concrete castings. These should be cast against a flat plane surface, and after the removal of the negative, sealed water tight and the volume determined in accordance with the procedure in Test Method D 4253.

A2.2.1.1 Determine the container volume to 1 % using water in accordance with the procedures described in Test Method D 4253.

A2.2.2 *Sand-Cone Apparatus*—Use a sand cone apparatus of the same size and design as will be used during field testing.

A2.2.2.1 Flow characteristics through different value assemblies have been shown to cause different bulk-density values. Bulk-density determinations will be required for each apparatus set unless other assemblies are determined to provide the same results.

A2.2.3 *Balance or Scale*—A balance or scale having a sufficient capacity to determine the mass of the calibration container filled with sand. For 0.500 ft^3 (14 200 cm^3) containers, a balance having a minimum capacity of 50 lb (20 kg) and meeting the requirements of Specification D 4753 for 0.01 lb (5 g) readability is required.

A2.2.4 *Metal Straightedge*, about 2 in. (50 cm) wide, at least ⅛ in. (3 mm) thick, and length approximately 1.5 times the diameter of the calibration container.

A2.3 Bulk-Density Determination

A2.3.1 Fill the assembled apparatus with sand. The sand is to be dried and conditioned to the same state anticipated during use.

A2.3.2 Determine and record the mass of the calibration container when empty.

A2.3.3 *Method A (Preferred):*

A2.3.3.1 When the calibration container has the same diameter as the flanged center hole in the base plate, invert and center the sand filled apparatus and base plate on the calibration container.

A2.3.3.2 Fully open the valve and allow the sand to fill the container. When the sand flow stops, close the valve.

A2.3.3.3 Determine the mass of the apparatus and remaining sand. Calculate the net mass of sand in the calibration container by subtracting the mass of sand contained in the cone and base plate (as determined in Annex A1) and record.

A2.3.4 *Method B (Alternative):*

A2.3.4.1 Invert and support the apparatus over the calibration container so that the sand falls approximately the same distance and location as in a field test, and fully open the valve.

A2.3.4.2 Fill the container until it just overflows and close the valve. Using a minimum number of strokes and taking care not to jar or densify the sand, carefully strike off excess sand to a smooth level surface. Any vibration or jarring during the bulk-density determination will result in settling and densifying the sand, leading to erroneous results.

A2.3.4.3 Clean any sand from the outside of the calibration container. Determine the mass of the container and sand. Record the net mass of the sand by subtracting the mass of the empty container.

A2.3.5 Perform at least three bulk-density determinations and calculate the average. The maximum variation between any one determination and the average will not exceed 1 %. Repeated determinations not meeting these requirements indicates nonuniform sand density, and the sand source should be re-evaluated for suitability. The average value obtained is to be used in the test calculations.

A2.4 Calculation

A2.4.1 Calculate the bulk-density of the sand as follows:

$$\rho_1 = M_5/V_1$$

where:

ρ_1 = bulk-density of the sand, g/cm^3, (multiply by 9.807 for KN/m^3, or 62.43 for lb/ft^3),

M_5 = mass of the sand to fill the calibration container, g, (from A2.3.4.3), and

V_1 = volume of the calibration container, cm^3 (from A2.2.1.1).

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Test Method for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lbf/ft^3 (2,700 kN-m/m^3))[1]

This standard is issued under the fixed designation D 1557; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers laboratory compaction procedures used to determine the relationship between water content and dry unit weight of soils (compaction curve) compacted in a 4- or 6-in. (101.6 or 152.4 mm) diameter mold with a 10-lbf. (44.5-N) rammer dropped from a height of 18 in. (457 mm) producing a compactive effort of 56,000 ft-lbf/ft^3 (2,700 kN-m/m^3).

NOTE 1—Soils and soil-aggregate mixtures should be regarded as natural occurring fine- or coarse-grained soils or composites or mixtures of natural soils, or mixtures of natural and processed soils or aggregates such as silt, gravel, or crushed rock.

NOTE 2—The equipment and procedures are the same as proposed by the U.S. Corps of Engineers in 1945. The modified effort test (see 3.2.2) is sometimes referred to as the Modified Proctor Compaction Test.

1.2 This test method applies only to soils that have 30 % or less by weight of their particles retained on the ¾-in. (19.0-mm) sieve.

NOTE 3—For relationships between unit weights and water contents of soils with 30 % or less by weight of material retained on the ¾-in. (19.0-mm) sieve to unit weights and water contents of the fraction passing the ¾-in. (19.0-mm) sieve, see Practice D 4718.

1.3 Three alternative procedures are provided. The procedure used shall be as indicated in the specification for the material being tested. If no procedure is specified, the choice should be based on the material gradation.

1.3.1 *Procedure A:*

1.3.1.1 *Mold*—4-in. (101.6-mm) diameter.

1.3.1.2 *Material*—Passing No. 4 (4.75-mm) sieve.

1.3.1.3 *Layers*—Five.

1.3.1.4 *Blows per layer*—25.

1.3.1.5 *Use*—May be used if 20 % or less by weight of the material is retained on the No. 4 (4.75-mm) sieve.

1.3.1.6 *Other Use*—If this procedure is not specified, materials that meet these gradation requirements may be tested using Procedures B or C.

1.3.2 *Procedure B:*

1.3.2.1 *Mold*—4-in. (101.6-mm) diameter.

1.3.2.2 *Material*—Passing ⅜-in. (9.5-mm) sieve.

1.3.2.3 *Layers*—Five.

1.3.2.4 *Blows per layer*—25.

1.3.2.5 *Use*—Shall be used if more than 20 % by weight of the material is retained on the No. 4 (4.75-mm) sieve and 20 % or less by weight of the material is retained on the ⅜-in. (9.5-mm) sieve.

1.3.2.6 *Other Use*—If this procedure is not specified, materials that meet these gradation requirements may be tested using Procedure C.

1.3.3 *Procedure C:*

1.3.3.1 *Mold*—6-in. (152.4-mm) diameter.

1.3.3.2 *Material*—Passing ¾-inch (19.0-mm) sieve.

1.3.3.3 *Layers*—Five.

1.3.3.4 *Blows per layer*—56.

1.3.3.5 *Use*—Shall be used if more than 20 % by weight of the material is retained on the ⅜-in. (9.53-mm) sieve and less than 30 % by weight of the material is retained on the ¾-in. (19.0-mm) sieve.

1.3.4 The 6-in. (152.4-mm) diameter mold shall not be used with Procedure A or B.

NOTE 4—Results have been found to vary slightly when a material is tested at the same compactive effort in different size molds.

1.4 If the test specimen contains more than 5 % by weight oversize fraction (coarse fraction) and the material will not be included in the test, corrections must be made to the unit weight and water content of the test specimen or to the appropriate field in place density test specimen using Practice D 4718.

1.5 This test method will generally produce well defined maximum dry unit weight for non-free draining soils. If this test method is used for free draining soils the maximum unit weight may not be well defined, and can be less than obtained using Test Methods D 4253.

1.6 The values in inch-pound units are to be regarded as the standard. The values stated in SI units are provided for information only.

1.6.1 In the engineering profession it is customary practice to use, interchangeably, units representing both mass and force, unless dynamic calculations ($F = Ma$) are involved. This implicitly combines two separate systems of units, that is, the absolute system and the gravimetric system. It is scientifically undesirable to combine the use of two separate systems within a single standard. This test method has been written using inch-pound units (gravimetric system) where the pound (lbf) represents a unit of force. The use of mass (lbm) is for convenience of units and is not intended to convey the use is scientifically correct. Conversions are given in the SI system in accordance with Practice E 380. The use of balances or scales recording pounds of mass (lbm), or the recording of density in lbm/ft^3 should not be regarded as nonconformance with this standard.

1.7 *This standard does not purport to address all of the safety problems, if any, associated with its use. It is the*

[1] This test method is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.03 on Texture, Plasticity and Density Characteristics of Soils.

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responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 *ASTM Standards:*

C 127 Test Method for Specific Gravity and Absorption of Coarse Aggregate[2]

C 136 Method for Sieve Analysis of Fine and Coarse Aggregates[2]

D 422 Method for Particle Size Analysis of Soils[3]

D 653 Terminology Relating to Soil, Rock, and Contained Fluids[3]

D 698 Test Method for Laboratory Compaction Characteristics of Soil Using Standard Effort [12,400 ft-lbf/ft^3 (600 kN-mJ/m^3)][3]

D 854 Test Method for Specific Gravity of Soils[3]

D 2168 Test Methods for Calibration of Laboratory Mechanical-Rammer Soil Compactors[3]

D 2216 Test Method for Laboratory Determination of Water (Moisture) Content of Soil, Rock and Soil Aggregate Mixtures[3]

D 2487 Test Method for Classification of Soils for Engineering Purposes[3]

D 2488 Practice for Description and Identification of Soils (Visual-Manual Procedure)[3]

D 4220 Practices for Preserving and Transporting Soil Samples[3]

D 4253 Test Methods for Maximum Index Density of Soils Using a Vibratory Table[3]

D 4718 Practice for Correction of Unit Weight and Water Content for Soils Containing Oversize Particles[3]

D 4753 Specification for Evaluating, Selecting and Specifying Balances and Scales For Use in Soil and Rock Testing[3]

E 1 Specification for ASTM Thermometers[4]

E 11 Specification for Wire-Cloth Sieves for Testing Purposes[4]

E 319 Practice for the Evaluation of Single-Pan Mechanical Balances[4]

E 380 Practice for Use of the SI International System of Units (SI)[4]

3. Terminology

3.1 *Definitions*—See Terminology D 653 for general definitions.

3.2 *Description of Terms Specific to This Standard:*

3.2.1 *modified effort*—the term for the 56 000 ft-lbf/ft^3 (2700 kN-m/m^3) compactive effort applied by the equipment and procedures of this test.

3.2.2 *modified maximum dry unit weight, γ_{dmax} (lbf/ft^3 (kN/m^3))*—the maximum value defined by the compaction curve for a compaction test using modified effort.

3.2.3 *modified optimum water content, w_o (%)*—the water content at which the soil can be compacted to the maximum dry unit weight using modified compactive effort.

3.2.4 *oversize fraction (coarse fraction), P_c (%)*—the portion of total sample not used in performing the compaction test; it may be the portion of total sample retained on the No. 4 (3.74-mm), 3/8-in. (9.5-mm), or 3/4-in. (19.0-mm) sieve.

3.2.5 *iest fraction (finer fraction), P_F (%)*—the portion of the total sample used in performing the compaction test; it may be fraction passing the No. 4 (4.75-mm) sieve in Procedure A, minus 3/8-in. (9.5-mm) sieve in Procedure B, or minus 3/4-in. (19.0-mm) sieve in Procedure C.

4. Summary of Test Method

4.1 A soil at a selected water content is placed in five layers into a mold of given dimensions, with each layer compacted by 25 or 56 blows of a 10-lbf (44.5-N) rammer dropped from a distance of 18-in. (457-mm), subjecting the soil to a total compactive effort of about 56 000 ft—lbf/ft^3 (2700 kN-m/m^3). The resulting dry unit weight is determined. The procedure is repeated for a sufficient number of water contents to establish a relationship between the dry unit weight and the water content for the soil. This data, when plotted, represents a curvilinear relationship known as the compaction curve. The values of optimum water content and modified maximum dry unit weight are determined from the compaction curve.

5. Significance and Use

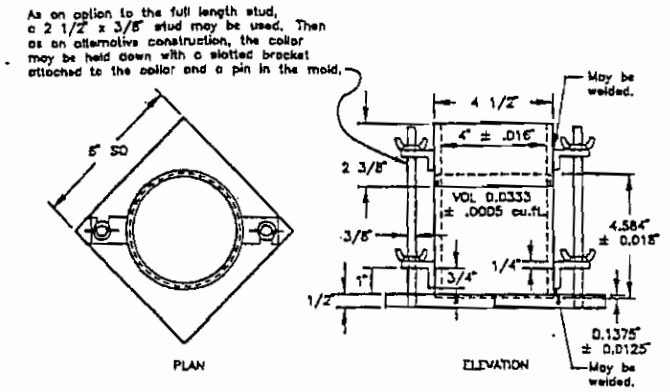
5.1 Soil placed as engineering fill (embankments, foundation pads, road bases) is compacted to a dense state to obtain satisfactory engineering properties such as, shear strength, compressibility, or permeability. Also, foundation soils are often compacted to improve their engineering properties. Laboratory compaction tests provide the basis for determining the percent compaction and water content needed to achieve the required engineering properties, and for controlling construction to assure that the required compaction and water contents are achieved.

5.2 During design of an engineered fill, shear, consolidation, permeability, or other tests require preparation of test specimens by compacting at some water content to some unit weight. It is common practice to first determine the optimum water content (w_o) and maximum dry unit weight (γ_{dmax}) by means of a compaction test. Test specimens are compacted at a selected water content (w), either wet or dry of optimum (w_o) or at optimum (w_o), and at a selected dry unit weight related to a percentage of maximum dry unit weight (γ_{dmax}). The selection of water content (w), either wet or dry of optimum (w_o) or at optimum (w_o) and the dry unit weight (γ_{dmax}) may be based on past experience, or a range of values may be investigated to determine the necessary percent of compaction.

6. Apparatus

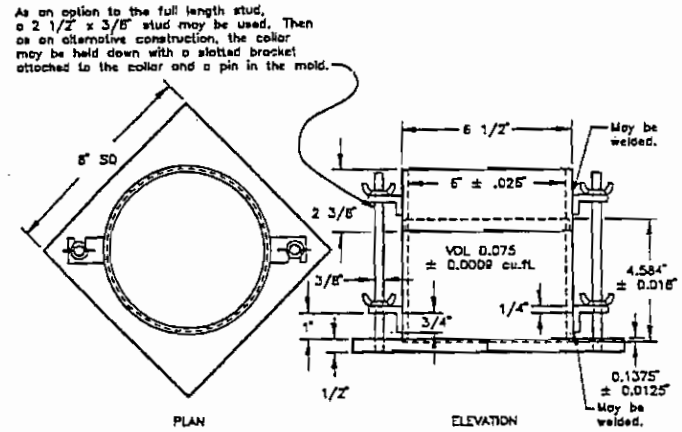
6.1 *Mold Assembly*—The molds shall be cylindrical in shape, made of rigid metal and be within the capacity and dimensions indicated in 6.1.1 or 6.1.2 and Figs. 1 and 2. The walls of the mold may be solid, split, or tapered. The "split" type, may consist of two half-round sections, or a section of pipe split along one element, which can be securely locked together to form a cylinder meeting the requirements of this section. The "tapered" type shall an internal diameter taper that is uniform and not more than 0.200 in./ft (16.7 mm/m)

[2] *Annual Book of ASTM Standards*, Vol 04.02.
[3] *Annual Book of ASTM Standards*, Vol 04.08.
[4] *Annual Book of ASTM Standards*, Vol 14.02.



see Table 2 for metric equivalents

FIG. 1 Cylindrical Mold, 4.0-in.



see Table 2 for metric equivalents

FIG. 2 Cylindrical Mold, 6.0-in.

of mold height. Each mold shall have a base plate and an extension collar assembly, both made of rigid metal and constructed so they can be securely attached and easily detached from the mold. The extension collar assembly shall have a height extending above the top of the mold of at least 2.0 in. (50.8 mm) which may include an upper section that flares out to form a funnel provided there is at least a 0.75-in. (19.0-mm) straight cylindrical section beneath it. The extension collar shall align with the inside of the mold. The bottom of the base plate and bottom of the centrally recessed area that accepts the cylindrical mold shall be planar.

6.1.1 *Mold, 4 in.*—A mold having a 4.000 ± 0.016-in. (101.6 ± 0.4-mm) average inside diameter, a height of 4.584 ± 0.018 in. (116.4 ± 0.5 mm) and a volume of 0.0333 ± 0.0005 ft^3 (944 ± 14 cm^3). A mold assembly having the minimum required features is shown in Fig. 1.

6.1.2 *Mold, 6 in.*—A mold having a 6.000 ± 0.026-in. (152.4 ± 0.7-mm) average inside diameter, a height of 4.584 ± 0.018 in. (116.4 ± 0.5 mm), and a volume of 0.075 ± 0.0009 ft^3 (2124 ± 25 cm^3). A mold assembly having the minimum required features is shown in Fig. 2.

6.2 *Rammer*—A rammer, either manually operated as described further in 6.2.1 or mechanically operated as described in 6.2.2. The rammer shall fall freely through a distance of 18 ± 0.05 in. (457.2 ± 1.6 mm) from the surface of the specimen. The mass of the rammer shall be 10 ± 0.02 lbm (4.54 ± 0.01 kg), except that the mass of the mechanical rammers may be adjusted as described in Test Methods D 2168 (see Note 5). The striking face of the rammer shall be planar and circular, except as noted in 6.2.2.3, with a diameter when new of 2.000 ± 0.005 in. (50.80 ± 0.13 mm). The rammer shall be replaced if the striking face becomes worn or bellied to the extent that the diameter exceeds 2.000 ± 0.01 in. (50.80 ± 0.25 mm).

NOTE 5—It is a common and acceptable practice in the inch-pound system to assume that the mass of the rammer is equal to its mass determined using either a kilogram or pound balance and 1 lbf is equal to 1 lbm or 0.4536 kg or 1 N is equal to 0.2248 lbm or 0.1020 kg.

6.2.1 *Manual Rammer*—The rammer shall be equipped with a guide sleeve that has sufficient clearance that the free fall of the rammer shaft and head is not restricted. The guide sleeve shall have at least four vent holes at each end (eight holes total) located with centers ¾ ± 1/16 in. (19.0 ± 1.6 mm) from each end and spaced 90° apart. The minimum diameter of the vent holes shall be ⅜ in. (9.5 mm). Additional holes or slots may be incorporated in the guide sleeve.

6.2.2 *Mechanical Rammer-Circular Face*—The rammer shall operate mechanically in such a manner as to provide uniform and complete coverage of the specimen surface. There shall be 0.10 ± 0.03-in. (2.5 ± 0.8-mm) clearance between the rammer and the inside surface of the mold at its smallest diameter. The mechanical rammer shall meet the calibration requirements of Test Methods D 2168. The mechanical rammer shall be equipped with a positive mechanical means to support the rammer when not in operation.

6.2.2.3 *Mechanical Rammer-Sector Face*—When used with the 6.0-in. (152.4-mm) mold, a sector face rammer may be used in place of the circular face rammer. The specimen contact face shall have the shape of a sector of a circle of radius equal to 2.90 ± 0.02 in. (73.7 ± 0.5 mm). The rammer shall operate in such a manner that the vertex of the sector is positioned at the center of the specimen.

6.3 *Sample Extruder (optional)*—A jack, frame or other device adapted for the purpose of extruding compacted specimens from the mold.

6.4 *Balance*—A class GP5 balance meeting the requirements of Specification D 4753 for a balance of 1-g readability.

6.5 *Drying Oven*—Thermostatically controlled, preferably of a forced-draft type and capable of maintaining a uniform temperature of 230 ± 9°F (110 ± 5°C) throughout the drying chamber.

6.6 *Straightedge*—A stiff metal straightedge of any convenient length but not less than 10 in. (254 mm). The total length of the straightedge shall be machined straight to a tolerance of ±0.005 in. (±0.1 mm). The scraping edge shall be beveled if it is thicker than ⅛ in. (3 mm).

6.7 *Sieves*—¾-in. (19.0-mm), ⅜-in. (9.5-mm), and No. 4 (4.75-mm), conforming to the requirements of Specification E 11.

6.8 *Mixing Tools*—Miscellaneous tools such as mixing pan, spoon, trowel, spatula, spray bottle, etc., or a suitable mechanical device for thoroughly mixing the sample of soil with increments of water.

7. Test Sample

7.1 The required sample mass for Procedures A and B is approximately 35 lbm (16 kg), and for Procedure C is approximately 65 lbm (29 kg) of dry soil. Therefore, the field sample should have a moist mass of at least 50 lbm (23 kg) and 100 lbm (45 kg), respectively.

7.2 Determine the percentage of material retained on the No. 4 (4.75-mm), ⅜-in. (9.5-mm), or ¾-in. (19.0-mm) sieve as appropriate for choosing Procedure A, B, or C. Make this determination by separating out a representative portion from the total sample and determining the percentages passing the sieves of interest by Test Methods D 422 or C 136. It is only necessary to calculate percentages for the sieve or sieves for which information is desired.

8. Preparation of Apparatus

8.1 Select the proper compaction mold in accordance with the procedure (A, B, or C) being used. Determine and record its mass to the nearest gram. Assemble the mold, base and extension collar. Check the alignment of the inner wall of the mold and mold extension collar. Adjust if necessary.

8.2 Check that the rammer assembly is in good working condition and that parts are not loose or worn. Make any necessary adjustments or repairs. If adjustments or repairs are made, the rammer must be recalibrated.

9. Calibration

9.1 Perform calibrations before initial use, after repairs or other occurrences that might affect the test results, at intervals not exceeding 1000 test specimens, or annually, whichever occurs first, for the following apparatus:

9.1.2 *Balance*—Evaluate in accordance with Specification D 4753.

9.1.3 *Molds*—Determine the volume as described in Annex A1.

9.1.4 *Manual Rammer*—Verify the free fall distance, rammer mass, and rammer face in accordance with 6.2. Verify the guide sleeve requirements in accordance with 6.2.1.

9.1.5 *Mechanical Rammer*—Calibrate and adjust the mechanical rammer in accordance with Test Methods D 2168. In addition, the clearance between the rammer and the inside surface of the mold shall be verified in accordance with 6.2.2.

10. Procedure

10.1 *Soils:*

10.1.1 Do not reuse soil that has been previously laboratory compacted.

10.1.2 When using this test method for soils containing hydrated halloysite, or where past experience with a particular soil indicates that results will be altered by air drying, use the moist preparation method (see 10.2).

10.1.3 Prepare the soil specimens for testing in accordance with 10.2 (preferred) or with 10.3.

10.2 *Moist Preparation Method (preferred)*—Without previously drying the sample, pass it through a No. 4 (4.75-mm), ⅜-in. (9.5-mm), or ¾-in. (19.0-mm) sieve, depending on the procedure (A, B, or C) being used. Determine the water content of the processed soil.

10.2.1 Prepare at least four (preferably five) specimens having water contents such that they bracket the estimated optimum water content. A specimen having a water content close to optimum should be prepared first by trial additions of water and mixing (see Note 6). Select water contents for the rest of the specimens to provide at least two specimens wet and two specimens dry of optimum, and water contents varying by about 2 %. At least two water contents are necessary on the wet and dry side of optimum to accurately define the dry unit weight compaction curve (see 10.5). Some soils with very high optimum water content or a relatively flat compaction curve may require larger water content increments to obtain a well defined maximum dry unit weight. Water content increments should not exceed 4 %.

NOTE 6—With practice it is usually possible to visually judge a point near optimum water content. Typically, soil at optimum water content can be squeezed into a lump that sticks together when hand pressure is released, but will break cleanly into two sections when "bent". At water contents dry of optimum soils tend to crumble; wet of optimum soils tend to stick together in a sticky cohesive mass. Optimum water content is typically slightly less than the plastic limit.

10.2.2 Use approximately 5 lbm (2.3 kg) of the sieved soil for each specimen to be compacted using Procedure A or B, or 13 lbm (5.9 kg) using Procedure C. To obtain the specimen water contents selected in 10.2.1, add or remove the required amounts of water as follows: to add water, spray it into the soil during mixing; to remove water, allow the soil to dry in air at ambient temperature or in a drying apparatus such that the temperature of the sample does not exceed 140°F (60°C). Mix the soil frequently during drying to maintain even water content distribution. Thoroughly mix each specimen to ensure even distribution of water throughout and then place in a separate covered container and allow to stand in accordance with Table 1 prior to compaction. For the purpose of selecting a standing time, the soil may be classified by Test Method D 2487, Practice D 2488 or data on other samples from the same material source. For referee testing, classification shall be by Test Method D 2487.

10.3 *Dry Preparation Method*—If the sample is too damp to be friable, reduce the water content by air drying until the material is friable. Drying may be in air or by the use of drying apparatus such that the temperature of the sample does not exceed 140°F (60°C). Thoroughly break up the aggregations in such a manner as to avoid breaking individual particles. Pass the material through the appropriate sieve: No. 4 (4.75 mm), ⅜ in. (9.5 mm), or ¾ in. (19.0 mm). When preparing the material by passing over the ¾ in. sieve for compaction in the 6 in. mold, break up aggregations sufficiently to at least pass the ⅜ in. sieve in order to facilitate the distribution of water throughout the soil in later mixing.

10.3.1 Prepare at least four (preferably five) specimens in accordance with 10.2.1.

10.3.2 Use approximately 5 lbm (2.3 kg) of the sieved soil for each specimen to be compacted using Procedure A or B,

TABLE 1 Required Standing Times of Moisturized Specimens

Classification	Minimum Standing Time, h
GW, GP, SW, SP	no requirement
GM, SM	3
All other soils	16

TABLE 2 Metric Equivalents for Figs. 1 and 2

in.	mm
0.016	0.41
0.026	0.66
0.032	0.81
0.028	0.71
½	12.70
2½	63.50
2⅝	66.70
4	101.60
4½	114.30
4.584	116.43
4¾	120.60
6	152.40
6½	165.10
6⅝	168.30
6¾	171.40
8¼	208.60
ft³	**cm³**
1/30 (0.0333)	943
0.0005	14
1/13.333 (0.0750)	2,124
0.0011	31

or 13 lbm (5.9 kg) using Procedure C. Add the required amounts of water to bring the water contents of the specimens to the values selected in 10.3.1. Follow the specimen preparation procedure specified in 10.2.2 for drying the soil or adding water into the soil and curing each test specimen.

10.4 *Compaction*—After curing, if required, each specimen shall be compacted as follows:

10.4.1 Determine and record the mass of the mold or mold and base plate.

10.4.2 Assemble and secure the mold and collar to the base plate. The mold shall rest on a uniform rigid foundation, such as provided by a cylinder or cube of concrete with a mass of not less than 200 lbm (91 kg). Secure the base plate to the rigid foundation. The method of attachment to the rigid foundation shall allow easy removal of the assembled mold, collar and base plate after compaction is completed.

10.4.3 Compact the specimen in five layers. After compaction, each layer should be approximately equal in thickness. Prior to compaction, place the loose soil into the mold and spread into a layer of uniform thickness. Lightly tamp the soil prior to compaction until it is not in a fluffy or loose state, using either the manual compaction rammer or a 2 in. (5 mm) diameter cylinder. Following compaction of each of the first four layers, any soil adjacent to the mold walls that has not been compacted or extends above the compacted surface shall be trimmed. The trimmed soil may be included with the additional soil for the next layer. A knife or other suitable device may be used. The total amount of soil used shall be such that the fifth compacted layer slightly extends into the collar, but does not exceed ¼ in. (6 mm) above the top of the mold. If the fifth layer does extend above the top of the mold by more than ¼ in. (6 mm), the specimen shall be discarded. The specimen shall be discarded when the last blow on the rammer for the fifth layer results in the bottom of the rammer extending below the top of the compaction mold.

10.4.4 Compact each layer with 25 blows for the 4 in. (101.6 mm) mold or with 56 blows for the 6 in. (152.4 mm) mold.

NOTE 7—When compacting specimens wetter than optimum water content, uneven compacted surfaces can occur and operator judgment is required as to the average height of the specimen.

10.4.5 In operating the manual rammer, take care to avoid lifting the guide sleeve during the rammer upstroke. Hold the guide sleeve steady and within 5° of vertical. Apply the blows at a uniform rate of approximately 25 blows/min and in such a manner as to provide complete, uniform coverage of the specimen surface.

10.4.6 Following compaction of the last layer, remove the collar and base plate from the mold, except as noted in 10.4.7. A knife may be used to trim the soil adjacent to the collar to loosen the soil from the collar before removal to avoid disrupting the soil below the top of the mold.

10.4.7 Carefully trim the compacted specimen even with the top and bottom of the mold by means of the straightedge scraped across the top and bottom of the mold to form a plane surface even with the top and bottom of the mold. Initial trimming of the specimen above the top of the mold with a knife may prevent tearing out soil below the top of the mold. Fill any holes in either surface with unused or trimmed soil from the specimen, press in with the fingers, and again scrape the straightedge across the top and bottom of the mold. Repeat the appropriate preceding operations on the bottom of the specimen when the mold volume was determined without the base plate. For very wet or dry soils, soil or water may be lost if the base plate is removed. For these situations, leave the base plate attached to the mold. When the base plate is left attached, the volume of the mold must be calibrated with the base plate attached to the mold rather than a plastic or glass plate as noted in Annex A1 (A1.4.1).

10.4.8 Determine and record the mass of the specimen and mold to the nearest gram. When the base plate is left attached, determine and record the mass of the specimen, mold and base plate to the nearest gram.

10.4.9 Remove the material from the mold. Obtain a specimen for water content by using either the whole specimen (preferred method) or a representative portion. When the entire specimen is used, break it up to facilitate drying. Otherwise, obtain a portion by slicing the compacted specimen axially through the center and removing about 500 g of material from the cut faces. Obtain the water content in accordance with Test Method D 2216.

10.5 Following compaction of the last specimen, compare the wet unit weights to ensure that a desired pattern of obtaining data on each side of the optimum water content will be attained for the dry unit weight compaction curve. Plotting the wet unit weight and water content of each compacted specimen can be an aid in making the above evaluation. If the desired pattern is not obtained, additional compacted specimens will be required. Generally, one water content value wet of the water content defining the maximum wet unit weight is sufficient to ensure data on the wet side of optimum water content for the maximum dry unit weight.

11. Calculation

11.1 Calculate the dry unit weight and water content of each compacted specimen as explained in 11.3 and 11.4. Plot the values and draw the compaction curve as a smooth curve

through the points (see example, Fig. 3). Plot dry unit weight to the nearest 0.1 lbf/ft³ (0.2 kN/m³) and water content to the nearest 0.1 %. From the compaction curve, determine the optimum water content and maximum dry unit weight. If more than 5 % by weight of oversize material was removed from the sample, calculate the corrected optimum water content and corrected maximum dry unit weight of the total material using Practice D 4718. This correction may be made to the appropriate field in place density test specimen rather than to the laboratory test specimen.

11.2 Plot the 100 % saturation curve. Values of water content for the condition of 100 % saturation can be calculated as explained in 11.5 (see example, Fig. 3).

NOTE 8—The 100 % saturation curve is an aid in drawing the compaction curve. For soils containing more than approximately 10 % fines at water contents well above optimum, the two curves generally become roughly parallel with the wet side of the compaction curve between 92 % to 95 % saturation. Theoretically, the compaction curve cannot plot to the right of the 100 % saturation curve. If it does, there is an error in specific gravity, in measurements, in calculations, in test procedures, or in plotting.

NOTE 9—The 100 % saturation curve is sometimes referred to as the zero air voids curve or the complete saturation curve.

11.3 *Water Content, w*—Calculate in accordance with Test Method D 2216.

11.4 *Dry Unit Weights*—Calculate the moist density (Eq 1), the dry density (Eq 2), and then the dry unit weight (Eq 3) as follows:

$$\rho_m = 1000(M_t - M_{md})/V \quad (1)$$

where:

ρ_m = moist density of compacted specimen, Mg/m³,
M_t = mass of moist specimen and mold, kg,
M_{md} = mass of compaction mold, kg, and

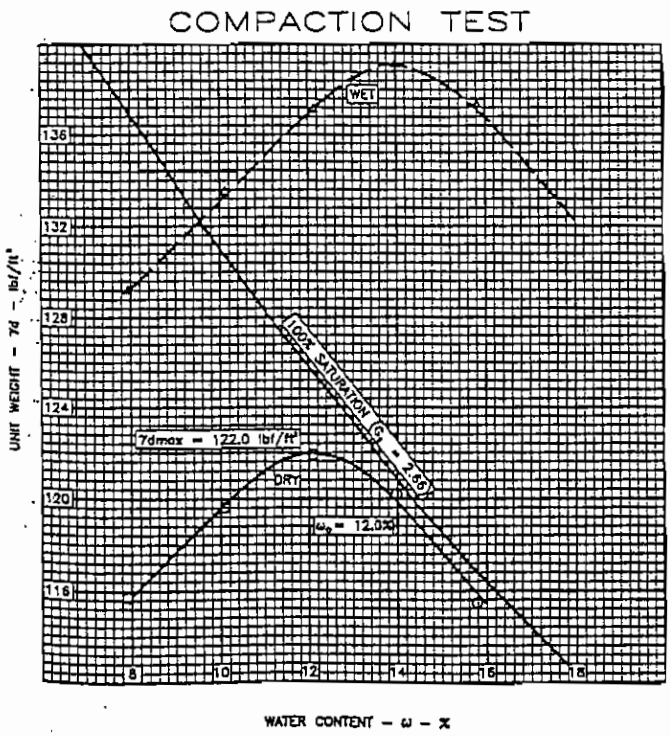


FIG. 3 Example Compaction Curve Plotting

V = volume of compaction mold, m³ (see Annex A1).

$$\rho_d = \rho_m/(1 + w/100) \quad (2)$$

where:

ρ_d = dry density of compacted specimen, Mg/m³, and
w = water content, %.

$$\gamma_d = 62.43\ \rho_d \text{ in lbf/ft}^3 \quad (3)$$
or
$$\gamma_d = 9.807\ \rho_d \text{ in kN/m}^3$$

where:

γ_d = dry unit weight of compacted specimen.

11.5 To calculate points for plotting the 100 % saturation curve or zero air voids curve select values of dry unit weight, calculate corresponding values of water content corresponding to the condition of 100 % saturation as follows:

$$w_{sat} = \frac{(\gamma_w)G_s - \gamma d}{(\gamma d)(G_s)} \times 100 \quad (4)$$

where:

w_{sat} = water content for complete saturation, %,
γ_w = unit weight of water, 62.43 lbf/ft³ (9.807 kN/m³),
γ_d = dry unit weight of soil, and
G_s = specific gravity of soil.

NOTE 10—Specific gravity may be estimated for the test specimen on the basis of test data from other samples of the same soil classification and source. Otherwise, a specific gravity test (Test Method D 854) is necessary.

12. Report

12.1 Report the following information:

12.1.1 Procedure used (A, B, or C).

12.1.2 Preparation method used (moist or dry).

12.1.3 As-received water content, if determined.

12.1.4 Modified optimum water content, to the nearest 0.5 %.

12.1.5 Modified maximum (optimum) dry unit weight, to the nearest 0.5 lbf/ft³.

12.1.6 Description of rammer (manual or mechanical).

12.1.7 Soil sieve data when applicable for determination of procedure (A, B, or C) used.

12.1.8 Description of material used in test, by Practice D 2488, or classification by Test Method D 2487.

12.1.9 Specific gravity and method of determination.

12.1.10 Origin of material used in test, for example, project, location, depth, and the like.

12.1.11 Compaction curve plot showing compaction points used to establish compaction curve, and 100 % saturation curve, point of maximum dry unit weight and optimum water content.

12.1.12 Oversize correction data if used, including the oversize fraction (coarse fraction), P_c in %.

13. Precision and Bias

13.1 *Precision*—Data are being evaluated to determine the precision of this test method. In addition, pertinent data is being solicited from users of the test method.

13.2 *Bias*—It is not possible to obtain information on bias because there is no other method of determining the values of modified maximum dry unit weight and optimum water content.

14. Keywords

14.1 compaction characteristics; density; impact compaction using modified effort; laboratory tests; modified proctor test; moisture-density curves; soil compaction

ANNEX

(Mandatory Information)

A1. VOLUME OF COMPACTION MOLD

A1.1 Scope

A1.1.1 This annex describes the procedure for determining the volume of a compaction mold.

A1.1.2 The volume is determined by a water-filled method and checked by a linear-measurement method.

A1.2 Apparatus

A1.2.1 In addition to the apparatus listed in Section 6, the following items are required:

A1.2.1.1 *Vernier or Dial Caliper*, having a measuring range of at least 0 to 6 in. (0 to 150 mm) and readable to at least 0.001 in. (0.02 mm).

A1.2.1.2 *Inside Micrometer*, having a measuring range of at least 2 to 12 in. (50 to 300 mm) and readable to at least 0.001 in. (0.02 mm).

A1.2.1.3 *Plastic or Glass Plates*—Two plastic or glass plates about 8 in.^{2} by ¼ in. thick (200 mm^2 by 6 mm).

A1.2.1.4 *Thermometer*—0 to 50°C range, 0.5°C graduations, conforming to the requirements of Specification E 1.

A1.2.1.5 *Stopcock Grease* or similar sealant.

A1.2.1.6 *Miscellaneous equipment*—Bulb syringe, towels, etc.

A1.3 Precautions

A1.3.1 Perform this procedure in an area isolated from drafts or extreme temperature fluctuations.

A1.4 Procedure

A1.4.1 *Water-Filling Method:*

A1.4.1.1 Lightly grease the bottom of the compaction mold and place it on one of the plastic or glass plates. Lightly grease the top of the mold. Be careful not to get grease on the inside of the mold. If it is necessary to use the base plate, as noted in 10.4.7, place the greased mold onto the base plate and secure with the locking studs.

A1.4.1.2 Determine the mass of the greased mold and both plastic or glass plates to the nearest 0.01 lbm (1 g) and record. When the base plate is being used in lieu of the bottom plastic or glass plate determine the mass of the mold, base plate and a single plastic or glass plate to be used on top of the mold to the nearest 0.01 lbm (1 g) and record.

A1.4.1.3 Place the mold and the bottom plate on a firm, level surface and fill the mold with water to slightly above its rim.

A1.4.1.4 Slide the second plate over the top surface of the mold so that the mold remains completely filled with water and air bubbles are not entrapped. Add or remove water as necessary with a bulb syringe.

A1.4.1.5 Completely dry any excess water from the outside of the mold and plates.

A1.4.1.6 Determine the mass of the mold, plates and water and record to the nearest 0.01 lbm (1 g).

A1.4.1.7 Determine the temperature of the water in the mold to the nearest 1°C and record. Determine and record the absolute density of water from Table A1.1.

A1.4.1.8 Calculate the mass of water in the mold by subtracting the mass determined in A1.4.1.2 from the mass determined in A1.4.1.6.

A1.4.1.9 Calculate the volume of water by dividing the mass of water by the density of water and record to the nearest 0.0001 ft^3 (1 cm^3).

A1.4.1.10 When the base plate is used for the calibration of the mold volume repeat steps A1.4.1.3 through A1.4.1.9.

A1.4.2 *Linear Measurement Method:*

A1.4.2.1 Using either the vernier caliper or the inside micrometer, measure the diameter of the mold six times at the top of the mold and six times at the bottom of the mold spacing each of the six top and bottom measurements equally around the circumference of the mold. Record the values to the nearest 0.001 in. (0.02 mm).

A1.4.2.2 Using the vernier caliper, measure the inside height of the mold by making three measurements equally spaced around the circumference of the mold. Record values to the nearest 0.001 in. (0.02 mm).

A1.4.2.3 Calculate the average top diameter, average bottom diameter and average height.

A1.4.2.4 Calculate the volume of the mold and record to the nearest 0.0001 ft^3 (1 cm^3) using Eq A1a (for inch-pound) or A1b (for SI):

$$V = \frac{(\pi)(h)(d_t + d_b)^2}{(16)(1728)} \quad \text{(A1a)}$$

$$V = \frac{(\pi)(h)(d_t + d_b)^2}{(16)(10^3)} \quad \text{(A1b)}$$

where:

V = volume of mold, ft^3 (cm^3),

TABLE A1.1 Density of Water[A]

Temperature, °C (°F)	Density of Water, γ/ml
18 (64.4)	0.99862
19 (66.2)	0.99843
20 (68.0)	0.99823
21 (69.8)	0.99802
22 (71.6)	0.99779
23 (73.4)	0.99756
24 (75.2)	0.99733
25 (77.0)	0.99707
26 (78.8)	0.99681

[A] Values other than shown may be obtained by referring to the *Handbook of Chemistry and Physics*, Chemical Rubber Publishing Co., Cleveland, OH.

h = average height, in. (mm),
d_t = average top diameter, in. (mm),
d_b = average bottom diameter, in. (mm),
$1/1728$ = constant to convert in^3 to ft^3, and
$1/10^3$ = constant to convert mm^3 to cm^3.

A1.5 Comparison of Results

A1.5.1 The volume obtained by either method should be within the volume tolerance requirements of 6.1.1 and 6.1.2.

A1.5.2 The difference between the two methods should not exceed 0.5 % of the nominal volume of the mold.

A1.5.3 Repeat the determination of volume if these criteria are not met.

A1.5.4 Failure to obtain satisfactory agreement between the two methods, even after several trials, is an indication that the mold is badly deformed and should be replaced.

A1.5.5 Use the volume of the mold determined using the water-filling method as the assigned volume value for calculating the moist and dry density (see 11.4).

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C24.0 – DUST MONITORING

Purpose and Scope: The purpose of this document is to provide procedures for measuring airborne dust concentrations associated with activities being performed at the site.

Equipment:
Particulate Dust Monitor with software and capable of logging
Five Foot Tripod or equivalent stand;
Miscellaneous Tools; and
Safety Equipment.

Documentation:
Daily Field Record (DFR)
Airborne Dust Monitoring Form (attached);
Personal Airborne Dust Exposure Monitoring Form (attached); and
Instrument Calibration Form.

Airborne dust may be generated at the site due to a variety of soil disturbance activities, including excavation, trenching, earthmoving, drilling, concrete demolition, and vehicle traffic. Airborne dust can present a worker exposure issue and may present concerns related to offsite transport.

This Standard Operating Procedure (SOP) is designed to assess airborne concentrations of nuisance particulate (total particulate and respiratory particulate) that does not contain hazardous constituents (e.g., heavy metals, acid waste, crystalline silica, etc.). If appropriate, additional SOPs will be developed for the purpose of measuring potential exposures to hazardous constituents in dust.

This SOP is to be used in conjunction with the Sampling and Analysis Plan (SAP) and future Focused Remedial Investigation (FRI) work plans. In addition to the SAP, the following SOPs should be consulted:

- SOP 1.0 – General Preparation and Mobilization Requirements
- SOP 2.0 – Basic Health and Safety for Field Operations
- SOP 3.0 – Field Documentation and Sample Handling
- SOP 12.0 – Test Pit Excavation
- SOP 13.0 – Drilling

Also refer to the Leviathan Mine Site Health, Safety, Security and Environmental (HSSE) Program Document by ENSR dated May 27, 2008, the Task Specific Health and Safety Plan by AMEC Geomatrix dated June 2009, and the Job Safety Analysis for the planned scope of work.

C24.1 INSTRUMENTATION

Airborne particulate monitoring (area monitoring and personal monitoring) will be performed using a directing reading dust monitor, which provides a continuous real-time measurement of airborne particulate concentrations in milligrams of particulate per cubic meter of air (mg/M^3). It should be capable of logging and have a size-selective impactor to allow specifically for respirable particulate (less than 10 microns in aerodynamic diameter) PM_{10} sampling. The manufactures manual must be read and understood prior to using the instrument.

C24.2 MONITORING

There are two types of dust monitoring, area and personal. Each of the two types is described below.

C24.2.1 Area Airborne Particulate Monitoring

In some instances it may be necessary to measure the concentration of airborne particulate in a specific area of site (e.g., immediately downwind of an excavation, at the downwind site boundary, etc). Area airborne particulate monitoring will be performed using the following procedures.

C24.2.1.1 Total Airborne Particulate Monitoring

- The direct reading instrument should be fully charged overnight prior to performing airborne particulate monitoring.
- Area air monitoring will measure total airborne particulate; therefore the instrument should be operated without any of the size-selective inlets installed.
- All instrument-specific information and field measurements should be recorded on the Area Airborne Dust Monitoring Form (attached).
- Turn on the instrument.
- Clear the instrument of any previous logged data.
- The instrument should be zero calibrated prior to each use.

- The instrument should operate in a survey mode and should be measuring total airborne particulate concentrations (mg/M^3). In this mode, the instrument can be carried from location to location to measure instantaneous total airborne particulate concentrations. The instrument should be held continuously in a given location for at least one minute prior to recording a measurement. The measurements should be recorded on Area Airborne Dust Monitoring Form (attached).

- If monitoring needs to be performed for a relatively long time period, the instrument can be placed on a tripod or hung on a fence and then operated in logging mode.

- Measurement data can be compared to the California Occupational Safety and Health Administration (CA/OSHA) permissible exposure limit (PEL) for Particulates Not Otherwise Regulated Total Dust of 10 mg/M^3.

C24.2.1.2 Particulate Matter Less than 10 microns in Aerodynamic Diameter (PM_{10}) Monitoring

In some situations it may be useful to measure potential offsite migration of PM_{10}. PM_{10} measurements would be collected using the same procedures as described above with the exception that 10 micron size selective inlet would be installed on the instrument prior to conducting the monitoring. The results of the PM_{10} monitoring can be assessed by comparing the measurement results to the California 24 hour average ambient air quality standard PM_{10} of 50 micrograms per cubic meter of air (µg/M^3).

C24.2.2 Worker Exposure Monitoring

Worker exposure monitoring will be conducted when visible dust is generated by construction activities. The following sections describe monitoring for nuisance particulate and respirable particulate (PM_{10}).

C24.2.2.1 Nuisance Particulate

- The direct reading instrument should be fully charged overnight prior to performing airborne particulate monitoring.

- Worker exposure monitoring for total nuisance particulate should be performed without any of the size selective inlets installed on the instrument.

- All instrument-specific information and field measurements should be recorded on the Personal Airborne Dust Exposure Monitoring Form (attached).

- Turn on the instrument.

- Clear the instrument of any previous logged data.

- The instrument should be zero calibrated prior to each use.
- The instrument should be operated in the survey mode and should be measuring total airborne particulate concentrations in milligrams per cubic meter (mg/M^3). To assess worker exposures to nuisance particulate, the instrument should be configured to logging mode.
- The instrument should then be clipped onto the employee with the inlet positioned as close as possible to the workers breathing zone.
- At the completion of the monitoring period disengage the logging.
- The measurement data will be compared to the California Occupational Safety and Health Administration (CAL-OSHA) Permissible Exposure Level (PEL) for Particulates Not Otherwise Regulated Total Dust of 10 mg/M^3.

C24.2.2.2 Worker Exposure Monitoring to Respirable Particulate (Particulate 10 microns or less in Aerodynamic Diameter.

Personal monitoring for PM_{10} would be performed to assess potential worker exposures to respirable particulate. Respirable particulate measurements would be collected using the same procedures as described above with the exception that the 10 micron size selective inlet would need to be installed on the instrument prior to conducting the monitoring. The results of worker respirable particulate monitoring should be compared to the CA/OSHA PEL for Particulates Not Otherwise Regulated Respirable Fraction of 5 mg/M^3.

C24.3 DUST MITIGATION STRATEGIES

In the event that airborne dust monitoring reveals excessive levels of airborne dust, the following strategies should be implemented to reduce the airborne dust levels.

- Soil disturbance work should be minimized during high wind events.
- During dry/windy conditions, soil piles should be securely covered with plastic sheeting.
- Water suppression should be used, as necessary, to minimize airborne dust generation along unpaved vehicle travel routes.
- Water suppression should be used to control airborne dust releases during excavation, earth moving, and demolition activities by routinely applying water to dust source(s).

- When the results of area air monitoring for airborne particulate reveal sustained (exceeding 5 minutes) concentrations exceeding 10 mg/M^3, the following actions should be initiated.
    - Soil disturbance or demolition activities should be temporarily halted.
    - The primary sources for the airborne particulate should be identified.
    - Water suppression or isolation with plastic sheeting should be used to minimize fugitive dust releases.
    - In the event that fugitive dust emissions cannot be effectively controlled, soil disturbance or demolition activities should cease until meteorological conditions abate and/or the dust control measures become effective.
- When the results of personal exposure monitoring for particulates reveals concentrations exceeding 10 mg/M^3 or 5 mg/M^3 (as respirable dust) the following actions should be initiated.
    - The employee should position themselves upwind of soil disturbance activities.
    - Water suppression should be applied to the excavation and/or soil stockpile.
    - Active ventilation (air movers, exhaust fans, radial fans) should be operated in the immediate area to dissipate the airborne dust.
    - In the event that these procedures do not effectively mitigate the airborne dust hazard, the employee should don an appropriate filtering face piece respirator (N100). Prior to donning a respirator, the employee must consult with the project safety officer to ensure that the employee has the necessary training and medical surveillance to wear respiratory protection. The project safety office will also be responsible for determining the appropriate model and size respirator for the employee through fit-testing.

ATTACHMENTS

- Airborne Dust Monitoring Form
- Personal Airborne Dust Exposure Monitoring Form

Airborne Dust Monitoring Form

Project Name: _____ Project No: _____

Evaluator: _____ Date: _____

A.M. Zero Value: _____ P.M. Zero Value: _____

Instrument ID: _____

Job Site Activities: _____

Location	Time of Day	Aerosol Concentration (mg/m^3)

Comments: _____

_____

_____

_____

_____

AMEC Geomatrix

Personal Airborne Dust Exposure Monitoring Form

Project Name: _____ Project No: _____

Evaluator: _____ Date: _____

Company Name: _____

Location: _____

Site Description: _____

Employee Name: _____

Employee SSN: _____

Employee Job Title: _____

Employee Job Description/Duties: _____

Work Shift Duration (Hrs): _____

Respiratory Protective Worn: _____

Frequency of use during Site Visit: ☐ Always ☐ Often ☐ Rarely ☐ Never

Airborne Particulate Monitor Type and ID Number: _____

Start Time: _____

Stop Time: _____

Total Time: _____

Results: TWA: _____ Peak Level: _____

Potential Airborne Particulate Sources: _____

_____

_____

_____

Comments: _____

_____

_____

_____

AMEC Geomatrix

C25.0 – MINI-PIEZOMETER INSTALLATION

Purpose and Scope: The purpose of this document is to provide procedures on how to install mini-piezometers within a streambed. It describes installation, development, and removal of mini-piezometers.

Equipment:
Drive point piezometer tip – Solinst® Model 615 or equivalent;
Tubing, as needed for the desired depth. Roll(s) of 5/8-inch or 3/4-inch outside diameter (o.d.) x 1/2-inch inside diameter (i.e.) low density polyethylene (LDPE), Teflon® tubing, or equivalent.
Manual slide hammer;
Manual drive head assembly (includes drivehead, drive extension, and tubing bypass);
Extensions, as needed for the required depth (in lengths of 2 ft or 3 ft);
Couplings, one per each extension;
O-rings (if needed);
Stainless steel cap;
Peristaltic pump, hand pump, inertial pump, or miniature bailer;
Handyman jack;
Pipe wrench
2 –five gallon plastic buckets;
Miscellaneous tools; and
Safety Equipment.

Documentation:
Daily Field Record (DFR);
Maps/plot plan; and
Camera.

Mini-piezometers are similar to monitoring wells and piezometers except that they are manually installed, are smaller in diameter, and are driven adjacent to or within a surface water body. They can be installed in a streambed to evaluate surface water-groundwater interactions.

The types of mini-piezometers that may be used at the site include temporary standpipes, drive-tip piezometers (various manufacturers), or perforated casing. This Standard Operating Procedure (SOP) describes the installation of a mini-piezometer using the Solinst® Drive-point piezometer (Model 615, 615N, 615S). Other types of mini-piezometers may be used, however; they must meet the following minimum criteria:

- Casing diameter of 2-inches or less;
- Perforated interval of a foot or less;

- Safely installed within the streambed and in a manner where surface water does not does not penetrate the annulus of the installed mini-piezometer;
- Installed without the use of heavy equipment to avoid disturbance to the streambed. Preferably using equipment that can be mobilized by hand;
- Developed as described in this SOP; and
- Secured in a manner such that if the mini-piezometers are left unattended, that they are visible and do not pose a risk to users of the site.

This SOP is to be used in conjunction with the Sampling and Analysis Plan (SAP) and future Focused Remedial Investigation (FRI) work plans. In addition to the SAP, the following SOPs should be consulted:

- SOP 1.0 – General Preparation and Mobilization Requirements
- SOP 2.0 – Basic Health and Safety for Field Operations
- SOP 3.0 – Field Documentation and Sample Handling
- SOP 4.0 – Sample Collection Techniques and Data Collection Strategies
- SOP 8.0 – Surface Water Sampling and Stream Flow Measurement
- SOP 17.0 – Groundwater Sampling
- SOP 21.0 – Bubble-Water Manometer

Also refer to the Leviathan Mine Site Health, Safety, Security and Environmental (HSSE) Program Document by ENSR dated May 27, 2008, the Task Specific Health and Safety Plan by AMEC Geomatrix dated June 2009, and the Job Safety Analysis for the planned scope of work.

C25.1 SOLINST® DRIVE-POINT PIEZOMETER

The Model 615/615S/615N drive-point piezometer is designed as a portable method for installing a mini-piezometer in a streambed. It can be installed with a slide hammer to various depths depending on the lithology (Figure 25.1). Model 615 is the standard piezometer with a barbed fitting that can be attached to tubing (with an inside diameter of ½-inch and an outside diameter of ¾-inch) for the collection of a water sample. Model 615N has no barb and therefore has an available diameter opening of ¾-inch in which a water level meter can be placed. Model 615S is designed to be driven just beyond the desired depth with a shield and

retracted to expose the screened interval to the depth of interest. All three models are shown on Figure 25.2.

Figure 25.1: Installation of the drive-point piezometer using a slide hammer. Picture from the manufacturer's website (www.solinist.com).

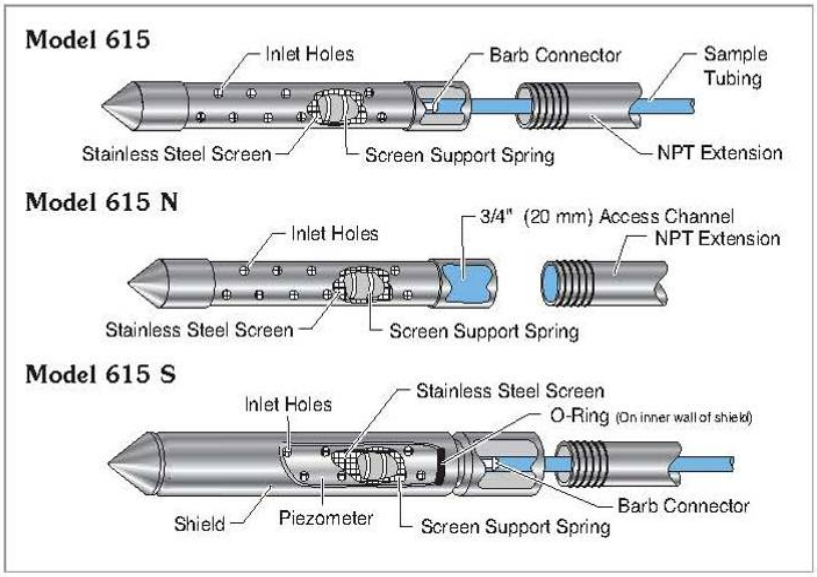

Figure 25.2: The three models of drive-point piezometers. Picture from the manufacturer's website (www.solinist.com).

C25.2 INSTALLATION

The following steps describe how to install the Model 615 drive-point piezometer if tubing is to be attached for the collection of a groundwater sample. The installation procedures also discuss the sleeve installation to avoid clogging during installation activities (Model 615S). A schematic of the drive-point piezometer is shown on Figure 25.3.

- Decontaminate all equipment, refer to SOP 7.0 – Equipment Decontamination.
- Cut the tubing to length for the proposed depth plus 5 feet.
- Connect the tubing to the barbed fitting on the piezometer tip by pushing firmly until the tubing is flush with the base of the fitting.
- Slide a length of extension drive pipe over the tubing, and thread it firmly onto the piezometer tip. Tighten with a pipe wrench.
- Prevent the tubing from turning and slide the Tubing Bypass fitting over the tubing and tighten it firmly onto the extension pipe, with the tubing extending through the side hole. Thread a Drive Extension fitting onto the Tubing Bypass fitting and tighten firmly. *Warning: When connecting or removing the Tubing Bypass fitting, it is very important to hold the tubing to prevent it from turning. Failure to do so may result in the tube being dislodged from the Drive-Point tip.*

- Thread the Drive Head onto the Drive Extension fitting and tighten firmly.
- Important Note about Shielded Piezometers – Before driving into the ground, ensure that the shield is firmly attached and the o-ring seats properly.
- Slide the Slide Hammer over the Drive Head and operate the hammer to drive the device until only about 6 inches of the extension pipe below the Tubing Bypass remains above the ground.
- Secure the tubing to prevent it from turning, and remove all sections of the Drive Head Assembly.
- Slide a coupling over the tubing and tighten firmly onto the extension pipe. Slide the next extension pipe over the tubing and tighten it securely to the coupling.
- Repeat steps 8 through 10 until the desired sampling depth is reached. If using a shielded piezometer, retract the piezometer the length of the shield to expose the screened interval to groundwater.
- Cut the piezometer tubing to fit flush to the top of the extension pipe. Attach a cap to the top of the piezometer to complete the installation.

C25.3 DEVELOPMENT

The drive-point piezometer must be developed prior to sampling by removing accumulated sediment. This can be performed using a peristaltic pump, inertial pump, or a miniature bailer. Water should be pumped or bailed from the mini-piezometer until clear, non-turbid water is recovered.

C25.3.1 Peristaltic Pump

A peristaltic pump uses the suction lift principle and provides a regulated and steady flow. This pump can be used to develop the mini-piezometer by pumping water out of the line to remove sediments.

C25.3.2 Inertial Pump

An inertial pump includes a check valve and tubing which is raised and lowered to lift a sample. The up and down action of an inertial pump is well-suited to development because it is similar to the surge and bail method which removes sediment while enhancing the hydraulic connectivity with the formation.

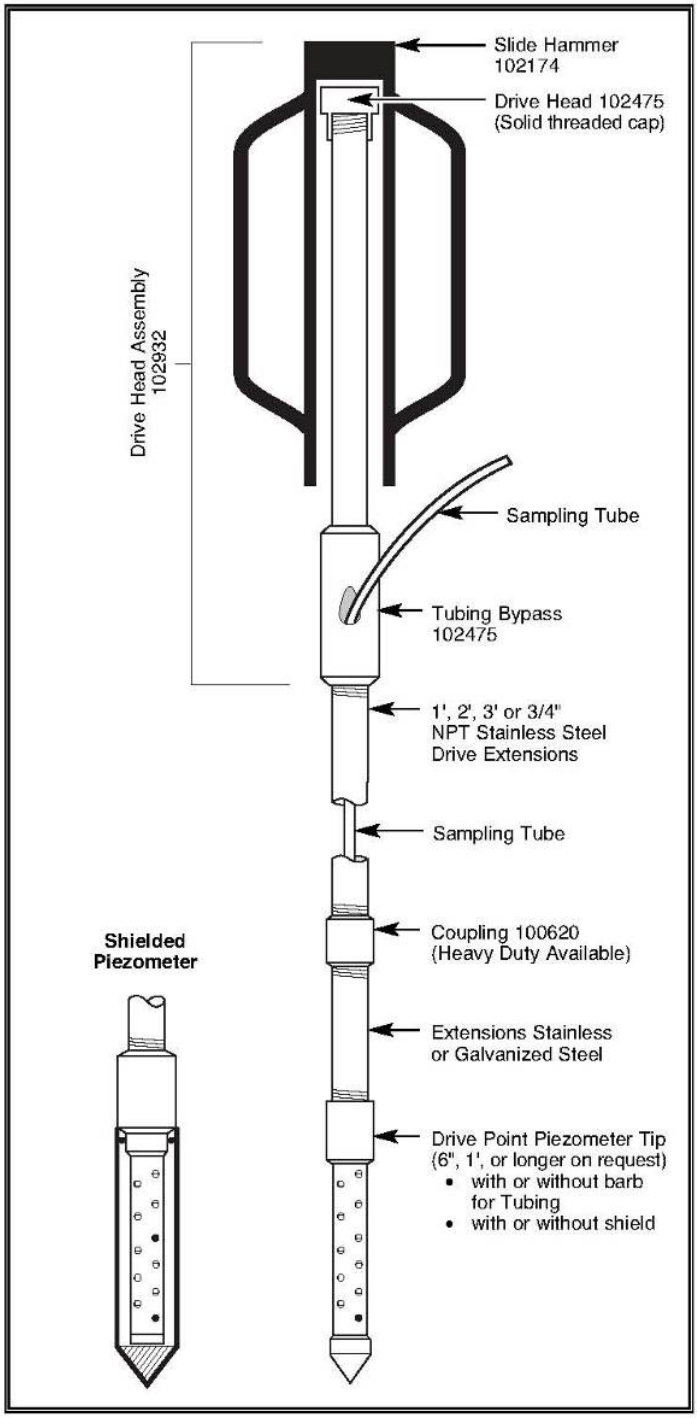

Figure 25.3: A schematic of the Drive-point assembly. Picture from the manufacturer's website (www.solinist.com).

C25.3.3 Miniature Bailer

A miniature bailer with an inside diameter of ½" may be used to surge and bail a drive-point piezometer.

C25.4 REMOVAL

A drive-point piezometer may be removed using a handyman jack and a chain-link. Wrap the chain link around the base of the pipe and to the handyman jack. Slowly operate the jack until the pipe pulls out. Backfill the hole by filling in the streambed sediments at the surface.

C26.0 – LYSIMETER

Purpose and Scope: The purpose of this document is to describe procedures for installation and operation of a lysimeter.

Equipment:
Lysimeter;
Tubing, sizing depends on the model used;
200 mesh silica flour slurry;
Bentonite slurry mix;
Potable water for slurry mixtures;
Various hand tools (wrenches, screw drivers, etc.);
Vacuum pump or hand pump;
Clean, 5-gallon plastic buckets (2);
Decontamination Equipment; and
Safety Equipment.

Documentation:
Daily Field Record (DFR);
Maps/plot plan; and
Camera.

Suction lysimeters collect pore water from unsaturated soils. After installation below ground level, vacuum is applied to the lysimeter through tubing leading from the lysimeter to the ground surface. The negative air pressure created inside the lysimeter draws pore water into the lysimeter through the porous filter (often ceramic). The pore water is transported to the surface by applying a positive pressure to the lysimeter through a second tube. Single chamber lysimeters can be installed to a depth of approximately 20 feet. Dual chamber models can be installed at depths of up to 500 feet or more.

This Standard Operating Procedure (SOP) describes general installation and operation of a suction lysimeter to collect water from the vadose zone. Depending on the type of lysimeter used, these procedures may change. Consult the manufacturer's recommended installation procedures for details.

This SOP is to be used in conjunction with the Sampling and Analysis Plan (SAP) and future Focused Remedial Investigation (FRI) work plans. In addition to the SAP, the following SOPs should be consulted:

- SOP 1.0 – General Preparation and Mobilization Requirements
- SOP 2.0 – Basic Health and Safety for Field Operations

- SOP 3.0 – Field Documentation and Sample Handling
- SOP 4.0 – Sample Collection Techniques and Data Collection Strategies
- SOP 7.0 – Equipment Decontamination
- SOP 13.0 – Drilling
- SOP 17.0 – Groundwater Sampling

Also refer to the Leviathan Mine Site Health, Safety, Security and Environmental (HSSE) Program Document by ENSR dated May 27, 2008, the Task Specific Health and Safety Plan by AMEC Geomatrix dated June 2009, and the Job Safety Analysis for the planned scope of work.

C26.1 INSTALLATION

The following general procedures are presented for the installation of a lysimeter. Consult the manufacturers recommended installation procedures for more details.

- Drill a borehole (SOP 13.0 - Drilling) of sufficient diameter to desired depth to access lysimeter.
- Place a silica flour-water slurry into the boring in the zone in which the porcelain bottom cup of the lysimeter will be placed.
- Visually inspect the lysimeter apparatus for cracks or other irregularities; replace parts as necessary. Decontaminate and initiate fluid rinsing of the lysimeter in accordance with manufacturer's recommendations.
- Insert the lysimeter into the silica flour slurry. Place a bentonite plug above silica flour slurry. Grout the remaining well annulus to the surface. Install a locking well protector.
- Allow the lysimeter to cure in place (e.g., 24-48 hours).

A schematic of a typically installed lysimeter is shown on Figure 26.1.

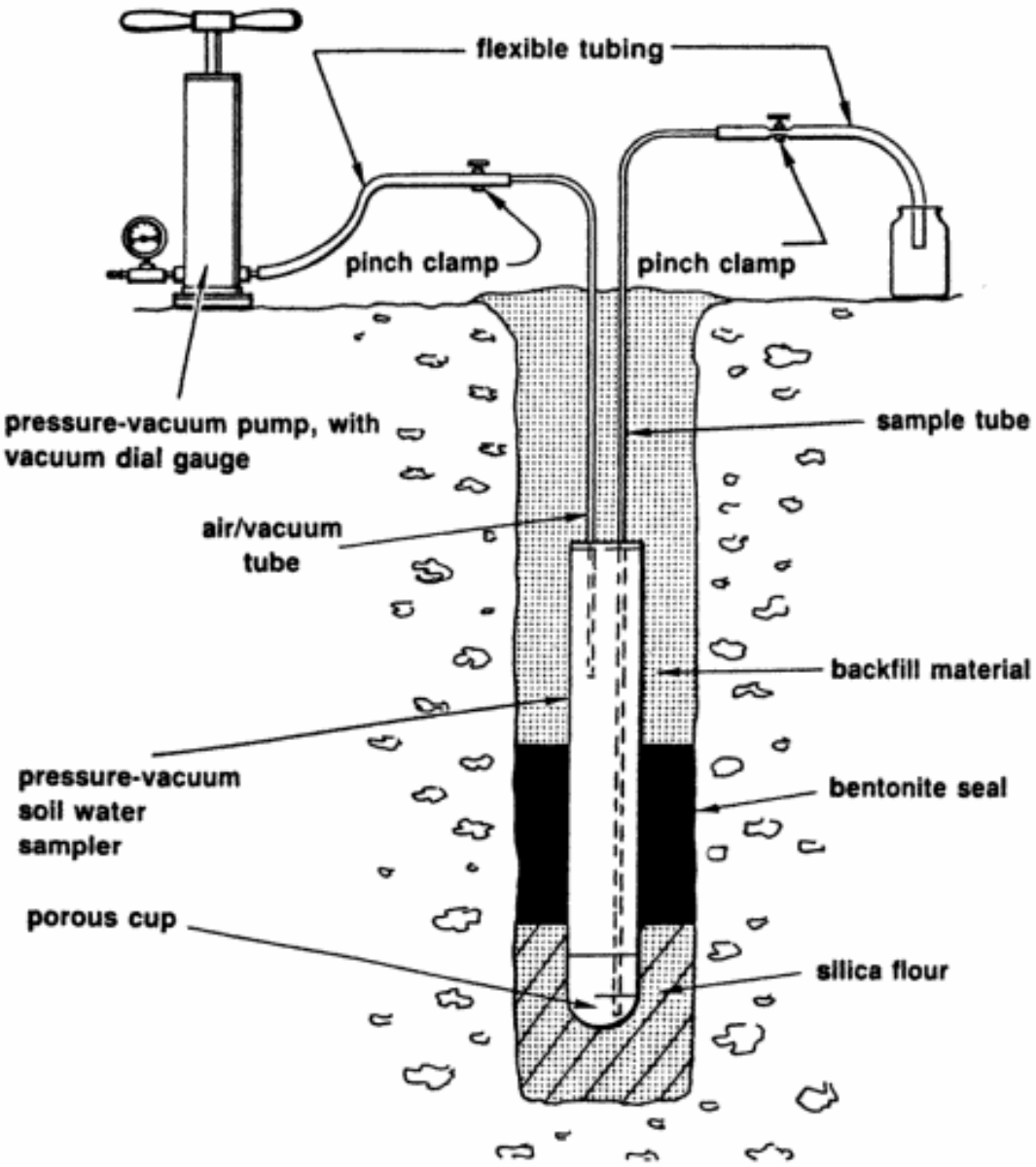

Figure 26.1 – Profile schematic of a general lysimeter installed into a borehole. Figure from the *Practical Handbook of Groundwater Monitoring* by David Nielson (1991).

C26.2 OPERATION

- Evacuate at least three volumes of fluid in the lysimeter to dewater the silica flour slurry prior to sample collection.
- Apply vacuum to appropriate port on lysimeter to attain a negative pressure of approximately 18 pounds per square inch (psi) on the system (refer to the manufacturer's recommendations).
- Install a pinch clamp or other valve to maintain negative pressure after desired pressure is created. Allow lysimeter to operate under negative pressure for between 24 hours and 7 days, depending upon soil conditions.
- Relieve negative pressure. Apply positive pressure to appropriate port at approximately five psi to force the collected sample to the surface.
- Collect sample in a decontaminated beaker to perform field parameter tests. Collect samples for laboratory analysis in appropriate containers. Refer to SOP 17.0 – Groundwater Sampling for sampling procedures.

C26.3 REMOVAL

Close the valves to the lysimeters and unhook the tubing from the pump. Secure the tubing to the well to prevent damage. If no other samples will be collected from borehole, refer to SOP 13.0 – Drilling for the abandonment procedures.

C27.0 – TENSIOMETER

Purpose and Scope: The purpose of this SOP is to provide information on how to install and operate a tensiometer.

Equipment:
Tensiometer
Hypodermic needle (if using a portable *puncture tensiometer* instrument)
Tubing, sizing depends on the model used;
200 mesh silica flour slurry;
Bentonite slurry mix;
Water for slurry mixtures;
Various hand tools (wrenches, screw drivers, etc.);
Vacuum pump or hand pump;
Clean, 5-gallon plastic buckets (2);
Decontamination Equipment; and
Safety Equipment.

Documentation:
Daily Field Record (DFR);
Maps/plot plan; and
Camera.

A tensiometer is a device used to determine water potential Ψ_m (soil matric potential) in the vadose zone. The components of a general tensiometer are shown on Figure 27.1. Tensiometers consist of a glass or plastic tube with a porous ceramic cup, and are filled with water. The top of the tube has either a built-in vacuum gauge or a rubber cap used with a portable *puncture tensiometer* instrument, which uses a hypodermic needle to measure the pressure inside the tensiometer.

This Standard Operating Procedure (SOP) describes the general installation and operation of a tensiometer to measure soil moisture tension in the vadose zone. Depending on the type of tensiometer used, these procedures may change. Consult the manufacturer's recommended installation procedures for details.

This SOP is to be used in conjunction with the Sampling and Analysis Plan (SAP) and future Focused Remedial Investigation (FRI) work plans. In addition to the SAP, the following SOPs should be consulted:

- SOP 1.0 – General Preparation and Mobilization Requirements
- SOP 2.0 – Basic Health and Safety for Field Operations

- SOP 3.0 – Field Documentation and Sample Handling
- SOP 4.0 – Sample Collection Techniques and Data Collection Strategies
- SOP 7.0 – Equipment Decontamination

Also refer to the Leviathan Mine Site Health, Safety, Security and Environmental (HSSE) Program Document by ENSR dated May 27, 2008, the Task Specific Health and Safety Plan by AMEC Geomatrix dated June 2009, and the Job Safety Analysis for the planned scope of work.

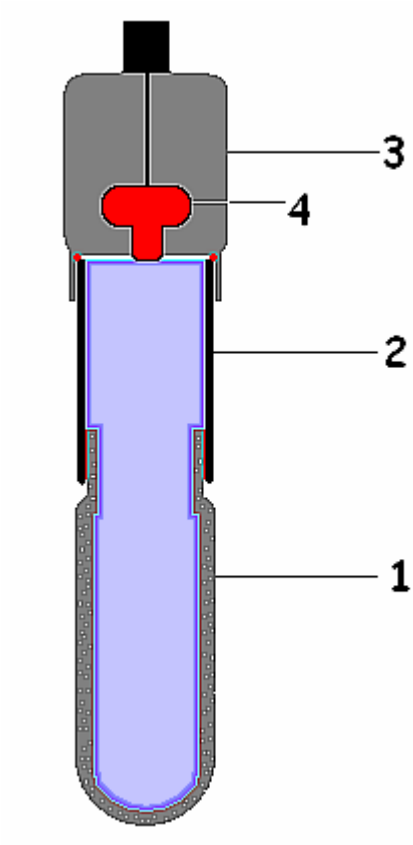

Figure 26.1 – General components of a tensiometer. (1) Porous Cup, (2) water filled tube, (3) sensor head (cap and reservoir), (4) pressure sensor, or rubber stopper. Typically, a vacuum gauge (located at the surface) is attached to the tensiometer.

C27.1 INSTALLATION

The following general procedures are presented for installation of a tensiometer. Newly purchased tensiometers or those to be re-used after a long-term dry storage, need to be

prepared prior to installation. Improperly prepared tensiometers will not provide true readings. Tensiometer preparation requirements depend on the brand being used; however, the steps below are common to most brands. Consult the manufacturer's recommended installation procedures for details.

- Decontaminate all equipment.
- Remove the reservoir cap and fill the tensiometer tube with distilled water and place the tensiometer in a bucket of distilled water for a few days with the cap off. The addition of an algaecide (usually supplied by the retailer) may be used.
- Prepare some water for final filling of a tensiometer.
- After the tensiometer has soaked for several days, empty the tensiometer, place the tensiometer in the bucket of water, and re-fill the tensiometer with distilled water.
- Remove any remaining bubbles by tapping the top of the tensiometer and applying a slight vacuum with the hand vacuum pump. Once the bubbles have been removed, seal the top and place in a bucket of water until ready for installation.
- Drill a bore hole of sufficient diameter to the desired depth to install the tensiometer. The hole should be slightly smaller than the diameter of the tensiometer as direct contact should be made with the soil once installed.
- Remove the tensiometer from the bucket and install it into the ground to the appropriate depth. It is important that there is good contact between the ceramic tip of the tensiometer and the soil. However, excessive pressure will snap the tip off of the tensiometer.
- Backfill the hole with native soil, sand pack, or slurry. See manufacturer's recommendations.

C27.2 OPERATION

The following general procedures are presented for operation of a tensiometer. Details depend on the type of tensiometer used, therefore, consult the manufacturer's recommended operation procedures for details.

Using the vacuum pump, apply an initial vacuum to the tensiometer. Once a tensiometer is installed, change in soil moisture can be determined by recording the change in vacuum over time. Water moves freely between the porous cup and the surrounding soil as the soil moisture changes. If water is pulled out of the soil by plants and evaporation, the vacuum inside the tube

increases. If water is added to the soil, moisture from the soil enters the tube and the vacuum inside the tube decreases. In theory, if the suction within the tensiomenter is equal to the suction in the soil then there will be no change in the pressure gauge.

The vacuum measurement at each tensiometer should be recorded initially and repetitively on a pre-determined schedule. The frequency of measurement depends on the scope of the investigation performed but can range from hours to days. Precipitation or irrigation events that occur during or just prior to the test period should be documented. A transducer and a data logger can be used to facilitate data collection on an ongoing basis.

C27.3 REMOVAL

Consult the manufacturer's recommendations for the removal of the tensiometer. Tensiometers may be removed, cleaned, calibrated, and re-used at different locations as long as the tensiometer has been tested for leaks.