December 17, 2012

Mr. Weiquan Dong, PE
Bureau of Corrective Actions, Special Projects Branch
Nevada Division of Environmental Protection
2030 E. Flamingo Rd., Suite 230
Las Vegas, Nevada 89119

Re: Remedial Investigation and Feasibility Study Work Plan; Nevada Environmental Response Trust Site; Henderson, Nevada

Dear Mr. Dong:

Please find enclosed the Remedial Investigation and Feasibility Study Work Plan for the Nevada Environmental Response Trust (NERT) Site in Henderson, Nevada. This report was prepared by ENVIRON International Corporation (ENVIRON) on behalf of the Nevada Environmental Response Trust (the Trust). The entire document is available in electronic format on CD located in the back folder of this binder.

Please contact Allan DeLorme at (510) 420-2565 if you have any comments or questions concerning this report.

Sincerely,

John M. Pekala, CEM #2347
Senior Manager

Allan J. DeLorme, PE
Managing Principal

cc: BMI Compliance Coordinator, NDEP, BCA, Las Vegas
Brian Rakvica, McGinley and Associates, Las Vegas
NDEP c/o McGinley and Associates, Reno

ec: Shannon Harbour, NDEP
Greg Lovato, NDEP
Stephen Tyahla, USEPA
Jay Steinberg, Le Petomane XXVII, Inc.
Andrew Steinberg, Le Petomane XXVII, Inc.
Jeff Gibson, AMPAC
Mark Paris, BMI
Lee Farris, Landwell
Ranajit Sahu, BMI
Joe Kelly, Montrose
Paul Sundberg, Montrose
Curt Richards, Olin
Jay Gear, Olin
Ed Modiano, de maximis
Chuck Elmendorf, Stauffer
Nick Pogoncheff, Stauffer
George Crouse, Syngenta
Kevin Lombardozzi, TIMET
Kirk Stowers, TIMET
Victoria Tyson, Tyson Contracting (for TIMET)
Enoe Marcum, WAPA

ENVIRON International Corp. 2200 Powell Street, Suite 700, Emeryville, CA 94608
V +1 510.655.7400 F +1 510.655.9517

environcorp.com

Remedial Investigation and Feasibility Study Work Plan

Nevada Environmental Response Trust Site; Henderson, Nevada

Prepared for:
Nevada Environmental Response Trust

Prepared by:
ENVIRON International Corporation
Emeryville, California

Date:
December 17, 2012

Project Number:
21-29100H

ENVIRON

Remedial Investigation and Feasibility Study Work Plan

Nevada Environmental Response Trust
(Former Tronox LLC Site)
Henderson, Nevada

Nevada Environmental Response Trust (NERT) Representative Certification

I certify that this document and all attachments submitted to the Division were prepared at the request of, or under the direction or supervision of the Trust. Based on my own involvement and/or my inquiry of the person or persons who manage the system(s) or those directly responsible for gathering the information or prepared the document, or the immediate supervisor of such person(s), the information submitted and provided herein is, to the best of my knowledge and belief, true, accurate, and complete in all material respects.

Le Petomane XXVII, Inc., not individually, but solely in its representative capacity as the Nevada Environmental Response Trust Trustee

Signature: Jay A Steinberg, not individually, but solely in his representative capacity as President of the Nevada Environmental Response Trust Trustee

Name: Jay A. Steinberg, not individually, but solely in his representative capacity as President of the Nevada Environmental Response Trust Trustee

Title: Solely as President and not individually

Company: Le Petomane XXVII, Inc., not individually, but solely in its representative capacity as the Nevada Environmental Response Trust Trustee

Date: 12/14/12

Remedial Investigation and Feasibility Study Work Plan

Nevada Environmental Response Trust
(Former Tronox LLC Site)
Henderson, Nevada

Responsible Certified Environmental Manager (CEM) for this project

I hereby certify that I am responsible for the services described in this document and for the preparation of this document. The services described in this document have been provided in a manner consistent with the current standards of the profession and, to the best of my knowledge, comply with all applicable federal, state and local statutes, regulations and ordinances. I hereby certify that all laboratory analytical data was generated by a laboratory certified by the NDEP for each constituent and media presented herein.

December 17, 2012

John M. Pekala, PG — Date

Certified Environmental Manager
ENVIRON International Corporation
CEM Certificate Number: 2347
CEM Expiration Date: September 20, 2014

The following individuals provided input to this document:

John M. Pekala, PG
Allan J. DeLorme, PE
Jessica E. Donovan, PG
Lynne Haroun, MPH
Christopher J. Ritchie, PE
Anne Gates, PE
Christopher M. Stubbs, PhD, PE
Kimberly Kuwabara, MS
Dan Clark
Craig J. Knox
Emily Lisker
Ruben So

Contents

List of Tables

List of Figures

List of Plates

List of Appendices

H:\LePetomane\NERT\RI.FS_Workplan\RI WP Report\12 17 2012 NERT RI Workplan.docx

Acronyms and Abbreviations

AECOM	AECOM, Inc.
AMPAC	American Pacific Corporation
AOC	Administrative Order on Consent
AP	ammonium perchlorate
AP&CC	American Potash and Chemical Company
ARAR	applicable or relevant and appropriate requirements
AWF	Athens Road Well Field
BCL	basic comparison level
BEC	Basic Environmental Company
bgs	below ground surface
BHRA	baseline health risk assessment
BHC	benzene hexachloride (also known as hexachlorocyclohexane)
BMI	Black Mountain Industrial
BRC	Basic Remediation Company
Broadbent	Broadbent & Associates, Inc.
CAA	Clean Air Act
CAMU	Corrective Action Management Unit
CEM	Certified Environmental Manager
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CIC	Community Involvement Coordinator
CIP	Community Involvement Plan
COH	City of Henderson
COPC	chemical of potential concern
CSM	conceptual site model
CWA	Clean Water Act
CZE	Capture Zone Evaluation
DDT	dichlorodiphenyltrichloroethane
DPE	Dual-Phase Extraction
DQO	data quality objective
DRO	diesel range organics
DVSR	Data Validation Summary Report

EC	electrical conductivity
ECA	Excavation Control Areas
EDDs	electronic data deliverables
ENSR	ENSR Corporation
ENVIRON	ENVIRON International Corporation
ERM-West	ERM-West, Inc.
Facility Area	The Site, excluding Parcels A, B, C, D, E, F, G, and H
FBR	Fluidized-Bed Reactor
FRTR	Federal Remediation Technology Roundtable
ft/ft	feet per foot
ft/yr	feet per year
FS	Feasibility Study
FSP	Field Sampling Plan
gpd/ft^2	gallons per day per square foot
gpm	gallons per minute
GRO	gasoline range organics
GWETS	Groundwater Extraction and Treatment System
GWTP	Groundwater Treatment Plant
HASP	Health and Safety Plan
HCB	hexachlorobenzene
HI	hazard index
HRA	health risk assessment
Integral	Integral Consulting Inc.
IWF	Interceptor Well Field
IX	ion exchange
KMCC	Kerr-McGee Chemical Corporation
lbs	pounds
LOU	Letter of Understanding
MCL	maximum contaminant level
MGD	million gallons per day
µg/L	micrograms per liter (parts per billion)
mg/L	milligrams per liter (parts per million)

MPE	Multi-Phase Extraction
mph	miles per hour
NAPL	non-aqueous phase liquid
NCP	National Contingency Plan
NDEP	Nevada Division of Environmental Protection
NERT	Nevada Environmental Response Trust
NFA	No Further Action
Northgate	Northgate Environmental Management, Inc.
NPDES	National Pollutant Discharge Elimination System
NRS	Nevada Revised Statute
OCHs	organochlorine herbicides
OCPs	organochlorine pesticides
O&M	operations and maintenance
OPPs	organophosphate pesticides
ORO	oil range organics
OSSM	Olin Chlor-Alkali/Stauffer/Syngenta/Montrose (formerly POSSM)
Parcel Areas	Parcels A, B, C, D, E, F, G, and H
PCBs	polychlorinated biphenyls
PCE	tetrachloroethene (also referred to as perchloroethene)
PE	Professional Engineer
PEPCON	Pacific Engineering and Production Company of Nevada (former)
PG	Professional Geologist
POTWs	Publicly Owned Treatment Works
PRB	permeable reactive barrier
QA	quality assurance
QAAP	Quality Assurance Project Plan
Qal	Quaternary alluvium
QC	quality control
RAO	remedial action objective
RAS	remedial alternative studies
RAW	removal action work plan
RCRA	Resource Conservation and Recovery Act

RI	remedial investigation
RIB	Rapid Infiltration Basin
RZ	remediation zone
SAP	Sampling and Analysis Plan
SDWA	Safe Drinking Water Act
Site	Nevada Environmental Response Trust (NERT) Site
SMP	Site Management Plan
SRC	site-related chemical
SRG	soil remediation goal
SVOCs	semivolatile organic compounds
SWF	Seep Well Field
SWMU	solid waste management unit
TBC	to-be-considered
TCE	trichloroethene
TDS	total dissolved solids
TEQ	toxic equivalents
TIMET	Titanium Metals Corporation
TOC	Total Organic Carbon
TPH	total petroleum hydrocarbons
Tronox	Tronox LLC
TSCA	Toxic Substances Control Act
UMCf	Upper Muddy Creek Formation
UMCf-cg1	Upper Muddy Creek Formation, first coarse-grained facies
UMCf-cg2	Upper Muddy Creek Formation, second coarse-grained facies
UMCf-fg1	Upper Muddy Creek Formation, first fine-grained facies
UMCf-fg2	Upper Muddy Creek Formation, second fine-grained facies
USEPA	U.S. Environmental Protection Agency
Veolia	Veolia Water North America – West, LLC
VOCs	volatile organic compounds
WAPA	Western Area Power Administration
WBZ	water-bearing zone
WECCO	Western Electrochemical Company

Work Plan	Remedial Investigation and Feasibility Study Work Plan
xMCF	Transitional Muddy Creek Formation
yd^3	cubic yard

1.0 Introduction

In accordance with the Interim Consent Agreement entered into by the Nevada Environmental Response Trust (NERT) Site (the Site), effective February 14, 2011, ENVIRON International Corporation (ENVIRON) submits this Remedial Investigation (RI) and Feasibility Study (FS) Work Plan (Work Plan) to the Nevada Division of Environmental Protection (NDEP) on behalf of the Nevada Environmental Response Trust (the Trust). The Site comprises approximately 410 acres located within the Black Mountain Industrial (BMI) Complex in unincorporated Clark County and is surrounded by the City of Henderson, Nevada (Figure 1-1).

The property comprising the Site has a long, complex ownership and operational history, as summarized in Section 2. The Site has been the location of industrial operations since 1942 when it was developed by the U.S. government as a magnesium plant to support World War II operations. Following the war, the Site continued to be the location of industrial activities, including production of perchlorates, boron, and manganese compounds. Former industrial and waste management activities conducted at the Site, as well as those conducted at adjacent properties, resulted in contamination of environmental media at the Site, including soil, groundwater, and surface water.

Tronox LLC (Tronox) most recently owned and operated the Site until February 14, 2011, on which date the Trust took title to the Site in conjunction with the settlement of Tronox's bankruptcy proceeding. Tronox currently leases a portion of the Site from the Trust, on which it continues to operate its chemical manufacturing business. The exclusive purpose and functions of the Trust include (among others): "(i) own the (Site) for purposes of implementing the Settlement Agreement[1], (ii) carry out administrative and property management functions related to the (Site), (iii) manage and/or fund implementation of Environmental Actions for the Henderson Legacy Conditions (as defined in the Settlement Agreement) that are approved by (NDEP)."

The Site has been the subject of extensive environmental investigations and removal actions since the 1970s. The on-site Hazardous Waste Landfill was closed and capped in 1985. A groundwater treatment system for removal of hexavalent chromium from groundwater was constructed in 1987. In 1994, NDEP identified 69 Letter of Understanding Potential Source Areas (NDEP 1994) (referred to in this and other reports as LOUs[2]). In 1997, perchlorate, later shown to originate from the Site and one other nearby property, was detected in Las Vegas Wash and the Colorado River (NDEP 2011a), and in 1999, an additional groundwater treatment system for removal of perchlorate was constructed. The on-site Hazardous Waste Landfill was closed and capped in 1985. At the end of 2010, Tronox excavated and disposed of the waste material from the landfill. More recently, over 500,000 cubic yards (yd^3) of impacted soils and tailings were removed and disposed of at an off-site location.

[1] Settlement Agreement shall mean that certain Consent Decree and Environmental Settlement Agreement, effective February 14, 2011, filed in *In re Tronox Incorporated, et al.,* Case No. 09-10156 (ALG).

[2] Appendix A includes a figure showing the locations of all LOUs (Figure A-1) and a comprehensive table (Table A-1) listing the LOUs, LOU name, and the work plans and investigations conducted for the individual LOUs.

Investigation and cleanup activities at the Site are being conducted in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), as amended, and the Interim Consent Agreement[3] between NDEP and the Trust. In accordance with CERCLA, a Remedial Investigation/Feasibility Study (RI/FS) is being conducted to investigate the nature and extent of contamination at the Site and downgradient plume (Figure 1-2) to develop and evaluate remedial action alternatives, as appropriate. As stated in RI/FS guidance (US Environmental Protection Agency [USEPA] 1988), the overall purpose of the RI/FS process is "to gather information sufficient to support an informed risk management decision regarding which remedy appears to be most appropriate for a given site."

This Work Plan identifies additional activities within the RI/FS process that are proposed to address remaining contamination at the Site. The overall format of the Work Plan follows that recommended in USEPA guidance (USEPA 1988) for conducting an RI/FS, as follows:

- Section 1 presents a brief introduction, identifying the purpose of the RI/FS and the contents of this report.
- Section 2 presents background information about the Site including descriptions of the ownership and operational history, physical setting, climate, and geology and hydrogeology.
- Section 3 summarizes regulatory actions and historical and recent field investigations of soil, soil gas, indoor air, and groundwater.
- Section 4 summarizes interim removal actions conducted to date and risk assessments evaluating the potential adverse effects associated with exposures to chemicals in soils, indoor air, and groundwater.
- Section 5 presents the Initial Site Evaluation, which includes (1) a preliminary conceptual site model (CSM), (2) a preliminary identification of regulatory requirements and remedial action objectives (RAOs), (3) a screening of remedial technologies and process options, and (4) a preliminary identification of data gaps.
- Section 6 outlines RI/FS tasks described in USEPA guidance (USEPA 1988) and discusses the planned activities for each of these tasks.
- Section 7 describes the project management structure and proposed schedule for completion of the RI/FS.
- Section 8 lists the references cited in this report.

Appendices to this Work Plan provide detailed analyses or supplementary information, as follows:

- Appendix A LOU Roadmap
- Appendix B Soil Remediation Goals for the 2011 Interim Soil Removal Action
- Appendix C Background Data Set for Soils

[3] Interim Consent Agreement, effective February 14, 2011.

- Appendix D PRB Bench Scale and Treatability Study Work Plan
- Appendix E In-Situ Soil Flushing Treatability Study Work Plan
- Appendix F Groundwater Extraction and Treatment System Optimization Study: Analysis of Groundwater Extraction Rates and Capture at the Interceptor and Athens Road Well
- Appendix G Community Involvement Plan (this plan was previously submitted to NDEP on April 30, 2012 [ENVIRON 2012a]).

2.0 Site Background

2.1 Operational History

The BMI[4] complex was first developed in 1942 by the U.S. government as a magnesium plant for World War II operations. Later, a part of the BMI complex that would ultimately become the Site was leased by Western Electrochemical Company (WECCO). WECCO produced manganese dioxide, sodium chlorate, sodium perchlorate, and other perchlorates. WECCO also produced ammonium perchlorate (a powerful oxidizer) for the Navy during the early 1950s using a plant that was constructed on the Site by the Navy. WECCO merged with American Potash and Chemical Company (AP&CC) in 1956, and continued production of ammonium perchlorate for the Navy. In 1967, Kerr-McGee Chemical Corporation (KMCC) purchased AP&CC. KMCC began production of boron chemicals in the early 1970s. The production processes included elemental boron, boron trichloride (a colorless gas used as a reagent in organic synthesis), and boron tribromide (a colorless fuming liquid used in a variety of applications). The production of boron tribromide was discontinued in 1994, and the production of sodium chlorate and ammonium perchlorate was discontinued in 1997 and 1998, respectively. Perchlorate was reclaimed at the Site using existing equipment until early 2002.

In 2006, Tronox took ownership of the facility formerly operated by KMCC on the Site and operated it to produce electrolytic manganese dioxide for use in the manufacture of alkaline batteries; elemental boron for use as a component of automotive airbag igniters; and boron trichloride for use in the pharmaceutical and semiconductor industries and in the manufacture of high-strength boron fibers for products that include sporting equipment and aircraft parts. In 2009, Tronox filed for Chapter 11 bankruptcy. As previously noted in Section 1.0, the Trust took title to the Site on February 14, 2011, as a result of the settlement of Tronox's bankruptcy proceeding. Tronox currently has a long-term lease for approximately 373 acres of the Site (ENVIRON 2012f), where it continues its manufacturing operations (identified on Figure 2-2 as "Tronox Operational Areas").

2.2 Site Description

The Site is located approximately 13 miles southeast of the city of Las Vegas and is located in an area of unincorporated Clark County, Nevada, that is surrounded by the City of Henderson. It covers approximately 410 acres[5], and lies in Sections 1, 12, and 13 of Township 22 S, Range 62 E. The Site is located within the BMI complex, which consists of several facilities owned and operated by a number of chemical companies (Figure 2-1).

The Site is located in an industrial land use area. The nearest residential areas are located just north (across North Boulder Highway) and south (across Lake Mead Parkway) of the Site (Figure 2-1). The Site is generally rectangular, but certain interior portions of the rectangle are

[4] The acronym "BMI" has been applied to several entities over the years. From 1941 until 1951 it referred to Basic Magnesium Incorporated; in 1951, a syndicate of tenants formed under the name of Basic Management, Inc. to provide utilities and other services at the complex; the group has also been known as Basic Metals, Inc., and at the present is called the Black Mountain Industrial complex.

[5] Previous documents have identified an area of approximately 450 acres. Following the sale of Parcels I and J and a part of Parcel B in 2008, the Site comprises approximately 410 acres.

owned and operated by other companies, specifically, Lhoist, Western Area Power Administration (WAPA), BMI, and Titanium Metals Corporation (TIMET). Facilities on the exterior borders of the Site are TIMET to the east, and Olin Chlor-Alkali (formerly known as [1] Pioneer Americas LLC, which includes former Stauffer and Montrose Sites; [2] Olin Chlor-Alkali/Stauffer/Syngenta/Montrose [OSSM]; and [3] Pioneer/Olin Chlor-Alkali/Stauffer/Syngenta/ Montrose [POSSM]). Olin Chlor-Alkali is hereafter referred to as the Olin property. BMI is located mainly to the east of the Site, although a BMI-owned Corrective Action Management Unit (CAMU) is located immediately to the west. A summary of the neighboring properties and their former property names is provided in Table 2-1. Areas referred to as Parcels I and J (and part of B), which were formerly part of the Site, were sold in 2008, and now represent a portion of the northern and eastern site boundary (Figure 2-2).

An area within the northwestern portion of the Site consists of groundwater treatment facilities, which are operated on behalf of the Trust by an outside contractor, Veolia Water North America – West, LLC (Veolia)[6]. Three lined ponds on the Site (known as WC-West, WC-East, and Mn-1 receive process-related wastewater discharges from ongoing operations, and an additional lined pond (known as GW-11) receives extracted groundwater from remediation activities. The Site is traversed (from west to east) by a drainage ditch known as the Beta Ditch that historically conveyed liquid wastes from the Site and from neighboring facilities located to the west. The Beta Ditch, which is currently blocked by an earthen dam near its eastern end, has been re-graded, channelized, and now includes a retention basin. The west end of the Beta Ditch at the Site continues to receive storm water drainage from the neighboring property to the west. These Site features are shown in Figure 2-2.

The major buildings on the Site include Units 1 through 6, which are aligned in a row extending in a west-east direction across the southern portion of the Site (Figure 2-2). These buildings were constructed during World War II for magnesium production. Within its leased area, Tronox uses Units 5 and 6 for production of manganese dioxide; Unit 5 is also used for storage. Units 1, 2, and most of unit 4 are no longer used and have been partially demolished. The remaining portion of Unit 4 has been retrofitted to house an advanced battery manufacturing process that started up in 2012. Tronox currently uses Unit 3 for office and storage activities. In addition, Tronox produces boron products within a Boron Plant to the north of Unit 4, and manganese sulfate solution (for use in the manganese dioxide production process) is produced within a Leach Plant north of Units 5 and 6. Other buildings present at the Site include an administration building, a change house, a laboratory building, a maintenance shop, a steam plant, and various storage buildings (Figure 2-2). The Site is crossed by asphalt and concrete roads, dirt roads, active utility lines, a gaseous chlorine line, and railroad spurs. An extensive network of active and inactive underground utility lines is present under the roads and open areas at the Site.

Within the boundaries of the Site, and as shown on Figure 2-2, are Parcels A, B, C, D, E, F, G, and H. The Parcels are at the edges of the Site, to the north, west, and south. Parcel E contains a portion of the Olin (also referred to as the OSSM or POSSM) groundwater treatment system. As noted above, Parcels I and J (and a portion of Parcel B) were sold to Rolly

[6] Veolia is referred to elsewhere in this report as the GWETS Contractor.

Properties LLC (Parcels B and I) and Robert and Sandra Ellis (Parcels B and J); these areas are no longer a part of the Site. Environmental investigations and responses completed at the Parcels that remain a part of the Site (i.e., Parcels A, B, C, D, E, F, G, and H) are summarized in Sections 3 and 4.

2.3 Physical Setting

Elevations across the Site range from 1,677 to 1,873 feet above mean sea level. The land surface across the Site generally slopes toward the north at a gradient of approximately 0.023 feet per foot (ft/ft). The developed portions of the Site have been modified by grading to accommodate building foundations, surface impoundments, and access roads. Further modifications to the Site were made as part of the Interim Soil Removal Action (ENVIRON 2012b) in which soils were typically excavated to depths of up to 10 ft below ground surface (bgs). In some cases, depths were extended to greater than 10 ft to remove discolored soils. Not all excavations were completely backfilled following excavation, resulting in some areas with depressions with 3:1 side slopes. Off-site to the north, the topographic surface continues at approximately the same gradient to approximately Sunset Road, at which point it flattens to a gradient of approximately 0.011 ft/ft to the Las Vegas Wash (ENSR 2005).

2.4 Climate

The climate of the Las Vegas Valley is arid, consisting of mild winters and dry hot summers. Average annual precipitation as measured in Las Vegas from 1971 to 2000 was 4.49 inches. Precipitation generally occurs during two periods, December through March and July through September. Winter storms generally produce low intensity rainfall over a large area. Summer storms generally produce high intensity rainfalls over a smaller area for a short duration. These violent summer thunderstorms account for most of the documented floods in the Las Vegas area. Winds frequently blow from the south or northwest at a mean velocity of approximately 9 miles per hour (mph); however, velocities in excess of 50 mph are not atypical when weather fronts move through the area. During these windy events, dust, sand, and soil at the ground surface can become airborne and may travel several miles. Temperatures can rise to 120°F in the summer, and the average relative humidity is approximately 20%. The mean annual evaporation from lake and reservoir surfaces ranges from 60 to 82 inches per year (summarized from Kleinfelder 1993).

2.5 Geology and Hydrogeology

The following subsections describe the regional geology, local geology, and local hydrogeology.

2.5.1 Regional Geology

The Site is located within the Las Vegas Valley, which occupies a topographic and structural basin trending northwest-southeast and extending approximately 55 miles from near Indian Springs on the north to Railroad Pass on the south. The valley is bounded by the Las Vegas Range, Sheep Range, and Desert Range to the north; by Frenchman and Sunrise Mountains to the east; by the McCullough Range and River Mountains to the south and southeast; and the Spring Mountains to the west. The mountain ranges bounding the east, north, and west sides of the valley consist primarily of Paleozoic and Mesozoic sedimentary rocks (limestones, sandstones, siltstones, and fanglomerates), whereas the mountains on the south and southeast

consist primarily of Tertiary volcanic rocks (basalts, rhyolites, andesites, and related rocks) that overlie Precambrian metamorphic and granitic rocks (ENSR 2007a).

In the Las Vegas Valley, eroded Tertiary and Quaternary sedimentary and volcanic rocks comprise the unconsolidated basin deposits, which can be up to 13,000 feet thick (ENSR 2007a). The valley floor consists of fluvial, paludal (swamp), playa, and lacustrine deposits surrounded by more steeply sloping alluvial fan aprons derived from erosion of the surrounding mountains. Generally, the deposits grade finer with increasing distance from their source and with decreasing elevation. The structure within the Quaternary and Tertiary-aged basin fill is characterized by a series of generally north-south trending fault scarps.

2.5.2 Local Geology

The local geology and hydrogeology are defined by data collected from more than 1,100 borings and wells that have been installed in the area. The following descriptions are summarized from the CSM report (ENSR 2005).

Alluvium. The Site is located on Quaternary alluvial deposits (Qal) that slope north toward Las Vegas Wash. The alluvium consists of a reddish-brown heterogeneous mixture of well-graded sand and gravel with lesser amounts of silt, clay, and caliche. Clasts within the alluvium are primarily composed of volcanic material. Boulders and cobbles are common. Due to the mode of deposition, no distinct beds or units are continuous over the area.

A major feature of the alluvial deposits is the stream-deposited sands and gravels that were laid down within paleochannels eroded into the surface of the Muddy Creek Formation during infrequent flood runoff periods. These deposits vary in thickness and are narrow and generally linear. These generally uniform sand and gravel deposits exhibit higher permeability than the adjacent, well-graded deposits. In general, these paleochannels trend northeastward.

The thickness of the alluvial deposits ranges from less than 1 foot to more than 50 feet beneath the Site. Soil types identified in on-site soil borings include poorly sorted gravel, silty gravel, poorly sorted sand, well sorted sand, and silty sand. The thickness of the alluvium, as well as the top of the underlying Muddy Creek Formation, was mapped to locate these paleochannels.

Transitional (or reworked) Muddy Creek Formation. Where present, Transitional Muddy Creek Formation (xMCf) is encountered at the base of the alluvium. The Transitional Muddy Creek Formation consists of reworked sediments derived from the Muddy Creek Formation, which is described below. Therefore, the xMCF appears similar to the Muddy Creek Formation, but it consists of reworked, less consolidated and indurated sediments.

Muddy Creek Formation. The Upper Muddy Creek Formation (UMCf) of Pleistocene age occurs in the Las Vegas Valley as valley-fill deposits that are coarse-grained near mountain fronts and become progressively finer-grained toward the center of the valley. Where encountered beneath the Site, the Muddy Creek Formation is composed of at least two thicker units of fine-grained sediments of clay and silt (the first and second fine-grained facies) interbedded with at least two thinner units of coarse-grained sediments of sand, silt, and gravel (the first and second coarse-grained facies). Except for the southernmost 1,000 feet adjacent to Lake Mead Parkway, the first fine-grained facies (UMCf-fg1) separates the first coarse-grained

facies (UMCf-cg1) from the overlying Quaternary alluvium at the Site. Within the southern 1,000 feet of the Site, the Muddy Creek Formation's UMCf-fg1 pinches out along a roughly west-northwesterly trending line. South of this line, the UMCf-cg1 directly underlies the Quaternary alluvium.

The Muddy Creek Formation represents deposition in an alluvial apron environment from the Spring Mountains to the west, grading into fluvial, paludal (swamp), playa, and lacustrine environments further out into the valley center. On the Site, the Muddy Creek does not crop out but instead subcrops beneath a veneer of Quaternary alluvium.

In on-site borings, the contact between the Quaternary alluvium and the Muddy Creek Formation (UMCf-fg1) is typically marked by the appearance of a well-compacted, moderate brown silt-to- sandy silt or stiff clay-to-sandy clay, whereas near the Las Vegas Wash, the contact is marked by gray-green to yellow-green gypsiferous clays and silts.

2.5.3 Local Hydrogeology

Background information is described in detail in the 2005 CSM report (ENSR 2005). Depth to groundwater ranges from about 27 to 80 ft bgs and is generally deepest in the southernmost portion of the Site, becoming shallower as it approaches the Las Vegas Wash to the north. A potentiometric surface map depicting shallow groundwater elevations during the May-June 2012 timeframe is presented on Plate 2 (ENVIRON 2012c). The groundwater gradient averages 0.015 to 0.02 ft/ft south of the Athens Road well field (AWF), flattening to 0.007 to 0.010 ft/ft north of the well field (Northgate Environmental Management, Inc. [Northgate] 2010a). The groundwater flow direction at the Site is generally north to north-northwesterly, whereas north of the Site the direction changes slightly to the north-northeast. This generally uniform flow pattern may be modified locally by subsurface alluvial channels cut into the underlying UMCf, the on-site bentonite-slurry groundwater barrier wall, on- and off-site artificial groundwater highs or "mounds" created around the on-site recharge trenches (not currently in use) and City of Henderson Water Reclamation Facility Rapid Infiltration Basins (RIBs), and by depressions created by the groundwater extraction wells at the three groundwater extraction well fields (Northgate 2010a).

NDEP has defined three water-bearing zones (WBZs) that are of interest in the BMI complex: the Shallow WBZ, which extends to approximately 90 ft bgs, is unconfined to partially confined, and is considered the "water table aquifer"; the Middle WBZ, which extends from approximately 90 to 300 ft bgs; and the Deep WBZ, which is defined as the contiguous WBZ that is generally encountered between 300 to 400 ft bgs (NDEP 2009a). Environmental investigations at the Site have primarily focused on the Shallow WBZ, although recent investigations (Northgate 2009, 2010b) have included a number of Middle WBZ wells to improve vertical delineation of hydrogeology and chemical constituent distribution. Plates 1a, 1b, and 1c show the locations of all former and current groundwater monitoring wells in the Shallow WBZ, Middle WBZ, and Deep WBZ, respectively.

At the Site, the Shallow WBZ is comprised of the saturated portions of the alluvium and the uppermost portion of the UMCf to depths of approximately 90 ft bgs. Beneath the northern portion of the Site, the first groundwater encountered occurs within the alluvium at depths of

30 ft bgs or more, and shallows northward, occurring near the ground surface at Las Vegas Wash. In the alluvial aquifer, groundwater flows towards the north-northeast with minor variations, generally mimicking the slope of the ground surface. The results of a 1998 pump test in the Athens Road area indicate a permeability of 50 gallons per day per square foot (gpd/ft^2), a transmissivity of 1,300 gpd/ft, and a groundwater velocity of 220 feet per year (ft/yr) for groundwater in the alluvial aquifer (KMCC 1998c). However, significantly higher groundwater velocities, ranging from approximately 600 to 2,500 ft/yr, have been calculated based on alluvial well pumping and slug tests (KMCC 1998c), and a groundwater velocity of over 12,000 ft/yr was reported based on a tracer test conducted in the alluvial channel between the Athens Road area and the Las Vegas Wash (Errol Montgomery and Associates 2000).

Beneath the central portion of the Site, groundwater is first encountered within the Shallow Zone in the UMCf-fg1, and can be more than 50 ft bgs, as documented in historic water level measurements. South of where UMCf-fg1 pinches out, beneath the southern portion of the Site, the first groundwater encountered occurs within the UMCf-cg1 and can be more than 70 ft bgs as documented in historical water level measurements from well M-103 and further confirmed from water level measurements from wells M-120 and M-121, which were installed as part of the upgradient investigation (ENSR 2006a). The gradient of the potentiometric surface in both UMCf-fg1 and UMCf-cg1 (south of where UMCf-fg1 pinches out) mimics the ground surface and the flow direction is to the north-northeast with minor variations. Both the horizontal and vertical hydraulic conductivities of the UMCf are one or more magnitudes of order less than those of the Qal (ENSR 2005).

Investigations of the Middle WBZ at the Site and surrounding sites indicate, with a few exceptions, a vertically upward gradient between the Middle and Shallow Zones that generally increases with depth. At the Site, the sediments within the Middle WBZ consist predominantly of the UMCf-fg1. The UMCf-cg2 occurs below the fine-grained unit at the base of the Middle WBZ, roughly between approximate depths of 280-300 ft bgs. The UMCf-cg2 unit has been defined below the western portion of the Site by six deep wells (TR-1, TR-5, TR-7, TR-9, TR-11, TR-12). The UMCf-cg2 unit is confined, as indicated by artesian groundwater elevations consistently measured in these wells.

Surface water in the vicinity of the Site flows to the north toward Las Vegas Wash. Surface flow occurs as infrequent storm runoff in shallow washes. Drainage and diversion structures have been constructed around the perimeters of the BMI complex to channel surface water flow, which is retained on the Site. Las Vegas Wash is a tributary to Lake Mead and it is the only channel through which the valley's excess water flows to the lake. Lake Mead is a major reservoir on the Colorado River. There are no water supply wells reported within four miles of the Site that extract water from the Shallow, Middle, or Deep Zones (ENSR 2005).

3.0 Regulatory Actions and Site Investigations

The Site has been the subject of numerous regulatory actions and environmental investigations since the early 1970s. The soil and groundwater investigations conducted through 2005 served as the basis of the first comprehensive CSM developed for the Site in 2005 by ENSR (ENSR 2005). A brief chronological summary of investigations conducted prior to 2005 is presented in Section 3.1.

Since 2005, additional investigations (described in Section 3.2) and interim removal actions (described in Section 4) have been conducted. For soils, these investigations included the Phase A and Phase B Source Area Investigations and additional investigations of specific Parcels. For presentation purposes, the soil investigations are presented separately for (1) the "Facility Area," a contiguous area which for purposes of this Work Plan excludes Parcels A through H, and (2) the "Parcel Areas," which comprises the noncontiguous areas occupied by Parcels A through H.

For groundwater and soil gas, the Phase A and Phase B investigations were conducted on a Site-wide basis that included both the Facility and Parcel Areas. These investigations, which serve as the primary basis for the updated CSM presented in this report, are described in Sections 3.2.

3.1 Overview of Regulatory Actions and Environmental Investigations: 1970 - 2005

This section provides a brief chronological summary of investigations conducted through 2005.

During the 1970s, the USEPA, the State of Nevada, and Clark County investigated potential environmental impacts from the BMI company operations, including atmospheric emissions, groundwater and surface water discharges, and soil impacts (ENSR 2007a).

Between 1971 and 1976, KMCC modified its manufacturing processes and constructed lined surface impoundments to recycle and evaporate industrial wastewater in response to the 1972 Federal Water Pollution Control Act (the Clean Water Act [CWA]). The facility achieved zero-discharge status in 1976 regarding industrial wastewater management, and in February 1977, KMCC obtained a National Pollutant Discharge Elimination System (NPDES) permit under the CWA authorizing up to 4 million gallons per day (MGD) discharge of non-contact cooling water to Las Vegas Wash. In 1980, the USEPA requested specific information from the BMI companies regarding their manufacturing and waste management practices by issuing a CWA Section 308 letter.

In July 1981, KMCC initiated a groundwater investigation to comply with federal Resource Conservation and Recovery Act (RCRA) standards for monitoring existing on-site impoundments. In December 1983, NDEP requested that KMCC investigate the extent of chromium impact in groundwater beneath the Site. Forty groundwater monitoring wells were installed, and in July 1985, KMCC submitted to NDEP a hydrogeological investigation report delineating a chromium plume within the "near surface groundwater" (KMCC 1985). A Consent Order between KMCC and NDEP was signed in September 1986 (NDEP 1986) that stipulated additional characterization and implementation of corrective action to address chromium in

groundwater. Remediation of hexavalent chromium in groundwater began in mid-1987, when four extraction wells (or "interceptor" wells) were installed downgradient of the Ammonium Perchlorate (AP) Plant. The extracted water was pumped to a chromium treatment facility where hexavalent chromium was reduced to trivalent chromium that was then precipitated and removed. Treated water was subsequently reinjected at a series of recharge trenches downgradient of the interceptor well field (IWF).

In April 1991, KMCC was one of six past or present entities that had conducted business within the BMI complex that entered into a Consent Agreement with NDEP (NDEP 1991) to conduct environmental studies to assess site-specific environmental conditions at individual company sites, the BMI Common Areas, and any off-site waste management areas that were the result of past and present industrial operations and waste disposal practices.

In April 1993, and in compliance with the 1991 Consent Agreement, KMCC submitted a Phase I Environmental Conditions Assessment report to NDEP (Kleinfelder 1993). The purpose of the report was to identify and document site-specific environmental impacts resulting from past or present industrial activities. The Phase I Environmental Conditions Assessment included a comprehensive assessment of the geologic and hydrologic setting, as well as historical manufacturing activities. The Environmental Conditions Assessment identified 31 solid waste management units (SWMUs), 20 areas of known or suspected releases or spills, and 14 miscellaneous areas where Site activities may have impacted the environment.

In 1994, NDEP issued a LOU to KMCC identifying 69 potential source areas or "items of interest" (LOU-1 through LOU-69) and specifying the level of environmental investigation to be conducted by KMCC (NDEP 1994). Subsequent to the issuance of the LOU, an additional potential source area, the former U.S. Vanadium site, was identified during planning for the Phase B 2008 investigation (NDEP 2011a). Although not formally designated as an LOU, the U.S. Vanadium site is hereafter referred to as LOU-70. A detailed discussion of the specific areas or items of interest identified in the LOUs, lists of the products made, years of production, and approximate waste volumes for WECCO, AP&CC, and Tronox, and actions taken for each LOU study item is presented in the 2005 CSM (ENSR 2005). The 70 LOUs are listed in Table A-1 of Appendix A to this Work Plan and the LOU locations are shown on Figure A-1.

In 1996, KMCC and the other parties at the BMI complex entered into a Consent Agreement with NDEP to perform a Phase II Environmental Conditions Assessment and to conduct Remedial Alternative Studies (RAS), Interim Measures, or Additional Work (NDEP 1996). KMCC collected additional data in 1996 and 1997 as part of a Phase II Environmental Conditions Assessment (ENSR 1997) that addressed 12 LOUs identified for additional soil and groundwater characterization in the Phase II Work Plan (KMCC 1997).

In late 1997, perchlorate contamination was discovered in Las Vegas Wash and determined to have originated from the KMCC and former Pacific Engineering and Production Company of Nevada (PEPCON) facilities (NDEP 2011a). KMCC undertook a characterization study to identify the subsurface pathway(s) and characterize perchlorate concentrations in shallow groundwater downgradient from the Site to the Athens Road area in Henderson (about one-mile south of Las Vegas Wash) (KMCC 1997). KMCC installed extraction wells in the Athens Road area in September 1998 to remove perchlorate-bearing shallow groundwater (KMCC 1998b).

By late 1999, a water collection system and temporary ion exchange (IX) treatment process for perchlorate removal was installed at the Las Vegas Wash and began operating as a result of a 1999 Consent Agreement between KMCC and NDEP that defined initial removal requirements (NDEP 1999). Additional interceptor wells were installed in 1998 and early 1999 for continued capture of on-site groundwater for removal of hexavalent chromium (ENSR 2005). These interceptor wells, in combination with the interceptor wells installed in 1987 as a result of the 1986 Consent Order, continued to capture on-site groundwater for removal of hexavalent chromium; however, instead of re-injecting the treated groundwater, the treated water was impounded in an 11-acre lined pond (GW-11, constructed in late 1998) and held for additional treatment for perchlorate. Untreated Lake Mead water was reinjected into the groundwater system via the recharge trenches (NDEP 2011a).

Between 1999 and 2001, KMCC conducted a supplemental Phase II Environmental Conditions Assessment, the results of which were submitted to NDEP in April 2001 (ENSR 2001). In comments on the Supplemental Phase II Environmental Conditions Assessment report on February 11, 2004, NDEP (2004) required additional work to investigate and characterize the Site. Specifically, NDEP emphasized the importance of developing a CSM to identify all site-related chemicals (SRCs), data gaps, and delineate the extent of groundwater contamination.

In 2001, an Administrative Order on Consent (AOC) (NDEP 2001) defined additional removal requirements that included a low-permeability barrier wall with an upgradient collection (interceptor) well field, the construction of the Athens Road groundwater collection well field, the construction of the seep area collection well field, and the development of a treatment process that removes chromium and perchlorate from the collected water and then discharges the water within limits set forth in an existing NPDES permit. The effectiveness of these systems at removing contaminant mass, reducing groundwater concentrations, and reducing contaminant mass flux into Las Vegas Wash is presented in annual and semi-annual monitoring reports (e.g., ENVIRON 2012c).

In response to this order, KMCC constructed a groundwater barrier wall along the downgradient side of the interceptor well line and installed additional groundwater extraction wells along the Athens Road Area and in the seep well field (SWF) area to enhance the recovery of perchlorate-contaminated groundwater. KMCC also constructed a biological fluidized-bed reactor (FBR) treatment system designed to remove perchlorate from recovered groundwater.

In 2005, an AOC (NDEP 2005) between NDEP and KMCC established a compliance schedule for treatment of the perchlorate residues of Pond AP-5 designed to reduce the amount of perchlorate in groundwater and surface water reaching the Las Vegas Wash and Lake Mead.

Additionally, in 2005 as a follow up to the Phase I and Phase II activities completed by KMCC, a CSM report was prepared for the Site that integrated information from the soil and groundwater investigations conducted to date to document information on Site-specific sources, release mechanisms, transport pathways, exposure routes, and potential receptors (ENSR 2005). The 70 LOUs were subdivided into common potential contaminant groups for discussion. For reference, Appendix A includes a figure showing the locations of all LOUs (Figure A-1) and a comprehensive table (Table A-1) listing the LOUs, LOU name, and the work plans and investigations conducted for the individual LOUs.

The 2005 CSM identified several data gaps related to soil characterization, including:

- Identification of background concentrations of metals and other naturally occurring chemicals of potential concern (COPCs) in the local area.
- Identification of other COPCs.
- Evaluation of historic data for usability for risk assessment purposes.
- Preparation of a risk assessment to evaluate risks posed by the Site to human receptors.

3.2 Regulatory Actions and Investigations: 2005 to Present

Site investigations conducted since completion of the 2005 CSM have included the Phase A and Phase B Source Area Investigations (Phase A and Phase B investigations) to further characterize soil, groundwater, and soil gas across the Site. Additional soil investigations were conducted at the Parcel Areas. The investigations were conducted on a "site-wide" basis (i.e., for both the Facility Area and Parcel Areas) or as separate investigations focused on either one or more locations within the Facility Area or Parcel Areas, as outlined below.

- **Soil:** Soils in the Facility Area were investigated in the Phase A and B investigations, as described in Section 3.2.1.1. Soils in the Parcels Areas were investigated by Tronox in the Phase A investigation and during investigations completed by other entities (working on a separate timeline). These soil investigations are described in Section 3.2.1.2.
- **Soil gas:** Investigation of soil gas was conducted as part of the Phase B investigation. At the request of NDEP (KMCC 2005), a "site-wide" investigation was conducted that included both the Facility Area and Parcel Areas. The Phase B soil gas investigation is described in Section 3.2.2.
- **Indoor air:** To assess the potential uncertainty associated with use of vapor intrusion models in the soil gas health risk assessment (HRA), an indoor air quality study was conducted at the operating Tronox facility as described in Section 3.2.3.
- **Groundwater:** Investigation of groundwater was conducted as part of the Phase A and Phase B investigations. At the request of NDEP (NDEP 2008a), groundwater was investigated on a "Site-wide" basis that included both the Facility Area and Parcel Areas. The groundwater investigations are described in Section 3.2.4.

3.2.1 Soil

Section 3.2.1.1 summarizes the Phase A and Phase B Investigations of Facility Area soils and Section 3.2.1.2 summarizes the soil investigations of the Parcel Area soils.

3.2.1.1 Phase A and Phase B Soil Investigations in the Facility Area

The objectives of the Phase A and B investigations were to refine the 2005 CSM, further characterize site conditions, and provide data for future risk assessments. To identify and characterize the distribution of SRCs in soils, the investigation focused on soil conditions associated with the 192 SRCs identified in the 2005 CSM report and their suspected source areas. A total of 127 soil samples were collected from 27 suspected source area locations in November and December of 2007. The sample locations were selected based on results from

past site investigations (ENSR 2005), information on chemical use at the Site, and the 70 LOU study areas identified by NDEP in 1994. In addition to the 192 SRCs previously identified, 44 additional parameters were analyzed and reported by the laboratory.

During the Phase A investigation, soil samples were collected at depths of 0.5 to 1 ft, and at 10-ft intervals thereafter, until groundwater was encountered (ENSR 2006b). The samples were analyzed for metals; volatile organic compounds (VOCs), including fuel oxygenates; semivolatile organic compounds (SVOCs); polychlorinated biphenyls (PCBs); dioxins and furans; total petroleum hydrocarbons (TPH as gasoline, diesel, and oil range organics [GRO, DRO, and ORO]); organochlorine herbicides (OCHs); organochlorine pesticides (OCPs); and organophosphate pesticides (OPPs). In addition, analyses were conducted for radionuclides, asbestos (surface soil samples only), and wet chemistry constituents. Not all samples were analyzed for all analytes, and at some locations, samples were collected at more frequent depth intervals. In addition, samples were collected from the manganese ore and tailings stockpile for analysis of metals and radionuclides, and two near surface (1.5 to 3 ft bgs) soil samples were collected and analyzed for physical and geotechnical parameters.

The objective of the Phase B investigation was to further characterize and evaluate the LOUs in the Facility Area and their potential impact on soil conditions across the Facility Area, based on the results of the Phase A investigation. For the Phase B investigation, the Facility Area was subdivided into four areas for investigation activities: Areas I, II, III, and IV. Table A.1 (Appendix A) identifies the LOUs within the four investigation areas. Separate work plans describing the Area-specific scope of work were prepared as follows: Area I Work Plan (ENSR 2008a, approved by NDEP on May 6, 2008); Area II Work Plan (ENSR 2008b, approved by NDEP on July 21, 2008); Area III Work Plan (ENSR 2008c, approved by NDEP on July 21, 2008); and Area IV Work Plan (ENSR 2008d, approved by NDEP on June 18, 2008). In addition, a revised investigation work plan was prepared that was applicable to the four Investigation Areas (AECOM, Inc. [AECOM] 2008, approved by NDEP on January 16, 2009).

During the Phase B investigation, samples were collected at initial soil depths of 0.5 and 10 ft bgs, the capillary fringe, and the midpoint between the capillary fringe and 10 ft bgs, without exceeding 20 ft between each vertical sample (AECOM 2008). Judgmental samples were collected at 0.5 ft and 10 ft bgs in locations where certain surface features were noted, including minor stains or above ground pipelines.

The number of soil borings and samples varied across the investigation areas, as follows:

- **Area I:** 6,493 environmental samples and 1,369 field quality control (QC) samples were collected from 65 borings (Northgate 2010c).
- **Area II:** 7,697 environmental and 1,719 field QC samples were collected from 86 borings (Northgate 2010d).
- **Area III:** 2,990 environmental and 676 field QC samples were collected from 33 borings (Northgate 2010e).
- **Area IV:** 5,999 environmental and 1,266 field QC samples were collected from 54 borings (Northgate 2010f).

During the Phase B investigation, soil samples were analyzed for the following analytical groups and analytes: metals, VOCs, SVOCs, organic acids, PCBs and PCB congeners, dioxin/furans, OCPs, OPPs, TPH, chlorate, perchlorate, cyanide, hexavalent chromium, formaldehyde, and radionuclides. In addition, based on the findings of the Phase A investigation, samples were collected from 0 to 2 inches bgs and analyzed for asbestos fibers, and samples collected from 0 to 0.5 ft bgs were analyzed for dioxin/furans. Samples for wet chemistry and geotechnical parameters were also collected (Northgate 2010c,d,e,f).

Supplemental sampling of shallow soils was conducted in December 2009 in accordance with two Tronox memoranda, Scope for Additional Sampling of Area I and Area II (approved by NDEP on November 24, 2009 and December 14, 2009, respectively). A total of 129 soil samples were collected at Phase B locations where contaminants exceeded Nevada Basic Comparison Levels (BCLs) to provide information for remediation planning and supplement post-excavation confirmation sampling (Neptune and Company 2010).

The results of the Phase A and B investigations identified a number of constituents within the upper 10 ft of soil with reported concentrations in excess of NDEP worker BCLs or modified risk-based goals (as agreed upon by NDEP), which are collectively referred to as “soil remediation goals” (SRGs). (SRGs are listed in Table B-1 of Appendix B.) These constituents included metals; SVOCs, including hexachlorobenzene (HCB); PCBs; OCPs; dioxin toxic equivalents (TEQs), asbestos, and perchlorate.

Interim soil removal actions were conducted in Areas I through IV based on the results of the Phase A and B investigations, as described in Section 4.

3.2.1.2 Investigations of Parcel Soils

Soil investigations of Parcels A through D, F, G, and H were conducted by Basic Environmental Company (BEC) in accordance with work plans (BEC 2007a,b,c,d,e,f and 2008a) approved by NDEP. The objectives of the investigations were to confirm existing environmental information for the Parcel Areas, characterize possible contamination of LOUs within the Parcels, and fill data gaps with respect to possible contamination. As identified in Figure A-1 (Appendix A), LOU 67 is located in Parcel A; LOU 68 is located in Parcels B, D, and I; LOUs 63 and 65c are located in Parcel F; and LOU 65d is located in Parcel G; no LOUs are located in Parcels C or H. LOU 69 is located in former Parcel J, which is no longer considered part of the Site, as previously mentioned in Section 2.2. No soil investigation of Parcel E has been conducted or is planned for the foreseeable future due to the continued operation of the Olin groundwater treatment system (NDEP 2010a).

The results of the soil investigation for Parcels A and B were reported in the Technical Memorandum Data Review (BEC 2007g), the Asbestos Data Review (BEC 2007h), and the Uranium Isotope Data Review (BEC 2007i). Within Parcels A and B, 64 samples were collected from 32 sample locations at soil depths of zero and 10 ft bgs in accordance with the Phase 2 Sampling and Analysis Plan (SAP) for Parcels A and B (BEC 2007a) approved by NDEP on August 24, 2007. In the first round of sampling, chrysotile and amphibole long asbestos fibers were detected. Surface soil (3 to 6 inches) was scraped in several areas to remove the asbestos and post-scrape samples were collected and analyzed for asbestos. The post-scrape

samples confirmed that asbestos-impacted soil had been removed (BEC 2007g,h), with completion of the removal action approved by NDEP on January 17, 2008. The uranium isotope concentrations were considered above the shallow soil background levels and were therefore included in the screening level HRA as described further in Section 4.2.1 (BEC 2007i).

Soil sampling in Parcels C, D, F, and G was conducted in August and September of 2007 (ERM-West 2008a) and in Parcel H in January and March 2008 (ERM-West 2008b) in accordance with the Phase II SAPs to Conduct Soil Characterization (BEC 2007b,c,f, approved by NDEP on November 20, 2007; BEC 2007d, approved by NDEP on October 29, 2007; and BEC 2007e, approved by NDEP on December 17, 2007). Based on the findings from the initial investigation, a supplemental investigation was conducted in Parcels C, D, F, G, and H in June and July 2008, in accordance with the SAP (BEC 2008a, approved by NDEP on June 5, 2008). The results of the investigation were reported in a Data Validation Summary Report (DVSR) (ERM-West 2009, approved by NDEP on January 12, 2009). Soil samples were also collected in Parcels A and H as part of the Phase A investigation. (The Phase A investigation was previously described for the Facility Area in Section 3.2.1.1).

The investigations at the Parcel Areas revealed a number of constituents within the upper 10 ft of soil in excess of SRGs. As previously reported in Northgate's (2012b) post-remediation screening HRA for Parcels C, D, F, G, and H, these constituents included long amphibole fibers, long chrysotile fibers, Aroclor 1254, arsenic, benzo(a)pyrene, benzo(b)fluoranthene, and dibenz(a,h)anthracene. The post-remediation screening HRA is described further in Section 4.2.2.

3.2.2 Soil Gas

The Phase B soil gas investigation involved collection of 95 soil gas samples at the Site in May 2008. Details of the soil gas sampling are provided in the *Phase B Source Area Investigation Soil Gas Survey Work Plan* (Soil Gas Work Plan; ENSR 2008a, approved by NDEP in March 2008) and summarized in the draft *Site-wide Soil Gas Health Risk Assessment* (Soil Gas HRA) (Northgate 2010g). Soil gas sample locations were based on the following: (1) results of the Phase A investigation (ENSR 2007a), which identified the presence of several VOCs in soil and/or groundwater samples collected at the Site; (2) historic soil and groundwater data collected during prior investigations; and (3) an assessment of former chemical usage at the individual LOUs (18 LOUs were identified as potential sources of VOCs or in areas where VOCs had been detected in soil or groundwater)[7].

The objective of the soil gas survey was to evaluate the nature and extent of VOCs in soil gas in potential VOC source areas. From a review of historic information and Phase A investigation results, the following areas were identified in the Soil Gas Work Plan as potential sources of VOCs or areas where VOCs were detected in soil and/or groundwater (ENSR 2008e):

[7] A plume sourced at a neighboring property and carrying VOCs, non-aqueous phase liquid (NAPL), and other contaminants enters the site along the western boundary. The NAPL and COPCs in the dissolved phase are expected to affect soil gas. This area was not adequately sampled during the 2008 soil gas investigation. Additional soil gas samples are proposed for collection in this area, as described in *Draft Soil Gas Investigation Work Plan for Parcels C, D, F, G and H* (ENVIRON 2012d).

- Former Hardesty Chemical Company site (LOU 4)
- On-site portion of the Beta Ditch, including small diversion ditches (LOU 5)
- Old P-2, Old P-3, and New P-2 Ponds, and Ponds S-1 and P-1 (LOUs 7, 8, 9, 13, and 14)
- Ponds AP-1 through AP-5 (LOUs 16, 17, 18, and 19)
- Former Truck Emptying/Dumping Site (LOU 35)
- Satellite Accumulation Point/AP Maintenance Shop (LOU 39)
- Unit 4 Basement and Old Sodium Chlorate Plant Decommissioning (LOU 43)
- Diesel Storage Tank Area (LOU 45)
- AP Plant Area Change House/Laboratory Septic Tank (LOU 54)
- Acid Drain System (LOU 60)
- Former State Industries, including impoundments and catch basin (LOU 62)
- Southern Nevada Auto Parts site (Pick-a-Part) (LOU 68)

Soil gas samples were collected in remediation zones (RZs) A though E (6 samples in RZ-A, 19 in RZ-B, 26 in RZ-C, 20 in RZ-D, and 2 in RZ-E). Soil gas samples were also collected in the Parcel Areas (5 samples in Parcel A; 7 in Parcel B; 1 each in Parcels C, D, E, F[8], and G; 2 in Parcel H; and 3 in former Parcel I). Samples were collected at 5 ft bgs, with the exception of 4 samples collected in RZ-B in the vicinity of Unit 3, Unit 5, and Unit 6 at 20 ft bgs (SG-36, SG-37, SG-38, and SG-41) (Northgate 2010g).

Results of the investigation indicated that chloroform, trichloroethene (TCE), chlorobenzene, carbon tetrachloride, and trichlorofluoromethane were detected at elevated concentrations in soil gas beneath the Site. Elevated concentrations of VOCs in soil gas appeared to be localized primarily within specific areas, such as the western area, Unit 4, the Old P-3 Pond, Pond S-1, the former truck emptying/dumping site, the ammonium perchlorate laboratory building and former satellite accumulation point, and the former State Industries catch basin. Analytical results for samples collected during the soil gas survey were presented in a DVSR (ENSR 2008f) that was submitted to NDEP on October 13, 2008 and approved by NDEP on October 20, 2008.

The draft Soil Gas HRA is summarized in Section 4.3.

3.2.3 Indoor Air

To assess the potential uncertainty associated with use of vapor intrusion models in the draft Soil Gas HRA, an indoor air quality study was conducted at the operating Tronox facility in 2010. The first round of indoor and outdoor air samples were collected at several locations

[8] As noted in NDEP's response to the Revised Closure and Post-Remediation Screening HRA Report for Parcels C, D, F, G, and H (NDEP 2012a), Northgate (2012b) stated that no soil gas samples were collected in Parcel F. However, a spatial review of the sample coordinates relative to the Parcel F boundary indicates that one sample, SG34, was in fact collected in Parcel F.

throughout the facility in May 2010 (Northgate 2010h) and analyzed for chloroform, carbon tetrachloride, and TCE. The sampling results were presented in the *Spring 2010 Indoor Air Quality Sampling and Analysis Report* (Northgate 2010h, approved by NDEP on November 1, 2010). Chloroform and carbon tetrachloride were detected in all but one indoor air sample and all outdoor air samples. TCE was detected in all indoor air samples and some outdoor air samples; however, the detection limits in the outdoor samples were elevated due to sampling conditions (Northgate 2010i).

A second round of indoor and outdoor air sampling was performed in December 2010. The objective of the additional round of sampling was to identify the seasonal meteorological variations and the potential difference in the building operations and activities, and to collect additional data to supplement the indoor air modeling efforts and the uncertainty evaluation in the draft Soil Gas HRA. The sampling results were presented in the December 2010 Indoor Air Quality Sampling and Analysis Report (Northgate 2011a, approved by NDEP on March 21, 2011). A total of 32 indoor and 18 outdoor air samples were collected at the Tronox facility in Spring and December 2010. The samples were analyzed for three target analytes: chloroform, carbon tetrachloride, and TCE. Chloroform was detected in all but one indoor air sample and in all outdoor air samples, and carbon tetrachloride was detected in all but one indoor and one outdoor sample. TCE was detected in approximately 80 percent of the samples. The maximum and mean indoor concentrations of the target analytes were significantly below their respective occupational exposure levels, and the mean indoor air concentrations were below their respective risk-based commercial air concentrations corresponding to a 1×10^{-5} risk level.

The results of the December 2010 indoor and outdoor air monitoring indicated that in general, the indoor chloroform concentrations were higher than ambient levels. However, based on the draft Soil Gas HRA, the modeled soil gas and groundwater chloroform concentrations do not entirely explain the measured indoor air concentrations, as the measured chloroform results are generally higher than the modeled values. Northgate (2011a) reported that the measured chloroform concentrations were below occupational levels and below the 1×10^{-5} risk level.

3.2.4 Groundwater

As previously described for soils, in 2005, as a follow up to the Phase I and Phase II activities completed by KMCC, a CSM Report was prepared for the Site that integrated information from the soil and groundwater investigations conducted to date to document information on site-specific sources, release mechanisms, transport pathways, exposure routes, and potential receptors (ENSR 2005).

As described in the 2005 CSM, based on the results of the groundwater investigations conducted during the 1980s, the initial focus of the on-site groundwater remediation was containment and treatment of hexavalent chromium in shallow groundwater. Remediation of hexavalent chromium began in mid-1987, when four extraction wells were installed downgradient of the ammonium perchlorate plant.

In mid-1997, analytical methods were developed to detect low perchlorate concentrations (down to 0.004 milligrams per liter (parts per million) [mg/L]) and governmental and regulatory concern increased regarding health hazards of perchlorate in drinking water. Perchlorate was

subsequently discovered in the Colorado River and traced upstream to Henderson and the location of two ammonium perchlorate manufacturing facilities, one of which was the Site. The other facility (American Pacific Corporation [AMPAC], formerly Pacific Engineering and Production Company of Nevada [PEPCON]) is located approximately 1.5 miles southwest of the Site.

In late 1997, KMCC undertook a perchlorate characterization study to determine the subsurface pathway(s) and the perchlorate concentrations in shallow groundwater downgradient from the Site to its discharge in Las Vegas Wash. Between March and June 1998, soil borings and monitoring wells were drilled and installed and the subsurface data was mapped and analyzed. The investigation results were presented in the Phase II Perchlorate Investigation Report (KMCC 1998b).

An outcome of this groundwater investigation report indicated that the perchlorate was generally confined to a Quaternary-age alluvial channel eroded into the underlying sediments. Subsurface mapping demonstrated that the deepest and best defined section of the channel lay beneath the Pittman Lateral (Athens Road) area, about one mile south of Las Vegas Wash. The north-trending perchlorate plume is displaced eastward from the main alluvial channel just north of the Site by a high total dissolved solids (TDS) plume that converges from the west and preferentially occupies the western part of the channel. The perchlorate plume eventually begins to merge and mix with the higher TDS plume at, and downgradient from, the Pittman Lateral. The Phase II investigation results provided the basis for installation of the first extraction well (PC-70) at the AWF in September 1998.

In the spring of 1999, hydrologists with the Southern Nevada Water Authority discovered a perchlorate-impacted seep on-trend with the buried alluvial channel, discharging into Las Vegas Wash. At the time of discovery, the seep was flowing at about 400 gallons per minute (gpm) and contained over 100 mg/L perchlorate. This led to another phase of off-site monitoring well installation, sampling, and groundwater characterization between March and September 2000. These results were presented in the *Seep Area Groundwater Characterization Report* (KMCC 2001). The report documented that groundwater was traveling at an average of 35 feet per day between Athens Road (now Galleria Drive) and the seep; that there were no other major downgradient sources of perchlorate along Las Vegas Wash; and that the entire saturated thickness of the alluvial channel contained perchlorate at varying concentrations.

Between 2001 and 2004, the SWF and the AWF were installed to mitigate perchlorate impacts. The on-site IWF was expanded in between 1998 and 2003 to include additional extraction wells to further address perchlorate and chromium impacts. In 2001, it was modified further by the addition of a groundwater barrier wall. The barrier wall was constructed along the downgradient side of the interceptor well line to a depth of 60 ft bgs.

The 2005 CSM identified several data gaps related to groundwater characterization, including:

- Background concentrations of metals and other naturally occurring COPCs in the local area.
- Configuration of the fine-grained facies of the Muddy Creek formation.

- Identification of other COPCs.
- Historic data need to be evaluated for their usability for human health and ecological risk assessment purposes.
- Risk assessment to evaluate risks posed by the Site to human and ecological receptors.

Investigations conducted since 2005 have addressed some of the identified data gaps related to groundwater characterization, as described below.

2006/2007 – Upgradient Investigation Results (ENSR). In March 2006, soil borings were drilled at six locations in the southern (upgradient) portion of the Site. Four of the borings were completed as 2-inch diameter monitoring wells (M-117, M-118, M-120, and M-121). The first saturated unit in this portion of the Site is the upper coarse-grained facies of the Muddy Creek Formation (UMCf-cg1). Wells M-120 and M-121 are about 100 feet deep and monitor the UMCf-cg1. Wells M-117 and M-118 are about 150 feet deep and monitor the lower fine-grained facies of the Muddy Creek Formation (UMCf-fg2). Groundwater samples were collected from the four new wells and six existing wells. The samples were analyzed for perchlorate, metals, VOCs including fuel oxygenates, TPH, pH, electrical conductivity (EC), alkalinity, carbonate, bicarbonate, water chemistry ions, and radionuclides. As part of the upgradient investigation, a comparison was performed to evaluate whether two sampling methods would yield significantly different analytical results. Two sets of groundwater samples were collected from nine of the wells, the first using bailers and the second using micro-purge sampling pumps. In general, the results yielded mixed results for metals and wet chemistry parameters. The results varied more for less soluble constituents than for the more highly soluble constituents.

In the wells sampled for this upgradient investigation, chromium was detected at concentrations up to 0.054 mg/L. None of the chromium detections were above the maximum contaminant level (MCL) for chromium of 0.1 mg/L. In shallow groundwater wells M-120 and M-121 at the southern (upgradient) Site boundary, perchlorate was detected at concentrations of 0.55 mg/L and 2 mg/L, respectively. These results indicate that perchlorate is migrating onto the Site from upgradient locations.

Soil samples collected during this investigation were analyzed for a broad suite of SRCs. The validated data were compared statistically to the City of Henderson (COH) and Basic Remediation Company (BRC)/TIMET background data (BRC/TIMET 2007) to assess whether they represented similar populations and could be combined for subsequent analyses. The statistical comparisons indicated that for arsenic and iron, the COH data set could be combined with the Site upgradient area data from depths of 20 feet or less. For calcium and lead, the BRC/TIMET data set could be combined with the Site upgradient area data from depths of 20 feet or less. For the radionuclides thorium-228, thorium-230, and uranium-235, the COH data set could be combined with the Site upgradient area data from depths up to 5 feet. For uranium-238, the BRC/TIMET data set could be combined with the Site upgradient area data from depths up to 5 feet. All other chemicals represented different populations and should not be combined for subsequent analyses (BRC/TIMET 2007).

2007-2009 – Phase A and Phase B Investigations. In conjunction with the soil samples collected during the Phase A and Phase B investigations described in Section 3.2.1.1, one-time

groundwater samples were collected from many of the deeper soil borings. In addition, groundwater samples were collected from new and existing monitoring wells during several sampling events.

The objectives of the Phase A groundwater investigation were to (1) characterize SRCs in groundwater at 27 suspected source areas at the Site and (2) characterize groundwater chemistry upgradient and downgradient of the Site (ENSR 2006b). As part of the Phase A investigation, groundwater samples were collected from 20 shallow groundwater monitoring wells and one groundwater interceptor well (I-AR), and groundwater grab samples were collected from open boreholes at 6 locations where nearby wells either did not exist or were not functional. The wells were sampled in November/December 2006 using micro-purge/low-flow sampling techniques. All groundwater samples were analyzed for inorganic compounds (metals and cyanide), fuel alcohols, OCPs, PCBs, radionuclides, OPPs, OCHs, VOCs and SVOCs. Of the 210 SRCs analyzed, 125 SRCs were not detected (ENSR 2007a).

The same 20 monitoring wells plus well M-98 were sampled again in May 2007 to assess the potential for analytical bias of metals and radionuclides in groundwater results based on high turbidity levels associated with sampling methodology. An addendum to the Phase A Work Plan was submitted on May 1, 2007 (ENSR 2007b, approved by NDEP the same day) to evaluate potential analytical bias in the results reported for metals and radionuclides reported for the November/December 2006 sampling. On two sampling events conducted in May 2007, three samples were collected from each of the 21 monitoring wells to assess the effect of turbidity on groundwater results for metals and radionuclides. Two unfiltered samples were collected from each well using two different low-flow rates to evaluate the effect of pump rates on turbidity levels, and a third sample was collected and field filtered to provide a baseline from which comparisons between filtered and unfiltered analytical results could be made (ENSR 2007b). Based on an evaluation of the results, and as reported in the NDEP approved Phase A investigation report, ENSR (2007a) concluded that analytical results appropriate for evaluation of metals and radionuclides in groundwater include the following:

- Unfiltered low-flow samples collected in May 2007.
- Filtered grab samples collected during the November/December 2006 sampling.
- For hexavalent chromium, results from all samples could be used (the analytical method employed for this constituent was essentially a filtered method).

Analytical results for metals and radionuclides from the unfiltered water samples collected during the November/December 2006 sampling event were found to be biased high due to elevated turbidity levels and should be excluded (ENSR 2007a).

Fourteen new on-site monitoring wells were installed during the Phase B investigation and an extensive focused sampling program was conducted. As described in Section 3.2.1, Phase B work plans were developed for each of the four investigation areas (i.e., Areas I, II, III, and IV). The objective of the groundwater portion of the Phase B investigation was to characterize the presence of SRCs in specific LOU source areas. The locations of the new monitoring wells were selected to allow for further delineation of SRCs detected in Phase A investigation grab samples (ENSR 2007a).

Samples were collected from 109 existing and new groundwater monitoring wells in Areas I, II, III, and IV, and wells north (downgradient), east, and west of Area I. The groundwater samples were collected and analyzed in accordance with the *Revised Phase B Investigation Work Plan* (AECOM 2008) and the *Revised Phase B Quality Assurance Project Plan* (AECOM-Northgate 2009). Samples were analyzed for metals, VOCs, SVOCs, PCBs, OCPs, OPPs, organic acids, perchlorate, hexavalent chromium, and total cyanide. In addition, analyses were conducted for radionuclides and wet chemistry constituents. Not all wells were sampled for all analytes. The Phase B sampling investigation resulted in 2,817 groundwater analyses and 746 field QC sample analyses. The validated data from this extensive groundwater sampling program is available for use in the RI to identify the COPCs in groundwater that will be evaluated further during the RI/FS process.

2008-2009 – Interim Capture Zone Evaluation and Vertical Delineation. In 2009, Northgate conducted an interim evaluation of the capture zones established by operation of the IWF and the AWF (Northgate 2009, submitted to NDEP for review). The report incorporates work conducted by ENSR in late 2007-2008. As part of this evaluation, eight deeper UMCf monitoring wells were installed near the ends of the IWF and barrier wall to allow evaluation of vertical head differences. A new extraction well (I-AB) was installed by Northgate immediately east of an extraction well previously installed by ENSR (I-AA) for future connection into the system, and an initial assessment of groundwater underflow and mass flux beneath both wells fields was conducted.

In response to an NDEP request, eight deep monitoring wells were installed at four on-site locations adjacent to existing shallow monitoring wells to form vertical well clusters. The purpose of the new well clusters was to further evaluate the vertical extent of contamination in the deeper UMCf as well as vertical head differences.

2010-Present – Removal Performance Monitoring and Numerical Groundwater Flow Model. Removal performance monitoring for chromium and perchlorate has been conducted on an annual and semiannual basis. The monitoring results are presented along with recommendations to improve the extraction system performance in the annual performance monitoring reports. As part of this effort, Northgate installed additional on-site and off-site monitoring wells to improve the monitoring well network as well as additional on-site extraction wells (I-AC and I-AD) on the east end of the IWF. The distributions of perchlorate, total chromium, and total dissolved solids in the Shallow WBZ in May-June 2012 are shown on Plates 3, 4, and 5, respectively (ENVIRON 2012c). Plate 6 is a north-south cross-section presenting vertical distribution of perchlorate, chromium, and total VOCs in the Shallow and Middle WBZs along this cross-section.

In addition, Northgate developed a numerical groundwater flow model for use in evaluating capture zones established by the groundwater extraction well fields. The numerical groundwater model is currently under review by NDEP. Once the model is approved by NDEP, it will be used to further evaluate the performance of the GWETS.

4.0 Interim Removal Actions

Sections 4.1, 4.2 and 4.3 describe soil removal actions and HRAs conducted at the Facility Area and Parcel Areas. Section 4.4 describes on-site and downgradient groundwater removal actions performed previously and currently in place. Section 4.5 describes the current groundwater monitoring program.

4.1 Interim Soil Removal Actions and Health Risk Assessments at the Facility Area

As previously described in Section 3.2.1.1, the results of the Phase A and B source investigations identified a number of constituents within the upper 10 ft of soil in excess of SRGs. On December 14, 2009, NDEP issued to Tronox a Finding of Alleged Violation and Order requiring Tronox to comply with the obligations pertaining to the Henderson facility under the various Consent Agreements previously issued for the Site, and setting forth a specified schedule for compliance (the "2009 Division Order") (NDEP 2009b). At a meeting on February 22, 2010, NDEP and Tronox discussed the conceptual scope and implementation of a soil remediation program to comply with the 2009 Division Order requiring the removal of all impacted soil from the Site by the end of 2010 to minimize potential health risks associated with the continued presence of contaminated soil. A detailed scope of work for the soil removal was presented in *Removal Action Work Plan for Phase B Soil Remediation of Remediation Zones RZ-B through RZ-E* (the "RAW") (Northgate 2010j, approved by NDEP on August 20, 2010).

For purposes of soil remediation activities, the main contaminated portions of the Site were divided into five separate remediation zones (RZs) roughly based on geographic groupings of elevated detections of contaminants and CSM considerations (Northgate 2010k). The RZs are listed below:

- RZ-A: the area on the southern portion of the Site
- RZ-B: the area around the Units
- RZ-C: the ammonium perchlorate production area, Koch Materials area, pond and diesel storage tank area, and manganese tailings area
- RZ-D: the former Trade Effluent ponds and ammonium perchlorate pad/drum recycling area (including the former hazardous waste landfill)
- RZ-E: the Beta Ditch

For RZ-A, the results of a soil HRA (Northgate 2010l, approved by NDEP on July 23, 2010) indicated that exposures to residual chemicals in the upper 10 ft of soil in RZ-A were below NDEP's point of departure for noncancer effects (hazard index [HI] of 1) and cancer risks (1×10^{-6}) for indoor commercial workers, outdoor commercial/industrial workers, and construction workers. The upper-bound estimated risks for death from lung cancer or mesothelioma for asbestos exposures to outdoor commercial/industrial workers were less than or equal to 1×10^{-6} for chrysotile and amphibole fibers. The best estimate and upper-bound estimates for asbestos exposures to construction workers were less than or equal to 1×10^{-6} for chrysotile fibers and ranged from zero to 6×10^{-5} for amphibole fibers. Since the risks estimated from asbestos exposures were evaluated based on constant lifetime exposures, not

short-term exposures such as construction activities, the results indicate that exposures to asbestos in soil should not result in unacceptable risks for the aforementioned receptors. Based on HRA results, RZ-A was not included in the removal program (Northgate 2010m).

For RZ-B through RZ-E, Voronoi/Thiessen polygons were generated for each RZ to define areas with SRG exceedances (Northgate 2010j). The general remediation strategy consisted of excavation of soils within designated polygons, sampling of discolored soil, removal of discolored soil if above SRGs or otherwise deemed appropriate to remove, and designation of Excavation Control Areas (ECAs) for inaccessible areas, including areas with COPCs and/or discolored soil left in place.

To further define the polygons of areas identified for excavation, pre-confirmation sampling was conducted in Spring 2010 in accordance with a pre-confirmation work plan (Northgate 2010k, approved by NDEP on March 30, 2010). Two types of borings were advanced during the pre-confirmation sampling program, including (1) 84 borings at existing locations (adjacent to Phase A and B sampling locations) and (2) 91 borings at new locations. Data from "existing locations" were used to establish polygon depths, while data from "new locations" were used to define the horizontal extent and vertical delineation of excavation of near-surface soils (0 to 10 ft bgs). Results from the Phase A, Phase B, and pre-confirmation sampling events are presented in Appendix A of the Excavation Plans for Phase B Soil Remediation for each RZ (RZ-B, Northgate 2010n; RZ-C, Northgate 2010o; RZ-D, Northgate 2010p; and RZ-E, Northgate 2010q).

Discolored soil was encountered in various locations during removal activities. Based on the location of the discolored soil, available nearby analytical results, the anticipated extent of discolored soil, and the excavation activities currently in progress, some areas of discolored soil were removed. Other areas of discolored soil were sampled and evaluated to determine if the soil should be removed or left in place in accordance with the *Work Plan for Evaluation of Discolored Soil and Confirmation Soil Sampling in Visually-Impacted Areas* (ENVIRON 2011a, approved by NDEP on May 12, 2011). Following the removal of discolored soil, confirmation soil samples were collected to verify that remaining COPC soil concentrations were below SRGs. If the analytical results indicated that concentrations were above SRGs, additional soil was typically removed and additional confirmation soil sampling performed.

As presented in Northgate's Manganese Tailings Removal Technical Memorandum (Northgate 2012a) under NDEP review, the manganese tailings pile area removal actions were initiated on April 29, 2010 and completed on July 19, 2010. The manganese tailings pile area, located north of the Manganese Leach Plant and south of Mn-1 Pond (Figure 2-2), is approximately 8.6 acres in size and was used from 1975 through 2004 for the disposal of manganese tailings from the leach plant process which included the leach beds (the historic manganese tails). This material is a non-hazardous solid waste product generated in the production of electrolytic-grade manganese dioxide. Manganese tailings material from all locations at the Site were consolidated to the current location and covered with soil sometime prior to 1985. The tailings pile was periodically graded to maintain the desired shape and drainage. Since 2004, manganese tailings from the Tronox operations (current tailings production) have been shipped to an appropriate off-site landfill.

A total of 284,232 tons of tailings and minor debris were removed from the manganese tailings pile. In accordance with a request by the NDEP, a confirmation sampling program was implemented subsequent to tailings removal. Based on the results of the confirmation sampling program, additional shallow soil excavation was conducted concurrent with Phase B soil remediation in accordance with the *Removal Action Work Plan* (Northgate 2010j), and the *Revised Excavation Plan for Phase B Soil Remediation of RZ-C Addendum to the Remedial Action Work Plan* (Northgate 2010o). The post-confirmation sampling excavation was conducted to address soil that contained concentrations of manganese, arsenic, cobalt, and/or asbestos that exceeded screening criteria.

The removal activities and post-removal conditions at the Site are described in detail in the *Revised Interim Soil Removal Action Completion Report* (ENVIRON 2012b, submitted to NDEP on September 28, 2012). Post-removal soils conditions are described in Section 5.1.3.

4.2 Soil Removal Actions and Health Risk Assessments at the Parcel Areas

The following subsections describe soil removal actions and HRAs for Parcels A and B (Section 4.2.1) and Parcels C, D, F, G, and H (Section 4.2.2).

4.2.1 Parcels A and B

The results of the soil investigation, removal actions, and HRA for Parcels A and B were reported in the *Technical Memorandum Data Review* (BEC 2007g), the *Asbestos Data Review* (BEC 2007h), and the *Uranium Isotope Data Review* (BEC 2007i). As previously described in Section 3.2.1.2, following the Phase 2 soil investigation for Parcels A and B, surface soils from several areas in these Parcels were scraped and removed due to asbestos impacts in 2007. Post scrape samples were collected from 10 locations and analyzed for asbestos. The post-scrape samples confirmed that asbestos-impacted soil had been removed (BEC 2007g,h), with completion of the removal action approved by NDEP on January 17, 2008.

A screening-level HRA was completed for exposure to soils at Parcels A and B, as presented in the *Technical Memorandum Data Review* (BEC 2007g). The HRA evaluated potential cancer risks and noncancer effects for exposures of a commercial/industrial worker to residual chemicals in soils. In addition, cancer risk was evaluated for potential exposures of a construction worker to asbestos. The estimated cancer risk for exposures of future commercial/industrial workers was 1×10^{-6}, at the lower end of the target risk range of 1×10^{-6} to 1×10^{-4}. The HI, a measure of the potential for noncancer effects, was below the comparison benchmark level of 1, indicating little potential for the occurrence of non-cancer health effects. Using upper bound concentrations of asbestos, risks to construction workers were below 1×10^{-6} for chrysotile fibers and ranged from zero to 5×10^{-6} for amphibole fibers. Based on the Parcels A and B investigation data and the results of the HRA, NDEP issued a No Further Action (NFA) letter for soil in the 0 to 10 ft depth interval, with conditions specified for deeper soils and groundwater (NDEP 2008b). The NFA conditions are summarized in Section 5.1.

For the vapor intrusion (indoor air) pathway, a separate screening-level HRA is being prepared for Parcels A and B, as presented in the *Revised Technical Memorandum: Screening-Level Indoor Air Health Risk Assessment* (Northgate 2010r). The November 12, 2010 draft HRA incorporates comments received from NDEP, dated August 31, 2010, on the second revision of

the report, dated June 29, 2010, along with clarifying comments received from NDEP during a September 7, 2010, teleconference (NDEP 2010b). The HRA evaluates potential cancer risks and noncancer effects for exposures of an indoor commercial worker to chemicals in soil gas that may migrate to indoor air. The HRA is based on the sampling results of 9 soil gas samples collected as part of the Phase B soil gas investigation, described previously in Section 3.2.2. All chemicals detected in at least one of the 9 soil gas samples were identified as COPCs. The estimated cumulative HI reported in the draft HRA ranged from 0.0008 to 0.002, depending on the assumptions for air exchange rate and vapor flow into a building. The cumulative cancer risk ranged from 5×10^{-7} to 1×10^{-6}, with chloroform the primary contributor. Northgate (2010b) reported that the apparent source of chloroform and other chemicals detected in soil gas was impacted groundwater located south and west (upgradient) of Parcels A and B[9].

4.2.2 Parcels C, D, F, G, and H

Impacted soil on Parcels C, D, F, G, and H was excavated and removed in March and April 2010 in accordance with the *Removal Action Workplan for Soil, Tronox Parcels "C", "D", "F", "G", and "H" Sites* (BEC 2008b, approved by NDEP on July 2, 2008). Similar to the approach previously described for RZ-B through RZ-E, Voronoi/Thiessen polygons were generated for each Parcel to define areas with SRG exceedances. For each polygon with exceedances, the top 1 ft or less of soil was scraped and removed. Following remediation, confirmation soil samples were collected from each polygon at the same locations as the original samples with exceedances. A total of 21 environmental and 16 field QC samples were collected and analyzed for arsenic, SVOCs, PCBs, dioxins, and asbestos (Northgate 2010s). At most locations, confirmation sample results indicated that chemical concentrations were below their respective SRGs and that four or fewer long chrysotile fibers and less than one long amphibole fiber were present (Northgate 2012b). Areas where concentrations of one or more chemicals exceeded their respective SRGs include a small area south of the existing South Haul Road fence line in Parcel C and small portions of proposed scrape areas in Parcels F, G, and H that were not scraped due to surface impediments (Northgate 2012b).

A post-remediation screening HRA was conducted for Parcels C, D, F, G, and H to evaluate potential human health risks associated with residual concentrations of chemicals in soil following remediation and to support the closure process for these parcels. The current draft of the HRA was submitted to NDEP on May 18, 2012 (Northgate 2012b) and NDEP provided comments on the draft HRA on August 7, 2012. Responses to NDEP comments and revisions to the draft HRA are in preparation.

4.3 Site-wide Health Risk Assessment for Soil Gas

The soil gas sampling results and data usability evaluation were also presented in the draft Soil Gas HRA (Northgate 2010g). The objective of the draft Soil Gas HRA was to evaluate the potential for adverse health impacts associated with potential exposure by future indoor commercial workers to chemicals in soil gas that may migrate to indoor and outdoor air. As

[9] An evaluation of the source(s) of chloroform and other VOCs detected in soil gas will be included in the HRA for the vapor intrusion pathway that will be prepared following collection of additional soil gas samples in the Parcels (ENVIRON 2012d).

described in the draft Soil Gas HRA, 65 of the 71 VOCs analyzed were detected in one or more samples during the Phase B soil gas survey. Based on a multi-step COPC selection process, including toxicity screen evaluation, frequency of detection, and CSM considerations, eight VOCs (benzene, bromodichloromethane, carbon tetrachloride, chloroform, hexachlorobutadiene, naphthalene, tetrachloroethene [PCE], and TCE) detected in soil gas were retained as COPCs for quantitative evaluation in the HRA.

For the HRA, the migration of COPCs in soil gas from the subsurface to indoor air was estimated using the USEPA vapor intrusion model (2004a) based on Johnson and Ettinger (1991). Cancer risks and hazard indices were quantified on a sample-by-sample basis. Non-cancer hazard indices associated with inhalation of vapors in indoor and outdoor air and theoretical excess cancer risks associated with inhalation of vapors in outdoor air were below NDEP's point of departure (hazard index of 1 and cancer risk of 1×10^{-6}) for indoor and outdoor commercial workers. Theoretical excess cancer risks associated with inhalation of vapors in indoor air under hypothetical future site conditions range from 2×10^{-9} (SG94, located in RZ-C) to 1×10^{-4} (SG32, also located in RZ-C). The results of the draft Soil Gas HRA indicate that at most locations evaluated, chloroform contributes up to 99% of the overall cancer risk from inhalation of vapors in indoor air, with carbon tetrachloride the only other VOC for which a cancer risk was above 1×10^{-5}. None of the other COPCs had cancer risk estimates greater than 1×10^{-6} (Northgate 2010g).

NDEP has not reviewed or approved the Soil Gas HRA. However, in comments on the draft submittal of the post-remediation screening HRA conducted for soil in Parcels C, D, F, G, and H, NDEP stated that the available soil gas sampling data were not adequate to characterize risk when the Parcels were evaluated individually. In addition, based on a review of figures showing the chloroform plume in shallow groundwater, NDEP noted that soil gas samples from the Phase B investigation were collected from locations where results for VOCs would likely be biased low. Finally, NDEP commented that it may be reasonable to use site-wide soil gas data in conjunction with groundwater data to develop a parcel-specific HRA. In response to this comment, ENVIRON submitted a soil gas investigation work plan for the parcels on October 26, 2012 (ENVIRON 2012d) and a vapor intrusion HRA is in preparation.

4.4 Interim Groundwater Removal Actions

The following subsections describe on-site and downgradient groundwater removal actions performed previously (Section 4.4.1) and those that are currently in place (Section 4.4.2).

4.4.1 Historical Groundwater Removal Actions

Groundwater remediation has been conducted at the Site dating back to the mid-1980s. This subsection summarizes historical groundwater removal actions conducted at the Site to address chromium (Section 4.4.1.1) and perchlorate (Section 4.4.1.2.).

4.4.1.1 Chromium Removal and the Interceptor Well Field

A groundwater investigation was initiated by KMCC in July 1981 to comply with federal RCRA standards associated with certain on-site impoundments. This investigation involved the installation of nine monitoring wells and identified elevated chromium concentrations in groundwater underlying the Site. In 1986, KMCC and NDEP entered into a Consent Order,

which required additional groundwater characterization activities and the implementation of removal activities to address elevated concentrations of chromium in groundwater (NDEP 1986). Pursuant to the Consent Order, KMCC installed an additional 43 monitoring wells and a groundwater interceptor well field (the IWF) consisting of 11 groundwater extraction wells (I-A[10] through I-K) in the shallow WBZ in late 1986 (ENSR 2005).

The 11 extraction wells initially were capable of producing a cumulative extraction rate of approximately 100 gpm; however, this level of extraction was not sustainable over the long term (see additional discussion below). The extracted groundwater was conveyed to a chromium treatment facility (called the Groundwater Treatment Plant or "GWTP"), constructed in 1986-87 along with the IWF, where hexavalent chromium was electrolytically reduced to trivalent chromium and then co-precipitated with iron oxide. The treated water was subsequently re-injected through two parallel recharge trenches located approximately 250 feet downgradient (north) of the IWF line of wells. The IWF, which still operates at the Site in an expanded configuration, is located in the central portion of the property, approximately 2,400 feet north and downgradient of the central process area of the Site. From initiation of removal activities through 1993, the IWF and GWTP have captured and treated over 200 million gallons of groundwater and removed an estimated 8,500 pounds of chromium from the environment (ENSR 2005).

Over the course of the next several years, additional groundwater monitoring wells were installed to evaluate the effectiveness of the IWF, GWTP and recharge trenches. Between 1986 and 1993 approximately 47 additional monitoring wells were installed at the Site. All of these wells were installed in the Shallow WBZ, some being entirely screened within the Qal, some being screened within the transition to the UMCf, and some entirely within the UMCf.

Evaluations of Site conditions in 1991 and 1993 concluded that the extensive dewatering of the Qal in the vicinity of the IWF and the localized groundwater flow in discrete channels in the UMCf were contributing to a decline in recovery volumes (ENSR 2005). Based on these findings, KMCC installed four additional extraction wells in 1993 (I-L, I-M, I-N, and I-O) to improve capture in the discrete channel flow areas. Over the next several years, additional extraction wells were installed as part of continued efforts to increase groundwater capture at the IWF. Two extraction wells (I-P and I-Q) were installed in 1998; five more wells (I-R, I-S, I-T, I-U, I-V) were installed in early 1999; and a large diameter well (I-AR) located upgradient of the IWF was installed in April 2000. To further enhance groundwater capture a bentonite-slurry barrier wall (the "barrier wall") was installed on the downgradient side of the IWF in 2001. The barrier wall, which is still in place, is approximately 1,600 feet in length and 60 feet deep and constructed to tie vertically into the uppermost 30 feet of UMCf. By November 2001, cumulative extraction from the IWF had increased from approximately 23 gpm to over 50 gpm.

4.4.1.2 Perchlorate Removal and the Athens Road and Seep Well Fields

In 1997, elevated concentrations of perchlorate were detected in the Colorado River, the source of which was ultimately traced to the Site and another ammonium perchlorate manufacturing

[10] Interceptor well I-A has since been plugged and abandoned.

facility in Henderson. Groundwater perchlorate investigations completed in 1997 and 1998 identified perchlorate concentrations ranging from 1,500 mg/L at the northern Site boundary to around 100 mg/L between the City of Henderson RIBs and the Las Vegas Wash (ENSR 2005). The investigations concluded that Quaternary-age alluvial channels eroded into the underlying sediments were significant transport pathways for downgradient perchlorate migration. Subsurface mapping indicated that the deepest and best defined section of the channel believed primarily responsible for transport of perchlorate from the Site lay beneath the Pittman Lateral area at Athens Road (now Galleria Drive) about one mile south of Las Vegas Wash (ENSR 2005). As an interim measure to address the perchlorate plume, a Shallow WBZ extraction well (PC-70) was installed at Athens Road (approximately 8,200 feet north of the barrier wall and the IWF) in September 1998. Groundwater extracted from this extraction well, as well as groundwater extracted from the IWF, was routed to an 11-acre, 70-million-gallon, double-lined pond (GW-11), which commenced operation in late 1998. The extracted groundwater was held in GW-11 until a permanent perchlorate treatment system could be implemented.

In the spring of 1999, hydrologists with the Southern Nevada Water Authority discovered an approximately 400 gpm seep discharging into Las Vegas Wash that contained over 100 mg/L of perchlorate. Following investigation of this seep, KMCC entered into a Consent Agreement with NDEP (dated July 26, 1999) to initiate removal measures to intercept and treat the seep discharge. Later in 1999, a weir-sump combination and temporary single-use resin ion exchange (IX) system were installed near the Las Vegas Wash to capture and treat the water discharged from the seep. After additional investigation of the seep was completed, in 2001 KMCC constructed four extraction wells in the seep vicinity (PC-99R2, PC-99R3, PC-115, and PC-116)[11], from which extracted groundwater was treated by the temporary IX system near the wash and later also by a second temporary single-use resin IX system located on-site. The pumping from these additional wells began in July 2002.

Another AOC, entered into by KMCC and NDEP on October 8, 2001, further defined removal requirements necessary to address the perchlorate contamination. Pursuant to this AOC, KMCC commenced construction of the existing off-site AWF, the off-site SWF, and an on-site perchlorate treatment system.

The AWF was initially constructed as a series of 15 groundwater extraction wells screened in the Qal at seven paired well locations (with one standalone well) that span approximately 1,200 feet across two alluvial paleochannels located on either side of an UMCf ridge. The AWF was completed in March 2002[12] and continuous pumping began in mid-October of that year. The well pairs act in concert with one well pumping while the adjacent well (the so called “buddy” well) is used to measure water levels and monitor the effect of pumping on the aquifer. In

[11] PC-99R2 (a 6-inch diameter well) and PC-99R3 (an 8-inch diameter well) were combined into one extraction well. PC-115 and PC-116 (6-inch diameter wells) were subsequently replaced by PC-115R and PC-116R (8-inch diameter wells) to improve performance.

[12] Eight extraction wells (ART-1 through ART-8) were completed between October 2001 and January 2002 allowing pumping to begin from these wells in March 2002. Seven additional extraction wells (ART-1A, 2A, 3A, 4A, 6A, 7A, and 8A) were installed in February through March 2003. ART-5 does not have a buddy well.

September 2006, another standalone well screened deeper into the alluvial channel on the east side of the AWF, ART-9, began full-time operation replacing ART-6A after groundwater elevations at the AWF dropped below a level where ART-6/6A could be effective.

The SWF is located approximately 4,500 feet north (downgradient) of the AWF near the Las Vegas Wash. As discussed above, when pumping began in July 2002, the SWF consisted of four extraction wells situated over the deepest part of the alluvial channel and a surface-capture sump for the seep. Five additional wells (PC-117 to PC-121) were installed in February 2003 and an additional well (PC-133) was installed in December 2004 to complete the SWF.

With regard to the perchlorate treatment system, KMCC initially designed and constructed an 825 gpm regenerable resin IX (ISEP®/catalytic destruction process) treatment plant. Due to difficulties in commissioning the regenerable resin IX system, a temporary single-use resin IX system was placed in service on-site to supplement the seep area temporary IX system (ENSR 2005). The permanent on-site ISEP/catalytic destruction process treatment system eventually proved to be unworkable and was abandoned in favor of a biological treatment system employing FBR technology (ENSR 2005). Construction of a 1,000 gpm (peak flow) biological treatment plant was completed in early 2004. Optimization of the plant operations continued into the fourth quarter of 2004. The temporary IX system at Las Vegas Wash near the SWF was shut down in June 2004 and the on-site temporary IX system was shut down in the first quarter of 2004.

Pursuant to the April 12, 2005 AOC, an additional reactor was added to the FBR system in 2006 to manage the decommissioning of an on-site impoundment, the AP-5 pond, which contained high concentrations of perchlorate. In August 2006, pumping of AP-5 pond water to the on-site treatment system commenced as part of the decommissioning process. After initial dewatering of the AP-5 pond, stabilized Lake Mead water was periodically pumped to the pond to solubilize residual ammonium perchlorate in the pond solids. According to on-site personnel, the last of these transfers occurred in January 2012. The resulting water was discharged to the treatment plant in batches via the GW-11 pond. Since the AP-5 pond pumping operation began in 2006, an estimated 1,176 tons of perchlorate were removed from the AP-5 pond and treated on-site.

Since the discovery of perchlorate in on-site and downgradient groundwater in 1997-1998 to the full-scale treatment of perchlorate via the biological perchlorate reduction FBR plant in 2005, over 220 additional groundwater monitoring wells have been installed on-site and at downgradient locations by KMCC. Some of these groundwater wells, as well as those previously installed as part of the various chromium investigations, have been plugged and abandoned; however, the majority of wells remain part of the active groundwater monitoring well network for use in evaluating the performance of the groundwater removal actions. The current groundwater monitoring program utilizing these wells, and others installed after 2005, is discussed in Section 4.5.

4.4.2 Current Groundwater Removal Actions

Current operations at the Site include the continued operation of an on-site Groundwater Extraction and Treatment System (GWETS) that acts to remove hexavalent chromium and perchlorate from shallow groundwater beneath the Site and at downgradient locations along the

existing contaminant plume. This section describes the current system (Section 4.4.2.1) and discusses its performance (Section 4.4.2.2).

4.4.2.1 Description of the Current Groundwater Extraction and Treatment System

The GWETS has been in place in essentially its current configuration since 2006. The GWETS operates by capturing groundwater from three extraction well fields and treating the captured groundwater via aboveground treatment facilities for subsequent discharge at the Las Vegas Wash. Perchlorate in extracted groundwater is treated in the on-site FBR process using ethanol as a carbon source. Chromium in extracted groundwater is treated via chemical reduction and precipitation using ferrous sulfate. A process flow diagram for the GWETS is included as Figure 4-1, and a location map covering the area from the Site to the Las Vegas Wash showing the primary components of the GWETS is included as Figure 4-2.

Groundwater is captured from a system of extraction wells installed into the Shallow WBZ at three strategic locations described previously in Section 4.4.1: (1) on-site at the IWF; (2) approximately 8,200 feet downgradient of the IWF at the AWF; and (3) approximately 4,500 feet beyond the AWF near the Las Vegas Wash at the SWF. The locations of the three well fields are shown on Figure 4-2 in relation to other GWETS features.

The IWF currently consists of 23 active extraction wells[13] located immediately upgradient (south) of the vertical barrier wall constructed in 2001. The IWF pumps at a cumulative extraction rate of between 60 and 73 gpm (ENVIRON 2012c) and captures the highest concentrations of both chromium and perchlorate (as compared with the downgradient well fields). From May 2011 through June 2012, chromium concentrations in the IWF pumping wells ranged from 0.16 to 31 mg/L, while perchlorate concentrations ranged from 96 to 2,300 mg/L during this same time period (ENVIRON 2012c). The highest concentrations of chromium observed are in the middle of the IWF well line around I-T (28-31 mg/L during quarterly sampling from May 2011 through June 2012) and decrease to below 1.0 mg/L at the western end of the IWF and to 1.3 mg/L at I-K at the eastern end of the IWF over this same time period. Higher perchlorate concentrations are observed in two areas of the IWF: on the western side of the IWF around I-AR (2,100-2,300 mg/L during quarterly sampling from May 2011 through June 2012) and on the eastern side around I-U (1,600-1,900 mg/L over the same time period).

The AWF currently consists of 7 active extraction wells[14] screened in the alluvium that span approximately 1,200 feet across two alluvial paleochannels located on either side of an UMCf ridge. The AWF cumulatively pumps at a rate of between approximately 250 and 273 gpm (ENVIRON 2012c) and captures chromium and perchlorate at concentrations significantly lower than those observed at the IWF. From May 2011 through June 2012, chromium concentrations

[13] Seven additional extraction wells (I-AA, I-AB, I-AC, I-AD, I-W, I-X, and I-Y) were installed between December 2007 and June 2010 and connected to the IWF in 2010-2011; however, extraction from these wells has not commenced. The 2012 Annual Remedial Performance Report presented an evaluation of these new extraction wells and proposed a plan to operate these new wells (ENVIRON 2012c). This evaluation has been included as Appendix F.

[14] In June/July 2010, additional groundwater wells were installed in the AWF including four large diameter monitoring wells that could be used as additional extraction wells (ART-7B, PC-148, PC-149, and PC-150). The 2012 Annual Remedial Performance Report presented an evaluation of these new wells and proposed a plan to operate them as extraction wells (ENVIRON 2012c).

in the AWF pumping wells have ranged from below laboratory quantitation limits to 1.5 mg/L, while perchlorate concentrations have ranged from 1.3 to 420 mg/L during this same time period (ENVIRON 2012c). The highest concentrations of chromium are at the east side of the AWF well line around ART-9 (1.2-1.5 mg/L during quarterly sampling from May 2011 through June 2012) and decrease to below laboratory quantitation limits at the eastern end of the AWF at ART-1. Higher perchlorate concentrations are observed in two areas of the AWF: on the western side of the AWF around ART-4 (330-420 mg/L during monthly sampling from May 2011 through June 2012) and on the eastern side around ART-9 (300-330 mg/L during the same time period). The locations of ART-4 and ART-9 correspond with two alluvial sub-channels that intersect the AWF. It is believed that these channels represent primary transport pathways for contaminated groundwater from the Site.

The SWF consists of 10 wells[15] screened across the full thickness of the Qal at the deepest portion of an alluvial channel just south of the Las Vegas Wash. The SWF cumulatively pumps at a rate of between approximately 510 and 622 gpm (ENVIRON 2012c). Chromium concentrations in the SWF pumping wells are below laboratory quantitation limits. Perchlorate concentrations in the SWF pumping wells from May 2011 through June 2012 ranged from 0.31 to 14 mg/L (ENVIRON 2012c). The highest perchlorate concentrations are generally observed in PC-99R2/R3 in the center of the SWF.

The two off-site well fields, the AWF and the SWF, are served by three lift stations that convey the captured groundwater to the aboveground treatment portions of the GWETS via underground pipelines. The locations of these lift stations and pipelines are shown on Figure 4-2. Lift Station 1, located at the Las Vegas Wash, conveys groundwater extracted by the SWF to Lift Station 2 located on Pabco Road just south of Galleria Drive (formerly Athens Road). Lift Station 3, located within the AWF well line along Galleria Drive, conveys groundwater extracted by the AWF to Lift Station 2. Lift Station 2 pumps the combined flows from Lift Stations 1 and 3 to the on-site equalization area for treatment.

The aboveground treatment system consists of two series-linked systems: (1) a hexavalent chromium treatment system that treats extracted groundwater from the IWF using ferrous sulfate to reduce hexavalent chromium to trivalent chromium,[16] which is then removed from solution via chemical precipitation, and (2) the FBR process that treats extracted groundwater from the IWF, AWF, and SWF.[17] Effluent from the chromium treatment system, historically referred to as the GWTP, is pumped to an equalization area where it is combined with water from the off-site well fields. From the equalization tanks, the blended water flows through activated carbon beds to remove organic compounds before being filtered and pumped to the FBRs for removal of perchlorate, chlorate, and nitrate. The effluent from the FBRs is

[15] Two of the extraction wells at the SWF (PC-99R2 and 99R3) are connected and operate as one combined extraction well and are also sampled as one.

[16] In addition, a small ferrous sulfate drip system is located at the AWF lift station (Lift Station 3) to treat the significantly lower concentrations of chromium present in groundwater extracted by the AWF.

[17] The FBRs are part of a biological treatment system that includes five 33,000-gallon primary reactors, four 28,800-gallon secondary reactors, and ancillary systems. See Figure 4-1 for a process flow diagram. For brevity, the system as a whole is often referred to as the "FBRs" or the "FBR Plant".

discharged to an outfall located at the Las Vegas Wash via an underground pipeline. Solids from the GWTP and the FBRs are conditioned and dewatered prior to being disposed off-site. The 11-acre double-lined pond, referred to as GW-11, holds off-specification effluent and feed bypass during treatment system maintenance.

There are some former components of the GWETS that are no longer operating. Groundwater recharge trenches formerly located downgradient (north) of the IWF and barrier wall were originally installed to receive extracted and treated groundwater, but have been used in the recent past to inject stabilized Lake Mead water into the subsurface to replace water extracted by the IWF. Reinjection ceased in September 2010, when the recharge trenches were partially removed to accommodate soil excavation activities at the Site. Also, a seep surface-flow capture sump located north of the SWF was formerly used to capture groundwater before it surfaced and flowed to the Las Vegas Wash; however, the seep has not flowed since April 2007.

4.4.2.2 Performance of the Current Groundwater Extraction and Treatment System

The GWETS has been effective at removing and treating large amounts of perchlorate and chromium in on-site and off-site groundwater. From July 2002[18] through June 2012 the estimate of perchlorate mass removed and treated by the GWETS is approximately 6,185,000 pounds (approximately 3,093 tons). The current estimate of chromium mass removed and treated during this same time period is approximately 38,000 pounds (approximately 19 tons).

Figures 4-3 and 4-4 present estimated monthly mass removals based on well extraction rates and individual well concentrations from July 2002 through June 2012 for perchlorate and chromium, respectively. This represents the time period where all three of the well fields were operating; however, as discussed in previous sections, the well fields have been expanded significantly during this time.

As shown in Figure 4-3, system-wide perchlorate mass removals have declined since the middle of 2003 primarily due to the sharp decline in perchlorate mass removal at the SWF. The decreased mass removal rates from the SWF result from decreased concentrations of perchlorate at the Las Vegas Wash, which is likely due to operation of the upgradient extraction well fields. In contrast, the perchlorate mass removals at the IWF and AWF have only marginally decreased during this time period.

Since July 2002, the maximum monthly perchlorate mass removal occurred in June 2003 when a total of approximately 76,300 pounds were removed and treated. At this time the percentages of perchlorate mass removal attributed to the IWF, AWF, and SWF were 39, 36, and 25 percent, respectively. Since then the perchlorate mass removed from the SWF has diminished significantly. Recently, in June 2012 the total monthly perchlorate mass removal was 37,600

[18] July 2002 was used as the start date for this performance evaluation since the extraction before this time was limited. This date corresponds to the time period when the AWF and SWF well fields were being installed and downgradient extraction from these well fields began.

pounds with the IWF and AWF accounting for 51 and 45 percent, respectively, while the SWF accounted for only 3 percent.

As shown on Figure 4-4, the IWF is responsible for the majority of chromium mass removal with the AWF responsible for a significantly smaller amount. As mentioned above, because concentrations of chromium at the SWF are consistently below laboratory quantitation limits, the chromium mass removal at the SWF is negligible, and therefore, is not shown on Figure 4-4. Figure 4-4 shows that chromium mass removal at the IWF has been decreasing since around the end of 2008, while chromium mass removal from the AWF has been slowly increasing during this same period. In fact, chromium mass removed at the AWF has slowly, but steadily increased since the end of 2003. This increase of chromium mass removal at the AWF is also evident in Figure 4-5, which presents a side-by-side comparison of extraction rates and chromium and perchlorate mass removal estimates for each of the three well fields.

Since July 2002, the maximum monthly chromium mass removal occurred in January 2005 when a total of approximately 366 pounds were removed and treated. At this time the percentages of chromium mass removal attributed to the IWF and AWF were 96 and 4 percent, respectively. Recently, in June 2012 the total monthly chromium mass removal was 243 pounds with the IWF and AWF accounting for 84 and 16 percent, respectively,

Figure 4-5 illustrates the relative efficiencies of the three extraction well fields based on the amount perchlorate and chromium mass removed and the overall extraction rates. Figure 4-5 illustrates that although the IWF has a relatively low overall extraction rate, it is responsible for the majority of chromium removal and about half of the perchlorate removal of the entire GWETS. The AWF is responsible for a relatively small amount of chromium removal and slightly less than half of the perchlorate removal. The SWF has by far the highest extraction rate, but negligible chromium removal and a relatively small percentage of the overall perchlorate removal (three percent in June 2012).

Although mass removal is an important measure of performance, the degree that the GWETS captures site contaminants, thereby mitigating migration of contaminants downgradient, is the ultimate measure of effectiveness. Northgate conducted a capture zone evaluation (CZE) to evaluate the efficacy of the GWETS in 2010. In conjunction with the CZE, a calibrated groundwater flow model was developed for the Site and additional monitoring and potential extraction wells were installed (Northgate 2010t and 2010u).

The groundwater flow model is currently under review by NDEP. On October 5, 2012, Northgate provided responses to all NDEP comments regarding the model, including those in the NDEP comment letters dated April 5, 2011 and August 1, 2012. Once the model is approved by NDEP, it will be used to further evaluate the performance of the GWETS. An updated CZE will be included as part of the RI/FS Report.

As discussed in the 2012 annual performance report (ENVIRON 2012c), potential gaps in plume capture have been observed as evidenced by elevated concentrations (primarily of perchlorate, but also chromium) at the ends of the IWF and downgradient of the AWF. The gaps are generally consistent with capture gaps identified in the 2010 CZE Report, and therefore, some of the potential new extraction wells installed previously could be utilized to enhance capture in

these areas. The proposed plan for addressing these capture zone gaps is discussed in Section 4.6.1.

Currently, there are certain limitations to operation of the existing GWETS that may require upgrades if expansion of the groundwater extraction network is deemed necessary. The treatment system is operating near its design average annual hydraulic loading of 950 gallons per minute (gpm) at the FBRs (the design 30-day average maximum flow is 1,000 gpm). The GWTP is operating near its current operational maximum hydraulic loading of 85 gpm (including 8-10 gpm of required recycle). Lift Station 3, which conveys extracted water from the AWF to Lift Station 2, is pumping at close to its maximum sustainable flow of 290 gpm. The pumping at Lift Station 2, which conveys water from the SWF and the AWF to the on-site treatment plant is also limited — it has a maximum sustainable flow of 900 gpm — but since Lift Station 2 is downstream of Lift Station 3, it is not directly limiting the flow from the AWF. A full evaluation of the GWETS, including the issues noted above, will be performed as part of the RI/FS.

4.5 Groundwater Monitoring Program

Pursuant to the aforementioned NDEP Orders, KMCC and then Tronox conducted groundwater monitoring and remediation system monitoring. In conjunction with the settlement of Tronox's bankruptcy proceeding, the Trust took title to the Site and the GWETS and continued the GWETS monitoring program.

The GWETS monitoring program consists of about 8,000 analyses per year including various and wide-ranging analytical methods from samples collected from the treatment processes, as well as from groundwater wells. Performance and compliance samples are collected and analyzed throughout the year including during weekly, bi-weekly, monthly, quarterly, and annual sampling events. However, the remainder of this section focuses on the groundwater monitoring program that is used to evaluate the overall effectiveness of the GWETS rather than monitoring related to permit compliance.

Currently, approximately 1,800 water level measurements and over 1,000 groundwater samples are collected from groundwater wells each year as part of the remediation monitoring program. Samples are collected on monthly, quarterly, and annual schedules in accordance with monitoring requirements outlined in the previous Consent Orders and AOC and through subsequent regulatory correspondence. The wells sampled as part of the monitoring program are shown on Figure 4-6. The current monitoring program is summarized in Table 4-1 and as follows (numbers referenced are from the 2011 monitoring year, but will vary slightly due to well access and status):

- **Monthly Sampling** – On a monthly basis, groundwater samples and water level measurements are collected from most active monitoring wells in the AWF, SWF, and within the plume between these two well fields. Samples are analyzed for perchlorate and TDS. Data are used to calculate the mass of perchlorate removed by the well fields and to provide groundwater level and quality data in the northern portion of the plume downgradient of the AWF. Water level measurements only are collected monthly from the IWF extraction wells and approximately 45 monitoring wells located

within or adjacent to the NERT facilities to characterize the groundwater levels and flow directions.

- **Quarterly Sampling** – Expanded monitoring events are conducted in the first, third, and fourth quarters and consist of collecting 138 groundwater samples and 163 water level measurements (inclusive of monthly monitoring activities described above). Groundwater samples are collected from wells screened in the Shallow WBZ located throughout the plume. Samples are analyzed for perchlorate, chromium, TDS, and pH. A small subset of wells is also sampled for hexavalent chromium for compliance with the Site's Underground Injection Control (UIC) permit #UNEV94218.
- **Annual Sampling** – Annually, a comprehensive monitoring event is conducted in the second quarter, and consists of 262 groundwater samples and 294 water level measurements collected from wells screened in the Shallow, Middle, and Deep WBZs. These wells include 29 wells that are owned by entities other than NERT including the City of Henderson, BMI, Olin, TIMET, and others. In addition to the analytes above, a subset of wells are analyzed for chlorate and nitrate.

Initially, separate quarterly progress reports were submitted for the chromium and perchlorate removal programs. In 2006, reporting for the two programs was combined, and since then the monitoring reports have been submitted semi-annually. The current semi-annual reports consist of text, tables, and figures documenting the status of remediation efforts, with appendices containing laboratory data reports, data validation reports, field documentation, and electronic data deliverables. An annual report submitted following the comprehensive second quarter monitoring event also includes a potentiometric surface map for the plume area and isoconcentration maps for the monitored constituents.

As described in Section 4.4.1, numerous groundwater investigations were conducted dating back to the early 1980s to characterize potential impacts to groundwater primarily related to chromium, and later, perchlorate. These investigations involved the installation of borings and groundwater wells to investigate specific data gaps; however, a systematic and critical evaluation of the groundwater monitoring network does not appear to have ever been performed. According to the NDEP's All Wells Database for the BMI Complex (September 2012 version) over 700 borings have been installed at the Site and downgradient of the Site by KMCC/Tronox including 390 that were constructed as groundwater wells. Of these 390 wells, it appears 103 were plugged and abandoned leaving 287 active wells at the Site. As noted above, most of these wells, and an additional 27 wells owned by others, are currently gauged and/or sampled as part of the groundwater monitoring program. In an effort to improve and streamline the groundwater monitoring program, a long-term monitoring optimization study is planned and will be presented as part of the RI/FS Report.

4.6 Proposed Additional Interim Removal Actions

Two additional interim removal actions have been proposed to address specific areas of concern in advance of preparation of this Work Plan. These proposed actions are described in the following sections.

4.6.1 Balanced-Flow Optimization of the IWF and AWF

As discussed above, potential gaps in plume capture have been observed as evidenced by elevated concentrations (primarily of perchlorate, but also chromium) at the ends of the IWF and downgradient of the AWF. The gaps are generally consistent with capture gaps identified in Northgate's 2010 CZE Report (Northgate 2010u), and therefore, some of the potential new extraction wells installed previously could be utilized to enhance capture in these areas. Seven additional extraction wells located within the IWF (I-W, I-X, I-Y, I-AA, I-AB, I-AC, and I-AD) have been installed, but have not yet been operated. Additionally, four large diameter groundwater wells at the AWF (ART-7B, PC-148, PC-149, and PC-150) that could be used as additional extraction wells were installed to support the CZE.

An analysis of these potential extraction wells indicated that adjusting extraction rates of currently active individual wells within the well fields to accommodate pumping from nine of the additional wells mentioned above could improve capture and mass removal efficiency at the IWF and AWF. This balanced-flow approach was deemed necessary due to the current limitations of the GWETS. The details of this analysis and the proposed changes to the extraction rates were included in Appendix E of the *2012 Annual Remedial Performance Report* (ENVIRON 2012c), and are also included in Appendix F of this Work Plan.

4.6.2 AP-5 Pond Solids Characterization and Disposal

A work plan has been prepared and submitted to NDEP to characterize and remove the residual solids remaining in an on-site lined surface impoundment (the AP-5 pond) at the Site (ENVIRON 2012h). The objective of this work plan is to methodically and efficiently characterize the solids to facilitate proper handling, management, and disposal.

This plan has been prepared in response to NDEP's approval letter dated June 28, 2012 to implement a *Proposal to Discontinue Treatment of AP-5 Pond Water at NERT Facility*, dated March 30, 2012 (ENVIRON 2012h). The proposal recommended implementation of the following four steps:

1. Permanently close the valve that allows flow of Lake Mead water into the AP-5 pond.
2. Pump all remaining water present in the AP-5 pond to the GW-11 pond and from there to the on-site groundwater treatment plant.
3. Characterize residual solids in the AP-5 pond for off-site disposal.
4. Remove residual solids from the AP-5 pond for disposal at an appropriately permitted off-site disposal facility.

To date, step one has been implemented and step two has been completed to the extent possible utilizing the existing AP-5 pond pumping system. The submitted work plan describes the activities proposed to implement steps three and four. Data collected from characterization sampling in step three will inform removal and disposal methods to be implemented during step four.

Once steps one through four are completed, all subsequent decommissioning work regarding the AP-5 pond (e.g., liner removal, underlying soil sampling, remediation as necessary) will be undertaken as part of the RI/FS.

5.0 Initial Site Evaluation

5.1 Conceptual Site Model

This preliminary identification of sources, release mechanisms, exposure media, exposure routes, and receptors is based on current understanding of on-site and off-site environmental conditions. The CSM will be revised, as appropriate, based on further evaluation of available on-site and off-site characterization data and additional environmental data collected during the RI.

The CSM for this RI Work Plan is developed for the Facility Area and Parcel E. Information from the Parcels will be reviewed and is considered within the CSM within the context of an evaluation of the nature and extent of contamination, but the baseline health risk assessment (BHRA) will not include the evaluation of health risks for Parcels A, B, C, D, F, G, and H. The Parcel Areas have generally been evaluated on a separate timeframe from that of the Facility Area. As presented in Sections 3 and 4, soil investigations at the Parcel Areas have been completed, surface and near surface soils in most Parcel Areas have been removed to levels below the SRGs, and HRAs are completed or in progress, as summarized below.

- **Parcels A and B.** Soil characterization, remediation, and risk characterization (HRAs) have been completed. NDEP issued a NFA Letter for soils less than 10 ft bgs for Parcels A and B on April 8, 2008 (NDEP 2008f), with the following conditions specified for deeper soils and groundwater.
  - The property owner retains the responsibility to address any environmental impacts to groundwater beneath the property referred to as Parcels A and B. As such, additional investigation may be necessary on this property for activities such as well or soil boring installations or other investigative or remedial efforts.
  - The materials presented to the NDEP do not evaluate the possibility of vapor intrusion concern from contamination in groundwater. It is anticipated that this issue will be addressed as part of the investigation of groundwater issues in the region.
  - The site soils beneath 10 ft bgs have not been evaluated to date. The property owner should note that these soils should not be disturbed without additional investigation or evaluation.
  - To limit liability, the property owner should ensure that activities at the property do not exacerbate existing subsurface environmental conditions.
  - The site use is suitable for purposes of commercial or industrial use only.
- **Parcels C, D, F, G, and H**. Soil characterization and remediation were completed in 2010, with the exception of a few localized areas with residual soil concentrations greater than SRGs (specifically, an area near the BMI haul road, paved roads, and rail lines). The most recent draft of the HRA for these Parcels was submitted to NDEP on May 18, 2012 (Northgate 2012b) and NDEP commented on the HRA on August 7, 2012 (NDEP 2012a). NDEP comments are currently being addressed.

Additional soil gas samples are being proposed (ENVIRON 2012d) for collection in the Parcel Areas to address a sampling data gap noted by NDEP in their comment letter of August 7, 2012. The Parcel HRA for the vapor intrusion pathway will be prepared on a timeline separate from that for the Facility RI (and BHRA) presented in this Work Plan (ENVIRON 2012e).

A comprehensive *Environmental Conditions Assessment* report was prepared for the Site in 1993 (Kleinfelder 1993). The report provided detailed summaries of processes and operations conducted during the periods of operation by the US Government and subsequent occupants of the Site and identified locations of former operations and associated support structures. Based on information from historical investigations and the 1993 *Environmental Conditions Assessment*, NDEP identified 70 LOUs as potential source areas (or areas requiring additional information, either in the form of further historical research or additional field sampling) in 1994 (NDEP 1994).

The 2005 CSM (ENSR 2005) presented detailed information on the LOU source areas identified by NDEP, including information on products made, years of production, and approximate waste volumes and actions taken to date. Available analytical results for each LOU were summarized and SRCs were identified based on a review of the activities and/or processes associated with each LOU. Potential contaminant migration pathways and receptors were also described. The 70 LOUs are listed in Table A-1 of Appendix A and the LOU locations are shown on Figure A-1.[19]

Since 2005, the Site has been the subject of additional field investigations and interim removal actions have been implemented, as described in Sections 3 and 4 of this Work Plan. For Facility Area soils, the investigations and interim removal actions include mainly the Phase A and Phase B Source Area Investigations and soil removal actions in RZ-B through RZ-E. In addition, an HRA was prepared for RZ-A to characterize risks for this specific area (Northgate 2010l).

The following sections provide an updated CSM based on current conditions at the Site, incorporating information from recent investigations, removal actions, and HRAs. Background information described in Section 2 of this Work Plan — site history, physical setting and climate, geology, and hydrogeology — was taken into consideration in the development of the CSM. Information from previous sections of this report is summarized below, as appropriate, for clarity in the development of the CSM. A schematic of the CSM is shown on Figure 5-1.

5.1.1 Potential Contaminant Sources and Release Mechanisms

The 5,000-acre BMI complex has been used for industrial activities since 1942, when the complex was sited and operated for the U.S. government as a wartime magnesium production plant (Kleinfelder 1993). During the period of government operations, the magnesium production operations consisted of the following major facilities, some of which were located on the area that is now the Site:

[19] Additional information for the LOUs can be found in "LOU Packets," provided on a compact disc accompanying the *Site Management Plan (SMP)* (ENVIRON 2012f).

- A brine purification facility that dissolved solar salt and removed calcium, potassium, strontium, sulfate, and bicarbonate impurities via a precipitation and filtering process.
- A chloralkali plant to produce sodium hydroxide and chlorine gas from the electrolysis of purified sodium chloride brine.
- A plant that created pellets of magnesium oxide and a carbon source.
- Ten identical, large buildings (Units 1 through 10), each of which contained chlorinators (furnaces) that created molten magnesium chloride by reacting the magnesium oxide/carbon pellets with chlorine gas at high temperature and banks of electrolytic cells that produced magnesium metal by electrochemical reduction of the molten magnesium chloride.
- An extensive system of surface impoundments that were used to receive process effluent for evaporative disposal. This system originally included the Trade Effluent Ponds, and later included the Upper and Lower BMI Ponds, and the associated Alpha and Beta Ditches used to transport effluent to the Ponds.
- Associated support buildings for the storage and transport of raw materials and the purification and processing of magnesium metal into ingots.

During the period of government operations, extensive volumes of liquid wastes were discharged to four unlined Trade Effluent Settling Ponds (Figure 5-2)[20]. These liquids were generally composed of acid effluent and waste caustic liquor containing high levels of TDS, dissolved metals, and to a lesser degree, chlorinated organic compounds (Kleinfelder 1993). Solid materials were placed in an open area south of the Trade Effluent Settling Ponds and north of the caustic settling ponds (Kleinfelder 1993). Waste water originating from the various production processes was discharged to a storm sewer system that emptied into unlined drainage ditches (e.g., the Alpha, Beta, and Northwest Ditches). The unlined drainage ditches routed waste water to a system of unlined ponds currently referred to as the Upper and Lower BMI ponds. The unlined surface conveyances and subsurface piping served to move waste water and chemicals across the Complex (with the potential for releases to soil) and impoundments allowed process effluents to infiltrate into soil and to groundwater in areas throughout the BMI Complex. Additionally, storm water and waste water originating from the former Stauffer and Montrose operations areas were diverted from the Lower to the Upper Ponds through the Beta Ditch Extension (BRC 2007).

Following the end of magnesium production in 1944, the BMI complex was subdivided into three primary production areas. Features located on what is now the Site include (Kleinfelder 1993):

- Six metal process unit buildings (Units 1 through 6) and the attached chlorination buildings, rectifier buildings, motor generator buildings, and bridges.
- A flux plant.

[20] Figure 5-2 identifies former and current surface water impoundments and conveyances located on the Site. The Alpha Ditch and Upper and Lower BMI Ponds, mentioned in this paragraph, were not located on the area currently occupied by the Site.

- Peat storage areas.
- An area with a salt storage building, pulverizer building, tunnel kiln building, rotary kiln building, pellet storage building, and magnesite silos.
- Various other buildings and open storage areas.
- An area occupied by approximately two and one-fifth of the original four Trade Effluent Ponds (Figure 5-2) used for management of liquid waste generated by the U.S. government operations.
- The Beta Ditch (specifically, the section crossing the Site), the Beta Ditch Extension, and the Northwest Ditch.

As described previously in Section 2, chemical manufacturing operations have continued at the Site since 1945, including production of chlorate and perchlorate compounds, boron and boron-related compounds, and refined manganese oxide.

5.1.1.1 Source Areas

The 70 source areas identified by NDEP include areas that are currently used for chemical production (e.g., some Units) and areas that are no longer active and/or where near surface soil contamination has been addressed (e.g., former surface water impoundments that have been closed). These current or former source areas include, but are not limited to:

- Units 1 through 6
- Surface water impoundments (over 15 former and current surface water impoundments were identified as LOUs)
- Former and current surface and subsurface water conveyances (e.g., the Beta Ditch, Beta Ditch Extension, Northwest Ditch, drainage systems, sewers, piping)
- Leach plant area
- Acid drain system
- Agricultural division plant
- Ammonium perchlorate plant and associated buildings
- Materials and product handling and storage areas
- Waste handling and storage areas
- Manganese tailings area
- Stock pile areas
- Former hazardous waste landfill and other hazardous waste storage areas

Historical releases from potential source areas have been documented or inferred from field investigations that have identified chemically impacted on-site soil, soil gas, and groundwater.

Specific examples of reported releases include process chemicals leaking to soil through cracks in the basements of Units 4 and 5 (LOUs 43 and 61) and the basement of Unit 6 (LOU 44). The

concrete basements served as sumps to collect process liquor, spillage, and wash water. Removal activities were undertaken in the Unit 6 basement in 1987 to remove the cracked concrete floor, followed by recontouring of the underlying soil and installation of a liner system. Other process leaks and spills (associated with the Units) to soils have been documented. The Unit process effluents contained high levels of TDS, perchlorate, and to a lesser degree, hexavalent chromium (Kleinfelder 1993).

From 1945 until the mid-1970s, process effluents from the chlorate, perchlorate, and boron-related production processes were sent to the unlined Upper and Lower BMI Ponds via the Beta Ditch (LOU 5) and manganese-related wastes were disposed of in on-site leach beds (LOU 24). In addition, other BMI companies used these same ditches for conveying wastes, providing an historical source of contaminants (from neighboring properties) unrelated to former Site operations to be present in Site environmental media. In the early 1970s, under the federal NPDES program, the industries at the BMI Complex curtailed waste discharges to the Upper and Lower BMI Ponds. KMCC achieved zero-discharge status in 1976, at which time process effluents were sent to on-site, lined surface impoundments. Over time, several of these lined surface impoundments reported known releases and liner failures; these early impoundments were eventually replaced with more effective double-lined systems.

5.1.1.2 Neighboring Properties

The Olin property to the west of the Site (formerly referred to as POSSM, Figure 2-1) occupies the location of the former BMI Complex chloralkali production facility. Post-1945 process activities on the property included operation of a chloralkali facility to produce chlorine gas, hydrochloric acid, and sodium hydroxide. In 1947, additional manufacturing facilities were constructed to produce pesticides and chlorinated organic compounds. Production of pesticides and organic compounds ceased in 1983, and production facilities were demolished and removed from the Olin property in 1984. Operation of the chloralkali facility is ongoing (Integral Consulting Inc. [Integral] 2009). Over time, extensive volumes of process effluents and solid wastes were disposed of in unlined ponds and buried on the Olin property. These wastes contained high levels of TDS, chlorinated organic compounds, and extensive amounts of phosphoric acid. Prior to 1976, certain process effluents were routed to the Upper and Lower BMI Ponds. These waste streams included large volumes of sulfuric and hydrochloric acid, as well as sulfonated metabolites of dichlorodiphenyltrichloroethane (DDT) (H+A 2008). Also to the west is the BMI CAMU (Figure 2-1). Both the Olin and BMI properties have been the subject of extensive environmental investigations, which have documented significant chemical impact to environmental media at the properties. It is noted that significant volumes of organochlorine pesticide and asbestos wastes were disposed of at what is now the Olin property.

Due to the direction of groundwater flow in the region (generally north to northeasterly), a groundwater contaminant plume has migrated onto the Site from the Olin property. Contaminants include VOCs, NAPL, and pesticides. The responsible parties for this plume are currently operating a groundwater treatment system and performing groundwater monitoring under NDEP oversight (ENVIRON 2011b).

The Lhoist property located in the center of the Site between RZ-B and RZ-C (formerly Chemstar, a lime producer) contributed to flows to the Beta Ditch prior to 1979. Lime production processes encompass mining and rock preparation, calcining to convert carbonate rock to calcium and/or magnesium oxides (quicklime), and hydrating the quicklime to hydroxides. The storm sewer system historically conveyed effluent from the Lhoist, Stauffer, and TIMET properties (Kleinfelder 1993).

The BMI landfill (located near the central portion of the BMI Complex in an area formerly used as a Trade Effluent pond) began operation in 1952. A number of different operating companies, including KMCC, sent solid and liquid wastes to the landfill. KMCC sent primarily the following types of wastes: housekeeping wastes (e.g., paper, cartons, bags, pallets, drums, and plastics), asbestos-containing material, elemental carbon powder (from boron operations), filter cake from the sodium chlorate operations, and dried residues from the cleaning of Ponds P-1 and AP-2 (ENVIRON 2011b). Specifically, from 1972 to 1979, KMCC used the BMI landfill for disposal of certain boron compound wastes and from 1975 to 1980, for disposal of chlorate wastes. In 1979, the boron compound wastes were disposed of off-site (Kleinfelder 1993). Between 1980 (when the BMI landfill closed) and 1983, the chlorate wastes were disposed of at an on-site hazardous waste landfill (subsequently closed). Between 1967 and 1975, manganese dioxide wastes were disposed of through on-site leach beds; subsequently, these wastes were disposed of at an on-site nonhazardous waste pile and more recently, off site.

The TIMET property to the east of the Site includes four former BMI process units (Units 7 through 10) and refinery buildings. Activities conducted on what is now the TIMET site from 1951 to present included production of magnesium ingot, titanium tetrachloride, titanium sponge, and titanium ingot (TIMET 2007). From 1951 until 1972, TIMET disposed of its caustic waste, leach liquor, and other process waste streams to the Upper BMI Ponds via the Beta Ditch. From 1970 to 1971, Stauffer and Montrose conveyed storm water and wastewaters from the Lower to the Upper BMI Ponds via the Beta Ditch Extension (Basic Remediation Company [BRC] 2007). Additionally the Northwest Ditch (LOU 6), which originates near the Beta Ditch and crosses the northern portion of the Site (Kleinfelder 1993), received and conveyed process waste streams from the BMI Complex facilities to the BMI Common Area and was identified under the Phases I and II BMI Common Area Consent Agreement as a BMI Common Areas issue (ENSR 2005, Broadbent & Associates, Inc. [Broadbent] 2011). From 1976 to 1982, TIMET built 31 lined surface impoundments on top of the southwestern portion of the Upper Ponds where its process waste streams were discharged. Several of the lined ponds reported liner failures and were upgraded to double-lined systems. In 2005, a water conservation facility went online and discharge to the ponds ceased. The TIMET process waste streams contained high levels of TDS and dissolved metal chlorides (LAW Engineering 1993).

These adjacent neighboring properties are considered potential “off-site” sources of contaminants to Site groundwater (as noted above), particularly from the west; surface soils (off-site storm water entering the Site); and air (airborne particulates released from contaminated surface soils and buildings on these adjacent properties).

5.1.2 Release Mechanisms and Potential Migration Pathways

Environmental media at the Site, including air, soil, soil gas, surface water, and groundwater, have been impacted, as shown through a review of historical records or confirmed through field investigations. The fate and transport of Site contaminants released from on-site (and off-site) sources was assessed to identify the environmental media potentially impacted by releases. The primary historical and/or current release mechanisms and impacted environmental media at the Site are identified as follows:

- Wind dispersal of fugitive dust from contaminated surface soils.
- Surface runoff over contaminated soil following precipitation, with transport to other on-site soil, on-site surface impoundments and off-site drainage areas.
- Overflow of surface impoundments.
- Leaching from surface impoundments and surface and subsurface conveyances through subsurface soil to groundwater.
- Leaching from contaminated surface and near surface soils to deep soils and migration to groundwater.
- Surfacing of groundwater or groundwater discharges to drainages or lakes, such as the Las Vegas Wash or Lake Mead.

5.1.3 Summary of the Soil CSM

As described in Section 4.1, an interim soil removal action was completed for the Facility Area (RZs B through E) in November 2011, in which accessible soils with COPC concentrations greater than worker SRGs were removed. Inaccessible soils (with COPC concentrations greater than SRGs) and incompletely characterized soils (due to access issues) were assigned to one of 38 ECAs established following the remediation program (7 in RZ-B, 18 in RZ-C, 10 in RZ-D, and 3 in RZ-E).

For purposes of the CSM, the surface and near surface soils (0-10 ft below the "new" ground surface[21]) within the Facility Area were placed into one of four categories:

Category 1 (All Soils in ECAs): Includes all soils in ECAs. Due to access or other constraints that precluded soil excavation, soils in ECAs with COPC concentrations exceeding SRGs were left in place. ECAs also include soils that have not been fully characterized due to access or other restrictions.

Category 2 (SRGs Not Exceeded, Not in ECA): Includes soils with COPC concentrations less than SRGs within the 0-10 ft depth interval that are not in ECAs. These soils are in areas that either (1) were not identified for remediation because COPC concentrations were less than SRGs, based on results of the Phase A and Phase B source investigations (or other historical investigations), or (2) were remediated and any soils exceeding SRGs

[21] The "new" ground surface refers to the soil surface following excavation, backfilling, and grading associated with the 2011 interim soil removal action (ENVIRON 2012b).

in the 0-10 ft depth interval were removed, either in 2011 during the interim soil removal action or during other removal actions (e.g., closure of surface water impoundments).

Category 3 (SRGs Exceeded, Not in ECA): Includes soils with COPC concentrations greater than SRGs within the 0-10 ft depth interval that are not in ECAs.

Category 4 (Inadequate Characterization, Not in ECA): Includes soils that are inadequately characterized that are not in ECAs.

Category 3 and 4 soil areas were identified during an ongoing comprehensive review of residual soil concentrations following completion of the 2011 interim soil removal action (ENVIRON 2012b, under NDEP review). Based on the review completed to date, 11 areas have been categorized as Category 3 (shown as numbers 1-11 on Figure 5-3)[22]. Information about these areas is presented in Table 5-1, including sample location, sample depth interval, chemicals exceeding their respective SRG[23], detected concentrations, and SRGs. The chemicals detected in one or more of these areas at concentrations above their respective SRG are arsenic, perchlorate, dioxin TEQs, benzo(a)pyrene TEQs, and hexachlorobenzene. One Category 4 area — the debris pile — was identified (shown on Figures 2-2 and 5-3). Materials in the debris pile (e.g., concrete) have not been characterized and soil has not been sampled (sampling in this area is identified as a data gap in Section 5.4).

The 2011 interim soil removal action addressed mainly soils in the 0 to 10 ft horizon (with some exceptions, as noted above). The primary concern with contamination in deeper soils (greater than 10 ft bgs) is the potential for leaching to groundwater, as discussed in the following sections.

5.1.4 Summary of the Groundwater CSM

The 2005 CSM presented a CSM for groundwater based on data collected at the Site and site vicinity since 1986 (ENSR 2005). An updated version of a generalized conceptual diagram of potential contaminant source areas, contaminant pathways, and potential receptors is presented on Figure 5-4.

As noted in the 2005 CSM, vadose zone transport of non-volatile chemicals is a function of having the necessary chemical environment and sufficient infiltration to mobilize the chemical through the unsaturated zone to underlying groundwater. Portions of the Site are paved or covered, which prevents infiltration of water. Given the arid climate and the current physical condition of the Site, there are only a few specific occurrences that can generate sufficient water to mobilize site-related chemicals that are present in the subsurface following the remediation of impacted soils in the upper surface and near surface (typically, 0-10 feet). These occurrences can include a rainstorm of sufficient quantity and duration to saturate the soil beyond its field capacity; a water supply pipeline break that discharges water to a specific area which then infiltrates to groundwater; or developing a leak in or beneath a synthetically lined pond that releases sufficient water to reach the water table (ENSR 2005).

[22] Additional Category 3 and 4 areas may be identified following completion of the data review.

[23] Within 0-10 ft of the new ground surface.

Volatile chemicals present in the vadose zone can also be transported to groundwater by vapor-phase diffusion, in addition to being transported by infiltration. If infiltration is limited, vadose zone soils will remain generally dry, which will allow diffusion of volatile chemicals in the vapor phase downward to the water table. Volatile chemicals that are soluble will dissolve in groundwater and may be transported downgradient through groundwater transport.

5.1.4.1 Leaching-Based Soil COPCs

Perchlorate and chromium are the primary chemicals present in soil that may impact groundwater. In addition, as documented in the July 21, 2011 NDEP Action Memorandum describing the soil removal action, the following metals have been observed in soils at concentrations that may pose a leaching concern and have the potential to impact groundwater at concentrations above MCLs or BCLs:

- Antimony
- Arsenic
- Boron
- Cadmium
- Chromium VI
- Copper
- Magnesium
- Manganese
- Nickel
- Uranium
- Zinc

An initial screening of organic chemicals present in on-site soils (RZ-A through RZ-E) for leaching potential was presented in the *Revised Technical Memorandum: Calculation of Leaching-Based, Site-Specific Levels (LSSLs) for the Soil-to-Groundwater Pathway using NDEP Guidance* by Northgate dated February 14, 2011. This document has not been approved by NDEP. Organic COPCs were identified in the initial screening by comparing site soil concentrations against leaching-based BCLs (LBCLs) using a default dilution attenuation factor (DAF) of 20. The following organic COPCs were identified:

- **Pesticides**: 4,4'-DDE; 4,4'-DDT; aldrin; alpha-BHC; beta-BHC; gamma-BHC; and dieldrin
- **SVOCs**: Benzo(a)anthracene; benzo(b)fluoranthene; and hexachlorobenzene
- **VOCs**: 1,2,3-trichloropropane; benzene; carbon tetrachloride; chloroform; and 1,2,4-trichlorobenzene.

Because the screening of soil results for leaching potential performed previously by Northgate was conducted prior to the soil removal action, the screening included soil results from locations that were excavated as part of the soil removal action and did not include soil results from confirmation samples collected as part of the removal action. ENVIRON is currently updating the screening of vadose zone soil concentrations against LBCLs using a soil dataset that has been revised to incorporate changes resulting from the interim soil removal action.

The revised leaching-based screening will be conducted on all vadose zone soil samples collected within the alluvium in RZ-A through RZ-E since 2006 that were not excavated. Leaching-based soil COPCs will be identified as chemicals detected in at least 5% of samples

that have at least one detection exceeding the LBCLs published by NDEP (2012b). If no NDEP LBCL is available, ENVIRON will calculate a generic LBCL using the approach presented in NDEP guidance. If warranted, ENVIRON may also calculate site-specific screening levels or perform unsaturated zone transport modeling to further refine the list of soil COPCs that may pose a leaching concern.

For metals and radionuclides, the site soil concentrations will be compared to background datasets to determine whether the concentrations found on-site are consistent with background. The background comparisons will be done using the background datasets described in Appendix C and consistent with the statistical approach presented in NDEP guidance (NDEP 2009g).

5.1.4.2 Groundwater COPCs

Perchlorate and chromium are the primary site-related chemicals detected in groundwater downgradient of the Site. ENVIRON developed a list of other COPCs in groundwater that exceed screening criteria. Groundwater screening criteria were selected according to the following hierarchy: 1) NDEP BCLs (NDEP 2012b), 2) USEPA MCLs, 3) USEPA tap water RSLs (USEPA 2012a), 4) USEPA secondary MCLs, and 5) risk-based target activities for thorium identified in the NDEP BCL User's Guide (NDEP 2012b).

The screening for groundwater COPCs was based on analysis of data from the Phase A investigation (low-flow samples only) conducted in May 2007 (ENSR 2007a, 2007b), Phase B investigations conducted from 2008 to 2009 (Northgate 2010v), the Upgradient Investigation (ENSR 2007d), the Capture Zone Evaluation data gaps investigation conducted in September 2010 (Northgate 2010u), and other groundwater sampling data collected since 2006. The analysis was limited to unfiltered samples for this initial screening. Groundwater samples were analyzed for metals, VOCs, SVOCs, pesticides, herbicides, dioxins, furans, radionuclides, organic acids, and other general chemistry parameters.

Groundwater COPCs were defined as chemicals with site-wide detection frequencies in groundwater greater than 5% with at least one detected concentration that exceeded the groundwater screening criteria. If no screening criterion was available, the chemical was retained as a COPC in this initial screening, but will be evaluated further in the future. Consistent with USEPA guidance, the essential nutrients calcium, potassium, and sodium were not included as COPCs. Also in a future evaluation, metals and radionuclide concentrations in groundwater will be compared to background concentrations to determine whether they are statistically different.

In the following list of COPCs in groundwater, an asterisk indicates that no comparison screening criterion was available:

Perchlorate		
Metals	Aluminum Arsenic Boron Cadmium Chromium VI Chromium (total) Cobalt Iron	Lead Magnesium Manganese Molybdenum Platinum* Strontium Tungsten Vanadium
VOCs	1,1-Dichloroethane 1,1-Dichloroethene 1,2,3-Trichlorobenzene 1,2,3-Trichloropropane 1,2,4-Trichlorobenzene 1,2-Dichlorobenzene 1,2-Dichloroethane 1,4-Dichlorobenzene Benzene Bromodichloromethane	Bromoform Carbon Tetrachloride Chlorobenzene Chloroform Chloromethane Dibromochloromethane Isobutyl Alcohol Methylene Chloride Tetrachloroethene Trichloroethene
Pesticides	alpha-BHC beta-BHC delta-BHC*	gamma-BHC Heptachlor epoxide
Radionuclides	Radium-226 and -228 Thorium-228 Thorium-230	Thorium-232 Uranium
SVOCs	bis(2-Ethylhexyl)phthalate	1,4-Dioxane
General Chemistry	Ammonia Bromide* Chlorate* Chloride Cyanide (total)	Nitrate Nitrite Phosphorus (total) Sulfate Total Dissolved Solids*
4-Chlorobenzenesulfonic acid		

As part of the RI, ENVIRON will review available groundwater data to determine whether any revisions to this list are necessary.

5.1.5 Land Use, Exposed Populations, and Exposure Pathways

The following sections identify current and future land use at the Site and potentially exposed populations. Potential exposure pathways for evaluation in the BHRA are discussed.

5.1.5.1 Land Use and Exposed Populations

The Site is situated within an area zoned for industrial use and as discussed previously, Tronox currently has a long-term lease for approximately 373 acres of the Site, where it conducts its manufacturing operations. Parcels A, B, C, D, F, G, and H are for sale and Parcel E contains a portion of the Olin groundwater treatment system.

Surrounding land use is predominantly industrial. The nearest residential developments are located north and south of the Site, with residential developments to the east and west located at a greater distance. Given the highly industrialized nature of the 5,000-acre BMI complex (which includes the Site and adjacent facilities), and the long-term lease with Tronox, future use of the Site is expected to remain industrial.

Potentially exposed populations (receptors) were identified considering current and expected future land use. Current and future on-site receptors include long-term indoor workers, long-term outdoor commercial or industrial workers, and short-term construction workers. Currently, approximately 101 full-time workers are employed at the Tronox facility and approximately 10 workers are employed at the GWETS.

Other potential on-site receptors include visitors and trespassers. However, as discussed in USEPA's *Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites* (USEPA 2002b), evaluation of exposures to members of the public entering an operating facility is generally not warranted for two reasons: (1) public access is restricted or controlled at industrial sites, and (2) while the public may have access to a property, exposures of an on-site worker would be much higher than those of a visitor because workers spend substantially more time at a site. Accordingly, on-site visitors and trespassers will not be quantitatively evaluated in the risk assessment.

Potential off-site receptors include workers, residents, and recreational users.

5.1.5.2 Exposure Media and Pathways

The potentially contaminated exposure media at the Site and nearby vicinity include ambient and indoor air, soil, surface water, and groundwater. Potentially complete exposure pathways for each on-site and off-site receptor and exposure medium are discussed in the following sections and identified on the preliminary CSM diagram (Figure 5-1).

Air. Chemicals detected in soil or soil gas can be transported into air through two primary mechanisms. Soil-bound chemicals can be released to air if impacted surface soils are subjected to wind erosion and/or mechanical disturbance. Volatile chemicals in soil gas can migrate through the unsaturated zone to ambient and indoor air.

- For on-site receptors, potential exposure pathways include inhalation of airborne particulates in ambient and indoor air and inhalation of VOCs in ambient and indoor air.

Because risks from inhalation of VOCs in indoor air would be higher than those estimated for ambient air, the ambient (outdoor) air pathway will be evaluated only if cancer risks for the vapor intrusion (indoor air) pathway exceed 1×10^{-6} or the HI is greater than one.

- For off-site receptors, inhalation exposures to airborne particulates or VOCs released from the Site would be substantially lower than the exposures of on-site outdoor workers. These pathways will be evaluated only if cancer risks for on-site receptors exceed 1×10^{-6} or the HI is greater than one. However, the vapor intrusion pathway for VOCs in the downgradient plume is considered a potentially complete exposure pathway for off-site receptors (indoor worker and residents). The importance of this pathway and need for quantitative assessment is under evaluation. The evaluation will consider the effectiveness of the current groundwater mitigation systems, depth of groundwater in the downgradient area, and contaminant (VOC) concentrations in downgradient groundwater.

Soil. Individuals may ingest soil inadvertently, by transfer of soil on fingers to the mouth, for example. Individuals may also be exposed to COPCs in soil through dermal contact.

- For on-site receptors, the two complete exposure pathways for outdoor workers are (1) incidental ingestion of soil and (2) dermal contact with soil. Consistent with USEPA guidance (USEPA 2002b), for the indoor worker, the dermal pathway is considered complete, but exposures would be negligible.
- For off-site receptors, deposition of airborne particulates released from the Site is a potential transport mechanism. However, potential exposures of off-site receptors to deposited particulates would be negligible.

Surface Water. The Site is located in a very arid region with few natural surface water bodies; however, surface water is present in areas of the Site, primarily in surface water impoundments receiving process wastewater. Surface water is also present following storm events, during which COPCs in contaminated surface soils can dissolve. Contaminants adsorbed to soils/sediments can also be transported via surface water transport. Off-site surface water bodies in the area include Las Vegas Wash and Lake Mead.

- For on-site receptors, exposures of outdoor workers to COPCs in stormwater runoff during the few yearly precipitation events would be insignificant and worker maintenance activities at the surface water impoundments and associated conveyances would be covered under regulations put forward by the Occupational Safety and Health Administration (OSHA). Based on these considerations, potential worker exposures to surface water are not identified for evaluation.
- For off-site receptors, exposure to COPCs (specifically, the SRCs) in surface water represents a potentially complete exposure pathway. As discussed in Section 3.2.4, impacted groundwater discharges to surface water at Las Vegas Wash, which empties into Lake Mead. Lake Mead is the source of approximately 90 percent of the drinking water in Southern Nevada (Las Vegas Water District 2012). The nine wells operating at the SWF were installed to mitigate this exposure pathway. This system has been extremely effective, reducing the amount of perchlorate entering Las Vegas Wash by

approximately 90 percent (Las Vegas Water District 2012). Nevertheless, exposures to SRCs present in Las Vegas Wash and Lake Mead represent potentially complete exposure pathways for off-site recreational users and residents serviced by the Las Vegas Water District.

Groundwater. Groundwater is not currently used as a source of drinking water, and given the high concentrations of TDS, will not be used in the future as a drinking water source. The only potential for direct contact with groundwater is associated with intrusive subsurface activities.

- For on-site receptors, direct contact with groundwater (i.e., incidental ingestion or dermal contact) during construction activities is considered to be an incomplete exposure pathway. Depth to groundwater ranges from about 27 to 80 ft bgs, deeper than excavations typically associated with construction activities. Further, potential exposures of workers (e.g., construction or utility workers) associated with activities at depths greater than 10 ft bgs are managed through the SMP (ENVIRON 2012f). Specifically, the SMP presents risk management measures and procedures to be implemented during construction to mitigate potential risks to human health and the environment from potential exposure to COPCs, and to manage soil and groundwater during construction activities.
- For off-site receptors, although depth to groundwater can be less than 20 ft in the downgradient area, potential exposures of construction workers to groundwater are considered negligible. Direct contact with groundwater (incidental ingestion or dermal contact) would be intermittent and standard engineering controls such as dewatering of excavations, minimize worker exposures.

In summary, the following exposure pathways are identified for quantitative evaluation in the risk assessment:

On-site receptors

- Long-term indoor commercial workers
  - Incidental ingestion of soil
  - Inhalation of vapors released from soil and groundwater to indoor air[24]
- Long-term outdoor industrial/commercial workers
  - Incidental ingestion of soil
  - Dermal contact with soil
  - Inhalation of airborne particulates
- Short-term construction workers
  - Incidental ingestion of soil

[24] As discussed previously, the inhalation pathway (for volatilization into indoor/ambient air) was evaluated in the *Site-wide Soil Gas Human Health Risk Assessment* (Northgate 2010g, under NDEP review). While a separate evaluation of this pathway will not be included in the BHRA, cumulative risks for soil and inhalation pathways will be presented in the BHRA. (The NDEP approval status of the risk estimates for the inhalation pathways will be noted.)

- Dermal contact with soil
- Inhalation of airborne particulates

Off-site receptors

- Recreational Users (at Las Vegas Wash and Lake Mead)
  - Incidental ingestion of surface water
  - Dermal contact with surface water
- Residents (drinking water from Lake Mead)
  - Ingestion of domestic water
  - Dermal contact with domestic water

5.2 Remedial Action Objectives and ARARs

Remedial action objectives (RAOs) are media-specific (e.g., soil or groundwater) objectives designed to protect human health and the environment from releases and exposures to hazardous substances. RAOs incorporate information regarding the specific setting, COPCs, potential future uses of the Site, and human health and ecological risk-based criteria. The RAOs reflect a preference for permanent solutions, incorporating approaches, where feasible and appropriate, that will reliably reduce contaminant toxicity, mobility, or volume.

Applicable or relevant and appropriate requirements (ARARs) are considered during the development of RAOs. Applicable requirements are those federal and state cleanup standards, standards of control, and other environmental protection requirements, criteria, or limitations promulgated under federal or state environmental or facility siting laws that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a site. If a requirement is not applicable, it may still be relevant and appropriate. A relevant and appropriate requirement addresses problems or situations that are substantially similar to those encountered at a similar site.

5.2.1 Identification and Selection of Applicable or Relevant and Appropriate Requirements

It is not unusual that multiple federal and/or state requirements are initially identified as being relevant, even though the requirements address similar issues or circumstances. USEPA ARAR guidance provides for screening of the "relevant" requirements to determine which requirements are "appropriate" and hence, an ARAR. "Relevant" requirements would not be considered "appropriate" when:

- "...another requirement is available that more fully matches the circumstances at the site," or
- "...another requirement is available that has been designed to apply to that specific situation, reflecting an explicit decision about the requirements appropriate to that situation."

For a state requirement to qualify as an ARAR, it must be promulgated, legally enforceable, more stringent than any corresponding federal requirement, consistently applied, and identified in a timely manner.

ARARs fall into one of three identified categories: chemical-specific, location-specific, and action-specific. Chemical-specific ARARs are health- or risk-based numerical limitations or standards that apply to site-specific conditions. Location-specific ARARs are restraints placed on activities conducted in a specific location. Action-specific ARARs are technology- or activity-based requirements or limitations on actions taken with respect to hazardous waste or site remediation activities.

In addition to chemical-, location-, and action-specific ARARs, advisories, criteria, and guidance developed by USEPA or other federal or state agencies may, as appropriate, be considered in developing remediation alternatives. These criteria are referred to as "to-be-considered" (TBC) criteria.

5.2.1.1 Potential Chemical-Specific ARARs and TBC Criteria

As discussed in the July 2011 NDEP Action Memorandum, federal chemical-specific ARARs determined to be practicable for the Site are as follows:

- Safe Drinking Water Act (SDWA)
- Toxic Substances Control Act (TSCA)

State chemical-specific ARARs determined to be applicable for the Site are as follows:

- Nevada Administrative Code (NAC) 445A.200 - 201 (Las Vegas Wash Beneficial Use Standards for Confluence of Las Vegas Wash with Lake Mead to Telephone Line Road).

The following state chemical-specific TBC criteria were identified for groundwater, soil, and surface water at the Site. These values are generally risk-based concentrations that are to be used as guidelines for preliminary screening evaluations.

- Under NAC 445A.226 – 22755, Action Levels (ALs) for contaminated sites are derived. BCLs are risk-based media concentrations for use in an initial screening evaluation to assist in risk assessment components such as the evaluation of data usability, determination of extent of contamination, identification of COPCs, and identification of preliminary remediation goals. The BCL values are derived as specified in NAC 445A.2272 and using equations from USEPA guidance, USEPA toxicity criteria, and USEPA exposure factors.

5.2.1.2 Potential Location-Specific ARARs

Location-specific ARARs are restraints placed on activities to be conducted in specific locations. Types of location-specific ARARs include requirements restricting actions or protecting floodplains, wetlands, historic places, archeological sites, and sensitive ecosystems. Potential federal location-specific ARARs at the Site are listed below.

- Clean Water Act (CWA) 40 CFR 131, 404 and 33 CFR Part 330 (Dredge and Fill Material Discharge into Waterways)
- Federal Migratory Bird Treaty Act (Federal Protection of Migratory Birds)
- Federal Endangered Species Act of 1973 (Conservation of Threatened and Endangered Plants and Animals and the Habitats)

Potential State location-specific ARARs at the Site are listed below.

- Nevada Revised Statute (NRS) 535 (Dams and Other Obstructions)
- NAC 534 (Underground Water and Wells)

5.2.1.3 Potential Action-Specific ARARs

Action-specific ARARs are technology- or activity-based requirements or standards that apply to specific remedial activities conducted as part of a selected remedy. Potential federal action-specific ARARs are presented below.

- National Pollution Discharge Elimination System (NPDES) Permits issued under the CWA 40 CFR 122-125 (Discharge of Treated Groundwater to Surface Water)
- National Pretreatment Standards for Discharges to Public Owned Treatment Works (POTWs) under the CWA 40 CFR 403 (Discharge of Wastewater and Treated Groundwater to Sewers)
- SDWA 40 CFR 144 (Groundwater Injection)
- Clean Air Act (CAA) 40 CFR 51 (New Source Review/Prevention of Significant Deterioration Rules for Nonfugitive Major Emission Sources)
- CAA 40 CFR 61 (National Emission Standards for the Hazardous Air Pollutants)
- Hazardous Materials Transportation Act 40 CFR 171-178 (Transportation of Hazardous Materials)
- Occupational Safety and Health Administration (OSHA) 29 CFR 1910.20 (Worker Training for Remediation Activities at Hazardous Waste Remediation Sites)
- Resource Conservation and Recovery Act (RCRA) 40 CFR 240-271 (Standards for the Generation, Management, and Disposal of Hazardous Wastes)

Potential State action-specific ARARs are listed below.

- NAC 459.970 - 9729 (Certification of Certain Consultants and Contractors)
- NAC 445A.228 - 263 (Discharge Permits)
- NAC 444.965 - 976 (Disposal of Asbestos)
- NAC 445A.810 - 925 (Underground Injection Control)
- NRS 533.437 - 4377 (Groundwater Appropriations — Environmental Permits)
- Clark County Air Quality Regulations

5.2.2 Potential RAOs for the Site

For consistency with the National Oil and Hazardous Substances Contingency Plan (NCP, 40 CFR 300), RAOs proposed for the Site must be technically feasible and comply with ARARs (40 CFR 300.430). As discussed above and in the NDEP Action Memorandum dated July 21, 2011 (NDEP 2011a), the primary chemical-specific ARARs that apply to groundwater at the Site include:

- SDWA USEPA Maximum Contaminant Levels (MCLs) under 40 CFR 142;
- Nevada Water Quality Standards under NAC 445A.200 - 201 which include Las Vegas Wash Beneficial Use Standards for Confluence of Las Vegas Wash with Lake Mead to Telephone Line Road.

In addition, TBC criteria would include the BCLs discussed above. With respect to perchlorate, the TBC criteria includes the Nevada Interim Action Level for perchlorate in drinking water of 18 µg/L (NDEP 2011a,c).

The proposed RAOs for groundwater have been selected to incorporate the following chemical-specific ARARs/TBCs:

- Perchlorate: Because there are no chemical-specific ARARs for perchlorate, the most applicable and relevant TBC for perchlorate that is protective of human health is the State of Nevada's Provisional Action Level for drinking water of 18 µg/L (NDEP 2011a,c).
- Other Site COPCs: The most prevalent COPC detected in groundwater at the Site other than perchlorate is chromium. The chemical-specific ARAR for chromium is the federal MCL of 100 µg/L, which the State of Nevada has adopted by reference (NAC 445A). For other Site COPCs, the chemical-specific ARARs/TBCs discussed above will be evaluated based on the results of a site-specific risk assessment and incorporated into the Site FS.

5.2.2.1 Short-Term Remedial Action Objectives

Short-term RAOs for the Site are those RAOs that are projected to be met in less than 5 years at the Site.

- **Off-Site Groundwater and Las Vegas Wash:** To meet the primary CERCLA objective of being protective of human health and the environment, discharge of COPCs originating at the Site to the Las Vegas Wash will be mitigated to help achieve chemical-specific ARARs/TBCs within the Wash. This RAO is currently being achieved and (in the short-term) will be met via continued operation of the SWF, the AWF, and the IWF and Barrier Wall System. RAOs associated with on-site soils and groundwater (described below) will be consistent with meeting this objective in the long-term.
- **Optimization/Enhancement of Groundwater Extraction and Treatment System:** Consistent with the short-term RAO regarding off-site groundwater and Las Vegas Wash (described above), the current groundwater extraction and treatment system will be investigated with the objective of optimizing operation and enhancing performance. The current system has been effective in reducing the concentrations of perchlorate in Las Vegas Wash, Lake Mead, and downgradient surface water to concentrations below current

regulatory criteria. The optimization program will investigate current groundwater pumping schemes and the system configuration to ensure that maximum capture efficiency is being achieved by the system and to evaluate whether alternatives could be used to enhance such efficiency and improve cost-effectiveness.

- **Shallow Soil:** Prevent human exposure to COPCs in soil that would pose an unacceptable health risk to on-site and off-site receptors under current and future land uses.

5.2.2.2 Long-Term Remedial Action Objectives

Long-term RAOs for the Site are those RAOs that will focus on achieving restoration of downgradient groundwater over a long time frame (i.e., greater than 5 years).

- **Downgradient Aquifer Restoration:** The overall RAO for groundwater downgradient of the Site is to restore the alluvial aquifer and UMCf to meet ARARs/TBCs. This RAO will be achieved incrementally by first focusing on the control of off-site migration of COPCs at the downgradient boundary of the Site (see below).
- **On-Site Groundwater Control:** To achieve the overall long-term RAO of downgradient aquifer restoration, the migration of COPCs present in groundwater at the Site will be mitigated. Specifically, groundwater immediately downgradient of the northern property boundary of the Site will meet ARARs/TBCs likely through a combination of the implementation of on-site vadose zone source control and the implementation (as required) of barrier groundwater control options (e.g., extraction, hydrogeologic barriers, or in-situ treatment).
- **Vadose Zone Source Control:** To be consistent with the preference for permanent remedies, incorporating approaches that will reliably reduce contaminant toxicity, mobility, or volume through treatment, this RAO will address the mitigation of significant leaching of perchlorate and other Site COPCs from vadose zone soils to underlying groundwater. The effectiveness and implementability of this RAO could be limited by the presence of existing operating units at the Site and therefore, will be evaluated in conjunction with on-site groundwater control alternatives to ensure that ARARs/TBCs will be achieved at the downgradient Site boundary. It is also anticipated that additional areas of vadose zone source control will be identified in the future as Site operations and unit buildings are altered and/or decommissioned.

5.3 Development of General Response Objectives and Screening of Remedial Technologies and Process Options

Under USEPA RI/FS guidance (USEPA 1988), a preliminary range of remedial action alternatives and associated technologies should be identified. This identification is not meant to be a detailed investigation of alternatives. Rather, it is intended to be a more general classification of potential remedial actions based upon the RAOs. To accomplish this, as described in this section, general response actions (GRAs) were developed for the Site. Following the identification of GRAs, and in accordance with USEPA RI/FS guidance, remedial technologies and process options were identified and initially screened. Following the initial screen, the process options retained for further analysis were further evaluated and screened. Process options were eliminated from further consideration if other process options within the

same technology type offer significant relative advantages. The purpose of this screening step is to minimize the number of process options that must be considered in the development of alternatives without limiting the flexibility of the remedial design.

5.3.1 General Response Actions

GRAs are media-specific actions that satisfy RAOs that have been developed for the Site. The GRAs that have been developed for groundwater and associated source areas at the Site are summarized below.

- **No Further Action**. Evaluation of a "no action" alternative, or a no further action alternative if removal or remedial actions have already been implemented, is required under the NCP (40 CFR §300.430). For this GRA, it is assumed that no further removal or remedial actions, other than those removal actions that have already been implemented at the Site, would be performed.
- **Institutional Controls.** Institutional controls are legal or physical means to prevent potential exposures to COPCs by limiting the use of contaminated property (e.g., limiting groundwater use).
- **Groundwater Monitoring.** Impacted groundwater may be monitored on a periodic basis to ensure that chemical concentrations do not increase such that there is an unacceptable risk to human health or the environment.
- **Monitored Natural Attenuation.** Monitored natural attenuation relies on natural processes to achieve site-specific remedial objectives and routine monitoring to measure progress toward those objectives. The "natural attenuation processes" include physical, chemical, or biological processes that, under favorable conditions, act without human intervention to reduce the mass, toxicity, mobility, volume, or concentrations of contaminants in groundwater.
- **Containment Actions.** These response actions reduce the mobility of COPCs, eliminate exposure pathways, and prevent the migration and transport of COPCs to unaffected media.
- **Groundwater Extraction.** These response actions provide for extracting groundwater prior to ex-situ treatment.
- **Ex-Situ Groundwater Treatment Actions.** These response actions provide for treatment of extracted groundwater prior to discharge/disposal.
- **Excavation**. These response actions provide for excavation of source areas, prior to ex-situ treatment or disposal.
- **Ex-Situ Source Area Treatment Actions.** These response actions provide for treatment of excavated source area soils.
- **In-Situ Groundwater Treatment Actions.** These response actions reduce the mobility of COPCs, eliminate exposure pathways and prevent the migration and transport of COPCs to unaffected media.

- **In-Situ Source Area Treatment Actions.** These response actions are intended to reduce the concentrations of COPCs within vadose zone source areas in order to reduce the toxicity, mobility, or volume of contamination and also to aid in the attainment of RAOs at downgradient locations.
- **Discharge of Water from Ex-Situ Groundwater Treatment Actions**. These response actions provide for the disposal of treated liquids resulting from groundwater extraction and treatment operations.
- **Ex-Situ Vapor/Air Emissions Treatment Actions**. These response actions provide for the ex-situ treatment of vapors or other air emissions resulting from other in-situ or ex-situ treatment operations.

5.3.2 Initial Screening of Remedial Technologies and Process Options

A list of potentially applicable technology types and process options has been identified, evaluated, and screened for each GRA that has been developed for the Site. The term "technology types" refers to general categories of remedial technologies, and the term "process options" refers to specific processes within each of the technology types. The technology types and process options that have been considered and evaluated in this section are based upon ENVIRON's experience at similar sites and readily available technical information from government, industry, and academia including the following sources:

- Department of Toxic Substances Control (DTSC), 2004. Perchlorate Contamination Treatment Alternatives. January.
- Evanko, C.R. and Dzombak, D.A., 1997. Technology Evaluation Report TE-97-01: Remediation of Metals-Contaminated Soils and Groundwater. Ground-Water Remediation Technologies Analysis Center (GWRTAC). October.
- Federal Remediation Technology Roundtable (FRTR). 2012. www.frtr.gov.
- Interstate Technology & Regulatory Council (ITRC), 2000. Technology Overview: Dense Non-Aqueous Phase Liquids (DNAPLs): Review of Emerging Characterization and Remediation. Interstate Technology & Regulatory Council. June.
- ITRC, 2007. Remediation Technologies for Perchlorate Contamination in Water and Soil. PERC-2. Interstate Technology & Regulatory Council, Perchlorate Team. www.itrcweb.org.
- Sale, T. and Newell, C, 2011. A Guide for Selecting Remedies for Subsurface Releases of Chlorinated Solvents, U.S. Department of Defense, Environmental Security and Technology Certification Program (ESTCP) Project ER-200530. March.
- Urbansky, E. T, 1998. Perchlorate chemistry: implications for analysis and remediation. Bioremediation Journal 2, 81–95.
- USEPA, 1986. Grouting Techniques in Bottom Sealing of Hazardous Waste Sites. (EPA/600/2-86/020).
- USEPA, 1997. Engineering Bulletin: Technology Alternatives for the Remediation of Soils Contaminated with As, Cd, Cr, Hg, and Pb. (EPA/540/S-97/500). August.

- USEPA, 2000. In-Situ Treatment of Soil and Groundwater Contaminated with Chromium, Technical Resource Guide. (EPA/625/R-00/005). October.
- USEPA, 2004b. In-Situ Thermal Treatment of Chlorinated Solvents: Fundamentals and Field Applications. (EPA/542/R-04/010). March
- USEPA, 2004c. DNAPL Remediation: Selected Projects Approaching Regulatory Closure. (EPA 542-R-04-016). December.
- USEPA, 2005. Perchlorate Treatment Technology Update, Federal Facilities Forum Issue Paper. (EPA/542/R-05/015). May.
- USEPA, 2009. DNAPL Remediation: Selected Projects Where Regulatory Closure Goals Have Been Achieved. (EPA 542/R-09/008). August.
- USEPA, 2012. Contaminated Site Clean-up Information Website. http://www.clu-in.org/.

According to USEPA guidance (USEPA 1988), technology types and process options are screened to retain implementable technologies that can be used in the development of remedial alternatives. During this initial screening step, process options are eliminated from further consideration on the basis of technical implementability (either as a stand-alone remedy or as a component of an overall remedial option). Readily available data concerning Site characteristics and chemical distributions are used to screen out technologies and process options that cannot be effectively implemented at the Site.

Because the Site covers a relatively large area, consists of variable geological features, and contains a number of different classes of contaminants, the relatively broad spectrum of technologies evaluated herein was required to fully evaluate technologies with potential applicability at the Site.

The results of the initial screening of remedial technologies and process options for the Site are summarized in Table 5-2. Table 5-2 lists GRAs, remedial technologies and process options that were considered during the initial screening process, descriptions of process options, and screening comments that support conclusions concerning the technical implementability of the various process options. Process options that were retained for secondary screening are shaded, while process options that were eliminated from further consideration are unshaded.

A total of 115 discrete process options were included in the initial screening matrix for the Site. Of these, 10 process options were eliminated from further consideration based on a lack of technical implementability, leaving 105 process options that were retained for further analysis.

5.3.3 Secondary Screening of Process Options

During this stage of the screening process, the process options that were retained within the initial screening process were further evaluated and screened on the basis of effectiveness, implementability, and relative cost.

5.3.3.1 Process Option Screening Criteria

As noted above, process options were screened in this step on the basis of effectiveness, implementability, and cost. These screening criteria are discussed below.

- **Effectiveness**: The effectiveness of process options that are considered to be technically implementable is evaluated relative to other processes within the same technology type. This evaluation focuses upon: (1) the potential effectiveness of process options in handling the estimated areas or volumes of media and meeting the remediation goals identified in the RAOs; (2) the potential impacts to human health and the environment during the construction and implementation phase; and (3) how proven and reliable the process is with respect to the contaminants and conditions at the Site.
- **Implementability**: Implementability encompasses both the technical and administrative feasibility of implementing a process option. Since technical implementability is used as a screening criterion during initial screening to eliminate technology types and process options, this secondary screening process places more emphasis on the institutional aspects of implementability such as the ability to obtain necessary permits, the availability of treatment, storage, and disposal facilities, and the availability of equipment and skilled workers necessary to implement the process option.
- **Cost:** At this early stage in the FS process, relative capital and operations and maintenance (O&M) costs are qualitatively compared using engineering judgment. Each process is evaluated as to whether costs are high, moderate, or low relative to other process options in the same technology type.

5.3.3.2 Preliminary Selection of Feasible Technologies

Results of secondary screening of process options on the basis of effectiveness, implementability, and cost are summarized in Table 5-3.

Of the 105 process options that were retained for further evaluation after the initial screening step, an additional 56 process options were screened out from further consideration in this step. A total of 49 process options were retained from the secondary screening process for remedial alternative development. A general summary of the process options retained for further analysis in the RI/FS is provided below.

No Further Action

This option is required under the NCP for comparison purposes. This option stipulates that no actions are to be taken beyond the previous and current interim removal actions described in Section 4 of this Work Plan, including the Interim Soil Removal Actions described in Sections 4.1 through 4.3, the historical and current groundwater removal actions described in Section 4.4 (i.e., the construction and operation of the GWETS), and the groundwater monitoring described in Section 4.5.

Management Options

Management options include those which limit exposures to COPCs through the use of institutional controls and other administrative instruments implemented at the Site. Examples of management options that have been retained for further evaluation include the following:

- Groundwater Use Restrictions
- Site Access Restrictions

- SMP to manage risk to Site occupants and workers by identifying remaining COPCs left in place and the appropriate risk management measures to follow when encountering/ disturbing media containing COPCs
- Legal Restrictions to Land Use
- Deed Restrictions

Monitoring Options

Monitoring options include those to limit exposures to COPCs through the methodic and routine observation, measurement, and/or sample collection/analysis of environmental media. Monitoring options are used to ensure that levels of COPCs do not exceed certain health or environmental standards and to alert site managers to changing conditions that may lead to such an exceedance in the future, so that preventative measures can be implemented. In the case of monitored natural attenuation, monitoring is used to measure the progress of natural processes to reduce the mass, mobility, and/or toxicity of COPCs. Examples of monitoring options that have been retained for further evaluation include the following:

- Groundwater Sampling and Monitoring
- Monitored Natural Attenuation of Groundwater

Source Control Options

Source control options include those which restrict or mitigate the transport of COPCs from sources areas to downgradient groundwater and off-site receptors. Contaminant discharge from sources can be reduced via containment and/or depletion. Some process options can perform both functions depending on how they are implemented, e.g., groundwater extraction. Examples of source control options employing a containment approach that have been retained for further evaluation include the following:

- Groundwater Extraction (including applicable ex-situ groundwater treatment options)
- Slurry Walls
- Single-Layer Synthetic Membrane Cap
- Multi-Layered Cap System
- Asphalt/Concrete Paving

Examples of source control options employing a source depletion approach that have been retained for further evaluation include the following:

- Groundwater Extraction (including applicable ex-situ groundwater treatment options)
- Soil Flushing
- In-Situ Chemical Reduction (ISCR)
- In-Situ Chemical Oxidation (ISCO)
- Soil Vapor Extraction (SVE) (including applicable ex-situ vapor treatment options)

- Dual-Phase Extraction (DPE) (including applicable ex-situ vapor and groundwater treatment options)
- Multi-Phase Extraction (MPE) (including applicable ex-situ vapor, groundwater, and DNAPL treatment options)
- Air Sparging (including applicable ex-situ vapor treatment options)
- In-Situ Well Stripping (including applicable ex-situ vapor treatment options)

Downgradient Plume Options

Downgradient plume options include those which restrict or mitigate the transport of off-site COPCs to further downgradient groundwater and off-site receptors. Ultimately, in keeping with the long-term RAOs, the downgradient plume options are those capable of also restoring off-site groundwater in the alluvial aquifer and UMCf to meet ARARs/TBCs. Examples of downgradient plume options that have been retained for further evaluation include the following:

- Groundwater Extraction (including applicable ex-situ groundwater treatment options)
- ISCR
- Enhanced Reductive Bioremediation – Mobile Amendments
- Enhanced Reductive Bioremediation – Fixed Biobarriers

In-Situ Process Enhancement Options

In-situ process enhancement options include those which can enhance the performance of the source control and downgradient plume options. These options can be employed within low-permeability formations to enhance either the yield of groundwater and/or vapor extraction process options or increase distribution of substrates or other subsurface amendments for enhancing the performance or longevity of in-situ biological/chemical options. Examples of in-situ process enhancement options that have been retained for further evaluation include the following:

- Pneumatic Fracturing
- Hydraulic Fracturing
- Funnel and Gate
- Directional Wells

Ex-Situ Groundwater Treatment

Ex-situ groundwater treatment options include those which can reduce the mass, mobility, and/or toxicity of COPCs in extracted groundwater from on-site and off-site groundwater extraction facilities. Examples of ex-situ groundwater treatment options that have been retained for further evaluation include the following:

- Air Stripping
- Liquid-Phase Carbon Adsorption Using Granular Activated Carbon (GAC)

- Chemical Oxidation
- Chemical Precipitation
- Coagulation/Flocculation
- IX Using Single-Use Resins
- Anaerobic FBRs
- Anaerobic Continuously-Stirred Tank Reactors (CSTRs)

Discharge Options

Discharge options include those allowing discharge of extracted groundwater. Examples of discharge options that have been retained for further evaluation include the following:

- Surface Water Discharge
- Sewer Discharge
- Water Reuse
- Subsurface Water Discharge

Ex-Situ Vapor/Air Emissions Treatment

Ex-Situ vapor/air emissions treatment options include those which remove COPCs from vapor or air emissions resulting from other process options. Examples of ex-situ vapor/air emissions options that have been retained for further evaluation include the following:

- Vapor Phase Carbon Adsorption
- Advanced Oxidation
- Catalytic Oxidation
- Thermal Oxidation
- Biofiltration

Following completion of site characterization, risk assessment, and treatability study tasks in the RI/FS, the above process options will be evaluated to determine their applicability in relevant regions of the Site. Following this evaluation, the process options will be assembled into several remedial alternatives for further evaluation in the FS.

5.3.4 Preliminary Remedial Action Alternatives

From the preliminary screening evaluation, a number of practicable remedial technologies and process options to address the COPCs in soil and groundwater at the Site were retained based on readily available Site information and professional experience. From this list of retained technologies and process options, the following preliminary remedial action alternatives (RAAs) were developed for further evaluation. ENVIRON notes that the RAAs presented here are not meant to be comprehensive and specific with respect to the retained process options to be evaluated in each. Rather, we have identified conceptual RAAs that would address the primary COPCs and RAOs identified for the Site. It is anticipated that numerous variations on each

conceptual RAA identified below will be included for analysis in the FS. As information is obtained in the RI to address data gaps, additional RAAs may be identified and included in future analyses.

The conceptual remedial alternatives developed from the preliminary screening include:

RAA-1 – No Further Action

The No Further Action alternative involves no remedial actions beyond the interim measures currently in place, and represents a baseline for comparison of the remaining remedial alternatives. The No Further Action alternative is not expected to meet RAOs defined for the Site.

RAA-2 – Enhancement of Groundwater Containment, Recovery, and Aboveground Treatment via Upgrades to the Existing GWETS

This alternative would include use of the existing GWETS as a primary component for both on-site containment of COPCs and for downgradient groundwater restoration. Enhancements to the existing GWETS would likely be required to meet RAOs and could include the installation of additional extraction wells to improve horizontal and vertical capture. Groundwater modeling would be used to optimize groundwater extraction using the new wells. Upgrades to the treatment system could be necessary to handle increased hydraulic and/or mass loading. Groundwater treatment process options and discharge options retained in the screening process described above would be considered for this purpose.

RAA-3 – Enhancement of Groundwater Containment, Recovery, and Aboveground Treatment via Upgrades to the Existing GWETS and On-site Source Control

This alternative would employ the same upgrades to the existing GWETS identified in RAA-2 and also examine the potential effectiveness of employing source control alternatives to mitigate the migration of COPCs from on-site vadose zone source area soils to groundwater. The methods of source control could include containment and/or source depletion options. Source control process options to be examined in the alternative would include capping, soil flushing, and in-situ treatment options. Soil flushing, which appears to be particularly promising as a source control option for perchlorate based on preliminary screening, is being designated for treatability/pilot testing in this Work Plan.

RAA-4 – Enhanced Groundwater Containment and Extraction at the IWF and AWF with In-Situ Treatment Downgradient of the AWF

This alternative would employ some of the same upgrades to the existing GWETS identified in RAA-2 or RAA-3 with the implementation of an in-situ treatment (e.g., enhanced bioremediation via a permeable reactive barrier) downgradient of the AWF. Depending on the demonstrated effectiveness of the in-situ treatment system, this alternative could ultimately include reducing (or eliminating) the operation of the SWF. Treatability/pilot testing of enhanced in-situ bioremediation is being proposed in this Work Plan.

5.4 Data Gaps

As discussed in Section 3, the Site has been the subject of numerous regulatory actions and environmental investigations since the early 1970s. The soil and groundwater investigations conducted through 2005 served as the basis of the first comprehensive CSM developed for the Site in 2005 by ENSR (ENSR 2005). Since then, additional investigations and interim removal actions (described in Section 4) have been conducted. For the RI/FS, additional areas have been identified that require investigation to determine the nature and extent of COPCs in groundwater and soil at the Site. Many of these areas were previously identified by NDEP as areas requiring further study.

5.4.1 Soil

Additional physical and chemical data are needed in both shallow and deep soil in four main areas as shown on Figure 5-5. The main focus of this soil investigation is to determine whether these areas serve as potential sources of COPCs in groundwater. The specific scope and data quality objectives (DQOs) for the additional soil investigation areas will be described in detail in the SAP, which will be submitted separately from this Work Plan. Conceptually, soil borings will be installed in the four areas shown in Figure 5-5 to a depth of first encountered groundwater. Soil samples will be collected continuously and analyzed for COPCs in groundwater. Soil samples will also be analyzed, at a minimum, for: redox potential, total organic carbon (TOC), pH, ferrous iron, ferric iron, chloride, nitrate, nitrite, pH, sulfide, sulfate, calcium, potassium, and sodium. In addition to a discussion of the nature and extent of soil investigation activities and DQOs for the areas of investigation, the SAP will include a Field Sampling Plan (FSP), Quality Assurance Project Plan (QAPP), and Health and Safety Plan (HASP).

The four main areas to be investigated and the general nature of the investigation in each area can be described as follows:

- **Pond AP-5.** Relatively high concentrations of perchlorate and chromium have been detected in groundwater in the AP-5 pond area. NDEP previously identified Pond AP-5 as a potential source of metals, hexavalent chromium, perchlorate, chlorate, and ammonium (NDEP 2011a). As discussed in Section 4.6.2, draining and removal of residual solids from the pond has been proposed to NDEP. Following draining and residual solids removal, approximately 6 to 8 soil borings are anticipated to be installed in area of the former Pond AP-5. The exact number and location of these borings will be identified in the SAP following analysis of DQOs and a field survey of the area to identify potential physical obstructions.
- **Debris pile**. Data are needed to evaluate the nature of the debris in the debris pile and the chemical and physical characteristics of the soil within and below the debris pile, as well as soil to the area south of the debris pile. NDEP has previously requested that this area be investigated during the RI. It is anticipated that three exploratory trenches will be constructed through the debris pile to observe the materials in the debris pile. Visual evidence of subsurface soil and debris along with field instrument readings will be used during exploratory trenching to track visual evidence of contamination from the debris in the waste pile. Up to 5 grab soil samples will be collected for analysis from each of the

exploratory trenches to determine if the materials in the debris pile are a source of COPCs at the Site. In addition, approximately 4 to 6 soil borings will be installed around the perimeter of the debris pile. The specific location of the exploratory trenches and the number of grab samples and the exact number and location of perimeter borings will be identified in the SAP following analysis of DQOs and a field survey of the area to identify potential physical obstructions.

- **Soil in the area between the debris pile and Pond AP-5**. Relatively high concentrations of perchlorate and chromium have been detected in groundwater in this area. Approximately 12 to 15 soil borings are anticipated to be installed in this area. The exact number and location of these borings will be identified in the SAP following analysis of DQOs and a field survey of the area to identify potential physical obstructions.
- **Area West of Pond Mn-1**. Relatively high concentrations of perchlorate, chromium and chloroform have been identified in groundwater in this area. Approximately 6 to 8 soil borings are anticipated to be installed in this area. The exact number and location of these borings will be identified in the SAP following analysis of DQOs and a field survey of the area to identify potential physical obstructions.

In addition, further characterization of Category 3 soils may be required to provide a sufficient data set for risk assessment.

5.4.2 Groundwater

The Site has been studied extensively; over 1,000 wells and borings have been drilled in and around the BMI complex to characterize subsurface conditions. Groundwater and surface water impacts have been monitored and evaluated, and removal actions have been implemented to mitigate chromium and perchlorate impacts.

As discussed in Section 2.5, lateral transport of shallow groundwater is primarily within paleochannels incised within the Muddy Creek Formation. In addition, infiltration of surface water from features such as the COH ponds in the Bird Viewing Preserve and Northern Rapid Infiltration Basins (RIBs) near the Las Vegas Wash affect groundwater flow in the northern portion of the downgradient plume. The May-June 2012 potentiometric surface map is shown along with the paleochannels and the pond locations on Figure 5-6. As can be seen on Figure 5-6, the on-site barrier wall/IWF, the off-site downgradient AWF, and the SWF adjacent to Las Vegas Wash operated by the Trust and the extraction well systems operated by OSSM and AMPAC are positioned across the paleochannel preferential flow pathways.

Perchlorate is the primary Site-related chemical detected in groundwater downgradient of the Site. Figure 5-7 presents the May-June 2012 perchlorate shallow groundwater isoconcentration contour map along with the paleochannels and locations of the on-site barrier wall/IWF, the off-site downgradient AWF, and the SWF adjacent to Las Vegas Wash. The May-June 2012 isoconcentration contour maps for total chromium and total dissolved solids are presented on Figures 5-8 and 5-9, respectively. The detailed maps showing the data for these schematic figures are presented on Plates 2 through 5.

The following data gaps for groundwater have been identified:

- **Background Determination.** As described in the 2005 CSM, although regional information is available, background concentrations of metals and other naturally occurring compounds of concern in soil and groundwater have not been determined for the localized area. This issue is being jointly evaluated by BMI complex members. An outline for a Background Study Work Plan was submitted to NDEP by Tronox in 2008 (Tronox 2008). For purposes of this RI/FS, naturally occurring compounds will be compared to upgradient concentrations in four wells located on the upgradient (southern) Site boundary. These include Shallow WBZ wells M-120 and M-121 (screened in UMCf-cg1) and Middle WBZ wells M-117 and M-118 (screened in UMCf-fg1). The alluvium is unsaturated at the upgradient Site boundary.
- **Chemicals of Potential Concern.** In Section 5.1.4.2, a preliminary list of groundwater COPCs is presented based on screening of groundwater data collected since 2006. ENVIRON is continuing to review the available groundwater data to determine whether any revisions to this list are necessary.
- **Middle Water-Bearing Zone/Muddy Creek Formation.** There are currently 23 on-site monitoring wells completed in the Middle WBZ. Three of these wells (MC-MW-18, MC-MW-39, MC-MW-42) are owned by Montrose and were installed to assess the extent of DNAPL originating at the OSSM property west of the Site. The DNAPL is a trespassing chemical and is discussed further below.

  At the Site, the soils within the Middle WBZ consist predominantly of the UMCf-fg1. The UMCf-cg2 occurs below the fine-grained unit at the base of the Middle WBZ. The top of the UMCf-cg2 unit varies depending on location; it has been encountered at depths ranging from 175 ft bgs to as deep as 272 ft bgs. The UMCf-cg2 unit has been defined below western portion of the Site by six deep wells (TR-1, TR-5, TR-7, TR-9, TR-11, TR-12) and below the northern portion of the Site by two deep wells (M-154 and M-155). The UMCf-cg2 unit is confined, as indicated by artesian groundwater elevations consistently measured in these wells. These eight wells were sampled for perchlorate and chromium in May 2012. Perchlorate was not detected (ND<0.254 µg/L) in any of the wells. Total chromium concentrations were all below the MCL of 100 µg/L; the detected chromium concentrations ranged from 13 to 48 µg/L. These results indicate that the UMCf-cg2 unit at the base of the Middle WBZ is not impacted by Site-related chemicals.

  Vertical Extent of Site-related Chemicals in the UMCf Fine-grained Unit — The vertical extent of Site-related chemicals in the UMCf-fg1 unit has been partially defined by recent deeper wells installed in the central portion of the Site and in the vicinity of the IWF. Installation of deeper wells to further delineate vertical extent is recommended at three Site locations to add one or more deeper wells to existing well clusters:

  - Adjacent to Middle WBZ monitoring well M-186 located on the eastern Site boundary.
  - Adjacent to Middle WBZ monitoring well M-161 located on the north-central side of the barrier wall and IWF.

- Adjacent to Middle WBZ monitoring well M-162 located on the north side of the barrier wall and IWF at its western end.

The recommended additional well locations are shown on Figure 5-10.

Additional Hydraulic Characterization – In order to better characterize hydraulic properties in the Middle WBZ UMCf fine-grained unit, slug tests will be conducted in all the existing and new Trust-owned wells completed in this unit. These data will be incorporated into the numerical model developed to assess remedial alternative extraction scenarios for Site groundwater. While the majority of groundwater flow and transport occurs in the shallow alluvial deposits, evaluation of flow rates and mass transport in the deeper Muddy Creek formation will be conducted as part of the FS assessment of the IWF effectiveness.

Evaluation of Vertical Head Differences – Previous investigations of the Middle WBZ at the Site and surrounding sites indicate, with a few exceptions, a vertically upward gradient between the Middle and Shallow Zones that generally increases with depth. Following installation of the recommended new Middle WBZ wells, the previous evaluations of vertical head differences will be updated with current data.

- **Trespassing Chemicals.** The Site is situated in between two other operating facilities that are part of the BMI complex. The Site is bordered by TIMET on the east and the Olin property on the west. All three facilities released wastewater into the former Beta Ditch for transport to former ponds in the BMI Common Area (see Figure 2-2 for the location of the former Beta Ditch). During the past decades of operation, chemicals released to groundwater at the individual facilities have become commingled, particularly in the areas near the property boundaries, below the unlined Beta Ditch, and in downgradient plume areas.

  At the Olin property, Montrose is conducting an investigation of DNAPL that has been detected in several wells completed in the Middle WBZ. As shown on Figure 5-10, DNAPL has also been found in well MC-MW-18 located on the Site. The DNAPL has been tested, and it contains several VOCs (primarily benzene, dichlorobenzenes, and chloroform), pesticides, and herbicides. The most recent phase of Montrose's investigation is an assessment of DNAPL mobility for recovery purposes.

  The Trust provides access to Montrose and its consultants for their ongoing monitoring and investigations. To further assess the extent of impact by dissolved VOCs from this adjacent site, VOCs will added to the Trust's groundwater sampling program as discussed in Section 5.4.2.1.

  Downgradient Plume – Lateral Extent. As a result of its high solubility, perchlorate is the primary Site-related chemical detected in groundwater downgradient of the Site. As illustrated on Figure 5-7, the lateral extent of the Site downgradient perchlorate plume is delineated by the 1 mg/L isoconcentration contour on its western side. As discussed in Section 3.2.4, perchlorate was also released to groundwater from the AMPAC facility located approximately 1.5 miles southwest of the Site. The downgradient AMPAC

perchlorate plume is located west of the Site-related downgradient plume. The AMPAC extraction and re-injection systems and the northern portion of the AMPAC perchlorate plume are shown on Figure 5-7. However, the separation between the two plumes is based on reasonable extrapolation of 1 mg/L contours. In order to confirm this interpretation, additional sampling will be conducted along Galleria Road east of the AWF. As shown on Figure 5-11, three existing wells (L637, L639, L641) are located along the road in this area. These wells will be evaluated for sampling. Assuming access can be obtained from the well owner, one additional new shallow well will be installed west of L645. If the three existing wells are not suitable for sampling, or if access cannot be obtained, 2-3 additional new shallow wells will be installed nearby. In addition, 2-3 new shallow monitoring wells will be installed along Sunset Road in the area between the Site-related downgradient plume and the AMPAC downgradient plume. The recommended well locations are shown on Figure 5-10.

The BMI Common Area pond complex, located to the east, appears to represent a separate and distinct source of perchlorate to shallow groundwater. As illustrated on Figure 5-12, perchlorate concentrations in wells located on the western portion of the BMI Common Areas property below former unlined ponds contain perchlorate at concentrations higher than 1 mg/L. The most recent data available in the BMI Complex database shows concentrations ranging from 3.6 to 9.6 mg/L in wells located east of Pabco Road. Based on this preliminary evaluation, separation between the Site downgradient plume and the BMI Common Area plume may need to be defined by a 5 or 10 mg/L contour. A more thorough evaluation of groundwater conditions and current data in wells along the east side of Pabco Road will be conducted during the RI.

- **Downgradient Plume – Vertical Extent.** The vertical extent of perchlorate in the Muddy Creek Formation beneath the AWF extraction wells has not been fully delineated. Existing wells PC-134A and PC-137 are screened in the UMCf. In May 2012, perchlorate concentrations were 32 mg/L in PC-134A and 0.27 mg/L in PC-137. Deeper monitoring wells will be installed adjacent to these two existing wells to define the vertical extent of perchlorate-impacted groundwater. The recommended well locations are shown on Figure 5-12.

The specific nature, extent and the DQOs for the elements of the additional groundwater investigation will be described in detail in the SAP.

5.4.2.1 Groundwater Analytical Program

As part of the ongoing groundwater monitoring program, groundwater samples from designated Site wells are analyzed for chlorate, chromium, hexavalent chromium, perchlorate, and TDS. It is proposed that for 2013, to address data gaps as part of the RI/FS, groundwater samples will be analyzed for the list of chemicals in presented in Section 5.1.4.2 identified as a preliminary list of groundwater COPCs that exceed USEPA MCLs, NDEP BCLs, or other criteria. The SAP will detail the proposed subset of wells and analytes and sampling frequency.

In addition, to gain a better understanding of Site geochemistry and the chemical partitioning between hexavalent chromium and total chromium in groundwater, groundwater samples will be

analyzed for: dissolved oxygen, redox potential, TOC, pH, alkalinity, ferrous iron, ferric iron, chloride, nitrate, nitrite, pH, sulfide, sulfate, calcium, potassium, and sodium. The SAP will present the details of the analytical program to be included following NDEP approval of this Work Plan.

5.4.2.2 Effectiveness of Extraction Well Fields

Recommendations to maximize efficiency of the IWF and AWF were provided in Appendix E of the *Annual Remedial Performance Report for Chromium and Perchlorate* (ENVIRON 2012c, under review by NDEP), which included as Appendix F of this RI/FS Work Plan. The recommended operational adjustments will serve as a first step in increasing the capture efficiency of these two well fields. Additional areas for evaluation may be identified following implementation of these recommendations.

6.0 Remedial Investigation/Feasibility Study Tasks

The following sections describe key tasks within the RI/FS framework identified in USEPA *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA* (USEPA 1988).

6.1 Task 1: Project Planning

The contents of this Work Plan and associated supporting documents – i.e., task-specific sampling and analysis plans, health and safety plans, and the Community Involvement Plan (CIP) (ENVIRON 2012a) – describe planning activities for the project. Activities under this task include:

- Collecting and evaluating available information on the Site, including information on historical operations, historical characterization data and analyses, regulatory actions, and removal actions completed to date (Sections 2.0 through 4.0);
- Developing a CSM on the basis of available information (Sections 5.1 and 5.2);
- Identifying data needs (data gaps are identified in Section 5.4, and DQOs will be developed in the SAP);
- Identifying ARARs (Section 5.2.1);
- Identifying preliminary RAOs (Section 5.2.2);
- Screening of preliminary remedial technologies and identifying potential remedial alternatives (Sections 5.3.2 and 5.3.4);
- Treatability studies (will be identified in the individual treatability study work plans);
- Identifying projection organization and project management (Section 7.1); and
- Developing schedules for completion of major project elements (Section 7.2).

All of these elements are included in this Work Plan and associated supporting documents (e.g., the SAP). Many elements are summaries of more comprehensive documents or identify the document in which the element is provided. Each of the summaries provided in this Work Plan reflects the current status of the respective tasks, with some tasks at the preliminary planning stage and others completed or nearing completion.

6.2 Task 2: Community Relations

Task 2 incorporates all efforts related to the preparation and implementation of the draft CIP (ENVIRON 2012a) that has been prepared for the Site and submitted to NDEP for review. The CIP was developed to guide the facilitation of communication between the community surrounding the Site with NDEP and the Trust and to encourage community involvement in Site activities. The CIP provides a Site description; a community profile and history of community involvement; information on community relations and community concerns; communication needs and strategies; lists of contacts and interested parties; and a description of activities the Trust is undertaking to ensure full public participation at the Site, as listed below. A previous CIP (ENSR 2007c) was implemented for the Site by Tronox, and NDEP has maintained a public website with various Site-related documents and related information since 2006. For the draft

2012 CIP, the Trust drew from multiple sources, including community input (through stakeholder calls and meetings; community interview meetings and questionnaires; and open communications with interested parties, such as local residents, business owners, schools, local industries, and municipal programs) and through reviews of public information and Site files to develop the plan. The major community involvement activities associated with this plan are identified below:

- Designate the Community Involvement Coordinator (CIC), the primary liaison between the community and the NDEP and the Trust. The CIC was designated in June 2012;
- Prepare and distribute fact sheets and technical summaries;
- Maintain a mailing list for the Site;
- Establish and maintain information repositories;
- Provide key resources for both general and specific information about the Site;
- Establish and maintain the Administrative Record;
- Hold public meetings or public availability sessions; and
- Revise the CIP as community input warrants or at least every three years until the Site is closed out.

The CIP is currently under review by NDEP. To date, information related to Site activities has been provided to the public through NDEP's *Remediation of the BMI Complex* website available at http://ndep.nv.gov/bmi/tronox.htm, fact sheets and technical summaries, public meetings, and briefings. The Trust will continue to use these public mechanisms to inform the public regarding activities at the Site. In addition, the public has access to documentation related to the RI/FS process for the Site at the NDEP office in Las Vegas, Nevada. Once the CIP is approved by NDEP, a local information repository will be established at the James I. Gibson Library on Lake Mead Parkway in Henderson, Nevada.

6.3 Task 3: Field Investigation

Task 3 involves field investigation activities to be undertaken during the RI phase to complete Site characterization activities (i.e., to address data gaps) and ensure that adequate data is available to conduct the BHRA and support the development and evaluation of remedial alternatives. As presented in Section 5.4, the following data gaps are to be addressed during field investigation activities:

- Additional characterization of shallow and deep soils to determine whether these areas serve as potential sources of COPCs in groundwater;
- Additional characterization of Category 3 soils, as needed, to provide a sufficient data set for risk assessment;
- Characterization of the Debris Pile (Category 4 area)
- Additional characterization of groundwater, to include (1) a background determination, (2) identification of groundwater COPCs, (3) further investigation of the Middle WBZ/Muddy Creek formation, (4) further investigation of trespassing chemicals from neighboring

properties, and (5) further investigation of the lateral and vertical extent of the downgradient plume.

Additional data gaps may be identified following further review and evaluation of existing data and data collected as part of the RI.

A SAP will be developed to address the data gaps. Upon NDEP approval of the SAP, subcontractors will be mobilized for field investigations. The following typical activities are anticipated to be conducted as part of Task 3:

- Mobilization of field activities;
- Exploratory trenching;
- Grab soil sampling;
- Soil boring installation and sampling;
- Well Installation, development and sampling;
- Laboratory analysis of soil and groundwater samples;
- Aquifer testing;
- Field measurements;
- Site surveys; and
- Task management and quality control.

All field investigations will be conducted in accordance with the HASP and the QAPP that are being developed as part of the SAP for the Site. The QAPP describes the quality assurance procedures, quality control specifications, and other technical activities that must be implemented to ensure that the results of a project or task performed during the RI/FS process will meet project specifications.

6.4 Task 4: Sample Analysis and Data Verification and Validation

Under Task 4, samples collected during the field investigations will be reviewed in accordance with the DQOs established for the specific field activity. Data validation will be conducted in accordance with NDEP's *Supplemental Guidance on Data Validation* (NDEP 2009d*)* and *Guidance on Validation for Asbestos Data in Soils for the BMI Plant Sites and Common Areas Projects* (NDEP 2012d). Electronic data deliverables (EDDs) will be prepared in accordance with the NDEP's *Guidance* on *Unified Chemical Electronic Data Deliverable Format* (NDEP 2012c).

6.5 Task 5: Data Evaluation

The data evaluation task includes the data usability evaluation, data analysis, and the data quality assessment. USEPA states in its *Data Usability Guidance* (USEPA 1992a) that "data usability is the process of assuring or determining that the quality of data generated meets the intended use," and that when risk assessment is the intended use, USEPA's guidance "provide[s] direction for planning and assessing analytical data collection activities for the

HRA…" The analytical data set identified for the BHRA will be evaluated using the six USEPA data usability criteria, as modified by NDEP (2010c).

As described by NDEP (2010c), the purpose of the data analysis step is to "use simple exploratory data analysis to compare data to the expectations of the CSM, to determine if the data adequately represent the source terms and exposure areas or evaluation areas." Consistent with guidance, summary statistics, simple data plots, and spatial plots of the data will be included in the BHRA.

Finally, the data quality assessment is conducted following completion of the risk assessment to evaluate whether the data meet the desired DQOs.

The data usability evaluation, data analysis, and the data quality assessment will be completed consistent with the following guidance documents from USEPA:

- *Data Usability Guidance* (USEPA 1992a).
- *Guidance for Data Usability in Risk Assessment (Parts A and B)* (USEPA 1992a,b),

and NDEP:

- *Guidance on the Development of Summary Statistic Tables at the BMI Complex and Common Areas in Henderson, Nevada* (NDEP 2008e).
- *Significance Levels for The Gilbert Toolbox of Background Comparison Tests for the BMI Plant Sites and Common Areas Projects* (NDEP 2009g).
- *NDEP Supplemental Guidance for Assessing Data Usability for Environmental Investigations at the BMI Facility in Henderson, NV* (*NDEP* 2010c).

Other NDEP guidances, available on NDEP's Technical Topics web site,[25] will be consulted, as appropriate to the intended use of the data, including NDEP's guidance for data processing (NDEP 2008c,d, 2012e) and evaluating radionuclide data (NDEP 2007, 2008g, 2009e,f).

6.6 Task 6: Risk Assessment

Task 6 includes activities related to the performance of the BHRA for the Site. The BHRA will evaluate the potential for adverse human health effects associated with exposures to impacted environmental media under current and anticipated future land-use conditions. For the evaluation of potential risks associated with current Site conditions, the BHRA will take into consideration all removal actions completed at the time the BHRA is prepared. The results of the BHRA will be used to support activities related to the screening of remedial alternatives and development of cleanup goals for impacted media. The elements of the BHRA report include (1) data evaluation (as described under Task 5, above); (2) identification of Site COPCs; (3) exposure assessment, including fate and transport modeling, as appropriate; (4) toxicity assessment; and (5) risk characterization. Uncertainties associated with the risk characterization will be discussed.

[25] http://ndep.nv.gov/bmi/technical.htm

6.7 Task 7: Treatability Studies

Under Task 7, information needs are identified and studies conducted to support the further development of the preliminary remedial action alternatives for evaluation during the RI/FS process. Treatability studies can provide data important to an adequate evaluation of certain technologies for a given response action – including information on performance, operating parameters, and cost – in sufficient detail to support the remedy selection process and subsequent design activities. This task can involve efforts for bench-scale or pilot-scale tests, including associated procurement activities. Treatability studies can be identified at different times during the RI/FS (e.g., from the scoping stage through the screening of preliminary alternatives).

Work plans for the following proposed treatability studies are included as appendices to this Work Plan:

- PRB Treatability Study Work Plan; and
- In-Situ Soil Flushing Treatability Study Work Plan.

Additional treatability studies may be identified as further information is developed during the RI.

6.8 Task 8: Remedial Investigation Report

Task 8 includes all activities undertaken to prepare and complete the RI report for the Site. This report will include the following:

- A comprehensive description of the area that comprises the Site;
- A brief Site history and discussion of the origin of contamination to provide rationale for the characterization activities completed;
- Summaries of field investigations and relevant Site characterization data, including historical data used to support the CSM and evaluation of remedial alternatives;
- A synthesis of previous groundwater investigations that will also incorporate the results of additional work conducted for the RI. As has been discussed previously, the Shallow WBZ has been well characterized, particularly with respect to the distribution of chromium, TDS, and perchlorate. However, additional evaluation of the lateral extent of the downgradient perchlorate plume will be conducted during the RI. The RI report will also present an evaluation of the presence and extent of other Site-related COPCs identified for groundwater. The RI report will include an evaluation of the nature and extent of COPC impacts to groundwater in the Middle WBZ, both from Site-related COPCs and trespassing chemicals. Existing and new information on aquifer properties will be compiled that will include estimates of groundwater gradient, flow velocities, and an evaluation of vertical head differences at well cluster locations.
- An updated CSM for the Site, revised to incorporate additional information obtained through the RI process;
- A summary of the BHRA performed for the Site. A separate report will be prepared to present the analysis and results of the BHRA based on the updated CSM.

The existing groundwater model, currently being reviewed by NDEP, was developed to evaluate the capture zones of the existing GWETS. Once the model is approved by NDEP, it will be used to help optimize the effectiveness of the GWETS. During the RI, the existing groundwater model will be updated based on new data collected. The model will also be revised so that it can be used to evaluate the broad range of remedial alternatives that will be considered in the FS.

6.9 Task 9: Remedial Alternatives Development

Task 9 involves the initial development and preliminary screening of remedial alternatives; the preliminary alternatives are then fully evaluated under Task 10. The objective of the screening process is to narrow the number of alternatives that undergo detailed evaluation. The screening process begins with identification of RAOs, then proceeds through narrowing of the potential technologies on the basis of applicability and effectiveness, and ends with the identification of a set of remedial action alternatives. Each remedial action alternative may involve application of a single technology or a combination of two or more technologies. Task 9 consists of the following activities:

- Identifying RAOs and ARARs (Section 5.2);
- Listing potential remedial technologies (Section 5.3);
- Screening remedial technologies and process options based on Site-specific criteria (initial screening performed in Section 5.3);
- Assembling potential remedial action alternatives from the screened technologies and process options;
- Evaluating potential remedial action alternatives on the basis of screening criteria (i.e., effectiveness, implementability, and cost); and

Identifying candidate remedial action alternatives for detailed evaluation is described under Task 10.

6.10 Task 10: Detailed Analysis of Alternatives

Under Task 10, the candidate remedial action alternatives that passed the screening process in Task 9 will be evaluated in detail. The following criteria, identified in USEPA guidance (USEPA 1988), will be used for evaluating the alternatives:

- Overall protection of human health and the environment;
- Compliance with ARARs;
- Long-term effectiveness and permanence;
- Reduction of toxicity, mobility, and volume;
- Short-term effectiveness;
- Implementability;
- Cost;

- Acceptance by the state; and
- Acceptance by the community.

A summary of each alternative, including the no-action alternative, will be prepared on the basis of these nine criteria, consistent with the NCP. The revised groundwater model will be used as appropriate to quantitatively evaluate the effectiveness of the alternatives.

6.11 Task 11: Feasibility Study Report

Task 11 involves the coordination and preparation of the FS report. The report will contain descriptions of the activities, results, and associated conclusions of the entire RI/FS process. The report will include a description of the screening process and a detailed evaluation of remedial action alternatives (from Tasks 9 and 10). A remedial action alternative will be recommended for implementation.

7.0 Project Schedule and Project Management

The following sections present the schedule for the RI/FS project tasks and outline the project organization and responsibilities.

7.1 Project Organization and Responsibilities

Mr. Weiquan Dong, PE is the NDEP Project Manager for the Site and handles all Site-related correspondence. Ms. Shannon Harbour, PE, previously the Project Manager for the Site, has responsibility for overall supervision of all projects in the NDEP Bureau of Corrective Actions Special Projects Branch. All Site characterization activities and remedial actions carried out by the Trust for the Site are subject to NDEP oversight under the Settlement Agreement, effective February 14, 2011.

The responsibilities of the two major organizations under contract to the Trust are as follows:

- ENVIRON
  - Provide overall project management support for the Trust's remediation of the Site. This support includes implementation and documentation of activities related to health and safety requirements, cost control procedures, sample and data management, and project schedule tracking.
  - Administer procurement and quality assurance functions.
  - Perform general administrative functions.
  - Assist with maintaining compliance with environmental permits and regulations.
  - Direct all engineering activities.
  - Provide technical input to the preparation of environmental documents.
  - Perform community relations duties.
- Veolia Water North America – West, LLC
  - Operate the groundwater treatment facilities as described in Section 2.2.

The ENVIRON project manager and task leaders working on this project include:

- Project Manager, **Allan J. DeLorme, PE** – The Project Manager is responsible for the overall technical and policy decisions involving the project, including interaction and coordination with ENVIRON project staff, the GWETS operator, the Trust, and NDEP.
- Task Leader, **John M. Pekala, PG, CEM** – This Task Leader is responsible for the overall development and implementation of ENVIRON's remediation strategy as approved by NDEP.
- Task Leader, **Jessica E. Donovan, PG** – This Task Leader is responsible for the overall execution of the approved Work Plan. She will work with the Project Manager and Quality Assurance (QA) Officer to ensure that work is conducted in compliance with project-specific objectives and applicable QA procedures.

- Task Leader, **Lynne Haroun, MPH** – This Task Leader is responsible for executing the health risk assessment components of the approved Work Plan. She will work with the Project Manager and QA Officer to ensure that work is conducted in compliance with project-specific objectives and applicable QA procedures.
- Project (QA) Officer, **John M. Pekala, PG, CEM –** The QA Officer is responsible for reviewing the project QA program as it relates to the collection and completeness of data from field and laboratory programs.
- Data Manager, **Craig J. Knox** – The data manager is responsible for management of the applicable databases, including updating and maintaining the databases as needed.

7.2 Project Schedule

The overall schedule for the RI/FS process at the Site is shown on Figure 7-1. The schedule identifies the primary RI/FS tasks, beginning with the submittal of this Work Plan and continuing through preparation and NDEP approval of the Site RI and FS reports. The projected durations of each task are provided, as well as the relationships between the various tasks.

The following major elements of the RI/FS process are identified in the schedule:

- NDEP review and approval of this RI/FS Work Plan, including two treatability study work plans, which would complete the initial scoping and planning phase of the RI/FS process.
- Preparation of a SAP to address data gaps, to include the HASP and QAPP.
- Preparation of a BHRA work plan.
- NDEP review and approval of the SAP, QAPP, HASP, BHRA work plan, and CIP.
- Implementation of the CIP.
- Implementation of additional field investigation activities to address the data gaps and the fieldwork outlined in the SAP.
- Preparation of the BHRA.
- Implementation of the treatability studies.
- Preparation and submittal of treatability study reports.
- Preparation of the RI report.
- Preparation of the FS report.
- NDEP review and approval of the treatability study, RI, and FS reports.

All listed documents include document submittal to NDEP for review, document revisions to address NDEP comments, and final NDEP approval. Figure 7-1 provides the anticipated RI/FS schedule based on currently available information and is subject to revision based on NDEP comments on work plans, contractor availability, and other factors.

8.0 References

AECOM, Inc. (AECOM), 2008. Revised Phase B Site Investigation Work Plan for Areas I, II, III and IV, Tronox LLC Facility, Henderson, Nevada, December. NDEP approved Response to Comments (dated January 16, 2009) January 16, 2009.

AECOM and Northgate Environmental Management, Inc. (AECOM-Northgate), 2009. Revised Phase B Quality Assurance Project Plan, Tronox LLC Facility, Henderson, Nevada, Revision, July. NDEP approved January 16, 2009.

Basic Environmental Company (BEC), 2007a. Phase 2 Sampling and Analysis Plan to Conduct Soil Characterization, Tronox Parcels "A" and "B" Site, Henderson, Nevada (Revision 1). August 14. NDEP approved August 24, 2007.

BEC, 2007b. Phase 2 Sampling and Analysis Plan to Conduct Soil Characterization, Tronox Parcels "C" and “D” Site, Henderson, Nevada. September 19. NDEP approved October 29, 2007.

BEC, 2007c. Phase 2 Sampling and Analysis Plan to Conduct Soil Characterization, Tronox Parcel "F" Site, Henderson, Nevada. September 19. NDEP approved October 9, 2007.

BEC, 2007d. Phase 2 Sampling and Analysis Plan to Conduct Soil Characterization, Tronox Parcel "G" Site, Henderson, Nevada. September 27. NDEP approved October 29, 2007.

BEC, 2007e. Phase 2 Sampling and Analysis Plan to Conduct Soil Characterization, Tronox Parcel "H" Site, Henderson, Nevada. December 12. NDEP approved December 17, 2007.

BEC, 2007f. Phase 2 Sampling and Analysis Plan to Conduct Soil Characterization, Tronox Parcel "H" Site and Errata Pages for Phase 2 Sampling and Analysis Plans to Conduct Soil Characterization, Tronox Parcels "C", "D" and "F" Sites, Henderson, Nevada. November 8. NDEP approved November 20, 2007.

BEC, 2007g. Technical Memorandum — Data Review for 2007 Tronox Parcels A/B Investigation, BMI Industrial Complex, Clark County, Nevada. December 6. NDEP found NFA January 17, 2008.

BEC, 2007h. Asbestos Data Review for 2007 Tronox Parcels A/B Investigation, BMI Industrial Complex, Clark County, Nevada. December 17. NDEP found NFA January 17, 2008.

BEC, 2007i. Uranium Isotope Data Review for 2007 Tronox Parcels A/B Investigation, BMI Industrial Complex, Clark County, Nevada. December 18. NDEP found NFA January 17, 2008.

BEC, 2008a. Sampling and Analysis Plan to Conduct Supplemental Soil Characterization, Tronox Parcels "C", "D", "F", "G", and "H", Henderson, Nevada, Dated May 28, 2008. June 5. NDEP approved June 5, 2008.

BEC, 2008b. Removal Action Workplan for Soil, Tronox Parcels “C”, “D”, “F”, “G” and “H” Sites, Henderson Nevada. July 1. NDEP approved July 2, 2008.

BRC, 2007. BRC Closure Plan, BMI Common Areas, Clark County, Nevada. May. NDEP conditionally approved July 16, 2007.

BRC and Titanium Metals Corporation (BRC/TIMET), 2007. Background Shallow Soil Summary Report, BMI Complex and Common Areas Vicinity. March 16.

Broadbent & Associates, Inc. (Broadbent), 2011. Quarterly Status Report for the 1st Quarter of 2011. Titanium Metals Corporation, Henderson, Nevada Facility, Facility ID #H000537. April 15.

Department of Toxic Substances Control (DTSC). 2004. Perchlorate Contamination Treatment Alternatives. January.

Evanko, C.R. and Dzombak, D.A. 1997. Technology Evaluation Report TE-97-01: Remediation of Metals-Contaminated Soils and Groundwater. Ground-Water Remediation Technologies Analysis Center (GWRTAC). October.

Federal Remediation Technology Roundtable (FRTR). 2012. www.frtr.gov.

ENSR Corporation (ENSR), 1997. Kerr-McGee Chemical Corporation, Phase II Environmental Conditions Assessment Located at Kerr-McGee Chemical Corporation, Henderson, Nevada. NDEP approved June 10, 1998.

ENSR, 2001. Supplemental Phase II Environmental Conditions Assessment. April 2001.

ENSR, 2005. Conceptual Site Model, Kerr-McGee Facility, Henderson, Nevada. February. NDEP requested response to comments during the next monthly meeting October 22, 2005.

ENSR, 2006a. Upgradient Investigation Results, Tronox Facility, Henderson, Nevada. October. NDEP commented March 23, 2007.

ENSR, 2006b. Phase A Source Area Investigation Work Plan, Tronox LLC Facility, Henderson, Nevada. September. NDEP conditionally approved October 26, 2006.

ENSR, 2007a. Phase A Source Area Investigation Results Report, Tronox LLC Facility, Henderson, Nevada. September. NDEP approved November 30, 2007.

ENSR, 2007b. Addendum to the Phase A Source Area Investigation Work Plan, Tronox LLC Facility, Henderson, Nevada. May. NDEP approved May, 2007 per email from Keith Bailey May 7, 2007.

ENSR, 2007c. Community Involvement Plan for Tronox LLC, Henderson, Nevada. August 28. NDEP. NDEP approved September 18, 2007.

ENSR, 2007d. Upgradient Investigation Results, Tronox Facility, Henderson, Nevada. September.

ENSR, 2008a. Phase B Source Area Investigation Work Plan, Area I (Northern LOUs), Tronox LLC Facility, Henderson, Nevada. April. NDEP conditionally approved May 6, 2008.

ENSR, 2008b. Phase B Source Area Investigation Work Plan, Area II (Central LOUs), Tronox LLC Facility, Henderson, Nevada. May. NDEP conditionally approved July 21, 2008.

ENSR, 2008c. Phase B Source Area Investigation Work Plan, Area III (Eastern LOUs), Tronox LLC Facility, Henderson, Nevada. June. NDEP conditionally approved July 21, 2008.

ENSR, 2008d. Phase B Source Area Investigation Work Plan, Area IV (Western and Southern LOUs), Tronox LLC Facility, Henderson, Nevada. May. NDEP conditionally approved June 18, 2008.

ENSR, 2008e. Phase B Source Area Investigation, Soil Gas Survey Work Plan, Tronox LLC Facility, Henderson, Nevada. March. NDEP approved March 26, 2008.

ENSR, 2008f. Revised Data Validation Summary Report Phase B Source Area Investigation Soil Gas Survey - Tronox LLC Facility Henderson, Nevada. October. NDEP approved October 20, 2008.

ENVIRON International Corporation (ENVIRON), 2011a. Workplan for Evaluation of Discolored Soil and Confirmation Soil Sampling in Visually-Impacted Areas. April 18. NDEP approved May 12, 2011.

ENVIRON, 2011b. Phase I Environmental Site Assessment of Tronox LLC, Clark County, Nevada. January.

ENVIRON, 2011c. Semi-Annual Remedial Performance Report for Chromium and Perchlorate, Nevada Environmental Response Trust Site, Henderson, Nevada, July 2011 – December 2011. February 29. Submitted to NDEP for review.

ENVIRON, 2012a. Draft Community Involvement Plan, Nevada Environmental Response Trust Site, Henderson, Nevada. April 30. Submitted to NDEP for review.

ENVIRON, 2012b. Interim Soil Removal Action Completion Report, Nevada Environmental Response Trust Site, Henderson, Nevada, August 2010 – November 2011. January. Revised September 28. Submitted to NDEP for review.

ENVIRON, 2012c. Annual Remedial Performance Report for Chromium and Perchlorate, Nevada Environmental Response Trust Site, Henderson, Nevada, July 2011 - June 2012. August 31. Submitted to NDEP for review.

ENVIRON, 2012d. Draft Soil Gas Investigation Work Plan for Parcels C, D, F, G and H, Nevada Environmental Response Trust Site, Henderson, Nevada. October. Submitted to NDEP for review.

ENVIRON, 2012e. Letter from Allan J. DeLorme, ENVIRON, to Shannon Harbour, NDEP, regarding Scope of Work for Response to NDEP Comments on the May 18, 2012 Sale Parcels Risk Assessment, Nevada Environmental Response Trust Site, Henderson, NV, September 11. NDEP approved September 19, 2012.

ENVIRON, 2012f. Site Management Plan (SMP) Nevada Environmental Response Trust Site, Clark County, Nevada. May 30. NDEP approved June 1, 2012.

ENVIRON, 2012g. Baseline Health Risk Assessment Work Plan. *In preparation*.

ENVIRON, 2012h. AP-5 Pond Solids Characterization and Disposal Work Plan, Nevada Environmental Response Trust Site, Henderson, Nevada. September 28. Submitted to NDEP for review.

ENVIRON, 2013. Sampling and Analysis Plan. *In preparation.*

ERM-West, Inc. (ERM-West), 2008a. Data Validation Summary Report, Tronox Parcels C, D, F, and G Investigation, November 2007, BMI Industrial Complex, Clark County, Nevada. February. NDEP approved April 3, 2008.

ERM-West, 2008b. Data Validation Summary Report, Tronox Parcel H Investigation, January 2008, BMI Industrial Complex, Clark County, Nevada. April. NDEP approved May 5, 2008.

ERM-West, 2009. Data Validation Summary Report, Tronox Parcels C, D, F, G and H Supplemental Investigations-June-July 2008, BMI Industrial Complex, Clark County, Nevada. January 2009. NDEP approved July 28, 2010.

Errol Montgomery & Associates, 2000. Analysis of Rate of Groundwater Movement Based on Results of Tracer and Hydraulic Tests Conducted Between Pittman Lateral and Seep Area.

Federal Remediation Technology Roundtable (FRTR). 2012. www.frtr.gov.

Hargis & Associates (H+A), 2008. Conceptual Site Model, Former Montrose and Stauffer Facilities and Downgradient Areas to Las Vegas Wash, Henderson, Clark County, Nevada. July.

H+A, 2011. Comprehensive Groundwater Data Evaluation Report, Former Montrose and Stauffer Facilities and Current Olin Facility, Henderson, Nevada. August 18.

Integral Consulting Inc. (Integral), 2009. Draft Risk Assessment Work Plan, Former Montrose and Stauffer Facilities, Henderson, Nevada. May.

ITRC (Interstate Technology & Regulatory Council). 2000. Technology Overview: Dense Non-Aqueous Phase Liquids (DNAPLs): Review of Emerging Characterization and Remediation. Interstate Technology & Regulatory Council. June.

ITRC, 2007. Remediation Technologies for Perchlorate Contamination in Water and Soil. PERC-2. Interstate Technology & Regulatory Council, Perchlorate Team. www.itrcweb.org.

Johnson and Ettinger, 1991. Model for Subsurface Vapor Intrusion into Buildings.

Kerr-McGee Chemical Corporation (KMCC), 1985. Hydrogeological Investigation, Kerr-Mcgee Chemical Corporation Henderson Facility. July. NDEP commented February 26, 1986.

KMCC, 1997. Phase II Work Plan. April. NDEP approved February 4, 1997.

KMCC, 1998a. Perchlorate Characterization Project: Historical Review Report/ Sampling Plan. January 16. NDEP commented on March 5, 1998.

KMCC, 1998b. Phase II Groundwater Perchlorate Investigation Report. July 15.

KMCC, 1998c. Preliminary Report on a Hydrologic Investigation of Channel-Fill Alluvium at the Pittman Lateral, Henderson, Nevada. October 19.

KMCC, 1998d. Response to Phase II Report Comments and Supplemental Phase II Work Plan. November 9. NDEP approved December 17, 1998.

KMCC, 2000. Work Plan for Seep Area Groundwater Characterization. March.

KMCC, 2001. Seep Area Groundwater Characterization Report, Kerr-McGee Chemical LLC, Henderson, Nevada. January 18.

KMCC, 2005. Kerr-McGee Henderson Source Area, Workplan Conceptual Approach. September 30. NDEP commented October 3, 2005.

Kleinfelder, 1993. Environmental Conditions Assessment, Kerr-McGee Chemical Corporation, Henderson, Nevada. April.

Las Vegas Water District, 2012. Perchlorate. http://www.lvvwd.com/wq/facts_perchlorate.html.

LAW Engineering, 1993. Final Report of Phase I Environmental Conditions Assessment, Volume 1: Text, Titanium Metals Corporation (TIMET), Henderson, Nevada. April 15.

National Oil and Hazardous Substances Pollution Contingency Plan (NCP). 1990. 55 FR 8666. March 8. (Codified at 40 CFR 300.1-300.920).

Nevada Division of Environmental Protection (NDEP), 1986. Consent Order between NDEP and Kerr-McGee. September 9.

NDEP, 1991. Consent Agreement, Phase I Environmental Conditions Assessment. April 25.

NDEP, 1994. Phase II Letter of Understanding between NDEP and Kerr-McGee. August 15.

NDEP, 1996. Consent Agreement, Phase II Environmental Conditions Investigation. August 1.

NDEP, 1999. Consent Agreement between NDEP and Kerr-McGee. July 26.

NDEP, 2001. Administrative Order on Consent between NDEP and Kerr-McGee. October 8.

NDEP, 2004. NDEP Response to: Supplemental Phase II Report – Environmental Conditions Assessment. February 11.

NDEP, 2005. Administrative Order on Consent between NDEP and Kerr-McGee. April 12.

NDEP, 2007. Advisement Regarding Radionuclide Analyses for Uranium, BMI Plant Sites and Common Areas Projects, Henderson, Nevada. December 7.

NDEP, 2008a. Meeting Minutes, Tronox Conference Call. March 27.

NDEP, 2008b. NDEP Response (Part 1) to: Technical Memorandum Data Review for.2007 Tronox Parcels A/B Investigation Dated December 6, 2007 And Asbestos Data Review for 2007 Tronox A/B Investigation dated December 17, 2007 And Uranium Isotope Data Review for 2007 Tronox A/B Investigation dated December 18, 2007 And Asbestos Data Review for

2007 Tronox A/B Investigation Dated January 9, 2008 And Supplemental information provided via electronic mail various dates. January 17.

NDEP, 2008c. Statistical Analysis Recommendations for Field Duplicates and Field Splits, BMI Plant Sites and Common Areas Projects, Henderson, Nevada. November 14.

NDEP, 2008d. Detection Limits and Data Reporting, BMI Plant Sites and Common Areas Projects, Henderson, Nevada. December 3.

NDEP, 2008e. Guidance on the Development of Summary Statistics Tables, BMI Plant Sites and Common Areas Projects, Henderson, Nevada. December 10.

NDEP, 2008f. Nevada Division of Environmental Protection Response to: *Technical Memorandum – Data Review for 2007 Tronox Parcels A/B Investigation.* April 8.

NDEP, 2008g. Advisement Regarding Radionuclide Analyses, BMI Plant Sites and Common Areas Projects, Henderson, Nevada. January 29.

NDEP, 2009a. BMI Plant Sites and Common Areas Project, Henderson, Nevada: Hydrogeologic and Lithologic Nomenclature Unification. January 6.

NDEP, 2009b. Finding of Alleged Violation and Order. December 14.

NDEP, 2009c. Supplemental Guidance on Data Validation, BMI Plant Sites and Common Areas Projects, Henderson, Nevada. March 19.

NDEP, 2009d. Supplemental Guidance on Data Validation, BMI Plant Sites and Common Areas Projects, Henderson, Nevada. April 13.

NDEP, 2009e. Guidance for Evaluating Radionuclide Data, BMI Plant Sites and Common Areas Projects, Henderson, Nevada. February 6.

NDEP, 2009f. Guidance for Evaluating Secular Equilibrium at the BMI Complex and Common Areas, BMI Plant Sites and Common Areas Projects, Henderson, Nevada. February 6.

NDEP, 2009g. Significance Levels for The Gilbert Toolbox of Background Comparison Tests for the BMI Plant Sites and Common Areas Projects, BMI Plant Sites and Common Areas Projects, Henderson, Nevada. July 9.

NDEP, 2009h. Cation-Anion Balance – Updated Guidance, BMI Plant Sites and Common Areas Projects, Henderson, Nevada. September 28.

NDEP, 2010a. Letter to Tronox LLC re: TRX Sale Parcels A through K, Tronox LLC. January 7.

NDEP, 2010b. Tronox (TRX) Project Meeting Minutes. September 7.

NDEP, 2010c. Supplemental Guidance for Assessing Data Usability for Environmental Investigations at the BMI Complex and Common Areas in Henderson, Nevada. September 1.

NDEP, 2010d. NDEP Response to: Results of Bioaccessibility Study for Dioxin/Furans in Soil, Tronox LLC, Henderson, Nevada (Revised) Dated: May 24, 2010. May 25.

NDEP, 2011a. Action Memorandum: Removal Actions, Nevada Environmental Response Trust Site, Clark County, Nevada. July 21.

NDEP, 2011b. Technical Guidance for the Calculation of Asbestos Related Risk in Soils for the Basic Management Incorporated (BMI) Complex and Common Areas, February 2011, BMI Plant Sites and Common Areas Projects, Henderson, Nevada. March 22.

NDEP, 2011c. Defining a Perchlorate Drinking Water Standard. http://ndep.nv.gov/bca/perchlorate02_05.htm

NDEP, 2012a. NDEP Response to: Revised Closure and Post-Remediation Screening Health Risk Assessment Report for Parcels C, D, F, G, and H, Nevada Environmental Response Trust Site, Henderson, Nevada, Dated: May 18, 2012. August 7.

NDEP, 2012b. User's Guide and Background Technical Document for the Nevada Division of Environmental Protection (NDEP), Basic Comparison Levels (BCLs) for Human Health for the BMI Complex and Common Areas, Revision 8. May.

NDEP, 2012c. Guidance on Unified Chemical Electronic Data Deliverable Format, BMI Plant Sites and Common Areas Projects, Henderson, Nevada. March 5.

NDEP, 2012d. Guidance on Validation for Asbestos Data in Soils, BMI Plant Sites and Common Areas Projects, Henderson, Nevada. July 24.

NDEP, 2012e. Revised Guidance on Qualifying Data due to Blank Contamination for the BMI Complex and Common Areas, BMI Plant Sites and Common Areas Projects, Henderson, Nevada. January 5.

NDEP, 2012f. NDEP Response to: Appendix B (Data Validation Summary Reports) of Revised Closure and Post-Remediation Screening Health Risk Assessment Report for Parcels C, D, F, G, and H, Nevada Environmental Response Trust Site, Henderson, Nevada, Dated: May 18, 2012. August 10.

Neptune and Company, 2010. Revised Data Validation Summary Report for Shallow Supplemental Soil Sampling in Areas I and II. July 21. NDEP approved July 28, 2010.

Northgate, 2009. Interim Groundwater Capture Evaluation and Vertical Delineation Report, Tronox LLC, Henderson, Nevada. December 29. NDEP provided comments January 26, 2010. Submitted to NDEP for review.

Northgate, 2010a. Annual Remedial Performance Report for Chromium and Perchlorate, Tronox LLC, Henderson, Nevada, July 2009-June 2010. August 27.

Northgate, 2010b. Capture Zone Evaluation Work Plan, Tronox LLC, Henderson, Nevada. May 13. NDEP approved May 24, 2010.

Northgate, 2010c. Revised Data Validation Summary Report, Phase B Investigation Area I Soil, Tronox LLC, Henderson, Nevada. January 15. NDEP approved January 20, 2010.

Northgate, 2010d. Data Validation Summary Report, Phase B Investigation Area II Soil, Tronox LLC, Henderson, Nevada. February 12. NDEP approved February 18, 2010.

Northgate, 2010e. Data Validation Summary Report, Phase B Investigation Area III Soil, Tronox LLC, Henderson, Nevada. February 18. NDEP approved March 17, 2010.

Northgate, 2010f. Revised Data Validation Summary Report, Phase B Investigation Area IV Soil, Tronox LLC, Henderson, Nevada. March 19. NDEP approved March 29, 2010.

Northgate, 2010g. Site-Wide Soil Gas Human Health Risk Assessment, Tronox LLC, Henderson, Nevada. November 22. Not reviewed by NDEP.

Northgate, 2010h. Spring 2010 Indoor Air Quality Sampling and Analysis Report, Tronox LLC, Henderson, Nevada. September 22. NDEP approved November 1, 2010.

Northgate, 2010i. Health Risk Assessment Work Plan, Tronox LLC Facility, Henderson, Nevada. March 9. NDEP approved March 16, 2010.

Northgate, 2010j. Removal Action Work Plan for Phase B Soil Remediation of Remediation Zones RZ-B through RZ-E, Tronox LLC, Henderson, Nevada, revised June 22, Errata August 13. NDEP approved Errata August 20. NDEP commented November 8, 2010.

Northgate, 2010k. Final Revised Pre-Confirmation Sampling Work Plan Remediation Zones RZ-A through RZ-E Phase B Investigation, Tronox Facility, Henderson, Nevada. March 25. NDEP approved March 30, 2010.

Northgate, 2010l. Revised Human Health Risk Assessment for Remediation Zone A, Tronox LLC, Henderson, Nevada. July 23. NDEP approved August 20, 2010.

Northgate, 2010m. Letter with Attachments to Shannon Harbour, NDEP, RE: Interim Approach for Unsaturated Zone Soil Remediation, Tronox LLC, Henderson Nevada. October 8.

Northgate, 2010n. Appendix A of the Excavation Plan for Phase B Soil Remediation of RZ-B, Addendum to the Removal Action Work Plan. August 20. NDEP approved September 3, 2010.

Northgate, 2010o. Appendix A of the Revised Excavation Plan for Phase B Soil Remediation of RZ-C, Addendum to the Removal Action Work Plan. September 1. NDEP conditionally approved December 1, 2010.

Northgate, 2010p. Appendix A of the Excavation Plan for Phase B Soil Remediation of RZ-D, Addendum to the Removal Action Work Plan. October 18. NDEP approved November 8, 2010.

Northgate, 2010q. Appendix A of the Excavation Plan for Phase B Soil Remediation of RZ-E, Addendum to the Removal Action Work Plan. November 3. NDEP conditionally approved November 29, 2010.

Northgate, 2010r. Revised Technical Memorandum: Screening-Level Indoor Air Health Risk Assessment for the 2008 Tronox Parcels A/B Soil Gas Investigation, BMI Industrial Complex, Clark County, Nevada. November 12. NDEP commented May 23, 2011.

Northgate, 2010s. Data Validation Summary Report Parcels “C”, “D”, “F”, “G”, and “H” Soil Confirmation, Tronox LLC, Henderson, Nevada. June 15. NDEP approved July 28, 2010.

Northgate, 2010t. Interim Groundwater Capture Evaluation and Vertical Delineation Report, Tronox LLC, Henderson, Nevada. March 23. Under NDEP review.

Northgate, 2010u. Capture Zone Evaluation Report, Tronox LLC. Henderson, Nevada. December 10. Under NDEP review.

Northgate, 2010v. Revised Data Validation Summary Report, Phase B Investigation Groundwater, Tronox LLC, Henderson, Nevada. April 7.

Northgate, 2011a. December 2010 Indoor Air Quality Sampling and Analysis Report, Tronox LLC, Henderson, Nevada. February 3. NDEP approved March 21, 2011.

Northgate, 2011b. Revised Technical Memorandum: Calculation of Leaching-Based Site-Specific Levels for the Soil-to-Groundwater Pathway Using NDEP Guidance, Tronox LLC, Henderson, Nevada. February 14. NDEP commented March 21, 2011. Submitted to NDEP for review.

Northgate, 2012a. Manganese Tailings Removal Technical Memorandum, Nevada Environmental Response Trust, Henderson, Nevada. November 9.

Northgate, 2012b. Revised Closure and Post-Remediation Screening Health Risk Assessment Report for Parcels C, D, F, G, and H. Nevada Environmental Response Trust Site, Henderson, Nevada. May 18. NDEP provided comments on August 7, 2012.

Sale, T. and Newell, C. 2011. A Guide for Selecting Remedies for Subsurface Releases of Chlorinated Solvents, U.S. Department of Defense, Environmental Security and Technology Certification Program (ESTCP) Project ER-200530. March.

TIMET, 2007. Conceptual Site Model, Titanium Metals Corporation Facility, Henderson, Nevada. April 25. NDEP issued final response August 14, 2008.

Tronox, 2008. Outline Proposal to Assess Background Water Quality, Tronox, LLC, Henderson Nevada. Letter, dated December 18, 2008, from Susan M. Crowley, Staff Environmental Specialist, to Shannon Harbour, P.E., NDEP.

Urbansky, E. T. 1998. Perchlorate chemistry: implications for analysis and remediation. Bioremediation Journal 2, 81–95.

U.S. Environmental Protection Agency (USEPA), 1986. Grouting Techniques in Bottom Sealing of Hazardous Waste Sites. (EPA/600/2-86/020).

USEPA, 1988. Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA, Interim Final. October.

USEPA, 1992a. Guidance for Data Usability in Risk Assessment (Part A), Final. Office of Emergency and Remedial Response, April. http://www.epa.gov/oswer/riskassessment/datause/parta.htm.

USEPA, 1992b. Guidance for Data Usability in Risk Assessment (Part B), Final. Office of Emergency and Remedial Response, April. http://www.epa.gov/oswer/riskassessment/datause/partb.htm

USEPA. 1997. Engineering Bulletin: Technology Alternatives for the Remediation of Soils Contaminated with As, Cd, Cr, Hg, and Pb. (EPA/540/S-97/500). August.

USEPA, 2000. In-Situ Treatment of Soil and Groundwater Contaminated with Chromium, Technical Resource Guide. (EPA/625/R-00/005). October.

USEPA, 2002a. Evaluating the Vapor Intrusion to Indoor Air Pathway from Groundwater and Soils (Subsurface Vapor Intrusion Guidance). Draft Guidance. EPA530-F-02-052. November.

USEPA, 2002b. Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites. Office of Solid Waste and Emergency Response, Washington, DC. OSWER 9355.4-24. December.

USEPA. 2003. Human Health Toxicity Values in Superfund Risk Assessments. OSWER Directive 9285.7-53, December 5. http://www.epa.gov/oswer/riskassessment/pdf/hhmemo.pdf

USEPA, 2004a. User's Guide for Evaluating Subsurface Vapor Intrusion into Buildings. February 22.

USEPA. 2004b. In-Situ Thermal Treatment of Chlorinated Solvents: Fundamentals and Field Applications. (EPA/542/R-04/010). March

USEPA. 2004c, DNAPL Remediation: Selected Projects Approaching Regulatory Closure. (EPA 542-R-04-016). December.

USEPA. 2005. Perchlorate Treatment Technology Update, Federal Facilities Forum Issue Paper. (EPA/542/R-05/015). May.

USEPA. 2009. DNAPL Remediation: Selected Projects Where Regulatory Closure Goals Have Been Achieved. (EPA 542/R-09/008). August.

USEPA, 2012a. Regional Screening Levels (RSL) for Chemical Contaminants at Superfund Sites. May.

USEPA. 2012b. Contaminated Site Clean-up Information Website. http://www.clu-in.org/.

Tables

Table 2-1. SUMMARY OF NEIGHBORING PROPERTIES
Nevada Environmental Response Trust Site; Henderson, Nevada

PROPERTY	LOCATION
American Pacific Corporation (AMPAC) formerly Pacific Engineering and Production Company of Nevada (PEPCON)	This property is located 1.5 miles southwest of the Site.
Black Mountain Industrial (BMI) Common Areas includes the following Eastside Sub-Areas: Hook-Open Space, Southern RIBs, Galleria North School Site, Galleria Alignment, Sunset North Commercial, Phase I Development, City of Henderson Water Reclamation Facility, Eastside Main, Mohawk, Parcels 4A and 4B. The following CAMU Sub-Areas include: Eastern W. Ditch, Northern Landfill Lobe, Northern Lobe of the Borrow Area, Slit Trench Area, Southern Landfill Lobe, Southern Lobe of the Borrow Area, and Western W. Ditch	The CAMU Sub-Areas are located adjacent to the west of the Site and north of the Olin property. The Eastside Sub-Areas are located east of the Site across the Boulder Highway.
Lhoist North America (Lhoist) formerly Chemstar Lime Company of Nevada and Chemstar, Inc.	This property is located in the center of the Site north of Unit Buildings 3 and 4.
Olin Chlor-Alkali Products (Olin) formerly Pioneer Americas LLC which was referred to as Pioneer Americas/Olin Chlor Alkali/Stauffer Management Company/Syngenta Crop Protection, Inc./Montrose Chemical Corporation of California (POSSM and OSSM)	This property is located adjacent to the west of the Site and south of the BMI CAMU Sub-Areas.
Titanium Metals Corporation (TIMET)	This property is located adjacent to the east of the Site. There is a small portion of the property that is located to the west of the Site, north of Parcel F.
Western Area Power Administration (WAPA)	This property is located south of Unit Buildings 1 through 6, east of Parcel G, and north of Parcel H.

Notes:

CAMU = Corrective Action Management Unit

RIB = Rapid Infiltration Basin

Site = Nevada Environmental Response Trust Site

TABLE 4-1. SUMMARY OF THE GROUNDWATER MONITORING PROGRAM
Nevada Environmental Response Trust Site; Henderson, Nevada

WELL ID	LOCATION	WELL TYPE	TOTAL WELL DEPTH	SCREEN INTERVAL [1]	MONTHLY SAMPLING	QUARTERLY SAMPLING	ANNUAL [2] SAMPLING
Interceptor wells: Located across the highest concentrations of the plume; comprise the on-site groundwater extraction network, the "IWF"							
I-AA	On-site	Extraction	46	24 - 43.7	W	P, T, Cr, pH	P, T, Cr, pH
I-AB	On-site	Extraction	51	25 - 45	W	P, T, Cr, pH	P, T, Cr, pH
I-AC	On-site	Extraction	50	25 - 44.5	W	P, T, Cr, pH	P, T, Cr, pH
I-AD	On-site	Extraction	50	25 - 44.5	W	P, T, Cr, pH	P, T, Cr, pH
I-AR	On-site	Extraction	45	25 - 45	W	P, T, Cr, pH	P, T, Cr, pH
I-B	On-site	Extraction	43	18 - 42.5	W	P, T, Cr, pH	P, T, Cr, pH
I-C	On-site	Extraction	43	13 - 42.5	W	P, T, Cr, pH	P, T, Cr, pH
I-D	On-site	Extraction	45	16 - 44.5	W	P, T, Cr, pH	P, T, Cr, pH
I-E	On-site	Extraction	44	22 - 43.5	W	P, T, Cr, pH	P, T, Cr, pH
I-F	On-site	Extraction	43.8	12 - 43.3	W	P, T, Cr, pH	P, T, Cr, pH
I-G	On-site	Extraction	39.3	9.5 - 38.8	W	P, T, Cr, pH	P, T, Cr, pH
I-H	On-site	Extraction	43.6	14 - 43.1	W	P, T, Cr, pH	P, T, Cr, pH
I-I	On-site	Extraction	41	11 - 40.5	W	P, T, Cr, pH	P, T, Cr, pH
I-J	On-site	Extraction	41	11 - 40.5	W	P, T, Cr, pH	P, T, Cr, pH
I-K	On-site	Extraction	35.8	7 - 35.2	W	P, T, Cr, pH	P, T, Cr, pH
I-L	On-site	Extraction	40	9 - 39	W	P, T, Cr, pH	P, T, Cr, pH
I-M	On-site	Extraction	40	9 - 39	W	P, T, Cr, pH	P, T, Cr, pH
I-N	On-site	Extraction	38	7 - 37	W	P, T, Cr, pH	P, T, Cr, pH
I-O	On-site	Extraction	40	9 - 39	W	P, T, Cr, pH	P, T, Cr, pH
I-P	On-site	Extraction	44.5	14 - 44	W	P, T, Cr, pH	P, T, Cr, pH
I-Q	On-site	Extraction	40	9.6 - 39.6	W	P, T, Cr, pH	P, T, Cr, pH
I-R	On-site	Extraction	43	9.8 - 39.8	W	P, T, Cr, pH	P, T, Cr, pH
I-S	On-site	Extraction	45.2	12 - 42	W	P, T, Cr, pH	P, T, Cr, pH
I-T	On-site	Extraction	45.2	12 - 42	W	P, T, Cr, pH	P, T, Cr, pH
I-U	On-site	Extraction	45	12 - 42	W	P, T, Cr, pH	P, T, Cr, pH
I-V	On-site	Extraction	45	12 - 42	W	P, T, Cr, pH	P, T, Cr, pH
I-W	On-site	Extraction	50.5	20 - 50	W	P, T, Cr, pH	P, T, Cr, pH
I-X	On-site	Extraction	50.5	20 - 50	W	P, T, Cr, pH	P, T, Cr, pH
I-Y	On-site	Extraction	50.5	20 - 50	W	P, T, Cr, pH	P, T, Cr, pH
I-Z	On-site	Extraction	35	15 - 35	W	P, T, Cr, pH	P, T, Cr, pH
M-series wells: On-site groundwater monitoring wells; for groundwater characterization/investigation and IWF performance monitoring							
M-10	On-site	Monitoring	67	43 - 63	W	P, T, Cr, pH, Cr6, *	P, T, Cr, pH, Cr6, Ch, N, *
M-100	On-site	Monitoring	30.5	19 - 29	W	P, T, Cr, pH, Cr6	P, T, Cr, pH, Cr6

TABLE 4-1. SUMMARY OF THE GROUNDWATER MONITORING PROGRAM
Nevada Environmental Response Trust Site; Henderson, Nevada

WELL ID	LOCATION	WELL TYPE	TOTAL WELL DEPTH	SCREEN INTERVAL [1]	MONTHLY SAMPLING	QUARTERLY SAMPLING	ANNUAL [2] SAMPLING
M-101	On-site	Monitoring	29	17 - 27	W	P, T, Cr, pH	P, T, Cr, pH
M-103	On-site	Monitoring	90	19 - 39.4			P, T, Cr, pH
M-11	On-site	Monitoring	58	33 - 53	W	P, T, Cr, pH, Cr6	P, T, Cr, pH, Cr6, Ch, N
M-115	On-site	Monitoring	45.2	35 - 45			P, T, Cr, pH
M-117	On-site	Monitoring	155	130 - 150			P, T, Cr, pH
M-118	On-site	Monitoring	163	138 - 158			P, T, Cr, pH
M-120	On-site	Monitoring	105	80 - 100			P, T, Cr, pH
M-121	On-site	Monitoring	102	77 - 97			P, T, Cr, pH
M-123	On-site	Monitoring	51.3	36 - 51			P, T, Cr, pH
M-124	On-site	Monitoring	49.3	34 - 49			P, T, Cr, pH
M-125	On-site	Monitoring	50.3	35 - 50			P, T, Cr, pH
M-126	On-site	Monitoring	40	20 - 39.7			P, T, Cr, pH
M-128	On-site	Monitoring	55.3	35 - 50			P, T, Cr, pH
M-129	On-site	Monitoring	40	40 - 55			P, T, Cr, pH
M-12A	On-site	Monitoring	50	20 - 40		P, T, Cr, pH, Cr6	P, T, Cr, pH, Cr6, Ch, N
M-13	On-site	Monitoring	52.5	28 - 48			P, T, Cr, pH, Ch, N
M-130	On-site	Monitoring	40	20 - 40			P, T, Cr, pH
M-131	On-site	Monitoring	39	29 - 38.7		P, T, Cr, pH	P, T, Cr, pH
M-132	On-site	Monitoring	90	80 - 89.7			P, T, Cr, pH
M-133	On-site	Monitoring	70	60 - 69.7			P, T, Cr, pH
M-134	On-site	Monitoring	70	60 - 69.7			P, T, Cr, pH
M-135	On-site	Monitoring	39	29 - 38.7		P, T, Cr, pH	P, T, Cr, pH
M-136	On-site	Monitoring	90	80 - 89.7			P, T, Cr, pH
M-137	Off-site	Monitoring	75	52 - 72			P, T, Cr, pH
M-138	On-site	Monitoring	65	51 - 65.5			P, T, Cr, pH
M-139	On-site	Monitoring	60	45 - 60			P, T, Cr, pH
M-140	On-site	Monitoring	43	23 - 42.7			P, T, Cr, pH
M-141	On-site	Monitoring	40	38 - 47.5			P, T, Cr, pH
M-142	On-site	Monitoring	45.3	30 - 45.3			P, T, Cr, pH
M-144	On-site	Monitoring	45	35 - 45			P, T, Cr, pH
M-145	On-site	Monitoring	60	45 - 60			P, T, Cr, pH
M-146	On-site	Monitoring	50	40 - 50			P, T, Cr, pH
M-147	On-site	Monitoring	40	25 - 40			P, T, Cr, pH
M-148A	On-site	Monitoring	50	35 - 50			P, T, Cr, pH
M-149	On-site	Monitoring	120	100 - 120			P, T, Cr, pH

TABLE 4-1. SUMMARY OF THE GROUNDWATER MONITORING PROGRAM
Nevada Environmental Response Trust Site; Henderson, Nevada

WELL ID	LOCATION	WELL TYPE	TOTAL WELL DEPTH	SCREEN INTERVAL [1]	MONTHLY SAMPLING	QUARTERLY SAMPLING	ANNUAL [2] SAMPLING
M-14A	On-site	Monitoring	40.2	20 - 40	W	P, T, Cr, pH	P, T, Cr, pH
M-150	On-site	Monitoring	145	125 - 145			P, T, Cr, pH
M-151	On-site	Monitoring	145	125 - 145			P, T, Cr, pH
M-152	On-site	Monitoring	145	125 - 145			P, T, Cr, pH
M-153	On-site	Monitoring	170	150 - 170			P, T, Cr, pH
M-154	On-site	Monitoring	195	175 - 195			P, T, Cr, pH
M-155	On-site	Monitoring	220	200 - 220			P, T, Cr, pH
M-156	On-site	Monitoring	195	175 - 195			P, T, Cr, pH
M-161	On-site	Monitoring	110	100 - 110			P, T, Cr, pH
M-162	On-site	Monitoring	110	100 - 110			P, T, Cr, pH
M-163	On-site	Monitoring	90	80 - 89.7			P, T, Cr, pH
M-164	On-site	Monitoring	70	60 - 69.7			P, T, Cr, pH
M-165	On-site	Monitoring	120	110 - 120			P, T, Cr, pH
M-166	On-site	Monitoring	32	22 - 31.7		W	W
M-167	On-site	Monitoring	30	20 - 29.7		W	W
M-168	On-site	Monitoring	32	22 - 31.7		W	W
M-169	On-site	Monitoring	35	25 - 34.7		W	W
M-170	On-site	Monitoring	35	25 - 34.7		W	W
M-172	On-site	Monitoring	37	27 - 36.7		W	W
M-173	On-site	Monitoring	40	25 - 39.7		W	W
M-174	On-site	Monitoring	28	18 - 27.7		W	W
M-175	On-site	Monitoring	29	19 - 28.7		W	W
M-176	On-site	Monitoring	30	20 - 29.7		W	W
M-177	On-site	Monitoring	30	20 - 29.7		W	W
M-181	On-site	Monitoring	115	105 - 115			P, T, Cr, pH
M-182	On-site	Monitoring	90	80 - 89.7			P, T, Cr, pH
M-186	On-site	Monitoring	115	105 - 115			P, T, Cr, pH
M-19	On-site	Monitoring	40	15 - 34.5	W	P, T, Cr, pH	P, T, Cr, pH
M-21	On-site	Monitoring	43	18 - 38			P, T, Cr, pH
M-22A	On-site	Monitoring	36.4	16 - 36	W	P, T, Cr, pH	P, T, Cr, pH
M-23	On-site	Monitoring	43	9.4 - 37.4	W	P, T, Cr, pH	P, T, Cr, pH, Ch, N
M-25	On-site	Monitoring	39	24 - 39	W	P, T, Cr, pH	P, T, Cr, pH, Ch, N
M-29	On-site	Monitoring	42	22 - 42			P, T, Cr, pH, Ch, N
M-2A	On-site	Monitoring	45	30 - 40			P, T, Cr, pH
M-31A	On-site	Monitoring	55	35 - 55		P, T, Cr, pH	P, T, Cr, pH

TABLE 4-1. SUMMARY OF THE GROUNDWATER MONITORING PROGRAM
Nevada Environmental Response Trust Site; Henderson, Nevada

WELL ID	LOCATION	WELL TYPE	TOTAL WELL DEPTH	SCREEN INTERVAL [1]	MONTHLY SAMPLING	QUARTERLY SAMPLING	ANNUAL [2] SAMPLING
M-32	On-site	Monitoring	45	30 - 45			P, T, Cr, pH
M-33	On-site	Monitoring	45	30 - 45			P, T, Cr, pH
M-35	On-site	Monitoring	40	25 - 40		P, T, Cr, pH	P, T, Cr, pH
M-36	On-site	Monitoring	35	20 - 35	W	P, T, Cr, pH, Cr6	P, T, Cr, pH, Cr6, Ch, N
M-37	On-site	Monitoring	35	20 - 35	W	P, T, Cr, pH, Cr6	P, T, Cr, pH, Cr6, Ch, N
M-38	On-site	Monitoring	35	20 - 35	W	P, T, Cr, pH, Cr6	P, T, Cr, pH, Cr6
M-44	On-site	Monitoring	35	5 - 35	W	P, T, Cr, pH, Cr6	P, T, Cr, pH, Cr6
M-48A	On-site	Monitoring	40	20 - 39.7	W	P, T, Cr, pH	P, T, Cr, pH, Ch, N
M-52	On-site	Monitoring	45	35 - 44.5		P, T, Cr, pH	P, T, Cr, pH
M-55	On-site	Monitoring	44.6	15 - 44.6	W	W	W
M-56	On-site	Monitoring	40	15 - 40	W	W	W
M-57A	On-site	Monitoring	40.2	20 - 40	W	P, T, Cr, pH	P, T, Cr, pH
M-58	On-site	Monitoring	45	15 - 45	W	W	W
M-5A	On-site	Monitoring	50	40 - 50		P, T, Cr, pH, **	P, T, Cr, pH, **
M-60	On-site	Monitoring	43	18 - 42.8	W	W	W
M-64	On-site	Monitoring	37.5	13 - 37.3	W	P, T, Cr, pH	P, T, Cr, pH
M-65	On-site	Monitoring	39.2	14 - 39	W	P, T, Cr, pH	P, T, Cr, pH
M-66	On-site	Monitoring	42.5	18 - 42.3	W	P, T, Cr, pH	P, T, Cr, pH
M-67	On-site	Monitoring	38	7.8 - 37.8	W	P, T, Cr, pH	P, T, Cr, pH
M-68	On-site	Monitoring	41	11 - 39.8	W	P, T, Cr, pH	P, T, Cr, pH
M-69	On-site	Monitoring	40	20 - 39.3	W	P, T, Cr, pH	P, T, Cr, pH
M-6A	On-site	Monitoring	43.6	27 - 41.5		P, T, Cr, pH, **	P, T, Cr, pH, **
M-70	On-site	Monitoring	40.2	15 - 40	W	P, T, Cr, pH	P, T, Cr, pH
M-71	On-site	Monitoring	42.2	18 - 42	W	P, T, Cr, pH	P, T, Cr, pH
M-72	On-site	Monitoring	35	10 - 34.8	W	P, T, Cr, pH	P, T, Cr, pH
M-73	On-site	Monitoring	36	11 - 35.8	W	P, T, Cr, pH	P, T, Cr, pH
M-74	On-site	Monitoring	39	9.2 - 38.8	W	P, T, Cr, pH	P, T, Cr, pH
M-75	On-site	Monitoring	51.5	35 - 49.3			P, T, Cr, pH
M-76	On-site	Monitoring	51.4	35 - 49.3			P, T, Cr, pH
M-77	On-site	Monitoring	45.9	29 - 43.8			P, T, Cr, pH
M-78	On-site	Monitoring	43.6	22 - 41.5	W	W	W
M-79	On-site	Monitoring	37.6	11 - 35.4	W	P, T, Cr, pH	P, T, Cr, pH
M-7B	On-site	Monitoring	52.5	26 - 50.5		P, T, Cr, pH, **	P, T, Cr, pH, **
M-80	On-site	Monitoring	43.7	12 - 41.5	W	W	W
M-81A	On-site	Monitoring	40	30 - 40	W	W	W

TABLE 4-1. SUMMARY OF THE GROUNDWATER MONITORING PROGRAM
Nevada Environmental Response Trust Site; Henderson, Nevada

WELL ID	LOCATION	WELL TYPE	TOTAL WELL DEPTH	SCREEN INTERVAL [1]	MONTHLY SAMPLING	QUARTERLY SAMPLING	ANNUAL [2] SAMPLING
M-83	On-site	Monitoring	42.5	11 - 40.3		P, T, Cr, pH	P, T, Cr, pH
M-92	On-site	Monitoring	45.5	35 - 44.9			P, T, Cr, pH
M-93	On-site	Monitoring	46	35 - 45.4			P, T, Cr, pH
M-95	Off-site	Monitoring	22	12 - 22			P, T, Cr, pH
M-96	Off-site	Monitoring	20.5	11 - 20.5	W	P, T, Cr, pH, Cr6	P, T, Cr, pH, Cr6
M-97	On-site	Monitoring	45.5	35 - 45			P, T, Cr, pH
M-98	On-site	Monitoring	31	19 - 29	W	P, T, Cr, pH	P, T, Cr, pH
M-99	On-site	Monitoring	33	16 - 31	W	P, T, Cr, pH	P, T, Cr, pH
MW-16	On-site	Monitoring	40	25 - 39.7			P, T, Cr, pH
ART (Athens Road Transect) wells: Located off-site at Galleria Drive at the COH WRF; comprise the mid-plume groundwater extraction network, the "AWF"							
ART-1	Downgradient	Extraction	56	14 - 54	P, T	P, T, Cr, pH	P, T, Cr, pH
ART-1A	Downgradient	Extraction	56	19 - 54	W	W	W
ART-2	Downgradient	Extraction	56	19 - 54	P, T	P, T, Cr, pH	P, T, Cr, pH
ART-2A	Downgradient	Extraction	58	21 - 56	W	W	W
ART-3	Downgradient	Extraction	47	15 - 45	P, T	P, T, Cr, pH	P, T, Cr, pH
ART-3A	Downgradient	Extraction	55	18 - 53	W	W	W
ART-4	Downgradient	Extraction	46.4	19 - 44.4	P, T	P, T, Cr, pH	P, T, Cr, pH
ART-4A	Downgradient	Extraction	45.4	18 - 43.4	W	W	W
ART-6	Downgradient	Extraction	39.9	18 - 37.9	P, T	P, T, Cr, pH	P, T, Cr, pH
ART-7	Downgradient	Extraction	41	19 - 39	W	W	W
ART-7A	Downgradient	Extraction	41.7	20 - 39.7	W	W	W
ART-7B	Downgradient	Extraction	50	30 - 44.5	P, T	P, T, Cr, pH	P, T, Cr, pH
ART-8	Downgradient	Extraction	50.5	18 - 48	P, T	P, T, Cr, pH	P, T, Cr, pH
ART-8A	Downgradient	Extraction	54	22 - 52	W	W	W
ART-9	Downgradient	Extraction	45.5	23 - 43	P, T	P, T, Cr, pH	P, T, Cr, pH
ARP (Athens Road Piezometer) wells: Located immediately downgradient of AWF on COH property; for monitoring ART well performance							
ARP-1	Downgradient	Monitoring	44.2	14 - 44	P, T	P, T, Cr, pH	P, T, Cr, pH
ARP-2A	Downgradient	Monitoring	54	24 - 53.7	P, T	P, T, Cr, pH	P, T, Cr, pH
ARP-3A	Downgradient	Monitoring	41	21 - 40.7	P, T	P, T, Cr, pH	P, T, Cr, pH
ARP-4A	Downgradient	Monitoring	33	18 - 32.7	P, T	P, T, Cr, pH	P, T, Cr, pH
ARP-5A	Downgradient	Monitoring	38	13 - 37.7	P, T	P, T, Cr, pH	P, T, Cr, pH
ARP-6B	Downgradient	Monitoring	43	28 - 42.7	P, T	P, T, Cr, pH	P, T, Cr, pH
ARP-7	Downgradient	Monitoring	39.2	14 - 39	P, T	P, T, Cr, pH	P, T, Cr, pH

TABLE 4-1. SUMMARY OF THE GROUNDWATER MONITORING PROGRAM
Nevada Environmental Response Trust Site; Henderson, Nevada

WELL ID	LOCATION	WELL TYPE	TOTAL WELL DEPTH	SCREEN INTERVAL [1]	MONTHLY SAMPLING	QUARTERLY SAMPLING	ANNUAL [2] SAMPLING
PC-series extraction wells: Located near the Las Vegas Wash; comprise the furthest downgradient groundwater extraction network, the "SWF"							
PC-99R2/R3	Downgradient	Extraction	55.4	10 - 50	P, T	P, T, Cr, pH	P, T, Cr, pH
PC-115R	Downgradient	Extraction	55.5	10 - 50	P, T	P, T, Cr, pH	P, T, Cr, pH
PC-116R	Downgradient	Extraction	55.5	10 - 50	P, T	P, T, Cr, pH	P, T, Cr, pH
PC-117	Downgradient	Extraction	53	11 - 51	P, T	P, T, Cr, pH	P, T, Cr, pH
PC-118	Downgradient	Extraction	51	9 - 49	P, T	P, T, Cr, pH	P, T, Cr, pH
PC-119	Downgradient	Extraction	47	15 - 45	P, T	P, T, Cr, pH	P, T, Cr, pH
PC-120	Downgradient	Extraction	47	15 - 45	P, T	P, T, Cr, pH	P, T, Cr, pH
PC-121	Downgradient	Extraction	38.5	6.5 - 36.5	P, T	P, T, Cr, pH	P, T, Cr, pH
PC-133	Downgradient	Extraction	40.2	5 - 40	P, T	P, T, Cr, pH	P, T, Cr, pH
PC-series monitoring wells: Most located in downgradient plume; for monitoring perchlorate and chromium plumes; some situated near AWF and SWF							
PC-1	Downgradient	Monitoring	30	15 - 29.7			P, T, Cr, pH, Ch, N
PC-101R	Downgradient	Monitoring	50.5	20 - 50	P, T	P, T, Cr, pH	P, T, Cr, pH
PC-103	Downgradient	Monitoring	29.5	9 - 29	P, T	P, T, Cr, pH	P, T, Cr, pH, Ch, N
PC-107	Downgradient	Monitoring	18	7.7 - 17.7			P, T, pH
PC-108	Downgradient	Monitoring	45	9.7 - 44.7			P, T, pH
PC-110	Downgradient	Monitoring	37	6.7 - 36.7			P, T, pH
PC-111	Downgradient	Monitoring	35.3	9.6 - 34.6			P, T, pH
PC-122	Downgradient	Monitoring	38.9	24 - 38.9	P, T	P, T, Cr, pH	P, T, Cr, pH
PC-123	Downgradient	Monitoring	35.2	20 - 35		P, T, Cr, pH	P, T, Cr, pH
PC-124	Downgradient	Monitoring	35.5	20 - 35.3		P, T, Cr, pH	P, T, Cr, pH, Ch, N
PC-125	Downgradient	Monitoring	33.9	19 - 33.7		P, T, Cr, pH	P, T, Cr, pH
PC-126	Downgradient	Monitoring	34.7	20 - 34.5		P, T, Cr, pH	P, T, Cr, pH, Ch, N
PC-127	Downgradient	Monitoring	35.5	15 - 35		P, T, Cr, pH	P, T, Cr, pH
PC-128	Downgradient	Monitoring	35	15 - 34.8		P, T, Cr, pH	P, T, Cr, pH, Ch, N
PC-129	Downgradient	Monitoring	39	38 - 12.8		P, T, Cr, pH	P, T, Cr, pH
PC-130	Downgradient	Monitoring	50	15 - 49.8		P, T, Cr, pH	P, T, Cr, pH, Ch, N
PC-131	Downgradient	Monitoring	40	9.8 - 39.8		P, T, Cr, pH	P, T, Cr, pH
PC-132	Downgradient	Monitoring	40	9.8 - 39.8		P, T, Cr, pH	P, T, Cr, pH, Ch, N
PC-134A	Downgradient	Monitoring	70	60 - 69.7			P, T, Cr, pH
PC-135A	Downgradient	Monitoring	51	31 - 50.7		P, T, Cr, pH	P, T, Cr, pH
PC-136	Downgradient	Monitoring	40.6	21 - 41		P, T, Cr, pH	P, T, Cr, pH
PC-137	Downgradient	Monitoring	73.3	63 - 73.3			P, T, Cr, pH
PC-142	Downgradient	Monitoring	32	22 - 31.7			P, T, Cr, pH

TABLE 4-1. SUMMARY OF THE GROUNDWATER MONITORING PROGRAM
Nevada Environmental Response Trust Site; Henderson, Nevada

WELL ID	LOCATION	WELL TYPE	TOTAL WELL DEPTH	SCREEN INTERVAL [1]	MONTHLY SAMPLING	QUARTERLY SAMPLING	ANNUAL [2] SAMPLING
PC-143	Downgradient	Monitoring	65	30 - 64.7			P, T, Cr, pH
PC-144	Downgradient	Monitoring	40	30 - 39.7		P, T, Cr, pH	P, T, Cr, pH
PC-145	Downgradient	Monitoring	40	25 - 39.7			P, T, Cr, pH
PC-146	Downgradient	Monitoring	30	20 - 29.7			P, T, Cr, pH
PC-147	Downgradient	Monitoring	32	22 - 31.7			P, T, Cr, pH
PC-148	Downgradient	Monitoring	50	25 - 44.5		P, T, Cr, pH	P, T, Cr, pH
PC-149	Downgradient	Monitoring	50	25 - 44.5		P, T, Cr, pH	P, T, Cr, pH
PC-150	Downgradient	Monitoring	45	20 - 39.5		P, T, Cr, pH	P, T, Cr, pH
PC-18	Downgradient	Monitoring	52	12 - 51.5	P, T	P, T, Cr, pH	P, T, Cr, pH
PC-2	Downgradient	Monitoring	30	14 - 29			P, T, Cr, pH, Ch, N
PC-21A	Downgradient	Monitoring	34.4	14 - 34.2			P, T, Cr, pH, Ch, N
PC-24	Downgradient	Monitoring	30.2	15 - 30			P, T, Cr, pH
PC-28	Downgradient	Monitoring	20	10 - 19.5			P, T, Cr, pH
PC-31	Downgradient	Monitoring	50	15 - 49.5			P, T, Cr, pH
PC-37	On-site	Monitoring	42	17 - 41.8		P, T, Cr, pH	P, T, Cr, pH
PC-4	Downgradient	Monitoring	43	18 - 42.7			P, T, Cr, pH, Ch, N
PC-40	On-site	Monitoring	55.2	15 - 55			P, T, Cr, pH
PC-50	Downgradient	Monitoring	42	12 - 41.8			P, T, Cr, pH
PC-53	Downgradient	Monitoring	33	13 - 32.5	P, T	P, T, Cr, pH	P, T, Cr, pH
PC-54	Downgradient	Monitoring	35	9.5 - 34.5	P, T	P, T, Cr, pH	P, T, Cr, pH
PC-55	Downgradient	Monitoring	56.3	15 - 55.3	P, T	P, T, Cr, pH	P, T, Cr, pH
PC-56	Downgradient	Monitoring	55	4.8 - 54.8	P, T	P, T, Cr, pH	P, T, Cr, pH
PC-58	Downgradient	Monitoring	33	7.8 - 32.8	P, T	P, T, Cr, pH	P, T, Cr, pH
PC-59	Downgradient	Monitoring	35	4.8 - 34.8	P, T	P, T, Cr, pH	P, T, Cr, pH
PC-60	Downgradient	Monitoring	40	4.5 - 38.5	P, T	P, T, Cr, pH	P, T, Cr, pH
PC-62	Downgradient	Monitoring	38	7.6 - 37.6	P, T	P, T, Cr, pH	P, T, Cr, pH
PC-64	Downgradient	Monitoring	19.5	4 - 19			P, T, Cr, pH
PC-65	Downgradient	Monitoring	19.1	4.1 - 18.7			P, T, Cr, pH
PC-66	Downgradient	Monitoring	27.3	6.9 - 26.9			P, T, Cr, pH
PC-67	Downgradient	Monitoring	36	11 - 35.6			P, T, Cr, pH
PC-68	Downgradient	Monitoring	55.3	9.9 - 54.9	P, T	P, T, Cr, pH	P, T, Cr, pH
PC-71	On-site	Monitoring	30.4	13 - 15		P, T, Cr, pH	P, T, Cr, pH
PC-72	On-site	Monitoring	37	15 - 20		P, T, Cr, pH	P, T, Cr, pH
PC-73	On-site	Monitoring	47.5	20 - 25		P, T, Cr, pH	P, T, Cr, pH
PC-74	Downgradient	Monitoring	50	40 - 10			P, T, pH

TABLE 4-1. SUMMARY OF THE GROUNDWATER MONITORING PROGRAM
Nevada Environmental Response Trust Site; Henderson, Nevada

WELL ID	LOCATION	WELL TYPE	TOTAL WELL DEPTH	SCREEN INTERVAL [1]	MONTHLY SAMPLING	QUARTERLY SAMPLING	ANNUAL [2] SAMPLING
PC-76	Downgradient	Monitoring	20.5	15 - 20			W
PC-77	Downgradient	Monitoring	40	30 - 39.5			P, T, pH
PC-78	Downgradient	Monitoring	22	12 - 21.5			W
PC-79	Downgradient	Monitoring	45	35 - 44.5			P, T, Cr, pH
PC-80	Downgradient	Monitoring	30	20 - 29.5			W
PC-81	Downgradient	Monitoring	15	9.5 - 14.5			W
PC-82	Downgradient	Monitoring	57.5	47 - 57			P, T, Cr, pH, Ch, N
PC-83	Downgradient	Monitoring	31	21 - 30.5			W
PC-86	Downgradient	Monitoring	28	18 - 27.5	P, T	P, T, Cr, pH	P, T, Cr, pH, Ch, N
PC-87	Downgradient	Monitoring	13	2.5 - 12.5			W
PC-88	Downgradient	Monitoring	50.5	40 - 50			W
PC-90	Downgradient	Monitoring	15	4.5 - 14.5	P, T	P, T, Cr, pH	P, T, Cr, pH, Ch, N
PC-91	Downgradient	Monitoring	37	27 - 36.5	P, T	P, T, Cr, pH	P, T, Cr, pH, Ch, N
PC-92	Downgradient	Monitoring	22	12 - 21.5			P, T, Cr, pH
PC-94	Downgradient	Monitoring	20	9.5 - 19.5		P, T, Cr, pH	P, T, Cr, pH
PC-96	Downgradient	Monitoring	39.5	29 - 39			P, T, pH
PC-97	Downgradient	Monitoring	33.5	23 - 33	P, T	P, T, Cr, pH	P, T, Cr, pH
PC-98R	Downgradient	Monitoring	40.5	20 - 35	P, T	P, T, Cr, pH	P, T, Cr, pH
TR-series wells: Located on-site along western property boundary; for Middle/Deep Water Bearing Zone monitoring							
TR-1	On-site	Monitoring	312	282 - 312			P, T, Cr, pH
TR-2	On-site	Monitoring	175	145 - 175			P, T, Cr, pH
TR-3	On-site	Monitoring	250	220 - 250			P, T, Cr, pH
TR-4	On-site	Monitoring	145	125 - 145			P, T, Cr, pH
TR-5	On-site	Monitoring	251.5	221 - 251			P, T, Cr, pH
TR-6	On-site	Monitoring	80	60 - 80			P, T, Cr, pH
TR-7	On-site	Monitoring	290.5	260 - 290			P, T, Cr, pH
TR-8	On-site	Monitoring	93.5	63 - 93			P, T, Cr, pH
TR-9	On-site	Monitoring	250.5	230 - 250			P, T, Cr, pH
TR-10	On-site	Monitoring	100.5	80 - 100			P, T, Cr, pH
TR-11	On-site	Monitoring	230.5	210 - 230			P, T, Cr, pH
TR-12	On-site	Monitoring	292.5	272 - 292			P, T, Cr, pH
Owned by BRC; located on east side of downgradient plume							
AA-01	Downgradient	Monitoring	49	29 - 49			P, T, pH
AA-11	Downgradient	Monitoring	29	9 - 29			P, T, Cr, pH

TABLE 4-1. SUMMARY OF THE GROUNDWATER MONITORING PROGRAM
Nevada Environmental Response Trust Site; Henderson, Nevada

WELL ID	LOCATION	WELL TYPE	TOTAL WELL DEPTH	SCREEN INTERVAL [1]	MONTHLY SAMPLING	QUARTERLY SAMPLING	ANNUAL [2] SAMPLING
BEC-1	Downgradient	Monitoring	40	25 - 40			P, T, pH
Owned by TIMET; located east of the IWF							
CLD-1R	Off-site	Monitoring	35	Shallow			P, T, Cr, pH
Owned by Stauffer; located on-site and off-site							
H-11	Off-site	Monitoring	116	Shallow			P, T, Cr, pH
H-28A	On-site	Monitoring	48	Shallow		P, T, Cr, pH, **	P, T, Cr, pH, **
H-48	On-site	Monitoring	35	Shallow			P, T, Cr, pH
H-58A	On-site	Monitoring	57	37 - 57			P, T, Cr, pH
Owned by COH; located downgradient of AWF; for downgradient plume monitoring							
HM-2	Downgradient	Monitoring	22	Shallow			P, T, pH
HMW-13	Downgradient	Monitoring	40	Shallow			P, T, pH
HMW-15	Downgradient	Monitoring	30	Shallow			P, T, pH
HMW-16	Downgradient	Monitoring	30	Shallow			P, T, pH
HSW-1	Downgradient	Monitoring	24	Shallow			P, T, pH
Owned by USEPA; located just to the west of the AWF; for downgradient plume monitoring							
L635	Downgradient	Monitoring	45	30 - 45	P, T	P, T, Cr, pH	P, T, Cr, pH
L637	Downgradient	Monitoring	29	14 - 29	P, T	P, T, Cr, pH	P, T, Cr, pH
Owned by OSSM; located on-site and off-site; installed by OSSM for monitoring VOCs west of Site							
MC29	On-site	Monitoring	50	38 - 50			P, T, pH
MC3	Off-site	Monitoring	44	Shallow			P, T, pH
MC50	On-site	Monitoring	49	24 - 49			P, T, pH
MC51	On-site	Monitoring	44	24 - 49			P, T, pH
MC53	On-site	Monitoring	38	20 - 40			P, T, Cr, pH
MC6	Off-site	Monitoring	42	Shallow			P, T, pH
MC65	On-site	Monitoring	41	20 - 41			P, T, Cr, pH
MC69	Off-site	Monitoring	44	29 - 44			P, T, pH
MC7	Off-site	Monitoring	39	Shallow			P, T, pH
MC45	Off-site	Monitoring	34	4 - 34			P, T, pH

TABLE 4-1. SUMMARY OF THE GROUNDWATER MONITORING PROGRAM
Nevada Environmental Response Trust Site; Henderson, Nevada

WELL ID	LOCATION	WELL TYPE	TOTAL WELL DEPTH	SCREEN INTERVAL [1]	MONTHLY SAMPLING	QUARTERLY SAMPLING	ANNUAL [2] SAMPLING
MC93	On-site	Monitoring	42	32 - 42			P, T, pH
MC97	On-site	Monitoring	41	31 - 41			P, T, pH
Owned by AMPAC; located downgradient of AWF							
MW-K4	Downgradient	Monitoring	50	9.5 - 50	P, T	P, T, Cr, pH	P, T, Cr, pH
MW-K5	Downgradient	Monitoring	44	29 - 44	P, T	P, T, Cr, pH	P, T, Cr, pH, Ch, N
TOTALS				**Sample/Water Level**	**197**	**163**	**294**
				Sample	**46**	**138**	**262**
				Water Level Only	**74**	**25**	**32**

Notes:

If a sampling field is blank for a well during a certain sampling event, then no action is taken for that well during that event.

[1] If a screen interval is unknown, then the known water bearing zone is listed.

[2] The annual sampling event takes place in the second quarter, replacing the quarterly event.

Abreviations:

P = Perchlorate
T = Total Dissolved Solids (TDS)
Cr = Total Chromium
Cr6 = Hexavalent Chromium
Ch = Chlorate
N = Nitrate
W = Water level measurement only

AMPAC = American Pacific Corporation
BRC = Basic Remediation Company
COH WRF = City of Henderson Water Reclamation Facility
OSSM = Olin/Stauffer/Syngenta/Montrose
TIMET = Titanium Metals Corporation
USEPA = United State Environmental Protection Agency

Additional explanations:

* Designates well sampled under National Pollution Discharge Elimination System (NPDES) Permit - additional analytes required as follows:

Ammonia Nitrogen
Nitrate as Nitrate
Nitrate as Nitrogen
Nitrite as Nitrogen
Total Inorganic Nitrogen
Total Boron
Total Iron
Total Manganese
Chloride

** Designates well sampled under the Resource Conservation and Recovery Act (RCRA) - additional analytes required as follows:

Chloride
Phenols
Specific Conductance
Sulfate
Total Boron
Total Iron
Total Manganese
Total Organic Carbon
Total Organic Halides (4 Replicates)
Total Sodium

TABLE 5-1. CATEGORY 3 AREA INFORMATION
Nevada Environmental Response Trust Site; Henderson, Nevada

AREA #	DESCRIPTION	SAMPLE INFORMATION				
		SAMPLE LOCATION	DEPTH INTERVAL (feet bgs)	CHEMICAL	RESULT (mg/kg)	SRG [1] (mg/kg)
1	Dioxin TEQ > BCL at ground surface (0-0.5 ft). Northgate did not define a soil removal polygon for this area and soil was not removed. This location is slightly north of an existing ECA and along fenceline where removal of the BMI Haul Road is anticipated.	RSAI7	0 - 0.5	Dioxin TEQ	29,000	2,700
			0 - 0.5	Dioxin TEQ	31,000	2,700
2	Dioxin TEQ and HCB > BCL originally at ground surface and is now buried by approximately 2 ft of soil. Northgate did not define a soil removal polygon for this area and soil was not removed.	SSAK3-05	2.5 - 3	Hexachlorobenzene	4.7	1.2
			2.5 - 3	Dioxin TEQ	11,000	2,700
3	Hexachlorobenzene > BCL at 1.5-2 ft deep. Northgate did not define a soil removal polygon for this area and soil was not removed.	RSAK4	1.5 - 2	Hexachlorobenzene	2.1	1.2
4	Arsenic slightly > background at 2-5 ft deep. These samples were originally collected at 10-13 ft deep. Polygon excavation was planned to 4 ft, but actual soil excavation was to ~8 ft (due to discolored soil or grading).	BDT-2-S-5	2 - 3	Arsenic	10	7.2
			4 - 5	Arsenic	7.7	7.2
			4 - 5	Arsenic	9.0	7.2
5	Perchlorate > BCL at various locations at and near ground surface (within retention basin). These samples were originally collected at 10-12 ft deep. Polygon excavation was performed to 10 ft. In consultation with NDEP, grading was performed to construct a retention basin in this area. Also, perchlorate is present at >9 ft below "new" ground surface in this area.	RSAM5	1 - 2.5	Perchlorate	2,620	795
		SA15	0 - 0.5	Perchlorate	1,160	795
			0 - 0.5	Perchlorate	1,210	795
			9 - 10.5	Perchlorate	943	795
		SA65	surface	Perchlorate	1,690	795
			8.5 - 10	Perchlorate	984	795
6	Arsenic slightly > background at 6-7 ft deep. These samples were originally collected at 5-6 ft deep. Polygon excavation was planned and performed to 1 ft, with approximately 1 ft of backfill placed in this area. Soil removal polygons were not originally designed to excavate this deep, presumably since the concentration of arsenic was only slightly above the arsenic background concentration.	SA63	6 - 7	Arsenic	7.5	7.2
7	Arsenic slightly > background at ~4 ft deep. After polygon excavation to 1 ft and additional discolored soil excavation, a confirmation sample was collected which indicated that arsenic was slightly above background. In consultation with NDEP and because arsenic concentrations were only slightly above background, no further excavation was performed in this area and the area was backfilled with approximately 4 ft of soil.	CS-D31A-1	4	Arsenic	8.1	7.2
8	Perchlorate > BCL at ~8.5-18 ft deep. These samples were originally collected at 12-21.5 ft deep. Polygon excavation was performed to 10 ft, then area partially backfilled.	SA106	8.5 - 10	Perchlorate	1,050	795
9	Arsenic > background at surface to 3.5 ft. After soil removal and cleanup following stockpile staging area use in this area, a confirmation sample (DS-C45-2) was collected which indicated arsenic was slightly above background. In consultation with NDEP and because arsenic concentrations were only slightly above background, no further excavation was performed in this area.	SA149	2 - 3.5	Arsenic	25	7.2
			2 - 3.5	Arsenic	21	7.2
		DS-C45-2	surface	Arsenic	10	7.2
			surface	Arsenic	12	7.2
10	Arsenic > background at ~8 ft deep. After polygon excavation and additional discolored soil removal to ~8 ft, a confirmation sample was collected which indicated arsenic was slightly above background. In consultation with NDEP and because the arsenic concentration was only slightly above background, no further excavation was performed in this area and the area was backfilled with approximately 8 ft of soil.	CS-C27-1	8	Arsenic	11	7.2
11	Arsenic slightly > background in upper 3 ft. This sample appears to have been collected on the neighboring property (Lhoist), so soil removal was not planned in this area.	RSAQ5	1 - 2.5	Arsenic	7.4	7.2
			1.5 - 2.5	Arsenic	8.7	7.2
			2.5 - 3.5	Arsenic	7.7	7.2

TABLE 5-1. CATEGORY 3 AREA INFORMATION
Nevada Environmental Response Trust Site; Henderson, Nevada

Notes:

Samples and analytical results listed on this table are from samples presently within 10 ft of the "new" ground surface. Analytical results for deeper samples are not provided on this table.

[1] An NDEP approved site-specific BCL is used as the SRG for dioxins/furans, i.e., dioxin TEQ of 2,700 mg/kg (NDEP 2010d). For arsenic, "contaminated" soil is defined as concentrations greater than a site-specific background concentration of 7.2 mg/kg.

Abbreviations:

bgs = below ground surface
BCL = Basic Comparison Level
BMI = Black Mountain Industrial
ECA = Excavation Control Area
ft = foot or feet
mg/kg = milligram per kilogram
NDEP = Nevada Division of Environmental Protection
SRG = Soil Remediation Goal
TEQ = toxicity equivalent
TIMET = Titanium Metals Corp.

References:

Nevada Division of Environmental Protection (NDEP), 2010d. NDEP Response to: *Results of Bioaccessibility Study for Dioxin/Furans in Soil, Tronox LLC, Henderson, Nevada (Revised) Dated: May 24, 2010.* May 25.

TABLE 5.2. INITIAL SCREENING OF REMEDIAL TECHNOLOGIES
Nevada Environmental Response Trust Site; Henderson, Nevada

GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTIONS	DESCRIPTION	SCREENING COMMENTS
NO FURTHER ACTION	**No Further Action**	**No Action**	No action to be taken beyond the previous and current Interim Removal Actions described in Section 4 of this Work Plan, including the Interim Soil Removal Actions described in Sections 4.1 through 4.3, the historical and current Groundwater Removal Actions described in Section 4.4 (i.e., the construction and operation of the GWETS), and the Groundwater Monitoring described in Section 4.5. The relevant technologies and process options implemented as part of these Interim Removal Actions are described and evaluated below along with comparable alternatives.	Not likely to meet RAOs. Required for comparison by National Contingency Plan (NCP).
INSTITUTIONAL CONTROLS	**Groundwater Use Restrictions**	**Access Restrictions to Groundwater**	Restrict use of groundwater in contaminated areas.	POTENTIALLY APPLICABLE.
	Site Access Restrictions	**Site Management Plan (SMP)**	Manage risk to site occupants and workers through implementation of an SMP identifying remaining contamination left in place in Excavation Control Areas (ECAs) and detailing the procedures necessary to follow when disturbing ECAs.	APPLICABLE as an SMP has been developed and implemented for the Site to manage risks from residual contamination.
		Fences / Gates	Block unauthorized access to parts of the Site to prevent exposure to residual contamination and/or hazardous materials and equipment.	APPLICABLE as it is currently in use at some areas of the Site.
		Warning Signs	Post signs to warn against unauthorized access and to inform of potential hazards to prevent exposure to residual contamination and/or hazardous materials and equipment.	APPLICABLE as it is currently in use at some areas of the Site.
	Legal Restrictions to Land Use	**Deed Restrictions**	Restrict use of the impacted land at the Site by writing land use restrictions into the property deed.	POTENTIALLY APPLICABLE.
MONITORING	**Groundwater Monitoring**	**Routine Sampling and Measurement of Groundwater**	Continue sampling and analysis of groundwater.	APPLICABLE as it is currently being conducted at the Site.
MONITORED NATURAL ATTENUATION	**Monitored Natural Attenuation**	**Monitored Natural Attenuation of Groundwater**	Conduct groundwater quality monitoring to demonstrate effectiveness of natural attenuation processes in reducing COPC concentrations to acceptable levels. Additional monitoring network/parameters may be required.	POTENTIALLY APPLICABLE where COPC concentrations are relatively low but are higher than RAOs, and aquifer conditions favorable to natural attenuation processes have been established.

TABLE 5.2. INITIAL SCREENING OF REMEDIAL TECHNOLOGIES
Nevada Environmental Response Trust Site; Henderson, Nevada

GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTIONS	DESCRIPTION	SCREENING COMMENTS
CONTAINMENT	Vertical Subsurface Barriers	Slurry Wall	Construct physical barrier using very low permeability slurry to isolate an area and/or control groundwater migration.	APPLICABLE as it is currently in use at the Site for controlling groundwater flow and contaminant migration.
		Grout Curtain	Create subsurface barrier to horizontal groundwater flow by grout injection.	POTENTIALLY APPLICABLE for controlling shallow groundwater flow and contaminant migration.
		Diaphragm Walls	Vertical barrier constructed of reinforced concrete panels.	POTENTIALLY APPLICABLE for controlling shallow groundwater flow and contaminant migration.
		Steel Sheet Pile Walls	Vertical barrier comprised of steel sheet piles.	POTENTIALLY APPLICABLE for controlling shallow groundwater flow and contaminant migration.
		Vibrating Beam Slurry Walls	Vertical barrier constructed by inserting a series of overlapping I-beams into the ground, followed by slurry injection under pressure.	POTENTIALLY APPLICABLE for controlling shallow groundwater flow and contaminant migration.
	Horizontal Subsurface Barriers	Grout Injection by Vertical Drilling	Create subsurface barrier to vertical migration of groundwater by grout injection at a fixed depth via tightly-spaced vertical boreholes.	POTENTIALLY APPLICABLE for controlling shallow groundwater flow and contaminant migration.
		Grout Injection by Vertical Drilling and Jet Grouting	Create subsurface barrier to vertical migration of groundwater by grout injection at a fixed depth via tightly-spaced vertical boreholes and jet grouting.	POTENTIALLY APPLICABLE for controlling shallow groundwater flow and contaminant migration.
		Grout Injection by Horizontal Drilling	Create subsurface barrier to vertical migration of groundwater by grout injection at a fixed depth via horizontal boreholes.	POTENTIALLY APPLICABLE for controlling shallow groundwater flow and contaminant migration.
	Capping / Surface Water Recharge Control	Single-Layer Clay Cap	Areas of concern (usually areas of impacted soil) are covered with a clay cap and protective surface cover to reduce storm water infiltration and prevent contaminant transport.	POTENTIALLY APPLICABLE to defined source areas within Site boundaries to reduce infiltration and contaminant migration.
		Single-Layer Synthetic Membrane	Areas of concern are covered using a synthetic membrane with protective base and cover material to reduce storm water infiltration and prevent contaminant transport.	POTENTIALLY APPLICABLE to defined source areas within Site boundaries to reduce infiltration and contaminant migration.
		Single-Layer Soil Cement / Clay Mixture	A barrier layer is formed by adding bentonite clay or Portland cement to surface soil in the areas of concern.	POTENTIALLY APPLICABLE to defined source areas within Site boundaries to reduce infiltration and contaminant migration.

TABLE 5.2. INITIAL SCREENING OF REMEDIAL TECHNOLOGIES
Nevada Environmental Response Trust Site; Henderson, Nevada

GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTIONS	DESCRIPTION	SCREENING COMMENTS
CONTAINMENT (continued)	**Capping / Surface Water Recharge Control (continued)**	**Multi-Layered Cap System**	Areas of concern are covered with a multi-layered cap system to reduce storm water infiltration and prevent contaminant transport.	POTENTIALLY APPLICABLE to defined source areas within Site boundaries to reduce infiltration and contaminant migration.
		Asphalt / Concrete Paving	Paving forms a relatively impervious surface to prevent erosion and infiltration of storm water into underlying soil thereby reducing contaminant transport.	POTENTIALLY APPLICABLE to defined source areas within Site boundaries to reduce infiltration and contaminant migration.
		Shotcrete	Shotcrete is sprayed concrete which forms a relatively impervious surface to prevent erosion and prevent storm water from contacting underlying impacted soil. The cap also prevents infiltration of storm water into underlying soil and groundwater.	POTENTIALLY APPLICABLE to defined source areas within Site boundaries to reduce infiltration and contaminant migration.
		Fly Ash Mixtures	Use of ash mixture as an absorbent in conjunction with other cover materials.	REJECTED; fly ash may contain metal residues.
GROUNDWATER EXTRACTION	**Groundwater Extraction ("Pump & Treat")**	**Extraction Wells**	Install extraction wells (vertical or horizontal) to capture contaminated groundwater to control plume migration and/or for groundwater restoration. May be used in concert with various containment process options and ex-situ treatment process options.	APPLICABLE as it is currently being conducted at the Site.
		Subsurface Drains and Interceptor Trenches	Install perforated pipe in trenches backfilled with porous media to capture contaminated groundwater to control plume migration and/or for groundwater restoration. May be used in concert with various containment process options and ex-situ treatment process options.	POTENTIALLY APPLICABLE.
EX-SITU GROUNDWATER TREATMENT	**Ex-Situ Physical-Chemical Treatment**	**Air Stripping**	Use forced air flow to transfer volatile contaminants from the aqueous phase to the vapor phase.	POTENTIALLY APPLICABLE for treatment of VOCs.
		Steam Stripping	Use forced steam to remove volatile contaminants from extracted groundwater.	POTENTIALLY APPLICABLE for treatment of VOCs/DNAPLs.
		Liquid- Liquid Separation / Extraction	Extract contaminants based on solubility using liquid extractants. Contaminants are solubilized into an extraction fluid that requires further treatment.	POTENTIALLY APPLICABLE for treatment of VOCs/DNAPLs.

TABLE 5.2. INITIAL SCREENING OF REMEDIAL TECHNOLOGIES
Nevada Environmental Response Trust Site; Henderson, Nevada

GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTIONS	DESCRIPTION	SCREENING COMMENTS
EX-SITU GROUNDWATER TREATMENT (continued)	**Ex-Situ Physical-Chemical Treatment (continued)**	**Liquid-Phase Carbon Adsorption Using Granular Activated Carbon (GAC)**	Use granular activated carbon (GAC) to remove organic compounds from water in a non-destructive process that results in clean water and spent GAC loaded with the target contaminants. Spent GAC requires regeneration (e.g. off-site thermal regeneration) or disposal.	APPLICABLE as it is currently being conducted at the Site for pretreatment of extracted groundwater prior to biological reduction of perchlorate.
		Liquid-Phase Carbon Adsorption Using Tailored GAC (T-GAC)	Use specially treated GAC to remove residual (low-level) perchlorate from extracted groundwater.	POTENTIALLY APPLICABLE for a polishing step for low-level perchlorate treatment.
		Chemical Reduction	Chemical treatment to reduce oxidation state of target contaminants in extracted groundwater thereby reducing mass, toxicity, and or mobility.	APPLICABLE as it is currently being conducted at the Site in conjunction with chemical precipitation for removal of Cr(VI) from extracted groundwater.
		Chemical Oxidation	Use chemical oxidants to destroy organic contaminants in extracted groundwater.	POTENTIALLY APPLICABLE for treatment of VOCs.
		Advanced Oxidation Processes	Use ultraviolet (UV) radiation, ozone, and/or hydrogen peroxide to destroy organic contaminants as water flows into a treatment tank.	POTENTIALLY APPLICABLE for treatment of VOCs.
		Chemical Precipitation	Use chemical amendments to remove metals from extracted groundwater as a sludge via precipitation.	APPLICABLE as it is currently being conducted at the Site in conjunction with chemical reduction for removal of Cr(VI) from extracted groundwater.
		Coagulation / Flocculation	Use chemical coagulants/flocculants (e.g., ferric chloride, various commercial polymers, etc.) to clarify water of settleable solids.	POTENTIALLY APPLICABLE for use in combination with other ex-situ process options as part of a treatment train.
		Electrochemical Precipitation	Use electrochemically generated ferrous ions from a sacrificial iron electrode to reduce metals in extracted groundwater thereby reducing mass, toxicity, and or mobility.	POTENTIALLY APPLICABLE for removal of Cr(VI) from extracted groundwater.
		Ion Exchange Using Single-Use Resins	Use ion-exchange resins to remove cations and/or anions from extracted groundwater in a non-destructive process that results in clean water and resins loaded with the target contaminants. Nonregenerable resins loaded with contaminant are properly disposed (e.g. incineration).	APPLICABLE for treatment of perchlorate and Cr(VI) and has been implemented at the Site in the past.

TABLE 5.2. INITIAL SCREENING OF REMEDIAL TECHNOLOGIES
Nevada Environmental Response Trust Site; Henderson, Nevada

GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTIONS	DESCRIPTION	SCREENING COMMENTS
EX-SITU GROUNDWATER TREATMENT (continued)	**Ex-Situ Physical-Chemical Treatment (continued)**	**Ion Exchange Using Regenerable Resins**	Use ion-exchange resins to remove cations and/or anions from extracted groundwater in a non-destructive process that results in clean water and resins loaded with the target contaminants. Contaminants are removed from resin before reuse.	APPLICABLE for treatment of perchlorate and Cr(VI) and has been implemented at the Site in the past.
		Reverse Osmosis	Use high pressure membrane to remove ionic contaminants in extracted groundwater in a non-destructive process that results in clean water and a concentrated brine solution requiring further treatment.	POTENTIALLY APPLICABLE as a polishing step in an aboveground treatment train.
		Nanofiltration / Ultrafiltration	Similar to reverse osmosis except uses membranes with larger pore sizes and lower pressures reducing energy usage. It is a non-destructive process resulting in clean water and a concentrated brine solution requiring further treatment.	POTENTIALLY APPLICABLE as a polishing or pretreatment step in an aboveground treatment train.
		Electrodialysis	An emerging technology that uses electric current and semi-permeable membrane to separate ions from extracted groundwater in a non-destructive process that results in clean water and a concentrated brine solution requiring further treatment.	POTENTIALLY APPLICABLE as a perchlorate removal process option in an aboveground treatment train. This technology is in the early stages of development.
		Electrolysis	An emerging technology that uses electricity to decompose an electrolyte solution into positive and negative ions and thereby reducing perchlorate and nitrates in a destructive process that leaves no brine solution requiring treatment.	POTENTIALLY APPLICABLE as a perchlorate removal process option in an aboveground treatment train. This technology is in the early stages of development.
		Ultraviolet (UV) Laser Reduction	An emerging technology using photons to reduce perchlorate. Photons provide the activation energy necessary for some stable molecules in water solution, such as perchlorate, to react and be destroyed leaving no brine requiring treatment.	POTENTIALLY APPLICABLE as a perchlorate removal process option in an aboveground treatment train. This technology is in the early stages of development.
		Capacitive Deionization	An emerging technology that uses an electric field between electrodes to separate anions and cations from extracted groundwater in a non-destructive process that results in clean water and electrodes loaded with the target contaminants. Reversing the electric charge unloads the contaminants into a concentrated brine solution requiring further treatment.	POTENTIALLY APPLICABLE as a polishing or pretreatment step in an aboveground treatment train. This technology is in the early stages of development.

TABLE 5.2. INITIAL SCREENING OF REMEDIAL TECHNOLOGIES
Nevada Environmental Response Trust Site; Henderson, Nevada

GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTIONS	DESCRIPTION	SCREENING COMMENTS
EX-SITU GROUNDWATER TREATMENT (continued)	**Ex-Situ Physical-Chemical Treatment (continued)**	**Zero Valent Iron (ZVI) Reduction of Perchlorate**	An emerging technology employing an enhanced method of chemical reduction using zero-valent iron (ZVI) reduction. Due to the high activation energy of perchlorate reduction, chemical reduction via ZVI is generally not feasible; however, enhancement of this process using UV radiation or phosphoric acid allows the reaction to proceed.	POTENTIALLY APPLICABLE as a perchlorate removal process option in an aboveground treatment train. This technology is in the early stages of development.
		Titanium Reduction	An emerging technology employing titanous ions [Ti(III)] to reduce perchlorate in aqueous solutions.	POTENTIALLY APPLICABLE as a perchlorate removal process option in an aboveground treatment train. This technology is in the early stages of development.
		Catalytic Hydrogen Gas Membrane	An emerging technology incorporating hydrogen gas and catalysts (screened for their hydrogen and perchlorate adsorption capacity and catalytic hydrogen reduction of perchlorate) into porous membrane that works to filter perchlorate from water.	POTENTIALLY APPLICABLE as a perchlorate removal process option in an aboveground treatment train. This technology is in the early stages of development.
		Nanoscale Materials and Bimetallic Particles	Nanoscale particles represent a new generation of remediation technologies that employ particles having large surface areas and high surface reactivity. Nanoscale zero-valent iron (nZVI) ,bimetallic particles (BNPs), and titanium dioxide (TiO_2) can potentially treat a wide variety of contaminants including VOCs/DNAPLs and perchlorate in contaminated water.	POTENTIALLY APPLICABLE for treatment of perchlorate and VOCs/DNAPLs. This technology is in the early stages of development.
	Ex-Situ Biological Treatment	**Anaerobic Fluidized Bed Reactors (FBRs)**	Use anaerobic and facultative bacteria growing on a hydraulically-fluidized bed of media within an upflow bioreactor to degrade contaminants in extracted groundwater under anaerobic conditions. A carbon source is added to establish anaerobic conditions and to provide an electron donor for biological reduction of perchlorate.	APPLICABLE as it is currently in use at the Site as the primary process option for treatment of perchlorate in groundwater.
		Anaerobic Packed-Bed Reactors (PBRs)	Use anaerobic and facultative bacteria growing on stationary media within an upflow or downflow bioreactor to degrade contaminants in extracted groundwater under anaerobic conditions. A carbon source is added to establish anaerobic conditions and to provide an electron donor for biological reduction of perchlorate.	POTENTIALLY APPLICABLE as an alternative to FBRs.

TABLE 5.2. INITIAL SCREENING OF REMEDIAL TECHNOLOGIES
Nevada Environmental Response Trust Site; Henderson, Nevada

GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTIONS	DESCRIPTION	SCREENING COMMENTS
EX-SITU GROUNDWATER TREATMENT (continued)	**Ex-Situ Biological Treatment (continued)**	**Anaerobic Continuously-Stirred Tank Reactors (CSTRs)**	Use anaerobic and facultative bacteria growing in suspension to degrade contaminants in extracted groundwater under anaerobic conditions. Lower pumping requirements than FBRs. A carbon source is added to establish anaerobic conditions and to provide an electron donor for biological reduction of perchlorate.	POTENTIALLY APPLICABLE as an alternative to FBRs.
		Aerobic Bioreactors	Use aerobic bacteria growing in suspension (e.g., activated sludge) or on fixed media (e.g., trickling filters and rotating biological contactors[RBCs]) to degrade contaminants in water under aerobic conditions.	REJECTED. This process option has limited applicability to the range of chemical constituents encountered at the Site.
		Constructed Wetlands	Discharge extracted groundwater and/or other process wastewaters to an artificially constructed wetland area. Uses natural geochemical and biological processes inherent in a wetland ecosystem to accumulate and remove metals, organics, and other contaminants from influent waters.	POTENTIALLY APPLICABLE for treatment of extracted groundwater.
EXCAVATION	**Source Area Soil Excavation**	**Excavation for Off-site Treatment/Disposal**	Excavation and removal of shallow source area soils for off-site treatment and/or disposal at an appropriate Treatment Storage Disposal Facility (TSDF).	POTENTIALLY APPLICABLE for removal and management of vadose zone source area soils.
		Excavation for On-site Treatment/Disposal	Excavation of shallow source area soils for ex-situ treatment.	POTENTIALLY APPLICABLE for removal and management of vadose zone source area soils.
EX-SITU SOURCE AREA TREATMENT	**Ex-Situ Physical-Chemical Treatment**	**Thermal Treatment**	Treatment of excavated soils to destroy contaminants via thermal processes such as electric infrared incineration, fluidized bed incineration, liquid injection incineration, multiple hearth incineration, pyrolysis, and rotary kiln incineration.	POTENTIALLY APPLICABLE for ex-situ treatment of excavated source area soils.
		Thermal Desorption	Lower-temperature thermal process for removing VOCs and low-boiling-point compounds from excavated soils by volatilization, followed by organic destruction in a high temperature combustion chamber, or recovery by condensation or GAC adsorption.	POTENTIALLY APPLICABLE for ex-situ treatment of excavated source area soils.
		Soil Aeration	Controlled aeration of excavated soils to reduce VOCs.	REJECTED. Difficulties in controlling releases of VOCs to the air. Does not address inorganic contaminants.

TABLE 5.2. INITIAL SCREENING OF REMEDIAL TECHNOLOGIES
Nevada Environmental Response Trust Site; Henderson, Nevada

GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTIONS	DESCRIPTION	SCREENING COMMENTS
EX-SITU SOURCE AREA TREATMENT (continued)	Ex-Situ Physical-Chemical Treatment (continued)	**Off-Site Land Disposal**	Transport excavated soils to an appropriately-permitted off-site land disposal facility.	POTENTIALLY APPLICABLE for management of excavated source area soils.
		On-Site Land Disposal	Dispose of excavated soils within an appropriately-designed on-site land disposal facility (or facilities).	POTENTIALLY APPLICABLE for management of excavated source area soils.
		Solidification / Stabilization (S/S)	Treatment of excavated soil to immobilize contaminants via various solidification/stabilization agents (e.g., absorbents, cement-based, lime-based or pozzolanic, thermoplastic, organic polymer, silicon- or organic-based, surface encapsulation).	POTENTIALLY APPLICABLE for ex-situ treatment of excavated source area soils.
		Vitrification	Thermal treatment and solidification process that converts contaminated soil into a chemically inert, stable glass and crystalline product. During this process, the increased temperature may also volatilize and/or destroy organic contaminants or volatile metal species that must be collected for treatment or disposal.	POTENTIALLY APPLICABLE for ex-situ treatment of excavated source area soils.
		Soil Washing	Physical/chemical removal of contaminants from excavated soil using water or water-containing additives as extraction fluids.	POTENTIALLY APPLICABLE for ex-situ treatment of excavated source area soils.
		Solvent Extraction	Separation/removal of contaminants from excavated soil by solubilizing/dissolving the contaminants into an organic extraction fluid.	POTENTIALLY APPLICABLE for ex-situ treatment of VOCs/DNAPL in excavated source area soils.
		Chemical Oxidation	Chemical treatment to increase oxidation state of target COPCs in excavated soil thereby reducing mass, toxicity, and or mobility.	POTENTIALLY APPLICABLE for ex-situ treatment of VOCs/DNAPL in excavated source area soils.
		Chemical Reduction	Chemical treatment to reduce oxidation state of target COPCs in soil thereby reducing mass, toxicity, and or mobility.	POTENTIALLY APPLICABLE for ex-situ treatment of Cr(VI) and VOCs in excavated source area soils.
		pH Adjustment	Neutralization of excavated soil.	POTENTIALLY APPLICABLE as an enhancement to other ex-situ process options for remediating excavated source area soils.

TABLE 5.2. INITIAL SCREENING OF REMEDIAL TECHNOLOGIES
Nevada Environmental Response Trust Site; Henderson, Nevada

GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTIONS	DESCRIPTION	SCREENING COMMENTS
EX-SITU SOURCE AREA TREATMENT (continued)	**Ex-Situ Biological Treatment**	**Biopiles**	Excavated soils are mixed with soil amendments and placed in aboveground enclosures. It is an aerated static pile composting process in which compost is formed into piles and aerated with blowers or vacuum pumps.	REJECTED. This process option has limited applicability to the range of chemical constituents encountered at the Site.
		Composting	Excavated soil is mixed with bulking agents and organic amendments such as wood chips, hay, manure, and vegetative (e.g., potato) wastes in a controlled environment and composted under thermophillic conditions. Composting can be performed in piles or windrows, in bags (e.g. "Ag-Bags"), or in concrete treatment cells.	POTENTIALLY APPLICABLE for ex-situ treatment of perchlorate and VOCs in excavated source area soils.
		Landfarming	Contaminated media (soils, sludges, or sediments) is applied into lined beds and periodically turned over or tilled to aerate the waste. The waste, soil, climate, and biological activity interact dynamically as a system to degrade, transform, and immobilize contaminants.	REJECTED. Difficulties in controlling releases of VOCs to the air. Does not address inorganic contaminants.
		Slurry-Phase Biological Treatment	Slurry-phase biological treatment involves the controlled treatment of excavated soil in an aerobic bioreactor. The excavated soil is first processed to physically separate stones and rubble. The solids are maintained in suspension in a reactor and mixed with nutrients and oxygen. When biodegradation is complete, the soil slurry is dewatered.	REJECTED. This process option has limited applicability to the range of chemical constituents encountered at the Site.
IN-SITU GROUNDWATER AND SOURCE AREA TREATMENT	**In-Situ Physical-Chemical Treatment**	**Soil Flushing with Water**	Inject water into the subsurface or apply water at the surface in infiltration basins to enhance recovery of mobile contaminants such as perchlorate under hydraulically controlled conditions.	POTENTIALLY APPLICABLE for removal of perchlorate and chromium under hydraulically controlled conditions.
		Co-Solvent / Surfactant Flushing	Inject surfactants or solvents into the saturated zone to facilitate desorption and removal of bound contaminants and/or DNAPL. Contaminants are solubilized/dissolved into an extraction fluid that requires further treatment.	POTENTIALLY APPLICABLE for remediation of VOC/DNAPL source areas under hydraulically controlled conditions.
		Air Sparging	Inject air into saturated zone to remove contaminants through volatilization. Requires vapor extraction for recovery and aboveground treatment for treatment of vapors.	POTENTIALLY APPLICABLE for remediation of VOCs in shallow saturated zones.
		In-situ Well Stripping (UVB Wells)	In-well air stripping, aeration, and water recirculation system for VOC removal.	POTENTIALLY APPLICABLE for remediation of VOCs in groundwater.

TABLE 5.2. INITIAL SCREENING OF REMEDIAL TECHNOLOGIES
Nevada Environmental Response Trust Site; Henderson, Nevada

GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTIONS	DESCRIPTION	SCREENING COMMENTS
IN-SITU GROUNDWATER AND SOURCE AREA TREATMENT (continued)	**In-Situ Physical-Chemical Treatment (continued)**	**Soil Vapor Extraction (SVE)**	Removal of VOCs in vapor form by applying vacuum to the subsurface. Can be used as a process option along with thermal and vapor treatment technologies.	POTENTIALLY APPLICABLE for remediation of VOCs in vadose zone source areas or for use in conjunction with thermal treatment technologies.
		Multi-Phase Extraction (MPE)	Use a central vacuum source and submersible pumps to extract contaminated groundwater, vapor, and DNAPL. Ex-situ treatment is typically required for each of the extracted phases.	POTENTIALLY APPLICABLE for remediation of shallow VOC source areas where DNAPL is present.
		2-Phase Extraction (TPE)	Simultaneous extraction of vapor and groundwater using a central vacuum source (e.g., a high-vacuum liquid ring blower). Depth of treatment is limited to about 30 feet below ground surface due to limitations of liquid suction lift. Similar to SVE with the addition of dewatering effects. Ex-situ treatment is typically required for each of the extracted phases.	REJECTED. Depth to groundwater where remediation of VOCs would potentially be implemented is expected to be deeper than the effective limit of this technology.
		Dual-Phase Extraction (DPE)	Removal of VOCs via simultaneous extraction of vapor and groundwater using combination of a central vacuum source and submersible pumps. Similar to SVE with the addition of dewatering effects. Ex-situ treatment is typically required for each of the extracted phases.	POTENTIALLY APPLICABLE for remediation of shallow VOC source areas and/or for excavation or construction dewatering in lower permeability formations.
		Electrokinetics	Application of a low-intensity current between electrodes placed in the soil to mobilize metals and polar organic compounds to the electrodes in the form of charged species, particles and ions. This is a non-destructive process requiring removal and treatment of the sequestered contaminants.	POTENTIALLY APPLICABLE for remediation of Cr(VI) in low-permeability zones.
		Solidification / Stabilization (S/S)	Solidification/stabilization (S/S) uses various chemical binders to immobilize contaminants within the soil matrix instead of removing them through chemical or physical treatment. Leachability testing is typically performed to measure the immobilization of contaminants.	POTENTIALLY APPLICABLE for immobilization of metals.

TABLE 5.2. INITIAL SCREENING OF REMEDIAL TECHNOLOGIES
Nevada Environmental Response Trust Site; Henderson, Nevada

GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTIONS	DESCRIPTION	SCREENING COMMENTS
IN-SITU GROUNDWATER AND SOURCE AREA TREATMENT (continued)	**In-Situ Physical-Chemical Treatment (continued)**	**Geochemical Fixation**	In-situ fixation of metals by oxidation/reduction, precipitation, and/or complexation reactions. This is a non-destructive process that immobilizes metals in the soil matrix. Chemicals are introduced into extracted groundwater and then re-injected via wells, or in some cases, by infiltration.	POTENTIALLY APPLICABLE for immobilization of Cr(VI) using ferrous sulfate.
		Vitrification	Thermal treatment and solidification process that converts contaminated soil into a stable glass and crystalline product. This is a non-destructive process (for inorganics) that immobilizes metals in a crystalline matrix. VOCs are volatilized, and in some cases, destroyed in the process, but off-gas from this process needs to be recovered and treated.	POTENTIALLY APPLICABLE for immobilizing Cr(VI) and simultaneously removing VOCs in shallow soil.
		Steam / Hot Water Injection	Thermal treatment using injected steam or hot water applied to porous media to remove and/or vaporize volatile or semivolatile compounds. Requires vapor/water recovery and ex-situ treatment process options.	POTENTIALLY APPLICABLE for remediation of VOCs/DNAPL in groundwater and vadose zone source areas.
		Electric Resistivity Heating (ERH)	Thermal treatment using electrical resistance to heat subsurface and remove and/or vaporize volatile or semivolatile compounds. Requires vapor recovery and ex-situ treatment process options.	POTENTIALLY APPLICABLE for remediation of VOCs/DNAPL in groundwater and vadose zone source areas.
		Radio Frequency (RF) Heating	Thermal treatment using radio frequencies to heat the subsurface and remove and/or vaporize volatile or semivolatile compounds. Requires vapor recovery and ex-situ treatment process options.	POTENTIALLY APPLICABLE for remediation of VOCs/DNAPL in vadose zone source areas.
		Thermal Conductive Heating	Thermal treatment using surface or subsurface conductive heating elements to heat the subsurface and remove, and/or vaporize volatile or semivolatile compounds. Requires vapor recovery and ex-situ treatment process options.	POTENTIALLY APPLICABLE for remediation of VOCs/DNAPL in groundwater and vadose zone source areas.

TABLE 5.2. INITIAL SCREENING OF REMEDIAL TECHNOLOGIES
Nevada Environmental Response Trust Site; Henderson, Nevada

GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTIONS	DESCRIPTION	SCREENING COMMENTS
IN-SITU GROUNDWATER AND SOURCE AREA TREATMENT (continued)	**In-Situ Physical-Chemical Treatment (continued)**	**In-Situ Chemical Reduction**	Apply reductants to treat contaminants in-situ. Zero valent iron (ZVI) or other reducing agents are introduced into the subsurface by direct injection, injection via wells, recirculation, in-situ soil mixing, or construction of permeable reactive barriers to initiate chemical reduction reactions. Combining ZVI with a carbon source, such as the commercial product EHC, would add biological reduction to this process option allowing removal of perchlorate.	POTENTIALLY APPLICABLE for remediation of Cr(VI) and VOCs/DNAPL in groundwater and vadose zone source areas.
		In-Situ Chemical Oxidation	Apply oxidants to destroy contaminants in-situ. Typically oxidants include ozone, hydrogen peroxide, sodium / potassium permanganate, and sodium persulfate. Application types include direct injection, injection via wells, recirculation, in-situ soil mixing, and construction of permeable reactive barriers.	POTENTIALLY APPLICABLE for remediation of VOCs/DNAPL in groundwater and vadose zone source areas.
		In-Situ Nanoscale Materials and Bimetallic Particles	Apply nanoscale particles for in-situ treatment of perchlorate and VOCs/DNAPLs. Nanoscale particles represent a new generation of remediation technologies that employ particles having large surface areas and high surface reactivity. Nanoscale zero-valent iron (nZVI) ,bimetallic particles (BNPs), and titanium dioxide (TiO_2) can potentially treat a wide variety of contaminants including VOCs/DNAPLs and perchlorate in contaminated water. Application types could include direct injection, injection via wells, recirculation, in-situ soil mixing, and construction of permeable reactive barriers.	POTENTIALLY APPLICABLE for remediation of VOCs/DNAPL and perchlorate in groundwater. This technology is in the early stages of development.
	In-Situ Biological Treatment	**Bioventing**	Uses low air flow rates to provide oxygen to stimulate the in-situ biodegradation of aerobically-degradable compounds in soil. Oxygen is most commonly supplied through direct air injection into residual contamination in soil.	REJECTED. Limited applicability to the range of chemical constituents encountered at the Site.
		Enhanced Reductive Bioremediation - Mobile Amendments	Use low-viscosity organic substrates to produce a reductive biological reaction zone in which contaminants are degraded by microorganisms. Substrate delivery modes can be active (e.g. recirculation via extraction and injection wells or passive (e.g., direct injection). Recirculation can be employed vertically or horizontally.	POTENTIALLY APPLICABLE for remediation of perchlorate and VOCs in groundwater.

TABLE 5.2. INITIAL SCREENING OF REMEDIAL TECHNOLOGIES
Nevada Environmental Response Trust Site; Henderson, Nevada

GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTIONS	DESCRIPTION	SCREENING COMMENTS
IN-SITU GROUNDWATER AND SOURCE AREA TREATMENT (continued)	**In-Situ Biological Treatment (continued)**	**Enhanced Reductive Bioremediation - Fixed Biobarriers**	Use solid or viscous organic substrates placed across the flow path of contaminated groundwater to form a permeable reactive barrier in which contaminants are reductively degraded by microorganisms. The fixed biobarrier approach can use engineered trenches or barriers containing solid-phase, slow-release substrates or viscous substrates placed crossgradient via direct-push injections. Pumping and injection of groundwater (in "active" mode) can be used to enhance performance.	POTENTIALLY APPLICABLE for remediation of perchlorate and VOCs in shallow groundwater.
		Bioaugmentation	Introduce a specialized microorganism or microbial consortium having demonstrated environmental benefits including the ability to perform biodegradation of specific contaminants. The introduction of microorganisms may add capabilities that are lacking or increase existing biodegradation rates. There are commercially-available consortia capable of a wide array of environmental activities. Delivery mechanisms are similar to those for substrates.	POTENTIALLY APPLICABLE as an enhancement to other in-situ biological treatments.
		Enhanced Reductive Bioremediation via Liquid Phase Substrate Addition to Vadose Zone	Liquid delivery of electron donors into the vadose zone to promote reductive biodegradation. Potential electron donors include ethanol, acetate, molasses, mushroom compost, and manure. Application methods include sprinkler irrigation, direct injection, or periodic flooding via infiltration galleries.	POTENTIALLY APPLICABLE for remediation of vadose zone source areas contaminated with perchlorate, Cr(VI), and VOCs.
		Enhanced Reductive Bioremediation via Gaseous Phase Substrate Addition or "Anaerobic Bioventing"	Inject gaseous electron donors in the vadose zone to promote reductive biodegradation. Gaseous substrate can also be sparged into (and through) the saturated zone to promote biodegradation. Potential electron donors include propane, hydrogen, carbon dioxide, various alkanes, or combinations thereof. Application methods include direct gas injection and soil vapor extraction, amendment and reinjection.	POTENTIALLY APPLICABLE for remediation of source areas contaminated with perchlorate.
		Enhanced Aerobic Biodegradation	Use air, oxygen, or an oxygen releasing compound and other nutrient amendments to aerobically degrade contaminants.	REJECTED. Limited applicability to the range of chemical constituents encountered at the Site.

TABLE 5.2. INITIAL SCREENING OF REMEDIAL TECHNOLOGIES
Nevada Environmental Response Trust Site; Henderson, Nevada

GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTIONS	DESCRIPTION	SCREENING COMMENTS
IN-SITU GROUNDWATER AND SOURCE AREA TREATMENT (continued)	**In-Situ Biological Treatment (continued)**	**Phytoremediation**	Use of plants to remove, transfer, stabilize, or destroy contaminant in soil, sediment, and groundwater. The mechanisms of phytoremediation include rhizosphere biodegradation, phytoextraction, phytodegradation, and phytostabilization.	POTENTIALLY APPLICABLE where concentrations are relatively low and contamination is shallow.
	In-Situ Process Enhancements	**Pneumatic Fracturing**	Inject pressurized gas to produce fractures in low permeability layers in order to increase effectiveness of extraction or to facilitate the delivery of chemicals/substrates in the subsurface.	POTENTIALLY APPLICABLE as an enhancement to extraction and/or various in-situ process options for increasing permeabilities in the UMCf.
		Hydraulic Fracturing	Inject high-pressure water and/or a polymer gel to produce fractures in low permeability layers in order to increase effectiveness of extraction or to facilitate the delivery of chemicals/substrates in the subsurface.	POTENTIALLY APPLICABLE as an enhancement to extraction and/or various in-situ process options for increasing permeabilities in the UMCf.
		Funnel and Gate	Direct groundwater flow with low permeability walls (funnel) to a high hydraulic conductivity treatment zone (gate). To ensure that flow beneath the system does not occur, the system must be keyed into an underlying low permeability layer.	POTENTIALLY APPLICABLE as an enhancement to extraction and/or various in-situ process options.
		Directional Wells	Use drilling techniques to position wells horizontally, or at an angle, to reach contaminants not accessible by direct vertical drilling.	POTENTIALLY APPLICABLE as an enhancement to extraction and/or various in-situ process options.
WATER DISCHARGE	**Surface Water Discharge**	**Surface Water**	Discharge treated water to storm sewer system or other surface water discharge under NPDES permit.	APPLICABLE as treated groundwater is currently being discharged to the Las Vegas Wash under an NPDES permit.
	Sewer Discharge	**Public Owned Treatment Works (POTW)**	Discharge treated water to public owned treatment works.	POTENTIALLY APPLICABLE for discharge of treated groundwater as an alternative to the Las Vegas Wash.
	Water Reuse	**Reclamation**	Provide treated groundwater as an alternate water resource for use on-site.	POTENTIALLY APPLICABLE for discharge of treated groundwater as an alternative to the Las Vegas Wash.

TABLE 5.2. INITIAL SCREENING OF REMEDIAL TECHNOLOGIES
Nevada Environmental Response Trust Site; Henderson, Nevada

GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTIONS	DESCRIPTION	SCREENING COMMENTS
WATER DISCHARGE (continued)	**Subsurface Water Discharge**	**Injection Wells**	Pump treated groundwater or amended groundwater into subsurface via injection wells.	POTENTIALLY APPLICABLE for discharge of treated groundwater as an alternative to the Las Vegas Wash or as a method of adding groundwater amendments (e.g., nutrients or substrates) for in-situ treatment.
		Deep Re-Injection Trenches (DRITs)	Re-injection of treated or amended groundwater into deep trenches backfilled with porous media.	POTENTIALLY APPLICABLE for discharge of treated groundwater as an alternative to the Las Vegas Wash or as a method of adding groundwater amendments (e.g., nutrients or substrates) for in-situ treatment.
		Infiltration	Discharge treated groundwater into infiltration basins/ trenches for artificial groundwater recharge.	POTENTIALLY APPLICABLE for discharge of treated groundwater as an alternative to the Las Vegas Wash or as a method of adding groundwater amendments (e.g., nutrients or substrates) for in-situ treatment.
		Solar Evaporation	Disposal of treated effluent in lined, bermed evaporation ponds.	POTENTIALLY APPLICABLE for discharge of treated groundwater as an alternative to the Las Vegas Wash.
EX-SITU VAPOR TREATMENT	**Ex-Situ Vapor / Emissions / Off-gas Treatment**	**Vapor Phase Carbon Adsorption**	Treatment of extracted soil vapors and other process vapors by physical adsorption onto vapor-phase GAC. Contaminants are not destroyed and GAC must be regenerated off-site.	POTENTIALLY APPLICABLE for extracted soil vapors from MPE/TPE/DPE systems and/or from ex-situ treatment train emissions.
		Advanced Oxidation	Treatment of extracted soil vapors and other process vapors by advanced oxidation including the use of UV light to break chemical bonds.	POTENTIALLY APPLICABLE for extracted soil vapors from MPE/TPE/DPE systems and/or from ex-situ treatment train emissions.
		Catalytic Oxidation	Treatment of extracted soil vapors and other process vapors by oxidation initiated by catalysts. Catalyst systems used to oxidize VOCs typically use metal oxides such as nickel oxide, copper oxide, manganese dioxide, or chromium oxide. Noble metals such as platinum and palladium may also be used.	POTENTIALLY APPLICABLE for vapors from MPE/TPE/DPE systems and/or from ex-situ treatment train emissions.
		Scrubbing	Treatment of extracted soil vapors and other process vapors by scrubbing. Scrubbing describes a wide array of processes, both wet and dry, for cleansing air of acid gases, particulates, and other contaminants.	REJECTED. Limited applicability to the range of chemical constituents encountered at the Site.

TABLE 5.2. INITIAL SCREENING OF REMEDIAL TECHNOLOGIES
Nevada Environmental Response Trust Site; Henderson, Nevada

GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTIONS	DESCRIPTION	SCREENING COMMENTS
EX-SITU VAPOR TREATMENT (continued)	**Ex-Situ Vapor / Emissions / Off-gas Treatment (continued)**	**Thermal Oxidation**	Treatment of extracted soil vapors and other process vapors by thermal oxidation using units equipped with a propane or natural gas burner and a stack.	POTENTIALLY APPLICABLE for vapors from MPE/TPE/DPE systems and/or from ex-situ treatment train emissions.
		Biofiltration	Vapor-phase organic contaminants are pumped through a bed of porous media where they sorb to the particle surface and are degraded by microorganisms. The media is typically a sieved compost material.	POTENTIALLY APPLICABLE for vapors from MPE/TPE/DPE systems and/or from ex-situ treatment train emissions.

Notes: COPCs = chemicals of potential concern; Cr(VI) = Hexavalent Chromium; DNAPL = Dense Non-Aqueous Phase Liquids; LNAPL = Light Non-Aqueous Phase Liquids; RAOs = Remedial Action Objectives; TDS = Total Dissolved Solids; UMCf = Upper Miuddy Creek Formation; VOCs = volatile organic compounds; ZVI = Zero Valent Iron

Shaded boxes indicate process options that are retained for the secondary screening evaluation.

Unshaded process options have been eliminated and will not be considered further.

TABLE 5.3. SECONDARY SCREENING OF REMEDIAL TECHNOLOGIES
Nevada Environmental Response Trust Site; Henderson, Nevada

GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTIONS	EFFECTIVENESS	IMPLEMENTABILITY	RELATIVE COST CAPITAL	RELATIVE COST O&M	SCREENING COMMENTS
NO FURTHER ACTION	**No Further Action**	**No Action**	Effective in meeting the short-term RAO of achieving chemical-specific ARARs/TBCs within the Las Vegas Wash, but is not effective in meeting long-term RAOs.	The No Action alternative has been implemented at the Site through the Interim Removal Actions described in Section 4 of this Work Plan.	Low	Low	Not likely to meet RAOs. Required for comparison by National Contingency Plan (NCP).
INSTITUTIONAL CONTROLS	**Groundwater Use Restrictions**	**Access Restrictions to Groundwater**	Demonstrated.	Implementable.	Low	Low	RETAINED.
	Site Access Restrictions	**Site Management Plan (SMP)**	Demonstrated effective and widely used to manage risks related to residual contamination remaining in place at industrial sites.	Readily implementable.	Low	Low	RETAINED. Already implemented at the Site to manage risks related to residual contamination.
		Fences / Gates	Demonstrated effective and widely used.	Readily implementable.	Low	Low	RETAINED. Already implemented to restrict access to certain areas of the Site.
		Warning Signs	Demonstrated effective and widely used.	Readily implementable.	Low	Low	RETAINED. Already implemented to restrict access to certain areas of the Site.
	Legal Restrictions to Land Use	**Deed Restrictions**	Demonstrated effective and widely used.	Readily implementable.	Low	Low	RETAINED.
MONITORING	**Groundwater Monitoring**	**Routine Sampling and Measurement of Groundwater**	This action alone does not meet RAOs	Readily implementable.	Low	Low	RETAINED. Already implemented at the Site to monitor groundwater contaminant plumes containing perchlorate and Cr(VI).
MONITORED NATURAL ATTENUATION	**Monitored Natural Attenuation**	**Monitored Natural Attenuation of Groundwater**	Demonstrated effective, particularly for VOCs.	Readily implementable.	Low	Low	RETAINED. May be applicable after sources of groundwater contamination have been addressed, or in areas where residual concentrations of contamination are low.

TABLE 5.3. SECONDARY SCREENING OF REMEDIAL TECHNOLOGIES
Nevada Environmental Response Trust Site; Henderson, Nevada

GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTIONS	EFFECTIVENESS	IMPLEMENTABILITY	RELATIVE COST CAPITAL	RELATIVE COST O&M	SCREENING COMMENTS
CONTAINMENT	**Vertical Subsurface Barriers**	**Slurry Wall**	Demonstrated and widely used to control groundwater flow. Currently in use at the on-site Barrier Wall to increase capture of contaminated groundwater at the IWF.	Readily implementable.	Low to Moderate	Low	RETAINED.
		Grout Curtain	Demonstrated to control groundwater flow, but generally regarded as less effective than slurry walls.	Readily implementable.	Low to Moderate	Low	REJECTED. Offers no distinctive advantages over slurry walls, which have been demonstrated effective at the Site.
		Diaphragm Walls	Demonstrated to control groundwater flow. Provides a greater degree of structural strength than other vertical barriers which may not be necessary.	Readily implementable.	Moderate	Low	REJECTED. The added structural strength of diaphragm walls is not anticipated to be necessary; therefore, this process option offers no distinctive advantages over slurry walls, which have been demonstrated effective at the Site.
		Steel Sheet Pile Walls	Demonstrated to control groundwater flow, but generally regarded as less effective than slurry walls.	Readily implementable.	Low to Moderate	Low	REJECTED. Offers no distinctive advantages over slurry walls, which have been demonstrated effective at the Site.
		Vibrating Beam Slurry Walls	Demonstrated to control groundwater flow, but generally regarded as less effective than slurry walls.	Readily implementable	Low to Moderate	Low	REJECTED. Offers no distinctive advantages over slurry walls, which have been demonstrated effective at the Site.
	Horizontal Subsurface Barriers	**Grout Injection by Vertical Drilling**	Effectiveness not well-demonstrated. Studies indicate that conventional grout technology cannot produce an impermeable horizontal barrier because it cannot ensure uniform lateral distribution.	Placement of horizontal barriers below existing contamination is difficult to implement successfully.	Low to Moderate	Low	REJECTED due to limited effectiveness and expected difficulties in implementation.

TABLE 5.3. SECONDARY SCREENING OF REMEDIAL TECHNOLOGIES
Nevada Environmental Response Trust Site; Henderson, Nevada

GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTIONS	EFFECTIVENESS	IMPLEMENTABILITY	RELATIVE COST CAPITAL	RELATIVE COST O&M	SCREENING COMMENTS
CONTAINMENT (continued)	**Horizontal Subsurface Barriers (continued)**	**Grout Injection by Vertical Drilling and Jet Grouting**	Effectiveness not well-demonstrated. Although studies indicate some success with jet grouting techniques in soils that contain fines with no large stones or boulders that deflect the cutting jet; however, it is difficult to ensure uniform lateral distribution.	Placement of horizontal barriers below existing contamination is difficult to implement successfully.	Low to Moderate	Low	REJECTED due to limited effectiveness and expected difficulties in implementation.
		Grout Injection by Horizontal Drilling	Effectiveness not well-demonstrated. Studies indicate that conventional grout technology cannot produce an impermeable horizontal barrier because it cannot ensure uniform lateral distribution of the grout.	Placement of horizontal barriers below existing contamination is difficult to implement successfully.	Low to Moderate	Low	REJECTED due to limited effectiveness and expected difficulties in implementation.
	Capping / Surface Water Recharge Control	**Single-Layer Clay Cap**	Demonstrated, but generally less effective than multilayered cap in reducing infiltration. Subject to erosion.	Readily implementable.	Low to Moderate	Low	REJECTED due to erosion concerns.
		Single-Layer Synthetic Membrane	Demonstrated, but generally less effective than multilayered cap in reducing infiltration.	Readily implementable.	Low to Moderate	Low	RETAINED, for possible use to reduce infiltration over localized areas. May be incompatible with future land use plans.
		Single-Layer Soil Cement / Clay Mixture	Demonstrated effective, but generally less effective than multi-layered cap in reducing infiltration. Subject to erosion.	Readily implementable.	Low to Moderate	Low	REJECTED due to erosion concerns.
		Multi-Layered Cap System	Demonstrated effective for reducing infiltration and contaminant migration. Precautions must be taken to avoid erosion or degradation of the cover materials, including the clay layer, in storm water drainage areas and steeply sloping areas.	Readily implementable in areas where slopes do not exceed 1.5:1. Multi-layer system includes a base clay layer, intermediate gravel drainage layer, and soil cover layer which must be protected from erosion.	Moderate to High	Moderate	RETAINED, for possible use to reduce infiltration over localized areas. May be incompatible with future land use plans.

TABLE 5.3. SECONDARY SCREENING OF REMEDIAL TECHNOLOGIES
Nevada Environmental Response Trust Site; Henderson, Nevada

GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTIONS	EFFECTIVENESS	IMPLEMENTABILITY	RELATIVE COST CAPITAL	RELATIVE COST O&M	SCREENING COMMENTS
CONTAINMENT (continued)	**Capping / Surface Water Recharge Control (continued)**	**Asphalt / Concrete Paving**	Demonstrated effective for reducing infiltration and contaminant migration. Concrete is subject to cracking.	Readily implementable.	Low to Moderate	Low	RETAINED, for possible use to reduce infiltration over localized areas. May be incompatible with future land use plans.
		Shotcrete	Demonstrated effective in certain applications. Shotcrete can be applied to steep slopes to form a seal for slope stabilization and erosion control. Shotcrete has a tendency to crack, which reduces its effectiveness as a cover material and in preventing infiltration.	Readily implementable.	Moderate	Low to Moderate	REJECTED. Steep drainages are not present at the Site.
GROUNDWATER EXTRACTION	**Groundwater Extraction ("Pump & Treat")**	**Extraction Wells**	Demonstrated effective and widely used for groundwater recovery. Effectiveness of recovery depends primarily on local hydrogeology.	Readily implementable.	Moderate	Low to Moderate	RETAINED. Already implemented at the Site for groundwater recovery for ex-situ treatment.
		Subsurface Drains and Interceptor Trenches	Demonstrated effective and widely used for groundwater recovery. Effectiveness of recovery depends primarily on local hydrogeology.	Readily implementable.	Low to Moderate	Low	RETAINED. Potentially applicable to enhance localized groundwater recovery.
EX-SITU GROUNDWATER TREATMENT	**Ex-Situ Physical-Chemical Treatment**	**Air Stripping**	Demonstrated effective and widely used for treatment of VOCs with high Henry's Law constant.	Readily implementable.	Moderate	Moderate	RETAINED. This process is feasible for VOCs, but not effective for inorganics.
		Steam Stripping	Demonstrated effective for treatment of VOCs, but not widely used in groundwater treatment applications.	Implementable.	High	High	REJECTED. This technology is not cost competitive with other comparable technologies.
		Liquid- Liquid Separation / Extraction	Demonstrated effective for removing organic contaminants, but not widely used in groundwater treatment applications.	Implementable, but produces a new and potentially difficult-to-treat liquid waste stream.	High	Moderate to High	REJECTED. This technology is not cost competitive with other comparable technologies.

TABLE 5.3. SECONDARY SCREENING OF REMEDIAL TECHNOLOGIES
Nevada Environmental Response Trust Site; Henderson, Nevada

GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTIONS	EFFECTIVENESS	IMPLEMENTABILITY	RELATIVE COST CAPITAL	RELATIVE COST O&M	SCREENING COMMENTS
EX-SITU GROUNDWATER TREATMENT (continued)	**Ex-Situ Physical-Chemical Treatment (continued)**	**Liquid-Phase Carbon Adsorption Using Granular Activated Carbon**	Demonstrated effective and widely used for treatment of organic contaminants. Not generally effective for inorganic contaminants.	Readily implementable.	Low to Moderate	Moderate	RETAINED. This process is feasible for treatment of VOCs.
		Liquid-Phase Carbon Adsorption Using Tailored GAC (T-GAC)	Demonstrated effective at smaller scales for treatment of various contaminants including perchlorate, but nitrate and sulfate will competitively adsorb resulting in faster breakthrough times for perchlorate.	Implementable, but treatability tests would be required. Limited commercial vendors for this specialized product.	Moderate	Moderate to High	REJECTED due to limited demonstrated use as full-scale groundwater treatment technology and current high costs.
		Chemical Reduction	Demonstrated effective and widely used for treatment of metal-containing and some organic waste streams. Ferrous sulfate currently used at the Site for Cr(VI) removal.	Readily implementable.	Low to Moderate	Moderate	RETAINED. This process is feasible for removal of elevated concentrations of Cr(VI) in conjunction with chemical precipitation.
		Chemical Oxidation	Demonstrated effective and widely used for treatment of organic compounds including VOCs in liquid waste streams. Not effective for treating perchlorate and Cr(VI).	Readily implementable.	Low to Moderate	Moderate to High	REJECTED. This technology is not cost competitive with other comparable process options for treatment of VOCs. Not effective for perchlorate or Cr(VI).
		Advanced Oxidation Processes	Demonstrated effective and widely used for treatment of organic compounds in liquid waste streams. Not effective for treating perchlorate and Cr(VI).	Implementable.	High	High	REJECTED. This technology is not cost competitive with other comparable technologies.
		Chemical Precipitation	Demonstrated effective and widely used for treatment of metal-containing waste streams.	Readily implementable.	Low to Moderate	Moderate	RETAINED. This process is feasible for removal of elevated concentrations of Cr(VI) in conjunction with chemical reduction and is currently in use as part of the interim measures.

TABLE 5.3. SECONDARY SCREENING OF REMEDIAL TECHNOLOGIES
Nevada Environmental Response Trust Site; Henderson, Nevada

GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTIONS	EFFECTIVENESS	IMPLEMENTABILITY	RELATIVE COST CAPITAL	RELATIVE COST O&M	SCREENING COMMENTS
EX-SITU GROUNDWATER TREATMENT (continued)	**Ex-Situ Physical-Chemical Treatment (continued)**	**Coagulation / Flocculation**	Demonstrated effective and widely used for clarification of suspended solids in various waste streams.	Readily implementable.	Low to Moderate	Moderate	RETAINED. Potentially applicable as a polishing or pretreatment step in an aboveground treatment train, but not likely a stand-alone or primary treatment.
		Electrochemical Precipitation	Demonstrated effective for treatment of Cr(VI) and other metal-containing waste streams. Reportedly, can produce less sludge than equivalent chemical reduction process, but involves more complexity and more intensive O&M. Used at the Site until 2004. On-site unit required weekly cleaning with hydrochloric acid to maintain effectiveness.	Readily implementable.	Moderate	Moderate	REJECTED. This process is feasible for removal of elevated concentrations of Cr(VI), but requires more intensive O&M than the ferrous sulfate process currently in use and offers no distinctive advantages.
		Ion Exchange Using Single-Use Resins	Demonstrated effective and widely used for treatment of ionic contaminants. Not effective for VOCs. Single-use ion-exchange treatment was in use at Site from 2001-2004.	Readily implementable.	Moderate	Moderate	RETAINED. This process is suitable for removal of perchlorate and Cr(VI), but not for VOCs. More cost effective at lower influent concentrations. Used at the Site from 2001-2004.
		Ion Exchange Using Regenerable Resins	Demonstrated for treatment of ionic contaminants. Not effective for VOCs. Ion-exchange using regenerable resins was in use at the Site for 6 months in 2002. Maintenance problems were reported due to elevated total dissolved solids, hardness, and sulfate.	Implementable, but requires studies on regerative capabilities and potentially long startup times.	Moderate	High	REJECTED. Difficulties in regeneration have been encountered during previous attempted use at the Site. Costs are expected to be higher than use of single-use resins with little or no performance gains.

TABLE 5.3. SECONDARY SCREENING OF REMEDIAL TECHNOLOGIES
Nevada Environmental Response Trust Site; Henderson, Nevada

GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTIONS	EFFECTIVENESS	IMPLEMENTABILITY	RELATIVE COST CAPITAL	RELATIVE COST O&M	SCREENING COMMENTS
EX-SITU GROUNDWATER TREATMENT (continued)	**Ex-Situ Physical-Chemical Treatment (continued)**	**Reverse Osmosis**	Demonstrated effective as a stand-alone technology to remove perchlorate at low concentrations and produce drinking-quality water. Effective as a polishing step to further reduce perchlorate concentrations from water treated by other technologies including bioreactors, GAC, and/or ion exchange.	Implementable.	High	High	REJECTED. This technology is not cost competitive with other comparable technologies.
		Nanofiltration / Ultrafiltration	Not yet demonstrated to effectively remove perchlorate ions, but capable of managing water with high total dissolved solids as a potential pretreatment step.	Implementable, but treatability tests would be required. Limited commercial vendors for this specialized process.	Moderate	Moderate	REJECTED due to limited effectiveness for treatment of perchlorate and high costs in relation to comparable options.
		Electrodialysis	Demonstrated effective at smaller scales for treating ionic contaminants including perchlorate at low concentrations, but is more effective as a polishing step when coupled with ion exchange. Capable of managing water with high TDS.	Potentially implementable, but treatability tests would be required. Limited commercial vendors for this specialized process.	High	High	REJECTED. This technology is not cost competitive with other comparable technologies.
		Capacitive Deionization	Demonstrated effective for desalination of brackish water at pilot-scale. Not demonstrated as a full-scale treatment.	Potentially implementable, but treatability tests would be required. Limited commercial vendors for this specialized process.	High	High	REJECTED due to low rates of regeneration and current high costs of specialized electrodes.
		Electrolysis	Demonstrated effective for removal of low levels of perchlorate and nitrates in water supply wells in a pilot-scale test. No full-scale demonstrations. Currently has high energy requirements.	Still in research and development; likely not implementable for some time.	High	High	REJECTED. This technology is still in development and is therefore not expected to be cost competitive with other comparable technologies for the foreseeable future.

TABLE 5.3. SECONDARY SCREENING OF REMEDIAL TECHNOLOGIES
Nevada Environmental Response Trust Site; Henderson, Nevada

GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTIONS	EFFECTIVENESS	IMPLEMENTABILITY	RELATIVE COST CAPITAL	RELATIVE COST O&M	SCREENING COMMENTS
EX-SITU GROUNDWATER TREATMENT (continued)	**Ex-Situ Physical-Chemical Treatment (continued)**	**Ultraviolet (UV) Laser Reduction**	Demonstrated in laboratory testing to be effective for decomposing low levels (<100 µg/L) of perchlorate dissolved in water. Not effective for high perchlorate concentrations. Preliminary tests using UV laser reduction indicate that other common perchlorate co-contaminants such as chlorinated solvents can also be decomposed.	Still in research and development; likely not implementable for some time.	High	High	REJECTED. This technology is still in development and is therefore not expected to be cost competitive with other comparable technologies for the foreseeable future.
		Zero Valent Iron (ZVI) Reduction of Perchlorate	Demonstrated in laboratory testing using UV light to be effective for reducing perchlorate to chloride ions, but rates were slow. Laboratory testing using phosphoric acid perchlorate was removed at low pH.	Still in research and development; likely not implementable for some time.	High	High	REJECTED. This technology is still in development and is therefore not expected to be cost competitive with other comparable technologies for the foreseeable future.
		Titanium Reduction	Normally a slow reaction, laboratory study has identified reaction media in which reduction of perchlorate to chloride by Ti(III) takes place quite rapidly (half-life of minutes). The products of the reaction are titanium dioxide (titania) and chloride salts. The produced Ti(IV) can be reduced to Ti(III) by electrochemical or chemical means.	Still in research and development; likely not implementable for some time.	High	High	REJECTED. This technology is still in development and is therefore not expected to be cost competitive with other comparable technologies for the foreseeable future.
		Catalytic Hydrogen Gas Membrane	Laboratory studies have shown that it is possible to reduce perchlorate to chloride in dilute aqueous solutions at greater than 90% efficiency using atomic hydrogen using nonprecious metal catalysts.	Still in research and development; likely not implementable for some time.	High	High	REJECTED. This technology is still in development and is therefore not expected to be cost competitive with other comparable technologies for the foreseeable future.

TABLE 5.3. SECONDARY SCREENING OF REMEDIAL TECHNOLOGIES
Nevada Environmental Response Trust Site; Henderson, Nevada

GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTIONS	EFFECTIVENESS	IMPLEMENTABILITY	RELATIVE COST CAPITAL	RELATIVE COST O&M	SCREENING COMMENTS
EX-SITU GROUNDWATER TREATMENT (continued)	**Ex-Situ Physical-Chemical Treatment (continued)**	**Nanoscale Materials and Bimetallic Particles**	Bimetallic Particles (BMPs) have been demonstrated effective in treating chlorinated solvents and perchlorate in bench-scale studies. Nanoscale ZVI (nZVI) has been demonstrated for treatment of VOCs/DNAPL. High surface energy of these materials make them highly reactive and susceptible to deactivation prior to contacting the targeted contamination. Agglomeration of particles can occur due to pH and other field conditions reduces effectiveness.	Potentially implementable, but treatability/pilot testing is needed to assess implementability under Site conditions. Research is ongoing regarding the potential toxicological/ecological effects of nanoscale materials.	High	High	REJECTED. This is an emerging technology limited to bench- and field studies. Costs are currently high in relation to comparable options. Concerns exist over nanoscale particles' fate, transport, and longevity in the environment.
	Ex-Situ Biological Treatment	**Anaerobic Fluidized Bed Reactors (FBRs)**	Demonstrated effective at sites with varying influent concentrations and flows. Demonstrated effective as long-term reliability as a perchlorate treatment alternative. Can support high-volume flows with smaller reactor sizes than comparable options. Requires pretreatment for Cr(VI) and VOCs to avoid toxic effects to microorganisms.	Implementable, but requires skilled system operators.	Moderate	High	RETAINED. Currently in use at the Site as the primary perchlorate treatment process option.
		Anaerobic Packed-Bed Reactors (PBRs)	Generally effective at lower influent concentrations, and can handle high inlet flows; however, unlike FBRs, there are no known full-scale PBRs treating perchlorate waste streams. Requires pretreatment for Cr(VI) and VOCs to avoid toxic effects to microorganisms.	Implementable, but requires skilled system operators.	Moderate	High	REJECTED. Unproven full-scale performance with no distinctive advantages over comparable process options.
		Anaerobic Continuously-Stirred Tank Reactors (CSTRs)	Demonstrated. Can be effective at high influent concentrations and with mixed waste streams (e.g. industrial process flows), but at lower flows than FBRs. Can operate as batch or continuous flow. Needs less pumping energy than FBRs. Requires pretreatment for Cr(VI) and VOCs to avoid toxic effects to microorganisms.	Implementable, but requires skilled system operators.	Moderate	High	RETAINED. This process option is retained as a potential alternative to FBRs.

TABLE 5.3. SECONDARY SCREENING OF REMEDIAL TECHNOLOGIES
Nevada Environmental Response Trust Site; Henderson, Nevada

GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTIONS	EFFECTIVENESS	IMPLEMENTABILITY	RELATIVE COST CAPITAL	RELATIVE COST O&M	SCREENING COMMENTS
EX-SITU GROUNDWATER TREATMENT (continued)	**Ex-Situ Biological Treatment (continued)**	**Constructed Wetlands**	Demonstrated for treatment of a wide variety of organic and inorganic contaminants. Generally more effective at lower inlet concentrations to avoid toxic effects of contaminants. One documented full-scale application for perchlorate had favorable results at ppb inlet concentrations. Pilot-scale tests warranted to evaluate effectiveness at the Site.	Implementable, but requires land that can be dedicated long-term to construction of a wetland. Pilot-scale tests warranted to evaluate effectiveness at the Site.	Moderate	Low	REJECTED. Experience to date with perchlorate waste streams limited to bench and pilot studies except for a single full-scale process treating ppb-level inlet concentrations.
Excavation	**Source Area Soil Excavation**	**Excavation for Off-site Treatment/Disposal**	Demonstrated effective and widely used for a wide variety of contaminants.	Readily implementable for shallow vadose zone source areas. Deeper source areas require excavation through clean soils with more engineering complexity (e.g., sidewall shoring, etc.).	High	Negligible	REJECTED. Shallow soils were excavated as part of the Interim Removal Actions and residual shallow contamination is managed by the SMP. Remaining deep source area soils, should they be identified, would not be remediated by excavation due to the impracticalities and costs of implementing this technology at depth.
		Excavation for On-site Treatment/Disposal	Demonstrated effective for a wide variety of contaminants, but not as widely used as off-site disposal.	Readily implementable for shallow vadose zone source areas. Deeper source areas require excavation through clean soils with more engineering complexity (e.g., sidewall shoring, etc.).	High	Negligible	REJECTED. Shallow soils were excavated as part of the Interim Removal Actions and residual shallow contamination is managed by the SMP. Remaining deep source area soils, should they be identified, would not be remediated by excavation due to the impracticalities and costs of implementing this technology at depth.

TABLE 5.3. SECONDARY SCREENING OF REMEDIAL TECHNOLOGIES
Nevada Environmental Response Trust Site; Henderson, Nevada

GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTIONS	EFFECTIVENESS	IMPLEMENTABILITY	RELATIVE COST CAPITAL	RELATIVE COST O&M	SCREENING COMMENTS
EX-SITU SOURCE AREA TREATMENT (continued)	**Ex-Situ Physical-Chemical Treatment (continued)**	**Thermal Treatment**	Effective for removing VOCs/DNAPLS and low-boiling semi-volatile organic compounds. High temperature incineration may have effectiveness with perchlorate, but experience with this is limited.	Implementable, although significant materials handling issues are involved.	High	Moderate to High	REJECTED. Although potentially applicable for VOCs/DNAPLs, this process option is rejected (as are all ex-situ source area soil treatments) because excavation is rejected above.
		Thermal Desorption	Effective in destroying organic contaminants including VOCs/DNAPLs. Limited experience at pilot-scale and on full-scale site demonstrates some effectiveness with perchlorate.	Implementable, although significant materials handling issues are involved.	High	Moderate to High	REJECTED. Although potentially applicable for VOCs/DNAPLs, this process option is rejected (as are all ex-situ source area soil treatments) because excavation is rejected above.
		Off-Site Land Disposal	Demonstrated effective and widely used for a wide variety of contaminants.	Readily implementable.	High	Negligible	REJECTED. Although potentially applicable, this process option is rejected (as are all ex-situ source area soil treatments) because excavation is rejected above.
		On-Site Land Disposal	Demonstrated effective for a wide variety of contaminants, but not as widely used as off-site disposal.	Implementable, but would require a potentially large area of the Site to be dedicated as a landfill.	High	Moderate	REJECTED. Although potentially applicable, this process option is rejected (as are all ex-situ source area soil treatments) because excavation is rejected above.
		Solidification / Stabilization (S/S)	Demonstrated for treatment of metals in soils; however, effectiveness varies by metal and the specific agent used. Cr(VI) is difficult to stabilize in cement due to formation of anions that are soluble at high pH. Typically, chemical reduction of Cr(VI) is required as a pretreatment step. Bitumen should not be used where strong oxidants, such as chlorate and perchlorate are present due to explosive hazards.	Implementable, although significant materials handling issues are involved.	Moderate to High	Moderate	REJECTED. Although potentially applicable, this process option is rejected (as are all ex-situ source area soil treatments) because excavation is rejected above.

TABLE 5.3. SECONDARY SCREENING OF REMEDIAL TECHNOLOGIES
Nevada Environmental Response Trust Site; Henderson, Nevada

GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTIONS	EFFECTIVENESS	IMPLEMENTABILITY	RELATIVE COST CAPITAL	RELATIVE COST O&M	SCREENING COMMENTS
EX-SITU SOURCE AREA TREATMENT (continued)	**Ex-Situ Physical-Chemical Treatment (continued)**	**Vitrification**	Demonstrated effective and widely used for metals. Most soils can be treated by vitrification and a wide variety of inorganic and organic contaminants can be targeted. Additional treatment steps may be necessary: including physical separation, mixing, and off-gas collection and treatment. Arsenic-containing wastes may require pretreatment to produce less volatile forms.	Implementable, although significant materials handling issues are involved.	High	Moderate	REJECTED. Although potentially applicable, this process option is rejected (as are all ex-situ source area soil treatments) because excavation is rejected above.
		Soil Washing	Demonstrated effective for metals including chromium, but under only certain soil conditions. Not demonstrated for perchlorate or VOCs. Conditions that favor soil washing include: having a single principal metal that occurs in dense, insoluble particles and very water or aqueous leachant soluble; and a soil containing a high proportion of soil particles >2 mm.	Implementable, although significant materials handling issues are involved.	Moderate to High	Moderate	REJECTED. Although potentially applicable, this process option is rejected (as are all ex-situ source area soil treatments) because excavation is rejected above.
		Solvent Extraction	Demonstrated effective in treating soils containing organic contaminants. Organically bound metals can be extracted along with the target contaminants, thereby creating residuals with special handling requirements. Traces of solvent may remain within the treated soil matrix. Higher clay content reduces extraction efficiency.	Implementable, although significant materials handling issues are involved. Produces a difficult-to-treat waste stream.	High	Moderate	REJECTED. Although potentially applicable, this process option is rejected (as are all ex-situ source area soil treatments) because excavation is rejected above. Also, there are concerns over residual solvents and heavy metals in the soil matrix and the production of a new complex liquid waste stream.
		Chemical Oxidation	Demonstrated effective for VOCs using commercial oxidizing agents including potassium permanganate, hydrogen peroxide, hypochlorite and ozone. However, it is an inefficient use of oxidizing agents within a soil matrix.	Implementable, although significant materials handling issues are involved.	Moderate	Low to Moderate	REJECTED. Although potentially applicable for VOCs, this process option is rejected (as are all ex-situ source area soil treatments) because excavation is rejected above.

TABLE 5.3. SECONDARY SCREENING OF REMEDIAL TECHNOLOGIES
Nevada Environmental Response Trust Site; Henderson, Nevada

GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTIONS	EFFECTIVENESS	IMPLEMENTABILITY	RELATIVE COST CAPITAL	RELATIVE COST O&M	SCREENING COMMENTS
EX-SITU SOURCE AREA TREATMENT (continued)	**Ex-Situ Physical-Chemical Treatment (continued)**	**Chemical Reduction**	Demonstrated effective for VOCs and metals using commercial reducing agents including alkali metals (Na, K), sulfur dioxide, sulfite salts, and ferrous sulfate. However, it is an inefficient use of reducing agents within a soil matrix. Not effective for perchlorate due to high activation energy of the perchlorate ion.	Implementable, although significant materials handling issues are involved.	Moderate	Low to Moderate	REJECTED. Although potentially applicable for VOCs and Cr(VI), this process option is rejected (as are all ex-situ source area soil treatments) because excavation is rejected above.
		Neutralization	Demonstrated effective for acidic soils.	Implementable, although significant materials handling issues are involved.	Moderate	Low to Moderate	REJECTED. Although potentially applicable as an amendment to other process options, this process option is rejected (as are all ex-situ source area soil treatments) because excavation is rejected above.
	Ex-Situ Biological Treatment	**Composting**	Demonstrated effective for perchlorate and VOCs.	Implementable, although significant materials handling issues are involved.	Moderate	Low to Moderate	REJECTED. Although potentially applicable for perchlorate and VOCs, this process option is rejected (as are all ex-situ source area soil treatments) because excavation is rejected above.
IN-SITU GROUNDWATER AND SOURCE AREA TREATMENT	**In-Situ Physical-Chemical Treatment**	**Soil Flushing**	Demonstrated in the homogeneous subsurface. Heterogeneity may greatly limit the extent of flushing. Fine soil fractions in the UMCf and caliche encountered in the alluvium at the Site may limit effectiveness. To limit mobilization of contaminants, hydraulic control would need to be established.	Implementable, but treatability/pilot-testing is required to evaluate site-specific performance.	Low to Moderate	Low to Moderate	RETAINED. This process option is potentially applicable for reducing high concentrations of perchlorate in on-site vadose zone soils upgradient--and within the capture zone--of the on-site extraction wells. Treatability/pilot-testing necessary to evaluate performance.

TABLE 5.3. SECONDARY SCREENING OF REMEDIAL TECHNOLOGIES
Nevada Environmental Response Trust Site; Henderson, Nevada

GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTIONS	EFFECTIVENESS	IMPLEMENTABILITY	RELATIVE COST CAPITAL	RELATIVE COST O&M	SCREENING COMMENTS
IN-SITU GROUNDWATER AND SOURCE AREA TREATMENT (continued)	**In-Situ Physical-Chemical Treatment (continued)**	**Co-Solvent / Surfactant Flushing**	Demonstrated for VOC source zone and DNAPL removal. Heterogeneity may greatly limit the extent of flushing. Limited data on performance for metals impacted soils. Fine soil fractions in the UMCf and caliche encountered in the alluvium at the Site may limit effectiveness. To limit mobilization of contaminants, hydraulic control would need to be established.	Implementable, but treatability/pilot-testing is required to evaluate site-specific performance. Relies on reagents that may hinder existing groundwater treatment.	Moderate	Moderate to High	REJECTED due to concerns of secondary effects and relatively high cost. Solubilizing concentrated contaminants into a diluted solvent/surfactant matrix makes recovery and treatment more difficult and costly. Offers no distinctive advantages over soil flushing for COPCs.
		Air Sparging	Demonstrated effective and widely used for treatment of VOCs in groundwater. Less effective in heterogeneous and low-permeability water bearing zones.	Implementable.	Low to Moderate	Low to Moderate	RETAINED. Potentially applicable for removal of VOCs from shallow groundwater. Could also be employed to deliver gaseous phase substrate for enhanced reductive bioremediation of perchlorate. Effectiveness may be limited in the UMCf.
		In-Situ Well Stripping ("UVB Wells")	Demonstrated for VOCs with high Henry's Law Constants. Radius of influence is significantly reduced in heterogeneous and low-permeability water bearing zones.	Implementable.	Moderate	Low	RETAINED. Potentially applicable for removal of VOCs from shallow groundwater.
		Soil Vapor Extraction (SVE)	Demonstrated for soil remediation of VOCs having high Henry's Law Constants. Radius of influence is significantly reduced in heterogeneous and low-permeability soils.	Implementable for shallow soils. Pilot testing is needed to assess implementability under Site conditions.	Low to Moderate	Low to Moderate	RETAINED. Potentially applicable for removal of VOCs from shallow source area soils and in conjunction with other in-situ process options (e.g., air sparging, thermal technologies).

TABLE 5.3. SECONDARY SCREENING OF REMEDIAL TECHNOLOGIES
Nevada Environmental Response Trust Site; Henderson, Nevada

GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTIONS	EFFECTIVENESS	IMPLEMENTABILITY	RELATIVE COST CAPITAL	RELATIVE COST O&M	SCREENING COMMENTS
IN-SITU GROUNDWATER AND SOURCE AREA TREATMENT (continued)	**In-Situ Physical-Chemical Treatment (continued)**	**Multi-Phase Extraction (MPE)**	Demonstrated for VOC/DNAPL source zone removal in shallow aquifers. Most effective with LNAPL; limited ability to recover DNAPL. Contaminants not destroyed in situ. Above ground treatment required.	Implementable in a shallow aquifer. Pilot testing is needed to assess implementability under Site conditions.	Moderate	Moderate	RETAINED. Potentially applicable for removal of VOCs/DNAPL from groundwater and source area soils.
		Dual-Phase Extraction (DPE)	Demonstrated for remediation of VOCs in shallow aquifers. Contaminants not destroyed in situ. Above ground treatment required.	Implementable in a shallow aquifer. Pilot testing is needed to assess implementability under Site conditions.	Moderate	Moderate	RETAINED. Potentially applicable for removal of VOCs from groundwater and source area soils.
		Electrokinetics	Demonstrated effective at bench- and pilot-scale for sequestering heavy metals, anions, and polar organics in soil, mud, sledge, and marine dredging. Effective in low permeability soils with moisture contents above 10%. There have been few, if any, commercial applications of electrokinetic remediation in the United States.	Potentially implementable, but additional studies would be necessary to assess implementability under Site conditions. Not implementable in the vicinity of underground structures, utilities, and/or buried metal debris.	High	High	REJECTED. Experience to date limited to bench and pilot studies except for a metal removal process that has been commercially operated by a single European vendor.
		Solidification / Stabilization (S/S)	In situ S/S has been demonstrated for treatment of heavy metals in soils. Cr(VI) can be difficult to stabilize due to formation of anions that are soluble at high pH. Typically, chemical reduction of Cr(VI) is required as a pretreatment step. Future usage of the site may "weather" the materials and affect the ability to maintain immobilization of contaminants.	Potentially implementable, but certain materials are incompatible with variations of this process. Also, there are challenges in achieving complete and uniform mixing in-situ. Additional studies would be necessary to assess implementability under Site conditions.	Moderate to High	Low	REJECTED. Concerns exist over effectiveness with Site contaminants and the long-term reliability of treatment. Difficulty in achieving uniform mixing in-situ limits implementability.

TABLE 5.3. SECONDARY SCREENING OF REMEDIAL TECHNOLOGIES
Nevada Environmental Response Trust Site; Henderson, Nevada

GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTIONS	EFFECTIVENESS	IMPLEMENTABILITY	RELATIVE COST CAPITAL	RELATIVE COST O&M	SCREENING COMMENTS
IN-SITU GROUNDWATER AND SOURCE AREA TREATMENT (continued)	**In-Situ Physical-Chemical Treatment (continued)**	**Geochemical Fixation**	Demonstrated effective at immobilizing Cr(VI) using ferrous sulfate reduction and precipitation. However, ferrous sulfate based reductants may result in iron precipitation and clogging aquifer pore spaces. Reduced Cr could re-oxidize to Cr(VI) under certain conditions including presence of manganese dioxide.	Implementable, but treatability/pilot-testing is required to evaluate site-specific performance and long-term reliability.	Low to Moderate	Low	REJECTED. Concerns exist over clogging aquifer pore spaces and the long-term reliability of treatment.
		Vitrification	In-situ methods still in demonstration phase. The maximum treatment depth has been demonstrated to be about 20 feet. Limited data on long-term effectiveness. When excess chlorides are present, there is a possibility that dioxins and furans may form and enter the off-gas treatment system.	Potentially implementable for a small depth horizon (>5 and <20 feet below grade), but not in the vicinity of underground structures, utilities, and/or buried metal debris. Requires extensive pilot testing. Limited commercial availability.	High	Low	REJECTED. In-situ vitrification is still in development stage and has depth limitations. Higher costs than comparable technologies. Concerns exist over the long-term reliability of treatment and the generation of off-gas that must be treated.
		Steam / Hot Water Injection	Demonstrated effective for removal of VOCs from unsaturated and saturated zones. Not demonstrated for perchlorate or Cr(VI), but is expected to have some soil flushing capability. Most effective when the steam is able to enter the pore space of the soils and best suited for zones of moderate to high permeability. Steam dissolves, vaporizes, and mobilizes contaminants, which must be recovered using vapor and liquid extraction equipment for subsequent treatment.	Implementable, but a pilot study likely necessary to evaluate vapor recovery. There are relatively few commercial vendors for this technology.	High	High	REJECTED. The primary target contaminant groups for steam or hot water flushing/stripping are SVOCs and fuels. VOCs also can be treated by this technology, but there are more cost-effective processes for VOCs.

TABLE 5.3. SECONDARY SCREENING OF REMEDIAL TECHNOLOGIES
Nevada Environmental Response Trust Site; Henderson, Nevada

GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTIONS	EFFECTIVENESS	IMPLEMENTABILITY	RELATIVE COST CAPITAL	RELATIVE COST O&M	SCREENING COMMENTS
IN-SITU GROUNDWATER AND SOURCE AREA TREATMENT (continued)	**In-Situ Physical-Chemical Treatment (continued)**	**Electric Resistivity Heating (ERH)**	Demonstrated effective for removal of VOCs from unsaturated and saturated zones. ERH is particularly suited to the treatment of lower permeability strata and to DNAPLs that have become consolidated within lower permeability zones with higher organic content. Has the potential for short-term mobilization of contaminants in groundwater that must be monitored/addressed.	Implementable, but a pilot study likely necessary to evaluate vapor recovery. There are relatively few commercial vendors for this technology.	High	High	REJECTED. This technology is not cost competitive with other comparable technologies.
		Radio Frequency (RF) Heating	RF-heating, a variety of ERH that uses radio-frequency energy, has been applied to remediation of VOCs in the unsaturated zone, but its applicability in the saturated zone has been limited. Has the potential for short-term mobilization of contaminants in groundwater that must be monitored/addressed.	Implementable, but a pilot study likely necessary to evaluate vapor recovery. There are relatively few commercial vendors for this technology.	High	High	REJECTED. The significant zones of low permeability soils at the Site are expected to be saturated; conditions where this process option has limited applicability. This technology is also not cost competitive with other comparable technologies.
		Thermal Conductive Heating	Thermal conductive heating is suited to treating VOC source zones and DNAPL in most hydrogeologic conditions. Thermal conductive heating differs from other heating methods in that it does not rely solely on steam as a heat source or water as a conductive path. It can heat soils to temperatures in excess of 500°C. Has the potential for short-term mobilization of contaminants in groundwater that must be monitored/addressed.	Implementable, but a pilot study likely necessary to evaluate vapor recovery. There are relatively few commercial vendors for this technology.	High	High	REJECTED. This technology is not cost competitive with other comparable technologies.

TABLE 5.3. SECONDARY SCREENING OF REMEDIAL TECHNOLOGIES
Nevada Environmental Response Trust Site; Henderson, Nevada

GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTIONS	EFFECTIVENESS	IMPLEMENTABILITY	RELATIVE COST CAPITAL	RELATIVE COST O&M	SCREENING COMMENTS
IN-SITU GROUNDWATER AND SOURCE AREA TREATMENT (continued)	**In-Situ Physical-Chemical Treatment (continued)**	**In-Situ Chemical Reduction (ISCR)**	Zero valent iron (ZVI) and other reducing agents are demonstrated for VOC and DNAPL removal. Organic contaminants destroyed in-situ; some inorganic contaminants are potentially immobilized. Iron particles may be difficult to distribute in a low permeability formation, such as the UMCf.	Implementable, but treatability/pilot testing needed to evaluate implementability at the Site.	Moderate	Low	RETAINED. Potentially applicable for remediation of VOCs in shallow groundwater.
		In-Situ Chemical Oxidation (ISCO)	Demonstrated effective at rapidly and completely destroying many VOCs and DNAPLs; other organics are amenable to partial degradation. Field applications demonstrate that matching the oxidant and in-situ delivery system to the target contaminants and the site conditions is the key to successful implementation. Naturally-occurring organics and other organic matter can increase oxidant demand. Not effective in treating perchlorate and Cr(VI).	Implementable, but treatability studies likely needed to determine implementability and dosing.	Moderate	Low	RETAINED. Potentially applicable for remediation of localized high concentrations of VOCs/DNAPLs in groundwater.
		In-Situ Nanoscale Materials and Bimetallic Particles	BNPs have been demonstrated effective in treating chlorinated solvents and perchlorate in bench and field-scale studies. nZVI has been demonstrated for treatment of VOCs/DNAPL in bench- and field-studies. High surface energy of nanoscale materials makes them highly reactive and susceptible to passivation (i.e., deactivation) prior to contacting the targeted contamination. Agglomeration of particles can occur due to pH and other field conditions reduces effectiveness.	Potentially implementable, but treatability/pilot testing is needed to assess implementability under Site conditions. Knowledge is limited on the fate and transport of nanoscale materials, and their longevity, in the environment.	High	High	REJECTED. This is an emerging technology limited to bench- and field studies. Costs are currently high in relation to comparable technologies. Research is ongoing regarding the potential toxicological effects of nanoscale materials.

TABLE 5.3. SECONDARY SCREENING OF REMEDIAL TECHNOLOGIES
Nevada Environmental Response Trust Site; Henderson, Nevada

GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTIONS	EFFECTIVENESS	IMPLEMENTABILITY	RELATIVE COST CAPITAL	RELATIVE COST O&M	SCREENING COMMENTS
IN-SITU GROUNDWATER AND SOURCE AREA TREATMENT (continued)	**In-Situ Biological Treatment**	**Enhanced Reductive Bioremediation - Mobile Amendments**	Demonstrated and widely used for VOCs and perchlorate contamination in groundwater. Perchlorate and VOCs destroyed in-situ. Cr(VI) can be reduced and immobilized by this process option, but not destroyed. Various substrate types and delivery approaches available. Biofouling of recirculation wells can hinder performance.	Implementable, but treatability/pilot testing is needed to evaluate performance under Site conditions.	Moderate	Moderate	RETAINED. Recirculation may not be cost-effective for plume-wide implementation compared to other substrate delivery modes and comparable process options due to the significant volume of groundwater to be processed.
		Enhanced Reductive Bioremediation - Fixed Biobarriers	Demonstrated and widely used for VOCs and perchlorate contamination in shallow aquifers. Perchlorate and VOCs destroyed in-situ. Cr(VI) can be reduced and immobilized by this process option, but not destroyed. Various substrate types available. Replacement of slow-release substrates for biobarrier systems may be required if the design life for remediation extends longer than the life span of the substrate.	Potentially implementable for shallow groundwater, but substrate longevity and groundwater velocity may limit implementability. Treatability/pilot testing is needed to assess implementability under Site conditions.	Moderate to High	Low to Moderate	RETAINED. Potentially applicable downgradient of Athens Road Well Field where concentrations are lower and groundwater is shallow. Life-cycle capital costs may be high if the perchlorate concentrations upgradient of the biobarrier do not attenuate.
		Bioaugmentation	Demonstrated for VOCs, but treatability studies are be required. Since perchlorate-reducing bacteria are considered ubiquitous, bioaugmentation has yet to be demonstrated as necessary for in-situ treatment of perchlorate. Cr(VI) can have inhibitory and/or toxic effects on introduced microorganisms.	Potentially implementable, but treatability/pilot testing is needed to assess implementability under Site conditions.	Moderate to High	Low	RETAINED. Potentially applicable as an enhancement to in-situ bioremediation process options for treatment of VOCs, but presence of Cr(VI) may limit implementability.

TABLE 5.3. SECONDARY SCREENING OF REMEDIAL TECHNOLOGIES
Nevada Environmental Response Trust Site; Henderson, Nevada

GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTIONS	EFFECTIVENESS	IMPLEMENTABILITY	RELATIVE COST CAPITAL	RELATIVE COST O&M	SCREENING COMMENTS
IN-SITU GROUNDWATER AND SOURCE AREA TREATMENT (continued)	**In-Situ Biological Treatment (continued)**	**Enhanced Reductive Bioremediation via Liquid Phase Substrate Addition to Vadose Zone**	Demonstrated at the bench- and field-scale for remediation of organic compounds and perchlorate. Perchlorate and VOCs destroyed in-situ. Cr(VI) can be reduced and immobilized by this process option, but not destroyed. Shallow fine-grained zones and caliche soils may limit infiltration. Biofouling and clogging of pore spaces is a concern under both infiltration and injection delivery scenarios. To limit mobilization of contaminants, hydraulic control may need to established.	Potentially implementable, but treatability/pilot testing is needed to assess implementability under Site conditions.	Moderate	Low to Moderate	RETAINED. Potentially applicable for remediation of perchlorate in vadose zone soils, but not cost-effective for VOCs alone.
		Enhanced Reductive Bioremediation via Gaseous Phase Substrate Addition or "Anaerobic Bioventing"	Demonstrated at the pilot scale for remediation of perchlorate, but still in the development stage. Perchlorate is destroyed in-situ. Theoretically, Cr(VI) could be reduced and immobilized by this process option, but there is limited data to support this. Shallow fine-grained zones and caliche soils may limit substrate delivery. May cause loss of soil moisture that sustains biological activity.	Potentially implementable, but treatability/pilot testing is needed to assess implementability under Site conditions. Limited commercial availability.	Moderate	Moderate to High	REJECTED. This technology is still in development phase and experience at this point is limited to pilot-scale demonstration.
		Phytoremediation	Demonstrated effective, but only at pilot-scale for perchlorate. Most effective where contaminated soil is within 3 feet of surface and contaminated groundwater is within 10 feet of the surface.	Implementable, but specific studies on the types of plants to be used and their viability in this environment would be necessary.	Low	Low	REJECTED. Phytoremediation is still in development stage and has depth limitations. Potential problems implementing in an arid environment.
	In-Situ Process Enhancements	**Pneumatic Fracturing**	Demonstrated. Fractures will close in non-clayey soils. For longer remediation programs, refracturing efforts may be required at 6- to 12-month intervals.	Potentially implementable in the UMCf, but pilot tests would need to be conducted. Not implementable in the shallow alluvium.	Moderate	Low	RETAINED. Potentially applicable in conjunction with other technologies to increase extraction or the effectiveness of substrate delivery in the UMCf.

TABLE 5.3. SECONDARY SCREENING OF REMEDIAL TECHNOLOGIES
Nevada Environmental Response Trust Site; Henderson, Nevada

GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTIONS	EFFECTIVENESS	IMPLEMENTABILITY	RELATIVE COST CAPITAL	RELATIVE COST O&M	SCREENING COMMENTS
IN-SITU GROUNDWATER AND SOURCE AREA TREATMENT (continued)	**In-Situ Process Enhancements (continued)**	**Hydraulic Fracturing**	Demonstrated effective for increasing pumping yields and delivery of substrates for in-situ remediation.	Potentially implementable in the UMCf, but pilot tests would need to be conducted. Not implementable in the shallow alluvium.	Moderate	Low	RETAINED. Potentially applicable in conjunction with other technologies to increase extraction or the effectiveness of substrate delivery in the UMCf.
		Funnel and Gate	Demonstrated effective for controlling groundwater flow and enhancing remedial technologies.	Implementable.	Moderate	Low	RETAINED. Potentially applicable in conjunction with other process options to increase their effectiveness.
		Directional Wells	Demonstrated. This type of well is usually within 100 feet of ground surface.	Implementable.	Moderate	Low	RETAINED. Potentially applicable in conjunction with other in-situ process options to increase their effectiveness.
WATER DISCHARGE	**Surface Water Discharge**	**Surface Water**	Demonstrated effective for discharge of treated groundwater.	Implementable.	Low	Low	RETAINED. This is the current process option for discharge under the Interim Removal Actions.
	Sewer Discharge	**Public Owned Treatment Works (POTW)**	Potentially applicable, depending on flow rates required to achieve dewatering, as well as POTW permit requirements.	Implementable if water can meet pretreatment standards and flow rate restrictions stipulated in permit.	Low	High	RETAINED. However, this option can be very costly compared to other discharge options. Likely only cost effective for small, discrete dewatering applications.
	Water Reuse	**Reclamation**	Limited effectiveness during wet periods. Effective for disposal of a limited portion of effluent.	Implementable if treated water can meet the water quality standards for specific applications.	Low	Low	RETAINED for discharge of treated groundwater if treated water can meet the water quality standards for specific applications.
	Subsurface Water Discharge	**Injection Wells**	Demonstrated effective for discharge of treated groundwater. However, there may be potential problems with biofouling and clogging.	Potentially implementable, but potential problems with biofouling and clogging would need to be studied/addressed.	Low to Moderate	Low to Moderate	RETAINED.

TABLE 5.3. SECONDARY SCREENING OF REMEDIAL TECHNOLOGIES
Nevada Environmental Response Trust Site; Henderson, Nevada

GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTIONS	EFFECTIVENESS	IMPLEMENTABILITY	RELATIVE COST CAPITAL	RELATIVE COST O&M	SCREENING COMMENTS
WATER DISCHARGE (continued)	**Subsurface Water Discharge (continued)**	**Deep Re-Injection Trenches (DRITs)**	Demonstrated effective for discharge of treated groundwater. However, there may be potential problems with biofouling and clogging.	Potentially implementable, but potential problems with biofouling and clogging would need to be studied/addressed.	Moderate	Low to Moderate	RETAINED.
		Infiltration	Demonstrated effective for discharge of treated groundwater. However, there may be potential problems with biofouling and clogging.	Potentially implementable, but potential problems with biofouling and clogging would need to be studied/addressed.	Low to Moderate	Low to Moderate	RETAINED.
		Solar Evaporation	Limited effectiveness during wet periods. Effective for disposal of a limited portion of effluent.	Potentially implementable, although space limitations may be an issue.	Moderate	Low	REJECTED. Anticipated volumes of water would require unreasonably large areas for evaporation to be effective.
EX-SITU VAPOR TREATMENT	**Ex-Situ Vapor / Emissions / Off-gas Treatment**	**Vapor Phase Carbon Adsorption**	Well-demonstrated and widely-used technology for VOCs and other organic and some inorganic compounds.	Implementable. Likely to require air permit.	Low to Moderate	Moderate	RETAINED. This process option applicable only in conjunction with technologies generating vapor emissions requiring treatment.
		Advanced Oxidation	Effective for VOCs, but may produce reaction by-products.	Implementable. Likely to require air permit.	Low to Moderate	Low to Moderate	RETAINED. This process option applicable only in conjunction with technologies generating vapor emissions requiring treatment.
		Catalytic Oxidation	Effective for VOCs, but may produce oxidation by-products.	Implementable. Likely to require air permit.	Moderate	Low to Moderate	RETAINED. This process option applicable only in conjunction with technologies generating vapor emissions requiring treatment.
		Thermal Oxidation	Effective for VOCs, but may produce combustion by-products.	Implementable. Likely to require air permit.	Moderate	Low to Moderate	RETAINED. This process option applicable only in conjunction with technologies generating vapor emissions requiring treatment.

TABLE 5.3. SECONDARY SCREENING OF REMEDIAL TECHNOLOGIES
Nevada Environmental Response Trust Site; Henderson, Nevada

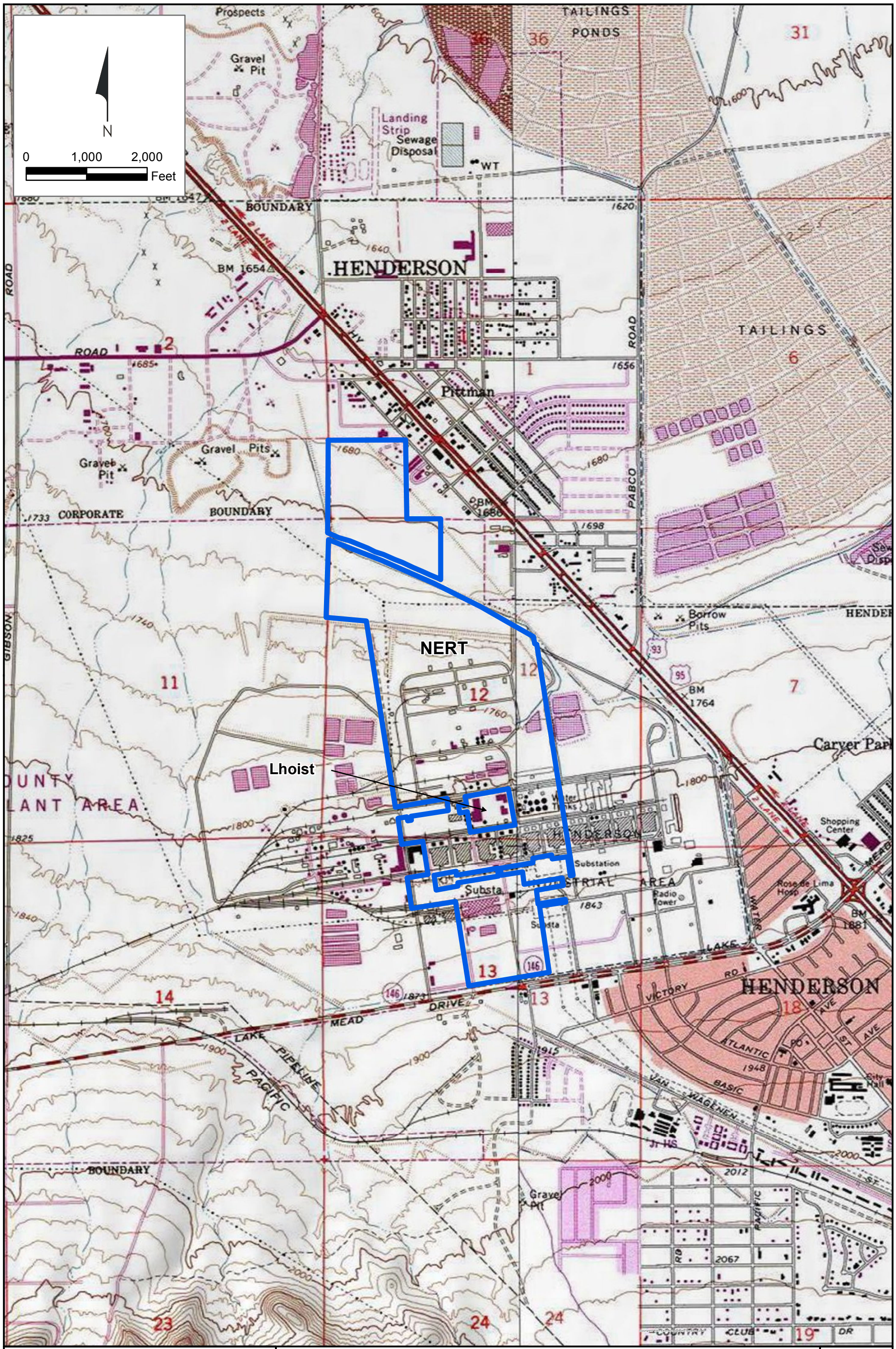
GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTIONS	EFFECTIVENESS	IMPLEMENTABILITY	RELATIVE COST CAPITAL	RELATIVE COST O&M	SCREENING COMMENTS
EX-SITU VAPOR TREATMENT (continued)	**Ex-Situ Vapor / Emissions / Off-gas Treatment (continued)**	**Biofiltration**	Effective for non-chlorinated VOCs and for odor control from biological processes.	Implementable. Likely to require air permit.	Low	Low	RETAINED. This process option applicable only in conjunction with technologies generating vapor emissions requiring treatment.

Notes: COPCs = chemicals of potential concern; Cr(VI) = Hexavalent Chromium; DNAPL = Dense Non-Aqueous Phase Liquids; LNAPL = Light Non-Aqueous Phase Liquids; RAOs = Remedial Action Objectives; TDS = Total Dissolved Solids; UMCf = Upper Miuddy Creek Formation; VOCs = volatile organic compounds; ZVI = Zero Valent Iron

Shaded boxes indicate process options that are retained for the secondary screening evaluation.

Unshaded process options have been eliminated and will not be considered further.

Figures



ENVIRON

2200 Powell St., Suite 700, Emeryville, CA 94608

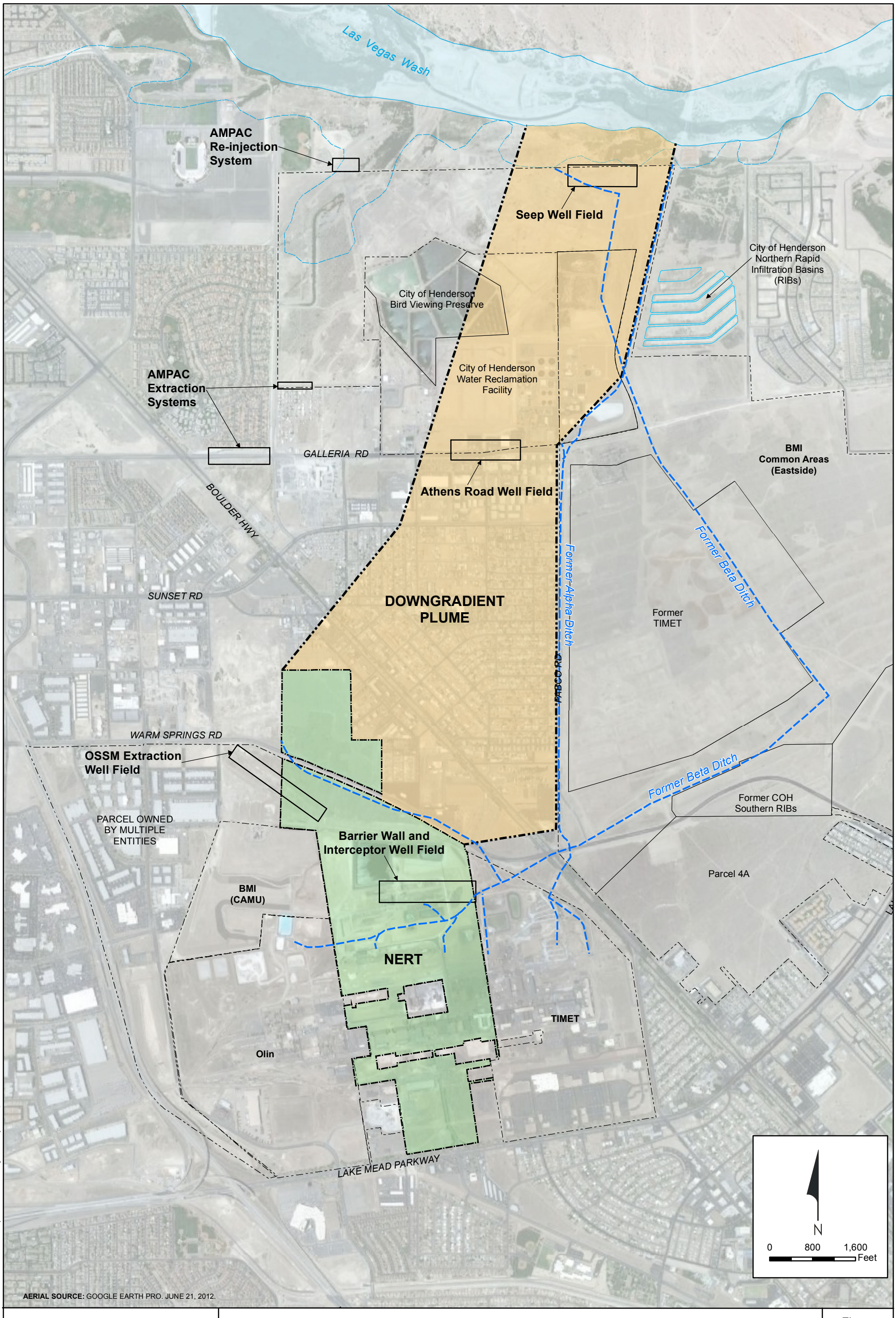
Site Location Map

Nevada Environmental Response Trust Site, Henderson, Nevada

Figure **1-1**

Drafter: RS | Date: 12/14/2012 | Contract Number: 21-29100H | Approved by: | Revised:

Path: H:\LePetomane\NERT\RI.FS_Workplan\GIS\Figure1-1_SiteVicinityMap.mxd



ENVIRON

Study Area
Nevada Environmental Response Trust Site
Henderson, Nevada

DRAWN BY: RS	DATE: 11/30/12	CONTRACT NUMBER: 21-29100H10	APPROVED BY:	REVISED:

Figure
1-2

Path: H:\LePetomane\NERT\GW\Annual Performance Reports\2012 Annual\Figures\StudyAreaMap-Detail1.mxd

N

1:36,000

1 inch = 3,000 feet

0 1,500 3,000 Feet

Las Vegas Wash

City of Henderson Bird Viewing Preserve

City of Henderson Water Reclamation Facility

City of Henderson Northern Rapid Infiltration Basins (RIBs)

GALLERIA RD (Formerly Athens Road)

SUNSET RD

BOULDER HWY

PABCO RD

WARM SPRINGS RD

LAKE MEAD PARKWAY

BMI Common Areas (Eastside)

Former TIMET

Parcel 4B

Former COH Southern RIBs

Parcel 4A

PARCEL OWNED BY MULTIPLE ENTITIES

BMI (CAMU)

NERT

TIMET

Olin

TIMET

Lhoist

WAPA

AMPAC (Former Pepcon)

LAKE MEAD PARKWAY

US HIGHWAY 95

Mc Cullough Range

NEVADA

HENDERSON

AERIAL SOURCE: GOOGLE EARTH PRO. JUNE 21, 2012.

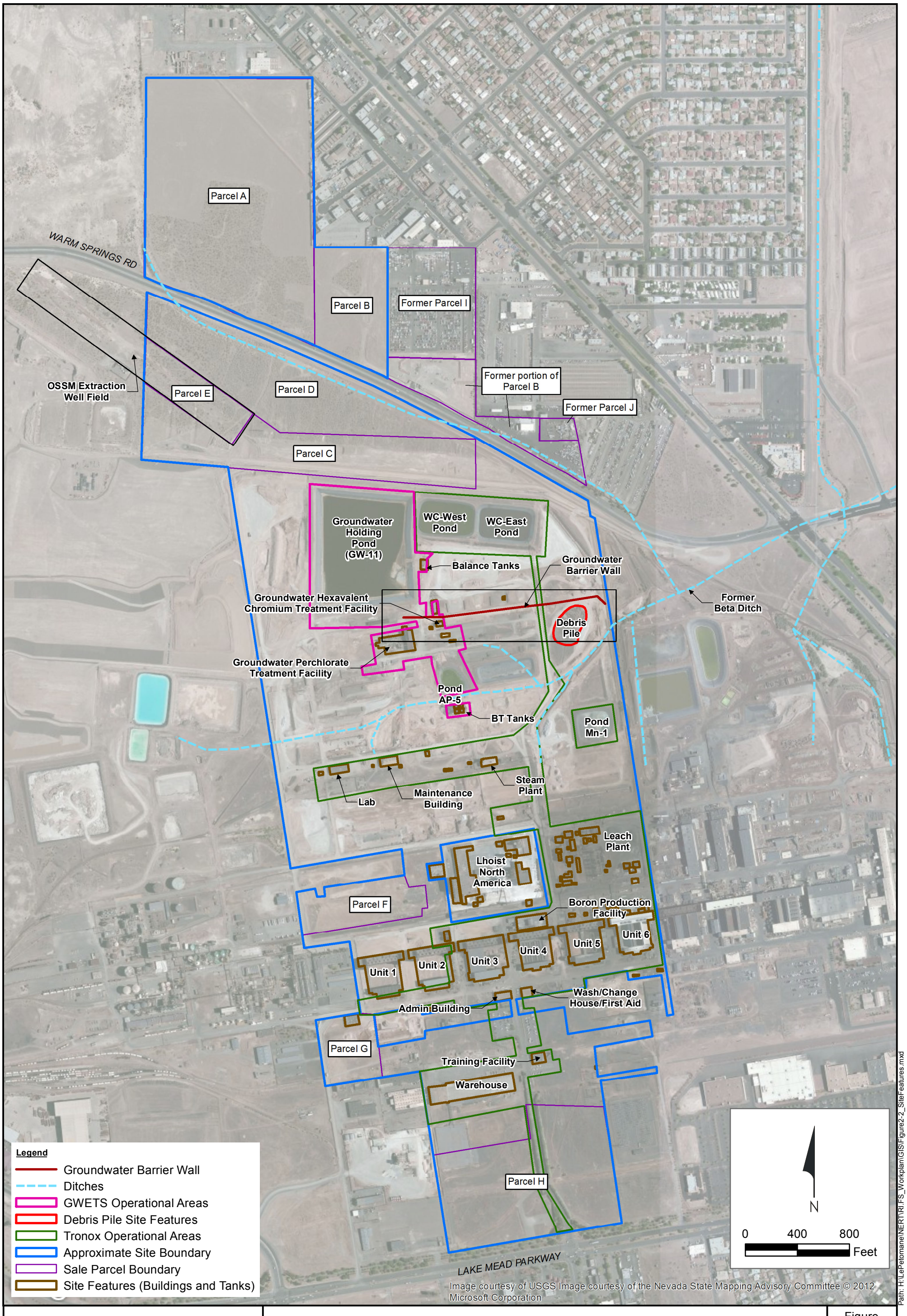
Path: H:\LePetomane\NERT\GWM\Annual Performance Reports\2012 Annual\Figures\StudyAreaMap.mxd

ENVIRON

Surrounding Facilities
Nevada Environmental Response Trust Site
Henderson, Nevada

DRAWN BY: RS | DATE: 11/30/12 | CONTRACT NUMBER: 21-29100H10 | APPROVED BY: | REVISED:

Figure
2-1



ENVIRON

2200 Powell St., Suite 700, Emeryville, CA 94608

Site Features

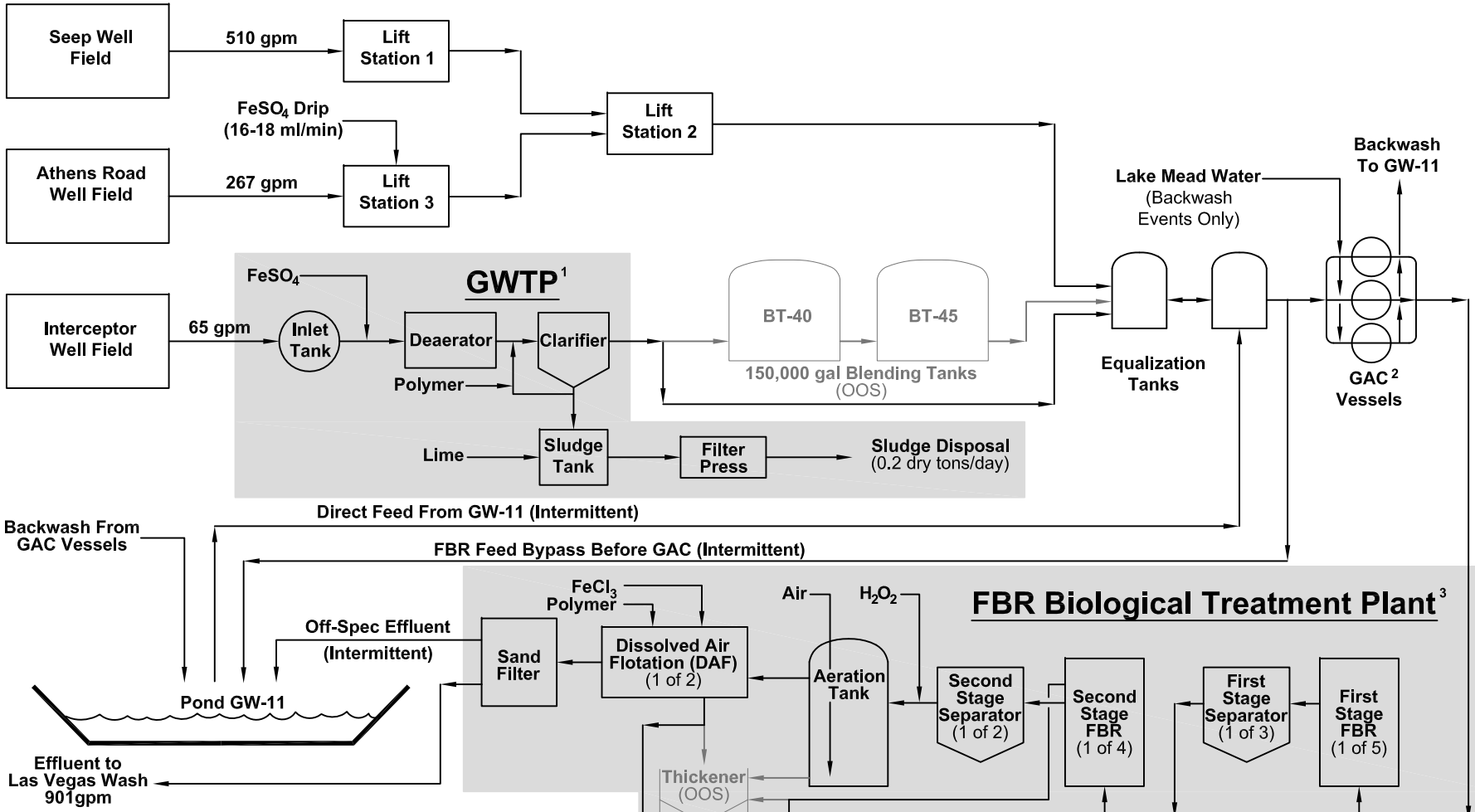
Nevada Environmental Response Trust Site, Henderson, Nevada

Figure **2-2**

Drafter: EA | Date: 12/14/2012 | Contract Number: 21-29100H | Approved by: | Revised:

Path: H:\LePetomane\NERT\RI.FS_Workplan\GIS\Figure2-2_SiteFeatures.mxd

H:\LePetomane\NERT\GWM\Annual Performance Reports\2012 Annual\Figures\Plates\cad\Process Flow Diagram.dwg – Mon, 17 Dec 2012 – 11:46am



NOTES:

The process flows shown are average flow rates from July 2011 through June 2012.
gpm = gallons per minute
ml/min = milliliters per minute
OOS = Out of Service

1) Groundwater Treatment Plant (GWTP) for hexavalent chromium removal. Ferrous sulfate ($FeSO_4$) added to chemically reduce hexavalent chromium. Clarifier settles solids. Sludge is removed and landfilled.
2) Carbon treatment to remove organic compounds consists of three 20,000-pound granular activated carbon (GAC) vessels.
3) Fluidized Bed Reactor (FBR) Biological Treatment Plant for removal of perchlorate consists of five 33,000 gallon first-stage FBRs, four 28,800 gallon second-stage FBRs, aeration (air and hydrogen peroxide, H_2O_2), dissolved air flotation (DAF), two plate and frame filter presses, and a sand filter.

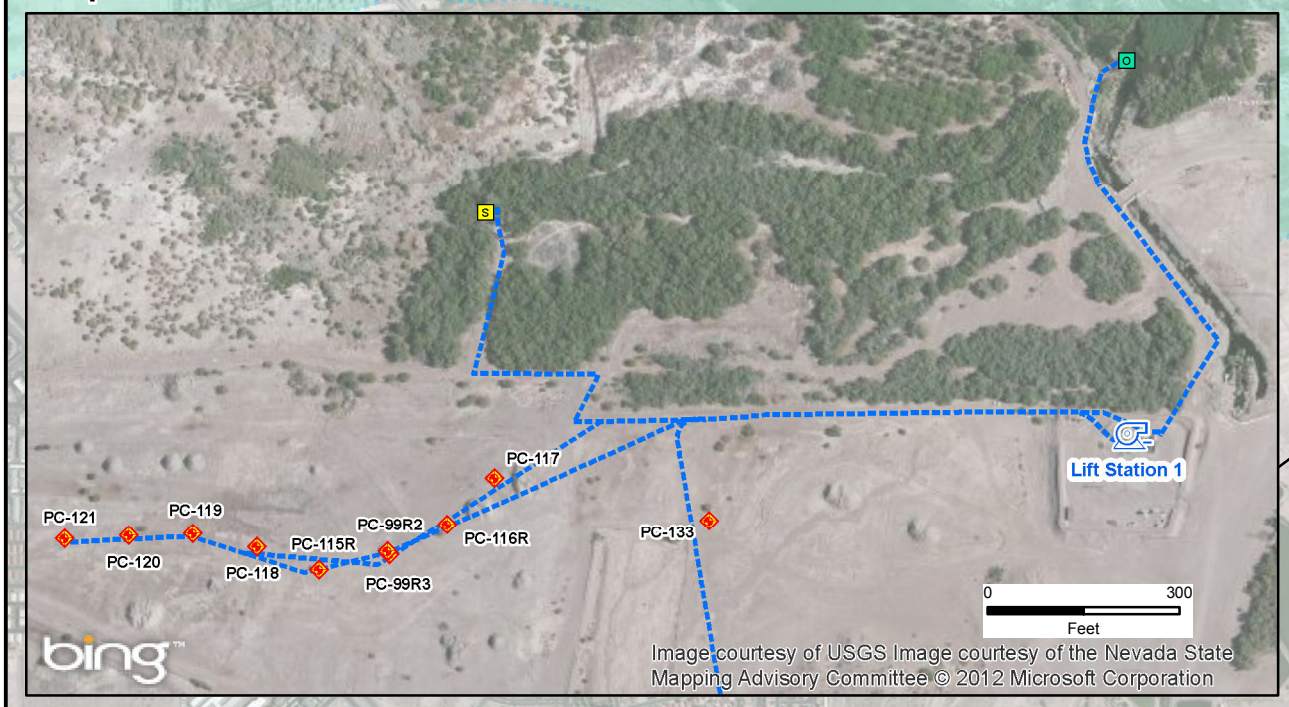
ENVIRON

Groundwater Extraction and Treatment System (GWETS) Flow Diagram
Nevada Environmental Response Trust (NERT)
Henderson, Nevada

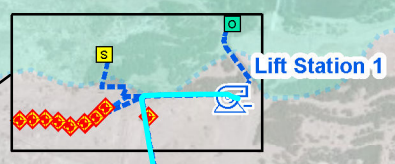
Figure
4-1

Drafter: RS | Date: 11/30/12 | Contract Number: 21-29100H | Approved: | Revised:

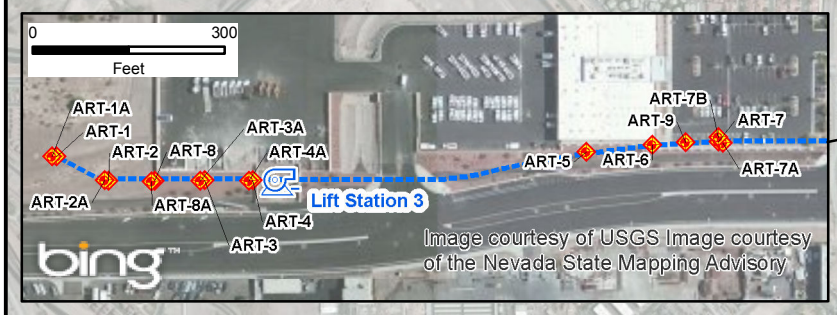
Seep Well Field and Lift Station 1



Las Vegas Wash



Athens Road Well Field and Lift Station 3



GALLERIA DRIVE

Lift Station 3

Lift Station 2

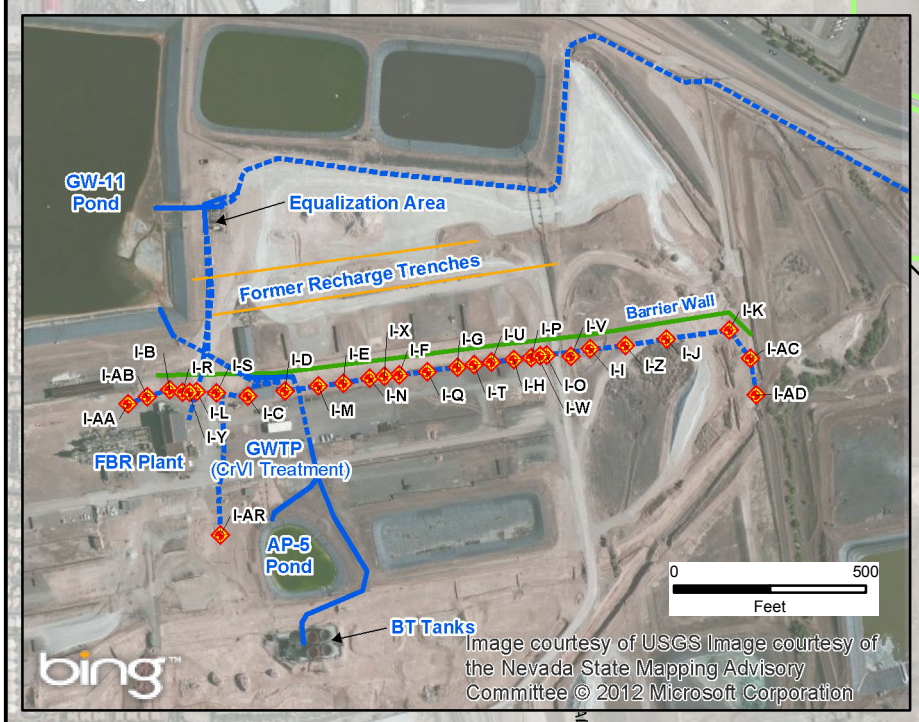
E SUNSET ROAD

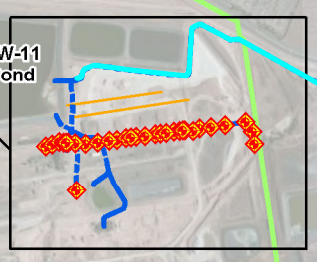
PABCO ROAD

N BOULDER HWY

WARM SPRINGS ROAD

Interceptor Well Field and Treatment Plant





1 : 18,000
1 inch = 1,500 ft
0
1,500
Feet

Legend

- Extraction Wells
- Lift Stations
- Outfall
- Surface Flow Capture Sump (Dry Since 2007)

Influent/Effluent Pipelines

- At Ground Surface
- Underground
- NERT Property Boundary

Pipeline locations are obtained from design drawings and from discussions with onsite personnel and are adjusted based on the relative locations of known facilities. Locations are approximate and are not to be used for construction.

W LAKE MEAD PARKWAY

bing

Image courtesy of USGS Image courtesy of the Nevada State Mapping Advisory Committee © 2012 Microsoft Corporation

Path: H:\LePetomane\NERT\GWETS\Drawings\Pipeline Extraction System\GW_ExtractionTreatmentMap.mxd

ENVIRON

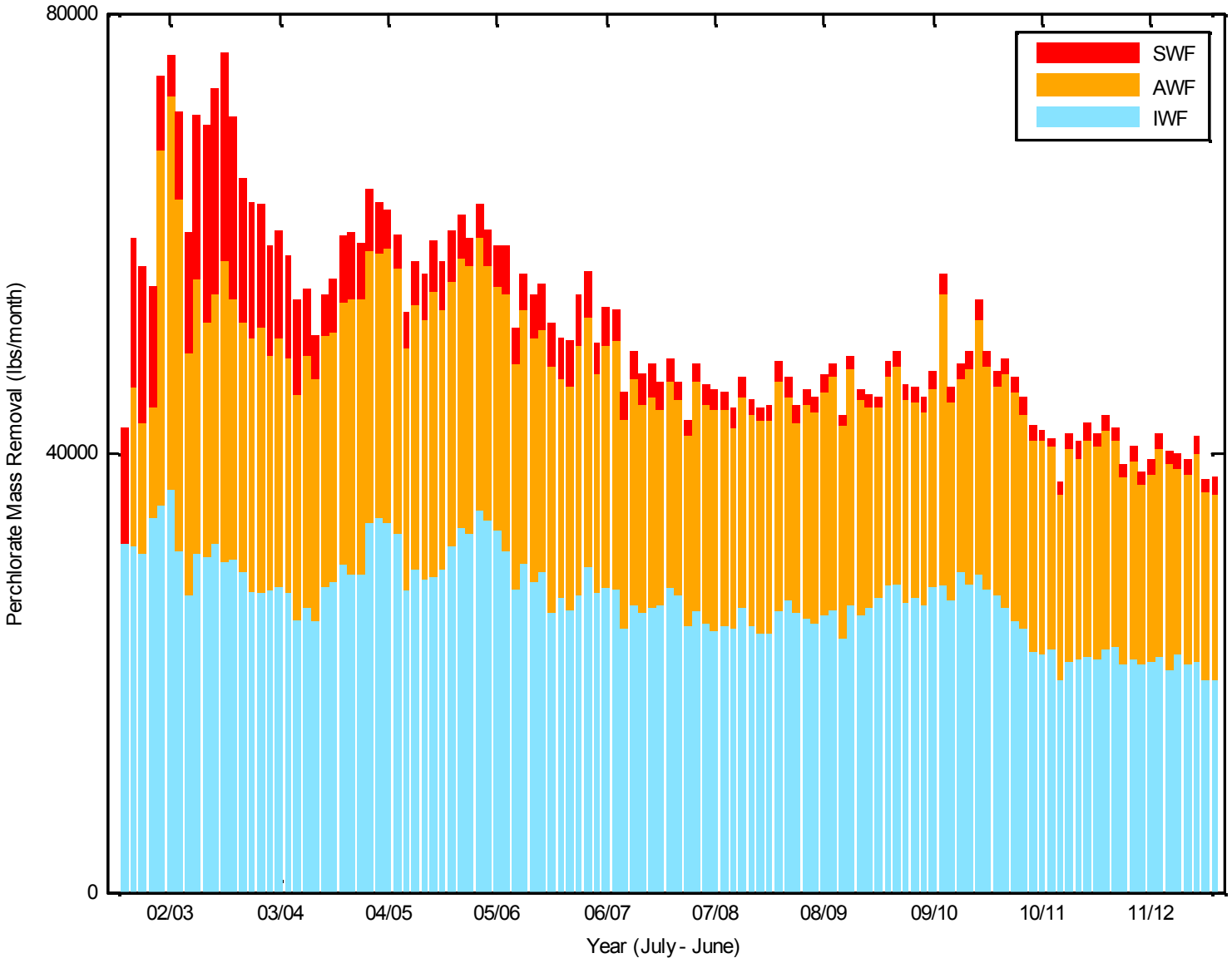
2200 Powell Street, Suite 700, Emeryville, CA 94608

Groundwater Extraction and Treatment System Map

Nevada Environmental Response Trust Site, Henderson, Nevada

Figure **4-2**

Drafter: EA | Date: 12/14/2012 | Contract Number: 21-29100H10 | Approved by: | Revised:



Note: Data are summarized monthly for the period July 2002 - June 2012.

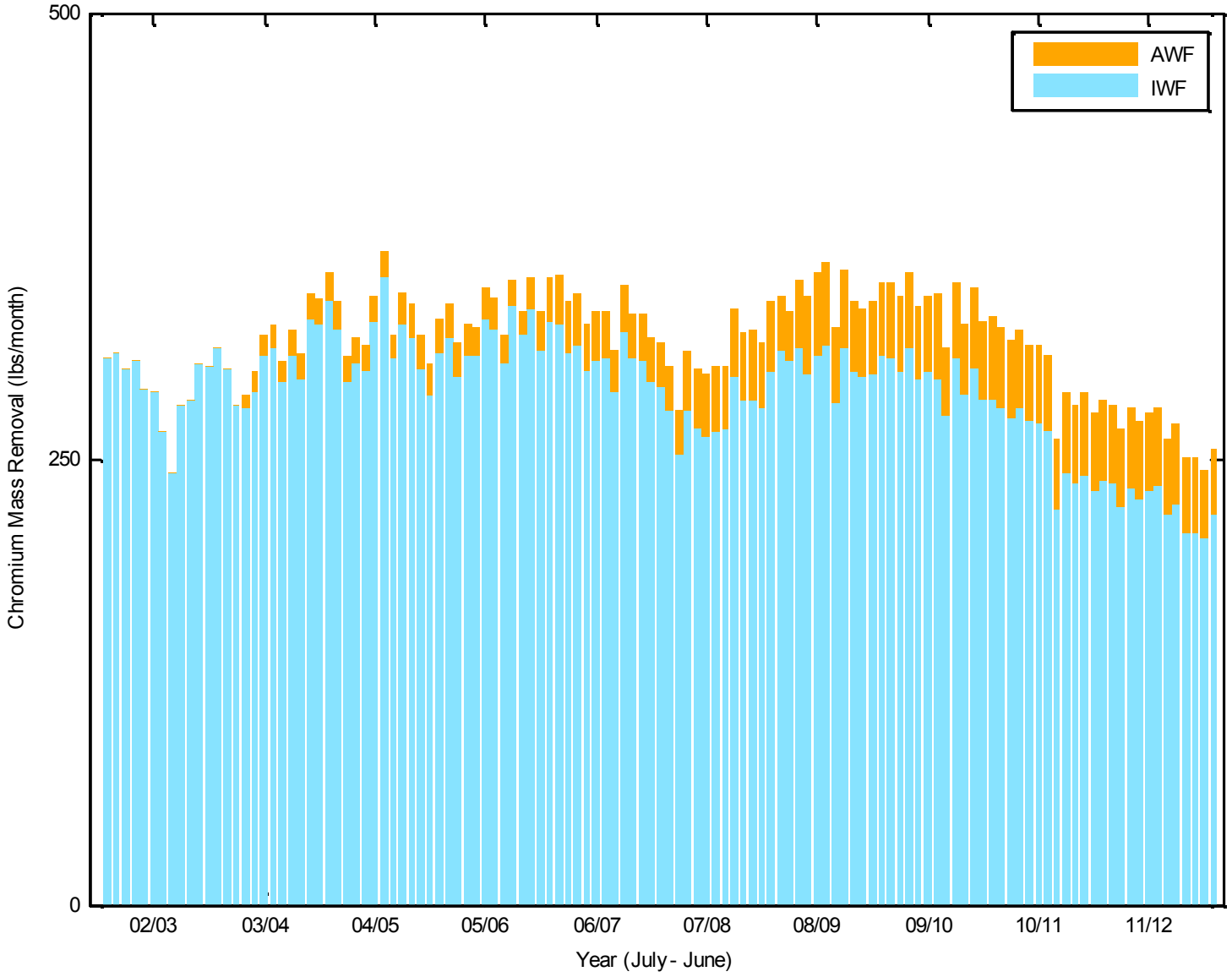
ENVIRON

Perchlorate Mass Removal from Groundwater, 2002-2012
Nevada Environmental Response Trust (NERT) Site
Henderson, Nevada

Figure
4-3

Drafter: JAW Date: 12/15/12 Contract Number: 21-29100H Approved: CJR Revised:

Path: H:\LePetomane\NERT\Matlab\Monthly Perchlorate Removal-2.mxd



Notes: Data are summarized monthly for the period July 2002 - June 2012. Chromium concentrations in the SWF are consistently below laboratory quantitation limits; therefore, the SWF is not included in the system-wide chromium mass removal estimates.

ENVIRON

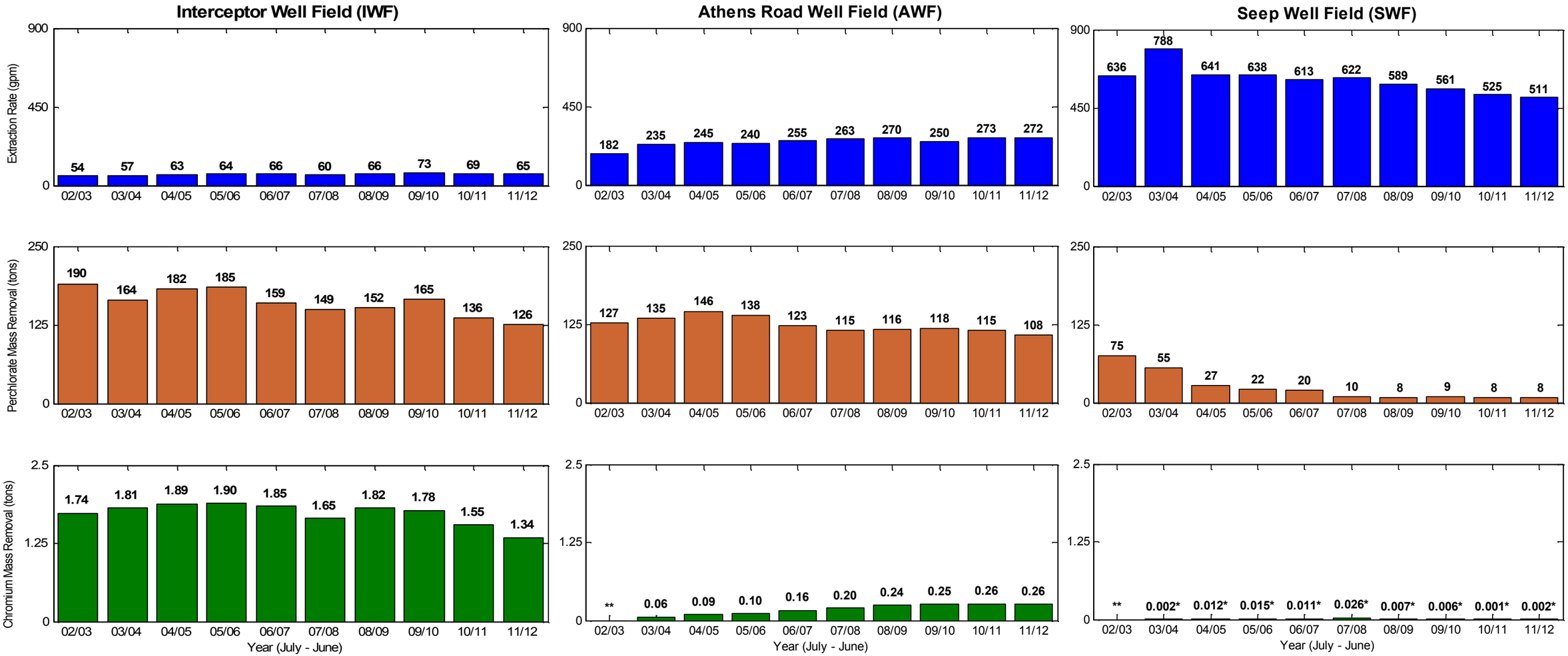
Chromium Mass Removal from Groundwater, 2002-2012
Nevada Environmental Response Trust (NERT) Site
Henderson, Nevada

Figure
4-4

Drafter: JAW Date: 12/15/12 Contract Number: 21-29100H Approved: CJR Revised:

Path: H:\LePetomane\NERT\Matlab\Monthly Chromium Removal-2.mxd

Path: H:\LePetomane\NERT\Matlab\Monthly Chromium Removal-2.mxd



* Chromium concentrations in the SWF are consistently below laboratory quantitation limits. Lacking detectable concentrations the chromium mass removal at the SWF cannot be reliably quantified. The estimates of chromium removal in the SWF were calculated by substituting half of the reporting limit for non-detect values and are presented here for comparison purposes only.

** Chromium analytical data are unavailable at the AWF before October 2003 and at the SWF before May 2004.

Figure **4-5**

Project No.: 21-29100

Well Field Extraction Rates and Chromium and Perchlorate Mass Removals
Nevada Environmental Response Trust (NERT) Site
Henderson, Nevada

DESIGNED BY:	REVISIONS			
JAW	No.	DESCRIPTION:	DATE:	BY:
DRAWN BY:	0	GENERATE APPROVED MAP	12/14/2012	JAW
JAW				
CHECKED BY:				
CJR				
APPROVED BY:				
CJR				

ENVIRON

Path: H:\LePetomane\NERT\Matlab\Mass Removal and Extraction Rate Summary.mxd

N
W E
S

1:24,000

1 inch = 2,000 feet

0 1,200 2,400
Feet

INSET B

ARP-1 ARP-2A ARP-3A MW-K4 ARP-4A ARP-5A ARP-6B ARP-7 PC-145 PC-143 PC-101R PC-144 ART-8A ART-8 PC-135A PC-134A ART-1 PC-142 PC-18 ART-4 ART-4A PC-150 ART-1A PC-55 ART-2 ART-2A ART-3 ART-3A PC-149 PC-148 PC-137 PC-136 ART-7 ART-9 PC-122 PC-147 ART-6 PC-146 ART-7A ART-7B

0 300 600
Feet

INSET C

PC-96 PC-97 PC-117 PC-86 PC-87 PC-119 PC-90 PC-116R PC-133 PC-121 PC-120 PC-88 PC-118 PC-115R PC-99R2/R3 PC-91 PC-92

0 300 600
Feet

INSET A

0 300 600
Feet

Former Recharge Trenches

M-83 M-81A M-80 M-79 M-162 M-164 M-71 M-163 M-72 M-73 M-132 M-74 M-165 M-133 M-129 M-135 M-134 M-69 M-140 M-70 M-161 M-136 M-55 M-78 I-X I-F I-Q I-U M-173 I-I I-Z I-J M-176 M-177 I-K M-130 M-174 M-175 M-68 I-AC I-AD I-V M-58 M-60 M-56 M-66 I-O I-W I-P M-67 I-G I-T I-H M-131 I-AB I-Y I-L I-S I-C I-D I-M I-N I-B M-166 M-168 M-169 M-170 I-AA I-R M-167 M-64 I-E M-65 M-172 Barrier Wall M-182 M-181 M-154 M-36 M-150 M-22A M-25 M-38 I-AR M-37

Las Vegas Wash

PC-74 PC-76 PC-77 PC-78 PC-79 PC-83 PC-81 PC-82 PC-80 PC-94 PC-68 PC-62 PC-60 PC-59 PC-56 PC-58 PC-111 PC-110 HMW-13 PC-108 Inset C Seep Well Field

36 31 32

HM-2 HSW-1 PC-103 PC-98R PC-53 PC-2 PC-4 PC-1 MW-K5 HMW-15 PC-107 Athens Road Well Field Pittman Lateral HMW-16 Inset B L-637 L-635 PC-123 PC-131 PC-130 PC-128 PC-24 PC-125 PC-124 PC-132 PC-50 PC-129 PC-127 PC-126

3 2 1 6 5

SUNSET RD BOULDER HWY PABCO RD PC-28 PC-31 AA-11 H-48 PC-40 PC-66 PC-67 PC-65 PC-64 H-58A TR-12 PC-73 PC-72 M-44 M-95 M-96 PC-71 M-152 M-156 MC-65 MC-6 MC-50 PC-37 PC-54 TR-11 MC-7 MC-53 MC-51 MC82 MC-69 MC-93 MC3 MC-29 MC-97 M-23 M-48A PC-21A BEC-1 M-6A M-7B M-98 M-99 M-155 M-101 H-28A M-151 M-100 Interceptor Well Field Inset A AA-01 CLD-1R M-5A TR-2 TR-1 MW-16 M-57A M-126 M-14A M-19 TR-4 M-125 TR-3 M-142 M-76 M-2A M-35 M-147 M-115 M-75 M-21 M-153 M-33 M-186 M-148A M-128 M-123 M-124 M-149 M-32 M-141 M-31A M-52 M-77 M-97 M-93 TR-6 M-12A M-11 M-29 TR-5 M-92 M-13 M-145 M-144 M-139 M-146 TR-8 M-10 TR-7 M-138 M-137 TR-9 TR-10 M-103 M-118 M-120 M-117 H-11 M-121 LAKE MEAD DR

12 11 10 7 8

15 14 13 18 17

22 23 24

LEGEND

- Sampled / Measured Well
- Nevada Environmental Response Trust Property Boundary

LAND OWNERSHIP

- BMI
- Lhoist
- OSSM
- Timet

Figure
4-6
Project No.: 21-29100

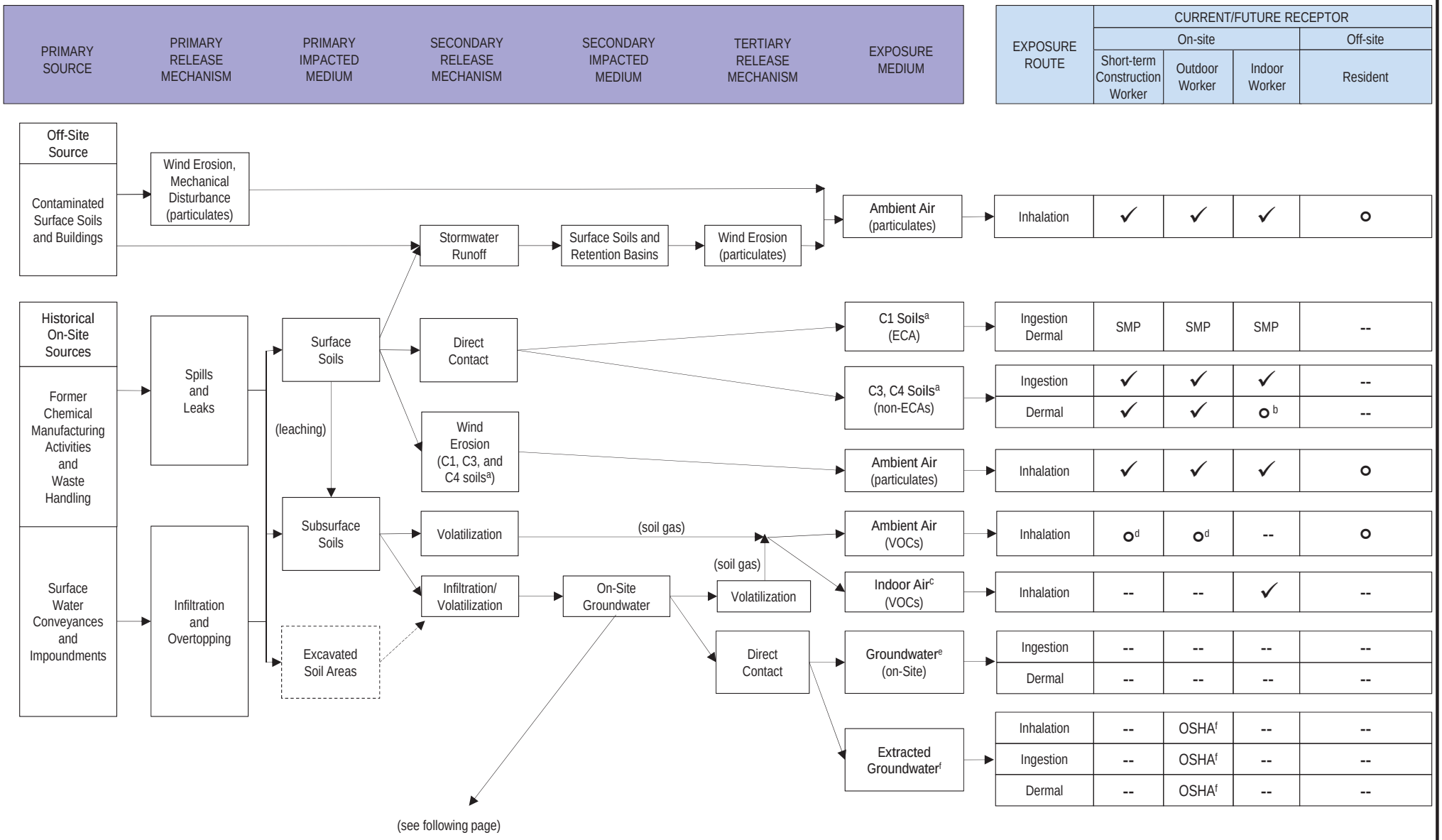
GROUNDWATER MONITORING LOCATIONS

Nevada Environmental Response Trust Site (NERT)
Henderson, Nevada

DESIGNED BY:	REVISIONS			
EJK	No.	DESCRIPTION:	DATE:	BY:
DRAWN BY:	0	GENERATE APPROVED MAP	11/29/2012	RS
RS				
CHECKED BY:				
CJR				
APPROVED BY:				
CJR				

ENVIRON

Path: H:\LePetomane\NERT\GWETS\Drawings\Pipeline Extraction System\GW_MonitoringLocs.mxd



H:\LePetomane\NERT\RI.FS_Workplan\RI WP Report\Figures

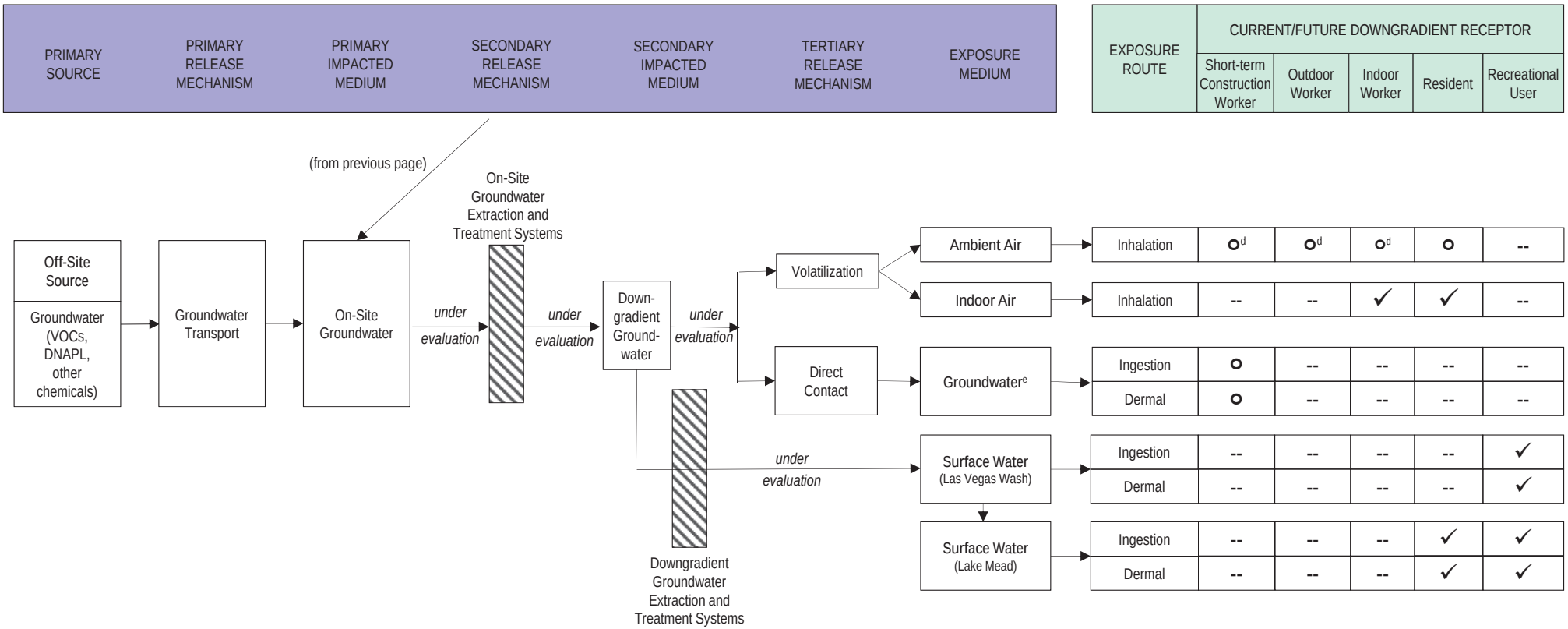
ENVIRON

2200 Powell St., Suite 700, Emeryville, CA 94608

Preliminary Conceptual Site Model Diagram: Site and Downgradient Plume
Nevada Environmental Response Trust Site, Henderson, Nevada

Figure **5-1**

Drafter: EL | Date: 12/14/2012 | Contract Number: 21-29100H | Approved by: | Revised:



H:\LePetomane\NERT\RI.FS_Workplan\RI WP Report\Figures

ENVIRON

2200 Powell St., Suite 700, Emeryville, CA 94608

Preliminary Conceptual Site Model Diagram: Site and Downgradient Plume
Nevada Environmental Response Trust Site, Henderson, Nevada

Figure **5-1**

Drafter: EL | Date: 12/14/2012 | Contract Number: 21-29100H | Approved by: | Revised:

Note:
This preliminary CSM, including the identification of sources, release mechanisms, exposure media, exposure routes, and receptors is based on current understanding of on-site and off-site environmental conditions. The CSM will be revised, as appropriate, based on further evaluation of available on-site and off-site characterization data and additional environmental data collected during the RI.

EXPLANATION:

a	C1, C3, C4 = Category 1, 3, and 4 soils, where C1 = soils 0 – 10 feet bgs in ECAs; C3 = soils 0 – 10 feet bgs with concentrations >BCLs; C4 = soils 0 – 10 feet bgs not previously sampled or available information considered inadequate. C2 soils (not shown in the CSM) are soils 0 – 10 feet bgs with concentrations <BCLs.
b	Not evaluated, consistent with USEPA 2002b.
c	--Parcels A and B: For the vapor intrusion (indoor air) pathway, a separate screening-level HRA has been conducted for these Parcels A, as presented in the *Revised Technical Memorandum: Screening-Level Indoor Air Health Risk Assessment* (Northgate 2010r; NDEP commented on May 23, 2011). --Parcels C, D, F, G, and H: Additional soil gas samples are proposed for collection in these Parcels to address a sampling data gap noted by NDEP in their comment letter of August 7, 2012. Parcel-specific soil-gas HRAs will be prepared (ENVIRON 2012d) on a timeline separate from that for the Facility Area RI and BHRA. --Site-Wide Soil Gas HRA: Volatilization into indoor/ambient air was evaluated in the *Site-Wide Soil Gas Human Health Risk Assessment* (Northgate 2010g, under NDEP review).
d	Inhalation of VOCs will be higher for the indoor air pathway; inhalation of indoor air serves as an upper-bound estimate of potential exposures to VOCs in ambient air.
e	Groundwater is not and will not be used as a source of drinking water. Incidental ingestion and dermal contact with groundwater by on-site construction workers are not considered complete exposure pathways because depth to groundwater is >20 ft bgs. For off-site workers, depth to groundwater in some areas is <20 ft; however, the intermittent exposures of a construction worker to groundwater would be negligible.
f	Workers at the groundwater extraction and treatment facilities could potentially be exposed to contaminants in extracted groundwater. However, potential exposures of these workers will not be evaluated quantitatively in the BHRA as the workers are regulated by the Occupational Safety and Health Administration (OSHA) and a comprehensive worker health and safety plan (HASP) is in place to mitigate potential exposures.
g	Contaminant transport mitigated by currently operating extraction and treatment systems. The effectiveness of these systems and degree of mitigation is currently under evaluation.
--	Incomplete pathway
✓	Complete or potentially complete exposure pathway and/or exposures evaluated for other receptors serve as an upper-bound estimate.
✓*	Potentially complete pathway; significance of pathway is under evaluation. The evaluation will consider the effectiveness of current mitigation systems, depth of groundwater in the downgradient area, and contaminant concentrations in downgradient groundwater.
O	Complete, but negligible exposure pathway; pathway will be discussed qualitatively.
ECA	Excavation Control Area
SMP	Potential exposures (direct-contact pathways) will be managed through the Site Management Plan (SMP).

H:\LePetomane\NERT\RI.FS_Workplan\RI WP Report\Figures

ENVIRON

2200 Powell St., Suite 700, Emeryville, CA 94608

Preliminary Conceptual Site Model Diagram: Site and Downgradient Plume
Nevada Environmental Response Trust Site, Henderson, Nevada

Figure **5-1**

Drafter: EL | Date: 12/14/2012 | Contract Number: 21-29100H | Approved by: | Revised:

N

1:7,800

1 inch = 650 feet

0 325 650 Feet

WARM SPRINGS RD

Former Northwest Ditch

Former Trade Effluent Pond T5 (1941-1944)

Former Trade Effluent Pond T6 (1941-1944)

Former Trade Effluent Pond T4 (1941-1944)

Groundwater Holding Pond (GW-11)

Pond WC-1

Pond WC-2

Former Beta Ditch

Debris Pile

Pond AP-6

Pond AP-5

Pond C-1

Pond AP-1

Pond Mn-1

Pond AP-3

Pond AP-4

Pond AP-2

Pond S-1

Beta Ditch Extension

Pond P-2

Pond P-1

Old Pond P-3

Old Pond P-2

Lhoist

LAKE MEAD PARKWAY

Legend

- Ditches
- Active Pond
- Inactive Pond

Lining Information:

- Unlined
- Originally single-lined, removed when decommissioned
- Originally single-lined, replaced with double-liners, removed when decommissioned
- Originally double-lined
- Originally double-lined, liners replaced
- Originally double-lined, removed liners
- Originally triple-lined
- Approximate Site Boundary

Path: H:\LePetomane\NERT\RI-FS_Workplan\GIS\Figure5-1_Historical and Current Locations.mxd

ENVIRON

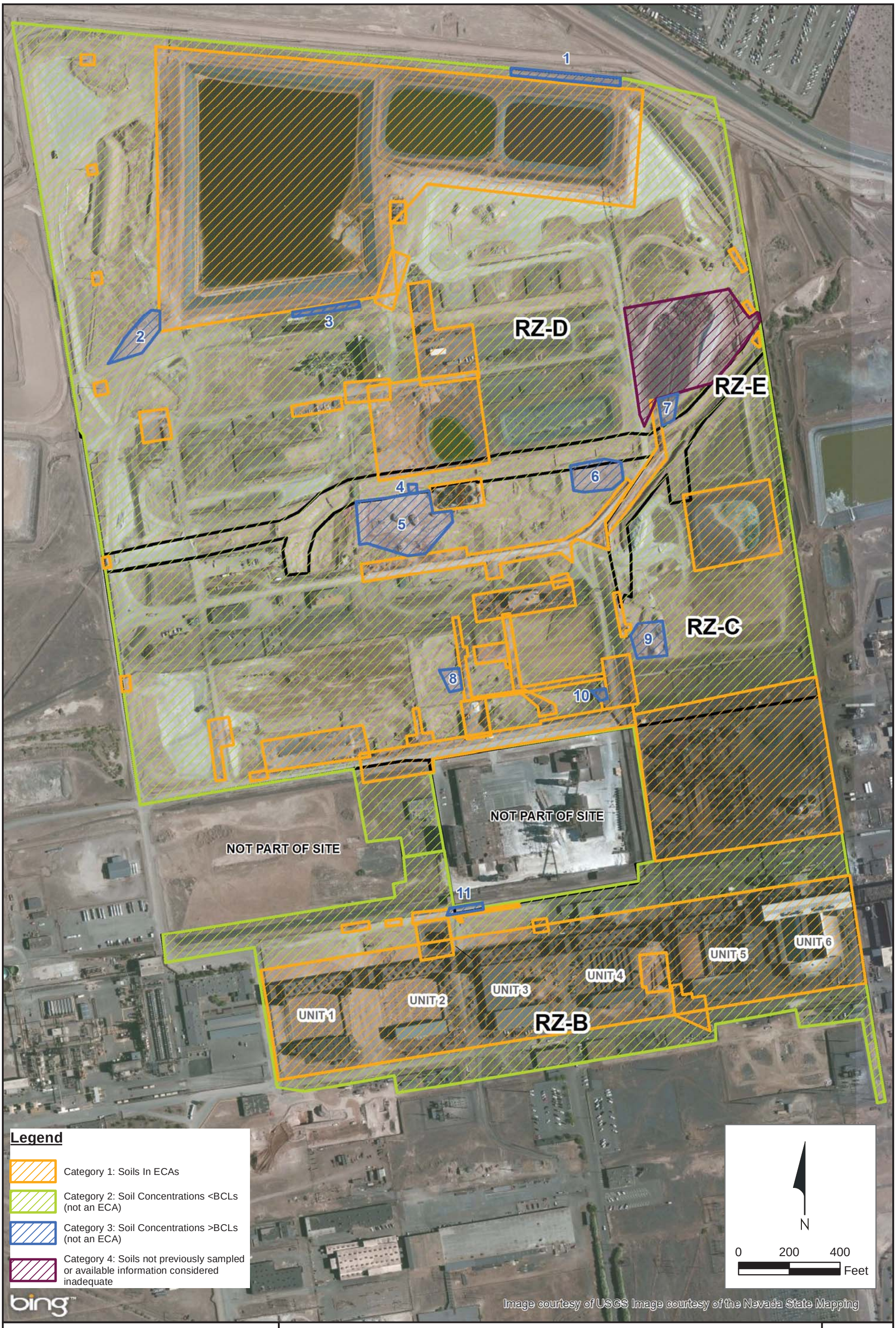
Historical and Active Pond Locations

Nevada Environmental Response Trust Site
Henderson, Nevada

DRAWN BY:	DATE:	CONTRACT NUMBER:	APPROVED BY:	REVISED:
RS	12/7/12	21-29100H10		

Figure

5-2



ENVIRON

2200 Powell St., Suite 700, Emeryville, CA 94608

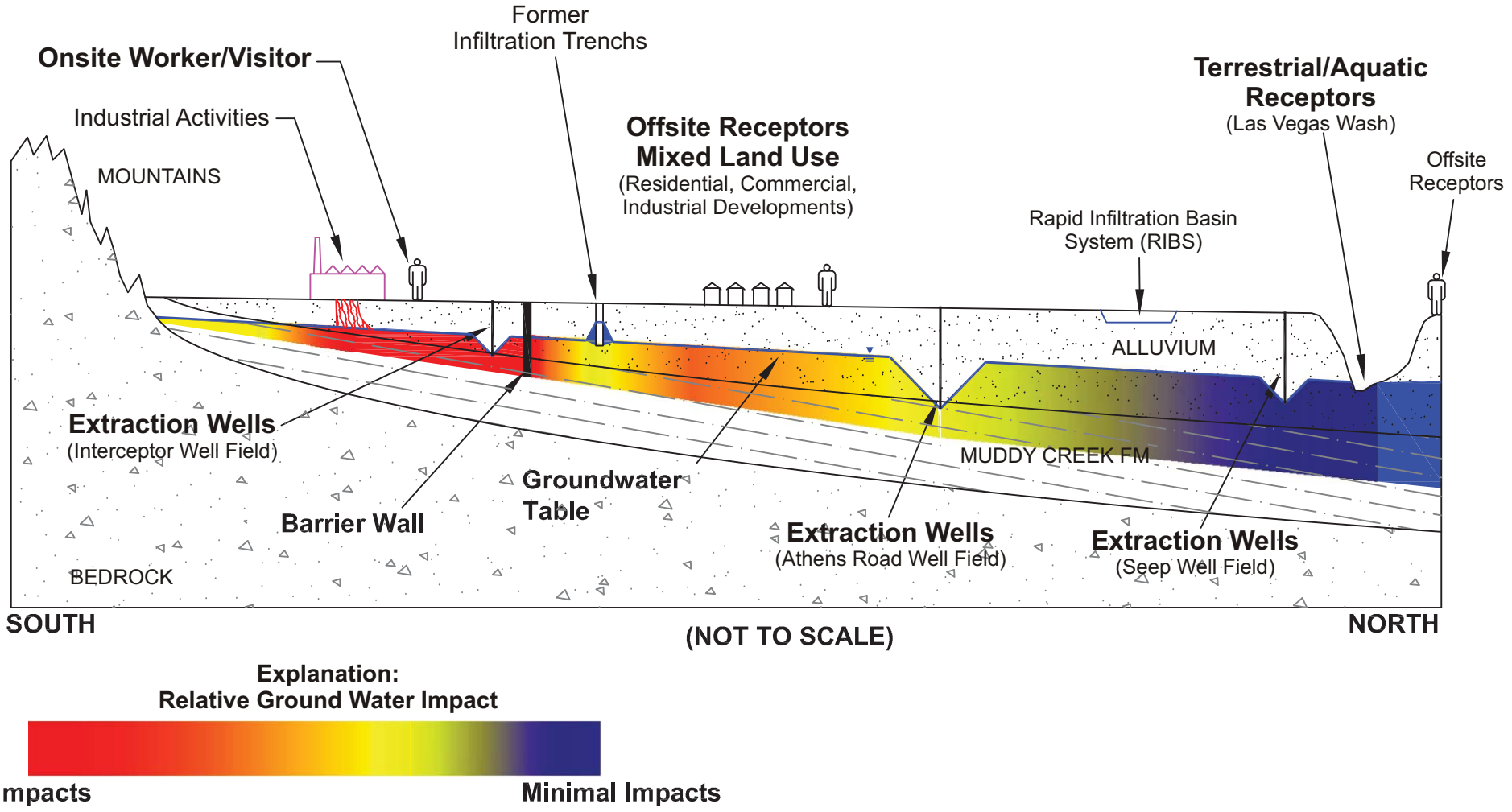
Categories for Surface and Near Surface Soils (0-10 ft below "new" ground surface)

Nevada Environmental Response Trust Site, Henderson, Nevada

Figure **5-3**

Drafter: RS/EL Date: 12/17/2012 Contract Number: 21-29100H Approved by: Revised:

Path: H:\LePetomane\NERT\RI.FS_Workplan\GIS\Figure5-3_Categories of Surface soils.mxd



Explanation:
Relative Ground Water Impact

Impacts — **Minimal Impacts**

Sources: ENSR|AECOM, 2007.
Northgate 2010.

H:/LEPETOME/NERT/VI RISK/CAD/CONCEPTUAL SITE MODEL2.CDR

ENVIRON

Preliminary Conceptual Site Model Illustration
Nevada Environmental Response Trust Site
Hendeson, Nevada

Figure
5-4

Drafter: RS | Date: 11/14/12 | Contract Number: 21-29100H10 | Approved: | Revised:

N

1:7,800

1 inch = 650 feet

0 325 650 Feet

WARM SPRINGS RD

Groundwater Holding Pond (GW-11)

WC-West Pond

WC-East Pond

Balance Tanks

Groundwater Barrier Wall

Former Beta Ditch

Debris Pile

2

3

1

Pond AP-5

FBRs

BT Tanks

4

Pond Mn-1

Steam Plant

Lab

Maintenance Building

Leach Plant

Lhoist

Boron Production Facility

Unit 1

Unit 2

Unit 3

Unit 4

Unit 5

Unit 6

Admin Building

Wash/Change House/First Aid

Training Facility

Warehouse

LAKE MEAD PARKWAY

Additional Soil Investigation Areas

1 Additional Soil Investigation Area Pond AP-5
2 Additional Soil Investigation Area Between Pond AP-5 and Debris Pile
3 Additional Soil Investigation Area Debris Pile
4 Additional Soil Investigation Area West of Pond Mn-1

Legend

- Groundwater Barrier Wall
- Ditches
- Additional Soil Investigation Area
- GWETS Operational Areas
- Debris Pile Site Features
- Tronox Operational Areas
- Approximate Site Boundary
- Site Features (Buildings and Tanks)

Path: H:\LePetomane\NERT\RI.FS_Workplan\GIS\Figure5-5_Additional Soil Investig.mxd

ENVIRON

Additional Soil Investigation Areas

Nevada Environmental Response Trust Site
Henderson, Nevada

DRAWN BY: RS | DATE: 11/30/12 | CONTRACT NUMBER: 21-29100I | APPROVED BY: | REVISED:

Figure **5-5**

Legend

- Seep Surface Flow Capture Sump (no longer opearating)
- Shallow Well
- Well Field Area
- Onsite Barrier Wall
- Groundwater Elevation Contour
- Paleochannel (Northgate 2010)

Las Vegas Wash

AMPAC Re-injection System

AMPAC Extraction Systems

OSSM EXTRACTION WELL FIELD

SEEP WELL FIELD

ATHENS ROAD WELL FIELD

BARRIER WALL AND INTERCEPTOR WELL FIELD

City of Henderson Bird Viewing Preserve

City of Henderson Northern Rapid Infiltration Basins (RIBs)

Olin

TIMET

PABCO ROAD

GALLERIA ROAD

E SUNSET ROAD

WARM SPRINGS ROAD

N US 95

N. BOULDER HWY

LAKE MEAD PARKWAY

Pittman Lateral

N

0 800 1,600 Feet

Path: H:\LePetomane\NERT\VI Risk Assessment\GIS\Maps\PaleoMap-2Q2012-Potmap.mxd

ENVIRON

2200 Powell St., Suite 700, Emeryville, CA 94608

Potentiometric Surface in Shallow Groundwater, May-June 2012
Nevada Environmental Response Trust Site, Henderson, Nevada

Figure **5-6**

Drafter: RS | Date: 12/14/2012 | Contract Number: 21-29100H10 | Approved by: | Revised:

Legend

- Shallow Water-Bearing Zone Well
- Perchlorate Isoconcentration Contour, mg/L

Perchlorate Concentration, mg/L

- >1,000
- 500-1,000
- 250-500
- 25-250
- <25
- Paleochannel (Northgate 2010)
- Onsite Barrier Wall
- NERT Property Boundary
- Seep Surface Flow Capture Sump (no longer opearating)

Las Vegas Wash

AMPAC Re-injection System

SEEP WELL FIELD

City of Henderson Bird Viewing Preserve

City of Henderson Northern Rapid Infiltration Basins (RIBs)

PABCO ROAD

AMPAC Extraction Systems

ATHENS ROAD WELL FIELD

GALLERIA ROAD

Pittman Lateral

E SUNSET ROAD

WARM SPRINGS ROAD

OSSM EXTRACTION WELL FIELD

BARRIER WALL AND INTERCEPTOR WELL FIELD

N US 95

N. BOULDER HWY

LAKE MEAD PARKWAY

Olin

TIMET

N

0 800 1,600 Feet

Path: H:\LePetomane\NERT\VI Risk Assessment\GIS\Maps\Perchlorate-PaleoMap-3.mxd

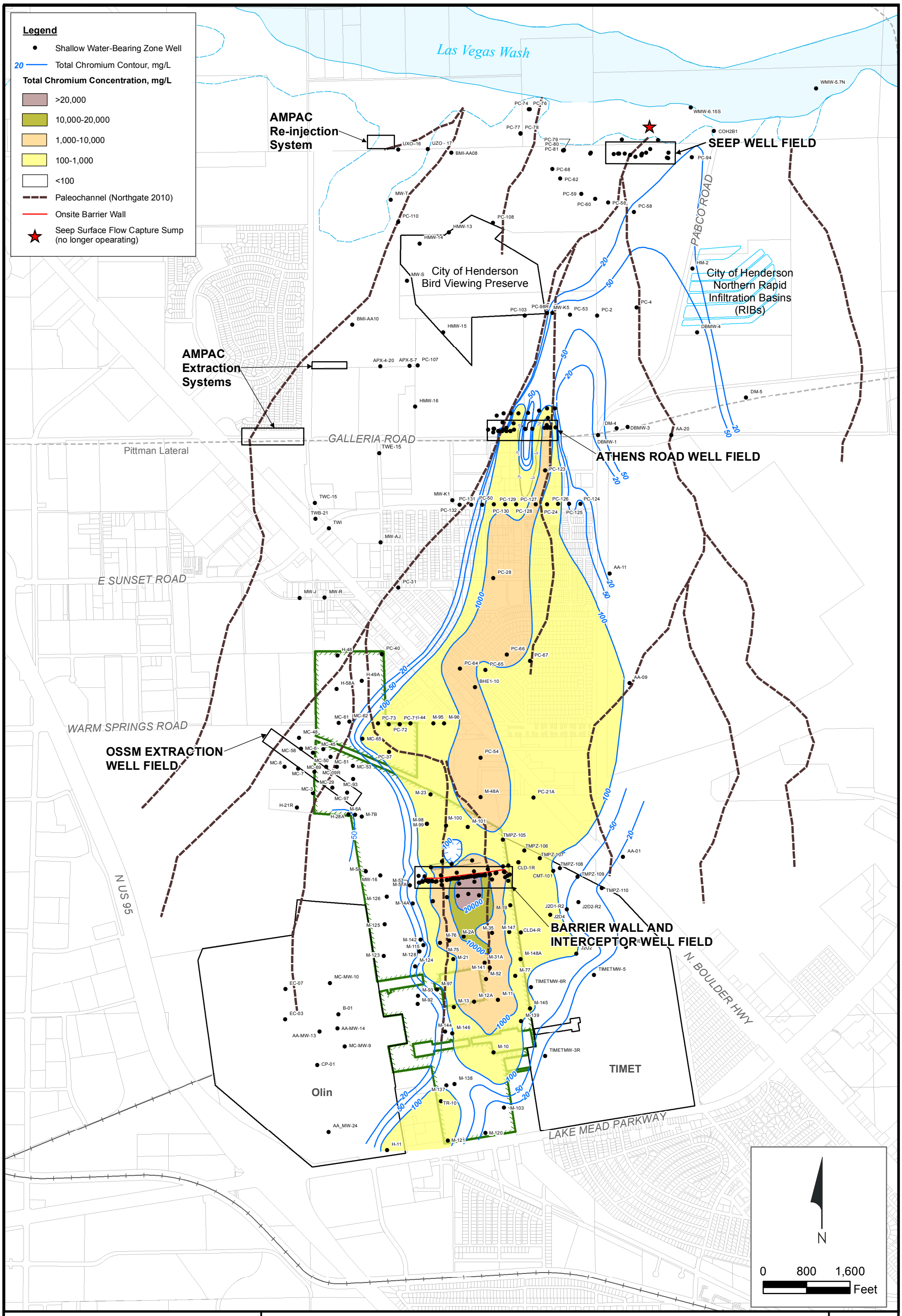
ENVIRON

2200 Powell St., Suite 700, Emeryville, CA 94608

Perchlorate in Shallow Groundwater, May-June 2012
Nevada Environmental Response Trust Site, Henderson, Nevada

Figure **5-7**

Drafter: RS | Date: 12/14/2012 | Contract Number: 21-29100H10 | Approved by: | Revised:



ENVIRON

2200 Powell St., Suite 700, Emeryville, CA 94608

Total Chromium in Shallow Groundwater, May-June 2012
Nevada Environmental Response Trust Site, Henderson, Nevada

Figure **5-8**

Drafter: RS | Date: 12/14/2012 | Contract Number: 21-29100H10 | Approved by: | Revised:

Path: H:\LePetomane\NERT\VI Risk Assessment\GIS\Maps\PaleoMap-TotalChromium.mxd

Legend

- Shallow Water-Bearing Zone Well
- 5000 — Total Dissolved Solids Contour, mg/L

Total Dissolved Solids, mg/L

- >20,000
- 15,000-20,000
- 10,000-15,000
- 5,000-10,000
- <5,000
- Paleochannel (Northgate 2010)
- Onsite Barrier Wall
- NERT Property Boundary
- Seep Surface Flow Capture Sump (no longer opearating)

Las Vegas Wash

AMPAC Re-injection System

SEEP WELL FIELD

PABCO ROAD

City of Henderson Bird Viewing Preserve

City of Henderson Northern Rapid Infiltration Basins (RIBs)

AMPAC Extraction Systems

ATHENS ROAD WELL FIELD

GALLERIA ROAD

Pittman Lateral

E SUNSET ROAD

WARM SPRINGS ROAD

OSSM EXTRACTION WELL FIELD

N US 95

BARRIER WALL AND INTERCEPTOR WELL FIELD

N. BOULDER HWY

LAKE MEAD PARKWAY

Olin

TIMET

PC-74 PC-76 PC-77 PC-78 PC-79 PC-80 PC-81 PC-94 PC-68 PC-62 PC-59 PC-60 PC-56 PC-58 PC-110 PC-108 PC-103 PC-98R PC-53 PC-2 PC-4 PC-123 PC-131 PC-50 PC-129 PC-127 PC-126 PC-124 PC-132 PC-130 PC-128 PC-24 PC-125 PC-28 PC-31 PC-40 PC-66 PC-67 PC-64 PC-65 PC-73 PC-71I-44 PC-72 PC-37 PC-54 PC-21A PC-107

UXO-16 UZO - 17 BMI-AA08 BMI-AA10 MW-T HMW-13 HMW-14 MW-S HMW-15 HMW-16 APX-4-20 APX-5-7 TWE-15 TWC-15 TWB-21 TWI MW-AJ MW-J MW-R

WMW-5.7N WMW-6.15S COH2B1 HM-2 DBMW-4 DM-5 DM-4 DBMW-3 DBMW-1 AA-20 AA-11 AA-09 MW-K5 MW-K1

H-48 H-49A H-58A BHE1-10 MC-61 MC-62 MC-48 MC-58 MC-6 MC-45 MC-50 MC-51 MC-69 MC-53 MC-8 MC-7 MC-09R MC-29 MC-93 MC-3 C-97 H-21R M-6A H-28A M-7B MC-65 M-95 M-96

M-23 M-48A M-98 M-99 M-100 M-101 TMPZ-105 TMPZ-106 TMPZ-107 TMPZ-108 TMPZ-109 TMPZ-110 CLD-1R CMT-101 M-5A MW-16 M-57 M-57A M-126 M-14A M-125 M-123 M-142 M-115 M-128 M-124 M-19 M-35 M-147 CLD4-R M-76 M-2A M-75 M-21 M-31A M-148A M-77 M-141 M-52 M-97 M-93 M-92 M-13 M-12A M-11 M-145 M-139 M-144 M-146 M-10 TIMETMW-3R TIMETMW-5 TIMETMW-6R M-138 M-137 TR-10 M-103 M-120 M-121 J2D1-R2 J2D2-R2 J2D4 J2U2

MC-MW-10 EC-07 EC-03 B-01 AA-MW-14 AA-MW-13 MC-MW-9 CP-01 AA_MW-24 H-11

5000 10000 15000 20000 50000 100000

N

0 800 1,600 Feet

Path: H:\LePetomane\NERT\VI Risk Assessment\GIS\Maps\PaleoMap-TotalDissolvedSolids.mxd

ENVIRON

2200 Powell St., Suite 700, Emeryville, CA 94608

Total Dissolved Solids in Shallow Groundwater, May-June 2012
Nevada Environmental Response Trust Site, Henderson, Nevada

Figure **5-9**

Drafter: RS | Date: 12/14/2012 | Contract Number: 21-29100H10 | Approved by: | Revised:

N

0 400 800

Feet

Legend

- Middle Water-Bearing Zone Monitoring Well
- Proposed Well Location
- Estimated Extent of DNAPL (Montrose 2012)

Notes

ft bgs = feet below ground surface
ND = not detected
ns = not sampled
Chemical concentrations are in mg/L (parts per million)

1. The most recent sampling data available in the BMI Complex Database are shown for wells located on the NERT property.
2. Wells MC-MW-18, MC-MW-39, and MC-MW-42 are owned and sampled by Montrose.
3. Total VOCs were calculated based on all positive detections of individual VOCs during the sampling event.

TR-12 (272-292 ft bgs)		
Perchlorate	<0.0003	5/12
Chromium	0.048	5/12
Total VOCs	1.0	10/11

M-152 (125-145 ft bgs)		
Perchlorate	**0.65**	5/12
Chromium	0.038	5/12
Total VOCs	ns	--

M-156 (175-195 ft bgs)		
Perchlorate	<0.0003	5/12
Chromium	0.011J	5/12
Total VOCs	ns	--

TR-11 (210-230 ft bgs)		
Perchlorate	<0.0003	5/12
Chromium	0.015	5/12
Total VOCs	All ND	10/11

M-151 (125-145 ft bgs)		
Perchlorate	<0.0003	5/12
Chromium	0.030	5/12
Total VOCs	ns	--

M-155 (200-220 ft bgs)		
Perchlorate	<0.0003	5/12
Chromium	0.018J	5/12
Total VOCs	ns	--

TR-2 (145-175 ft bgs)		
Perchlorate	<0.0003	5/12
Chromium	0.021	5/12
Total VOCs	All ND	7/08

TR-1 (282-312 ft bgs)		
Perchlorate	<0.0003	5/12
Chromium	0.017J	5/12
Total VOCs	ns	--

M-162 (100-110 ft bgs)		
Perchlorate	**3.0**	5/12
Chromium	0.023	5/12
Total VOCs	ns	--

M-161 (100-110 ft bgs)		
Perchlorate	**0.023**	5/12
Chromium	0.024	5/12
Total VOCs	ns	--

TR-4 (125-145 ft bgs)		
Perchlorate	0.0013J	5/12
Chromium	0.025	5/12
Total VOCs	0.0064	5/10

TR-3 (220-250 ft bgs)		
Perchlorate	<0.0003	5/12
Chromium	0.016J	5/12
Total VOCs	ns	--

MC-MW-42 (96-116 ft bgs)		
Perchlorate	0.0006	5/11
Chromium	0.00091J	5/11
Total VOCs	0.013	5/11

M-150 (125-145 ft bgs)		
Perchlorate	**0.17**	5/12
Chromium	0.038	5/12
Total VOCs	ns	--

M-154 (175-195 ft bgs)		
Perchlorate	<0.0003	5/12
Chromium	0.036	5/12
Total VOCs	ns	--

M-181 (105-115 ft bgs)		
Perchlorate	<0.0003	5/12
Chromium	0.042	5/12
Total VOCs	All ND	9/10

MC-MW-18 (97-117 ft bgs)		
Perchlorate	0.011	4/11
Chromium	<0.005	4/11
Total VOCs	**DNAPL**	4/11

MC-MW-39 (100-120 ft bgs)		
Perchlorate	0.0093	4/11
Chromium	0.0014J	4/11
Total VOCs	**0.351**	4/11

M-186 (105-115 ft bgs)		
Perchlorate	**92**	5/12
Chromium	**1.8**	5/12
Total VOCs	ns	--

M-149 (100-120 ft bgs)		
Perchlorate	**270**	5/12
Chromium	**2.1**	5/12
Total VOCs	**0.073**	4/11

M-153 (150-170 ft bgs)		
Perchlorate	**0.019**	5/12
Chromium	0.021	5/12
Total VOCs	All ND	7/10

TR-5 (221-251 ft bgs)		
Perchlorate	<0.0003	5/12
Chromium	0.016J	5/12
Total VOCs	All ND	7/10

TR-7 (260-290 ft bgs)		
Perchlorate	<0.0003	5/12
Chromium	0.013J	5/12
Total VOCs	All ND	3/06

TR-9 (230-250 ft bgs)		
Perchlorate	<0.0003	5/12
Chromium	0.013J	5/12
Total VOCs	All ND	3/06

M-118 (138-158 ft bgs)		
Perchlorate	<0.0003	5/12
Chromium	0.023	5/12
Total VOCs	0.0016	7/09

M-117 (130-150 ft bgs)		
Perchlorate	<0.0003	5/12
Chromium	0.016J	5/12
Total VOCs	All ND	7/09

WARM SPRINGS ROAD
BOULDER HIGHWAY
PABCO ROAD
LAKE MEAD PARKWAY
OSSM EXTRACTION WELL FIELD
BARRIER WALL AND INTERCEPTOR WELL FIELD
BMI (CAMU)
NERT
TIMET
Olin

MCF-11, MCF-09B, MCF-09A, MCF-25A, MCF-01A, TR-12, M-152, M-156, TR-11, M-151, M-155, TR-2, TR-1, M-161, M-162, DMC-MW-28, MC-MW-42, MC-MW-41, TR-3, TR-4, M-150, M-154, M-181, MC-MW-18, MC-MW-39, M-186, M-149, M-153, EC-14, MW-08, MC-MW-12, MC-MW-11, EC-13, TR-5, DPT-01, DMC-MW-26, EC-12, RB-02-DEEP, DMC-MW-27, DMC-MW-27R, CP-1, TR-7, TR-9, M-117, M-118

Path: H:\LePetomane\NERT\RI.FS_Workplan\GIS\Figure5-9ProposedOn-SiteWells.mxd

ENVIRON

Proposed On-site Wells, Middle Water-Bearing Zone
Nevada Environmental Response Trust Site
Henderson, Nevada

DRAWN BY: RS | DATE:12/13/12 | CONTRACT NUMBER: 21-29100H10 | APPROVED BY: | REVISED:

Figure
5-10

Legend

- Shallow Water-Bearing Zone Well
- Decommissioned Well
- Existing Well to be Evaluated for Sampling
- Proposed Shallow Well Location
- Proposed Deeper Well Location
- 1 — Perchlorate Isoconcentration Contour, mg/L

Perchlorate Concentration, mg/L

- >1,000
- 500-1,000
- 250-500
- 25-250
- <25
- NERT Property Boundary
- Area of Shallow Upper Muddy Creek (UMCf) deposits (so called "UMCf Ridge")
- Seep Surface Flow Capture Sump (no longer opearating)

Las Vegas Wash

AMPAC Re-injection System

AMPAC Extraction Systems

SEEP WELL FIELD

ATHENS ROAD WELL FIELD

City of Henderson Bird Viewing Preserve

NERT

GALLERIA ROAD

SUNSET ROAD

BOULDER WAY

PC-74 PC-76 PC-77 PC-78 PC-96 PC-97 PC-80 PC-81 PC-79 PC-82 PC-83 PC-68 PC-62 PC-59 PC-60 PC-56 PC-58 UXO–16 UZO - 17 BMI-AA08 MW-T PC-110 PC-108 HMW-13 HMW-14 MW-S BMI-AA10 PC-103 PC-98R MW-K5 PC-53 PC-2 PC-4 HMW-15 APX-4-20 APX-5-7 PC-107 HMW-16 L639 L637 L645 L641 TWE-15 DM-4 DBMW-1 DBMW-3 AA-20 PC-123 TWC-15 MW-K1 PC-131 PC-50 PC-129 PC-127 PC-126 PC-124 PC-132 PC-130 PC-128 PC-24 PC-125 TWB-21 TWI MW-AJ PC-28 AA-11 PC-31 MW-J MW-R PC-66 PC-67 PC-64 PC-65 BHE1-10 H-48 PC-40 H-49A H-58A MC-61 MC-62 PC-73 PC-71 PC-72 M-44 M-95 M-96

1 10 25 100 250 500

N

0 400 800 Feet

Path: H:\LePetomane\NERT\VI Risk Assessment\GIS\Maps\Perchlorate-GW-Area-map.mxd

ENVIRON

2200 Powell St., Suite 700, Emeryville, CA 94608

Proposed Downgradient Plume Wells
Nevada Environmental Response Trust Site
Henderson, Nevada

Figure **5-11**

Drafter: RS | Date: 12/15/2012 | Contract Number: 21-29100H10 | Approved by: | Revised:

N

0 800 1,600 Feet

Las Vegas Wash

SEEP WELL FIELD

City of Henderson
Bird Viewing Preserve

City of Henderson
Water Reclamation
Facility

ATHENS ROAD WELL FIELD

BARRIER WALL AND
INTERCEPTOR WELL FIELD

City of Henderson
Northern Rapid
Infiltration Basins
(RIBs)

BMI
Common Areas
(Eastside)

Former
TIMET

Former COH
Southern RIBs

Parcel 4A

Parcel 4B

TIMET

NERT

Pittman Lateral

Former Beta Ditch

Former Alpha Ditch

PABCO ROAD

BOULDER HWY

LAKE MEAD PARKWAY

WMW5.58SS 09/03/09 0.018
DBMW-20 09/30/09 3.2
COH-2A 09/11/09 5.4
PC-93 05/08/09 7.89
MW-K8 11/08/04 2
PC-94 May/June 2012 9
AA-30 09/09/09 2.5
AA-26 09/11/09 0.049 J
DBMW-22 09/28/09 0.14
AA-23 01/19/05 <0.002
AA-23R 05/19/08 0.682
PC-58 May/June 2012 2.5
DBMW-19 09/24/09 6.5
AA-22 09/23/09 1.7
HM-2 May/June 2012 4.1
PC-2 May/June 2012 4.4
PC-4 May/June 2012 8.4
PC-53 May/June 2012 3.6
PC-1 05/08/08 12.1
DBMW-4 10/13/11 4.6
DBMW-5 10/13/11 5
AA-07 08/10/09 0.46
DBMW-6 05/27/08 1.97
MCF-06C 09/09/09 4.3
DBMW-7 09/25/09 3.3
DBMW-8 09/23/09 3.6
MCF-06B 08/28/09 4.6 J+
BEC-12 05/05/04 0.022
DBMW-16 10/02/09 0.016
ARP-7 May/June 2012 5.1
DBMW-2 09/04/09 7.5
DBMW-3 10/11/11 9.6
PC-10 03/11/04 2.5
DBMW-1 10/11/11 8.9
AA-20 10/12/10 5.2
DBMW-9 09/29/09 2.7
DBMW-10 09/29/09 0.52
DBMW-11 10/01/09 14 J-
DBMW-13 09/29/09 9.8 J-
DBMW-15 09/30/09 1.4
DBMW-17 10/02/09 0.012
BEC-10 05/05/04 16
AA-18 08/11/09 0.11
DBMW-12 09/24/09 12
DBMW-14 09/29/09 14 J-
MCF-12B 08/19/09 18
AA-19 08/22/07 2.6
BEC-9 08/18/09 0.27
PC-125 May/June 2012 7.1
PC-124 May/June 2012 8
AA-15 07/18/04 3.73 J-
BEC-7 05/04/06 0.17 D
MCF-16C 09/30/09 11 J-
AA-UW6 08/27/09 0.052
AA-11 10/12/10 3.6
BEC-5 05/05/04 0.32
POD2-R2 08/09/07 4.5
AA-14 07/17/04 0.087
BEC-6 09/28/09 15
BEC-4 05/04/06 5 D
AA-09 10/06/11 7.9
AA-13 08/13/09 0.097
AA-UW5 09/15/09 0.056 J+
PC-21A May/June 2012 3.2
PC-21 05/05/04 4.4
TMPZ-107 10/24/11 2.8
BEC-1 05/04/06 1 D
MCF-03B 08/17/09 0.084 J
CMT-101 10/31/11 1.5
CMT-501 04/14/08 17 J
CMT-102 04/02/08 3.8
CMT-503 03/27/08 0.18 J
CMT-502 03/27/08 20 J
TMPZ-106 10/24/11 2.1
TMPZ-108 10/25/11 2.7
MCF-01B 08/07/09 0.7
AA-01 May/June 2012 2.5
TMPZ-109 10/25/11 0.68
TMPZ-110 10/25/11 1.6
AA-UW4 08/26/09 0.081
CMT-103 04/02/08 <0.004 UJ
J2D2-R2 10/25/11 0.67
AA-UW1 10/10/11 0.75
AA-27 10/10/11 0.26
CMT-202 03/19/08 9.6
J2D1-R2 10/25/11 1.7
CMT-201 04/22/08 14
J2D4 10/27/11 3.1 J
CMT-303 04/09/08 <0.004 UJ
CMT-302 04/10/08 0.49
CMT-603 04/06/09 0.42
M-148A May/June 2012 3.5
M-141 May/June 2012 630
TIMETMW-4 10/19/11 0.14
J2U2 10/26/11 0.55
TIMETMW-5 10/18/11 0.45
AA-UW2 08/11/09 0.099
AA-UW3 08/25/09 0.068
TIMETMW-6R 10/19/11 1.5
M-145 May/June 2012 0.6
M-146 May/June 2012 3.8
TIMETMW-3R 10/17/11 0.16
BRW-R1 10/18/11 0.29
TMMW-101 10/12/11 0.15
TMMW-102 04/21/10 0.15
TMMW-103 04/26/10 0.69 J
TMMW-104 10/11/11 0.26

Legend

- Shallow Water-Bearing Zone Well

Off-Site Perchlorate Concentrations, mg/L

- < 1.0
- 1.0 - 2.5
- 2.5 - 5.0
- 5.0 - 10
- > 10
- J Estimated Concentration

Source: BMI Complex Database

- Nevada Environmental Response Trust Property Boundary

Site-related Shallow Groundwater Perchlorate Plume

- 1 Perchlorate Isoconcentration Contour, mg/L
- >1,000
- 500-1,000
- 250-500
- 25-250
- <25

ENVIRON

Downgradient Plume, Eastern Detail

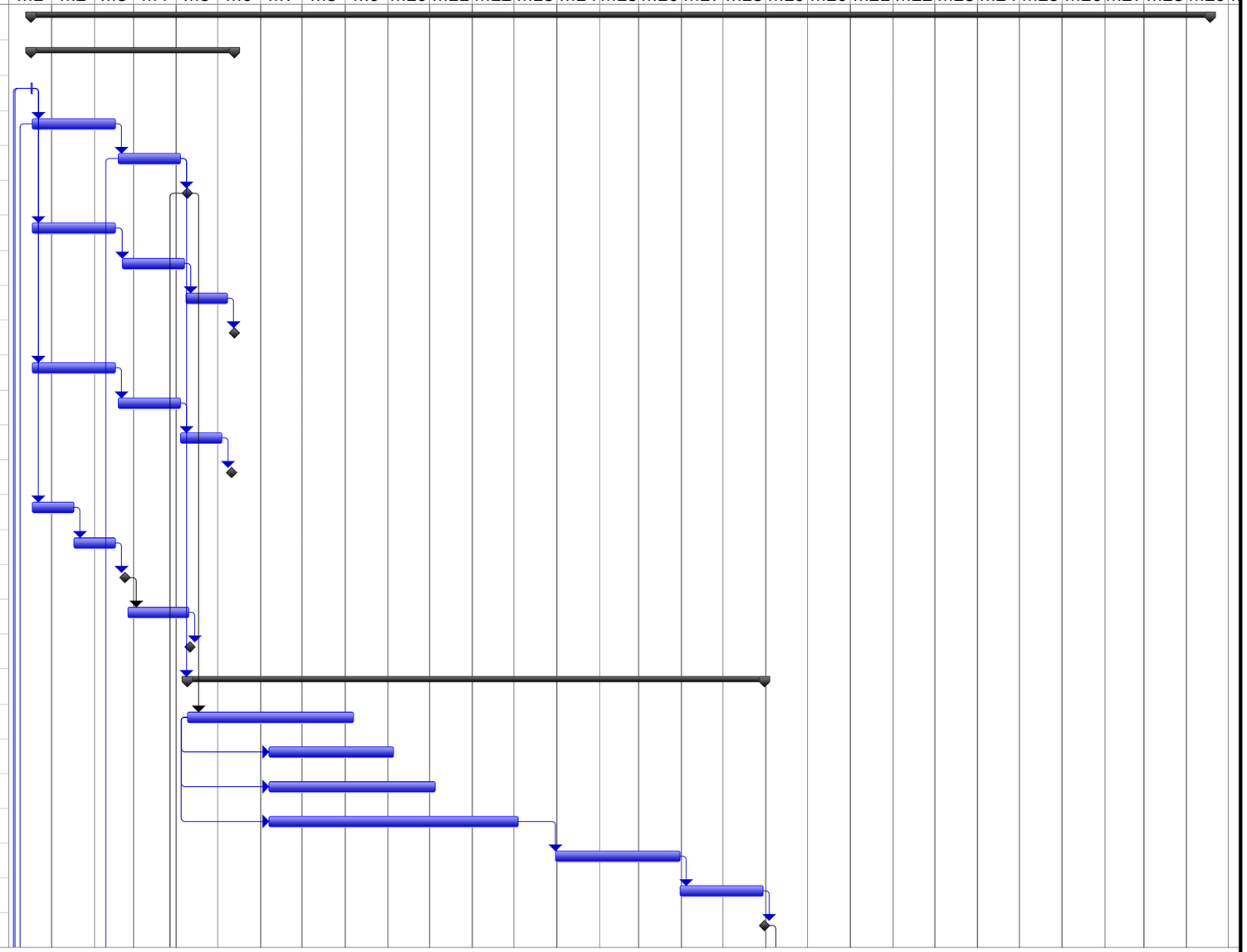
Nevada Environmental Response Trust Site
Henderson, Nevada

Figure 5-12

DRAWN BY: RS | DATE: 12/15/12 | CONTRACT NUMBER: 21-29100H10 | APPROVED BY: | REVISED:

Path: H:\LePetomane\NERT\RI.FS_Workplan\GIS\NERT_OffSitePerchlorateDetail2.mxd

ID	Task Name	Calendar Days
1	**REMEDIAL INVESTIGATION / FEASIBILITY STUDY (RI/FS)**	**855**
2	**RI/FS Work Plan**	147
3	**Submit RI/FS Work Plan to NDEP**	1
4	NDEP Review of RI/FS Work Plan	60
5	Respond to Comments / Finalize RI/FS Work Plan	45
6	NDEP Approval of RI/FS Work Plan	5
7	**Prepare SAP, QAPP, and HASP**	60
8	NDEP Review of SAP, QAPP, and HASP	45
9	Respond to NDEP Comments / Finalize SAP, QAPP, and HASP	30
10	NDEP Approval of SAP, QAPP, and HASP	5
11	**Prepare Basline Health Risk Asessment (BHRA) Work Plan**	60
12	NDEP Review of BHRA Work Plan	45
13	Respond to NDEP Comments / Finalize BHRA Work Plan	30
14	NDEP Approval of BHRA Work Plan	5
15	**NDEP Review of Draft Community Involvement Plan (CIP)**	30
16	Respond to NDEP Comments / Finalize CIP	30
17	NDEP Approval of Final CIP	5
18	Establish Information Repository	44
19	Initiate Implementation of CIP (in advance of RI field work)	1
20	**Remedial Investigation (RI) and BHRA**	417
21	Data Gap Field Investigation(s)	120
22	Evaluate Additional Data Collected	90
23	Perform BHRA	120
24	Preparation of the RI Report	180
25	NDEP Review of the RI Report	90
26	Address NDEP Comments and Finalize RI Report	60
27	NDEP Approval of RI Report	1



Task
Milestone
Summary
Rolled Up Task
Rolled Up Milestone
Rolled Up Progress
Split
External Tasks
Project Summary
Group By Summary
Inactive Task
Inactive Milestone
Inactive Summary
Manual Task
Duration-only
Manual Summary Rollup
Manual Summary
Start-only
Finish-only
Progress

Schedule subject to change based on NDEP and contractor input.

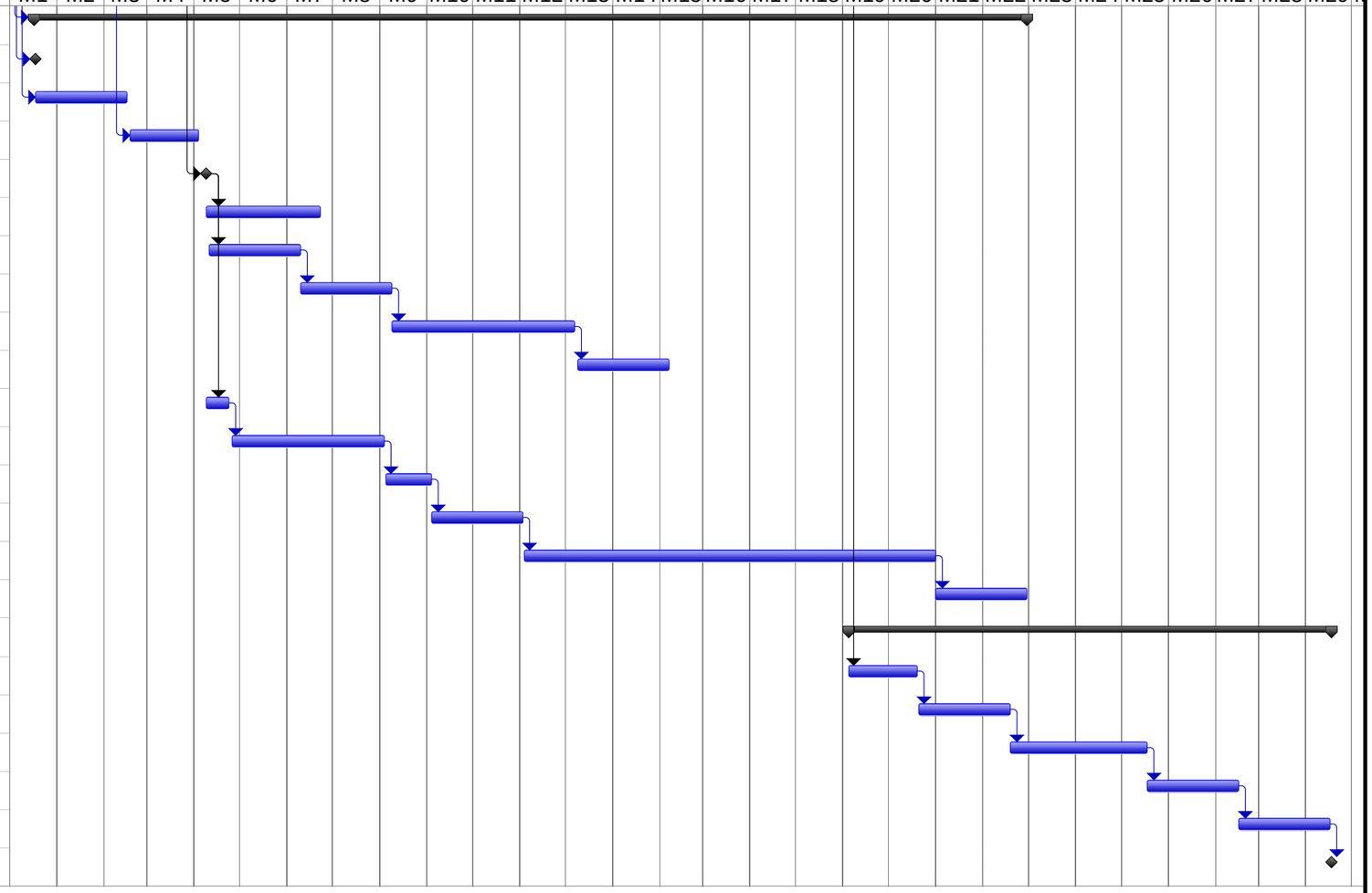
ENVIRON
2200 Powell St., Suite 700, Emeryville, CA 94608

Remedial Investigation and Feasibility Study Schedule
Nevada Environmental Response Trust Site, Henderson, Nevada

Drafter: EA | Date: 12/17/2012 | Contract Number: 21-29100H | Approved by: | Revised:

Figure 7-1

ID	Task Name	Calendar Days
28	**Treatability Study (TS)**	652
29	Submit TS Work Plans to NDEP	1
30	NDEP Review of TS Work Plans	60
31	Respond to NDEP Comments / Finalize TS Work Plans	45
32	NDEP Approval of TS Work Plans	5
33	Apply for and Obtain Permits	75
34	Soil Flushing Field-Scale Pilot Design	60
35	Soil Flushing Field-Scale Pilot Construction	60
36	Soil Flushing Field-Scale Pilot Operation	120
37	Soil Flushing Treatability Study Report Preparation	60
38	PRB Field-Scale Pilot Preliminary Field Sampling	15
39	PRB Bench-Scale Testing	100
40	PRB Field-Scale Pilot Design	30
41	PRB Field-Scale Pilot Construction	60
42	PRB Field-Scale Pilot Operation	270
43	PRB Treatability Study Report Preparation	60
44	**Feasibility Study (FS)**	320
45	Remedial Alternatives Development	45
46	Detailed Analysis of Alternatives	60
47	Prepare FS Report	90
48	NDEP Review of FS Report	60
49	Address NDEP Comments / Finalize FS Report	60
50	NDEP Approval of FS Report	1



Task
Milestone
Summary
Rolled Up Task
Rolled Up Milestone
Rolled Up Progress
Split
External Tasks
Project Summary
Group By Summary
Inactive Task
Inactive Milestone
Inactive Summary
Manual Task
Duration-only
Manual Summary Rollup
Manual Summary
Start-only
Finish-only
Progress

Schedule subject to change based on NDEP and contractor input.

ENVIRON
2200 Powell St., Suite 700, Emeryville, CA 94608

Remedial Investigation and Feasibility Study Schedule
Nevada Environmental Response Trust Site, Henderson, Nevada

Drafter: EA | Date: 12/17/2012 | Contract Number: 21-29100H | Approved by: | Revised:

Figure 7-1

Plates

Inset B

0 100 200 400

Feet

Inset A

0 100 200 400

Feet

Former Recharge Trenches

Inset C

0 100 200 400

Feet

Las Vegas Wash

City of Henderson
Bird Viewing Preserve

City of Henderson
Water Reclamation
Facility

Inset B

Inset C

Inset A

BMI
Common Areas
(Eastside)

Former
TIMET

Former COH
Southern RIBs

Parcel 4B

Parcel 4A

TIMET

BMI
(CAMU)

NERT

PARCEL OWNED
BY MULTIPLE
ENTITIES

Olin

AMPAC
(Former Pepcon)

E RUSSELL RD

BOULDER HWY

E SUNSET RD

N BOULDER HWY

LAKE MEAD PARKWAY

S BOULDER HWY

W LAKE MEAD DR

N US 95

LEGEND

Shallow Water-Bearing Zone Wells (0-90 ft bgs)

- Active
- Plugged & Abandoned
- Inactive or paved over
- Nevada Environmental Response Trust Property Boundary
- Area of shallow Upper Muddy Creek (UMCf) deposits (so called "UMCf Ridge")

Grid: State Plane, Nevada East, NAD83, Feet

N

1 : 15,000
1 inch = 1,250 ft

0 1,000 2,000

Feet

Path: H:\LePetomane\NERT\RI.FS_Workplan\GIS\NERT_AllWells_ShallowNEW.mxd

Plate
1a

PROJECT: 21-29100H10

WELL LOCATION MAP
SHALLOW WATER-BEARING ZONE

Nevada Environmental Response Trust (NERT)
Henderson, Nevada

DESIGNED BY:	REVISIONS			
EJK	NO.	DESCRIPTION:	DATE:	BY:
DRAWN BY:	0	GENERATE APPROVED MAP	12/17/2012	RS
EJK/RS				
CHECKED BY:				
AS				
APPROVED BY:				
CJR/EJK				

ENVIRON

Las Vegas Wash

City of Henderson
Bird Viewing Preserve

City of Henderson
Water Reclamation
Facility

PARCEL OWNED
BY MULTIPLE
ENTITIES

BMI
(CAMU)

NERT

TIMET

Olin

AMPAC
(Former Pepcon)

BMI
Common Areas
(Eastside)

Former
TIMET

Parcel 4B

Former COH
Southern RIBs

Parcel 4A

E RUSSELL RD
BOULDER HWY
E SUNSET RD
N BOULDER HWY
N US 95
PABCO
LAKE MEAD PARKWAY
S BOULDER HWY
W LAKE MEAD DR

COH-1
MCF-08B-R
AAY-13
MW-K2
TWE-107
TWC-126
TWB-140
TWA-180
MCF-11
MCF-24B
MCF-16B
MCF-32B
MCF-02B
TR-12
M-152 M-156
TR-11
FX-180
M-155
M-151
CMT-506 CMT-507
CMT-505
CMT-504
AMX-98
AMX-166
AGX-230
AGX-160
AGX-190
TR-2
TR-1
M-161
M-162
CMT-106 CMT-107
CMT-105
CMT-104
M-154
M-150
M-181
DMC-MW-28
MC-MW-42
ADY-166
MC-MW-41
TR-4
TR-3
CMT-203
CMT-306
CMT-307
CMT-305
CMT-206
CMT-304
CMT-605 CMT-606
CMT-604
DY-106 DY-169
AEX-166
MC-MW-18
MC-MW-39
M-149
M-153
M-186
EC-14
MW-08
MC-MW-12
MC-MW-11
EC-13
TR-5
ADX-156
ADX-112
ADX-135
EC-12
DPT-01
DMC-MW-26
IW-1
IDX-161A
IDX-270
IDX-121
IDX-121A
MC-MW-09
CP-1
TR-7
TR-9
M-118
M-117
MW-AL

Path: H:\LePetomane\NERT\RI.FS_Workplan\GIS\NERT_AllWells_MiddleNEW.mxd

Plate
1b

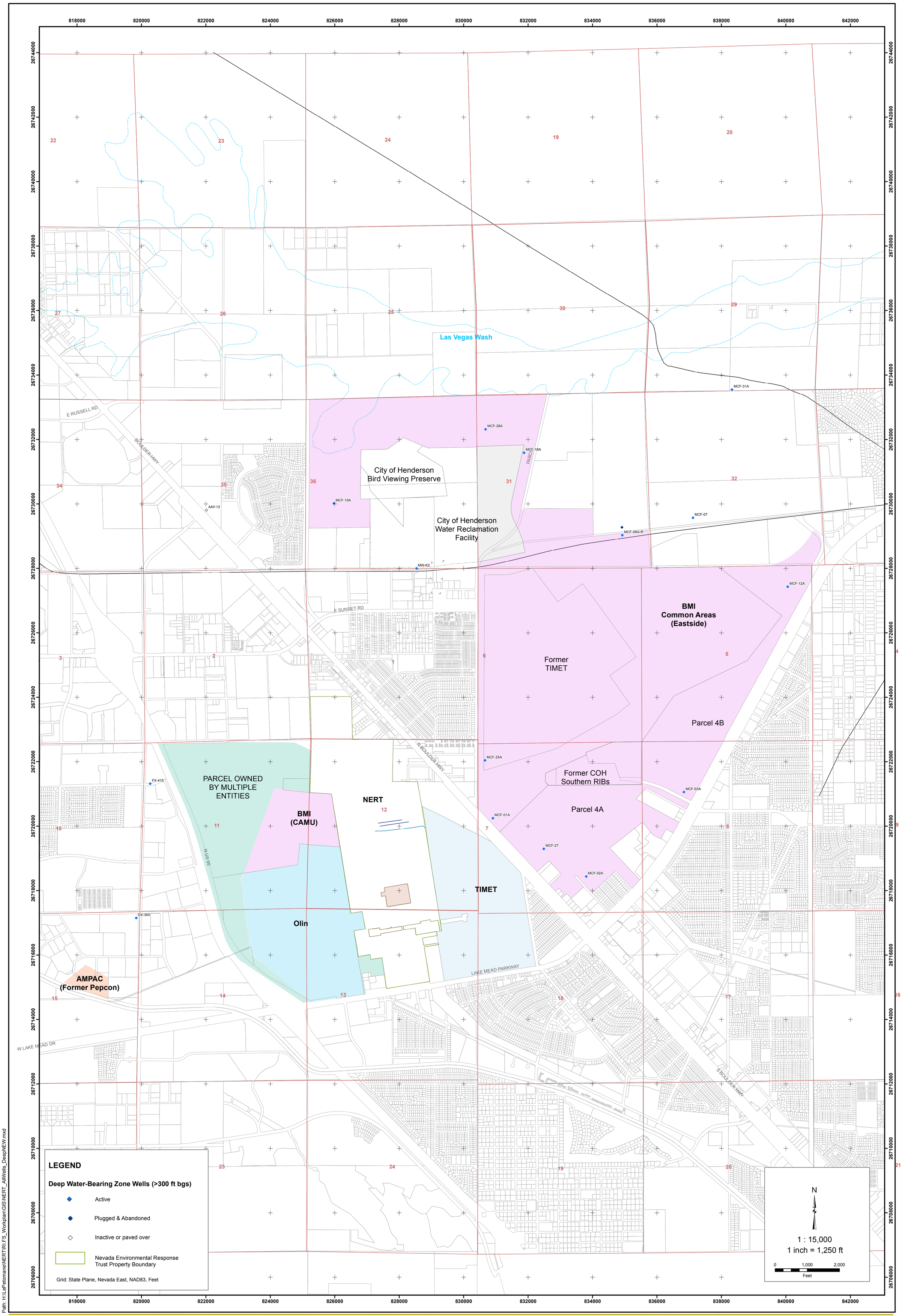
PROJECT: 21-29100H10

WELL LOCATION MAP
MIDDLE WATER-BEARING ZONE

Nevada Environmental Response Trust (NERT)
Henderson, Nevada

DESIGNED BY:	REVISIONS			
EJK	NO.	DESCRIPTION:	DATE:	BY:
DRAWN BY:	0	GENERATE APPROVED MAP	12/17/2012	RS
EJK/RS				
CHECKED BY:				
AS				
APPROVED BY:				
CJR/EJK				

ENVIRON



Path: H:\LePetomane\NERT\RI.FS_Workplan\GIS\NERT_AllWells_DeepNEW.mxd

Plate
1c

PROJECT: 21-29100H10

WELL LOCATION MAP
DEEP WATER-BEARING ZONE

Nevada Environmental Response Trust (NERT)
Henderson, Nevada

DESIGNED BY:	REVISIONS			
EJK	NO.	DESCRIPTION:	DATE:	BY:
DRAWN BY:	0	GENERATE APPROVED MAP	12/17/2012	RS
EJK/RS				
CHECKED BY:				
AS				
APPROVED BY:				
CJR/EJK				

ENVIRON

Inset B

0 100 200 400
Feet

Inset A

0 100 200 400
Feet

Former Recharge Trenches

Inset C

0 100 200 400
Feet

Las Vegas Wash

Inset C

Inset B

Inset A

E RUSSELL RD

BOULDER HWY

N US 95

E SUNSET RD

N BOULDER HWY

PABCO

LAKE MEAD PARKWAY

LEGEND

Wells Identified for Sampling (May - June 2012)

- Shallow Water Bearing Zone Well (used in Contouring)
- Deeper Water Bearing Zone (not used in Contouring)
- 1700 — Potentiometric Surface Contour (ft) (Dashed where approximate)
- 1700 — Groundwater Elevation (ft) (M-121 - Surface in Upper Muddy Creek Formation)
- NR — No Reading
- Direction of Groundwater Flow
- Nevada Environmental Response Trust Property Boundary
- Area of shallow Upper Muddy Creek (UMCf) deposits (so called "UMCf Ridge")

Note: Results shown may have been rounded for clarity. See Table A-1 and A-2 for all results reported to full precision.

Grid: State Plane, Nevada East, NAD83, Feet

N

1 : 12,000
1 inch = 1,000 ft

0 1,000 2,000
Feet

Path: H:\LePetomane\NERT\RI FS_Workplan\GIS\Plate2_2012Q2-Pot Surf Map_v2_KT3D.mxd

Plate
2

PROJECT: 21-29100H10

POTENTIOMETRIC SURFACE MAP SHALLOW WATER-BEARING ZONE SECOND QUARTER 2012

Nevada Environmental Response Trust (NERT)
Henderson, Nevada

DESIGNED BY:
EJK
DRAWN BY:
EJK/RS
CHECKED BY:
AS
APPROVED BY:
CJR/EJK

REVISIONS

NO.	DESCRIPTION:	DATE:	BY:
0	GENERATE APPROVED MAP	12/13/2012	RS

ENVIRON

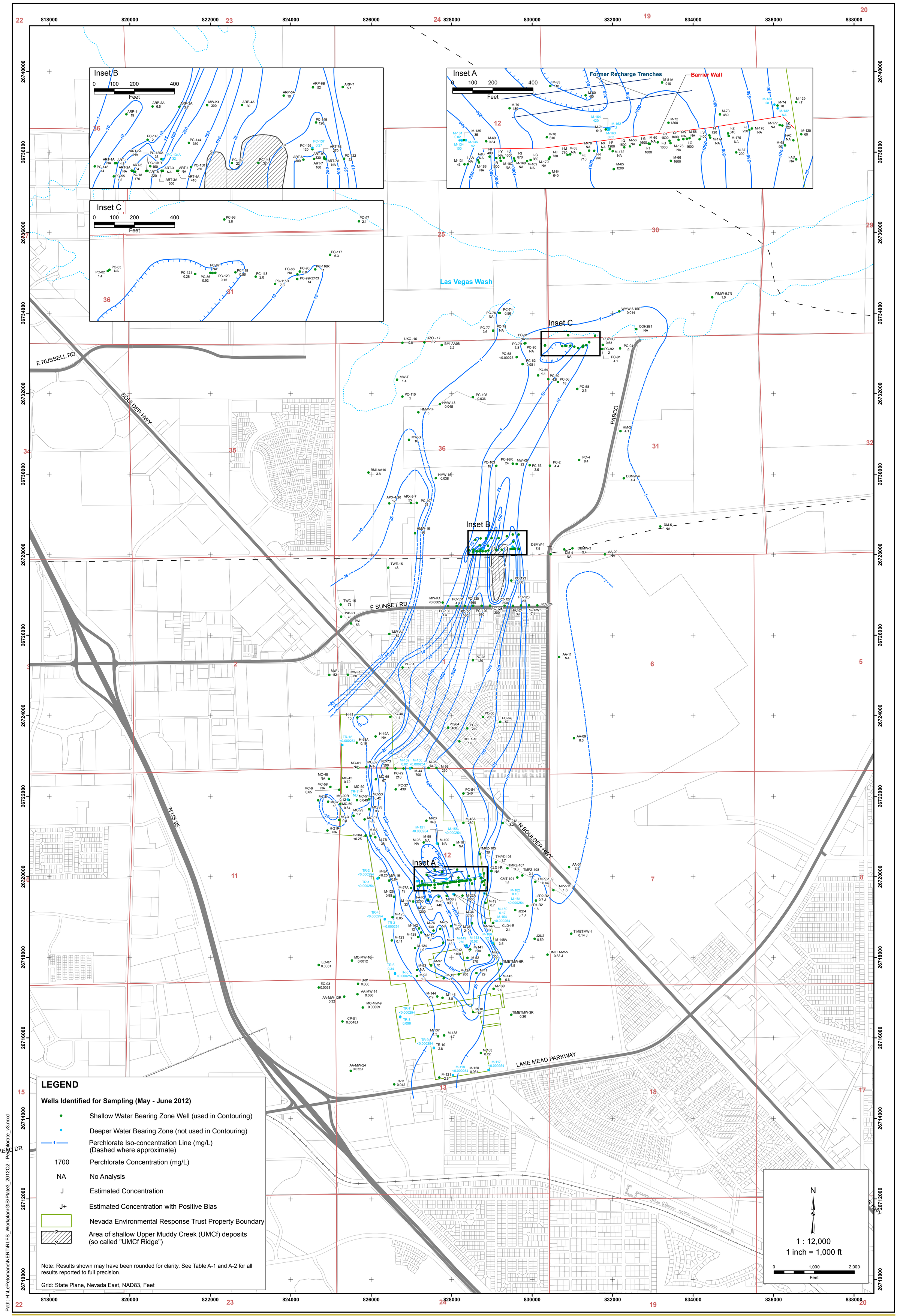


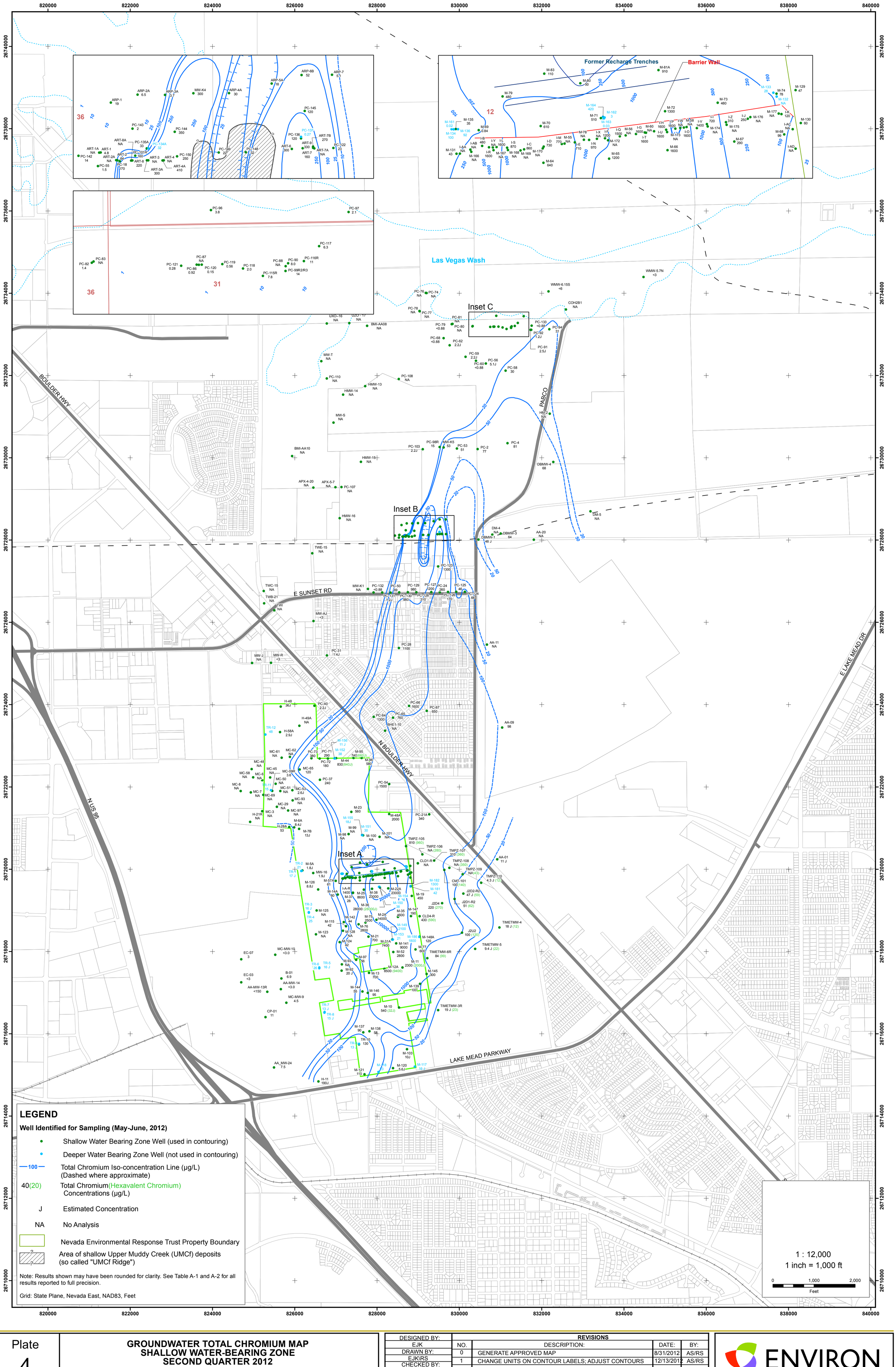
Plate 3

PROJECT: 21-29100H10

GROUNDWATER PERCHLORATE MAP
SHALLOW WATER-BEARING ZONE
SECOND QUARTER 2012
Nevada Environmental Response Trust (NERT)
Henderson, Nevada

DESIGNED BY:	REVISIONS			
EJK	NO.	DESCRIPTION:	DATE:	BY:
DRAWN BY:	0	GENERATE APPROVED MAP	12/13/2012	AS/RS
EJK\RS				
CHECKED BY:				
AS				
APPROVED BY:				
CJR/EJK				

ENVIRON



LEGEND

Well Identified for Sampling (May-June, 2012)

- Shallow Water Bearing Zone Well (used in contouring)
- Deeper Water Bearing Zone Well (not used in contouring)
- 100 — Total Chromium Iso-concentration Line (µg/L) (Dashed where approximate)
- 40(20) Total Chromium(Hexavalent Chromium) Concentrations (µg/L)
- J Estimated Concentration
- NA No Analysis
- Nevada Environmental Response Trust Property Boundary
- Area of shallow Upper Muddy Creek (UMCf) deposits (so called "UMCf Ridge")

Note: Results shown may have been rounded for clarity. See Table A-1 and A-2 for all results reported to full precision.

Grid: State Plane, Nevada East, NAD83, Feet

1 : 12,000
1 inch = 1,000 ft
0 1,000 2,000
Feet

Path: H:\LePetomane\NERT\RI.FS_Workplan\GIS\Plate4_2012Q2 - Cr(Cr6)_v3.mxd

Plate 4

PROJECT: 21-29100H10

GROUNDWATER TOTAL CHROMIUM MAP SHALLOW WATER-BEARING ZONE SECOND QUARTER 2012

Nevada Environmental Response Trust (NERT)
Henderson, Nevada

DESIGNED BY:
EJK
DRAWN BY:
EJK\RS
CHECKED BY:
AS
APPROVED BY:
CJR/EJK

REVISIONS

NO.	DESCRIPTION:	DATE:	BY:
0	GENERATE APPROVED MAP	8/31/2012	AS/RS
1	CHANGE UNITS ON CONTOUR LABELS; ADJUST CONTOURS	12/13/2012	AS/RS

ENVIRON

GROUNDWATER TOTAL DISSOLVED SOLIDS MAP
SHALLOW WATER-BEARING ZONE
SECOND QUARTER 2012

Nevada Environmental Response Trust (NERT)
Henderson, Nevada

Plate 5

PROJECT: 21-29100G

Inset A

Inset B

Inset C

Former Recharge Trenches

Barrier Wall

Las Vegas Wash

E RUSSELL RD

BOULDER HWY

E SUNSET RD

N US 95

PABCO

N BOULDER HWY

LAKE MEAD PARKWAY

W LAKE MEAD DR

LEGEND

Wells Identified for Sampling (May - June 2012)

- Shallow Water Bearing Zone Well (used in Contouring)
- Deeper Water Bearing Zone (not used in Contouring)
- Total Dissolved Solids (TDS) Iso-concentration Line (mg/L) (Dashed where approximate)
- 1700 — Total Dissolved Solids (TDS) Concentration (mg/L)
- J- — Estimated Concentration with Negative Bias
- 4242 — Calculated TDS Concentration (mg/L) from Conductivity X0.707
- NA — No Analysis
- Nevada Environmental Response Trust Property Boundary
- Area of shallow Upper Muddy Creek (UMCf) deposits (so called "UMCf Ridge")

Note: Results shown may have been rounded for clarity. See Table A-1 and A-2 for all results reported to full precision.

Grid: State Plane, Nevada East, NAD83, Feet

N

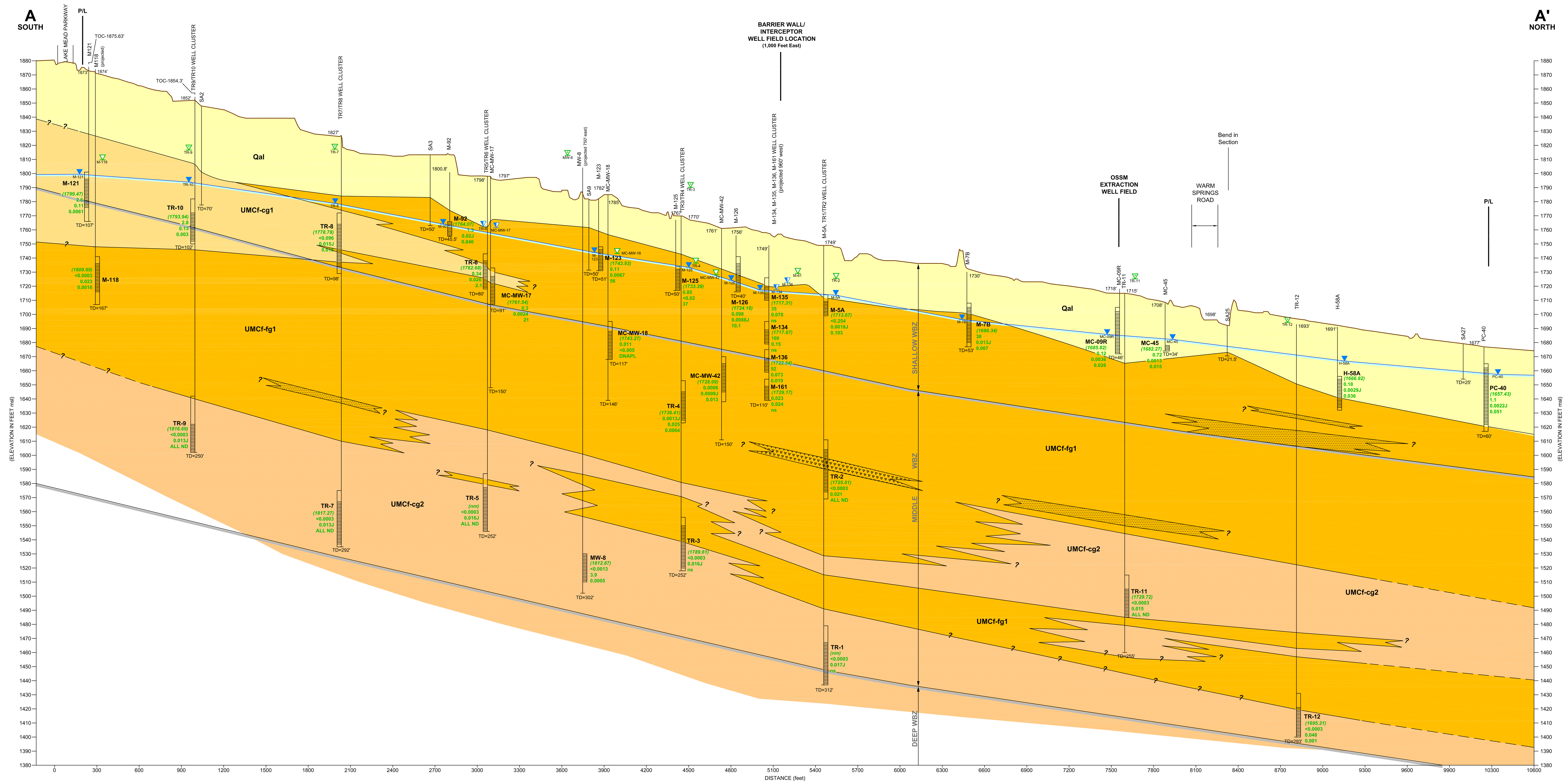
1 : 12,000
1 inch = 1,000 ft

0 1,000 2,000 Feet

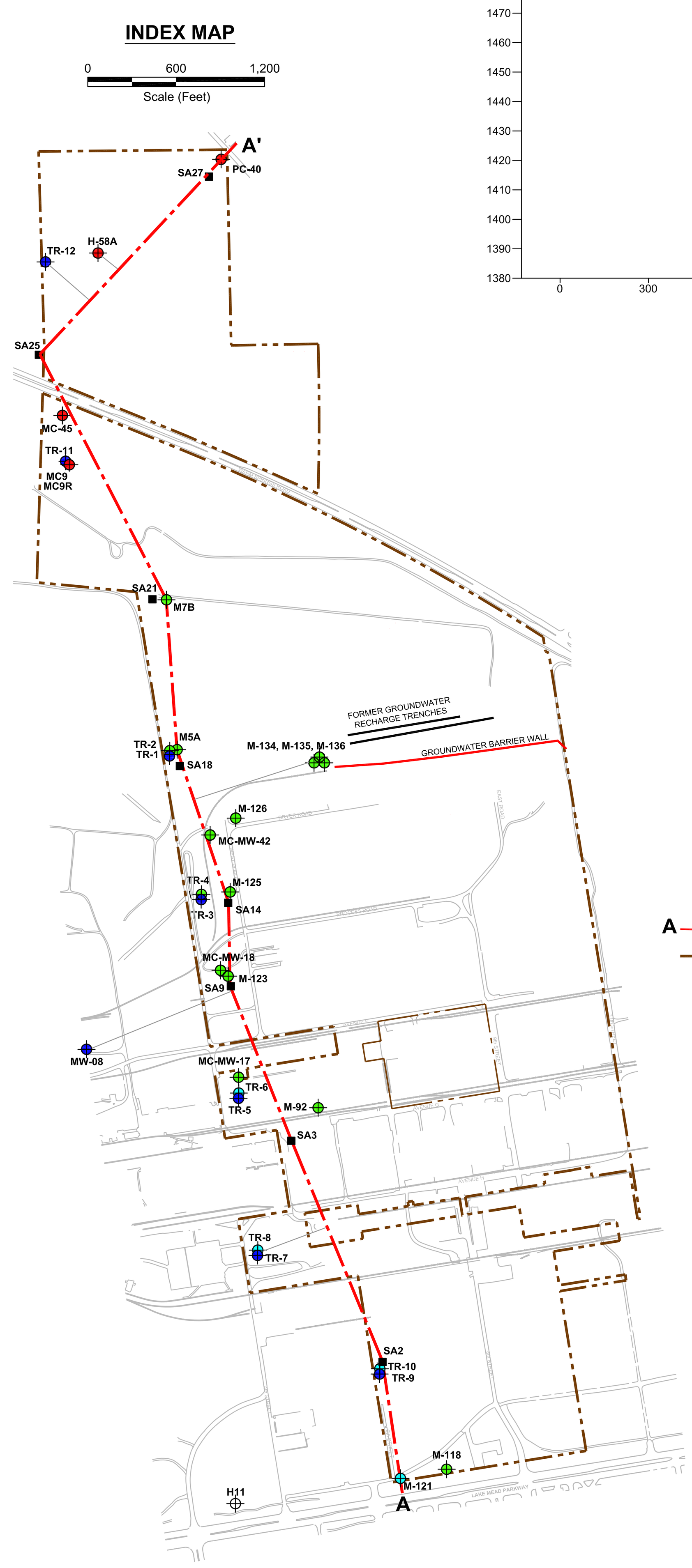
DESIGNED BY:	REVISIONS			
EJK	NO.	DESCRIPTION:	DATE:	BY:
DRAWN BY:	0	GENERATE APPROVED MAP	12/13/2012	AS/RS
EJK\RS				
CHECKED BY:				
AS				
APPROVED BY:				
CJR/EJK				

ENVIRON

Path: H:\LePetomane\NERT\RI.FS_Workplan\GIS\Plate5_2012Q2 - TDS v3.mxd



INDEX MAP



A — A' LINE OF GEOLOGIC SECTION

PROPERTY BOUNDARY

MONITORING WELL WITH SCREEN IN THE ALLUVIAL AQUIFER (Qal)

MONITORING WELL WITH SCREEN IN THE MUDDY CREEK FINE GRAIN FACIES (UMCf-fg1)

MONITORING WELL WITH SCREEN IN THE MUDDY CREEK COARSE GRAIN FACIES 1 (UMCf-cg1)

MONITORING WELL WITH SCREEN IN THE MUDDY CREEK COARSE GRAIN FACIES 2 (UMCf-cg2)

LEGEND

Qal QUATERNARY ALLUVIUM

UMCf-fg1 MUDDY CREEK FORMATION FINE-GRAINED FACIES #1

MUDDY CREEK FORMATION FINE-GRAINED FACIES #1 SILTY SAND AND SANDY BED

MUDDY CREEK FORMATION FINE-GRAINED FACIES #1 VOLCANIC ASH DEPOSIT

UMCf-cg1 MUDDY CREEK FORMATION COARSE-GRAINED FACIES #1

UMCf-cg2 MUDDY CREEK FORMATION COARSE-GRAINED FACIES #2

GROUNDWATER ELEVATIONS
(feet, mean sea level datum)

Shallow Water-Bearing Zone (0-90 ft)

Water Table Zone Well

Deeper Shallow WBZ Well

Middle Water-Bearing Zone (90-300 ft)

Upper Muddy Creek Formation, First Fine-Grained Unit (UMCf-fg1)

Upper Muddy Creek Formation, Second Coarse-Grained Unit (UMCf-cg2)

TR-1 — EXISTING BORING/WELL IDENTIFICATION

1797' — GROUND SURFACE ELEVATION (ft, msl)

FILTER PACK

SCREEN INTERVAL

TR-1 — WELL (SCREEN) IDENTIFICATION

TD=40' — TOTAL DEPTH OF BORING/WELL

EXPLANATION:

(1799.47)	GROUNDWATER ELEVATION (April/May 2012)
2.6	PERCHLORATE CONCENTRATION (May 2012) in milligrams/liter (mg/L).
0.11	TOTAL CHROMIUM CONCENTRATION (May 2012) in milligrams/liter (mg/L).
10.1	TOTAL VOCs in milligrams/liter (mg/L).

NOTES:

"<"	NOT REPORTED AT THE PRACTICAL QUANTITATION LIMIT SHOWN
(nm)	NO WATER LEVEL
ND	NOT DETECTED
NS	NOT SAMPLED
WBZ	WATER-BEARING ZONE

1. Chemical Data for wells MC-MW-17 and MC-MW-18 are from April 2011.
2. Chemical data for well MC-MW-42 are from May 2011.
3. Chemical data for well MW-8 are from October 2011.
4. Total VOCs were calculated based on all positive detections of individual VOCs during the most recent sampling event.

REFERENCES:

APPENDIX A - ANNUAL REMEDIAL PERFORMANCE REPORT FOR CHROMIUM AND PERCHLORATE, JULY 2011 THROUGH JUNE 2012 [NEVADA ENVIRONMENTAL RESPONSE TRUST, HENDERSON, NEVADA] (AUGUST 2012)

BMI COMPLEX DATABASE

ADAPTED FROM FIGURE 4-1, PHASE A SOURCE AREA INVESTIGATION, TRONOX FACILITY, HENDERSON, NEVADA (ENSR/AECOM 2008)

HYDROSTRATIGRAPHIC NOMENCLATURE FOLLOWS UNIFIED HYDROGEOLOGIC NOMENCLATURE PROPOSED BY NDEP IN JANUARY 6, 2009 LETTER

SCALE
30'
0'
0'
300'
Vertical Exaggeration 10x

ENVIRON

Subsurface Cross-Section A-A'
Nevada Environmental Response Trust Site
Henderson, Nevada

DATE:	CONTRACT NUMBER:		PLATE
11/21/12	21-29100H10		6
DRAFTER: RS	APPROVED:	REVISED:	