Prepared for
Nevada Environmental Response Trust
Henderson, Nevada

Prepared by
Ramboll Americas Engineering Solutions, Inc.
Oakland, California

Project Number
1940106394-013

Date
February 13, 2024

REMEDIAL INVESTIGATION REPORT FOR OU-1 AND OU-2, REVISION 2

NEVADA ENVIRONMENTAL RESPONSE TRUST SITE
HENDERSON, NEVADA

Remedial Investigation Report for OU-1 and OU-2, Revision 2

Nevada Environmental Response Trust Site
(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 NERT. 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 preparing 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.

Office of the Nevada Environmental Response Trust

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

Not Individually, but Solely
as President of the Trustee

Signature: Jay A Steinberg, President

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: February 13, 2024

Remedial Investigation Report for OU-1 and OU-2, Revision 2

Nevada Environmental Response Trust Site
(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.

Kimberly Kuwabara

Kimberly Kuwabara
Senior Managing Consultant

February 13, 2024
Date

Certified Environmental Manager
Ramboll Americas Engineering Solutions, Inc.
CEM Certificate Number: 2353
CEM Expiration Date: March 20, 2025

Remedial Investigation Report for OU-1 and OU-2, Revision 2
Nevada Environmental Response Trust Site
Henderson, Nevada

Date	**February 13, 2024**
Prepared for	**Nevada Environmental Response Trust**
Prepared by	**Ramboll Americas Engineering Solutions, Inc.**
Description	**Remedial Investigation Report for OU-1 and OU-2, Revision 2**
Project No.	**1940106394-013**

CONTENTS

TABLES

FIGURES

APPENDICES

ACRONYMS AND ABBREVIATIONS

1,1-DCA	1,1-dichloroethane
1,1-DCE	1,1-dichloroethene
1,2-DCA	1,2-dichloroethane
4,4’-DDE	4,4'-dichlorodiphenyldichloroethylene
4,4’-DDT	4,4'-dichlorodiphenyltrichloroethane
4-CBSA	4-chlorobenzenesulfonic acid
ABM	Advanced Battery Material
ACD	agricultural chemicals division
AL	action level
alpha-BHC	alpha benzene hexachloride
AMPAC	American Pacific Corporation
AOC3	Settlement Agreement and Administrative Order on Consent: BMI Common Areas, Phase 3
AP Plant	ammonium perchlorate plant
AP&CC	American Potash and Chemical Company
ARARs	Applicable or Relevant and Appropriate Requirements
AST	aboveground storage tank
AWF	Athens Road Well Field
Basic Magnesium	Basic Magnesium, Inc.
Basic Management	Basic Management, Inc.
BMI	Basic Management, Inc. or Basic Magnesium, Inc.
BCL	Basic Comparison Level
beta-BHC	beta benzene hexachloride
BHC	benzene hexachloride/lindane
BHRA	baseline human health risk assessment
Birding Ponds	Bird Viewing Preserve
BMI Complex	Black Mountain Industrial Complex
BRC	Basic Remediation Company LLC
Burris Oil	Burris Oil and Chemical Company
BWPC	Bureau of Water Pollution Control
Cadence	Cadence master-planned community
CalEPA	California Environmental Protection Agency

CAMU	Corrective Action Management Unit
CAPD	Chlor Alkali Products Division
Cascade	Cascade Drilling, LP
CCR	California Code of Regulations
CEM	Certified Environmental Manager
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
Chemstar	Chemstar, Inc.
chlorate	sodium chlorate and potassium chlorate
cm/sec	centimeters per second
CIP	Community Involvement Plan
COH	City of Henderson
Combined Metals	Combined Metals Reduction Company
COP	Continuous Optimization Program
COPC	chemical of potential concern
CPT	cone penetration test
CRC	Colorado River Commission
CSM	conceptual site model
CWA	Clean Water Act
DAF	dilution attenuation factor
DDT	dichlorodiphenyltrichloroethane
DNAPL	dense non-aqueous phase liquid
DOI	US Department of Interior
EC	electrical conductivity
ECA	excavation control area
EMD	EMD Acquisitions LLC
Endeavour	Endeavour LLC
Envirogen	Envirogen Technologies, Inc.
ENVIRON	ENVIRON International Corporation
EPP	evaporation and percolation ponds
ERA	ecological risk assessment
ESA	Endangered Species Act
ESS	environmental sequence stratigraphy

FA	facies association
FBR	fluidized bed reactor
FS	Feasibility Study
FSP	Field Sampling Plan
ft bgs	feet below ground surface
ft msl	feet above mean sea level
ft/day	feet per day
ft/ft	feet per foot
ft/yr	feet per year
gamma-BHC	gamma benzene hexachloride
gpm	gallons per minute
GW-11	groundwater holding pond within the NERT Site
GWETS	groundwater extraction and treatment system
GWSL	groundwater screening level
GWTP	groundwater treatment plant
Hardesty	Hardesty Chemical Company
HASP	health and safety plan
HHRA	human health risk assessment
HISSC	Henderson Industrial Site Steering Committee
HLC	Henderson Legacy Conditions
HRA	health risk assessment
HSSL	human health-based soil screening levels
HSTP1	Henderson Sewage Treatment Plant 1
HSTP2	Henderson Sewage Treatment Plant 2
HSTP3	Henderson Sewage Treatment Plant 3
Industrial Supply	Industrial Supply Company
ISB	in-situ bioremediation
IWF	Interceptor Well Field
IX	ion exchange
J.B. Kelley	Jack B. Kelley Trucking
Kerr-McGee	Kerr-McGee Chemical Corporation
Koch	Koch Materials Company (also known as Koch Asphalt Company)
lbs/d	pounds per day

LOU	Letter of Understanding
LSSL	leaching-based soil screening levels
magnesium oxide	magnesia
MCL	maximum contaminant level
MCLG	maximum contaminant level goal
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
Montrose	Montrose Chemical Company
mph	miles per hour
MTBE	methyl tertiary butyl ether
MTP	manganese tailings pile
muriatic acid	synthetic hydrochloric acid
NAPL	non-aqueous phase liquid
NCP	National Contingency Plan
NDEP	Nevada Division of Environmental Protection
NERT or the Trust	Nevada Environmental Response Trust
NFA	no further action
NMR	nuclear magnetic resonance
Northgate	Northgate Environmental Management, Inc.
NPDES	National Pollutant Discharge Elimination System
OCH	organochlorine herbicide
OCP	organochlorine pesticide
Olin	Olin Chlor-Alkali Products
OU	Operable Unit
OPP	organophosphate pesticide
OSHA	Occupational Safety and Health Administration
OSSM	Olin, Stauffer, Syngenta, and Montrose
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PCE	tetrachloroethene
PEPCON	Pacific Engineering and Production Company of Nevada
Pioneer	Pioneer Chlor Alkali Company, Inc.
PRG	preliminary remediation goal

Qal	Quaternary alluvial deposits
QAPP	quality assurance project plan
Ramboll	Ramboll US Corporation; Ramboll US Consulting, Inc.; or Ramboll Americas Engineering Solutions, Inc.
Ramboll Environ	Ramboll Environ US Corporation
RAOs	remedial action objectives
RAS	remedial alternatives study
RAW	removal action work plan
RCRA	Resource Conservation and Recovery Act
RI	remedial investigation
RI/FS	remedial investigation/feasibility study
RIB	rapid infiltration basin
ROD	record of decision
RZ	remediation zone
SAP	sampling and analysis plan
SGSLs	soil gas screening levels
Site	NERT Site
SLERA	screening level ecological risk assessment
SMP	site management plan
SNAP	Southern Nevada Auto Parts
SNWA	Southern Nevada Water Authority
SRC	site related chemical
SRG	soil remediation goal
State Industries	State Industries, Inc.
Stauffer	Stauffer Chemical Company
SVOC	semi-volatile organic compound
SWF	Seep Well Field
SWMU	solid waste management unit
TBA	tert butyl alcohol
TBC	to-be-considered
TCE	trichloroethene
TDS	total dissolved solids
TEF	toxic equivalency factor

TEQ	toxic equivalent
Tetra Tech	Tetra Tech, Inc.
TIMET	Titanium Metals Corporation of America
TOC	total organic carbon
TPH	total petroleum hydrocarbons
Tronox	Tronox LLC
Trust	Nevada Environmental Response Trust
TSE	Treatment System Extension
TTHMs	total trihalomethanes
µg/kg	micrograms per kilogram
µg/L	micrograms per liter
µg/m^3	micrograms per cubic meter
UIC	Underground Injection Control
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
UNLV	University of Nevada Las Vegas
US	United States
US Vanadium	United States Vanadium Corporation
USCS	Unified Soil Classification System
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
UST	underground storage tank
Valite	Valite Industries, Inc.
Veolia	Veolia Water North America
VOC	volatile organic compound
WAPA	Western Area Power Administration
WBZ	water-bearing zone
WECCO	Western Electrochemical Company
WRF	Water Reclamation Facility
xMCf	transitional Muddy Creek Formation

EXECUTIVE SUMMARY

The Nevada Environmental Response Trust (NERT or the Trust) was created on February 14, 2011, by the bankruptcy court as part of the confirmation of the Tronox bankruptcy. The Trust's primary purpose is to remediate environmental impacts created by historical manufacturing operations at the former Kerr-McGee Chemical Company (Kerr-McGee)/Tronox LLC (Tronox) site located in Henderson, Nevada. As such, NERT is implementing a Remedial Investigation (RI) consistent with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). The NERT RI Study Area occupies approximately 5,200 acres (8.1 square miles) within the City of Henderson (COH) and Clark County, Nevada (Figure ES-1). The southern-most portion of the NERT RI Study Area is located within a portion of the Black Mountain Industrial (BMI) Complex, and then extends north towards the Las Vegas Wash and east towards Lake Mead Parkway, as depicted in Figure ES-2a and Figure ES-2b. The BMI Complex was initially developed by the US Government for industrial purposes in the early 1940s in support of World War II wartime efforts and continues to house multiple private industrial manufacturing operations today. As depicted within Figure ES-3a, the NERT RI Study Area has been divided into three Operable Units (OUs). Operable Unit 1 (OU-1) is approximately 346 acres and is located within a portion of the BMI Complex. As shown in Figure ES-2a, property owned by NERT (the NERT Site) is located within the boundaries of OU-1.[1] Operable Unit 2 (OU-2) is approximately 2,645 acres, is located immediately north of OU-1, and extends to the east. Operable Unit 3 (OU-3) is approximately 2,200 acres and located north of OU-2.

This RI Report defines the nature and extent of contamination within OU-1 and OU-2, consistent with CERCLA and in accordance with the Interim Consent Agreement between the Nevada Division of Environmental Protection (NDEP) and the Trust (NDEP 2011a). While this report presents the results of the investigation of OU-1 and OU-2, the results of the investigation of OU-3 will be presented in a separate and forthcoming RI Report for OU-3.

The RI Report is not a remedy decision-making document. Rather, its purpose is to characterize site conditions, including the nature and extent of contamination within the NERT RI Study Area. The nature and extent of contamination documented in the RI Reports, in conjunction with the risk assessments, will be used to support the evaluation of remedial action alternatives in each of the two planned NERT Feasibility Study (FS) documents.[2] Following approval of the FS documents, plans will be prepared summarizing the proposed remedial action alternatives, which will be made available for public comment. After the close of the public comment periods, NDEP will review and respond to public comments, and

---

[1] OU-1 and the NERT Site occupied the same area prior to May 8, 2020 when Sale Parcels C, D, and H (shown in Figure ES-2a and Figure 1-4 within the main report text) were sold by the Trust. Within this report the term "NERT Site" refers to property owned by the Trust after May 8, 2020. The term "OU-1" refers to the area inclusive of the "NERT Site" as well as Sale Parcels C, D, and H. The term "NERT Site Study Area" refers to the property owned by the Trust after February 14, 2011 and prior to May 8, 2020 and has the same boundaries as OU-1.

[2] It is anticipated that one FS report will be prepared for OU-1 and OU-2 and a second FS report will be prepared for OU-3. The forthcoming RI Report for OU-3 will also be used to support the evaluation of remedial action alternatives in OU-3.

Record of Decisions (RODs) will be issued identifying the selected remedial action alternatives representing the final remedy.

Scope of the RI

This report documents the findings of investigations conducted to determine the nature and extent of chemicals of potential concern (COPCs) in OU-1 and OU-2, related to historical industrial activities within OU-1. Since the historical operations within and immediately adjacent to OU-1 contributed to current day contamination within OU-1, OU-2, and OU-3, this report also presents relevant off-site data and relates it to NERT's obligations consistent with CERCLA and the abovementioned Interim Consent Agreement. The RI was conducted to address the following objectives:

- Collect geologic and hydrogeologic data necessary to characterize the environmental setting of the NERT RI Study Area including the collection of subsurface soil and groundwater samples, the completion of aquifer testing, and Nuclear Magnetic Resonance (NMR) logging.
- Identify a comprehensive list of COPCs that exceed screening levels and should be evaluated in greater detail in the baseline human health risk assessments (BHRAs), the ecological risk assessments (ERAs), and in the forthcoming FS if present at levels that pose an unacceptable risk to the target receptor.
- Identify and characterize the sources of the COPCs related to historical activities within OU-1, such as the Unit 4 and 5 Buildings.
- Identify and characterize the sources of the COPCs related to historical activities immediately adjacent to OU-1, to the extent such activity affects OU-1 and OU-2 due to trespass or migration.
- Complete the lateral and vertical delineation of COPCs, including trespassing COPCs within OU-1.
- Characterize the COPCs migrating via groundwater from OU-1 into the NERT Off-Site Study Area component of OU-2 west of Pabco Road (see Figure ES-3a).
- Complete the lateral and vertical delineation of COPCs within the NERT Off-Site Study Area component of OU-2 west of Pabco Road, including COPCs migrating from areas other than OU-1 into OU-2, but limited only to perchlorate and chlorate in the Eastside Sub-Area component of OU-2 east of Pabco Road.
- Update the Conceptual Site Model with data acquired during the RI related to geologic and hydrogeologic conditions, identification of migrations pathways and COPC concentrations, land use, and exposure pathways.
- Characterize groundwater migration pathways in order to support the BHRAs and evaluation of remedial alternatives in the upcoming FS.
- Obtain soil gas data to support the evaluation of volatilization from shallow groundwater into soil gas and any resultant potential vapor intrusion risk that is presented in the BHRAs for soil gas and groundwater in OU-1 and OU-2.

Phases of the Remedial Investigation

The NERT RI as it relates to OU-1 and OU-2 was conducted in three phases. Phase 1 RI activities represent NERT's initial data collection effort as part of the RI and were conducted between October 2014 and May 2015. Phase 1 RI activities included investigation of soil, soil gas, and groundwater data gaps within the NERT Site Study Area (OU-1) and the NERT Off-Site Study Area (within OU-2 and OU-3). Within the NERT Site Study Area, the Unit 4 and 5 Buildings (located within OU-1) were investigated separately as a potential source area between October 2015 and December 2017.

The Phase 2 RI activities, which included 15 modifications to address additional data gaps, was conducted between February 2017 and April 2019. Phase 2 RI activities centered upon additional investigation to resolve soil and groundwater data gaps identified within the NERT Site Study Area (OU-1) and the NERT Off-Site Study Area (in both OU-2 and OU-3) as part of the earlier Phase 1 investigation.

The Phase 3 RI activities were initiated following NDEP's directive to investigate specific contaminants within the Eastside Sub-Area (within OU-2). The originally planned Phase 3 RI scope of work was conducted between December 2017[3] and November 2018, and it was subsequently expanded to include 15 modifications to address additional data gaps. Sampling activities for the modifications conducted within OU-1 and OU-2 were completed between June 2018 and January 2020. Implementation of the Phase 3 RI modifications solely within OU-3 continued through October 2022 and will be discussed in the forthcoming RI Report for OU-3.

Summary of COPCs for OU-1 and OU-2

The COPCs for soil and groundwater in OU-1 and OU-2 were developed based on the initial and secondary screening processes described in Section 7 (OU-1) and Section 8 (OU-2) of this report. In addition, COPCs in the Eastside Sub-Area have been administratively limited to perchlorate and chlorate. A summary of COPCs by area is shown in Figure ES-3b.

In OU-1, initial and secondary screening of COPCs was applied to both vadose zone soil and groundwater. The COPCs within OU-1 have been divided into two categories, Primary COPCs and Other COPCs. Primary COPCs are limited to perchlorate, chlorate, chromium and chloroform. The second category of COPCs, Other COPCs, includes general chemistry, metals, radionuclides (groundwater only), VOCs, semi-volatile organic compounds (SVOCs, soil only), polycyclic aromatic hydrocarbons (PAHs, soil only), dioxins and furans (soil only), polychlorinated biphenyls (PCBs, soil only), organochlorine pesticides (OCPs, soil only), and other organics. Out of 46 soil COPCs in OU-1, 44 are associated with historical operations in OU-1, and two are solely associated with trespassing groundwater from the neighboring Olin, Stauffer, Syngenta, and Montrose (OSSM) site to the west of and adjacent to OU-1. Out of 34 groundwater COPCs in OU-1, there are 10 COPCs that are solely associated with trespassing groundwater from the OSSM site and 7 COPCs (including the Primary COPC chloroform) that are associated with trespassing groundwater from the OSSM site as well as

---

[3] Prior to the start of Phase 3 RI, well inspections were performed as part of Phase 3 RI Modification No. 1 beginning in August 2017.

sources within OU-1. These COPCs and their source sites are identified and discussed further in the OU-1 Sources of Contamination section below.

NERT's obligations in OU-2 are different than in OU-1 in that in the Eastside Sub-Area, which is shown in Figure ES-3b and located east of Pabco Road. Due to the facts surrounding previous settlements made between NDEP and third party property owners, the COPC list in the Eastside Sub-Area has been administratively limited, and NERT is only responsible for evaluating the nature and extent of perchlorate and chlorate in the environment. In the NERT Off-Site Study Area component of OU-2, which is located west of Pabco Road (Figure ES-3b), the primary mechanism by which contaminants migrated to this area has been by groundwater transport. Since vadose zone soil in the NERT Off-Site Study Area was not directly impacted by historical operations within OU-1, the screening for COPCs was limited to groundwater. Each of the Primary COPCs identified in OU-1 groundwater are also evaluated in this area of OU-2. In addition to the four Primary COPCs, 13 Other COPCs (from the following chemical classes: general chemistry, metals, and VOCs) were identified in the NERT Off-Site Study Area component of OU-2 west of Pabco Road, versus the 34 identified in OU-1. Of the 17 total groundwater COPCs in the NERT Off-Site Study Area component of OU-2 west of Pabco Road, 12 have migrated in groundwater from sources within OU-1. Ten of the 17 total COPCs migrate from the OSSM site, across OU-1, and into OU-2. Contamination within OU-2 from four of these 10 COPCs is solely a result of migration from sources on the OSSM site. As such, there are multiple sources for several COPCs other than just the sources within OU-1. Of the 17 COPCs identified in OU-2, one has solely migrated from the TIMET site directly into OU-2, and three COPCs that are associated with releases from both OU-1 and OSSM are also found to have migrated from TIMET. Two COPCs migrating from OU-1 (perchlorate and chlorate) have also migrated from the former American Pacific Corporation (AMPAC) site directly into OU-2. This has created a situation where COPCs from multiple parties are migrating into and out of each NERT OU, creating an extraordinarily complex environment of commingling groundwater plumes. These COPCs and their source sites are identified and discussed further in the OU-2 Sources of Contamination section below.

OU-1 Sources of Contamination

Following the comprehensive investigation of OU-1 during the RI, the areas that have been identified as the sources of contamination within OU-1, which are shown in Figure ES-4a, are: the Unit 4 and 5 Buildings, the former Beta Ditch, the former ammonium perchlorate plant (AP Plant) and associated facilities located near the Beta Ditch, the former P and S Ponds, the former Trade Effluent Ponds, and the former recharge trenches. Each of these features are summarized below. In addition, groundwater in the western portion of OU-1 has been and continues to be impacted by trespassing chemicals from the adjacent OSSM site.

Unit 4 and 5 Buildings

The Unit 4 and 5 Buildings were used for multiple purposes, including the production of magnesium, chlorates and perchlorates. Reported historical releases included process chemicals leaking to soil through cracks in the basements of the Unit 4 and 5 Buildings (NDEP 1994b). Sumps in the concrete basements collected process liquor, spillage, and wash water associated with production.

A comprehensive investigation of the Unit 4 and 5 Buildings source area was conducted by the Trust between 2015 and 2017. The objective of this investigation was to determine the nature of contamination and the vertical extent of impacted soil and groundwater underneath the Unit 4 and 5 Buildings. In addition to perchlorate and hexavalent chromium, several other COPCs were identified in soil and groundwater above their respective leaching-based soil screening levels (LSSLs), groundwater screening levels (GWSLs), or other screening criteria. These other COPCs included chlorate, chloroform, and nitrate. In addition, elevated total dissolved solids (TDS) concentrations were observed. Perchlorate was found to be the most widespread of these COPCs in both soil and groundwater within the Unit 4 and 5 Buildings source area. Perchlorate concentrations in groundwater exceeded the GWSL of 0.015 milligrams per liter (mg/L) throughout most of the Unit 4 and 5 Buildings Investigation Area. The highest concentrations of perchlorate in groundwater were observed directly below and downgradient of the Unit 4 Building (up to 6,600 mg/L) in the Upper Muddy Creek Formation (UMCf) within a depth interval between 75 and 125 feet below ground surface (bgs), with perchlorate concentrations decreasing below 125 feet bgs and non-detect at 240 feet bgs.

The lateral extent of perchlorate and other COPCs found in groundwater in the Unit 4 and 5 Buildings source area was evaluated as part of the RI. Perchlorate (and other chemicals associated with releases at the Unit 4 Building) migrated downward through the alluvium and UMCf until they encountered low permeability silty clay soils at an approximate depth of 110 feet bgs that impeded the downward migration and caused impacted groundwater to migrate laterally, first toward the north-northeast within a depth interval of 90 to 130 feet bgs, for a distance of approximately 1,800 feet, where groundwater and contaminants were deflected toward the east due to the presence of low permeable soils in this area. The area of perchlorate-impacted groundwater above the GWSL extends for a distance of approximately 2,500 feet northeast of the Unit 4 Building within the 90-130 feet depth interval.

The distribution of Primary COPCs besides perchlorate (i.e., chlorate, chromium, and chloroform) is similar to perchlorate in the Unit 4 and 5 Buildings source area in that the highest concentrations were found in wells located adjacent to the Unit 4 Building, below the Unit 4 Building basement, and northeast of the Unit 4 Building between approximate depths of 90-110 feet. The lateral extent of groundwater impacted by the other Primary COPCs is within the perchlorate groundwater plume footprint at this depth. These similar distribution patterns are consistent with historic operations and releases from the Unit 4 Building area. Groundwater monitoring of the depth interval of 130 to 175 feet bgs indicates that the Primary COPCs are migrating northward of the Unit 4 and 5 Buildings for a limited distance but do not migrate into OU-2 at this depth interval.

Former Beta Ditch

The Beta Ditch was an unlined ditch that carried wastewater from the BMI Complex to the Upper BMI Ponds from 1943 until the mid-1970s. After all segments were complete, the former Beta Ditch started on the OSSM site to the west, crossed OU-1 onto the TIMET site, then continued to the system of disposal ponds within the Eastside Sub-Area via a siphon and pipe segment under what is now Boulder Highway. The Upper BMI Ponds were constructed in the early 1940s within the Eastside Sub-Area, which was historically referred to as BMI Common Areas, to provide additional discharge capacity beyond that of the original on-site Trade Effluent Ponds. From 1943 to 1944, process wastewater from magnesium production within the BMI Complex, which includes OU-1, migrated to primarily the Upper BMI Ponds via the Beta Ditch. From 1945 until the mid-1970s, process effluents from the chlorate-, perchlorate-, and boron-related production processes within OU-1, as well as effluents associated with historical tenants within OU-1 and process effluents from chlorine- and pesticide-related production processes at the OSSM site and titanium tetrachloride-related production processes at the TIMET site migrated to the Upper BMI Ponds via the Beta Ditch.

Discharges to the Beta Ditch would have likely included perchlorate, chlorate, chloroform, and chromium associated with former production processes in OU-1. In addition, chloroform discharges to the Beta Ditch would likely have occurred from the OSSM and TIMET sites, because chloroform[4] is known to be a waste by-product of the chemical production processes occurring at both the OSSM and TIMET sites (Converse 1993; Weston 1993; USEPA 2007; US Patent Office 1957).

For approximately 35 years, percolation of wastewater from the unlined Beta Ditch resulted in contamination of underlying soil and shallow groundwater related to former operations in OU-1 and other users of the ditch, such as OSSM and TIMET. With respect to the segments of the ditch system west of OU-1, this use of the ditches by OSSM, or other entities operating within the present day OSSM site, represented a historical source of contaminants to OU-1 environmental media unrelated to former OU-1 operations (Geraghty & Miller 1993). Since the Beta Ditch was unlined, discharges to the Beta Ditch outside of OU-1 would have impacted groundwater beneath the Beta Ditch within OU-1, and COPCs in the affected groundwater would have migrated downgradient.

In the early 1970s, under the federal National Pollutant Discharge Elimination System (NPDES) program, the BMI Complex companies[5] curtailed waste discharges to the Beta Ditch and the Upper and Lower BMI Ponds (Geraghty & Miller 1993). Kerr-McGee, operating in OU-1 at the time, achieved zero-discharge status in 1976, at which time process effluents were sent to on-site lined surface impoundments. Around that same time, process waste discharges from all parties to the Beta Ditch ceased.

Within OU-1, the inactive Beta Ditch and underlying soil were excavated in 2010-2011 as part of a soil removal action and concurrent construction of the Central Retention Basin.[6] In the area north (downgradient) of the Beta Ditch, between the Beta Ditch and the Interceptor Well Field (IWF) and barrier wall, there is an extensive area of residual soil and groundwater contamination related at least in part to infiltration from the former unlined ditch. Groundwater is impacted by perchlorate (up to 1,900 mg/L), chlorate (up to 4,400 mg/L), chromium (up to 23 mg/L), chloroform (up to 1,400 micrograms per liter [µg/L]) and Other COPCs to a depth of approximately 70 feet bgs in this area.

---

[4] Carbon tetrachloride, which readily degrades to chloroform, was also a waste by-product at the OSSM site and TIMET site.

[5] Companies operating within the BMI Complex have changed over time. By the early 1970s, the primary operators within the BMI Complex included Kerr-McGee, Stauffer Chemical Company (Stauffer), Montrose Chemical Corporation of California (Montrose), TIMET, and Flintkote Company (previously US Lime).

[6] The Beta Ditch within OU-1 was excavated in 2010-2011 (ENVIRON 2012a) and 2013 (ENVIRON 2014d). Portions of the Beta Ditch within the TIMET site were primarily excavated in 2013 (GEI 2013).

Former AP Plant and Associated Facilities

The AP Plant and associated waste containment ponds and other facilities were located in the northern half of OU-1 south of the former Trade Effluent Ponds and former recharge trenches (Figure ES-4a). Investigations in this area have shown elevated concentrations of COPCs in soil above LSSLs and in groundwater above GWSLs to depths of approximately 90 feet bgs through most of this area, including perchlorate in groundwater up to 1,600 mg/L, chlorate up to 2,100 mg/L, and chromium up to 6 mg/L. After closure of the former AP-5 Pond in September 2018, investigation results showed perchlorate concentrations above 1 mg/L in underlying groundwater to a depth of approximately 85 feet and perchlorate above the GWSL was found to extend to a depth of approximately 145 feet at an isolated location. The highest concentration of perchlorate in groundwater at this location was 950 mg/L between 60 and 70 feet bgs. At a depth interval of 90 to 100 feet bgs, perchlorate in groundwater at this location was 0.6 mg/L.

Former Trade Effluent Ponds

Between 1942 and 1944, process wastewater generated by industrial operations within OU-1 and the BMI Complex was discharged via the Distribution Flume following treatment in the wastewater acid neutralization plant to the Trade Effluent Ponds (partially located outside of OU-1), the original wastewater disposal ponds that were used prior to the Upper and Lower BMI Ponds (Kleinfelder 1993). Details regarding Trade Effluent Pond usage after 1944 were not reported (Kleinfelder 1993). The GW-11 and WC ponds, which are currently in operation, are located where some of the former Trade Effluent Ponds were located and the northern berms of these in service ponds appear to have been originally constructed for the former Trade Effluent Ponds. Soil characterization data from the GW-11 and WC pond berms indicates the presence of select COPCs above LSSLs in the pond berms. As such, these COPCs may impact groundwater quality within OU-1 and ultimately migrate off-site into OU-2.

Former IWF Recharge Trenches

Between mid-1987 and 1998, treated groundwater from the IWF was conveyed to two shallow recharge trenches north of the barrier wall. At that time, the extracted groundwater from the IWF was treated only for chromium and then reinjected into the ground. Data indicates that this activity may have contributed to the high concentrations of perchlorate, chlorate, and chloroform found in groundwater north of the barrier wall observed today. Following the discovery of perchlorate in groundwater, stabilized Lake Mead water was used to recharge groundwater downgradient of the IWF from 1998 until September 2010, when the recharge trenches ceased operation prior to soil removal activities at the Site. The Primary COPCs detected in groundwater north of the barrier wall include perchlorate (up to 1,200 mg/L), chlorate (up to 3,300 mg/L), chromium (up to 11,000 µg/L), and chloroform (up to 740 µg/L). In general, the highest concentrations occur within the Shallow water-bearing zone (WBZ) to a depth of 70-75 ft bgs. Perchlorate concentrations above the GWSL extend to depths of 90 ft bgs along the northern OU-1 boundary and to depths of 145-150 ft bgs near the northeastern portion of the northern OU-1 boundary.

Trespassing Chemicals

With respect to chemicals trespassing into OU-1, groundwater contaminants and dense non-aqueous phase liquid (DNAPL) have migrated and continue to migrate into OU-1 from the

OSSM site located immediately to the west of OU-1. In addition, and as discussed above, OSSM historically discharged wastewater to the unlined Beta Ditch which allowed contaminants to seep into the subsurface within OU-1. As a result, the following 17 COPCs have been identified along the western boundary of OU-1 as originating on the OSSM site: arsenic, magnesium, manganese, chloroform, benzene, chlorobenzene, 1,2-, 1,3- and 1,4-dichlorobenzene, carbon tetrachloride, 1,1-dichloroethane (1,1-DCA), 1,2-dichloroethane (1,2-DCA), 1,4-dioxane, 1,1,2,2-tetrachloroethane, 1,2,3-trichloropropane, methylene chloride, and tetrachloroethene (PCE). These COPCs have migrated into OU-1 via multiple mechanisms. Migration into OU-1 of DNAPL and dissolved-phase VOCs originating from the DNAPL continues to occur. The OSSM groundwater plume associated with the trespassing DNAPL encroaches onto OU-1 across its western boundary for a distance of at least 1,000 feet, migrates downgradient within OU-1, and ultimately off-site into OU-2. This trespassing plume is clearly discernable from the chloroform plume originating from the Unit 4 and 5 Buildings source area. It includes free-phase VOCs (DNAPL) at depths of 100-120 feet bgs as well as dissolved-phase VOCs in the Shallow and Middle WBZs. Of the VOCs detected in the DNAPL, chloroform is the most persistent and soluble (i.e., mobile) in the trespassing plume and represents the most prevalent VOC found in the dissolved phase in OU-1. Chloroform is detected at concentrations up to 19,000 µg/L in samples from Shallow WBZ wells within OU-1 impacted by the OSSM plume. For comparision, the highest chloroform concentration in the vicinity of the Unit 4 and 5 Buildings source area within OU-1 in the Shallow WBZ was 310 µg/L.

As previously indicated, the Primary COPCs in groundwater are migrating northeastward from the Unit 4 and 5 Buildings source area at a depth interval of 90 to 130 feet bgs. These COPCs are migrating from OU-1 onto the neighboring TIMET site where they are slowly migrating upward, due to an upward vertical gradient, to the water table within the TIMET site. Based on the distribution of Primary COPC concentrations in the affected area of the TIMET site and their concentrations, chloroform originating from the Unit 4 and 5 Buildings source area cannot be solely responsible for the higher concentrations of chloroform in groundwater at the water table within the TIMET site. This was confirmed using a particle tracking evaluation. Thus, multiple lines of evidence indicate that there are chloroform sources within the TIMET site that are directly impacting shallow groundwater in this area.

OU-1 Vadose Zone Soil

The OU-1 vadose zone soil has been thoroughly characterized through implementation of the RI. Based on the data presented in this RI Report, NERT concludes the majority of the COPCs identified in soil above LSSLs in OU-1 have not migrated into groundwater at concentrations above GWSLs. Only perchlorate, chlorate, hexavalent chromium, chloroform, nitrate, arsenic, boron, magnesium, manganese, benzene, carbon tetrachloride, chlorobenzene, methylene chloride, 1,2,3-trichloropropane, and 1,4-dioxane have been determined to have impacted groundwater quality such that the GWSLs have been exceeded in OU-1. No data gaps or additional investigation are needed, and the investigation of soil within OU-1 is considered complete.

OU-1 Groundwater

OU-1 groundwater has also been thoroughly characterized through implementation of the RI. Based on the data presented in this RI Report, NERT concludes the following regarding the investigation of OU-1 groundwater:

- The alluvium has become dewatered throughout almost all of OU-1, and first groundwater now primarily occurs in the low permeability UMCf. Only a few thin sandy units were found in the UMCf, predominantly in the southern part of OU-1. These preferential flow pathways are, however, limited in lateral extent and, due to its low permeability, contaminants migrate very slowly through the UMCf.
- The lateral extent of both the Primary COPCs (perchlorate, chlorate, chromium, and chloroform) and Other COPCs in OU-1 groundwater has been defined. Perchlorate and chlorate are the most widespread contaminants in groundwater within OU-1, and the distribution of Other COPCs in groundwater which are attributed to OU-1 generally occur within the footprint of the perchlorate and chlorate plumes. The lateral extent of the Primary COPCs in OU-1 and OU-2 west of Pabco Road is illustrated in Figure ES-5.
- The vertical extent of both the Primary and Other COPCs in OU-1 groundwater has been defined. In OU-1, the Unit 4 and 5 Buildings were found to be a significant source of perchlorate and other COPCs historically released within the NERT Site Study Area, with higher groundwater levels from wastewater infiltration and density-driven flow likely contributing to the downward migration of the highest perchlorate concentrations to depths of 90-120 feet bgs. Perchlorate in groundwater above the GWSL extends to a depth of approximately 175 feet bgs beneath the Unit 4 Building. In contrast, the highest perchlorate concentrations are in shallow groundwater above a depth of 90 feet bgs in the northern part of OU-1 between the former Beta Ditch and the IWF. In this area, separate sources related to other operational areas (such as the AP Plant area and associated ponds, and the former recharge trenches) historically released perchlorate and Other COPCs to soil and shallow groundwater.
- In addition to the chloroform attributed to the trespassing OSSM plume, chloroform was also found in groundwater beneath and downgradient of the Unit 4 Building in samples collected from wells screened between 90-115 ft bgs. The highest concentrations (up to 8,300 µg/L) were found beneath the Unit 4 Building and extend north-northeast for a distance of approximately 1,600 feet, with a distribution pattern similar to perchlorate at this depth. This suggests chloroform migrated downward beneath the Unit 4 Building along with perchlorate and other Primary COPCs found at this depth interval.

No data gaps for groundwater in OU-1 were identified and no additional investigation is needed, and as such, the investigation of groundwater within OU-1 is considered complete.

OU-1 Soil Gas

OU-1 soil gas has also been thoroughly characterized through implementation of the RI. Based on the data presented in this RI Report, NERT concludes the following regarding the investigation of OU-1 soil gas:

- Chloroform was the only VOC in OU-1 detected in soil gas above screening levels, and it was detected at all sample locations and depths across OU-1 during the RI sampling events. The highest soil gas concentrations for chloroform are attributed to two sources with one area located next to the Unit 4 Building and the other over the portion of the DNAPL plume which trespasses from the OSSM site onto the western side of OU-1. In general, chloroform concentrations in soil gas increased with depth indicating that the source of chloroform in soil gas in both instances is chloroform in groundwater rather than a shallow vadose zone source. In addition, the DNAPL associated with the OSSM trespassing plume is also a source of elevated COPCs in soil gas.
- Three additional VOCs (PCE, carbon tetrachloride, and trichloroethene [TCE]) were detected at elevated concentrations but below screening levels in OU-1 soil gas. These additional VOCs are not considered COPCs in OU-1 soil, but are considered COPCs in groundwater largely due to groundwater contamination that is trespassing from the OSSM site. The highest concentrations of PCE and carbon tetrachloride in soil gas were located along the western OU-1 boundary where VOCs in groundwater trespass from the OSSM site onto OU-1. TCE was detected at relatively low concentrations in soil gas across OU-1, with the highest TCE concentrations detected in the central portion of OU-1, correlated with the locations of higher concentrations of TCE in groundwater originating in and trespassing from the Western Area Power Administration (WAPA) property.

For chloroform and other VOCs in groundwater, an evaluation of volatilization from shallow groundwater into soil gas and any resultant potential vapor intrusion risk is presented in the BHRA for soil gas and groundwater in OU-1.

OU-2 Sources of Contamination

The sources of contamination in OU-2 are divided into two distinct areas: OU-2 west of Pabco Road (NERT Off-Site Study Area) and OU-2 east of Pabco Road (Eastside Sub-Area). The locations of sources of contamination to OU-2 are shown in Figure ES-4b.

Sources of Contamination within OU-2 West of Pabco Road (NERT Off-Site Study Area)

Land use in the NERT Off-Site Study Area within OU-2 has been used for residential or commercial purposes unrelated to operation of the BMI Complex. COPC concentration gradients clearly indicate that properties in OU-2 do not have an observable impact on groundwater quality. Therefore, a comprehensive survey of the history of each property in OU-2 has not been completed. Currently, the area is occupied by casinos, gas stations, retail stores, auto dealerships, auto wreckers, a large data center, and a wide variety of other small businesses. While some of these operations could result in localized soil or groundwater contamination, none of the identified operations are likely to have significantly contributed to the wide-spread distribution of COPCs within OU-2 based on NERT's evaluation of COPC concentrations in OU-2 groundwater.

Therefore, there are no primary sources of Site-related contamination within the NERT Off-Site Study Area portion of OU-2. The groundwater contamination in this area has resulted from migration of contaminants in groundwater from upgradient sources and possibly from the infiltration of contaminants from wastewater that migrated through former ditches while they were in operation. In addition, residual contamination that has migrated and continues to migrate downgradient from OU-1 in the UMCf represents a long-term secondary source to shallow groundwater in this area of OU-2.

Migration in Groundwater from Upgradient Sites

As indicated, in OU-2 west of Pabco Road, a primary source of the contamination in groundwater has been the migration of COPCs in groundwater from upgradient sites, including OU-1, the OSSM site, the TIMET site, and the former AMPAC site. Therefore, and as expected, the highest concentrations of COPCs in OU-2 groundwater downgradient of these sites are found in the southern (upgradient) portion of OU-2, north of Warm Springs Road.

The four primary sources of COPCs in groundwater migrating to OU-2 can be summarized as follows:

- NERT Site Study Area/OU-1. The Primary COPCs in OU-2 groundwater resulting from releases that occurred in OU-1 are perchlorate (up to 1,200 mg/L), chlorate (up to 1,100 mg/L), chromium (up to 2,000 µg/L), and chloroform (up to 650 µg/L). In addition, nitrates, arsenic, boron, magnesium, bromodichloromethane, carbon tetrachloride, 1,4-dioxane, and 1,2,3-trichloropropane present in groundwater within OU-2 originated from releases in OU-1.
- OSSM site. The OSSM site is located immediately west of OU-1 and is the source of a groundwater plume that encroaches onto OU-1 and eventually migrates off-site into OU-2. Downgradient (north) of the OSSM site and its groundwater extraction and treatment system (GWETS), the COPCs above GWSLs currently found in OU-2 groundwater associated with releases on the OSSM site are arsenic, magnesium, manganese, and six VOCs (1,1-DCA, 1,2,3-trichloropropane, 1,4-dioxane, benzene, chlorobenzene, and chloroform). In addition, groundwater in this area contains elevated TDS (up to 15,000 mg/L) related to releases from the OSSM site. The portion of the groundwater plume originating on the OSSM site that trespasses onto OU-1 is largely not captured by the OSSM GWETS and continues to migrate in an uncontrolled manner northward through OU-1 into OU-2.
- TIMET site. COPCs from the TIMET site, located immediately east of OU-1, have also migrated downgradient directly to OU-2. In 2014, a bentonite slurry wall and GWETS were installed along the northern boundary of the TIMET site designed to capture and treat groundwater contaminated by TIMET's VOCs. Chloroform and PCE are present in groundwater above GWSLs at the northern TIMET site boundary, as indicated by their presence in both monitoring wells and the treatment plant influent (Tetra Tech EMI 2005; GEI 2020b). Chloroform trespassing onto TIMET at the 90 to 130 foot bgs depth interval from OU-1 is contributing to chloroform concentrations in TIMET shallow groundwater; however, the chloroform concentrations in the OU-1 deep plume are up to two orders of magnitude less than found in shallow groundwater on the TIMET site. This indicates that additional chloroform sources within the TIMET site are directly impacting shallow groundwater quality. Directly downgradient of the TIMET site, chloroform and PCE are detected above their GWSLs in OU-2 groundwater north of Warm Springs Road. In addition, groundwater directly downgradient of the

TIMET site is impacted by 1,4-dioxane (up to 23 µg/L), 1,2,3-trichloropropane (detected concentrations up to 0.088 µg/L and detection limits up to 4.0 µg/L) and elevated TDS (up to 11,000 mg/L). As such, releases from the TIMET site have also contributed to elevated VOC contamination in OU-2.

- Former AMPAC site. In addition to the groundwater contamination sources from the upgradient sites within the BMI Complex, a separate perchlorate plume associated with the former AMPAC site located approximately 1.5 miles west of OU-1 has commingled with the NERT perchlorate plume near NERT's Athens Road Well Field (AWF) in OU-2. AMPAC's plume also is present within the western part of OU-3 and discharges perchlorate to the Las Vegas Wash in this area. Additional information regarding delineation of the AMPAC and NERT perchlorate plumes will be presented in the forthcoming RI Report for OU-3.

Sufficient data have been collected in the RI to determine the origins of the various contaminants in OU-2 groundwater west of Pabco Road and no additional data collection is necessary. As indicated in Figure ES-5, the shape of the perchlorate, chlorate, and chromium plumes are nearly identical as these COPCs all originate from the same source areas, with the Unit 4 and 5 Buildings being the most significant source area. The Unit 4 and 5 Buildings source area is also the only source area associated with historical operations in OU-1 that contains chloroform. However, the shape of the chloroform plume within OU-2 is significantly different than perchlorate, chlorate, and chromium indicating that other sources, such as the OSSM and TIMET sites, have impacted groundwater quality in OU-2. This conclusion is also supported by multiple lines of evidence including particle tracking that has been performed using NERT's Phase 6 groundwater flow model.

Residual Contamination in the UMCf

Another primary source of groundwater contamination within the alluvium throughout each of the three NERT OUs is the effect of matrix diffusion, in which slow upward migration of contaminants from the UMCf causes concentrations in the higher permeability alluvium to remain above regulatory levels for a long period of time. Matrix diffusion is and will continue to be a primary source of contamination to shallow groundwater. Primary COPCs (perchlorate, chlorate, chromium, and chloroform) that have impacted the UMCf first in OU-1 and then migrated within the UMCf into OU-2 will migrate upwards into the alluvium. The lower permeability UMCf across all of the NERT OUs is the unit in which most of the contaminant mass originating from OU-1 is stored. This mass in the UMCf slowly migrates upwards into the alluvium. As a result, groundwater concentrations of perchlorate and chromium in the alluvium have been declining relatively slowly, even though active remediation of the higher permeability alluvium has been in progress for over 20 years.

Sources of Contamination within OU-2 East of Pabco Road (Eastside Sub-Area)

The portion of OU-2 east of Pabco Road was historically referred to as the Eastside Area or BMI Common Areas. For purposes of the NERT RI, this area is referred to as the Eastside Sub-Area. The Eastside Sub-Area historically contained a network of unlined ditches, flumes, and unlined ponds developed during the mid-1940s that were used for industrial process wastewater and other aqueous byproducts from the BMI Complex manufacturing facilities. The Upper BMI Ponds operated from approximately 1943 through the mid-1970s. Contaminants in wastewater generated within OU-1 migrated to the Eastside Sub-Area via the Beta Ditch. The locations of sources of contamination to OU-2 are shown in Figure ES-4b.

Due to the facts surrounding previous settlements made between NDEP and third party property owners, the COPCs investigated by NERT in the Eastside Sub-Area are administratively limited to perchlorate and chlorate in soil deeper than 10 feet bgs and in groundwater. The major sources of perchlorate and chlorate in the Eastside Sub-Area are residual contamination in vadose zone soils below 10 feet, and residual contamination in shallow groundwater (primarily found in the UMCf, as the alluvium is largely dewatered).

OU-2 Vadose Zone Soil

Within the Eastside Sub-Area, perchlorate and chlorate concentrations in vadose zone soils below 10 feet were investigated during the RI. Perchlorate concentrations above its LSSL of 0.0155 milligrams per kilogram (mg/kg) and chlorate concentrations above its LSSL of 1.03 mg/kg were found in soil samples from nearly all of the Eastside Sub-Area boring locations. In general, the highest concentrations were found in the western part of the Eastside Sub-Area beneath the area previously occupied by the former ditches and unlined wastewater ponds. The perchlorate results are generally consistent with previous soil sampling conducted by Basic Remediation Company (BRC) at approximately 740 boring locations. Perchlorate was detected above the LSSL in soil samples below 10 feet in approximately 80% of the borings sampled by BRC. The residual contamination in the deeper vadose zone soil represents a potential continuing source of perchlorate and chlorate to underlying shallow groundwater in the Eastside Sub-Area.

No data gaps for soil in OU-2 east of Pabco Road were identified and no additional investigation is needed, and as such, the investigation of soil within the Eastside Sub-Area is considered complete.

OU-2 Groundwater

OU-2 groundwater has been thoroughly characterized through implementation of the NERT RI. The extent of contamination in groundwater (including perchlorate and chlorate, the most widespread of all COPCs) has been delineated within OU-2. Based on the data presented in the RI Report, NERT concludes the following regarding the investigation of OU-2 groundwater:

- The lateral extent of perchlorate and other COPCs in OU-2 groundwater has been defined (see Figure ES-5). Perchlorate and chlorate are the most widespread contaminants in groundwater within OU-2. The distribution of all COPCs in groundwater are related to their presence in groundwater at upgradient sites and subsequent migration into OU-2, as discussed above. The extent of NERT's perchlorate contamination is bounded to the west by the AMPAC plume and delineated to the south/southeast at Lake Mead Parkway where concentrations are below the background concentration adopted by NDEP (NDEP 2016a), and to the east at Galleria Drive (east of the Tuscany Village community) within OU-3 where the concentrations are below the GWSL.
- The vertical extent of perchlorate and other COPCs in OU-2 groundwater has been defined and does not extend into the Deep WBZ.

- There is a difference between the depth of perchlorate-impacted groundwater in the southern (upgradient) and northern (downgradient) areas of OU-2 west of Pabco Road. Perchlorate is detected above the GWSL to depths of 145 feet in the southern area near the OU-1/OU-2 boundary, whereas the depth of perchlorate above the GWSL decreases to less than 90 feet bgs in the northern area near the OU-2/OU-3 boundary. North of the AWF along the OU-2/OU-3 boundary, perchlorate concentrations in groundwater above the GWSL are limited to the Shallow WBZ (i.e., above a depth of 90 feet bgs).
- Along most of the Eastside Sub-Area northern boundary, perchlorate concentrations above the GWSL extend to depths of 110 feet bgs at several locations. At the eastern end of the OU-2/OU-3 boundary along Galleria Drive, perchlorate was also detected in groundwater above the GWSL in a deeper sandy silt lens between 157-177 feet bgs.
- Within OU-2 west of Pabco Road, the alluvium remains saturated. In general, the perchlorate concentrations decrease with distance from OU-1 and with depth. Perchlorate in the alluvium is captured by NERT through its operation of the AWF near Galleria Drive at the boundary of OU-2 and OU-3. However, significant mass remains in the saturated UMCf south (upgradient) of the AWF. As a result, slow upward migration due to the combination of an upward hydraulic gradient and matrix diffusion from the UMCf into the alluvium will be a significant factor affecting the long-term persistence of perchlorate (and other COPCs) in OU-2 groundwater.
- Within OU-2 east of Pabco Road, the alluvium has become dewatered across much of the central and eastern portions of the Eastside Sub-Area, and in this part of the Sub-Area, first groundwater now occurs in the UMCf. As noted above, contaminants migrate very slowly though the UMCf, leading to long-term persistence of COPCs in groundwater in the eastern portion of OU-2.
- During the period of operation of the unlined Upper BMI Ponds and the associated unlined ditches (e.g., the former Beta Ditch), COPCs including perchlorate and chlorate migrated into soil and groundwater in the Eastside Sub-Area, and then subsequently migrated north into OU-3 via groundwater. Although much of the alluvium has become dewatered in the Eastside Sub-Area, the alluvium remains saturated in OU-3. The potential for matrix diffusion (i.e., slow upward migration) of the mass stored in the low permeability UMCf into shallow groundwater in OU-3 will be evaluated in the forthcoming RI Report for OU-3. The slow upward migration of the mass stored in the low permeability UMCf within OU-2 could potentially serve as a secondary long-term source of perchlorate and chlorate and cause concentrations of these COPCs in the higher permeability alluvium in OU-3 to remain above regulatory levels for a long period of time.
- The presence of COPCs within OU-2 groundwater is due to migration from multiple upgradient sites, as discussed above. This creates an extraordinarily complex environment of commingling groundwater plumes. The commingling of groundwater within OU-2 migrating from sites to the south of OU-2 (OSSM, OU-1, and TIMET) is thoroughly discussed in this report. Perchlorate and chlorate from the AMPAC plume enter OU-2 from the west near the AWF and the OU-2/OU-3 boundary, commingle with the perchlorate and chlorate from the NERT plume, and extend north into OU-3. The AMPAC plume is chemically distinguishable from the NERT plume and the

delineation between the two plumes will be discussed in more detail in the forthcoming RI Report for OU-3.

No data gaps for groundwater in OU-2 were identified and, as such, no additional investigation is needed to delineate the extent of contamination in groundwater within OU-2.

OU-2 Soil Gas

OU-2 soil gas west of Pabco Road has been thoroughly characterized through implementation of the NERT RI. Based on the data presented in this RI Report, NERT concludes the following regarding the investigation of OU-2 soil gas:

- In the commercial/industrial land use areas of OU-2 west of Pabco Road, chloroform was the only VOC detected in soil gas above screening levels. In the residential land use area, chloroform and bromodichloromethane are the only VOCs detected in soil gas above screening levels. Chloroform and bromodichloromethane are trihalomethanes and by-products of chlorination of municipal water for domestic use. Though bromodichloromethane is a COPC in OU-1 and OU-2 groundwater, its isolated presence in OU-2 soil gas is not co-located with screening level exceedances in OU-2 groundwater, does not originate from OU-1, and may be related to municipal water distribution and use. In general, chloroform concentrations in soil gas increase with depth indicating that the source of chloroform in soil gas is most likely chloroform in groundwater rather than a vadose zone soil source.
- Similar to OU-1, three additional VOCs (TCE, carbon tetrachloride, and PCE) were detected in soil gas in OU-2 west of Pabco Road at elevated concentrations but below screening levels. In this area of OU-2, carbon tetrachloride and PCE have been identified as COPCs in groundwater. Carbon tetrachloride is one of the trespassing VOCs from the OSSM site that has and continues to migrate via groundwater into OU-2 through OU-1, and PCE has migrated in groundwater from the TIMET site directly into OU-2. The soil gas concentrations of TCE and carbon tetrachloride are generally lower in OU-2 than in OU-1. However, the PCE concentrations measured in the most recent sampling events at RISG-3 in March and November 2019, located in OU-2 just downgradient of the TIMET site, are higher than any of the locations in OU-1.

For chloroform and other VOCs in groundwater, an evaluation of volatilization from shallow groundwater into soil gas and any resultant potential vapor intrusion risk is presented in the BHRA for soil gas and groundwater in OU-2.

Next Steps

Based on the RI results for OU-1 and OU-2, the nature and extent of contamination associated with both OUs has been defined and no data gaps or additional investigation are required to complete the RI. Characterization of subsurface conditions and the nature and extent of COPCs is sufficient to support evaluations of human health and ecological risk, as well as, remedial technologies and remedial alternatives to be developed as part of a FS for OU-1 and OU-2. Sufficient knowledge has been gained regarding non-NERT sources of contamination that have impacted groundwater quality in OU-1 and OU-2; thus, the NERT FS will be limited to what is NERT's responsibility to the extent technically feasible. In addition, as NDEP indicated in their comments on the RI Report for OU-1 and OU-2, Revision 0, NDEP will work with other responsible parties to address in their FSs and remediation plans any COPCs that are trespassing onto the NERT site.

While this RI Report will present limited information with respect to OU-3, the conditions in OU-3 will be further evaluated in greater detail in the forthcoming RI Report for OU-3. In addition to presenting the nature and extent of contamination within OU-3, the RI Report for OU-3 will present an updated NERT CSM, building upon what is presented herein, including an evaluation of contaminant migration through OU-3, COPC discharge to the Las Vegas Wash, a detailed analysis presenting the delineation between the AMPAC and NERT perchlorate plumes, and COPC mass estimates based on additional data collected during the OU-3 investigation. Concurrent with preparation of this RI Report, NERT has advanced its efforts related to human health and ecological risk assessments and has continued its development of a groundwater flow and transport model and associated hydrostratigraphic characterization covering all three OUs. The various risk assessments associated with OU-1 and OU-2 were submitted in 2021 subsequent to Revision 0 of this RI Report. NDEP provided comments on the various risk assessments in 2022. Revisions to the various risk assessments associated with OU-1 and OU-2 were submitted in 2023 subsequent to Revision 1 of this RI Report.[7] The various risk assessments associated with OU-1 and OU-2 have now been approved by NDEP.

NERT will utilize the information from the RIs, the risk assessments, the groundwater flow and transport model, and the pilot and treatability studies to conduct the FS for all three OUs, which will provide the basis for selecting the final remedy for the entirety of the NERT RI Study Area. Specifically, the forthcoming FS Report for OU-1 and OU-2 and subsequent FS Report for OU-3 will evaluate the applicable remedial technologies and assemble a number of remedial action alternatives designed to meet the approved Remedial Action Objectives (RAOs) for the NERT RI Study Area. Following approval of the FS documents, plans will be prepared summarizing the proposed remedial action alternatives, which will be made available for public comment. After the close of the public comment periods, NDEP will review and respond to public comments, and RODs will be issued identifying the selected remedial action alternatives representing the final remedy.

---

[7] One exception includes the BHRA Report for OU-1 Soils. Revision 2 of the BHRA Report for OU-1 Soils was submitted on May 6, 2022 (Ramboll 2022b) and approved by NDEP on June 2, 2022.

1. INTRODUCTION

In accordance with the Interim Consent Agreement[8] entered into by the Nevada Environmental Response Trust (NERT or the Trust), effective February 14, 2011, Ramboll Americas Engineering Solutions, Inc.[9] (Ramboll) has prepared this Remedial Investigation (RI) Report for Operable Unit 1 and Operable Unit 2 (OU-1/OU-2) of the NERT RI Study Area in Henderson, Nevada for submittal by the Trust to the Nevada Division of Environmental Protection (NDEP) and the United States Environmental Protection Agency (USEPA). The initial RI Report for OU-1 and OU-2 (Revision 0) was submitted on July 9, 2021 (Ramboll 2021e). NDEP's comments on Revision 0 were received on February 9, 2022 (NDEP 2022a). NERT submitted annotated responses to NDEP's comments (RTC) on June 9, 2022 (Ramboll 2022c), and NDEP provided responses to the RTC on August 31, 2022 (NDEP 2022b). Revision 1 of the RI Report for OU-1 and OU-2 incorporated changes to the Revision 0 submittal to address NDEP's comments and was submitted on August 15, 2023 (Ramboll 2023b). NDEP's comments on Revision 1 were received on December 21, 2023 (NDEP 2023b) and January 11, 2024 (NDEP 2024). Revision 2 has been updated and incorporates changes to the Revision 1 submittal to address NDEP's comments consistent with NERT's response to comments.

The exclusive purpose and function of the Trust was defined within the Settlement Agreement[10] and includes, but is not limited to: "(i) own the (NERT Site) for purposes of implementing the Settlement Agreement, (ii) carry out administrative and property management functions related to the (NERT Site), and (iii) manage and/or fund implementation of Environmental Actions for Henderson Legacy Conditions (as defined in the Settlement Agreement) as approved by NDEP." Henderson Legacy Conditions (HLCs) are defined in the Settlement Agreement as "the presence or release […] of hazardous substances in or into the environment at, on or below any portion of the Henderson Property, including the presence in any environmental media of such released hazardous substances as a result of migration from any portion of the Henderson Property, whether before or after the Effective Date"[11] (NDEP 2011a).

The Henderson property, commonly referred to as the NERT Site (or the "Site")[12] is located within Sections 12 and 13 of Township 22 S, Range 62 E within the Black Mountain Industrial (BMI)[13] Complex in unincorporated Clark County and is surrounded by the City of Henderson

---

[8] Interim Consent Agreement, effective February 14, 2011 (NDEP 2011a).

[9] Formerly known as Ramboll US Consulting, Inc. (Ramboll); Ramboll US Corporation (Ramboll); Ramboll Environ US Corporation (Ramboll Environ); and ENVIRON International Corporation (ENVIRON).

[10] Settlement Agreement shall mean that certain Consent Decree and Environmental Settlement Agreement, effective February 14, 2011, filed in Tronox Incorporated, et al., Case No. 09-10156, Docket No. 2812 (Nevada Environmental Response Trust Agreement 2011).

[11] The "Effective Date" was February 14, 2011.

[12] The NERT Site and OU-1 occupied the same area prior to May 8, 2020 when Sale Parcels C, D, and H (see Figures 1-3a and 1-4) were sold by the Trust. Within this report the terms "NERT Site" or "Site" refer to property owned by the Trust after May 8, 2020. The term "OU-1" refers to the area inclusive of the "NERT Site" as well as Sale Parcels C, D, and H.

[13] The acronym "BMI" has been applied to several entities over the years. From 1941 until 1951, it referred to Basic Magnesium, Inc.; in 1951, a syndicate of tenants formed under the name Basic Management, Inc. to

(COH), Nevada (Figure 1-1). Currently, the "NERT RI Study Area" collectively consists of four study areas (Figure 1-2). These are the NERT Site Study Area[14] and the NERT Off-Site Study Area (established in 2012 as the original NERT RI Study Area), the Downgradient Study Area (added in 2015), and the Eastside Study Area (added in 2016 and comprised of the Eastside Sub-Area and the Northeast Sub-Area).

The NERT RI Study Area has been divided into three Operable Units (OUs) for the purposes of investigation and determination of future remedial action (Figure 1-2). Operable Unit 1 (OU-1) consists of the NERT Site, as well as Sale Parcels C, D, and H. Operable Unit 2 (OU-2) comprises the southern portion of the NERT Off-Site Study Area and the Eastside Sub-Area. Operable Unit 3 (OU-3) encompasses the Downgradient Study Area, the Northeast Sub-Area and the northern portion of the NERT Off-Site Study Area. Although OU-3 is not the subject of this RI Report, relevant data and analyses from OU-3 are included in this report where necessary or helpful to more fully understand the nature and extent of contamination in OU-1 and OU-2. General descriptions of OU-1 and OU-2 are provided below. More detailed descriptions of the operational and ownership histories of these units are provided in Section 2.

Operable Unit 1

OU-1 comprises approximately 346 acres and is located within the current BMI Complex. The property comprising OU-1 has a long, complex ownership and operational history, as discussed in detail in Section 2. OU-1 has been the location of industrial operations since 1942 when it was developed by the United States (US) Government as a magnesium plant to support World War II operations. Following the war, OU-1 continued to be the location of industrial activities, including production of chemical products including perchlorates, boron, and manganese compounds. Former industrial and waste management activities conducted at OU-1, as well as those conducted at adjacent BMI Complex properties, resulted in contamination of environmental media within the NERT RI Study Area, including soil, groundwater, and surface water.

The BMI Complex currently consists of several facilities owned and operated by a number of companies, as shown in Figure 1-3a. OU-1 comprises the entire NERT Site, as well as former Sale Parcels C, D, and H (shown in Figure 1-4), which are no longer owned by NERT. Lhoist owns a generally rectangular parcel of land within the central portion of the NERT Site on which it operates a lime production facility. Western Area Power Administration (WAPA) owns property containing electrical power equipment and transmission lines within and adjacent to the southern portion of the NERT Site. Major facilities on the exterior borders of the NERT Site include the Titanium Metals Corporation of America (TIMET) facility to the east, the BMI Corrective Action Management Unit (CAMU) to the northwest, and the Pioneer Americas LLC (Pioneer) d/b/a Olin Chlor-Alkali Products (Olin) facility (hereafter referred to as the Olin property) to the west. TIMET produces titanium products for industrial, defense,

---

provide utilities and other services at the complex; the group has also been known as Basic Metals, Inc., and at the present time is called the Black Mountain Industrial Complex.

[14] The original "NERT Site Study Area" area was established as part of the initial NERT RI/FS Work Plan in 2012 where it was referred to as simply the "NERT Site." The NERT Site Study Area is identical to the OU-1 area, includes Sale Parcels C, D, and H no longer owned by the Trust, and refers to the property owned by the Trust after February 14, 2011 and prior to May 8, 2020.

and commercial aerospace markets. The BMI CAMU is a lined, 52-acre landfill that primarily received impacted soil removed by Basic Remediation Company (BRC) from the BMI Common Areas between 2008 and 2014. The CAMU was closed in 2015, and BRC is responsible for providing post-closure care and monitoring of the landfill. Olin produced a variety of chlor-alkali chemicals until 2016 when it ended the production of chemicals other than bleach. Currently, Olin only produces bleach at its facility.

Certain remediation system components jointly operated by Olin, Stauffer Management Company LLC (Stauffer), Syngenta Crop Protection, LLC (Syngenta), and Montrose Chemical Corporation of California (Montrose) (collectively referred to as the OSSM Companies) are located northwest of the NERT Site on property owned by Henderson Groundwater LLC, as well as a small portion of NERT property known as Parcel E (located north of the main NERT-owned property and surrounded by property owned by Henderson Groundwater LLC and former Sale Parcels C and D). Former Basic Management Inc./Basic Remediation Company LLC (BMI/BRC)-owned property is located northeast of Boulder Highway in the Eastside Sub-Area. The property ownership described above is shown in Figure 1-3a. The investigation areas for the NERT Site Study Area (OU-1), the OSSM site, the TIMET site, the former American Pacific Corporation (AMPAC) site, and BMI are shown in Figure 1-3b. The boundaries of these investigation sites differ in specific areas from the current land ownership shown in Figure 1-3a due to the historical sale of specific parcels within each of the sites. For example, the TIMET site investigation area shown in Figure 1-3b includes property now owned by WAPA and Nevada Power. Similarly, the southeastern corner of the OSSM site investigation area shown in Figure 1-3b is not currently part of the Olin-owned property. Figure 1-3b depicts the OSSM, TIMET, former AMPAC, and BMI site boundaries, as presented within each party's investigation reports or agreements with NDEP, relative to the NERT Site Study Area and OUs. Similar to NERT, investigation activities associated with each of the neighboring sites extend beyond the depicted site boundaries.

Since the 1970s, extensive environmental investigations have been conducted in OU-1 and on neighboring properties adjacent to OU-1. These investigations have identified impacts to the subsurface conditions within OU-1, as further described in Section 3. The first removal action within OU-1 took place in 1987 and included the construction of a groundwater treatment system for removal of hexavalent chromium from groundwater. In 1994, in a Letter of Understanding (LOU), NDEP identified 69 LOU Potential Source Areas (NDEP 1994a) (referred to in this and other reports as LOUs), which were primarily within OU-1. In 1997, perchlorate, later shown to originate from the Site and the former AMPAC site, was detected in the Las Vegas Wash and the Colorado River (NDEP 2011c). In 1999, a temporary groundwater treatment system for the removal of perchlorate originating from OU-1 was constructed near the Las Vegas Wash and in 2002, an additional temporary perchlorate treatment system was constructed at the Site. The temporary treatment systems were replaced by a biological fluidized bed reactor (FBR) treatment system in 2004. This FBR treatment system is still in operation and is discussed in Section 2. Beginning in 2010 and ending in late 2011, approximately 850,000 cubic yards of impacted soils and manganese tailings were removed from the Site and disposed of at an off-site location. An addditional FBR treatment system, called the Treatment System Extension (TSE), was brought online in June 2023 to treat perchlorate-impacted groundwater extracted on the TIMET site.

Tronox LLC (Tronox) most recently owned and operated the Site until February 14, 2011, on which date the Trust took title in conjunction with the settlement of Tronox's bankruptcy proceeding. Tronox had a long-term lease for approximately 114 acres of the NERT Site, on which it continued to operate its chemical manufacturing business until August 2018 when Tronox's Henderson operations were purchased by EMD Acquisitions LLC (EMD) and EMD assumed the lease with the Trust. As of the date of this report, EMD continues to operate within the leased portion of the NERT Site.

Operable Unit 2

OU-2 comprises approximately 2,645 acres and mostly consists of developed and undeveloped residential and commercial property (Figures 1-2 and 1-3a). Within this report, Pabco Road serves as a boundary demarcating differing historical land use within OU-2 and is also used to identify NERT's obligations related to the RI/FS. Much of the Eastside Sub-Area within OU-2 (i.e., OU-2 east of Pabco Road) was historically part of the BMI Common Areas, the operations of which are discussed in detail in Section 2. Much of this area is rapidly being redeveloped, primarily for residential use, as part of a Master-Planned Community. As of the date of the most recently available aerial photo (August 2022), approximately 50% of the master-planned community has been redeveloped. Unlike that of the Eastside Sub-Area, most of the NERT Off-Site Study Area within OU-2 (i.e., OU-2 west of Pabco Road) was historically used for residential, commercial, and light industrial purposes, unaffiliated with operations at the NERT Site or the BMI Complex. This delineation between areas west and east of Pabco Road within OU-2 is an important concept that will be highlighted in subsequent sections of this report.

Large portions of OU-2 have been the subject of numerous regulatory actions and environmental investigations, as described in detail in Section 3. Portions of the approximate 1,983-acre Eastside Sub-Area were historically used for the accumulation of process wastewater generated at the neighboring BMI Complex. In 2006, BRC and other companies within the BMI Complex executed the *Settlement Agreement and Administrative Order on Consent: BMI Common Areas, Phase 3*, known as AOC3, defining the framework for characterization and remediation of the BMI Common Areas and defined steps by which the remedial actions should be performed (NDEP 2006). The AOC3 boundary is shown in Figure 1-3b, along with four subareas identified by BMI as the Western Hook, East Common Areas, Parcel 9, and CAMU. BRC conducted soil and groundwater investigations and remediation activities (completed in 2014), which served as the basis for NDEP granting No Further Action (NFA) determinations on the majority of the parcels comprising the Eastside Sub-Area within OU-2, which is located east of Pabco Road. NDEP's NFA determinations were restricted to the upper 10 feet of the soil horizon consistent with proposed future land uses (BRC 2014).

In July 2016, NDEP directed the Trust to expand its NERT RI Study Area and investigate HLCs in "areas to the southeast of the Site, known as the BMI Common Areas [...] due to migration of hazardous substances released at the Henderson Property [Site] prior to the Effective Date of the Trust" (NDEP 2016c). Within the Eastside Sub-Area (the portion of OU-2 located east of Pabco Road), HLCs are administratively limited to perchlorate and chlorate impacts to the subsurface. While hexavalent chromium and other potential contaminants may be present in soil and groundwater within the Eastside Sub-Area, consistent with NDEP's July 2016 directive, NERT's investigations within the Eastside Sub-Area were limited to the investigation of perchlorate and chlorate impacts to the subsurface, particularly in soil deeper than 10 feet bgs and in underlying groundwater. Consistent with AOC3, the potential presence of hexavalent chromium and other potential contaminants in groundwater within the Eastside Sub-Area will be addressed separately by BRC under the oversight and direction of NDEP. While NERT's investigation included soil and groundwater samples within the area but below the depth for which NDEP previously issued NFA determinations, NDEP has expressed no intention to re-open the NFA determinations, and the new data obtained by the Trust is included in this RI Report solely for the purposes of addressing the nature and extent of perchlorate and chlorate.

The portion of OU-2 west of Pabco Road does not have a history of significant surface activities associated with the BMI Complex.[15] This area is included within the RI Study Area due to the migration of contaminated groundwater originating from OU-1 downgradient into OU-2. As discussed within this report, NERT, OSSM, and TIMET have each over the course of the last four decades installed a groundwater treatment system to address various contaminants migrating from the BMI Complex to groundwater beneath OU-2.

1.1 Purpose of the Remedial Investigation and Feasibility Study

Investigation and cleanup activities are being conducted in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), as amended, and the Interim Consent Agreement between NDEP and the Trust (NDEP 2011a). In accordance with CERCLA, a Remedial Investigation/Feasibility Study (RI/FS) is being conducted to investigate the nature and extent of contamination within OU-1 and downgradient plume to develop and evaluate remedial action alternatives, as appropriate. As stated in RI/FS guidance (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."

Before commencing field work for the remedial investigation, consistent with 40 CFR 300.430(c)(2)(ii), the Trust developed a Community Involvement Plan (CIP) to facilitate communication between the community, NDEP and the Trust, and to encourage community involvement in investigation and remediation activities. The Trust utilized the community involvement activities outlined in the CIP throughout the RI to ensure that the community was informed and provided opportunities to provide input. The activities implemented under the CIP address the public involvement requirements consistent with the National Contingency Plan (NCP) for CERCLA sites.

1.2 Scope of Work

The RI Report on its own is not a remedy decision-making document, rather its purpose is to document the nature and extent of contamination within the RI Study Area. Remedial decisions made as part of the CERCLA process will occur as part of the Record of Decision (ROD), as further discussed in Section 4. This RI Report documents the findings of investigations conducted to determine the nature and extent of chemicals of potential concern (COPCs) from historical industrial activities (i.e., HLCs as discussed above) in OU-1.

---

[15] Former Sale Parcels A and B, which were formerly owned by the Trust and its predecessors, are located in OU-2 west of Pabco Road. It does not appear that significant industrial operations associated with the BMI Complex were ever conducted within these parcels, as detailed in Section 2.3.1.

Since the inception of the Trust in February 2011, approximately 192 monitoring wells have been installed and 380 boreholes advanced within OU-1 and OU-2, which have yielded approximately 6,000 investigative samples. These investigations, which are described in this RI Report, were performed under the oversight of the NDEP and USEPA and consistent with work plans also approved by these agencies. Evaluation of these data, in addition to the substantial environmental data set collected prior to the Trust's inception, are discussed in detail within Sections 7 and 8. Specifically, this RI for OU-1 and OU-2 includes the results of investigations as defined in:

1. The Phase 1 RI, as described in the RI/FS Work Plan, Revision 2 (the "RI/FS Work Plan"; ENVIRON 2014c);
2. The investigation of the Unit 4 and 5 Buildings within OU-1 (the "Unit 4 and 5 Buildings Investigation"), as described in the Unit 4 and 5 Buildings Investigation Work Plan (the "Unit 4 and 5 Buildings Investigation Work Plan"; Tetra Tech 2015);
3. The Phase 2 RI Data Gap Investigation (the "Phase 2 RI"), as described in the Technical Memorandum for the Remedial Investigation Data Evaluation (Ramboll Environ 2016c) and 15 Phase 2 RI modifications approved by NDEP (Ramboll Environ 2017b-h,l; Tetra Tech 2017b; Ramboll 2018a,d,f,g,h,k); and
4. The Phase 3 RI, as described in the RI/FS Work Plan Addendum: Phase 3 Remedial Investigation, Revision 1 (the "Phase 3 RI Work Plan"; Ramboll Environ 2017m) and three of the 15 Phase 3 RI modifications (Phase 3 RI Modification Nos. 1, 3 and 9) approved by NDEP that relate to OU-1 and OU-2 (Ramboll Environ 2017p; Ramboll 2018e, 2019e).

Results from 12 of the 15 Phase 3 RI modifications (Phase 3 RI Modification Nos. 2, 4, 5, 6, 7, 8, 10, 11, 12, 13, 14, and 15) (Ramboll 2018c,l,m, 2019b,d, 2020b,c,e, 2021c,g,k, 2022d), which pertain solely to areas in OU-3 will be discussed in the forthcoming RI Report for OU-3. In addition, various work plans associated with the investigation of the Downgradient Study Area within OU-3 (AECOM 2016a,b) are briefly discussed, but are not the focus of this report. The objective of these investigations was to characterize conditions and address data gaps within OU-3 of the NERT RI Study Area, including detailed evaluation of the Las Vegas Wash and the surrounding area. The Downgradient Study Area investigations will be extensively discussed in the forthcoming RI Report for OU-3, which is anticipated to be submitted to NDEP under separate cover in late 2023.

Concurrent with preparation of this RI Report for OU-1 and OU-2 and the forthcoming RI Report for OU-3, human health and ecological risk assessments and an update to the groundwater transport model covering all three OUs are being prepared. NERT will utilize the information from the RIs, the risk assessments, the groundwater flow and transport model, and the pilot and treatability studies to conduct the Feasibility Study (FS), which will provide the basis for selecting the final remedy. Specifically, the forthcoming FS Report for OU-1 and OU-2 and subsequent FS Report for OU-3 will evaluate the applicable remedial technologies and assemble a number of remedial action alternatives designed to meet the Remedial Action Objectives (RAOs). RAOs for OU-1 and OU-2 were originally established as part of the 2014 RI/FS Work Plan (ENVIRON 2014c), revised within the Phase 3 RI Work Plan (Ramboll Environ 2017m), and are discussed within Section 4 of this report. Following approval of the Feasibility Studies, Proposed Plans will be prepared summarizing the proposed remedial action alternatives, which will be made available for public comment. After the close of the public comment period, NDEP will review and respond to public comments and RODs will be issued identifying the selected remedial action alternatives to be implemented.

1.3 Report Organization

The overall format of the RI follows recommendations in USEPA guidance (USEPA 1988) for conducting an RI/FS. The report is organized as follows:

- Section 1 provides an introduction to the report, including the purpose of the RI/FS, the scope of the work, and the organization of this report.
- Section 2 provides a history of OU-1, OU-2, and surrounding areas, and a discussion of the origin of contamination;
- Section 3 provides an overview of relevant regulatory actions and environmental investigations from 1970 to the present;
- Section 4 presents an overview of the RAOs and Applicable or Relevant and Appropriate Requirements (ARARs) for OU-1 and OU-2;
- Section 5 describes the physical and environmental setting (including the geology, hydrogeology and ecological features) of the OU-1 and OU-2 area;
- Section 6 provides a description of the scope of the various field investigations included in the RI Report;
- Section 7 presents the results of the RI within OU-1;
- Section 8 presents the results of the RI within OU-2;
- Section 9 includes the conceptual site model (CSM), an evaluation of the nature and extent of contamination, an estimate of contaminant mass, the fate and transport of contamination, and an analysis of potential receptors;
- Section 10 presents a summary of conclusions of the RI for OU-1 and OU-2; and
- Section 11 presents a list of references for this report.

Appendices to this report provide a description of the RI field investigation program implementation and groundwater elevation data (Appendix A1); compiled boring logs and well construction diagrams (Appendix A2); an evaluation of perchlorate capture and matrix diffusion at the Athens Road Well Field (AWF) (Appendix B); detailed subsurface cross-sections (Appendix C); aquifer testing results (Appendix D); nuclear magnetic resonance (NMR) well logs (Appendix E); soil physical test results (Appendix F); a description of how soil, groundwater, and soil gas screening levels (SGSLs) were determined (Appendix G); analytical data for soil (Appendix H); an analysis of soil background concentration data (Appendix I); and analytical data for groundwater and soil gas (Appendices J and K).

2. NERT RI STUDY AREA HISTORY

This section summarizes the land use history of property within the NERT RI Study Area, with a focus on OU-1 and OU-2, beginning with the development of the Basic Magnesium, Inc. (Basic Magnesium) facility in 1941, and continuing to the current use of OU-1 within the BMI Complex. Some limited discussion of activities conducted within OU-3 are included for the purpose of providing context and clarity. A more detailed and comprehensive history of OU-3 will be provided in the forthcoming RI Report for OU-3. Section 2.1 discusses the history of OU-1 and Section 2.2 discusses other major chemical manufacturing operations adjacent to OU-1. Section 2.3 discusses the history of OU-2, followed by Section 2.4 which summarizes the historical ditches, wastewater migration pathways, and ponds/surface impoundments throughout OU-1, OU-2, and OU-3. Regulatory actions and environmental investigations within the NERT RI Study area are discussed in Section 3.

2.1 Operable Unit 1 History

This section describes historical operations within the boundaries of OU-1. The information presented in this section was compiled from a review of several reports, including: Basic Magnesium (1944); BRC (2007); ENSR (2005); ENSR/AECOM (2008); ENVIRON (2011); Geraghty & Miller (1993); Kerr-McGee (1996b); Kleinfelder (1993); Law Engineering (1993); Ramsey (1943); and Schumacher (1999). A timeline summary of historical owners, operators, and products manufactured is shown in Figure 2-1. Figure 2-1 also includes major process wastewater distribution features within the NERT RI Study Area and associated dates of use. Additional historical details are provided within the following subsections: Section 2.1.1 and Figure 2-2 cover the period from 1941 to 1944; Section 2.1.2 and Figure 2-3 cover the period from 1945 to approximately 1950; Section 2.1.3 and Figure 2-4 cover the period from approximately 1951 to 1967; Section 2.1.4 and Figures 2-5a and 2-5b cover the period from 1967 to 2005; Section 2.1.5 and Figure 2-6 cover the period from 2005 to the present.

OU-1, which includes the NERT Site and is part of the current BMI Complex, has seen the manufacture and production of a variety of chemicals throughout its history. The BMI Complex area was first developed as a magnesium metal manufacturing facility during World War II with 10 identical Unit Buildings, six of which (the Unit 1 through 6 Buildings) are within the boundaries of OU-1. The first production operations (for magnesium metal) began on August 31, 1942. Approximately 82,500 tons of magnesium metal were produced by Basic Magnesium within the entire BMI Complex (the Unit 1 through 10 Buildings) between 1942 and 1944 (Table 2-1 and Figure 2-1). Wastewater management features were also established during this period, including a series of unlined ditches leading to infiltration/evaporation ponds located north and east of the current BMI Complex, as further discussed in Section 2.3.

After World War II, the Basic Magnesium facility was repurposed, leased, and eventually sold to several chemical manufacturers. The portion that includes OU-1 was operated as a perchlorate and chlorate manufacturing facility beginning in 1945, with the later addition of manganese dioxide (1951), elemental boron (1973), and boron trichloride (1973) operations, in addition to several other chemical products (Kleinfelder 1993). More than 900,000 tons of chlorate products and over 340,000 tons of perchlorate products were produced within OU-1 during its operational history (Table 2-1 and Figure 2-7). Much of the chlorate and perchlorate manufacturing process was conducted within the Unit 4 and 5 Buildings, as well as an area to the north near the Beta Ditch. Process liquids associated with chlorate and perchlorate production, which also contained hexavalent chromium,[16] were collected in the basement areas of the Unit 4 and 5 Buildings resulting in subsurface soil and groundwater contamination via cracks in the concrete basement floor. Contamination also occurred via discharge to lined and unlined on-site process water ponds, unlined wastewater conveyance ditches, and infiltration/evaporation ponds.

Subsequent to US Government ownership, OU-1 has been owned by several companies throughout its operational history. The Western Electrochemical Company (WECCO) leased property from the government starting in 1945 before purchasing the leased property in 1952. WECCO merged with the American Potash and Chemical Company (AP&CC) in 1955. Kerr-McGee Chemical Corporation (Kerr-McGee) acquired the property in 1967 following a merger with AP&CC. In 2005, Tronox took ownership of the facility from Kerr-McGee. In 2009, Tronox filed for Chapter 11 bankruptcy. The Trust took title to the Site on February 14, 2011 as a result of the settlement of Tronox's bankruptcy proceeding. Tronox maintained a lease for a portion of the Site between 2011 and 2018, where it continued some of its manufacturing operations. EMD acquired Tronox's operations in 2018 and continues manufacturing within the leased portion of the NERT Site.

2.1.1 OU-1 History from 1941 to 1944

Figure 2-2 depicts major operations and wastewater handling features within the OU-1 boundary between 1941 and 1944.

The current BMI Complex, including OU-1 was initially developed by the US Government (under the Defense Plant Corporation) as a magnesium production facility during World War II. Facility construction began in 1941 under a contract with Basic Magnesium and the plant was operated from August 31, 1942 to November 15, 1944 in support of the war effort (Geraghty & Miller 1993; BRC 2007). During this time, approximately 82,500 tons of magnesium metal were produced by Basic Magnesium (BRC 2007). The major buildings within OU-1 include the Unit 1 through 6 Buildings, which were constructed for magnesium production and are aligned in a row extending in a west-east direction across OU-1. Four additional Unit Buildings (the Unit 7 through 10 Buildings) are located on the TIMET site east of OU-1 and were also originally constructed for magnesium production. All 10 Unit Buildings had identical construction with three primary production areas within each building, including the northern Chlorination Building, the central Electrolysis Building, and the southern Rectifier Building. In the Rectifier Building, alternating current was converted to direct current for use in the electrolysis units and chlorinators.

Magnesium was produced by converting magnesia (magnesium oxide) to magnesium chloride in a series of 80 chlorinators followed by separation of the magnesium chloride into elemental magnesium and chlorine in 880 electrolytic cells, and subsequent refinement of the magnesium to remove residual salts and impurities. Initially, a chlorinator feedstock was developed in a proportioning plant where magnesia, magnesite, peat, coal and salts were mixed and fed through a pug mill to be blended with a magnesium chloride solution to a

---

[16] Hexavalent chromium was generated during the production of sodium chlorate and sodium perchlorate between 1945 and 1997 due to the use of sodium dichromate in the production process.

thick dough-like consistency (Geraghty & Miller 1993). Bricks and balls of the dough were subsequently dried in an oven and transported to the chlorinators. Batches of the feedstock were poured into the chlorinators, which were electrically heated to approximately 850 degrees Celsius and chlorine gas was injected into the base of the units. Peat was added to the feedstock to "fluff" the material and improve the efficiency of the reaction. Chlorine used in the chlorinator came from two sources: up to 200 tons per day (Ramsey 1943) came from the chlorine plant in the western portion of the BMI Complex (current Olin site) via two 12-inch pipelines and from recovery of chlorine generated in the electrolysis units south of each chlorinator building (Basic Magnesium 1944); once the plant was fully operational, a significant percentage of the chlorine used in the chlorinators came in the form of recovered chlorine from the electrolysis of magnesium chloride (Ramsey 1943).

Gases generated in the chlorinators flowed through a two-stage wash tower system to recover hydrochloric acid for the production of the magnesium chloride solution used in the chlorinator feedstock. The exhaust gases flowed from the wash towers to scrubbers to remove residual acid and other gases prior to discharge to the atmosphere (Ramsey 1943). Each of the chlorinator buildings (one in each of the ten Unit Buildings) was equipped with primary and secondary acid recovery wash towers and a scrubber. Due to the potential reaction of chlorine and carbon, a variety of byproduct chlorinated hydrocarbons including carbon tetrachloride may have formed in the chlorinators (Landsberg 1985), which would have been carried with the exhaust gases to the acid recovery buildings. The subsequent fate of these compounds may have included degradation or capture in various scrubbing systems as the wastewaters moved through the acid recovery, neutralization, and pellet formation processes. Following recovery of acid and possibly other chlorinator byproducts in the primary and secondary acid recovery wash towers, residual acidic gases were treated in dedicated caustic scrubbers (one per chlorinator building) to neutralize the gases prior to discharge to the atmosphere. These gases may have contained residual volatile chlorinated hydrocarbons from the chlorinators, which were captured in the scrubbers and discharged to the caustic drain system (Kleinfelder 1993).

Volatile chlorinated byproducts captured in the acid recovery wash towers would have been carried through the acid recovery system and onto the neutralization process where they may have been degraded or volatilized in the clarifiers. The neutralizer process included a series of turbo reactors, which generated exhaust gases that may have contained residual chlorinated hydrocarbon byproducts that were captured in a scrubber and discharged to the acid drain system. If any of the residual byproducts were not removed in the neutralization process, they would have been carried to the pellet formation system where they would have been volatilized in the pre-heaters and rotary kilns. Exhaust from these units, which would have carried residual byproduct chlorinated compounds, was treated in a scrubber that discharged wastewater and any captured residual chlorinated byproducts to the acid drain system.

At each Unit Building, magnesium chloride produced in the eight chlorinators was transferred to the adjacent electrolysis building where magnesium was recovered in electrolytic cells (88 cells at each unit). Liquid magnesium, which coalesced at the cathode in each cell was recovered and transferred to the central refining unit where all of the recovered magnesium generated in the 10 magnesium production units was refined. Chlorine generated at the anode in each electrolytic cell was captured and returned to the chlorinators in each production unit to generate additional magnesium chloride (Geraghty & Miller 1993). Various chlorinated hydrocarbons including carbon tetrachloride may have been produced due to the reaction of chlorine gas generated at graphite anodes in the electrolytic cells with the graphite (Wendt 1990). The majority of these volatile compounds would have been carried with the chlorine gas, which was filtered prior to reuse in the chlorinators. A portion of the byproduct hydrocarbons may have been carried with chlorine gas that bled into the cathode exhaust gas, which was subsequently scrubbed in wash towers (two per electrolysis building). The effluent from the scrubbers, which may have contained various chlorinated byproducts, discharged to the caustic drain system.

Process wastewater from Basic Magnesium's operations within OU-1 and surrounding BMI Complex was initially accumulated in the Trade Effluent Ponds (partially located within OU-1) via the Distribution Flume following treatment in the wastewater acid neutralization plant (Geraghty & Miller 1993). Table 2-2 contains additional information regarding operation of the Trade Effluent Ponds. Following closure of the magnesium operations in 1944, process wastewater was rerouted to the Beta Ditch, which was an unlined west-east trending ditch constructed circa 1941 or 1942. As further discussed in Section 2.4.1, effluent migrating off-site via the Beta Ditch ended up in either the Upper BMI Ponds (located within OU-2) or the Lower BMI ponds (located primarily within OU-3).

The acid and caustic drain systems, which are further discussed in Section 2.4.1, were piping networks originally designed to collect acid and caustic effluents, respectively, generated primarily from magnesium operations within the Unit Buildings, but the acid drain system carried a variety of effluents, potentially including chlorinated hydrocarbon byproducts, from the Unit Building basements and other areas within the BMI Complex during OU-1's operational history (Geraghty & Miller 1993).

As discussed in Section 2.4.1, most buildings within OU-1 have been connected to the sanitary sewer system since the US Government's development during the 1940s. The historical record indicates that wastewater from a building within OU-1, which was occupied by a changehouse with shower facilities associated with the AP Plant and a chemistry laboratory constructed in the 1980s, was disposed via an on-site septic system. Spent chemicals from the laboratory were not discharged to the septic system, although it did receive laboratory rinse water from cleaning laboratory tools and instruments (Kleinfelder 1993).

2.1.2 OU-1 History from 1945 to Approximately 1950

Figure 2-3 depicts major operations and the wastewater management systems within the OU-1 boundary between 1945 and approximately 1950.

Following the end of World War II, magnesium production ceased, and various federal and state entities undertook efforts to repurpose the industrial facility. Starting in 1945, WECCO began leasing a portion (the Unit 4 and 5 Buildings) of what is now OU-1 from the US Government. The converted magnesium plant was used by WECCO as a chlorate (sodium chlorate and potassium chlorate) and perchlorate (sodium perchlorate and potassium perchlorate) production facility (Schumacher 1999).

To produce chlorate and perchlorates, WECCO modified the Unit 4 and 5 Buildings of the former Basic Magnesium plant as described by Kleinfelder (1993). In the Unit 4 Building, the electrolytic cells used for magnesium production were replaced with 1,300 Schumacher cells equipped with graphite anodes and steel cathodes (Kleinfelder 1993). The primary chemical, sodium chlorate, was produced by electrolytically converting sodium chloride to sodium chlorate. The process included a brine dissolving system, external holding tanks, the electrolytic cells, and a chlorate recovery system. The brine solution was continuously fed to the electrolytic cells where it was blended with chlorate mother liquor and necessary additives including sodium dichromate to control reactions at the cell cathode. Solution from the cell, which contained dissolved sodium chlorate, was continuously bled from the cells and transferred to the chlorate recovery system. In the recovery system, urea and caustic soda were added to remove residual sodium hypochlorite and enhance filtration of the solution, which contained particulate carbon due to degradation of the graphite anodes. The solution was then filtered and subjected to a salt dissolving process followed by a crystallization process to precipitate out the sodium chlorate, which were recovered by cyclone and then washed in centrifuge process. The wash water was returned to the process. The chlorate crystals were subsequently dried in a hot air dryer and stored for either sale or use in subsequent processes.

Wastes associated with the sodium chlorate production included filter cake from the filtration process, which contained carbon, soda ash, calcium sulfate, salt, sodium chlorate, calcium carbonate, and hexavalent chromium. The filter cake was sluiced and migrated via the Beta Ditch to the Upper BMI Ponds (Kleinfelder 1993). An unknown quantity of wastewater from WECCO may have migrated to the Lower Ponds prior to 1971, but historical records suggest the vast majority of wastewater generated by WECCO migrated to the Upper Ponds via the Beta Ditch. Additional details on how wastewater from the Beta Ditch was managed and migrated to the Upper and Lower BMI Ponds can be found in Section 2.4.1. During the period when graphite anodes were used in the electrolytic cells (1945-1990), various chlorinated hydrocarbons such as carbon tetrachloride and chloroform may have formed in the recirculating chlorate mother liquor due to the reaction of chlorine and sodium hypochlorite with particulate carbon related to the decrepitation of the graphite anodes.

WECCO used a portion of the sodium chlorate to produce potassium chlorate in batches by the double decomposition of sodium chlorate and potassium chloride (Kleinfelder 1993). Potassium chloride was dissolved in water, heated, and filtered before transfer to a crystallization tank containing a sodium chlorate solution. In the reaction, potassium chlorate, which rapidly crystalized, was recovered in a centrifuge and washed. In a purification step, the recovered crystals were re-slurried and captured again on a centrifuge. The resultant cake was dried in a counter-current rotary dryer equipped with a wet scrubber, screened, and stored for sale or further processing. Wastes associated with the process included filter cake from the potassium chloride solution and mother liquor generated in the centrifuge, which migrated via the Beta Ditch primarily to the Upper BMI Ponds.

A portion of the sodium chlorate was used to produce sodium perchlorate in the eastern portion of the Unit 5 Building (Kleinfelder 1993). The batch process involved the oxidation of the sodium chlorate in electrolytic cells equipped with platinum anodes. Like the chlorate process, sodium dichromate was added to minimize cathodic reduction of the chlorate and perchlorate. The resulting solution containing dissolved sodium perchlorate was subsequently filtered and stored. Wastes generated in the process included filter cake and cell bottoms from the electrolytic cell. The filters were washed and, along with the cell bottoms, migrated via the Beta Ditch primarily to the Upper BMI Ponds. Given that the sodium chlorate went through a drying process, which would have volatilized any volatile chlorinated hydrocarbons, and that the sodium perchlorate process used platinum anodes, chlorinated hydrocarbons (such as chloroform) would not have formed during the sodium perchlorate process.

WECCO produced potassium perchlorate in the Unit 4 Building using the same equipment as the potassium chlorate process. As before, the product was formed by a double decomposition process wherein an aqueous potassium chloride salt solution was heated, filtered, and fed to a crystallizer containing sodium perchlorate solution. Like in the potassium chlorate process, the potassium perchlorate, which rapidly crystalized, was centrifuged, and washed. The resultant material was re-slurried and centrifuged to create a filter cake that was dried in a counter-current rotary dryer equipped with a wet scrubber and stored. Process waste consisted of potassium chloride filter cake and mother liquor, containing sodium chloride, potassium chloride, potassium chlorate, sodium perchlorate, sodium carbonate, calcium carbonate and chromium, which migrated via the Beta Ditch primarily to the Upper BMI Ponds.

In 1949, ownership of a majority of the overall industrial complex was transferred from the US Government to the State of Nevada's Colorado River Commission (CRC), which subsequently sold portions of the BMI Complex to various entities as discussed below in Section 2.1.3 (Kleinfelder 1993; Law Engineering 1993; BRC 2007).

Other operators within OU-1 during this period included:

- The Hardesty Chemical Company (Hardesty; later the AMECCO Chemical Company) leased and operated eight buildings in the BMI Complex (only some of which were definitively located within OU-1), including the Unit 2 Building, from approximately 1945 to 1949 (Kleinfelder 1993). Chemicals produced by Hardesty/AMECCO included chlorobenzol, soda arsenite, synthetic hydrochloric acid (muriatic acid), monochlorobenzene, paradichlorobenzene, orthodichlorobenzene, dichlorodiphenyltrichloroethane (DDT), and synthetic detergents.[17] Chloral may also have been produced in Unit 2. Chloral processes may generate byproduct chlorinated hydrocarbons including chloroform and carbon tetrachloride. In addition, hydration of chloral forms chloral hydrate, which readily degrades to chloroform. Hardesty also operated several tank farms north of the Unit 2 Building, including underground storage tanks (USTs) containing kerosene, benzene, and fuel oil, and aboveground storage tanks (ASTs) related to electrolysis (one containing chlorinated alcohols and another containing sludges) and sulfuric acid. These tanks are no longer present within OU-1.
- Valite Industries, Inc. (Valite) leased a portion of OU-1 starting in 1947 for operations that involved building materials and plastics (Kleinfelder 1993). The leased facility was located north of the Unit 5 and 6 Buildings in the current manganese Leach Plant

---

[17] These chemicals were likely produced within the BMI Complex, but it is unclear which products, if any, were produced within OU-1.

area. Based on the timing of manganese production north of the Unit 5 and 6 Buildings, Valite's operations likely ended prior to 1951.

- United States Vanadium Corporation (US Vanadium) leased facilities within the BMI Complex to produce refined tungsten compounds. Detailed information regarding the years and extent of operations within OU-1 could not be identified (Kleinfelder 1993; Geraghty & Miller 1993). In 1947, US Vanadium operations were reported to involve reclaiming concentrates from settling ponds and production of synthetic scheelite, tungstic acid, molybdenum trisulphate, and ammonia parathustate. The US Vanadium leased area was reportedly located north of the Unit 6 Building in the current manganese Leach Plant area.

As discussed in greater detail within Section 2.4.1, the Beta Ditch, in addition to receiving storm water and non-contact cooling wastewater, continued to receive wastewater from process operations. This wastewater likely included process wastes from the chlorate, perchlorate, and manganese dioxide production, organic wastes from Hardesty's operations, and discharges from the acid drain system (Kleinfelder 1993).

By 1950, the Beta Ditch extended east of OU-1 to a siphon inlet/pond location on what is now the adjacent TIMET site. The siphon pipe then conveyed flows from the western section of the Beta Ditch under Boulder Highway to the eastern section of the Beta Ditch and subsequently to the Upper BMI Ponds, located within what is now OU-2, and Lower BMI ponds, located mostly within OU-3. The Upper and Lower BMI Ponds were operated as evaporation/infiltration ponds with numerous small cells that followed the contours of the natural land surface and received effluent waste from the BMI Complex (Geraghty & Miller 1993). Section 2.4.1 provides additional details of these wastewater management features.

Although there were many subsequent changes in operations, as discussed below, the chemical manufacturing and wastewater collection and wastewater migration from OU-1 during this period accounts for much of the current contaminant distribution within the NERT RI Study Area.

2.1.3 OU-1 History from Approximately 1951 to 1967

Figure 2-4 depicts major operations and wastewater management systems within OU-1 between approximately 1951 and 1967.

In the early 1950s, WECCO began operating an ammonium perchlorate plant (AP Plant) on property owned by the US Navy in the vicinity of the Beta Ditch near the center of OU-1 (Schumacher 1999). The following process summary is based on details presented in the Kerr-McGee Environmental Conditions Assessment Report (Kleinfelder 1993). The majority of the sodium chlorate produced was used to produce ammonium perchlorate. Similar to the potassium perchlorate process, the ammonium perchlorate process utilized a double decomposition reaction. Initially, the sodium perchlorate was purified in a multi-step process to remove (1) chromate, by reduction with sulfur dioxide and subsequent filtration; (2) calcium, by reaction with soda ash and subsequent filtration; and (3) sodium chlorate, in the first in a series of reactions with ammonia and hydrochloric acid to form ammonia perchlorate. Chlorine driven off in the reaction was captured in a lime scrubber tower, along with other chlorine derivatives and hydrochloric acid and migrated via the Beta Ditch primarily to the Upper BMI Ponds. Ammonium perchlorate crystals formed in the reaction were recovered in a crystallizer, re-slurried, centrifuged, dried, screened, and prepared for sale, which may have included addition of anti-caking agents. The eluant[18] from the crystallizer was used in several processes following further treatment as follows: (1) a portion was treated in a crystallizer and associated centrifuge to recover sodium chloride, which was used in the sodium chlorate plant following a washing process, with the liquor recycled to the ammonium perchlorate reactor; (2) a portion was used in the sodium perchlorate purification process; and (3) a portion was used in the Rotoclone dust control system; however, the operational timeframe of this process is unknown.

WECCO also expanded its operations to include production of synthetic electrolytic manganese dioxide beginning in 1951 and high purity manganese metal beginning in 1953 (Kleinfelder 1993; ENSR 2005). The manganese dioxide process involved the reduction and leaching of ore to produce a manganese sulfate concentrate, which was subsequently processed in electrolytic cells to plate out the manganese dioxide. Plated manganese dioxide was recovered following crushing of the graphite anode and washed. Finally, the material was filtered, dried, and bagged. Leach beds and manganese tailings piles (MTPs) were operated north of the Unit 5 and 6 Buildings in approximately the same location where manganese dioxide is currently produced at the Leach Plant. The electrolytic process was housed in the Unit 6 Building. Following completion of the plating process, the cell solution was recycled back to the leach plant. Unlike most process water, which was discharged to the Beta Ditch, wastewater from washing the manganese dioxide was discharged to the sanitary sewer prior to May 1989 (Kleinfelder 1993).

In 1952, the five principal operating companies operating within the BMI Complex at the time (WECCO, Stauffer, US Lime, TIMET, and Combined Metals Reduction Company [Combined Metals])[19] purchased operational facilities from the CRC (Geraghty & Miller 1993). During this time, WECCO purchased a large share of what is now OU-1 from the CRC, although the US Government continued to retain ownership of approximately 290 acres within the current OU-1 boundary. The CRC conveyed most of its remaining property to Basic Management, Inc. (Basic Management or "BMI"), a new organization, which was owned by the five principal operating BMI Complex companies. BMI was formed to manage facilities and utilities common to all tenants at the complex, including water, power, sanitary sewers, and transportation. Operations historically conducted within OU-2 by BMI are further discussed in Sections 2.3.2 and 2.3.3.

WECCO merged with AP&CC in 1955[20] and continued production of ammonium perchlorate, in addition to the production of potassium perchlorate, sodium chlorate, and potassium chlorate. In 1962, AP&CC purchased the remaining areas of OU-1 from the US Government, including the AP Plant located near the center of OU-1, the sodium perchlorate plant

---

[18] The term "eluant" is used for consistency because it is a term used in previous reports presenting OU-1 history. "Eluant" refers to the solution that ammonium perchlorate crystals were grown in after the crystals were removed.

[19] Of these five original principal operating companies, only WECCO operated within OU-1. Section 2.2 summarizes historical manufacturing conducted by the other original principal operating companies within the BMI Complex.

[20] Production accounting procedures use 1955 as the end date of WECCO production and 1956 as the start date of AP&CC production; however, AP&CC began acquiring WECCO stock in 1954 (Schumacher 1999).

(primarily an intermediate product for ammonium perchlorate), and half of the sodium chlorate plant.

As further described in Section 2.4.1, the Beta Ditch, in addition to receiving storm water and non-contact cooling wastewater, continued to receive wastewater from on-site process operations, including the chlorate, perchlorate, and manganese manufacturing operations, as well as discharges from the acid drain system, a piping network that collected a variety of effluents from the Unit Building basements and other areas within the BMI Complex during this time period.

2.1.4 OU-1 History from 1967 to 2005

Figures 2-5a and 2-5b depict major operations and wastewater handling features within OU-1 between approximately 1967 and 2005.

Kerr-McGee acquired the OU-1 property in 1967 following a merger with AP&CC. Kerr-McGee produced the same chemical products as WECCO and AP&CC, but the following additional chemical products were also introduced: boron trichloride, elemental boron, boron tribromide, sodium perchlorate (produced as a finished product between approximately 1968 and 1990), magnesium perchlorate (produced between approximately 1969 and 1975), and a sodium chlorate-based bleaching agent known as Tumbleaf Defoliant® (produced between approximately 1975 and 1985) (Kleinfelder 1993). Tumbleaf Defoliant® was produced by dry blending sodium chlorate, soda ash, urea and sodium alpha olefin sulfonate. No wastes were generated in the process.

In 1969, Kerr-McGee began production of magnesium perchlorate by the reaction of ammonium perchlorate with magnesium carbonate using steam condensate as the liquid carrier (Kleinfelder 1993). The slow process was limited by the rate of removal of ammonia and carbon dioxide, which were treated in a tower scrubber using slightly acidic ammonium salt solution as the scrubber liquor. Upon completion, the batch was allowed to settle in a storage tank. Following removal of sulfate by a reaction with barium hydroxide, the solution was subjected to electrolysis to remove chloride and chlorate with magnesium carbonate added to control pH. Following settlement in storage tanks, the solution was filtered, packaged or bulk loaded for transport. Wastes associated with the process included filter cake and wash water containing magnesium carbonate, ammonium perchlorate, and magnesium perchlorate. The wastes migrated via the Beta Ditch primarily to the Upper BMI Ponds until the mid-1970s when the wastes were rerouted to the lined on-site ponds S-1 and P-1. The magnesium perchlorate process was terminated in 1976.

Kerr-McGee produced elemental boron between 1972 and 1990 (Kleinfelder 1993). A blend of boric acid and magnesium metal was ignited in a reaction chamber. The resultant product was crushed in preparation for leaching in a bath of water and sulfuric acid to precipitate out the boron, which was captured in a filter cake. Between 1972 and 1976, the liquid wastes from the process migrated via the Beta Ditch to the Upper BMI Ponds. In the mid-1970s, the filtrate was neutralized and discharged to surface impoundment C-1 and other liquid wastes were discharged to surface impoundments S-1 and P-1.

Starting in approximately 1973, Kerr-McGee produced boron trichloride gas by the reaction of heated boron carbide with chlorine gas (Kleinfelder 1993). As the exothermic reaction proceeded, boron trichloride was removed and condensed. The condensed gas was filtered to remove metal halide and oxychloride crystals formed during condensation. The filtered gas was then distilled to remove residual chlorine, which was recycled through the system. The boron trichloride gas was condensed to a liquid in preparation for additional distillation steps to purify the gas. As the gas was purified, a portion of the stream was bled to a refined distillation column to remove silicon tetrachloride. The final product was transferred to a portable storage tank. Wastes associated with the process included ash generated in the ignition reactors, which was filtered to capture residual unreacted boron carbide to be returned to the process. The ash was disposed in the off-site BMI landfill, which is further discussed in Section 2.2.4, from 1972 to 1979 after which it was disposed outside of the BMI Complex. The impurities (silicon tetrachloride) were discharged to the surface impoundment C-1 in the mid-1970s. The chlorine gas and associated dissolved chlorine was stripped in the cooling tower for the boron process, which migrated via the Beta Ditch to the Upper BMI Ponds until 1976, after which it was discharged to surface impoundments S-1 and P-1. In 1983, the scrubber water was discharged to surface impoundment C-1. The metal halide and oxychloride solids were also discharged to surface impoundment C-1.

The carbochlorination process used to produce boron trichloride may have resulted in the byproduct formation of chlorinated hydrocarbons such as carbon tetrachloride, which would likely be carried by residual chlorine gas, which was stripped in the cooling tower for the boron process.

Starting in approximately 1973, Kerr-McGee started producing boron tribromide in the Unit 5 Building using the same equipment as the boron trichloride process with chlorine gas replaced by bromine gas (Kleinfelder 1993). The waste streams were managed similarly to the boron trichloride wastes. The boron tribromide process was terminated in 1994 (ENVIRON 2011).

In addition to these new processes, Kerr-McGee continued production of sodium chlorate and potassium chlorate in the Unit 3, 4, and 5 Buildings (Kleinfelder 1993). The production of perchlorates (excluding ammonium perchlorate) was conducted in the Unit 4 and 5 Buildings. Production of ammonium perchlorate was conducted within the central portion of OU-1. Production of high purity, battery active manganese dioxide was conducted in two areas: (1) the ore was prepared and leached in the Leach Plant area located north of Unit 5 and 6 Buildings, and (2) the resulting manganese sulfate solution was fed to electrolytic cells in Unit 6 Building. Manganese tailings were stockpiled north of the Leach Plant between 1975 and 2004, after which manganese tailings were disposed of at an off-site landfill. Manganese dioxide product wash water was diverted to on-site wastewater collection ponds WC-West and WC-East, rather than the sanitary sewer, beginning in 1989 (Kleinfelder 1993).[21] Kerr-McGee discontinued production of sodium chlorate and ammonium perchlorate in 1997 and 1998, respectively. Perchlorate that had already gone through a portion of the production process and existed in on-site ponds was reclaimed using existing equipment until 2002 (ENVIRON 2011).

---

[21] The WC-West and WC-East ponds have been referred to in prior reports as the WC-1 and WC-2 ponds, respectively.

Historical information suggests that various tenants leased space from Kerr-McGee within OU-1 (Kleinfelder 1993; Kerr-McGee 1996b; ENSR 2005; ENSR/AECOM 2008):

- State Industries, Inc. (State Industries) leased an area from Kerr-McGee for the manufacture and storage of hot water heaters between 1969 and 1988. The area leased by State Industries included portions of Unit 1 Building and a large open area located south of Unit 2 and 3 Buildings and approximately 0.25 miles north of West Lake Mead Parkway. From at least 1970 to 1972, State Industries reportedly conveyed various process wastewater potentially containing sulfuric acid, borax, soda ash, and phosphate through the acid drain system to the Beta Ditch. The company also reportedly discharged wastewater containing cyanide to the Beta Ditch via the acid drain system between 1970 and 1971. State Industries operated two ponds, referred to as the Western and Eastern Surface Impoundments, which received spent "pickling process water" generated during the manufacture of water heaters and are further described in Table 2-2. These ponds were located within the State Industries lease area shown in Figure 2-5b.
- Jack B. Kelley Trucking (J.B. Kelley) leased an area approximately 0.1 mile north of Unit 1 Building between 1986 to the mid-1990s. Activities within the leased area included: washing truck interiors and exteriors, vehicle fueling, and minor repair work (e.g., oil changes). J.B. Kelley operated a 10,000-gallon diesel UST and a 600-gallon UST for used oil. These tanks were removed in 1991 under Clark County oversight. Exterior truck wash water was reportedly conveyed to the Beta Ditch via the storm sewer system until 1988, when Kerr-McGee requested that J.B. Kelley end the practice. Interior truck wash water was discharged to several locations including metal ASTs, a system of concrete vaults, and the Beta Ditch via the storm sewer system. Known discharges to the Beta Ditch by J.B. Kelly are summarized in Table 2-3. Prior to J.B. Kelley's tenancy, similar truck cleaning and maintenance operations were conducted by W.S. Hatch Company between 1980 and 1986.
- The Koch Materials Company (Koch), also known as the Koch Asphalt Company, leased an area north of the J.B. Kelley leasehold from 1983 to the mid-1990s. Prior to Koch's occupancy, the Burris Oil and Chemical Company (Burris Oil), conducted operations in the same area (1979 to 1983). Operations within the leased area historically included a plant for blending and packaging asphalt emulsions used in road construction and road sealing. While it does not appear Koch regularly discharged wastewater on-site, an oily liquid was reportedly discharged from Koch's operations to the Beta Ditch at least once in 1983.
- Additional historical lessees have used OU-1, and portions of OU-2 previously owned by Kerr-McGee or its predecessors (located immediately north of OU-1), for operations, including: Nevada Precast Concrete Products (1973-1978), Green Ventures International (1980-1981), Buckles Construction Company (steel fabrication and equipment storage, 1973-1989), Ebony Construction Company (construction management and staging, 1977-1978), Delbert Madsen (automobile storage and salvage yard, 1976 to mid-1990s), and Southern Nevada Auto Parts (SNAP) (automobile storage and salvage yard, 1972-present), Dillion Potter (livestock pasture

and vehicle storage, 1972 until at least 1993). Limited information was available regarding the historical operations of these lessees.[22]

Primarily due to changes in environmental regulations in the early 1970s, including the 1972 Federal Water Pollution Control Act (the Clean Water Act [CWA]) and the 1976 Resource Conservation and Recovery Act (RCRA), Kerr-McGee modified production processes and waste management methodologies.

Following closure of the off-site BMI landfill in 1980, an on-site landfill was operated in the northwest area of OU-1 between 1980 and 1983 (depicted as "Waste Landfill" within Figure 2-5a) (ENSR 2005) and used for the disposal of sodium chlorate filter cakes, which could have contained chlorinated organic chemicals, originating from the sodium chlorate process and materials (soils, pond liner, and dry pond contents) originating from the closure of the S-1 pond. A review of aerial photos indicates a larger area surrounding the Waste Landfill was used for the disposal of additional materials, most of which remain unknown, between approximately 1960 and 1979 (Kleinfelder 1993). The on-site landfill was capped in 1985 under an NDEP-approved plan in accordance with RCRA (NDEP 1989). Materials were removed from the on-site landfill in 2010-2011 as part of the soil removal action conducted within OU-1, as further described in Section 3.2. In addition, the Leasehold Debris Pile,[23] which contains demolition debris, has been located in the northeast area of OU-1 since at least 1999 and is further discussed in Section 6.2.2.

In summary, during this period, as shown in Figures 2-5a and 2-5b and described in Table 2-2, process water, which was initially managed via the Beta Ditch, came to be stored in a variety of on-site ponds, including ponds AP-1, AP-2, AP-3, AP-4, AP-5, AP-6, C-1, Mn-1, Mn-2, P-1, New P-2, Old P-2, Old P-3, S-1, WC-West, WC-East, and the State Industries Surface Impoundments. As further discussed in Section 2.3.1, a Beta Ditch Extension was constructed between 1965 and 1967 on the neighboring Stauffer and Montrose facility to the west (OSSM site) to convey process wastewater from Stauffer and Montrose via the Beta Ditch across OU-1 between at least 1971 and 1976 (BRC 2007).[24] Use of the Beta Ditch for process wastewater conveyance ceased in 1976 when each of the companies operating within the BMI Complex was required to implement zero discharge industrial wastewater management practices. The Beta Ditch Extension continued to receive storm water originating from the facility to the west (current Olin site) between 1976 and approximately 2011. With regards to process wastewater, Kerr-McGee/Tronox/EMD has been a "zero discharge" facility since 1976.

---

[22] Operations at Green Ventures International and Nevada Precast Concrete Products appear to have been limited to office space.

[23] Pursuant to the Trust Agreement, the Trust is only responsible for the presence or release, prior to or on February 14, 2011, of hazardous substances in or into the environment at, on or below any portion of the Site. Therefore, the Trust is only responsible for releases of hazardous substances from the Leasehold Debris Pile that occurred on or before February 14, 2011. Any releases of hazardous substances after February 14, 2011 and any removal of the Leasehold Debris Pile from the leasehold is not a Trust obligation.

[24] While text within the 1993 Phase I for the BMI Complex (Geraghty and Miller, Inc. 1993) suggest that discharges to the Beta Ditch extension from Stauffer/Montrose only took place between 1970 and 1976, aerial photographs clearly indicate that the Beta Ditch extension was installed sometime between 1965 and 1967.

As further discussed in Section 3, groundwater extraction and treatment facilities were installed beginning in the 1980s and continuing into the 2000s to address chromium and perchlorate-impacted groundwater. The GW-11 pond, which was constructed in 1998 to contain extracted contaminated groundwater, is shown in Figure 2-5a and further discussed in Table 2-2.

2.1.5 OU-1 History from 2005 to Present

Figure 2-6 depicts major OU-1 operations between 2005 and the present.

In 2005, Kerr-McGee spun off its chemical business and changed the company's name to Tronox (ENVIRON 2011). Tronox continued substantially similar operations to Kerr-McGee, producing 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 (ENVIRON 2011).

In 2009, Tronox filed for Chapter 11 bankruptcy. The Trust took title to the Site on February 14, 2011 as a result of the settlement of Tronox's bankruptcy proceeding. Tronox maintained a lease for approximately 114 acres of Trust-owned property between 2011 and 2018, where it continued its manufacturing operations. EMD acquired Tronox's operations within the leased area in 2018 and has continued manufacturing operations.

Prior to inception of the Trust, certain parcels of land to be conveyed to the Trust were identified by Tronox as "Sale Parcels". The Sale Parcels denoted in Figure 2-8 were identified as areas that were either generally undeveloped and/or were not likely to have been significantly impacted by current or former industrial activities. Most of the parcels have undergone remediation and all have been evaluated as part of a Health-Risk Assessment (HRA) process, as described in Table 2-4. As of the date of this report, only Sale Parcels E, F, and G are retained by the Trust.

Industrial Supply Company (Industrial Supply) is currently the only subtenant to EMD on the NERT Site. Industrial Supply has been a subtenant at the Site since August 31, 2006 and provides warehousing of maintenance, repair, and operating supplies that Tronox, now EMD, uses in its operations, as well as direct sales of tools and supplies used in manufacturing, construction, and utilities to third parties. Pronto Constructors, which provided construction services, was a subtenant to Tronox between 2001 and 2017. Angelo & Newton LLC, which provided Tronox with technical and managerial consulting services, specializing in chemical process plant safety compliance, regulatory compliance, and battery and energy systems, was a subtenant to Tronox from July 2007 until 2018.

Process wastewaters from EMD's current operations are conveyed to on-site lined ponds by a system of surface and subsurface pipelines. From there, the wastewaters are reused or allowed to evaporate. Current active process ponds used by EMD are Mn-1, Mn-2, WC-West, and WC-East. These ponds are further described in Table 2-2. NERT has no oversight role with respect to EMD's facility operations, ponds, and associated permits. Although NERT does not have an obligation to oversee EMD's operations, NERT monitors activities within the Leasehold through implementation of the NDEP-approved Site Management Plan (SMP), which is currently SMP, Revision 8 (Ramboll 2023a). The SMP requires work plans for soil disturbing activities. These work plans are reviewed by NERT and submitted to NDEP for approval. EMD provides an annual certification of SMP compliance and provides work plans and reports for projects conducted under the SMP. Additionally, EMD's lease requires compliance with all laws and regulations. EMD must notify NERT if a spill occurs and EMD must copy NERT on all spill-related correspondence with NDEP. Furthermore, EMD must provide notice to NERT prior to performance of any structural alterations or any non-structural alterations that exceed $50,000. For any structural or non-structural alterations that exceed $75,000, EMD must obtain approval from NERT of its plans prior to performance.

Groundwater treatment operations continued during this period and are further discussed in Section 3.3.3.

2.2 Major Chemical Manufacturing Operations Adjacent to Operable Unit 1

As previously discussed in Sections 2.1.2 and 2.1.3, following the BMI Complex's initial development during World War II as a magnesium production facility, the BMI Complex was home to several major chemical manufacturing operations by the early 1950s. These chemical manufacturing operations have resulted in multiple sources of groundwater contamination within the NERT RI Study Area, including from the OSSM site (located west of OU-1) and the TIMET site (located to the east of OU-1). As has been discussed, the Beta Ditch, which was an unlined west-east trending ditch that traversed OU-1, allowed co-mingled process wastewater from several BMI Complex parties including OSSM and TIMET to migrate to the Upper and Lower BMI Ponds.

These industrial operations within the BMI Complex and surrounding area, but not within the OU-1 boundary, are described in the following subsections and shown in Figure 1-3b.

2.2.1 Olin/Pioneer/Stauffer/Montrose History

The OSSM site, located to the west of OU-1, was operated at various times by Olin, Pioneer Chlor Alkali Company, Inc. (Pioneer), Stauffer, and Montrose. The following discussion regarding the OSSM site history is primarily based on the Environmental Conditions Assessment reports prepared for Stauffer (Weston 1993) and Montrose (Converse 1993). Historical years of operation mentioned below are approximate. The information in this section is not intended to provide a comprehensive summary of the OSSM site history. Rather, this summary has been assembled to provide context for contamination originating at the OSSM site which migrated through groundwater or the unlined Beta Ditch to OU-1 and OU-2.

To the west of OU-1, Basic Magnesium built a chlorine plant in 1941/1942, which operated until November 1944 to support the production of magnesium during World War II. Although sodium hydroxide was also produced in the chlorine production process, it was not commercialized during the war. After the war, Stauffer leased the chlorine plant and sodium hydroxide caustic plant to continue production of chlorine and commercialize the production of sodium hydroxide. Between 1951 and 1953, Stauffer acquired the property from the CRC and Hercules Powder Company. Stauffer acquired additional property in the 1970s for the caustic evaporation ponds and in the 1980s for the operation of a groundwater treatment plant (GWTP). During their time operating at the property, Stauffer expanded their operations to produce several other chemicals besides chlorine and sodium hydroxide, including parachlorothiophenol/thiophenol (1960-1984), trithion/imidan (intermittently during 1958-1984), lindane (gamma benzene hexachloride [gamma-BHC]) (1946-1958), and hydrochloric acid (1945-2016).

Stauffer leased approximately 20 acres of the property to Montrose from 1947 to 1994; however, operations at the Montrose property were conducted from 1947 to 1983, at which time the Montrose operations ceased. Montrose produced chlorobenzene (1947-1983), polychlorinated benzenes (1947-1983), chloral (trichloroacetaldehyde) (1947-1983), dichlorobenzil (1967-1983), ethyl chloride (1958-1961), and muriatic (hydrochloric) acid (1947-1983).

Pioneer acquired Stauffer's operations in 1988, which by then were limited to the chlor-alkali operations including the chlorine, sodium hydroxide, and muriatic acid plants. Olin acquired Pioneer in 2007 and continued to produce chlor-alkali chemicals until 2016 when Olin converted the facility to produce bleach, which is still produced as of the date of this report. NDEP is currently overseeing the investigation of subsurface soil and groundwater contamination associated with historical operations at the OSSM site. The following discussion provides additional details regarding historical operations at the OSSM site.

Beginning in 1942, Basic Magnesium produced chlorine from a clarified brine solution using Hooker Type S electrolytic cells. In addition to chlorine, the process generated hydrogen gas and cell liquor, which consisted of a dilute sodium hydroxide solution. Due to the reaction of chlorine generated at the graphite (carbon) anode in the Hooker cells, various byproduct chlorinated hydrocarbons were generated including chloroform and carbon tetrachloride (Laubusch 1959; Broadbent 2021). These byproduct compounds were carried with the chlorine gas. A portion of the byproduct chlorinated hydrocarbons may have dissolved in the cell liquor. The hydrogen gas was used on-site as a fuel source. During Basic Magnesium's tenure, the cell liquor was not further processed to commercial quality due to the focus on production of magnesium for the war effort, which did not require commercial-grade sodium hydroxide. When Stauffer assumed operation of the chlor alkali plant from the US Government in 1945, the cell liquor was further processed to produce a 50% sodium hydroxide solution. Between 1942 and 1958, impurities in the chlorine gas, which included various chlorinated hydrocarbons such as chloroform and carbon tetrachloride, were carried with the chlorine through the associated industrial processes. In 1958, Stauffer incorporated a chlorine liquefaction process to remove impurities in the chlorine. Stauffer continued operating the chlorine plant using Hooker Type S Cells until 1976, when Diamond Shamrock Cells were installed, which used titanium anodes instead of graphite. After Pioneer acquired Stauffer's operations in 1988, the production of chlorine continued until 2016, when the plant was modified to produce bleach.

Wastes generated during the production of chlorine using the Hooker Type S Cells between 1942 and 1976 included cell liquor (sodium hydroxide and any residual byproduct chlorinated hydrocarbons), brine sludge, cell parts, asbestos, sodium hypochlorite, sulfate slurry, fume scrubber waste, and chlorine liquefaction waste (from 1958 to 1976). Prior to 1945, cell liquor flowed to two caustic ponds in the northern portion of the Stauffer property possibly via the caustic drain that ran from the chlorine production area up 3rd Street. Similarly, brine sludge was discharged as a slurry to the two caustic ponds until 1973, after which it was discharged to the lined Chlor Alkali Products Division (CAPD) evaporation ponds in the northern portion of the Stauffer property. In 1990, the sludge was dewatered and transported off-site for disposal, with the resulting treated process water circulating back to the process. Waste cell parts from the Hooker Type S Cells were transported by truck to the BMI landfill[25] within the BMI Common Areas from 1945 to 1976, when Diamond Shamrock Cells were installed. Asbestos waste generated during cell reconditioning was also disposed of in the BMI Common Areas (BMI ponds and BMI landfill) from 1942 until 1981, when a filtration system was installed to minimize the volume of waste, which was then transported off site for disposal.

From 1958 to 1976, chlorine liquefaction waste, which consisted of chlorinated organics, was disposed in leach beds in the northwestern portion of the Stauffer property and/or in the BMI landfill. After 1976, the waste was no longer generated due to the replacement of the Hooker Type S Cells with Diamond Shamrock Cells. However, a tail gas carbon tetrachloride waste was generated, which was disposed in the BMI landfill until 1980, after which it was disposed off-site. Sodium hypochlorite waste was generated during scrubbing of residual chlorine gas with sodium hydroxide. The fate of this waste is unknown prior to 1963. From 1963 to 1974, it was discharged to the caustic ponds. After 1974, it was discharged to the CAPD ponds. Prior to 1976, sulfate slurry waste generated by sulfate removal from the salt slurry was disposed to either the caustic ponds or the Western Ditch (referred to in some reports as the Stauffer Effluent Ditch), which flowed to the Upper BMI Ponds. After 1976, the waste was discharged to the CAPD ponds. Fume scrubber waste from the cell renewal building, which may have contained a variety of organics and metals, was reportedly discharged to the Beta Ditch Extension.

Stauffer produced parachlorothiophenol/thiophenol as intermediates of pesticides and herbicides in the agricultural chemicals division (ACD) process area in the northwestern portion of the Stauffer property from 1960 through 1984. Waste streams were limited to phosphoric acid waste, product aqueous waste, and caustic wastewater. From 1960 until 1970, phosphoric acid waste was discharged to the phosphoric acid pond and three associated trenches (leach beds) north of the ACD process area. A portion of the drummed material may have been disposed in the drum burial area in the northwest portion of the Stauffer property. After 1970, it was disposed of off-site. Product aqueous wastewater was discharged to two on-site evaporation ponds (Wastewater Ponds 1 and 2) until 1975 when a wastewater treatment facility was installed. Following treatment, the wastewater was discharged to the lined ACD ponds. The caustic wastewater was discharged to the ACD wastewater treatment plant or ponds.

Stauffer produced trithion/imidan, which were organophosphorus insecticides, in the ACD process area from 1958 through 1984 (trithion) and 1964 through 1976 (imidan). Wastes generated in these processes included aqueous waste, organic waste, and dithio acid salt waste. The aqueous waste was discharged to the on-site leach beds through 1974, after which it was discharged to the ACD ponds until 1984. The fate of the organic waste generated prior to 1969 is unknown. From 1969 to 1974 the organic waste was drummed

---

[25] The BMI Landfill, which was located within the BMI Common Areas and within the boundaries of what is now the CAMU, received wastes from facilities within the BMI Complex between 1943 and 1980.

and buried in the drum burial area. The fate of the dithio acid salt waste until the mid-1970s is unknown, after which it was disposed off-site.

Stauffer produced lindane (gamma-BHC), which is a chlorinated insecticide, in a dedicated plant in the central portion of the Stauffer property from 1946 through 1958. Wastes generated in the lindane process included alpha benzene hexachloride (alpha-BHC) and beta benzene hexachloride (beta-BHC) isomer cake and cooling water from the process equipment. The isomer cake was transferred by front end loaders to three stockpiles in the northwest portion of the Stauffer property, which were subsequently consolidated and capped. The cooling water, which may have contained small amounts of organics, was likely discharged to the site's wastewater sewer, which likely flowed to the Lower BMI Ponds via the Western Ditch.

Montrose produced monochlorobenzene and polychlorinated benzenes from 1947 through 1983 in a process area located west of the chlorine cell house No. 2. Wastes generated in the process included: hydrochloric acid, sulfuric acid, polychlorinated benzene still bottoms, and spent caustic from acid neutralization (from 1980 through 1983). Chlorination of benzene to produce chlorobenzenes could have produced incidental chloroform if toluene, xylenes, or aliphatic hydrocarbons were present in the feed benzene (Broadbent 2021). Hydrochloric acid waste and sulfuric acid waste were discharged to the process sewer that likely flowed to the Beta Ditch Extension after it was installed in approximately 1967. Prior to this time, it is unclear where the process sewer discharged; however, other wastes generated at Stauffer's plant apparently flowed to the Lower BMI Ponds via the Western Ditch. After 1976, these wastes were discharged to the lined Montrose evaporation ponds in the southern portion of the property. Still bottoms were disposed in the BMI landfill from 1947 to 1976, after which they were disposed in the Montrose ponds. Between 1980 and 1983, the still bottoms were drummed and temporarily stored in the southern portion of the plant prior to transport off-site for disposal. The spent caustic from the acid neutralization was disposed in the Montrose ponds.

Montrose produced chloral, chloral hydrate, and a chloral-monochlorobenzene mixture from 1947 to 1983. The primary waste generated in the chloral process was spent sulfuric acid, containing minor amounts of by-products including chloral, chloroform, and carbon tetrachloride. Prior to 1976, this waste was discharged to the process sewer. From 1947 until approximately 1967 it is unknown where the process sewer discharged wastewater; however, as noted above, other wastes at Stauffer flowed to the Lower BMI Ponds via the Western Ditch. From approximately 1967 to 1976, the sulfuric acid waste likely flowed to the Beta Ditch Extension and on to the Upper BMI Ponds. After 1976, the sulfuric acid waste was discharged to the Montrose ponds.

Montrose produced dichlorobenzil in the main plant from 1967 to 1983 in a multistep process. Wastes generated in the process included spent sulfuric acid, wash water, excess water, and empty bags. Prior to 1976, the sulfuric acid waste, which contained small amounts of chloral, the wash water, and the excess water were discharged to the process sewer. From 1947 until approximately 1967, it is unknown where the process sewer discharged wastewater; however, as noted above, other wastes at Stauffer flowed to the Lower BMI Ponds via the Western Ditch. From approximately 1967 to 1976, these wastes likely flowed to the Beta Ditch Extension and on to the Upper BMI Ponds. After 1976, the sulfuric acid waste, wash water, and excess water were discharged to the Montrose ponds. The empty bags were disposed in the BMI landfill until 1979, after which they were transported off-site for disposal.

Although Montrose produced hydrochloric acid in the chloral process as early as 1947, commercial production of hydrochloric acid was initiated in 1954 and expanded in 1977. Following the closure of the Montrose operations, Stauffer and then Pioneer and Olin continued the production of hydrochloric acid. Waste from this process is limited to low pH water, which was recycled to the brine process.

2.2.2 Lhoist/US Lime History

US Lime (operated later by the Flintkote Company, Genstar Lime Company, Chemstar, Inc. [Chemstar]) operated a lime manufacturing facility near the center of the BMI Complex beginning in the late 1940s. US Lime's historical discharges to the Beta Ditch are presented in Table 2-3. Lime manufacturing operations are currently conducted in the same location near the center of the BMI Complex by Lhoist.

2.2.3 TIMET/Combined Metals History

To the east of OU-1, between approximately August 1942 and November 1944, the Unit 7 through 10 Buildings[26] were used for the same magnesium production processes conducted in Unit 1 through 6 Buildings within OU-1, as described in Section 2.1.1.

TIMET subsequently began titanium metal ingot production operations in 1951 within the Unit 7 through 9 Buildings. TIMET has produced titanium products for industrial, defense, and commercial aerospace markets. Around the same time, Combined Metals operated within Unit Building 10 and produced ferromanganese alloys between 1947 and 1955. While Combined Metals was one of the original principal operating companies that formed BMI in 1952, the company's operational areas were sold to TIMET in approximately 1956, which established the footprint currently owned by TIMET.

The primary products historically produced by TIMET include titanium ingots, titanium tetrachloride, titanium sponge, and titanium fines. As described within the Environmental Conditions Assessment for TIMET prepared by Law Engineering (1993), titanium tetrachloride is generated as an intermediate product during the chlorination of rutile ore, which is achieved by passing chlorine gas through a mixture of rutile and coke at approximately 1,000°C. The crude titanium tetrachloride is collected with other volatile chlorides as off-gas from the chlorinator unit. According to the patent for this process, carbon tetrachloride is produced as a major by-product and is present in the off-gas (US Patent Office 1957). Since carbon tetrachloride readily degrades to chloroform, the off-gas may also contain chloroform. The crude titanium tetrachloride is then purified via a confidential, proprietary chemical process which removes trace metal impurities. Following purification, the reduction process reacts titanium tetrachloride with molten magnesium metal within an inert helium atmosphere to create a mixture of titanium and magnesium chloride salt, a by-product. Crushing and leaching operations remove residual magnesium and magnesium chloride salts from the titanium, which creates titanium sponge, a porous

---

[26] The Unit Buildings were constructed from west to east between 1941 and 1943. The Unit 1 Building began magnesium production in August 1942. The Unit 10 Building was not completed and operational until July 1943.

form of titanium metal. The titanium metal is then melted and blended into ingots and metal alloys. The magnesium chloride salts are subsequently electrolytically converted to magnesium metal and chlorine gas in the magnesium recovery unit, purified, and reused in the titanium production process. In late 2020, much of TIMET's manufacturing capacity was idled indefinitely following a sharp decline in demand for titanium sponge (Wright 2020). As of the date of this report, there has been no change in manufacturing capacity.

TIMET's historical wastewater discharges to the Beta Ditch between 1951 and 1976 and other wastewater migration features operated by TIMET within OU-2 after 1976 are discussed in Sections 2.4.1 and 2.4.2. Portions of the Beta and Northwest Ditches, which are also further discussed in Section 2.4.1, historically traversed the northern portion of the TIMET site. The former ditch areas within the TIMET facility were excavated in 2013 (TIMET 2013). Similar to the OSSM site, the TIMET site's historic contributions of wastewater to the ditch system within the BMI Complex, as well as the infiltration to groundwater, have impacted the current distribution of contaminants and are further discussed in Section 9.

While not contiguous with the above-mentioned property, TIMET formerly owned an additional parcel located southwest of the Unit 1 Building within the BMI Complex (see Figure 1-4). This property was sold to Colvin Steel in December 2021. Jones Chemicals operated on this property repackaging swimming pool maintenance chemicals from at least 1968 until 1993. Hydrochloric acid and hypochlorite solution were stored in ASTs and bulk chlorine generated in the neighboring OSSM site was stored in mobile tanks (Law Engineering 1993). This area is not a focus of TIMET's investigation or remediation activities.

2.2.4 BMI Corrective Action Management Unit History

The BMI CAMU is a lined, 52-acre landfill, constructed in six phases, with a storage capacity of approximately 3.4 million cubic yards that received wastes from a number of different parties within the BMI Complex, including soil and sludge excavated from the Eastside Sub-Area, Western Ditch, and Stauffer/Montrose slit trenches (Geosyntec 2015, 2010, 2008). The north and south landfill lobes have also been capped to reduce infiltration and the creation of chemical leachates (BRC 2017). The BMI CAMU is located northwest and immediately adjacent to OU-1.

Historical features within the boundaries of the CAMU include the BMI Landfill (which received wastes from facilities within the BMI Complex between 1943 and 1980), portions of the former Western Ditch (see Section 2.4.1), slit trenches (which received unknown wastes between at least 1957 and 1980), and a borrow area (BRC 2017, 2007; Geraghty & Miller 1993).

2.2.5 AMPAC History

Although not located within the BMI Complex, the former AMPAC site was operated by AMPAC from 1982 to 1988 and the Pacific Engineering and Production Company of Nevada (PEPCON) from 1958 to 1982. AMPAC and PEPCON produced perchlorates at a plant located approximately 1.5 miles west of the BMI Complex, as shown in Figure 1-3b. As part of the perchlorate production process, chlorate was also generated as a byproduct. This process, which involved the electrolysis of brine to produce chlorine and sodium chlorate with a graphite anode plated with lead dioxide, had the potential to generate incidental chloroform (Broadbent 2021). The facility experienced a catastrophic explosion in 1988.

2.3 Operable Unit 2 History

This section describes the historical operations within OU-2, which is generally divided into two areas: 1) OU-2 located west of Pabco Road; also referred to as the southern portion of the NERT Off-Site Study Area; and 2) OU-2 located east of Pabco Road; also referred to as the Eastside Sub-Area (see Figure 1-2). The majority of the Eastside Sub-Area was historically operated by BMI for general facility and utility operations in areas referred to as the BMI Common Areas, which included the Upper BMI Ponds and much of the area south of the Beta Ditch within the Eastside Study Area. As discussed throughout this report, Pabco Road serves not only as a boundary demarcating differing historical land use but also to identify NERT’s obligations related to the RI/FS. The following sub-sections describe specific historical operations conducted within OU-2 west of Pabco Road (Section 2.3.1) and OU-2 east of Pabco Road (Sections 2.3.2 and 2.3.3). A detailed discussion regarding how this information, and the RI data presented in Sections 7 and 8, relates to NERT’s obligations is found in Section 9.

2.3.1 OU-2 West of Pabco Road: History from 1940s to Present

The area of OU-2 located west of Pabco Road was mostly vacant in the early 1950s with scattered structures located north and south of what is now North Boulder Highway (Figure 2-9). The Northwest Ditch and Alpha Ditch, which conveyed primarily storm water and non-contact cooling water starting in the mid-1940s, were located along the southern boundary (Warm Spring Road) and eastern boundary (Pabco Road) of this area, respectively (see Section 2.4.1 for additional information). Based on a review of historical aerial photographs, it does not appear that the Northwest Ditch was used very often, and there are no records of whether historical discharges from OU-1 were directed to the Northwest Ditch. By the early 1980s, much of OU-2 west of Pabco Road had been developed with a combination of commercial and residential structures. This portion of OU-2 continues to be used primarily for residential housing (generally northeast of Boulder Highway, west of Pabco Road, and south of Sunset Road) with commercial and light industrial operations to the north (between Sunset Road and Galleria Drive) and the southwest (along Boulder Highway and between Boulder Highway and Warm Springs Road). The residential community in this area, which is known as the Pittman neighborhood currently includes approximately 1,500 single-family dwellings, 30 multi-family dwellings, and two mobile home parks.

Groundwater elevations in the Pittman neighborhood rose soon after magnesium production began in 1942. This rise in the water table was believed to be the cause of flooding in basements and cesspools in the original Pittman development located just north of OU-1. An underdrain was installed in the Pittman neighborhood prior to 1963 to lower groundwater levels (Westergard 1969). The alignment for the Pittman Drain, also known as the Pittman Leach Line, is shown in Figures 2-9 and 2-10. The need for the Pittman Drain was greatly reduced by the installation of the Pittman By-Pass. The Pittman By-Pass (see Section 2.4.2) was installed in the western portion of OU-2 in 1985 to replace the Alpha Ditch with an underground pipeline to transfer wastewater from the BMI Complex to the Las Vegas Wash (see Figure 2-10). The Pitman By-Pass continues to convey non-contact cooling water from the TIMET facility. According to a United States Geological Survey (USGS) Water Resources Investigations Report (USGS 1989), after two years of operation of the Pittman By-Pass, water levels in the vicinity of the bypass declined by approximately 15 feet. Although information on the current status of the Pittman Drain is unavailable, the flow in the Pittman

Drain would have decreased significantly following the decrease in groundwater elevations. The design and construction details for the Pittman Drain are unavailable.

Immediately north of the former industrial operations within OU-1, two of the Sale Parcels previously owned by Tronox or the Trust, referred to as Parcels A and B, are located in the southwestern portion of OU-2 (Figure 2-8). It does not appear that significant industrial operations associated with the BMI Complex were ever conducted within these parcels, as detailed in Table 2-4, and NDEP issued a NFA for both parcels. Some of Kerr-McGee's historical lessees, described in Section 2.1.4, likely operated within these parcels.

2.3.2 OU-2 East of Pabco Road: History from 1940 to 1975

Figure 2-9 depicts the area of OU-2 located east of Pabco Road, which was largely comprised of historical wastewater ponds and conveyance ditches operated by BMI.

The Upper BMI Ponds began receiving process water via the Beta Ditch in approximately 1943 (under the ownership of the US Government) and were subsequently operated by BMI from 1952 until 1976. The Beta Ditch, which originated within OU-1,[27] entered OU-2 on the southern side of the Upper BMI Ponds and then extended north-northwest through the center of the Upper BMI ponds towards OU-3 and the Las Vegas Wash. The Upper BMI Ponds included numerous small evaporation ponds aligned in 18 rows of varying length that followed the contours and surface drainages of the natural land surface and covered approximately 915 acres (Geraghty & Miller 1993). Historical records and aerial photographs indicate that only the southern-most eight rows were used (BRC 2007), corresponding to approximately 50% of the total area of the Upper BMI Ponds (see Figure 2-9). Wastewater that migrated to the unlined ponds eventually infiltrated into the subsurface and/or evaporated. Limited information is available regarding the specific types and quantities of liquid wastes that migrated to the ponds via the Beta Ditch and originating within the BMI Complex including OU-1, but available information is presented in Table 2-3 (Geraghty & Miller 1993).

A sewage treatment plant constructed immediately south of the Upper BMI Ponds received sanitary sewer waste from the BMI Complex and COH beginning in 1942 (Geraghty & Miller 1993). BMI operated the plant until 1974. The COH continued to operate the sewage treatment plant until it was closed in 1985.

2.3.3 OU-2 East of Pabco Road: History from 1976 to Present

Figure 2-10 depicts historical waste ponds established after 1976 within OU-2 east of Pabco Road.

By the mid-1970s, companies operating within the BMI Complex discontinued the discharge of industrial wastewater via the existing unlined ditches/ponds, including the Beta Ditch. While many facilities within the BMI Complex began to manage their wastewater on their properties, TIMET achieved this requirement by constructing a series of lined surface

---

[27] The Beta Ditch originated within OU-1 prior to the addition of the Beta Ditch Extension, which extended the Beta Ditch onto the Montrose/Stauffer facility to the west by 1967.

impoundments within the Eastside Sub-Area, which received process wastewater discharges between 1976 and 2005 (BRC 2007).

Between 1985 and 1990, TIMET discharged liquid process waste concentrates from its salt recovery system to a center post irrigation system (the TIMET Spray Wheel), which discharged to bare ground within the BMI Common Areas (see additional discussion in Section 2.4.2). The circular 125-acre area, located immediately north of the TIMET lined surface impoundments, operated under an authorization to discharge from NDEP and received approximately 50 million gallons of liquid wastes annually (Law Engineering 1993). The discharged liquids were high in TDS, magnesium, chloride, nitrates, sulfates and trace metals including titanium, vanadium, iron, and trivalent chromium (Law Engineering 1993).

Between 1992 and 2002, a series of unlined ponds were used for the discharge of treated municipal wastewater by the COH (BRC 2007). The ponds, referred to as the Southern Rapid Infiltration Basins (RIBs), were operated south of TIMET's lined surface impoundments (see additional discussion in Section 2.4.2).

Aerial photographs taken between the late 1960s and 1980s suggest that natural groundwater seeps or near-surface moisture may have existed in an area of lower ground elevation near the northwest boundary of the Eastside Sub-Area. Previous work by BRC, the entity formed to complete remediation work on former BMI property, has also identified the presence of apparent seeps in the same area (BRC 2007). The location of this apparent former surface seep area is shown in Figure 2-10. As discussed in Section 8.2, this is the area where the highest residual concentrations of perchlorate and chlorate are detected in vadose zone soil at and below a depth of 10 feet below ground surface (bgs).

As discussed in Section 3.2, extensive investigation and remediation activities have been conducted within OU-2 east of Pabco Road (i.e., the Eastside Sub-Area/BMI Common Areas) since the late-1990s.

Approximately 50% of the former BMI Common Areas within OU-2 has been developed. By the time the development is complete, it is anticipated that as many as 13,250 planned residences, as well as parks, schools, and retail stores, will be constructed within much of the remaining vacant areas as part of the Cadence master-planned community (LandWell 2019). The southern-most portion of OU-2 is partially occupied by a number of commercial businesses along Lake Mead Parkway.

2.4 Historical Wastewater Management

This section describes infrastructure used to convey wastewater and non-contact cooling water from OU-1 to unlined ponds within OU-2 and OU-3 prior to the mid-1970s. It also describes major process and wastewater management features used after the mid-1970s. The historical management of wastewater from the BMI Complex via the historical system of unlined ponds/ditches has resulted in relatively widespread migration of contaminants, originating at the BMI Complex, to soil and groundwater within the NERT RI Study Area, particularly OU-2. More detailed descriptions of ponds/surface impoundments used within OU-1 are summarized in Table 2-2.

2.4.1 Wastewater Management Features Established Prior to 1975

Most of the wastewater management features discussed in this section are shown in Figure 2-9, unless otherwise noted.

Acid Drain System – The acid drain system, which is shown in Figures 2-2, 2-3, and 2-4, was a piping network originally designed to collect acid effluent associated with industrial operations from throughout the BMI Complex and existed in Unit Buildings located both within and east of OU-1. The system carried a variety of process wastewaters from the Unit Building basements during the operational history of OU-1, as documented in this and previous reports (Kleinfelder 1993). Process wastewaters collected via the acid drain system migrated off-site via the Beta Ditch to primarily the Upper BMI Ponds.

Caustic Drain System – The caustic drain system was a piping network originally designed to collect caustic effluent associated with industrial operations from throughout the BMI Complex and existed in Unit Buildings located both within and east of OU-1. Process wastewaters collected via the caustic drain system migrated off-site, historically, to the Trade Effluent Ponds and, subsequently, via the Beta Ditch to primarily the Upper BMI Ponds._A separate caustic drain system transferred caustic effluent generated at the OSSM site to the caustic ponds in the northern portion of the OSSM site.

Sanitary Wastewater – Portions of OU-1 have been connected to the sanitary sewer system since the US Government's development of the area during the 1940s, although the historical record indicates instances where wastewater was disposed via on-site septic systems (e.g., the AP Plant Area Change House and Chemistry Laboratory) (Kleinfelder 1993). There are also several accounts of process wastewater migration to the sanitary sewer system, either during overflows of the sanitary sewer system or as part of regular operations (i.e., manganese dioxide product wash water prior to 1989) (Kleinfelder 1993).

Alpha Ditch – The Alpha Ditch was constructed in approximately 1943 and, while historic operational records are incomplete, it was likely primarily used to convey storm drainage and non-contact cooling water from the BMI Complex to the Las Vegas Wash and, possibly, the Lower BMI ponds (Geraghty & Miller 1993). As shown in Figure 2-9, two collection segments of the Alpha Ditch, located on what is now the TIMET site, directed flow north and northwest, and then routed the combined flow northeast under Boulder Highway to the main segment of the Alpha Ditch. The main segment of the Alpha Ditch historically flowed northward along the western boundary of the Upper BMI Ponds before curving to the east near the southern edge of the Lower BMI Ponds and discharging to the Las Vegas Wash within OU-3.

Beta Ditch – Whereas the Alpha Ditch's primary historical use was to convey storm and non-contact cooling water, the Beta Ditch was used for the migration of process wastewater from industrial operations. To provide additional capacity beyond that of the Trade Effluent Ponds, the Upper BMI Ponds were constructed in the early 1940s within the BMI Common Areas to the east of the BMI Complex within OU-2 (BRC 2007).[28] As discussed throughout this report, process wastewater migrated to the Upper BMI Ponds via the Beta Ditch, which was an unlined west-east trending ditch originating in OU-1 and constructed circa 1941 or 1942

---

[28] The Trade Effluent Ponds, the Upper BMI Ponds, and the Lower BMI Ponds are further discussed in this section below.

(Geraghty & Miller 1993). From there, the Beta Ditch continued to the northwest towards the Lower BMI Ponds mostly within OU-3. The Beta Ditch extended east of OU-1 to a siphon inlet/pond location on what is now TIMET site. The siphon pipe then conveyed flows from the western section of the Beta Ditch under Boulder Highway to the eastern section of the Beta Ditch and subsequently to the Upper BMI Ponds. A cross over pipe, located in the southwest corner of the Upper BMI Ponds, allowed for water to migrate to the Alpha Ditch (Geraghty & Miller 1993). Daily operational records associated with this cross over pipe are not available. After the discontinuation of process wastewater discharges in 1976, the segment of the Beta Ditch located within the BMI Complex was used to convey non-contact cooling water and storm water runoff to the Pittman By-Pass Pipeline, as discussed in Section 2.3.2 below.

Beta Ditch Extension – Between 1970 and 1976,[29] the Upper BMI Ponds also received process wastewater and cooling water from the Stauffer and Montrose Facilities via the Beta Ditch Extension in the western portion of OU-1 (Kleinfelder 1993). Prior to this, process wastewater from these facilities (as discussed in detail in Section 2.2.1) migrated to the Lower BMI Ponds via a ditch located west of the Stauffer and Montrose Facilities (referred to as the Western Ditch). By the late 1970s, each of the companies operating within the BMI Complex was required to achieve zero discharge process wastewater management status, which substantially altered the management of process wastewater within the BMI Complex. The Beta Ditch Extension continued to receive storm water originating from the facilities located west of OU-1 between 1976 and approximately 2011, during which time the neighboring facility was owned or occupied by OSSM.

Northwest Ditch – The Northwest Ditch was constructed in the early 1940s to convey effluent to the Lower BMI Ponds (located mostly in OU-3). After extending northwest through what is now the TIMET site, plant effluents were conveyed along the northern boundary of OU-1 before joining a natural drainage channel, located west of the NERT RI Study Area, leading to the Lower BMI Ponds. Limited information is available regarding the ditch's operation, but historical records indicate that wastewater from US Government operations likely migrated to the Northwest Ditch in the early 1940s, as well as storm water and wastewater (unknown time period) from Stauffer and Montrose (Geraghty and Miller 1993). Historical aerial photos of the Northwest Ditch indicate that it was infrequently used. Kerr-McGee may have also infrequently sent small-scale discharges of excess storm water originating from OU-1 to the Northwest Ditch (Geraghty & Miller 1993).

Trade Effluent Ponds – Process wastewater generated by industrial operations within OU-1 and the BMI Complex were initially accumulated in the Trade Effluent Ponds which were partially located outside of OU-1 until the need for additional capacity became apparent in the early 1940s (Kleinfelder 1993). The Trade Effluent Ponds were comprised of four surface impoundments with earthen sides, a distribution pipeline, and a French drain system. Additional information regarding the Trade Effluent Ponds is included in Table 2-2.

---

[29] These dates are consistent with the 1993 Phase I for the BMI Complex (Geraghty & Miller 1993), but aerial images indicate the Beta Ditch extension was installed between 1965 and 1967. Therefore, the Beta Ditch could have received wastes from Stauffer and Montrose as early as 1967.

Upper BMI Ponds – The Upper BMI ponds began operating in approximately 1943, continued operating until the mid-1970s, and received process wastewater from the BMI Complex via the Beta Ditch. The Upper BMI Ponds included numerous small evaporation ponds aligned in 18 rows of varying length that followed the contours and surface drainages of the natural land surface and covered approximately 915 acres (Geraghty & Miller 1993). Historical records and aerial photographs indicate that only the southern-most eight rows were used (BRC 2007), corresponding to approximately 50% of the total area of the Upper BMI Ponds (see Figure 2-9). Migration occurred via the Beta Ditch to the Upper Ponds from WECCO, AP&CC, and Kerr-McGee (1945-1976), TIMET (1951-1977), US Lime (1969-1972), and Stauffer/Montrose (1971-1976).[30] Additional information regarding historical wastewater migration to the Upper BMI Ponds is summarized in Table 2-3.

Lower BMI Ponds – The Lower BMI Ponds, which are mostly located within OU-3 and will be further discussed in the RI Report for OU-3, were constructed concurrently with the Upper BMI Ponds in approximately 1943 and received process wastewater from the BMI Complex via the Western Ditch (originating west of OU-1) and Northwest Ditch. The Lower BMI Ponds included numerous small ponds that followed the contours of the natural land surface and covered approximately 430 acres (Geraghty & Miller 1993). Migration to the Lower Ponds occurred from Stauffer (1946-1970) and Montrose (1947-1970). Additional information regarding historical wastewater migration to the Lower BMI Ponds is summarized in Table 2-3.

Henderson Sewage Treatment Plant #1 (HSTP1) – A sewage treatment plant was constructed by the COH in 1958 approximately one quarter mile south of the Lower BMI Ponds and outside of the NERT RI Study Area (Geraghty & Miller 1993). Although HSTP1 was established after HSTP2 (described further below), the plant was named HSTP1 because the City did not operate HSTP2 until 1974. The HSTP1 is located west of OU-3 and treated domestic and light industrial effluent from the Henderson/Pittman area until its closure in 1985, with a daily treatment capacity of approximately 1.0-1.5 million gallons (Geraghty & Miller 1993).[31] Sewage from the HSTP1 reportedly underwent only minor treatment before it was discharged to one of two lagoons (one lined and one unlined) or an area of the Lower BMI Ponds designated as the evaporation and percolation ponds (EPP) area, within OU-3 (Geraghty & Miller 1993; UNLV 2003). The EPP later became the COH Bird Viewing Preserve (COH Birding Ponds), described further in Section 2.4.2. As shown in Figure 2-9, HSTP1 is located adjacent to OU-3 and it will therefore be described further in the forthcoming RI Report for OU-3. The HSTP1 discharge would have contributed to localized mounding of the potentiometric surface which would therefore influence contaminant concentrations near the Las Vegas Wash.

Henderson Sewage Treatment Plant #2 (HSTP2) – In 1942, a sewage treatment plant was constructed south of the Upper BMI Ponds and used to treat sewage effluent from the BMI Complex (including from within OU-1) and COH until its closure in 1985 (Geraghty & Miller

---

[30] See footnote 25. Aerial photographs indicate that the Beta Ditch Extension existed by 1967.

[31] Other sources have referred to the HSTP as wastewater treatment plant (WWTP) and have indicated that HSTP1/WWTP1 closed in 1983 when HSTP3/WWTP3 began operating (Batista et al. 2003).

1993). The plant was operated by BMI and its predecessors until the COH began operating the plant in 1974.

2.4.2 Wastewater Management Features Established After 1975

Wastewater management features discussed in this section are shown in Figure 2-10.

TIMET Surface Impoundments and Spray Wheel – From 1976 to 1982, TIMET installed 31 lined surface impoundments within the southwestern portion of the former Upper BMI Ponds area for the evaporation and storage of its process waste streams (Law Engineering 1993). Several of the lined ponds were reported to have had liner failures and were subsequently upgraded to double-lined systems. In 2005, use of the ponds ceased following construction of a water conservation facility at the TIMET plant. Between approximately 1985 and 1990, TIMET also operated a Spray Wheel within this area for evaporation of its high TDS effluent (Law Engineering 1993).

Rapid Infiltration Basins and Henderson Bird Viewing Preserve – The COH operated several unlined basins, known as the Southern RIBs, in the former BMI Common Areas within OU-2 between approximately 1992 and at least 2002 (BRC 2007). A similar set of basins, the COH Northern RIBs, were operated between 1992 and the early 2000s within OU-3. Both sets of RIBs received treated effluent from the City's municipal wastewater treatment process and were replaced in the early 2000s by the COH Birding Ponds, which is located near the former Lower BMI Ponds on the western edge of OU-3. The Northern RIBs and COH Birding Ponds will be further discussed in the forthcoming RI Report for OU-3.

Pittman By-Pass Pipeline – The Pittman By-Pass Pipeline is an 18-inch diameter buried pipeline that generally follows the same path as the Alpha Ditch, and originally included two inlets and one outlet. It was constructed in 1985 to convey non-contact cooling water from TIMET and rainwater runoff from OU-1 to the Las Vegas Wash, thereby eliminating the unlined Alpha Ditch. The project was designed to reduce the amount of dissolved salts entering Lake Mead (Geraghty & Miller 1993). The inflow point, used to discharge storm water from OU-1, was capped in 2012 leaving only the inlet branch located on the TIMET site.[32] The pipeline continues to convey non-contact cooling water from the TIMET facility via the remaining inlet, while rainwater runoff from OU-1 is now retained on-site in several large infiltration retention basins (i.e., the central retention basin and northern retention basin).

Current Sanitary Wastewater Practices – Sanitary wastewater generated in OU-1 is discharged to the municipal sanitary sewer system, except at restrooms at the NERT and Envirogen offices which discharge to in-ground holding tanks and is subsequently disposed off-site. The COH, Department of Utility Services has issued a waste discharge authorization to the collective BMI companies for discharge of sanitary effluent from each facility.

Henderson Sewage Treatment Plant #3 (HSTP3) – A sewage treatment plant (HSTP3) with an initial daily treatment capacity of 6.3 million gallons began operating in 1983 within the boundaries of the former Lower BMI Ponds in OU-3 and north of HSTP1 (BRC 2007). The daily treatment capacity of HSTP3 was expanded to 9.5 million gallons in 1989. HSTP3 was

---

[32] According to a personal email correspondence with John Ladd, dated August 13, 2019.

operated until 1994 when it was replaced by the COH Water Reclamation Facility (located in OU-3). Throughout HSTP3's operational period from 1983 to 1994, effluent from the plant was sent to unlined ponds within OU-3 for infiltration (Batista et al. 2003). Similar to the discharge from HSTP1 described earlier in Section 2.4.1, the discharge from HSTP3 would have contributed to localized mounding of the potentiometric surface, thus influencing the contaminant concentrations near the Las Vegas Wash. Within OU-2, the Southern RIBs (described above) also received treated municipal effluent from HSTP3. The re-use of treated municipal effluent from HSTP3 for the irrigation of local golf courses began in 1985 (Batista et al. 2003). The Chimera Golf Course, located in the eastern portion of OU-3, currently uses municipal effluent for irrigation and has operated since 1999. HSTP3 and the Chimera Golf Course will be further described in the forthcoming RI Report for OU-3.

3. REGULATORY ACTIONS, ENVIRONMENTAL INVESTIGATIONS, AND REMEDIAL ACTIONS

As described within Section 2, beginning in 1942, various industrial operations, including the manufacture of magnesium and perchlorates, and the use of unlined ditches and ponds for wastewater management, occurred within OU-1 and OU-2. Since the early 1970s, the NERT RI Study Area has been the subject of numerous regulatory actions, environmental investigations, and remedial actions. The investigations performed in OU-1 and OU-2 have found that soil and shallow groundwater in the vicinity and downgradient of OU-1 is impacted by perchlorate, hexavalent chromium, and other contaminants as a result of former industrial operations.

Section 3.1 describes regulatory actions pertaining to OU-1 and OU-2 which occurred between 1970 and 2011, prior to the Trust's ownership. Section 3.2 describes environmental investigations and remedial actions pertaining to OU-1 and OU-2 during this same time period. These include soil removal efforts within both OU-1 and OU-2, as well as the design and implementation of the NERT Site's groundwater extraction and treatment system (GWETS). Section 3.3 discusses regulatory actions, environmental investigations, and remedial actions pertaining to OU-1 and OU-2 since the Trust took title to the Site in 2011, including descriptions of the current GWETS operation and environmental investigations and remedial actions conducted by others.

3.1 Regulatory Actions: 1970 to 2011

This subsection provides a chronological summary of the major regulatory actions pertaining to OU-1 and OU-2 prior to inception of the Trust. Some regulatory actions also involve other former and current operators within the BMI Complex.

Initial USEPA, State of Nevada, and Clark County (ENSR 2007b) involvement included examination of potential environmental impacts from operations within the BMI Complex during the 1970s, including the OU-1 area then operated by Kerr-McGee. The agencies' involvement included review of atmospheric emissions, groundwater and surface water discharges, and soil impacts.

In response to the 1972 Clean Water Act, Kerr-McGee and other operators within the BMI Complex modified their manufacturing processes between 1971 and 1976 to end the practice of discharging process wastewater to the Complex's unlined ditches (e.g., Beta Ditch), and thus utilization of the Upper BMI Ponds within the BMI Common Areas. The operators within the BMI Complex instead constructed lined surface impoundments to recycle and evaporate industrial wastewater. This included the addition of lined ponds constructed by TIMET over a portion of the former Upper BMI Ponds.

The Kerr-McGee facility achieved zero-discharge status in 1976 regarding industrial wastewater management and obtained a NPDES permit under the CWA authorizing up to 4 million gallons per day discharge of non-contact cooling water to the Las Vegas Wash in 1977 via the Alpha Ditch (USEPA 1980). In 1980, USEPA requested specific information from companies within the BMI Complex regarding their manufacturing and waste management practices by issuing a CWA Section 308 letter, which allows the USEPA to request information from potential pollutant dischargers.

The 1986 Consent Order (NDEP 1986) between NDEP and Kerr-McGee stipulated additional subsurface characterization and implementation of corrective action to address chromium in groundwater. These actions initiated installation of an on-site extraction well system. The initial set of on-site extraction wells installed following the 1986 Consent Order were gradually expanded into the Site's current Interceptor Well Field (IWF).

The 1991 Consent Agreement (NDEP 1991) between NDEP, Kerr-McGee and five additional companies[33] within the BMI Complex stipulated that each entity conduct an environmental assessment to evaluate 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.

Letters of Understanding (NDEP 1994a,b) issued by NDEP for both Kerr-McGee and the BMI Common Areas identified potential source areas or "items of interest" requiring further investigation. For Kerr-McGee, NDEP identified 69 LOUs (LOU-1 through LOU-69) and specified the level of environmental investigation to be conducted at each location (NDEP 1994b). Of these LOUs, it was determined that 20 did not require further action at that time (NDEP 1994b) and two items originally associated with Kerr-McGee were added to the Common Areas investigation (ENSR 1997). Subsequent to the identification of the LOUs, an additional potential source area within OU-1, the former US Vanadium site, was identified during planning for the Phase B 2008 investigation (NDEP 2011c). Although not formally designated as a LOU, the US Vanadium site is commonly referred to as LOU-70. A detailed discussion of the specific areas or items of interest identified in the OU-1 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 1996 Consent Agreement (NDEP 1996a-c) between NDEP and Kerr-McGee required the completion of a Phase II Environmental Conditions Assessment, as well as a RAS, interim measures, or other additional work (NDEP 1996d). Other parties at the BMI Complex[34] entered into separate Consent Agreements with NDEP in 1996 that included similar requirements.

The 1999 Consent Agreement (***NDEP 1999a)*** between NDEP and Kerr-McGee defined initial perchlorate removal actions, including development of a seep water collection system and temporary ion exchange (IX) treatment process for perchlorate removal near the Las Vegas Wash.

NDEP granted No Further Action (ERM 1997; NDEP 1999b,c) status in 1999 to certain non-impacted areas of the BMI Common Areas located outside of historical operations areas following preparation of an Environmental Characterization Report. These areas, many of which are within OU-2, are known as the Exclusion Areas.

---

[33] Chemstar, Montrose, Pioneer, Stauffer, and TIMET were the other parties in the 1991 Consent Agreement with NDEP. Together these parties made up the Henderson Industrial Site Steering Committee (HISSC), which is sometimes referenced in reports and documents.

[34] Montrose (NDEP 1996a), Pioneer and Stauffer (NDEP 1996b), and TIMET (NDEP 1996c) also entered into separate Consent Agreements with NDEP in 1996.

A Liability Transfer and Assumption Agreement (NDEP 1999d) was established by NDEP, Basic Management, and the other companies within the BMI Complex in late 1999. The agreement assigned primary responsibility for the cleanup and remediation of certain identified soils in the BMI Common Areas within OU-2 to BRC.

The 2001 Administrative Order on Consent (NDEP 2001a) defined additional removal actions within present-day OU-1, including the construction of a low-permeability barrier wall located downgradient of the on-site IWF, the construction of the AWF located near the boundary between OU-2 and OU-3, the construction of the Seep Well Field (SWF) located within OU-3 near the Las Vegas Wash, and the design and installation of a treatment process to remove chromium and perchlorate from the collected water prior to discharge under a NPDES permit.

A Record of Decision (NDEP 2001b) was issued in 2001 for soils within portions of the BMI Common Areas and certain other areas of OU-2 and OU-3 (Upper Ponds, Lower Ponds, Alpha Ditch, Beta Ditch, Western Ditch and Northwestern Ditch) based on the alternatives described within an earlier RAS, which was submitted by BRC in 2000. The alternative approved by NDEP required encapsulation of excavated soil within a dedicated landfill referred to as the CAMU. BRC sought a cleanup standard that would allow future residential use within large portions of the BMI Common Areas within OU-2.

The 2005 Administrative Order on Consent (NDEP 2005) between NDEP and Kerr-McGee established a compliance schedule for treatment of the perchlorate residuals within the AP-5 Pond in an effort to reduce the amount of perchlorate in groundwater and surface water reaching the Las Vegas Wash and Lake Mead.

The Settlement Agreement and Administrative Order on Consent, Phase 3 (AOC3) (NDEP 2006) between NDEP, BRC and other companies within the BMI Complex (including Tronox) was executed in 2006 for the BMI Common Areas. The AOC3 defined a framework for BRC's characterization and remediation of soil and groundwater impacts and defined steps by which the remedial actions should be performed.

NDEP issued a Finding of Alleged Violation and Order (NDEP 2009b) on December 14, 2009 (the "2009 Division Order"), requiring Tronox (which took ownership of the facility in 2006) to comply with obligations under the various Consent Agreements previously issued for the Site, setting forth a specified schedule for compliance. The 2009 Division Order directed Tronox to remove all soil containing COPCs in excess of soil remediation goals (SRGs) in order to reduce the human health risks associated with contaminated soil.

Regulatory activities undertaken since the Trust took ownership of the Site on February 14, 2011 are discussed in Section 3.3.1.

3.2 Environmental Investigations and Remedial Actions: 1970 to 2011

This subsection provides a chronological overview of significant investigations and remedial actions pertaining to OU-1 and OU-2 prior to inception of the Trust. This section is not intended to present comprehensive and detailed results of each and every investigation or action. Rather, the section provides an overview of relevant historical investigation and other significant remedial actions taken. Specific results of previous investigations, which are relevant to the evaluation of current conditions within OU-1 and OU-2, are included in Sections 7 and 8.

In response to Federal RCRA standards, Kerr-McGee initiated a groundwater investigation in 1981 for monitoring two existing on-site surface impoundments (Ponds S-1 and P-1) (Kerr-McGee 1984).

Investigation of hexavalent chromium impacts to groundwater beneath what is now OU-1 was requested by NDEP in December 1983. Forty groundwater monitoring wells were installed, and Kerr-McGee submitted a hydrogeological investigation report to NDEP in July 1985 delineating a chromium plume within the "near surface groundwater" (Kerr-McGee 1985).

Operation of OSSM's GWETS began in December 1983 following a Consent Order between NDEP, Stauffer, and Montrose in April 1983 (NDEP 1983). The location of OSSM's GWETS is shown in Figure 3-1, which also shows the location of all current extraction wells. At startup, the OSSM GWETS treated groundwater extracted from ten wells for VOCs using an air stripper (NDEP 1983; Stauffer 1984). Treated groundwater was then discharged via a series of recharge trenches located approximately 500 feet downgradient of the extraction wells.

Initial remediation of hexavalent chromium in groundwater beneath present-day OU-1 began in mid-1987 when extraction wells (the original "interceptor" wells) were installed downgradient of historic manufacturing operations. These interceptor wells, which continue to operate today, later became part of what is now referred to as the IWF, the development of which is further discussed below (with current operations described in Section 3.3.3). The extracted water was pumped to a chromium treatment facility (referred to as the GWTP)[35] where hexavalent chromium was reduced to trivalent chromium that was then precipitated and removed. Treated water was subsequently reinjected via recharge trenches located downgradient of the IWF. Performance Reports for the Chromium Mitigation Program were issued quarterly beginning in 1987 (Kerr-McGee 1987) until reporting was changed to a semi-annual schedule in 1990.

An Environmental Conditions Assessment for Kerr-McGee (Kleinfelder 1993) was submitted to NDEP in April 1993 in compliance with the 1991 Consent Agreement. The purpose of the report was to identify and document site-specific environmental impacts resulting from past or present industrial activities. The Environmental Conditions Assessment included an 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 activities associated with historical operations may have impacted the environment.

An Environmental Conditions Assessment for the BMI Common Areas (Geraghty & Miller 1993) was completed in 1993 by the HISSC, made up of BMI Complex operators. As with the report prepared by Kerr-McGee the same year, the purpose of the document was to

---

[35] By convention, the "GWTP" consists of only the on-site hexavalent chromium treatment plant. The name pre-dates the installation of any of the perchlorate treatment systems and related components.

identify and document site-specific environmental impacts resulting from past or present industrial activities.

Environmental Conditions Assessments for the OSSM site were completed in 1993, prepared by Montrose, Pioneer, and Stauffer pursuant to consent decrees entered in 1991. Subsequently, Phase II consent decrees were established in 1996 to perform environmental conditions investigations, which have been ongoing. In 2008, the OSSM Companies prepared a CSM for the combined site (Hargis 2008).

The Phase II Environmental Conditions Investigation for Kerr-McGee (ENSR 1997) investigated 11 LOUs (of the 70 originally identified as part of NDEP's 1994 Letters of Understanding and subsequent correspondence; NDEP 1994a,b, 2011c) that NDEP had identified as requiring additional soil and groundwater characterization following the 1996 Consent Agreement (Kerr-McGee 1996a). The 11 LOUs included the Trade Effluent settling ponds (LOU 1 and 2), Old P-2 and Old P-3 Ponds (LOU 7 and 8), Truck Unloading Area (LOU 35), Diesel Fuel Storage Tank (LOU 45), AP Plant Area Change House/Lab Septic Tank (LOU 54), J.B. Kelley Trucking Site (LOU 63), AP Satellite Accumulation Point/AP Maintenance Shop (LOU 39), the Unit 1 Building Tenant Stains (LOU 41), AP-1, AP-2 and AP-3 Ponds (LOUs 16 and 17), and Hardesty Chemical (LOU 4).

A Phase II Environmental Conditions Investigation for the BMI Common Areas (ERM 1996) was completed in 1996 and addressed LOUs within the BMI Common Areas identified for soil and groundwater characterization as part of the 1996 Consent Agreement.

Perchlorate contamination in the Las Vegas Wash was discovered in late 1997. This finding followed a period of increased governmental and regulatory concern regarding the potential health hazards of perchlorate. The Kerr-McGee and AMPAC facilities were subsequently found to be the source of perchlorate contamination within Las Vegas Wash (NDEP 2011c). AMPAC's operations are discussed in Section 2.2.5. Kerr-McGee undertook an initial perchlorate characterization study, in conjunction with AMPAC, to determine subsurface pathways and perchlorate concentrations in shallow groundwater downgradient from OU-1 to its discharge in the Las Vegas Wash (Kerr-McGee 1998). Between March and June 1998, soil borings and monitoring wells were installed within OU-2 and the subsurface data was mapped and analyzed.

The Phase II Groundwater Investigation Report (Kerr-McGee 1998) presented initial investigation results of the groundwater perchlorate investigation undertaken by Kerr-McGee and AMPAC. The groundwater investigation indicated that perchlorate was generally confined to a Quaternary-age alluvial channel, referred to as a paleochannel, eroded into the underlying sediments. Subsurface mapping demonstrated that the deepest and best-defined section of the paleochannel was present in the area beneath Athens Road (now Galleria Drive) near the boundary between OU-2 and OU-3. As described in the report, the north-trending perchlorate plume was displaced eastward from the main paleochannel just north of OU-1 (within OU-2) by a high TDS plume, originating from the former Stauffer/Montrose property, that converges from the west and preferentially occupies the western part of the channel. The perchlorate plume eventually began to merge and mix with the higher TDS plume at, and downgradient from, the Pittman Lateral (an east-west trending pipeline conveying water from Lake Mead to municipal treatment plants for use as drinking water, located near the boundary of OU-2 and OU-3). The Phase II investigation results provided the basis for installation of the first extraction well located outside the boundaries of OU-1. The well was installed adjacent to Athens Road in September 1998, in the area that would later become the site of the AWF.

Additional IWF wells were installed to increase capture of on-site groundwater for the removal of hexavalent chromium within OU-1 during 1998 and 1999 (ENSR 2005). These IWF wells, in combination with the IWF 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 a lined pond (GW-11, constructed in late 1998) and held until a perchlorate treatment system was constructed (NDEP 2011c). Stabilized Lake Mead water was instead injected into shallow groundwater via the recharge trenches until the removal of a portion of the trenches as part of the 2010-2011 Soil Removal Action.

A perchlorate-impacted surface seep was discovered by hydrologists with the Southern Nevada Water Authority (SNWA) in early 1999. This Seep Area discharging into the Las Vegas Wash (within OU-3) was aligned with a buried alluvial paleochannel. At the time of discovery, the seep was flowing at about 400 gallons per minute (gpm) and contained over 100 milligrams per liter (mg/L) of perchlorate (ENSR 2005).

A seep water collection system and temporary IX treatment system for perchlorate removal was installed near the Las Vegas Wash and began operating as a result of a 1999 Consent Agreement between Kerr-McGee and NDEP which defined initial removal actions (NDEP 1999a). A temporary IX system near the Las Vegas Wash operated from late 1999 until 2004 (ENSR 2005).

As part of implementation of the ROD within the BMI Common Areas, investigation of soil and groundwater, as well as significant soil excavation, was performed and a large amount of data characterizing impacts to soil and groundwater was collected in the Eastside Sub-Area of present day OU-2. Most investigations were conducted between 1996 and 2007 and included a wide variety of contaminants (e.g., perchlorate, chlorate, asbestos, metals, pesticides/PCBs, SVOCs, VOCs, and radionuclides) (BRC 2007).

The Seep Area Groundwater Characterization Report (Kerr-McGee 2001) was issued following another phase of off-site monitoring well installation, sampling, and groundwater characterization between March and September 2000. The report was based on a cooperative regional groundwater sampling event jointly performed by Kerr-McGee and AMPAC. The report documented that groundwater was traveling at an average of 35 feet per day (ft/day) between Athens Road (now Galleria Drive) and the Seep Area (shown in the Seep Well Field insert in Figure 3-2), that the bulk of perchlorate was entering the Las Vegas Wash in the area of the Lower BMI Ponds and Seep Area, and that the entire saturated thickness of the alluvial channel contained perchlorate at varying concentrations.

A low-permeability barrier wall and additional downgradient well fields were constructed in response to the 2001 Administrative Order on Consent between NDEP and Kerr-McGee. Kerr-McGee completed construction of a groundwater barrier wall along the downgradient side of the IWF and installed additional groundwater extraction wells to complete the AWF and SWF. Between approximately 2002 and 2004, Kerr-McGee installed an on-site IX system, located adjacent to the current Equalization Area on the east side of the GW-11 pond, designed to treat perchlorate (ENSR 2005). However, numerous operational issues associated with the newly-installed IX system led to Kerr-McGee abandoning this treatment process in favor of a biological FBR treatment system, installed in 2004. Operation of the FBR perchlorate treatment system continues today, as described in Section 3.3.3.

Quarterly perchlorate performance reports were issued by Kerr-McGee beginning in at least 2003 until 2007, in addition to the quarterly chromium mitigation reports issued since the late 1980s (Kerr-McGee 2003).

A Supplemental Phase II Environmental Conditions Assessment (ENSR 2001) was conducted between 1999 and 2001 consistent with the 1996 Consent Agreement between Kerr-McGee and NDEP. NDEP's response to the report recommended completion of a CSM (NDEP 2004).

The 2005 Conceptual Site Model report (ENSR 2005) integrated information from soil and groundwater investigations conducted within OU-1 from the early 1970s through 2005 to document information on Site-specific sources, release mechanisms, transport pathways, exposure routes, and potential receptors. The 2005 CSM was the first comprehensive effort to examine fate and transport of contaminants, as well as how various historical operations contributed to the presence and distribution of contaminants. The 2005 CSM identified several data gaps related to soil and groundwater characterization, including:

- Identification of background concentrations of metals and other naturally occurring COPCs in the local area;
- Configuration of the Upper Muddy Creek Formation (UMCf), which is one of the geologic formations underlying the NERT RI Study Area and is further discussed in Section 5;
- Identification of COPCs (in addition to perchlorate and hexavalent chromium);
- Further evaluation of the nature and extent of contamination source areas within OU-1;
- Evaluation of historic data for usability for risk assessment purposes; and
- Preparation of a risk assessment to evaluate risks posed to human and ecological receptors.

AMPAC's in-situ bioremediation (ISB) groundwater remediation system began treatment of perchlorate in shallow groundwater on June 19, 2006 (AMPAC 2007). The ISB system included extraction wells, re-injection wells, an ISB water processing plant, and associated storage tanks, pipes, and conduits. The original system operated as an ISB plant from 2006 to 2012 and was expanded to include an ex-situ FBR in 2012 (AMPAC 2012).

As part of the Upgradient Groundwater Investigation (ENSR 2007c), soil borings were drilled at six locations in the southern (upgradient) portion of OU-1 in March 2006. The samples were analyzed for perchlorate, metals (including hexavalent chromium), VOCs (including fuel oxygenates), total petroleum hydrocarbons (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 (ENSR 2007c). Two sets of groundwater samples were collected from nine wells (four new wells and six existing wells), the first using bailers and the second using micro-purge sampling pumps.

The chromium and perchlorate mitigation reports, which had previously been issued as separate quarterly reports by Kerr-McGee, were issued jointly on a semi-annual basis beginning in 2007 (ENSR/AECOM 2007). Reports tracking chromium and perchlorate mitigation continue to be produced semi-annually by the Trust as the Annual Groundwater Monitoring and GWETS Performance Report, which includes twelve months of data, and the Semi-Annual Groundwater Monitoring and GWETS Performance Memorandum, which includes six months of data (e.g., Ramboll 2022a,e).

A Closure Plan was prepared for the BMI Common Areas (BRC 2007) in response to AOC3, which described risk-assessment and risk-based decision making as it relates to remediation, future land use, and NFA determinations.

TIMET's CSM and RAS Reports were first submitted to NDEP in 2007 and 2008, respectively (TIMET 2007, 2008). The RAS recommended hydraulic control along the northern boundary of the TIMET site. Upon review of TIMET's RAS, NDEP issued a ROD in 2009 which required the installation of a slurry wall and a groundwater extraction and treatment system as the selected remedy. TIMET's GWETS began operating in March 2014, as discussed below in Section 3.3.4.1.

The Phase A investigation, which was conducted in 2007 within what is now OU-1, assessed soil conditions associated with the 192 site related chemicals (SRCs) identified in the 2005 CSM report and their suspected source areas, in order to identify and characterize the distribution of SRCs in soils (ENSR 2007a, 2006). Soil samples were collected from multiple depths at 27 suspected source area locations in November/December of 2006 (ENSR 2007b). The sample locations were selected based on results from past investigations, information on previous chemical use within OU-1, 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 (ENSR 2007b).

During the Phase A investigation, soil samples were collected at depths of 0.5 to 1 feet, and at 10-foot intervals thereafter, until groundwater was encountered (ENSR 2007b). The samples were analyzed for metals, VOCs (including fuel oxygenates), SVOCs, PCBs, dioxins and furans, TPH as gasoline, diesel, and oil range organics (GRO, DRO, and ORO, respectively), 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 a manganese ore and tailings stockpile located north of the Leach Plant 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.

In conjunction with the soil samples collected during the Phase A, one-time grab 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 within what is now OU-1 and (2) characterize groundwater chemistry upgradient and downgradient within what is now OU-1 (ENSR 2006). Groundwater samples were collected from 20 shallow groundwater monitoring wells and one groundwater interceptor well (well I-AR), and groundwater grab samples were collected from open boreholes at six 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 2007b).

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 to evaluate potential analytical bias in the results reported for metals and radionuclides for the November/December 2006 sampling (ENSR 2007a). During 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 pumping 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 2007a). Based on an evaluation of the results, the NDEP-approved Phase A investigation report (ENSR 2007b) identified which analytical results are appropriate for evaluation of metals and radionuclides in groundwater:

- 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 2007b).

The Phase B investigation, which was conducted between 2008 and 2009 within OU-1, was designed to further characterize and evaluate the LOUs and their potential impact on soil conditions across what is now OU-1, based on the results of the Phase A investigation. For the Phase B investigation, the Site was subdivided into four investigation areas: Areas I, II, III, and IV. Separate work plans describing the Area-specific scopes of work were prepared as follows: Area I Work Plan (ENSR 2008b); Area II Work Plan (ENSR 2008c); Area III Work Plan (ENSR 2008e); and Area IV Work Plan (ENSR 2008d). In addition, a revised investigation work plan was prepared that was applicable to all four Areas (AECOM 2008).

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 feet between each vertical sample (AECOM 2008). Judgmental samples were collected at 0.5 and 10 ft bgs in locations where certain surface features were noted, including minor stains or above ground pipelines. 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 and 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. Samples for wet chemistry and geotechnical parameters were also collected (Northgate 2010a, 2010b, 2010c, 2010e).

In late 2009, supplemental sampling of shallow soils was conducted in accordance with two memoranda, Scope for Additional Sampling of Area I and Area II (Northgate 2009a, 2009b). A total of 129 additional 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 feet of soil with concentrations in excess of worker BCLs or modified risk-based goals (as agreed upon by NDEP), which are collectively referred to as SRGs. These constituents included metals, SVOCs (including hexachlorobenzene), PCBs, OCPs, dioxin toxic equivalents (TEQs), asbestos, and perchlorate.

Fourteen new on-site monitoring wells were installed during the Phase B investigation and an extensive focused sampling program was conducted. As described above, 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 (ENSR 2008b-e). The locations of the new monitoring wells were selected to allow for further delineation of SRCs detected in Phase A investigation grab samples (ENSR 2007b).

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 quality control sample analyses (Northgate 2010d).

The Phase B soil gas investigation was conducted in May 2008 to evaluate the nature and extent of VOCs in soil gas in potential source areas. Details of the soil gas sampling are provided in the Phase B Source Area Investigation Soil Gas Survey Work Plan (the "Soil Gas Work Plan"; ENSR 2008a) and summarized in the draft Site-wide Soil Gas Health Risk

Assessment (the "Draft Soil Gas HRA";[36] Northgate 2010j). Soil gas sample locations were based on the following: (1) results of the Phase A investigation (ENSR 2007b), which identified the presence of several VOCs in soil and/or groundwater samples collected within OU-1, (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). This report also identifies the OSSM site as a potential source of trespassing contaminants including VOCs, non-aqueous phase liquid (NAPL), and other contaminants. Historical operations at the OSSM site are discussed in Section 2.2.1.

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 2008a):

- Former Hardesty 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)
- The Unit 4 Building 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 site, including impoundments and catch basin (LOU 62)
- SNAP site (LOU 68)

A total of 95 soil gas samples were collected throughout OU-1 and the southern portion of OU-2.[37] Samples were collected at 5 ft bgs, with the exception of four samples collected in the vicinity of the Unit 3, 5, and 6 Buildings at 20 ft bgs (SG-36, SG-37, SG-38, and SG-41) (Northgate 2010j). In a July 18, 2007 conference call (NDEP 2007), NDEP and Tronox agreed that deeper soil gas samples would be collected from areas with higher chemical concentrations in groundwater, as well as from less impacted areas. Further, as specified in NDEP's March 26, 2008 approval (NDEP 2008a) of the Soil Gas Work Plan (ENSR 2008a), NDEP stated that samples in the vicinity of the Unit 3 Building should be collected below the depth of the Unit 3 Building basement, which was occupied with engineering staff (Northgate

---

[36] The Draft Soil Gas HRA was submitted in 2010, but not approved by NDEP since upon establishment of NERT in February 2011, it was recognized that NERT would be performing health risk assessments as part of the RI being planned at the time.

[37] Of the 95 soil gas samples collected as part of the Phase B soil gas investigation, there were 15 samples collected within what is now OU-2 (the former Sale Parcels north of Warm Springs Road, which are shown in Figure 2-8).

2010j). Based on these discussions, 20-ft bgs samples were collected as follows: SG-41, near the Unit 3 Building; SG-36, near an area of high chloroform concentrations in groundwater (ENSR 2008a); and SG-37 and SG-38, near areas with relatively low chloroform concentrations in groundwater (ENSR 2008a).

Results of the investigation indicated that chloroform, TCE, chlorobenzene, carbon tetrachloride, and trichlorofluoromethane were detected at elevated concentrations in soil gas beneath OU-1. Elevated concentrations of VOCs in soil gas appeared to be localized within specific areas, such as the western OU-1 boundary, the Unit 4 Building, 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 Data Validation Summary Report (ENSR 2008g) that was submitted to NDEP on October 13, 2008. No actions with respect to soil gas were required by NDEP following this investigation or submittal of the Draft Soil HRA, but soil gas has been further investigated as part of the RI, as discussed in Section 7 and 8.

An evaluation of indoor air was conducted at the operating Tronox facility in 2010 to assess the potential uncertainty associated with use of vapor intrusion models in the Draft Soil Gas HRA (Northgate 2010j). The first round of indoor and outdoor air samples was collected at several locations throughout the facility in June 2010. The sampling results were presented in the Spring 2010 Indoor Air Quality Sampling and Analysis Report (Northgate 2010i). A second round of indoor and outdoor air sampling was performed in December 2010. The objectives of the additional round of sampling were 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 2011). Both sampling and analysis reports were approved by NDEP.

A total of 32 indoor and 18 outdoor air samples were collected at the Tronox facility and 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 air sample. TCE was detected in approximately 80% of the samples. Although the detection limits for several of the indoor and outdoor samples were elevated, the excess cancer risk due to vapor intrusion of the three target analytes at the Tronox facility was estimated to be below 10^{-5} (Northgate 2011).

Capture zone evaluations of the GWETS were performed at the three extraction well fields associated with the NERT Site from 2008 to 2010. Supporting field work performed in early 2008 included well installation, geotechnical sampling, and well testing. A capture zone evaluation was submitted as Appendix B of the 2008 Annual Remedial Performance Report (ENSR 2008f). In response to NDEP comments, eight deeper UMCf monitoring wells were installed in September and October 2009 to evaluate the vertical extent of contaminant plumes and vertical hydraulic head differences. The data collected from the new wells was incorporated into an interim capture zone evaluation of the IWF and the AWF (Northgate 2010f). Several new extraction wells designed to address specific capture gaps (wells I-AA, I-AB, I-AC, I-AD, I-W, I-X, and I-Y) were installed by Tronox between late 2007 and mid-2010 as a result of the Interim Groundwater Capture Zone Evaluation and Vertical Delineation Report (Northgate 2010a) and the 2010 Capture Zone Evaluation (Northgate 2010k). However, these wells were not activated until 2014 as part of the 2013 GWETS Optimization Project (ENVIRON 2015), which is discussed in Section 3.3.2.

As proposed in the Capture Zone Evaluation Work Plan prepared by Northgate (2010g), an additional 41 new monitoring and recovery wells and eight replacement monitoring wells were installed at the IWF and AWF during April-July 2010. Based on the new data and in response to NDEP comments, the Capture Zone Evaluation Report provided an evaluation of the capture zones of all three well fields (Northgate 2010k). In Appendix E of the report, Northgate described a numerical groundwater flow model that was developed for use in evaluating capture zones. Although the report itself has not been approved by NDEP,[38] this initial groundwater model was approved by NDEP on April 4, 2013 for use in the capture zone evaluation.

A Removal Action Work Plan for Phase B Soil Remediation of Remediation Zones RZ-B through RZ-E (Northgate 2010h) was prepared in May 2010, which included a strategy for excavating accessible impacted soil within the upper 10-ft bgs horizon in contaminated portions of OU-1.

Manganese tailings were removed from the MTP area within OU-1 in 2010, located south of the Mn-1 pond in the current location of the Mn-2 pond, which was constructed in 2013 (Figures 1-4 and 2-6). The MTP area covered approximately 8.6 acres and contained manganese tailings generated by the Leach Plant process between approximately 1975 and 2004. The excavation work was conducted in two separate mobilizations. First, 280,572 cubic yards of manganese tailings were removed, then an additional 3,660 cubic yards of soil was removed in response to confirmation samples that were found to contain elevated levels of manganese, cobalt, arsenic, and/or asbestos. Material generated during the excavation activities described above was considered non-hazardous and was transported to the Apex Landfill for disposal. The MTP removal effort is described in detail in the Manganese Tailings Pile Removal Technical Memorandum (Northgate 2013).

Soil removal action was conducted within OU-1 in 2010 and 2011 based on the results of the Phase A and B investigations, which had identified areas with contaminants in excess of SRGs. The soil removal action program was implemented by Tronox from August 2010 to February 13, 2011. The action was subsequently implemented by the Trust, beginning on February 14, 2011 through project completion in November 2011. The soil removal action is described in detail in the 2012 Soil Removal Action Completion Report (ENVIRON 2012a).

Soil removal within OU-1 occurred within four different Remediation Zones (RZs; RZ-B through RZ-E) that were found to have COPCs above SRGs.[39] Each RZ was divided into

---

[38] The Capture Zone Evaluation Report was submitted in 2010, but not approved by NDEP since upon establishment of NERT in February 2011, it was recognized that NERT would be evaluating well field capture as part of the ongoing remedial performance monitoring program and the RI being planned at the time.

[39] The results of the HHRA for Remediation Zone A (Northgate 2010d, 2010e) indicate that exposures to residual chemicals in the upper 10 feet of soil in RZ-A did not result in unacceptable risks for all future on-site receptors.

polygons and the horizontal and vertical extent of the remediation polygons were defined based on soil sampling analytical results from the Phase A and B sampling programs and additional pre-confirmation sampling conducted in Spring 2010. The locations, shape, and depth of removal polygon excavation areas are shown in Figure 3-3. The general remediation strategy consisted of excavation of soils within designated remediation polygons, sampling of discolored soil, and removal of discolored soil if above SRGs or otherwise deemed appropriate to remove. The injection of stabilized Lake Mead water at the recharge trenches located downgradient of the barrier wall was discontinued to accommodate the soil excavation and removal activities (ENVIRON 2012a).

The remediation polygons were generally excavated to the designed horizontal and vertical extent. However, some remediation polygons were not excavated to their designed extent due to physical obstructions and/or inaccessible areas. These obstructions generally included subgrade and aboveground utilities, facility buildings, and roadways, parking lots, and other paved areas. These areas were designated as excavation control areas (ECAs) due to the remediation polygon soil being left in place (Figure 3-4). The ECA soils are managed in accordance with the NERT Site's SMP, which is currently SMP, Revision 8 (Ramboll 2023a). Remediation polygon soils were excavated, and an estimated 567,770 cubic yards of contaminated soil was removed from OU-1 and disposed at the Apex Landfill in Clark County, Nevada during this removal action (ENVIRON 2012a).

Remediation activities were conducted within the BMI Common Areas by BRC between 2007 and 2015.[40] BCLs were used as screening levels to guide remedial excavations; excavations were expanded laterally and vertically in an iterative manner depending on confirmation sample results. Final confirmation sample results were then used to conduct human health risk assessments (HHRAs). The HHRAs included comprehensive evaluation of residential and commercial/industrial exposure pathways, depending on planned future use, related to shallow soil (less than 10 ft bgs). Except for localized areas where BCL exceedances led to excavation of soil from depths greater than 10 feet, groundwater and soil deeper than 10 feet were not addressed as part of the remediation effort. All areas within the AOC3 boundary, with the exception of areas occupied by the COH WRF and the CAMU, have received NFAs from NDEP between 2011 and 2015 (NDEP 2015b-g, 2013a-d, 2011b,c) for the upper 10 feet of soil (Figure 3-5).

3.3 Activities Conducted from 2011 to 2022

While previous sections provided a historical context for regulatory and remedial actions pertaining to OU-1 and OU-2 or the BMI Complex, regulatory actions subsequent to the inception of the Trust that shaped development of the NERT RI Study Area and establishment of the OUs are described in Section 3.3.1. Investigations and actions conducted by the Trust prior to the completion of this RI Report are described in Section 3.3.2, and descriptions of NERT's current GWETS operations are provided in Section 3.3.3.

The results of the data quality assessment indicate that a sufficient number of samples were collected in RZ-A to support the conclusions of the health risk assessment. Therefore, excavation activities were not conducted in this area.

[40] Remedial activities conducted by BRC in the BMI Common Areas extend beyond 2015 (and some activities, such as NFA determinations for certain parcels and monitoring activities related to the CAMU, are currently ongoing); however, these activities are included in this section for continuity.

Finally, investigations and actions conducted by others in proximity to the NERT Site are described in Section 3.3.4. The various phases of the RI, which have been conducted by the Trust, are described in detail in Section 6, with results of the RI investigation in OU-1 and OU-2 discussed in Sections 7 and 8, respectively.

3.3.1 Regulatory Activities Under NERT

The Trust was established on February 14, 2011, in conjunction with the settlement of Tronox's bankruptcy proceedings, as provided in the Settlement Agreement.[41] The Settlement Agreement defines the purpose and function of the Trust which includes, but is not limited to: "(i) own the (NERT Site) for purposes of implementing the Settlement Agreement, (ii) carry out administrative and property management functions related to the (NERT Site), and (iii) manage and/or fund implementation of Environmental Actions for Henderson Legacy Conditions (as defined in the Settlement Agreement) as approved by NDEP." The Interim Consent Agreement (NDEP 2011a) between the Trust and NDEP, effective February 14, 2011, set forth specific requirements for the Trust to investigate and remediate contamination associated with historical operations, including the requirement to perform an RI/FS.

Initiation of the RI began as required by the Interim Consent Agreement in 2011 (NDEP 2011a). The NERT RI Study Area currently consists of four separate study areas (one of which includes two sub-areas) that were established at various points in time between 2012 and 2016 (Figure 1-2). The first two study areas were the NERT Site Study Area (the area now referred to as OU-1) and NERT Off-Site Study Area (now part of OU-2 and OU-3), which were initially designated in 2012 (Figure 1-2) during preparation of the Remedial Investigation and Feasibility Study Work Plan (ENVIRON 2012b).[42] The Downgradient Study Area was designated by NDEP in 2015, as first presented in AECOM's Groundwater Sampling Plan for the Downgradient Study Area (AECOM 2016a). The Eastside Sub-Area of the Eastside Study Area was formally established by the Phase 3 RI Work Plan (Ramboll Environ 2017m) after NDEP directed the Trust to expand the RI Study Area in 2016 to include perchlorate and chlorate in the BMI Common Areas (NDEP 2016c). The Northeast Sub-Area was established in 2017 as part of the Phase 3 RI Work Plan (Ramboll Environ 2017m) to investigate perchlorate and chlorate in groundwater within this sub-area.

The NERT RI Study Area was divided into three OUs (Figure 1-2) for the purposes of optimizing and accelerating investigation and determination of future remedial action. The OUs were established in the Phase 3 RI Work Plan (Ramboll Environ 2017m). OU-1 consists of the NERT Site, as well as former Sale Parcels C, D, and H. OU-2 comprises the southern portion of the NERT Off-Site Study Area and the Eastside Sub-Area. OU-3 encompasses the Downgradient Study Area, the Northeast Sub-Area and the northern portion of the NERT Off-Site Study Area.

---

[41] 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, Docket No. 2812 (Nevada Environmental Response Trust Agreement 2011).

[42] These initial study areas were described in the RI/FS Work Plan as the NERT Site (now the NERT Site Study Area or OU-1) and Downgradient Plume areas.

3.3.2 Environmental Investigation/Remediation Conducted by NERT

A soil removal action, previously discussed in Section 3.2, was implemented by Tronox and managed by Northgate from August 2010 to February 13, 2011, then continued by the Trust and implemented by ENVIRON (following Tronox's bankruptcy) from February 14, 2011, until project completion in November 2011. Activities conducted as part of the soil removal effort are described in Section 3.2, in the Soil Removal Action Completion Report (ENVIRON 2012a) and shown in Figures 3-3 and 3-4.

Related to the 2010-2011 soil removal activities, excavation of a former ECA located at the east end of RZ-E (the former Beta Ditch) was performed by NERT in 2013. During the 2011 removal program, ECAs were established in areas where remediation could not be completed due to access constraints. This included the establishment of an ECA at the east end of RZ-E, where structures and equipment prevented the removal of soil from polygon E-16B and a small portion of polygon E-16A during the 2010-2011 Soil Removal Action (ENVIRON 2012a). These excavation polygons are shown in Figures 3-3 and 3-4. The excavation of these polygons occurred in October 2013 concurrent with TIMET's excavation of a portion of the former Beta Ditch within their adjacent property. Prior to the start of the ECA remediation activities, existing structures and equipment were removed and the perimeter fence was relocated. With the area cleared of obstructions, the remaining polygon soil that was included in the ECA, as well as discolored soil known to be impacted by asbestos, was excavated. When the excavation was completed in October 2013, the ECA area was backfilled and compacted, the perimeter roadway was restored, and the perimeter fence was replaced (ENVIRON 2014b).

Excavation of soil with elevated dioxin concentrations was initiated after a spatial analysis conducted during preparation of the Interim Report: Identification of COPCs and Decision Units for OU-1 Soils (Ramboll Environ 2017o) identified an area with elevated dioxin TEQ concentrations near the southwest corner of the GW-11 pond. The soils with elevated dioxin concentrations were excavated in 2019 following pre-excavation soil sampling designed to further delineate the vertical and lateral extent of elevated dioxin concentrations (Ramboll 2019a, Ramboll 2020a). The excavation polygons are shown in Figures 3-3 and 3-4. Consistent with previous soil removal activities conducted at the Site, the excavation boundary was based on polygons generated during the prior soil removal program, and on polygons generated based on pre-excavation sampling results (Ramboll 2019a). These excavated areas are shown in Figures 3-3 and 3-4. The combined area of the excavation polygons is approximately 0.4 acres. Excavated soil was transported to Republic Services Apex Regional Landfill for disposal as non-hazardous waste. Approximately 2,400 tons of soil were removed. A portion of the excavation within ECA D3 was placed in lined roll-off bins and composite soil samples were collected for chemical analysis of all chemicals of concern associated with ECA D3 (Ramboll 2020a). In addition, a bottom confirmation sample was also collected from the center of the ECA area. After the excavation was completed, the area was backfilled with clean fill and restored based on previous surface topography and features, including a portion of the GW-11 access roadway (Ramboll 2020a).

The GWETS has operated continuously since the Trust took responsibility for its operation in 2011, with the exception of occasional maintenance activities and system downtimes. Veolia Water North America (Veolia), which previously operated the treatment plant for Tronox, served as the Trust's GWETS operator from February 2011 until July 2013.

Envirogen Technologies, Inc. (Envirogen) currently operates and maintains the GWETS on behalf of the Trust. Section 3.3.3 contains additional information about NERT's GWETS.

The activation of extraction wells within the IWF (seven wells; I-AA, I-AB, I-AC, I-AD, I-W, I-X, and I-Y) **and AWF** (two wells; ART-7B and PC-150) occurred in 2014 as part of the 2013 GWETS Optimization Project (ENVIRON 2015). See Figure 3-2 for well locations. These wells had been installed by Tronox between 2007 and mid-2010 as part of the Interim Groundwater Capture Zone Evaluation and Vertical Delineation Report (Northgate 2010a) and the 2010 Capture Zone Evaluation (Northgate 2010c). Subsequent to the activation of these nine extraction wells, the eight AP Area extraction wells, which are located approximately 300 feet south of the IWF just west of the former AP-5 Pond and associated with the AP Area Down and Up Flushing Treatability Study, were permanently integrated into the GWETS and began continuous operation in November 2016, as directed by NDEP (Tetra Tech 2018), and continue to operate.

The Continuous Optimization Program (COP) was initiated by the Trust in January 2015 at the direction of NDEP (NDEP 2015a) to enhance the performance and efficiency of the GWETS, resulting in various GWETS infrastructure optimizations and extraction well field rebalancing. A supplementary IX system located near the SWF was brought online in February 2017 to treat perchlorate in groundwater extracted from a portion of the SWF to reduce the water level in GW-11 and ease long-term management of the pond (Envirogen 2016). Currently, the GW-11 pond is occasionally used as an equalization basin but is primarily used to hold untreated groundwater and well field diversions during GWETS maintenance and effluent quality diversions. The IX system located near the SWF continues to operate and treat water extracted from a portion of the SWF. Following implementation of infrastructure improvements and groundwater extraction modifications, the COP was considered complete.

The NERT RI was implemented in three phases, beginning in 2014. RI field activities pertaining to OU-1 and OU-2 were completed in January 2020, and field activities pertaining to OU-3 were completed in October 2022. The Phase 1 RI is described within the RI/FS Work Plan (ENVIRON 2014c), which included an initial CSM, initial RAOs, and identified data gaps for the portions of the NERT RI Study Area identified as the NERT Site Study Area and NERT Off-Site Study Area (ENVIRON 2014c). The majority of the Phase 1 RI field investigation was conducted between October 2014 to May 2015. The Phase 2 RI is described within the Technical Memorandum: Remedial Investigation Data Evaluation (Ramboll Environ 2016c), which provided the results of the Phase 1 RI field investigation and identified data gaps within the NERT Site Study Area and NERT Off-site Study Area. The majority of the Phase 2 RI field investigation was conducted between February and November 2017, with 15 modifications to the original Work Plan continuing through April 2019. These modifications are further discussed in Section 6. The Phase 3 RI was initiated in 2016 after NDEP directed the Trust to investigate perchlorate and chlorate impacts in the Eastside Sub-Area to evaluate the nature and extent of impacts in the subsurface, particularly in soil and the underlying groundwater due to the migration of COPCs from OU-1. The investigation of the Eastside Sub-Area and Northeast Sub-Area is described in the Phase 3 RI Work Plan (Ramboll Environ 2017m). The initial Phase 3 RI field investigation was conducted between December 2017[43] and November 2018, with 15 modifications to the original Work Plan continuing through October 2022. Three of the 15 Phase 3 RI modifications (Phase 3 RI Modification Nos. 1, 3, and 9) pertained to OU-1 and OU-2; field investigations for these Phase 3 RI modifications conducted within OU-1 and OU-2 were completed between June 2018 and January 2020. Field investigations for Phase 3 RI modifications conducted solely within OU-3 continued through October 2022. These modifications are further discussed in Section 6. Details of the field investigation and technical methodologies used in the RI field program (e.g., procedures for drilling, soil sampling, monitoring well installation, groundwater sampling, soil gas sampling) are described in Appendix A1, as well as survey information for soil borings, wells, and soil gas probes, construction details for monitoring wells, and groundwater elevation data for monitoring wells. The results of the RI investigations performed for OU-1 and OU-2 are discussed in detail in Sections 7 and 8. The results of the OU-3 investigation will be presented in the forthcoming RI Report for OU-3.

The Groundwater Flow and Transport Model began as a steady-state model developed by Northgate for use in a capture zone evaluation (Northgate 2010f). The Northgate model was updated in 2014 and was referred to as the Phase I groundwater model (ENVIRON 2014a). The Phase II groundwater model was prepared in 2014 (ENVIRON 2014f), the Phase III groundwater model was prepared in 2015 (Ramboll Environ 2015b), and the Phase 4 and Phase 5 groundwater models were prepared in 2016 (Ramboll Environ 2016b, 2016d). The Phase 6 groundwater model, which was submitted to NDEP in 2019 and represents groundwater conditions from 2014 to 2018 (Ramboll 2019g), is the most recent iteration of the groundwater models that have been reviewed by NDEP (NDEP 2020a). The Phase 6 model was the first to simulate the fate and transport of perchlorate. The Phase 7 model, currently contemplated to be the final iteration of the model, is anticipated to be submitted in 2024 after completion of the RI Report for OU-3. The Phase 7 model will include data prepared by Desert Research Institute associated with groundwater residence time distributions and remote sensing of evapotranspiration.

Three separate baseline human health risk assessments (BHRAs) have been approved as part of the RI/FS for OU-1 and OU-2. The BHRAs evaluate potential human health risks to on-Site and off-Site populations from exposures to hazardous substances in OU-1 soil, OU-1 soil gas and groundwater, and OU-2 soil gas and groundwater. The methodologies used for the OU-1 soil BHRA are described in the Identification of COPCs and Decision Units for OU-1 Soils, Revision 1 (Ramboll Environ 2017o). The BHRA Report for OU-1 Soils, Revision 2 was submitted to NDEP on May 6, 2022 (Ramboll 2022b) and was approved by NDEP on June 2, 2022. The soil gas and groundwater BHRAs for OU-1 and OU-2 followed the methodologies described in the BHRA Work Plan for OU-1 and OU-2 Soil Gas and Groundwater, Revision 1 (Ramboll 2018n). The BHRA Report for OU-1 Soil Gas and Groundwater, Revision 1 was submitted to NDEP on November 3, 2023 (Ramboll 2023d) and approved by NDEP on January 2, 2024. The BHRA Report for OU-2 Soil Gas and Groundwater, Revision 1 was submitted to NDEP on September 15, 2023 (Ramboll 2023c)

---

[43] Prior to the start of the initial Phase 3 RI, well inspections were performed as part of Phase 3 RI Modification No. 1 beginning in August 2017.

and approved by NDEP on November 27, 2023.[44] Section 10 provides additional details regarding the BHRAs. A separate BHRA will be conducted for OU-3 as part of the ongoing RI/FS for OU-3.

Two separate screening level ecological risk assessments (SLERAs) have been submitted to NDEP as part of the RI/FS for OU-1 and OU-2. The SLERAs evaluate whether chemicals released during historical manufacturing activities in and around OU-1 have the potential to pose unacceptable risks to ecological resources within OU-1 and OU-2. The SLERAs were performed according to the Refined SLERA Work Plan for OU-1, Revision 2 (Ramboll Environ 2015a) and the SLERA Work Plan for OU-2, Revision 1 (Ramboll 2018i). The Refined SLERA Report for OU-1, Revision 2 was submitted to NDEP on December 18, 2023 (Ramboll 2023e) and approved by NDEP on February 1, 2024. The Refined SLERA Report for OU-2, Revision 2 was submitted to NDEP on December 20, 2023 (Ramboll 2023f) and approved by NDEP on February 1, 2024. Section 10 provides additional details regarding the SLERAs. A separate ecological risk assessment will be conducted for OU-3 as part of the ongoing RI/FS for OU-3.

A barrier wall integrity evaluation was conducted between 2017 and 2019 to identify and characterize locations that may be providing preferential pathways for groundwater to flow through, around, and underneath the on-site bentonite-slurry groundwater barrier wall located approximately 50-feet downgradient of the IWF (Ramboll Environ 2017i). The barrier wall was constructed with the dual purpose of increasing capture of perchlorate-contaminated groundwater by the IWF and providing source control by hydraulically limiting the movement of groundwater downgradient. The location of the barrier wall is shown in Figure 3-2. The evaluation mapped the barrier wall with geophysics, verified select wall locations using excavation, and used cone penetration tests (CPTs) and tracer testing to explore the physical integrity of the wall. The barrier wall integrity evaluation has provided additional geophysical, hydraulic, in-situ physical, and in-situ tracer test evidence that the wall is not compromised and that it is functioning as designed (Ramboll 2019f). NDEP approved this report on December 23, 2019 (NDEP 2019). Additional containment options to supplement the barrier wall will be considered in the FS.

An evaluation of perchlorate capture and matrix diffusion at the AWF was conducted between 2017 and 2019 to investigate potential causes of persistently elevated perchlorate concentrations in shallow wells located downgradient of the AWF (within OU-3). The study was prepared in response to NDEP comments on the 2015 and 2016 Annual Remedial Performance Reports (NDEP 2015i, 2016d). As described in the work plan (Ramboll Environ

---

[44] In a letter dated September 8, 2021, NDEP directed the Trust to complete a targeted indoor air investigation in the Pittman neighborhood to confirm the results of the vapor intrusion modeling presented in the BHRA Report for OU-2 Soil Gas and Groundwater and "to confirm that chloroform indoor air levels remain below long-term health-based thresholds". As such, NERT implemented a targeted indoor air investigation between March and May 2022, in accordance with the NDEP-approved BHRA Work Plan for OU-1 and OU-2 Soil Gas and Groundwater Modification No. 1 (Ramboll 2021j), and submitted a Technical Memorandum summarizing the results of the data collected on August 29, 2022 (Ramboll 2022f). The data demonstrated the validity of the modeled results as presented in the BHRA Report for OU-2 Soil Gas and Groundwater and that the human health risks due to vapor intrusion associated with the groundwater plume in the Pittman Neighborhood are within the NDEP and USEPA risk range of 10^{-6} to 10^{-4}. On October 13, 2022, NDEP provided comments on both the BHRA Report for OU-2 Soil Gas and Groundwater and the Technical Memorandum. Comments on the Technical Memorandum were incorporated into Revision 1 of the BHRA Report for OU-2 Soil Gas and Groundwater.

2017j), two potential causes for the elevated concentrations were evaluated in the study: (1) incomplete capture of the NERT plume at the AWF, and (2) upward migration of perchlorate from the UMCf into the alluvium as a result of matrix diffusion and upward flow caused by a natural upward vertical gradient. Tracer testing was used to evaluate capture at the AWF, and a combination of field and laboratory testing was used to quantify the effects of matrix diffusion. The tracer test showed no material evidence of a gap in the AWF capture zone either to the west or the east of the UMCf ridge in the vicinity of the AWF. However, upward migration of perchlorate from the UMCf to the alluvium through advection and diffusion was found to be a significant cause of the observed elevated perchlorate concentrations in wells downgradient of the AWF. Upward migration of perchlorate into the alluvium is also expected to be significant in other parts of the NERT RI Study Area that have similar conditions. The effect of matrix diffusion on perchlorate concentrations are summarized in Section 9 and will be evaluated as part of the FS. The complete results of this evaluation are presented in Appendix B.

Closure of the AP-5 Pond was completed in accordance with the AP-5 Pond Closure Plan (Tetra Tech 2016b). The pond was within OU-1 south of the IWF and east of the AP Area Extraction wells, as shown in the lower left inset in Figure 3-2. Pond closure included removing the contents of the AP-5 Pond and the pond liner, removing abandoned above-ground piping from in and around the pond, removing the berm, and backfilling and grading to reclaim the pond footprint to the original site topography (Tetra Tech 2019b). The NERT Site's Groundwater Discharge Permit (NEV2001515) required the primary liner system to be free of leaks. Because there was a leak in the primary liner system of AP-5, NERT could have either: (1) removed the solids in order to repair the leak and maintain compliance with the permit, or (2) closed AP-5 and removed it from the permit; NERT chose the second option. Additionally, closure of this pond eliminated a potential source of groundwater contamination at OU-1. Through closure of the AP-5 Pond, a total of 1.4 million pounds of perchlorate was removed and subsequently treated or disposed. The most recent permit was issued by NDEP, Bureau of Water Pollution Control (BWPC), on July 10, 2011 and had been administratively extended by BWPC since the permit's expiration on July 10, 2016 and NERT's January 8, 2016 application to renew the permit. AP-5 closure documentation has been submitted (Tetra Tech 2019b) and is currently awaiting administrative closure. The GW-11 Pond is also maintained under the same Groundwater Discharge Permit NEV2001515 but was not part of the AP-5 Pond closure project and will continue to be maintained and operated in accordance with the permit.

The soil background concentration study provides a more representative data set for metals and radionuclides within the UMCf for comparison to the results of the RI, as well as previous and future investigations (Ramboll Environ 2017g). This study was prepared in response to an NDEP comment requesting use of a background data set (NDEP 2016c) because few background samples were available from soil at depths greater than 10 ft bgs in the alluvium or UMCf. To allow for the possibility that there may be a greater range of naturally-occurring concentrations of COPCs in the UMCf in the vicinity of OU-1, a full background data set was compiled from 46 samples that were collected in June 2018. These data were summarized in the Soil Background Data Set Summary Report (Ramboll 2021d), which recommended use of the data from these samples for all analytes with the exceptions of antimony, cadmium, niobium, silver, thallium, tungsten, and radium-228. Use of data from 24 samples previously collected in the UMCf was recommended for all analytes with the exceptions of radium-226, thorium-230, uranium-234, and uranium-238. Usable data from all 70 UMCf background samples were recommended to be combined into a single background data set for the UMCf. This combined UMCf background data set is appropriate for supporting future assessment and decision making with respect to UMCf soils, and is used for the OU-1 final COPC selection process in Section 7. NDEP approved the Soil Background Data Set Summary Report on April 12, 2021 (NDEP 2021c).

3.3.3 NERT's Current Groundwater Extraction and Treatment System

The current GWETS utilizes three groundwater capture well fields, as shown in Figure 3-2, including the IWF, the AWF, and the SWF, as well as eight AP Area extraction wells located approximately 300 feet south of the IWF just west of the former AP-5 pond. The IWF, which currently contains 27 active extraction wells located in OU-1 that pump at a combined rate of approximately 55-65 gpm, coupled with the on-site barrier wall provides capture of the highest concentrations of perchlorate and chromium and significantly reduces the amount of perchlorate and chromium in downgradient groundwater. Extraction wells installed to support the AP Area Down and Up Flushing Treatability Study continue to extract groundwater (as directed by NDEP) and contribute an approximate additional 10 gpm to on-site groundwater extraction. The off-site AWF, located in OU-2 approximately 8,200 feet downgradient of the IWF near the boundary of OU-3, consists of eight active extraction wells and captures moderate concentrations of both perchlorate and chromium (in comparison to groundwater captured by the IWF), but operates at higher extraction rates than the IWF (at a combined rate of approximately 300-460 gpm), resulting in significant contributions to overall perchlorate mass removal from the environment and mitigation of perchlorate migration further downgradient in groundwater. The SWF, located in close proximity to the Las Vegas Wash within OU-3 approximately 1.2 miles downgradient of the AWF, currently includes nine extraction wells and operates at the highest extraction rate of the three well fields (at a combined rate of approximately 530-760 gpm), but captures groundwater containing significantly lower perchlorate concentrations.

Treatment of chromium-contaminated groundwater extracted at the IWF and the AP Area occurs via the on-site GWTP, which chemically reduces hexavalent chromium and removes total chromium via chemical precipitation. Treatment of perchlorate-contaminated groundwater extracted at the IWF, AWF, SWF, or AP Area occurs via either (1) the on-site FBRs, which biologically remove perchlorate as well as chlorate, nitrate, and trace concentrations of residual chromium, or (2) an IX treatment system. The locations of all major treatment system components are shown in Figure 3-2. The IX treatment system was brought online in February 2017 to treat perchlorate in groundwater extracted from a portion of the SWF. Veolia, formerly US Filter Operating Services, operated the GWETS on behalf of Tronox beginning in 2005. After the Trust took title to the NERT Site, Veolia continued to serve as the GWETS operator until July 24, 2013. Envirogen currently operates and maintains the GWETS on behalf of the Trust.

The FBR and IX systems discharge treated water to the Las Vegas Wash from a combined effluent pipe that discharges to a side channel of the Las Vegas Wash located immediately west of the Pabco Road Weir under authority of NPDES Permit #NV0023060. Treated effluent discharged from the GWETS typically does not contain detectable concentrations of perchlorate or hexavalent chromium (and has never exceeded the effluent limits specified in

NERT's NPDES permit). A simplified treatment process flow diagram is presented in Figure 3-6.

As directed by NDEP, the TSE was constructed in 2022 through early 2023 to remove perchlorate, chlorate, and chromium from groundwater that migrates from the NERT Site and is captured by TIMET's GWETS (described below in Section 3.3.4.1). The captured groundwater is initially treated by TIMET for VOCs using an air stripper. The groundwater treated by TIMET is then pumped to the TSE located on the NERT Site via an underground 8-inch diameter, high density polyethylene pipe, where it is treated for perchlorate, chlorate, and chromium. The TSE accommodates up to 100 gpm of flow from TIMET. The treated groundwater is returned to TIMET for injection into TIMET's recharge trenches, which are regulated by an Underground Injection Control (UIC) permit. The TSE and associated pipelines and lift station are shown in Figure 3-2.

The current effectiveness of these systems (excluding the TSE) at removing contaminant mass, reducing groundwater concentrations, and reducing contaminant mass flux into the Las Vegas Wash is presented in annual groundwater monitoring and GWETS performance reports and semi-annual groundwater monitoring and GWETS performance memorandums (e.g., Ramboll 2022a,e). As stated in the 2021 Annual Groundwater Monitoring and GWETS Performance Report, approximately 2,010 pounds of total chromium and 300,090 pounds of perchlorate were removed from groundwater by the GWETS (excluding the TSE) between July 2020 and June 2021 (Ramboll 2022a). Of the total chromium mass removed, approximately 1,720 pounds (86%) were captured by the IWF and 280 pounds (14%) were captured by the AWF. The SWF and AP Area Wells each removed an estimated 6 pounds of chromium, together representing less than one percent of the total chromium removed during this performance period. Of the total perchlorate removed, approximately 117,600 pounds (39%) were captured by the IWF, approximately 27,140 pounds (9%) were captured by the AP Area extraction wells, approximately 132,420 pounds (44%) were captured by the AWF, and approximately 22,940 pounds (8%) were captured by the SWF. The effectiveness of the TSE, which was brought online in June 2023, at removing contaminant mass will be reported in future annual groundwater monitoring and GWETS performance reports and semi-annual groundwater monitoring and GWETS performance memorandums.

The remaining contaminant masses in the subsurface as of second quarter 2021 is estimated to be approximately 4,877 ± 879 tons for perchlorate and 110 ± 48 tons for hexavalent chromium (Ramboll 2022a).[45] The mass estimate boundary for perchlorate includes the entire NERT RI Study Area, as well as the adjacent area beneath the TIMET facility that is formally outside of the NERT RI Study Area, but excludes perchlorate mass from the AMPAC plume present in the NERT RI Study Area, while the mass estimate boundary for chromium is limited to OU-1 and the NERT Off-Site Study Area. Attachment A of the 2021 Annual Groundwater Monitoring and GWETS Performance Report includes additional technical information about the mass estimates generated for chromium and perchlorate. These

---

[45] The 95% confidence limits are shown following the mass estimates. As discussed in greater detail within Attachment A of the 2021 Annual Groundwater Monitoring and GWETS Performance Report, a standard linear uncertainty assessment was conducted to quantify the relative uncertainty in the total mass estimates by chemical, OU and zone. The major sources of uncertainty associated with the mass estimate calculations include soil properties, chemical concentrations, elevation of the UMCf/Qal contact, interpolation procedures, and the hexavalent chromium partitioning coefficient.

estimates will be updated and refined as part of future Annual Groundwater Monitoring and GWETS Performance Reports and as part of the RI Report for OU-3.

3.3.4 Environmental Investigation/Remediation Conducted by Others

Relevant environmental investigations and actions conducted by TIMET, OSSM, BRC, or AMPAC between 1970 and 2011 are included above in Section 3.2. This section describes significant relevant environmental investigations and actions conducted by other (non-NERT) entities between 2011 and 2022. While TIMET, OSSM, BRC, and AMPAC have conducted numerous investigations and remedial activities the following subsections are intended to discuss only those that are material to NERT's RI of OU-1 and OU-2.

3.3.4.1 TIMET

NDEP is currently overseeing the investigation of soil and groundwater contamination associated with TIMET's historical operations, which resulted in the release of uranium, total dissolved solids (TDS), tetrachloroethane (PCE), trichloroethane (TCE), chloroform, and various semi-volatile organic compounds (SVOCs) to the subsurface (NDEP 2012). By 2014, a bentonite slurry wall and groundwater remediation system were installed along the northern boundary of the TIMET site to capture contaminated groundwater (GEI 2019a). Extracted groundwater is treated to remove VOCs and subsequently discharged to recharge trenches on the TIMET site under TIMET's UIC Permit.

TIMET's GWETS began operating in March 2014, treating extracted groundwater for VOCs as part of the site's First Water-Bearing Zone Groundwater Remediation Program (TIMET 2014). TIMET currently operates 22 active extraction wells located upgradient of OU-2 near Pabco Road (shown in Figure 3-1). An approximately 2,400-foot-long barrier wall is located immediately downgradient of TIMET's extraction well field. Of the site's 22 currently installed extraction wells, 19 were installed as part of the original system, two were added in February 2019 (and replaced in April 2022) and one was added in April 2022 (GEI 2020a, 2022a). TIMET's recent quarterly monitoring report indicated that each of the three wells installed in 2022 became operational in September 2022 (GEI 2022a). Beginning in June 2023, effluent from the TIMET air stripper is being routed to NERT's TSE, where it is treated for perchlorate, chlorate, and chromium, prior to being returned to TIMET. Following treatment via air stripper and the TSE, groundwater is re-injected downgradient of the TIMET barrier wall. Additional information on the TSE is presented in Section 3.3.3.

TIMET submitted a revised CSM in 2015, following supplemental investigation that was performed from 2013 to 2014 (GEI 2015). NDEP further directed TIMET to utilize monitored natural attenuation to address downgradient groundwater in the first WBZ (GEI 2015). The 2015 CSM identified planned investigation and remediation activities which included additional investigations of select management areas on the TIMET site in pursuit of administrative closure or NFA determinations. NDEP responded to the 2015 CSM in a letter dated December 9, 2015, which requested TIMET submit an updated schedule for remaining work (including all sub areas) on a biennial frequency (NDEP 2015h).

3.3.4.2 OSSM

NDEP is currently overseeing the investigation and remediation of soil and groundwater contamination associated with the OSSM site historical operations, as summarized above, which resulted in the release of various volatile organic compounds (VOCs), including chloroform and inorganic chemicals to the subsurface (de maximis 2019; Olin 2019). In 1983, Stauffer and Montrose installed a GWETS located north of the OSSM site and BMI CAMU to capture contaminated groundwater and to remove VOCs.[46] Treated groundwater is discharged to recharge trenches located approximately 100 feet downgradient of the groundwater extraction wells. As of 2021, the OSSM GWETS had been expanded to treat groundwater from 17 wells with an average VOC influent concentration of approximately 14,900 µg/L and an average effluent concentration of 0.9 µg/L (de maximis 2022a).

OSSM's Groundwater Remedial Alternatives Study (RAS) Report (Revision 3) was submitted to NDEP in June 2019 (Geosyntec 2019). The revised RAS was developed following the 2008 CSM for the combined OSSM site and it provided an evaluation of potential remedial alternatives including treatment or containment measures to supplement or enhance the existing OSSM GWETS. The RAS concluded with a recommendation to continue operation of the existing GWETS, potentially modified for the removal of dissolved arsenic, combined with long-term monitoring of groundwater downgradient of the extraction system and establishment of institutional controls prohibiting groundwater extraction for potable use (Geosyntec 2019).

On January 7, 2020, in a letter to the OSSM Companies, NDEP indicated that they transmitted recently collected groundwater and geologic data from NERT to the OSSM Companies and requested that the OSSM Companies review the data and provide a summary that demonstrates the fate and transport of site related chemicals known to trespass onto the NERT property (NDEP 2020b). The OSSM Companies provided their Demonstration of the Fate and Transport of Trespass Site Related Chemicals Report to NDEP on May 8, 2020, which reiterated their interpretations and conclusions in their 2019 Groundwater RAS (Hargis 2020).

On October 13, 2020, NERT, NDEP, and the OSSM Companies met to discuss NERT's groundwater and geologic data and conclusions regarding the nature and extent of trespassing contaminants from the OSSM site; however, after NERT provided its response to OSSM's May 8, 2020 submittal, OSSM indicated it was not prepared to discuss and would respond at a later date. On March 24, 2021, the OSSM Companies sent correspondence to the Trust indicating that the OSSM Companies had questions and data requests for the Trust, but would reserve sending questions and data requests until after the submittal of the RI Report for OU-1 and OU-2, Revision 0 to NDEP (OSSM Companies 2021). OSSM received a copy of the RI Report and associated data on July 9, 2021. On January 26, 2023 NDEP requested NERT attend a meeting with OSSM where OSSM would present its response to NERT's October 2020 comments and present OSSM's plans with regard to its trespassing plume. At the meeting OSSM continued to assert that any contamination originating from their site was ultimately captured by their groundwater extraction and treatment system, which is contrary to the evaluation presented in Section 9 and the conclusions presented in Section 10 of this RI Report. The meeting minutes prepared by NDEP state "if remediation efforts implemented by NERT gather groundwater contaminants from the OSSM site,

---

[46] The treatment system is located on property owned by Henderson Groundwater, LLC. The extraction well field is partially located on property owned by Henderson Groundwater, LLC and partially on Parcel E, which is owned by the Trust.

contingency language should be provided in the OSSM Groundwater Remedial Alternatives Study to assure NERT that OSSM will work with NERT to address those contaminants." Additionally, in NDEP's comments to the RI Report for OU-1 and OU-2, Revision 0 the agency stated "NDEP will work with other responsible parties to address in their FSs and remediation plans any COPCs that are trespassing onto the NERT site."

Additionally, studies regarding the presence and extent of dense non-aqueous phase liquid (DNAPL) within the eastern portion of the OSSM site and trespassing onto the NERT Site have been conducted by Hargis + Associates, Inc. (Hargis), Geosyntec, and AECOM on behalf of Montrose since 2007. These studies have confirmed that the DNAPL present in this area is composed primarily of 1,2-dichlorobenzene, 1,3-dichlorobenzene, 1,4-dichlorobenzene, chlorobenzene, and benzene. NDEP has requested OSSM to address the presence of DNAPL in OU-1 in a separate RAS.

3.3.4.3 BRC

NDEP is currently overseeing the investigation and remediation of soil and groundwater contamination within the BMI Common Areas. As indicated previously, BRC conducted soil remediation activities within the BMI Common Areas (including the Eastside Sub-Area of OU-2) between 2007 and 2015. Recent activities have been focused on an evaluation of groundwater quality and development of a Remedial Alternatives Study of the Eastside Sub-Area.

A CAMU Long-Term Groundwater Monitoring Report was submitted to NDEP by BRC in January 2017 (BRC 2017). Groundwater beneath the CAMU has been impacted by many of the chemicals detected upgradient of the landfill (including VOCs, SVOCs, polychlorinated biphenyls [PCBs], dioxins and furans from the OSSM site, and perchlorate from the AMPAC site). Data from soil and groundwater samples collected beneath the landfill suggest the CAMU area may also be an additional source of contamination (BRC 2017). NDEP plans to defer further action or investigation of groundwater impacts at the CAMU until the RAS is completed for the former OSSM site, which is currently in progress as discussed in Section 2.2.1 (Geosyntec 2019; NDEP 2017b).

A Shallow Groundwater Conceptual Site Model and Remedial Alternatives Study (CSM/RAS) Report for the Eastside Sub-Area was submitted to NDEP by BRC in August 2019 (DBS&A 2019). The report describes the following subjects for the Eastside Sub-Area: history and operations, the physical hydrogeologic setting, the history of site investigations, the distribution of groundwater impacts, the fate and transport of residual constituents in groundwater, and a screening of remedial alternatives developed to select a preferred remedy for the shallow groundwater within the Eastside Sub-Area with respect to the BRC COPCs. As earlier described, NDEP granted NFA determinations on the majority of the parcels comprising the Eastside Sub-Area within OU-2 and these were restricted to the upper 10 feet of the soil horizon, consistent with proposed future land uses and the results of groundwater and soil investigations and remediation activities completed in 2014 (BRC 2014). Following evaluation, institutional controls and groundwater monitoring were selected by BRC as the recommended Remedial Alternative for the shallow WBZ within the Eastside Sub-Area of NERT's OU-2.

Following review of the 2019 Shallow Groundwater CSM/RAS Report for the Eastside Sub-Area, NDEP provided conditional approval on January 20, 2021, which included comments for the administrative record. The comments acknowledge that NDEP was in the process of "developing a chloroform CSM for the BMI Complex and surrounding areas" and that upon completion of NDEP's chloroform CSM, there was a potential need for BRC to amend its CSM if there were significant differences or data gaps found. The conditional approval comments included the possibility of NDEP requesting additional investigative/sampling work to be performed and presented in a potentially amended CSM for shallow groundwater in the Eastside Sub-Area (NDEP 2021a).

At the request of NDEP, BRC prepared a Sampling and Analysis Plan (SAP) for Groundwater for the Eastside Sub-Area (as well as the Western Hook located in OU-3), which was submitted in November 2022 (BRC 2022). The SAP, currently under NDEP review, was developed to support BRC's conclusion from its 2019 Shallow Groundwater CSM/RAS Report for the Eastside Sub-Area that the appropriate remedy for BRC is groundwater monitoring to demonstrate that groundwater impacts are attenuating (DBS&A 2019). As of the date of this RI report, the 2019 Shallow Groundwater CSM/RAS Report for the Eastside Sub-Area remains conditionally approved, pending completion of the sampling that was recently proposed in BRC's SAP.

3.3.4.4 Lhoist

This facility has never been identified as a source of significant contamination concerns. Only minor spills of quicklime, hydrated lime, finished lime products, and fuel, as well as a leaking UST were identified as contamination concerns during the 1993 Phase I conducted at the Chemstar facility (Chemstar 1993). NERT is not aware of any additional investigation that is ongoing.

3.3.4.5 AMPAC

The groundwater perchlorate and chlorate plumes associated with the former AMPAC facility are generally located to the west of the NERT plumes. Although the former AMPAC facility is not located within the BMI Complex, the environmental investigation and remediation of the facility is relevant as the perchlorate and chlorate plumes associated with the former AMPAC facility commingle with the perchlorate and chlorate plumes associated with NERT within OU-2. AMPAC's perchlorate production process may have generated incidental chloroform; however, site investigations conducted at the former AMPAC facility have not included sampling of groundwater for chloroform or other volatile organic compounds. Perchlorate from the AMPAC plume also discharges to the Las Vegas Wash within OU-3 similar to the NERT plume although predominately in an area upstream of discharges associated with the NERT plume. Endeavour LLC (Endeavour) currently operates an FBR treatment system that is designed to treat perchlorate in groundwater extracted from a series of 14 extraction wells located in two clusters located outside of the NERT RI Study Area as shown in Figure 3-1. One cluster is located approximately one mile west of OU-1 and the other is located approximately 1.5 miles north of OU-1 (Endeavour 2018). The treated groundwater is discharged to the Las Vegas Wash under NPDES Permit #NV0024112. Discussion of the commingling of the NERT and AMPAC perchlorate and chlorate plumes is provided in Sections 8 and 9.

4. REMEDIAL ACTION OBJECTIVES

The information presented in this section includes the RAOs, ARARs and TBCs for the NERT RI Study Area. RAOs provide a high-level summary of what the final CERCLA cleanup will be designed to accomplish through implementation of a ROD. RAOs are developed as 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 specific setting, COPCs, potential future uses of the site, and human health and ecological risk-based exposure criteria. Consistent with CERCLA, the RAOs reflect a preference for permanent solutions, incorporating approaches, where feasible and appropriate, that will reliably reduce contaminant toxicity, mobility, or volume. As data has been gathered and analyzed during performance of the RI/FS, the RAOs have been refined, as necessary. The current RAOs, which are a slightly modified version of the RAOs presented in the RI/FS Work Plan, (ENVIRON 2014c), were established within the approved Phase 3 RI Work Plan (Ramboll Environ 2017m). Final RAOs will be determined after completion of the RI (inclusive of the ongoing OU-3 RI) and the FS and incorporated into the ROD.

RAOs will address those COPCs which are specific to each respective area of the NERT RI Study Area. The term "COPCs" is used generally in this report to refer to chemicals of potential concern throughout the NERT RI Study Area. However, individual OUs or investigation areas, each contain a unique and specific set of COPCs which the RAOs are designed to address. For example, and as previously discussed in Section 1.0, within the Eastside Sub-Area, the COPCs are administratively limited to only perchlorate and chlorate.

COPCs were initially designated in the RI/FS Work Plan (ENVIRON 2014c) and were subsequently updated as part of the evaluation of Phase 1 RI investigation results in 2016 (Ramboll Environ 2016c); these COPCs are referred to as "investigative COPCs" since they were designated prior to the formal evaluation of data collected during the RI. Through this report, the investigative COPCs for OU-1 and OU-2 were updated based on the analysis presented within Sections 7 and 8 of this report. Possible updates to the COPCs for OU-3 will be evaluated in the forthcoming RI Report for OU-3.

Under CERCLA, RAOs must be consistent with ARARs. 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 sufficiently similar to those encountered at the NERT RI Study Area that their use is well suited to the NERT RI Study Area.

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. Advisories, criteria, and guidance developed by the USEPA or other federal or state agencies, as appropriate, may be considered in developing remediation alternatives during the FS process. These criteria are referred to as "to-be-considered" (TBC) criteria.

An extensive discussion of the ARARs and TBCs that apply to the NERT RI Study Area was presented in the RI/FS Work Plan (ENVIRON 2014c).

4.1 Applicable or Relevant and Appropriate Requirements (ARARs)

The following requirements have been identified by NDEP and USEPA as ARARs for the NERT RI Study Area:

- Chromium: The most prevalent COPC detected in groundwater within OU-1 other than perchlorate is hexavalent chromium/total chromium.[47] The chemical-specific ARAR for total chromium is the federal maximum contaminant level (MCL) of 100 µg/L, which the State of Nevada has adopted by reference (NAC 445A).
- Chlorate: The chemical-specific ARAR for chlorate is the Nevada BCL of 1.0 mg/L for residential water (NDEP 2023a).
- Other COPCs: For Other COPCs, chemical-specific ARARs will be evaluated based on the results of the risk assessments and incorporated into the FS.

4.2 To-Be-Considered (TBC) Criteria

The following state and federal requirements have been identified by NDEP and USEPA as TBCs for the NERT RI Study Area:

- Perchlorate: There are no chemical-specific ARARs for perchlorate. The most applicable and relevant TBC for perchlorate that is protective of human health is the Interim Drinking Water Health Advisory and federal preliminary remediation goal (PRG) of 15 micrograms per liter (µg/L) (USEPA 2009, 2008b), chosen over the

---

[47] A detailed analysis of hexavalent chromium to total chromium ratios was performed as part of the 2016 Groundwater Monitoring Optimization Plan (Ramboll Environ 2016a). The analysis found that the ratio of hexavalent chromium to total chromium was approximately 1 within the NERT groundwater plume (i.e., the concentration of total chromium is generally equal to the concentration of hexavalent chromium in groundwater). With NDEP approval, hexavalent chromium was generally eliminated from NERT's on-going monitoring program in 2016. Therefore, interpretations of the lateral and vertical extent and mass estimates of hexavalent chromium in groundwater, performed as part of the RI will primarily rely on total chromium data (rather than hexavalent chromium data).

Nevada Interim Action Level (AL) of 18 μg/L since it is the lower of the two values.[48] The NDEP and USEPA have also identified California's MCL for perchlorate of 6 μg/L (California Code of Regulations [CCR] Title 22, Section 64431) and California's Public Health Goal (PHG) of 1 μg/L for perchlorate as TBCs for perchlorate at the NERT RI Study Area Site.

- Chloroform: There are no chemical-specific ARARs for chloroform. The most applicable and relevant TBC for chloroform that is protective of human health is the maximum contaminant level goal (MCLG) of 70 μg/L. The MCLG for chloroform is chosen over the MCL for total trihalomethanes (TTHMs)[49] of 80 μg/L since it is chemical-specific and the lower of the two values.
- Chromium: While there is a chemical-specific ARAR for chromium, the NDEP and USEPA have also identified California's MCL for total chromium of 50 μg/L and California's proposed MCL of 10 μg/L for hexavalent chromium as TBCs for the NERT RI Study Area.
- Other COPCs: For other COPCs, chemical-specific TBCs will be evaluated based on the results of the risk assessments and incorporated into the FS.

4.3 Groundwater RAOs for the NERT RI Study Area

The initial RAOs were proposed and approved in 2014 in the RI/FS Work Plan (ENVIRON 2014c). These initial RAOs were developed for only the NERT Site and the NERT Off-Site Study Area. In 2017, the RAOs were modified to incorporate the findings of the NERT Phase 1 RI and the expansion of the NERT RI Study Area to include the Downgradient Study Area and the Eastside Study Area (Ramboll Environ 2017m). While final RAOs will be determined after completion of the RI (inclusive of the ongoing OU-3 RI) during the FS and incorporated into the ROD, the RAOs approved by NDEP are reiterated below and appropriate based on NERT's determination of the nature and extent of contamination and potential impacts to human health and the environment.

Plume Containment and Source Control (OU-1): The migration of COPCs present in groundwater within OU-1 will be mitigated. Specifically, on-site source control and containment at the downgradient property boundary of the NERT Site will be achieved

---

[48] On February 11, 2011, EPA determined that perchlorate meets the criteria for regulation under the Safe Drinking Water Act of 1974 (the "Act") ("2011 Determination"). On February 18, 2016, the National Resources Defense Council, Inc. (NRDC) brought an action in the Southern District of New York alleging that EPA failed to comply with its nondiscretionary duties under the Act to propose and finalize a maximum contaminant level goal ("MCLG") and promulgate a national primary drinking water regulation ("NPDWR"). On July 21, 2020, EPA withdrew its 2011 Determination and issued its final determination not to regulate perchlorate in drinking water. On September 3, 2020, NRDC filed a separate challenge in the D.C. Circuit and argued EPA lacks the authority to withdraw its 2011 Determination. On May 9, 2023, the D.C. Circuit ruled that the Act does not permit EPA to withdraw a regulatory determination and vacated EPA's 2011 Determination and remanded the matter to the EPA for further proceedings. A petition for rehearing was filed on July 24, 2023 and was denied on September 7, 2023. In a January 5, 2024 Stipulation to Modify Consent Decree, EPA committed to sign for publication in the Federal Register a proposed MCLG and NPDWR for perchlorate no later than November 21, 2025 and no later than May 21, 2027, EPA shall sign for publication in the Federal Register a final MCLG and NPDWR for perchlorate.

[49] TTHMs consist of the sum of the concentrations of bromodichloromethane, bromoform, dibromochloromethane, and chloroform.

through a combination 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).

Mid-Plume Containment and Mass Removal (OU-2)**:** The migration of COPCs present in off-site groundwater within OU-2 will be mitigated through a combination of plume containment and, where feasible, COPC mass removal. Specifically, groundwater quality immediately downgradient of Galleria Drive and the Eastside Sub-Area northern boundary will be substantially improved likely through a combination of the implementation of on-site vadose zone source and groundwater mass removal actions. As discussed earlier, while NERT is responsible for its COPCs in OU-2 west of Pabco Road, NERT will only address perchlorate and chlorate impacts in OU-2 east of Pabco Road. The northern boundary of OU-2 is considered to be the mid-plume containment boundary, which is shown in Figure 4-1.

Mitigate Discharge in Las Vegas Wash (OU-3): The overall RAO for groundwater downgradient of a mid-plume groundwater containment boundary is to mitigate the discharge of COPCs in groundwater to the Las Vegas Wash by reducing COPC concentrations in the alluvial aquifer and UMCf consistent with the ARARs and TBCs.

While acknowledging that other sources are contributing contaminants to the Las Vegas Wash and Lake Mead, any remedial action selected through issuance of the NERT ROD will mitigate only NERT's contribution to the Las Vegas Wash and Lake Mead and will help achieve out-of-state MCLs at downstream state boundaries, namely, California and Arizona.

These RAOs are illustrated on Figure 4-1. Figure 4-2 shows the RAOs compared to the current interpretation of the perchlorate groundwater plume.[50] These RAOs are consistent with Nevada regulations, which may take technical feasibility and cost, as well as the groundwater's status as a drinking water source, into account when considering clean-up standards.

---

[50] Any remedial action selected to achieve RAOs will be designed to mitigate only NERT's contribution of contaminants to the Las Vegas Wash and Lake Mead, to the extent technically feasible.

5. PHYSICAL AND ENVIRONMENTAL SETTING

This section provides details regarding the physical and environmental setting of the NERT RI Study Area with emphasis on OU-1 and OU-2. The details provided in this section include the OU-1 and OU-2 surface features, regional climate data, local ecology, regional and local geological and hydrogeological conditions, and site-specific and regional hydrology.

5.1 Surface Features

As discussed in Section 4, the NERT RI Study Area is composed of three OUs. OU-1 is located in an industrial land use area, while OU-2 is primarily a mixture of residential and commercial land use areas with some light industrial operations (Figure 5-1). The Eastside Study Area within OU-2 includes a master-planned community, which is currently under development, that includes a mixture of single and multi-family housing, parks, community buildings, retail and other commercial property. OU-3 generally comprises a mix of residential land use, disturbed yet undeveloped open space, and the natural area surrounding the Las Vegas Wash. The COH WRF and associated ponds are also located within OU-3 near the northern OU-2 boundary. OU-3 is not the subject of this report and will be discussed in the forthcoming RI Report for OU-3.

5.1.1 OU-1 Surface Features

OU-1 (i.e., the NERT Site Study Area) is generally rectangular in shape, but several interior portions of the rectangle are owned by other companies, specifically, Lhoist, WAPA, and TIMET (Figure 1-3a). As described in Section 1, OU-1 consists of approximately 269 acres of NERT-owned property (i.e., the NERT Site), as well as former Sale Parcels C, D, and H (approximately 71 acres).[51] EMD has a long-term lease for approximately 114 acres of the NERT Site, which is currently used for its manufacturing operations (Figure 1-4).

Elevations across OU-1 range from 1,700 to 1,873 feet above mean sea level datum (ft msl), and the land surface across the Site generally slopes toward the north at a gradient of approximately 0.02 feet per foot (ft/ft). The developed portions of the OU-1 have been modified by grading to accommodate building foundations, surface impoundments, and access roads. Further modifications were made as part of the Soil Removal Action (ENVIRON 2012a), in which soils were typically excavated to depths of up to 10 ft bgs, as detailed in Section 3.1.2 of this report. In some cases, depths were extended to greater than 10 feet to remove discolored soils. As part of storm water management at the Site, some excavations were only partially backfilled or not backfilled at all, generally resulting in depressions with 3:1 side slopes.

The far northern portion of OU-1 is composed of Parcel E and former Sale Parcels C and D. The parcels are currently undeveloped, but some of the active OSSM extraction wells and associated piping are located within Parcel E in the northwest corner of OU-1.

The area south of Parcels C, D, and E within the NERT Site is largely occupied by the NERT GWETS operational areas, including a groundwater holding pond (GW-11) and separate groundwater treatment facilities for removal of perchlorate and hexavalent chromium. An outside contractor, Envirogen, operates the groundwater treatment facilities on behalf of the

---

[51] Former Sale Parcels C, D, and H were sold by the Trust on May 8, 2020.

Trust. Envirogen and the Trust both have office trailers in the vicinity of the GWETS operational areas. The GWETS operational area also includes the former AP-5 pond, which was closed in 2019 (Tetra Tech 2019b). Pond AP-6, which has been out of service since approximately 2001, is located directly to the east of the former AP-5 pond. The property east of the GWETS operational areas is part of EMD's leasehold, and includes lined ponds WC-West and WC-East (both of which receive process-related wastewater discharges from ongoing EMD facility operations) and the debris pile that has been present since approximately 1999, for which EMD is responsible.

Directly south of the GWETS operational areas, OU-1 was historically traversed (from west to east) by the Beta Ditch that received liquid wastes from the Site and from neighboring facilities located to the west as discussed earlier in this report. The former Beta Ditch is no longer in use and has since been largely re-graded and channelized as part of the 2010-2011 Soil Removal Action. Portions of the former Beta Ditch have also been reworked and incorporated into the Central and Northern Retention Basins, which are described in more detail in Section 5.6. The area directly south of the former Beta Ditch is also part of EMD's leasehold and includes a lab, a maintenance building, a steam plant, and several other small structures. Lined ponds Mn-1 and Mn-2, used by EMD, are located near the eastern OU-1 boundary south of the former Beta Ditch.

The southern portion of OU-1 is occupied by EMD's Leach Plant and the Unit 1 through 6 Buildings, which are described in further detail in Section 2, as well as a warehouse building and several other small structures.

5.1.2 OU-2 Surface Features

As shown in Figure 1-2, OU-2 is composed of the southern portion of the NERT Off-Site Study Area, as well as the Eastside Sub-Area within the Eastside Study Area.

OU-2 West of Pabco Road (NERT Off-Site Study Area). The portion of the NERT Off-Site Study Area within OU-2 is located north of the NERT Site between Warm Springs Road and just north of Galleria Drive. Topographic elevations in this area range from 1,605 to 1,701 ft msl. The topographic surface continues to decrease from south to north at approximately the same gradient as within the NERT Site, extending to approximately Sunset Road, at which point it flattens to a gradient of approximately 0.01 ft/ft to the Las Vegas Wash.

This area is primarily occupied by a residential neighborhood consisting primarily of single-family and apartment homes. Commercial and light industrial operations are located in areas along major roadways (i.e., Warm Spring Road, North Boulder Highway, Sunset Road, and Galleria Drive). The AWF extraction wells, a component of the NERT GWETS, are located immediately north of Galleria Drive near the OU-2/OU-3 boundary. One school, Edna F Hinman Elementary School, is located within OU-2 in the NERT Off-Site Study Area.

OU-2 East of Pabco Road (Eastside Sub-Area). As of August 2022, approximately 50% of the Eastside Sub-Area has been developed. By the time the development is complete, it is expected that additional residential housing, parks, schools, and retail stores will cover much of the remaining vacant area as part of a master-planned community (Figure 5-1). The southern portion of the Eastside Sub-Area is partially occupied by a number of commercial businesses along Lake Mead Parkway. Two schools, Lake Mead Christian Academy and the

Pinecrest Academy Cadence charter school, are located in the southern portion of the Eastside Sub-Area.

Surface topography in vacant portions of the Eastside Sub-Area has been influenced by historical activities including construction of the BMI Upper Ponds, as well as extensive soil excavation as part of BRC's remediation efforts (described in Section 3.2). Extensive grading is currently underway associated with ongoing and rapid development of the area.

Topographic elevations within the Eastside Sub-Area range from approximately 1,600 to 1,860 ft msl. The land surface across the Eastside Sub-Area generally slopes toward the north at a gradient of approximately 0.02 ft/ft.

5.2 Climate and Precipitation

The climate of the Las Vegas Valley is arid with mild winters and dry, hot summers. Average annual precipitation as measured in Las Vegas between 1980 and 2020 was 4.20 inches (NOAA 2021). 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 (Shevenell 1996).

5.3 Ecological Features

The ecosystem type in this region of southern Nevada is Mojave Desert scrub (CCDCP 2000). The Mojave Desert scrub ecosystem includes creosote-bursage and Mojave mixed scrub vegetation communities, invasive, transitional grasslands, as well as large tracts of urban development; and small areas of barren land; and agricultural development. Figure 5-2 shows the distributions of Mojave Desert scrub and other vegetation, disturbed/urban land, and ecosystems in the vicinity of the NERT RI Study Area. As shown in the figure, the NERT RI Study Area and surrounding area are primarily occupied by disturbed urban land.

The desert scrub ecosystem serves as habitat for a variety of different mammals, reptiles, amphibians, birds, insects, and fish species. A list of species commonly found in the Mojave Desert Scrub Ecosystem of southern Nevada that are known to be susceptible to contamination-related food web exposures[52] as reported by USEPA (1993) is being assembled as part of the NERT Site's SLERA, as further discussed in Section 10.2.

The United States Fish and Wildlife Service and NDEP are the federal and state agencies, respectively, responsible for monitoring and managing at-risk and protected species. Species with threatened or endangered listing status in Clark County were assembled as part of the SLERA process (Ramboll Environ 2015a). However, based on field reconnaissance

---

[52] Alternatively, the animals may be representative prey of organisms that are susceptible to food web exposures.

performed in December 2014 and April 2018, no critical habitat[53] was observed for any of the listed species on or in the immediate vicinity surrounding OU-1 or OU-2 (Ramboll Environ 2015a; Ramboll 2018i).

5.4 Geology

5.4.1 Regional Geology

The NERT RI Study Area 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 in the north to Railroad Pass to the south. The valley is bounded by the Las Vegas Range, Sheep Range, and Desert Range to the north; by the Frenchman and Sunrise Mountains to the east; by the McCullough Mountains and River Mountains to the south and southeast; and by 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 (basalt, rhyolite, andesite, and related rock types) that overlie Precambrian metamorphic and granitic basement rocks.

Within the Las Vegas Valley, eroded Tertiary and Quaternary sedimentary and volcanic rocks comprise the unconsolidated basin deposits, which can be over 5,000 feet thick (Plume 1989). 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 thickness of the Las Vegas Valley fill is illustrated in Figure 5-3 (Plume 1989). The structure within the Quaternary and Tertiary basin fill is characterized by a series of generally north-south trending fault scarps, also shown in Figure 5-3.

The valley fill deposits consist of a relatively thin series of Quaternary alluvium deposits over a thick unit of older Tertiary Muddy Creek Formation sediments. As shown in Figure 5-3, the NERT RI Study Area is situated near the southeast edge of the Las Vegas Valley hydrologic basin between the McCullough Mountains to the south and the River Mountains to the east, in an area where the total basin fill reaches thicknesses between 3,000 to 4,000 feet. The north-south trending ridge of the McCullough Mountains forms a local divide between the sources of the sediment accumulated near the NERT RI Study Area. On the northwest side of the ridge, the overall direction of both surface water runoff and groundwater flow is north-northeast. The larger valley area from the Spring Mountains to the west contributes a greater volume of higher energy surface water runoff flow and associated coarser-grained sediment transport than the relatively small sub-basin between the McCullough and River Mountains southeast of the Site. In the smaller sub-basin, the overall surface water runoff and groundwater flow direction is toward the northwest. In general, this smaller sub-basin contributes finer-grained sediments to the basin fill due to the lower quantity and lower energy of surface water runoff flow.

---

[53] Critical habitat is a term defined and used in the Endangered Species Act (ESA). It is a specific geographic area that contains features essential to the conservation of an endangered or threatened species and that may require special management and protection (USFWS 2014).

The alluvial deposits in the vicinity reflect the basin geography described above. Figures 5-4a and 5-4b present the surficial geologic map in the vicinity of the NERT RI Study Area. The Henderson fan alluvial deposits that underlie the majority of the NERT RI Study Area originate from the smaller sub-basin on the east side of the McCullough Mountains. In the eastern portion of OU-2 and OU-3, the Henderson fan deposits are separated from the adjacent alluvial fan apron along the River Mountains by a thin south to north trending channel of recent alluvium. West of the Henderson fan deposits is an extensive body of multiple overlapping alluvial units and piedmont terraces originating from the northwest side of the McCullough Mountains and the larger valley area to the west. The generally coarser-grained sediments associated with these alluvial deposits underlie the western portion of the OSSM site as well as the nearby former AMPAC site.

The Tertiary Muddy Creek Formation is a widespread geologic unit within the Lake Mead region, and Las Vegas Valley is situated at its western extent. At the time of deposition, Las Vegas Valley was a closed inland basin, forming a terminal playa in the Lake Mead region drainage network (Faulds et al. 2016). Figure 5-5 presents a generalized sedimentation model (or facies model) modfied for the NERT RI Study Area that illustrates the depositional environments for sediments and evaporites within the arid closed inland basin. The proximal portions of the fan, adjacent to the mountains, are steeply graded with a main channel carrying coarse-grained sediments, which is often entrenched in the fan. As the sediments are transported by surface water runoff from the surrounding mountains toward the interior of the basin, slopes decrease reducing the stream competency resulting in the coarser grained sediments being deposited near the toe of the slope and finer grained sediments being deposited with increasing distance from the mountains. Coarse-grained alluvial fan aprons along the mountain front transition to finer-grained sand flats, then mud flats, and finally to saline lacustrine/mudflat deposits in the basin interior. The saline mudflats in the basin interior are characterized by abundant gypsum and other evaporite salt deposits. Sediments in the sand flat and dry mudflat environments are often characterized by carbonate caliche deposits. During the period of basin fill (typically many thousands to millions of years), the shoreline of the interior playa lake and the transitions between the surrounding mudflats and alluvial fans have expanded and receded in response to variations in rainfall and storm events over that period of geologic time. This has resulted in extensive interfingering of these deposits at depth within the basin.

5.4.2 Local Geology

This section provides descriptions of the major geologic units within the NERT RI Study Area.

***Quaternary Alluvium*.** The surface of the NERT RI Study Area is primarily Quaternary alluvial deposits (Qal) that slope northward toward the 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. The thickness of the alluvial deposits within the NERT RI Study Area ranges from less than 1 foot to more than 100 feet, particularly in the northern part of the NERT RI Study Area near the Las Vegas Wash.

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 underlying 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 hydraulic conductivity than the adjacent, well-graded deposits. In general, these paleochannels trend northeast.

The contact between the alluvium and the Muddy Creek Formation is typically marked by the appearance of moderate brown silt to sandy silt or stiff clay to sandy clay. Near the Las Vegas Wash, the contact is marked by gray-green to yellow-green gypsiferous clays and silts. Often, a layer of calichified sediments is observed at the contact.

***Transitional (or reworked) Muddy Creek Formation*.** Where present, the transitional Muddy Creek Formation (xMCf) is encountered at the base of the alluvium. The xMCf 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 a mixture of alluvium and reworked, disturbed fine-grained sediments.

***Muddy Creek Formation*.** The Muddy Creek Formation of Tertiary 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. Within the NERT RI Study Area, the Muddy Creek Formation does not crop out but instead subcrops beneath a veneer of Qal sediments. Subsurface investigation in the NERT RI Study Area has been focused on characterization of the alluvium and the Muddy Creek Formation to depths of up to 300-400 feet. Therefore, the Muddy Creek Formation has been informally termed the UMCf in this area.

Beneath OU-1, the Muddy Creek Formation is composed of a thick unit of fine-grained sediments of clay and silt (the UMCf-fg1) interbedded with at least two thinner units of coarse-grained sediments of sand, silt, and gravel (the UMCf-cg1 and second coarse-grained facies [UMCf-cg2]). There are also coarse-grained lenses present within the UMCf-fg1, as illustrated in the cross sections presented in Appendix C. Within OU-1, these lenses are coarser grained in nature (sands and silts) and in greater abundance than in OU-2. Based on the abundance of coarse-grained lenses within the UMCf-fg1 in OU-1, these deposits appear to be associated with an anastomosing stream complex that transported sediment from the adjacent mountains to the eastern flank of the Las Vegas Valley. Anastomosing and meandering stream deposits are typically characterized by coarse-grained channel deposits surrounded by finer-grained bank sediments (Rust 1978). Within OU-2, the lenses appear to be in less abundance and the sediments are finer-grained in nature (i.e., silt with little to no sand) as distance from the mountains increases. Anastomosing stream environments have been recognized to be transitional in nature, evolving into single-channel meandering streams (Smith, Cross, Dufficy, and Clough 1989).

***Site Hydrostratigraphic Units*.** The three WBZs defined by NDEP within the BMI Complex are the Shallow WBZ, Middle WBZ, and the Deep WBZ, as described in the Hydrogeologic and Lithologic Nomenclature Unification guidance document (NDEP 2009a). The Site hydrostratigraphic units are illustrated on Subsurface Cross-Section A-A′, shown in Figures 5-6a and 5-6b. This cross-section was first developed in 2008 based on the understanding of the Site hydrostratigraphic units at that time and has been updated with more recent information. In addition, detailed subsurface cross-sections have been developed that incorporate data from the RI. Subsurface conditions within OU-1 are shown in Figure 5-7 (south to north cross-section M-M′) and Figure 5-8 (west to east cross-section F-F′). Subsurface conditions within OU-2 are shown in Figure 5-9 (south to north cross-section L-L′) and Figures 5-10a, 5-10b, and 5-10c (west to east cross-sections K-K′, K′-K″, and K″-K‴ along the OU-2/OU-3 boundary, respectively). Subsurface conditions and the distributions of investigative COPCs in groundwater in OU-1 and OU-2 are further discussed in Sections 7 and 8, respectively. A complete set of full-scale subsurface cross-sections within OU-1 and OU-2 is presented in Appendix C.

Additional Geologic Formations within the Northeast Sub-Area. Bedrock formations mapped as outcropping at the ground surface near the very northernmost part of the Northeast Sub-Area, within OU-3, include the Horse Springs Formation, which is dominated by carbonate rocks interbedded with white to yellow calcareous siltstone and shale, and the Thumb Formation, which is locally dominated by red to pink calcareous siltstone and sandstone, gypsiferous shale and claystone (Bell and Smith 1980). These bedrock formations are part of the River Mountains shown in the area geologic map (Figures 5-4a and 5-4b).

5.4.3 Stratigraphic Analysis

The geologic units within the NERT RI Study Area have been identified based on lithostratigraphic correlation while leveraging an understanding of the depositional facies model for the Las Vegas Basin using concepts such as those presented in USEPA’s (2017) approach to Environmental Sequence Stratigraphy (ESS). Lithostratigraphy is a commonly used method of correlation that separates geologic units on the basis of lithology (Boggs 2001). The ESS approach leverages the lithologic data to interpret depositional environments and construct depositional facies models. Factors such as relative sea level change, sediment influx, climate, and tectonic activity influence the movement of the depositional environments and ultimately the types of sediments that are deposited at any specific location. Sequence stratigraphy leverages the relative movements of the various facies to frame geologic units within a time-relative framework focusing on surfaces of erosion or non-deposition and their correlative conformities (Van Wagoner et al. 1990).

The ESS approach improves the evaluation of heterogenous lithologic deposits for a more accurate correlation of geologic units and subsequent interpretation of the hydrostratigraphic connection of these units.

Depositional Environment and Facies Model A depositional environment is a geographic area where sediments accumulate over time (USEPA 2017). Physical, chemical, and biological processes control the erosion, transport, and deposition of sediments within a depositional environment resulting in sediment packages (also known as architectural elements) that have characteristic vertical grain size profiles, dimensions, and lithologies. These characteristic sediment packages are more commonly referred to as sedimentary facies and typically consist of lithologically similar sediments. The interaction of these processes to produce three dimensional sediment packages of various related facies have been extensively studied and distilled into depositional models or facies models. The facies model can then be used to understand the distribution of sediment packages within an area and predict sediment packages in adjacent areas.

Graphic grain size logs, which plot sediment grain size described in the boring log, can be an important tool for identifying depositional environments, depositional trends, and facies changes. Figure 5-11a uses graphic grain size logs to illustrate typical depositional sequences found in the NERT RI Study Area along with their facies associations (FA). Two generalized stratigraphic sections are shown. Profile 1 shows a generalized stratigraphic section in the southern portion of OU-1 near the valley margin where the UMCf-cg1 and UMCf-cg2 units are present. Profile 2 shows a similar generalized section in the valley interior (OU-2) where the UMCf-fg1 underlies the alluvium. The lithology is represented by typical graphic grain size logs to help illustrate the characteristics of the sediments associated with the depositional environments listed in the right column. The depositional FAs are described below.

Quaternary Deposits

Quaternary Alluvium – The Qal sediments of the Quaternary alluvium facies (Quaternary Alluvium FA) consist 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. The thickness of the alluvial deposits within the NERT RI Study Area ranges from less than 1 foot to more than 50 feet, particularly in the northern part of the NERT RI Study Area near the Las Vegas Wash. This facies is present across OU-1, OU-2, and OU-3

Channel Fill – The Qal sediments of the channel fill facies (Channel Fill FA) consist of heterogeneous mixtures of well-graded sand and gravel with lesser amounts of silt, clay, and caliche. Clasts within the alluvium are primarily composed of volcanic material. Gravel and cobbles are common. The channel fill is distributed in a linear geometry and is often incised into the older underlying deposits. These incised channel features are termed paleochannels. The channel fill within the paleochannels may be characterized by basal calichified zones with cemented layers and caliche nodules. Paleochannels containing channel fill sediments extend across OU-1, OU-2, and OU-3.

Tertiary Deposits (in order from proximal alluvial fan to distal alluvial fan deposition)

Proximal Alluvial Fan – The southern boundary of OU-1 is approximately one mile north from the base of the McCullough Mountain, which was the source of sediment deposited within OU-1. As a result, coarse debris flow deposits characteristic of a proximal alluvial fan at the base of the mountain slope are not present in the NERT RI Study Area.

Distal Alluvial Fan – The coarse-grained sediments of the UMCf alluvial fan-associated facies (Distal Alluvial Fan FA) typically consist of laterally continuous, interbedded fine to coarse sand, sandy gravel, and silty sand. Where present, the coarse-grained sediments grade laterally into the finer-grained sheet sands away from the source area. These sediments were likely deposited fluvially by intermittent meandering channels rather than debris flow as evidenced by the grain size, the interbedded nature of the material, and the lack of boulders and cobbles. This facies was likely deposited on the alluvial braid plain portion of the alluvial fan downslope from the coarser sediments associated with the proximal portion of the alluvial fan where debris flow processes are common. This facies is present in OU-1 and in the southwest corner of OU-2 at depth.

Sheet Sands – The finer-grained sediments of the UMCf alluvial fan-associated facies (Sheet Sands FA) typically consist of laterally continuous, interbedded sandy silt, silt, and silty fine sand with lesser amounts of clay-rich sediments. Caliche may be present. These sediments were likely deposited fluvially by intermittent meandering channels or sheet floods rather than debris flow as evidenced by the finer grain size, the interbedded nature of the material, and the lack of boulders and cobbles. This facies was likely deposited on a gently sloping alluvial plain with finer grain sizes compared to the Distal Alluvial Fan facies. This facies is present within OU-1 and the southern portion of OU-2.

Siliciclastic Mudflat – The sheet sand sediments grade laterally into fine-grained silt and clay that is typically medium to dark yellowish brown in color (Siliciclastic Mudflat FA). Sedimentary features including bedding and mottling (evidence of bioturbation) are occasionally observed, and caliche deposits and cemented layers are common. The yellowish color and the caliche deposits indicate that these sediments were deposited in an oxygen-rich environment commonly subject to subaerial exposure. The Siliciclastic Mudflat is a laterally continuous facies that represents deposition of sediments between the alluvial fan and the interior saline lake during higher lake water levels (likely the result of seasonal precipitation fluctuations or other hydrologic changes). At higher water levels, the dissolved solids within the lake water are diluted and evaporites are not deposited. This facies is present within OU-2 and OU-3, and at depth within OU-1.

Ephemeral Sands – Thin lenses of well-sorted medium to coarse-grained sand and fine gravel sometimes occur but are interpreted as ephemeral sands that are not laterally continuous (Ephemeral Sands FA). These sands may represent transitory channels migrating across the mudflats. Ephemeral sands are present at depth below OU-1 and the southern portion of OU-2. However, discontinuous ephemeral sand units are rarely encountered in the UMCf in the northern portion of OU-2 and OU-3.

Saline Mudflat – Further into the valley, away from the alluvial fan system, deposits of light-colored fine clay and thick bedded evaporite crystals (gypsum) represent frequent wetting-drying cycles within a playa (dry lake bed) environment (Saline Mudflat FA). The Saline Mudflat sediments were deposited at the margins of the confined lake at lower water levels, in a hypersaline environment caused by the evaporation of the water (with little new precipitation input). During lower lake levels, the adjacent Siliclastic Mudflats were subaerially exposed resulting in the precipitation of caliche within the Siliclastic Mudflat sediments. This facies is present in the northern portion of OU-2 and OU-3.

Lacustrine – Toward the valley interior, fine grained, organic-rich sediment that is dark greenish gray in color indicates an intermittent saline lake lacustrine environment (Lacustrine FA). The sediments often show evidence of high organic content such as black mottling or organic odor and are sometimes finely laminated. Accumulations of evaporite crystals (gypsum) are common. This facies is present in the northern portion of OU-2 at depth and in OU-3.

The generalized stratigraphic sections shown in Figure 5-11a illustrate the overall coarsening upward trend and transition in depositional environment at greater depths within the UMCf. Figure 5-11b is a conceptual illustration of the approximate lateral extent of the UMCf FAs in OU-1 and OU-2 within the Shallow WBZ depth interval (0-90 ft bgs). As can be seen in Figure 5-11b, the coarser-grained Distal Alluvial Fan FA and Sheet Sands FA present in OU-1 transition into the finer-grained Siliciclastic Mudflat FA in the southern portion of OU-2, and further north, into Saline Mudflat FA approaching OU-3. As discussed in Section 5.4.2, there are also coarse-grained lenses present within the UMCf-fg1. Within OU-1, these lenses are coarser grained in nature (sands and silts) and in greater abundance than in OU-2. Based on the abundance of coarse-grained lenses within the UMCf-fg1 in OU-1, these deposits appear to be associated with an anastomosing stream complex that transported sediment from the adjacent mountains to the eastern flank of the Las Vegas Valley. Within OU-2, the lenses appear to be in less abundance and the sediments are finer-grained in nature (i.e., silt with little to no sand) as distance from the mountains increases.

The ESS approach improves the evaluation of heterogenous lithologic deposits for a more accurate correlation of geologic units and subsequent interpretation of the hydrostratigraphic connection of these units, particularly within the Muddy Creek Formation. A stratigraphic analysis based on the principles of ESS will be most effective when applied to the sediments and depositional environments across the entire NERT RI Study Area (i.e., OU-1, OU-2, and OU-3). This will allow a more comprehensive evaluation of potential migration pathways from OU-1 across OU2 and OU-3 toward the Las Vegas Wash. A more detailed evaluation evaluation of ESS within the NERT RI Study Area will be included in the RI Report for OU-3.

5.5 Hydrogeology

5.5.1 Regional Hydrogeology

The location of the NERT RI Study Area within the southeastern portion of the Las Vegas Valley Hydrologic Basin is shown in Figure 5-12. This arid northwest trending valley is bounded on all sides by several mountain ranges and drains a 1,564 square mile watershed southeastward through the Las Vegas Wash into Lake Mead (USGS 1999). Deep aquifers in the west central portion of the valley are a source municipal water supply. As shown in Figure 5-12, the Las Vegas Valley Water District's (LVVWD) main well field is located approximately 12 miles northwest of the NERT RI Study Area. Based on records from 1965-1995, the area of highest groundwater withdrawal (summer) and recharge activities (winter) shown in Figure 5-12 encompasses the LVVWD's main well field, and additionally auxiliary well fields a few miles to the north and west, and City of North Las Vegas production wells to the north (USGS 2000). Other private wells are located within the central valley area where the aquifers are present. There is limited groundwater withdrawal in the southeast portion of the hydrologic basin near the NERT RI Study Area. The NERT RI Study Area is situated in an area of predominantly fine-grained mudflat and playa deposits comprising the Muddy Creek Formation, described above in Section 5.4.1.

Groundwater is generally pumped from the upper 2,000 feet of unconsolidated sediments that constitute the aquifer system in the western central part of the valley. In the western central part of the valley, the basin-fill deposits are grouped into two water-bearing units, an upper unit (the near-surface reservoir) and a lower unit (the principal aquifer). The deeper aquifer units, generally below 300 feet, are capable of transmitting significant quantities of groundwater, and are generally referred to collectively as the principal aquifer. In places, the principal aquifer is more than 1,000 feet thick and consists mainly of sands and gravels beneath terraces along the margins of the valley. In the eastern part of the valley, clays and silts predominate. Overlying the principal aquifer in the central part of the valley is a 100 to 300 feet thick section of clay, sand, and gravel deposits known as the "near surface reservoir." The principal aquifer and the near surface reservoir are separated by a variably thick, laterally discontinuous aquitard, or confining unit (USGS 1999).

Based on USGS publications (1999, 2010), the following sections present the development of water resources in the Las Vegas Valley Hydrologic Basin to contextualize historical groundwater withdrawal effects on the basin's aquifers.

Prior to 1905

Prior to the development of the Las Vegas metropolitan area, the water sources in the Las Vegas Valley consisted of six springs located in the western part of the basin. The largest desert oasis in the central valley was named Las Vegas, which is Spanish for "the Meadows". The primary sources of recharge to the valley were runoff from the Spring Mountains bounding the valley to the west and the Sheep and Las Vegas Ranges to the northwest. Historically, more than 24 inches of precipitation fell annually in the Spring Mountains, and more than 12 inches fell annually in the Sheep and Las Vegas Ranges, but less than four inches on the valley floor. Prior to development, the average amount of water recharging the aquifer system was in balance with the amount discharging, chiefly from the springs and evapotranspiration. Estimates of annual natural recharge of the aquifer system ranged from 25,000 to 35,000 acre-feet (USGS 1999). Under natural predevelopment conditions, groundwater flowed from the northwest and west across the valley to the southeast and east, toward the Las Vegas Wash (USGS 2010).

1905 to 1971

In 1905, a railroad was built in the valley along the route between Los Angeles and Salt Lake City with a stop at the flowing Las Vegas springs, which were located near the current Las Vegas Valley Water District main well field (see Figure 5-12). The surface water supply, which was used to operate steam locomotives, was soon supplemented by a well. The first major water supplier, the Las Vegas Land and Water Company, was formed in 1905 to support the settlement of Las Vegas. In 1907, the first uncapped flowing artesian well was installed by the Vegas Artesian Water Syndicate. This was eventually followed by intensive groundwater production to support urban development in the valley. The first uncapped artesian wells were allowed to flow continuously until the Comprehensive Underground Water Act was passed in 1939, after which well heads were capped. Additional rapid urban growth was fueled by the resort hotel industry, which began in 1941.

The Las Vegas Land and Water Company was replaced by the Las Vegas Valley Water District (LVVWD), which was created by the Nevada Legislature and began operation in 1954. Groundwater has been withdrawn continuously from the basin-fill deposits since that time, leading to declines in groundwater levels and spring flows. Following construction of Hoover Dam in 1932 and beginning in 1942, surface water from Lake Mead was conveyed to the BMI complex near Henderson to support manufacturing efforts during World War II. In 1955, the LVVWD also began to use this Lake Mead surface water pipeline to supplement groundwater supplies. Beginning in the early 1950s, groundwater use consistently exceeded natural recharge, with the maximum groundwater withdrawals reaching nearly 88,000 acre-feet in 1968.

By the early 1960s, five of the six largest valley springs, including the Las Vegas springs, had dried out. In 1995, only the Corn Creek springs located in the northwest part of Las Vegas Valley were still flowing (USGS 2000).

1971 to 2022

Prior to 1973, Las Vegas Valley relied primarily on groundwater to meet its water needs (USGS 2000). Beginning in 1971, surface water from Lake Mead was imported through a second larger pipeline constructed by the Southern Nevada Water Project[54]. Large scale imports began in 1972, leading to a reduction in groundwater pumping from nearly 85,000 acre-feet in 1971 to 71,000 acre-feet in 1972. The imports from Lake Mead continued to increase and since 1973, treated surface water from Lake Mead has been the primary source of water for the Las Vegas Valley. However, groundwater withdrawals continued to exceed natural groundwater recharge. Most of the groundwater production since 1973 has been from the municipal well fields in the west central part of the valley (see Figure 5-12). By 1990, groundwater elevations in the principal aquifer in this area had decreased by as much as 300 feet compared to predevelopment conditions. This area also experienced more than 5 feet of land subsidence between 1963 and 1987 (USGS 1999).

Since 1988, the LVVWD and the City of North Las Vegas have implemented artificial groundwater recharge programs to replenish the aquifers by injecting treated surface water imported from Lake Mead. By 1995, a total of nearly 115,000 acre-feet had been injected through more than 40 wells at an annual rate of up to 25,000 acre-feet during the winter, when water demand was less. Between 1988-2005, groundwater withdrawals stabilized at about 71,000 acre-feet per year, and groundwater levels recovered by almost 100 feet in the vicinity of the artificial groundwater recharge (USGS 2010).

Since the early 2000s, the southwestern US has experienced extended drought conditions that have resulted in unprecedented low surface water levels in the Colorado River reservoirs, including Lake Mead. In August 2022, the US Department of Interior (DOI) announced plans to reduce the annual allotment of Lake Mead surface water to Nevada, including Las Vegas (USDOI 2022). In May 2023, the DOI announced that the Bureau of Reclamation's draft Supplemental Environmental Impact Statement (SEIS) issued in April 2023 would be temporarily withdrawn to allow consideration of a Lower Basin, consensus-based system conservation proposal agreed upon by the three Lower Basin states (Nevada, Arizona, and California). The response to potential reduction in imported surface water, which may include increased groundwater withdrawals in addition to conservation efforts, was being evaluated by LVVWD and other water users at the time of this report.

Changes in the Regional Aquifer

Generalized cross-sections across the central Las Vegas Valley illustrate the difference between predevelopment and modern conditions (USGS 2010). These conceptual

---

[54] The Pittman Lateral pipeline, which crosses the NERT RI Study Area near the boundary between OU-2 and OU-3, was constructed as part of this surface water pipeline.

illustrations are reproduced in Figure 5-13. In this area of the basin, the combination of alluvium and underlying Muddy Creek Formation sediments form a thick sequence of coarse-grained sand and gravel deposits on the west side of the valley adjacent to the Spring Mountains. The basin-fill deposits become increasingly finer grained toward the east.[55] The predevelopment conditions shown in block A illustrate the shallow water table, with natural recharge primarily from mountain front recharge balanced by discharge to the flowing springs in the center of the valley and upward seepage to the surface washes on the eastern side. Modern conditions are illustrated schematically in the lower half of the figure (block B). A cone of depression of groundwater levels is present around the pumping wells, which represent approximately 75% of the groundwater discharge. The natural recharge from the mountain front runoff is supplemented by artificial recharge of Lake Mead surface water and excess infiltration of urban irrigation water (USGS 2000).

Over time, the municipal pumping has created large cones of depression in both the near-surface reservoir and the principal aquifer, which have changed the direction of groundwater flow in the regional aquifers. Instead of flowing generally to the southeast, the regional groundwater now flows toward the major pumping centers. In some areas of the central part of the valley, the natural upward hydraulic gradient has been reversed such that there is no upward leakage from the principal aquifer (USGS 2010). In addition, daily oscillating piezometric pressure responses to the regional groundwater pumping cycles have been observed in deeper monitoring wells. A study conducted by the USGS showed groundwater elevation oscillations on the order of 2 to 10 feet at a location approximately two miles from the LVVWD production wells (USGS 2000).

Effects of Regional Aquifer Pumping in the Vicinity of the NERT RI Study Area

No nearby groundwater production wells have been identified in the vicinity of the NERT RI Study Area that may affect local groundwater flow directions. At the NERT Site (OU-1), small daily piezometric pressure (or piezometric head) oscillations have been observed in transducer records for deep monitoring wells in the vicinity of Unit Building 4. In June 2018, daily pressure oscillations were observed in the transducer record for one well during pre-design for a treatability study at Unit Building 4. To further evaluate whether piezometric pressure oscillations could affect the treatability study design, transducers were installed in 14 existing onsite monitoring wells completed at depths between 90 and 290 feet bgs. Depending on the well completion depth, daily oscillating piezometric head variations between 0.25 inches and 2.5 inches of water were observed in the wells between November 9 and16, 2018. These small piezometric pressure response oscillations indicate confined groundwater conditions and may reflect the influence of distant regional groundwater pumping; however, they are not large enough to affect groundwater flow directions in the NERT RI Study Area or vicinity.

As part of the NERT Phase 6 Groundwater Flow and Transport Model report (Ramboll 2019g), a comprehensive review of the Nevada Division of Water Resources (NDWR) groundwater pumpage inventories from 2000 through 2018 was conducted in order to identify any other groundwater extraction occurring within the model area. For each year (2000-2018), any non-environmental extraction wells were identified in the groundwater pumpage data

---

[55] The generalized cross-section doesn’t distinguish the alluvium and the underlying Muddy Creek Formation coarse-grained sediments.

available from the Las Vegas Valley Water Use Report from Clark County, Nevada on the NDWR website (NDWR 2021).[56] This information has been updated for the period 2018-2021, the most recent NDWR data available.

In the Phase 6 model report, Ramboll identified two non-environmental (one industrial and one commercial) groundwater wells within the model boundary at locations approximately one mile west of OU-1, as shown in Figure 5-14. Neither well was actively pumping during the Phase 6 model simulation period (2014-2018). Subsequently, a third former non-environmental well was identified as described below.

- The industrial well is designated by its location (212 S22 E62 14) in Figure 5-14. According to the information on the NDWR website, the well is owned by Thatcher Chemical Company. It was installed on April 8, 1987 with a screen interval of 140-400 ft bgs. The well was active between 2000 through 2003, pumping between 0.06 and 2.23 gpm. There are no pumpage records after 2003, and the current status of this well is unknown (NDWR 2021).

- The commercial well is designated by its location (212 S22 E62 14CBAB1) in Figure 5-14. According to the information on the NDWR website, the well was owned by Savage Industries, Inc. It was installed on August 16, 1990 with a screen interval of 164-244 ft bgs. The well was active between 2000 through 2004, pumping between 0.5 and 1.18 gpm. There are no pumpage records after 2004, and NDWR records indicate the well was plugged in 2008 (NDWR 2021).

- A third former non-environmental industrial well was also identified at a location within OU-3. This former industrial well is designated by its location (212 S21 E63 31AAAA1) in Figure 5-14. According to the information on the NDWR website, the well was owned by Stewart Brothers and was active before 1998. There was no use after 1998, and the NDWR records note “Well not visible” after 2004. The last NDWR entry is dated March 13, 2008 (NDWR 2021).

Six non-environmental groundwater wells located near the NERT groundwater model extent are also shown in Figure 5-14. These include two irrigation wells to the northwest; neither well was active between 2018-2021. Two wells designated as mining use are located to the southwest; neither well has been active since 2002. Two quasi-municipal wells are located to the southeast approximately 1.5 miles from the OU-2 boundary. The well designated by location 212 S22 E63 09DABD1 is owned by Gillon. It was installed on March 8, 1980 and is screened from 380-460 ft bgs. Based on the NDWR pumpage records review, this well was active from 2000 through 2021, with pumping ranging between 0.19 and 2.73 gpm. The second well designated by location 212 S22 E63 09DACC1 is owned by the Strodel Trust. It was installed on September 9, 2006 and is screened from 350-450 ft bgs. Based on the records available, the well was active from 2008 through at least 2021, with pumping ranging between 0.06 and 0.62 gpm. Based on the well depths and distance from the NERT

---

[56] http://water.nv.gov/PumpageInventoryFiles.aspx. The model extent lies within Township 21 South Range 62 East, Township 21 South Range 63 East, Township 22 South Range 62 East, and Township 21 South Range 63 East.

RI Study Area, these low pumpage rates would not affect local groundwater flow directions within the NERT RI Study Area (NDWR 2021).

5.5.2 Local Hydrogeology

This section provides a general description of groundwater conditions within the NERT RI Study Area along with more detailed hydrologic information based on the findings of the RI. Comprehensive groundwater elevation tables for OU-1 and OU-2 wells are included in Appendix A1.

The south-to-north cross section shown in Figure 5-15 illustrates how the depth-to-groundwater varies across the three OUs. Within OU-1, first groundwater is mostly encountered between 30 and 45 ft bgs and tends to be deepest within the southern portion of the NERT Site Study Area near Lake Mead Parkway, generally becoming more shallow moving north towards the OU-1/OU-2 boundary. Within OU-2, groundwater is typically encountered between 20 and 60 ft bgs depending on topography and relative downgradient location; and there is a more irregular slope from south to north than found in OU-1, especially in the Eastside Sub-Area. Immediately north of the OU-1/OU-2 boundary, the depth to groundwater is approximately 20 ft bgs, before it becomes more shallow in the middle of OU-2, and deepens again further north approaching the OU-2/OU-3 boundary. Within OU-3, groundwater is generally encountered between 5 and 35 ft bgs, becoming shallower to the north and occurring near the ground surface at the Las Vegas Wash.

The groundwater flow direction within OU-1 is generally north to north-northwest, whereas within OU-2 and OU-3 the direction changes to north-northeast toward the Las Vegas Wash, which is the major drainage outlet for the Las Vegas basin. These generally uniform flow patterns may be influenced locally by: (a) lateral zones of coarser and more transmissive material (otherwise referred to as paleochannels) eroded into the underlying UMCf that serve as preferential flow pathways; (b) artificial groundwater highs or “hydraulic mounds” created around the COH Birding Ponds; and (c) hydraulic depressions created by the groundwater extraction well fields. The potentiometric surface based on data from second quarter 2018 is shown in Figure 5-16a. The effect of mounding around the COH Birding Ponds is evident in the higher groundwater elevation contours beneath the ponds compared to the adjacent area. Figure 5-16a also shows the extent of the saturated alluvium and the locations of the paleochannels that influence groundwater flow pathways in the saturated alluvium. As described in Section 5.4.2, stream-deposited sands and gravels were laid down within paleochannels eroded into the surface of the underlying Muddy Creek Formation during infrequent historic flood runoff periods. These channel fill deposits vary in thickness and are typically narrow and generally linear. These generally uniform sand and gravel deposits exhibit higher transmissivity than the adjacent, well-graded alluvial deposits. The configuration of paleochannels near the OU-1/OU-2 boundary is shown in Subsurface Cross-Section F-F’ (Figure 5-8). Along the OU-2/OU-3 boundary, the paleochannel intercepted by the Athens Road Well Field is illustrated on Subsurface Cross-Section K-K’ (Figure 5-10a). Further east, three smaller paleochannels along the OU-2/OU-3 boundary were investigated as part of the Phase 2 RI. All three were found to be above the water table and dry, and thus they would not currently serve as preferential groundwater flow pathways from OU-2 into OU-3 at this location. Paleochannel Transects A and B are shown in Subsurface Cross-Section K’-K” (Figure 5-10b). Paleochannel Transect C is shown in Subsurface Cross-Section K”-K”’ (Figure 5-10c).

As previously discussed, NDEP has defined the Shallow WBZ, Middle WBZ, and the Deep WBZ as the three WBZs present in the BMI Complex as described in the Hydrogeologic and Lithologic Nomenclature Unification guidance document (NDEP 2009a). The Shallow WBZ is defined by the first occurrence of groundwater in either the Qal, xMCf, or the UMCf where the xMCf is missing, is unconfined to partially confined, and is considered the "water table aquifer". The Middle WBZ extends from approximately 90 to 300 ft bgs. The Deep WBZ is defined as the contiguous WBZ that is generally encountered between 300 to 400 ft bgs. Environmental investigations within the NERT RI Study Area have historically focused on the Shallow WBZ, although recent investigations, including the RI, have included a number of Middle WBZ wells to improve vertical delineation of hydrogeology and chemical constituent distribution. Since the Deep WBZ wells are generally not impacted by COPCs above groundwater screening levels (GWSLs), these wells are not monitored on a regular basis.

5.5.2.1 Shallow Water-Bearing Zone

The Shallow WBZ comprises the saturated portions of the alluvium and the uppermost portion of the UMCf to a depth of approximately 90 ft bgs. The groundwater table contour map based on data from second quarter 2018 is shown in Figure 5-16a. These results are consistent with more recent results from the ongoing groundwater monitoring program. The alluvium was once saturated below the northern portion of OU-1. However, recent groundwater elevations measured during annual groundwater monitoring events show that, except for a few small areas, the alluvium has become dewatered and first groundwater now occurs within the UMCf. This condition is important because the water table is generally encountered in the UMCf where groundwater flow occurs at a significantly reduced rate, which reduces contaminant migration. Similarly, there are significant areas within the eastern portion of OU-2 where the alluvium is dewatered. Within OU-3, the alluvium is generally saturated. As described above, the groundwater flow direction within OU-1 is generally north to north-northwest, whereas within OU-2 and OU-3 the direction changes towards the north-northeast.

As part of the RI, many new wells were installed in the UMCf in the lower depth interval of the Shallow WBZ, generally between approximately 55-90 ft bgs. Potentiometric surface maps of the Shallow WBZ (55-90 ft bgs) in OU-1 and OU-2 are presented in Figures 5-16b and 5-16c, respectively. The overall groundwater flow directions in the UMCf within the Shallow WBZ (55-90 ft bgs) are generally similar to the Shallow WBZ (0-55 ft bgs). Additional wells screened in the Shallow WBZ (55-90 ft bgs) are planned to be installed in OU-3, and the groundwater flow directions in OU-3 will be evaluated as part of the forthcoming OU-3 RI.

The transmissivity of the alluvial sands and gravels is generally high, particularly within paleochannels and closer to the Las Vegas Wash. The transmissivity of the underlying UMCf, which is generally finer-grained, is significantly lower. A summary of aquifer testing results conducted as part of the RI (including treatability studies) is provided in Appendix D. The geometric mean hydraulic conductivity from slug tests screened only in the alluvium is 20 ft/day (7.1×10^{-3} centimeters per second [cm/sec]). The geometric mean is 4.4 ft/day (1.6

x 10^{-3} cm/sec) in wells screened across both the alluvium and UMCf,[57] and 0.12 ft/day (4.2 x 10^{-5} cm/sec) in wells screened only across the UMCf. Thus, groundwater flow rates in the Shallow WBZ are substantially higher within the alluvium, where saturated, than within the UMCf. The highest flow rates occur within paleochannels in the alluvium where the saturated thickness is greatest. In the paleochannel downgradient of the AWF, the alluvium hydraulic conductivity from a slug test was approximately 300 ft/day (0.11 cm/sec), which is more than an order of magnitude higher than the geometric mean hydraulic conductivity in the alluvium (which includes the finer grained sediments surrounding the paleochannels).

In the area between the northern boundary of OU-1 and the AWF, the average groundwater velocity in the alluvium is estimated to be within the range of 1,900 to 3,700 feet per year (ft/yr). In the area between the AWF and the SWF, the average groundwater velocity in the alluvium is estimated to be within the range of 2,600 to 5,700 ft/yr. In the Phase 6 model (Ramboll 2019g), a value of 45 feet per day is applied as the hydraulic conductivity of alluvium throughout the model domain. Using the hydraulic gradient of 0.015 ft/ft (shown in Figure 5-16c), along with modeled effective porosity value of 0.10, would result in a groundwater velocity of about 2,565 feet per year. However, the flow field in the model varies due to the presence of paleochannels, pumping wells, and stagnation zones in between the capture zones of individual pumping wells. Thus, the range of modeled estimated groundwater velocity is reasonable. These groundwater velocities, estimated using the groundwater model (Ramboll 2019g), are equivalent to travel times in the alluvium of 2.9 to 5.7 years from the OU-1 boundary to the AWF, and 0.8 to 1.8 years from the AWF to the SWF.

5.5.2.2 Middle Water-Bearing Zone

Within OU-1, the sediments within the Middle WBZ consist predominantly of the UMCf-fg1. Consistent with the discussions of COPC distributions in groundwater presented in Sections 7 and 8, groundwater flow directions have been evaluated in three depth intervals: from 90-130 ft bgs, from 130-175 ft bgs, and from 175-300 ft bgs.

The potentiometric surface maps for the Middle WBZ 90-130 ft bgs depth interval in OU-1 and for the entire NERT RI Study Area (OU-1, OU-2, and OU-3) are presented in Figure 5-17a and Figure 5-17b, respectively. As illustrated in Figure 5-17a, the groundwater flow direction within OU-1 is northerly. As shown in Figure 5-17b, there are fewer Middle WBZ wells in OU-2 and OU-3; however, the available groundwater elevation data indicates a change in groundwater flow direction toward the northeast, particularly in OU-2. Within the northern portion of OU-3, data from wells located near the Las Vegas Wash indicate a groundwater flow direction toward the northeast. In the southeast corner of OU-3, data from well ES-18 located indicates a northwesterly flow direction.

The potentiometric surface map for the Middle WBZ 130-175 ft bgs depth interval in OU-1 is shown in Figure 5-17c. The overall groundwater flow direction within OU-1 is northerly,

---

[57] The hydraulic conductivity of a cross-screened well is influenced by the relative proportion of low and high conductivity intervals exposed at the well screen, which varies by well. As such, the overall geometric mean of hydraulic conductivity of cross-screened wells is presented to show the aggregate results of hydraulic testing of cross-screened wells and should not be interpreted as the average conductivity of the alluvium and UMCf formations.

consistent with the flow direction in other depth intervals beneath OU-1. Figure 5-17d presents the groundwater elevations for wells within the entire NERT RI Study Area. While the number of wells in this depth interval are limited, the available data indicates a northerly flow direction across OU-2. The available data from wells located in the southeast and northeast corners of OU-3 are consistent with a north-northeasterly groundwater flow direction below OU-3.

The potentiometric surface map for the Middle WBZ 175-300 ft bgs depth interval in OU-1 is shown in Figure 5-17e. Within OU-1 and within this depth interval, the UMCf-cg2 occurs below the fine-grained unit at the base of the Middle WBZ, roughly between approximate depths of 280 to 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, and TR-12) and by four wells at the adjacent OSSM site (MW-08, DMC-MW-26, DMC-MW-27R, and DMC-MW-28). The UMCf-cg2 unit is confined, as indicated by artesian groundwater elevations consistently measured in these wells. Figure 5-17e shows potentiometric elevation contours for the ten wells screened in the UMCf-cg2, which indicate a northeasterly groundwater flow direction. The UMCf-cg2 unit pinches out a short distance north of Warm Springs Road and is not present further to the north in OU-2 and OU-3. Other wells are screened in the UMCf fine-grained sediments. As shown in Figure 5-17f, the number of deeper Middle WBZ wells in OU-2 and OU-3 is very limited; however, the available data indicate an overall northerly groundwater flow direction in the UMCf fine-grained sediments within this depth interval.

To better characterize hydraulic properties in the Middle WBZ UMCf fine-grained unit, slug tests were conducted in all the existing and new Trust-owned wells completed in this unit. The slug testing results are presented in Appendix D. The hydraulic conductivities for the 16 wells screened in silt were very low, ranging from 0.00093 ft/day (3.3×10^{-7} cm/sec) to 0.084 ft/day (3.0×10^{-5} cm/sec). For the five wells screened in sandy silt intervals, the hydraulic conductivities were higher, ranging from 0.22 ft/day (7.8×10^{-5} cm/sec) to 0.69 ft/day (2.4×10^{-4} cm/sec). In the area between the northern boundary of OU-1 and the AWF, the average groundwater velocity in the UMCf fine-grained unit is estimated using the groundwater model to range from 18 to 32 ft/yr. In the area between the AWF and the SWF, the average groundwater velocity in this unit is estimated using the groundwater model to range from 14 to 24 ft/yr. These groundwater velocities are equivalent to travel times of 64 to 116 years from the OU-1 boundary to the AWF, and 72 to 119 years from the AWF to the SWF.

As described above, the UMCf-cg2 occurs below the fine-grained unit at the base of the Middle WBZ, roughly between approximate depths of 280 to 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, and TR-12). The UMCf-cg2 unit is confined, as indicated by artesian groundwater elevations consistently measured in these wells. The hydraulic conductivities calculated based on slug tests in wells TR-7 and TR-9 were 1.2 ft/day (4.2×10^{-4} cm/sec) and 2.9 ft/day (1.0×10^{-3} cm/sec), respectively. Within OU-1, the range of average groundwater velocities in this unit from the groundwater model range from 80 to 90 ft/year.

5.5.2.3 Deep Water-Bearing Zone

The Deep WBZ is present below a depth of 300 ft bgs. The sediments within the Deep WBZ consist predominantly of the UMCf fine-grained deposits. Twenty-two Deep WBZ wells installed by BRC as part of their investigations are located within OU-2 and OU-3. As indicated, the Deep WBZ wells are not impacted by COPCs above GWSLs. As a result, the NERT and BRC sampling plans (both approved by NDEP) do not require monitoring of these wells on a regular basis. The well locations are shown in Figure 5-18 along with groundwater elevations measured in eight wells in the second quarter of 2018 as part of the Phase 3 RI investigation in the Eastside Sub-Area. Approximate potentiometric surface contours based on this limited data set show an overall groundwater flow direction toward the north.

5.5.2.4 Historical Groundwater Elevations and Flow Directions

Historical groundwater contour maps from 1980 through 1998 are included as Figures 5-19a through 5-19j. The sources of the maps are referenced on each of the corresponding figures. The groundwater contour map from 1980 (Figure 5-19a) documents a northern groundwater flow direction beneath OU-1 and OU-2 that shifts to the northeast and then east near the Las Vegas Wash. Groundwater flow across the OSSM Site was generally to the northeast. Groundwater flow directions were generally similar on the contour maps shown in Figures 5-19b, 5-19c, and 5-19d.[58] The groundwater contour map from 1985 (Figure 5-19e) shows a northwestern groundwater flow across OU-1. This change in direction is attributed to the activation of the OSSM GWETS in 1983. The cone of depression for the GWETS is clearly visible near the northwest corner of the NERT site. The groundwater contour maps shown in Figures 5-19f through 5-19i indicate that the groundwater flow direction in the area north of OU-1 is generally to the north from 1984 to 1987. The 1998 (Figure 5-19j) groundwater contour map continues to document the northwestern flow across OU-1 toward the OSSM GWETS extraction wells, but also shows a generally north to northeastern flow in OU-2 and OU-3 similar to current conditions.

The groundwater elevations near the southern and middle extent of OU-1 are nearly the same in 1985 (Figure 5-19e) as in the second quarter of 2018 (Figure 5-16a). A comparison of the 1985 and 2017-2018 water table elevations along the OU-1 south to north cross-section M-M’ is presented in Figure 5-19k. The location of the OU-1 barrier wall/IWF Well Field, which began operation in mid-1987, is shown on the cross-section. Recharge trenches on the downgradient (north) side of the barrier wall were in operation from the time the IWF was installed until September 2010. As can be seen in Figure 5-19k, the 1985 and 2017-2018 groundwater elevations upgradient (south) of the IWF are nearly the same. This suggests that the shallow alluvium in OU-1 was no longer saturated in the 1980s as the result of the discontinuation of the use of unlined ponds in the 1970s. In the area of OU-1 and OU-2 north of the IWF, the water table elevation in 1985 prior to the operation of the IWF was higher than in 2017-2018. After the recharge trenches ceased operation in 2010, shallow OU-1 monitoring wells screened in the alluvium north of the IWF gradually became dewatered and were completely dry by 2011-2012. The dewatering of the more permeable alluvium reduced the potential for migration of shallow impacted groundwater from OU-1 and the northern portion of OU2.

---

[58] The quality of the historical map reproductions shown in these figures is generally poor due to the poor quality of the source documents.

In summary, there is no significant change in groundwater flow direction from the 1980s to present day. However, in 1985 shallow groundwater flow across OU-1 appears to be more northwest as a result of the operation of OSSM's GWETS. With initiation of the IWF in 1987, groundwater flow appears to have slightly shifted to the north.

5.5.2.5 Vertical Gradients

Investigations of the Middle WBZ within OU-1 and OU-2 indicate, with a few exceptions, a vertical upward gradient is present between the Middle and Shallow WBZs that generally increases with depth. In the area immediately downgradient of the IWF, vertical head differences between Middle and Shallow WBZ wells ranged from 5 to 26 feet during second quarter 2018 with calculated vertical gradients ranging between 0.05 and 0.2 ft/ft in the upward direction. Upward vertical gradients were generally more prominent near the western and central portions of the barrier wall. At the AWF, two wells were installed as part of the Phase 1 RI that are screened deeper within the Shallow WBZ, PC-134D and PC-137D, to depths of 90 feet. During second quarter 2018, the vertical head differences measured between PC-134D and PC-137D and corresponding wells screened within the Qal were 6.0 and 2.8 feet, respectively, with upward vertical gradients of 0.1 and 0.05 ft/ft.

Tetra Tech, Inc. (Tetra Tech) evaluated vertical groundwater gradients between the Middle and Shallow WBZs in the vicinity of the OU-2/OU-3 boundary as part of their pre-design investigation for the Galleria Drive Bioremediation Treatability Study. The gradient in that area was found to be downward in the range of 0.16 to 0.32 ft/ft (Tetra Tech 2019a). Ramboll also evaluated vertical gradients along Galleria Drive as part of the Phase 1 pre-design investigations performed in support of the ZVI-Enhanced Bioremediation Treatability Study. Vertical gradients between the Shallow and Middle WBZs in the Galleria Drive ZVI Study Area were also found to be downward in the range of 0.02 to 0.04 ft/ft (Ramboll 2021h).

Vertical gradients in the vicinity of the SWF will be evaluated using groundwater elevation data obtained from newly installed deep wells and presented in the forthcoming RI Report for OU-3.

Vertical gradients were also evaluated using available transducer data collected along with manual groundwater elevation measurements during second quarter 2018 and the first two quarters of 2019. Clusters of wells within an approximately 135-foot radius were first identified and vertical gradients were then calculated for each well within each cluster. The location of the mid-screen elevation for each well was used to calculate the vertical distance between wells in a cluster, and the mid-screen elevation of the deeper well in each cluster were compared to the depths of the Shallow, Middle, and Deep WBZs defined above to determine the WBZ of each cluster. These well clusters and approximate vertical gradients for the Shallow, Middle, and Deep WBZs are shown in Figures 5-20a, 5-20b, and 5-20c. For space considerations, Middle WBZ clusters shallower than 110 ft bgs are shown in Figure 5-20a with the Shallow WBZ clusters, and Middle WBZ clusters deeper than 220 ft bgs are shown in Figure 5-20c with the Deep WBZ clusters. All vertical gradient calculations are presented in Table 5-1.

There is generally an upward vertical gradient that increases with depth at the Site and surrounding areas; however, downward vertical gradients have been identified in two areas.

The area west of the Site in the vicinity of AMPAC's deep extraction wells has a downward vertical gradient between the Middle and Shallow WBZs due to operation of these deep extraction wells. Downward vertical gradients have also been measured in the vicinity of the OU-2/OU-3 boundary at the former Galleria Drive Bioremediation Study Area and the former ZVI-Enhanced Bioremediation Study Area, and recorded by transducers installed in paired wells AA-07 and MCF-07. The alluvium is not saturated near these Treatability Study Areas (see Figure 5-16a) and there are no extraction well lines nearby to influence the vertical gradient. Well cluster AA-07 and MCF-07 may be locally impacted by surface water infiltration from the Chimera Golf Course. Vertical gradients in this area and other areas within OU-3 will be further evaluated in the RI Report for OU-3 once sufficient data are available from deployed transducers and newly installed wells. The presence of upward vertical gradients is a significant finding of the NERT RI, which will be further evaluated with respect to its long term effects on contaminant transport.

During the historical period of perchlorate and chlorate production between 1945 and prior to the use of lined on-site ponds in 1977, there were likely significant releases of wastewater from unlined ponds and ditches. As a result, groundwater levels would have been much higher than they are currently and the natural upward gradient would have been reversed to a downward gradient between the Shallow and Middle WBZs, particularly within OU-1 and the portion of OU-2 east of Pabco Road. In the vicinity of the perchlorate and chlorate production areas, particularly the Unit 4 and 5 Buildings, releases of high-density brines used in the production process would also have contributed to the upward gradient reversal due to density effects. There are no data on the density of the brine released during prior operations, but the patent for the type of electrolytic cell used for perchlorate production at the Unit 4 and 5 Buildings specifies the use of a brine with a total dissolved solids (TDS) concentration greater than 500,000 mg/L (US Patent Office 1950). As described in the Unit Buildings 4 and 5 Source Area Characterization Report, TDS concentrations up to 48,000 mg/L were measured in groundwater beneath the Unit 4 and 5 Buildings indicating that brines were released during manufacturing operations (Tetra Tech 2020). It was principally during this period with a downward gradient that perchlorate and other COPCs would have moved downward into the UMCf. In areas with larger downward gradients and/or where the UMCf was coarser-grained, perchlorate and other COPCs would have migrated to greater depths.

5.5.2.6 Temporal Groundwater Elevation Trends

Groundwater elevation trends for representative wells in OU-1 and OU-2 are shown in Figures 5-21a and 5-21b, respectively. Representative wells were selected based on the availability of long data records that are generally representative of groundwater conditions because the pattern of groundwater elevation changes in these wells is very similar to that of other nearby wells. In OU-1, water levels in Shallow WBZ wells (see top panel of Figure 5-21a) are stable or are trending downwards, while water levels in Middle WBZ wells screened in the UMCf-cg2 (see bottom panel of Figure 5-21a) are trending upwards. As noted above, there is an upward gradient from the Middle WBZ to the Shallow WBZ. In addition, there is also a downward trend in Shallow WBZ wells which is attributed to recent drought conditions, increased groundwater extraction, and the decommissioning of the recharge trenches in 2010. Shallow WBZ wells near the IWF (e.g., M-75) have stable water levels because they are highly influenced by the float switches controlling pumping rates at the IWF. The reason for the upward trend in water levels in the UMCf-cg2 is not known but may be a response to changes in regional water supply pumping rates. During treatability studies in the area of the Unit 4 Building, continuous water level monitoring in Middle WBZ wells detected diurnal water level fluctuations. These fluctuations appear to be caused by diurnal fluctuations in regional groundwater pumping from units below 300 ft bgs, as described by Pavelko (2000).

The water level trends in OU-2 are generally similar to those in OU-1 (see Figure 5-21b). The Shallow WBZ wells have a general downward trend, while there is an upward trend in TR-12 which is the only OU-2 well screened in the UMCf-cg2 formation before it pinches out. The water level trend in shallower Middle WBZ wells (such as M-156 screened from 175 to 195 ft bgs) resembles the Shallow WBZ wells.

Seasonal hydraulic trends were evaluated using an autocorrelation method in the 2021 Annual Groundwater Monitoring and GWETS Performance Report (Ramboll 2022a). The temporal autocorrection of water levels was calculated at 85 locations throughout the NERT RI Study Area with at least 18 months of transducer data. The autocorrelation of a time series is a measure of the degree of correlation that any point in the time series has with other points in the same series. A high autocorrelation is shown at a difference of one month for all wells, indicating the elevation in one month is highly correlated with the elevation in the prior and next months. A seasonal trend would be observed as a high autocorrelation at a difference of 12 months (possibly also at differences of multiples of 12 months). Seasonal patterns were not observed in the wells evaluated except for two wells located immediately adjacent to the Las Vegas Wash (WMW3.5S and WMW6.9S), indicating that any other trends may be responses to more irregular recharge events.

5.5.3 Nuclear Magnetic Resonance Investigation

As directed by NDEP, NMR logging has been conducted to date in more than 240 wells within the NERT RI Study Area. A selection of representative NMR logs is discussed in this section to illustrate the technique, while a more complete description of the NMR logging and all of the NMR logs of RI wells is provided in Appendix E. NMR is a geophysical technique that is sensitive to formation water content and pore structure in the vicinity of the well casing. The physical property measured by NMR is the magnetic spin of the hydrogen protons in water molecules. A magnetic field is applied which perturbs the spins of the protons, and then the time it takes for the spins to return to equilibrium is measured by the instrument. This time, called the relaxation time, is longer for larger water-filled pores and shorter for smaller water-filled pores. Since geologic materials are heterogeneous, there is a distribution of relaxation times corresponding to the distribution of pore sizes within the geologic material. The relaxation time distribution can be used to estimate the total water-filled porosity, as well as the fraction of total porosity associated with larger pores (referred to as mobile porosity). Using empirical correlations, the relaxation time and porosity can be used to roughly estimate hydraulic conductivity. As described in Appendix E, the hydraulic conductivity estimates from NMR were not found to be consistently accurate when compared to aquifer testing results from the same well, particularly in very low conductivity units.

A key showing the elements of the NMR log is shown in Figure 5-22a. There are three main columns on the log: 1) relaxation time distribution (in color) and mean (in white), 2) mobile water content (in blue) and total water content (in gray), and 3) hydraulic conductivity. Between the first two main columns, there is a narrow column showing the NMR noise level, a measure of NMR accuracy. Between the second and third main columns, the stratigraphic unit and Unified Soil Classification System (USCS) soil classification from the geologic log are shown for reference. When available, laboratory measurements of effective and total porosity are shown as point symbols on the water content column. Similarly, when available, slug test results are shown at the depth of the well screen on the hydraulic conductivity column. The locations of representative logs are shown in Figure 5-22b, with the representative logs shown in Figures 5-23a through 5-30.

Representative logs from OU-1 wells TR-9, M-271, and M-268 are shown in Figures 5-23a through 5-25. On the log for well TR-9 located in the southern portion of OU-1, both of the coarse-grained UMCf-cg1 and UMCf-cg2 units can be clearly seen in the relaxation time and mobile porosity columns. The estimate of hydraulic conductivity from the NMR readings almost exactly matches the measured conductivity from a slug test. On the logs for M-271 and M-268, located in the northern portion of OU-1, only the finer-grained UMCf-fg is visible because the UMCf-cg1 unit has pinched out and the wells do not go deep enough to encounter the UMCf-cg2 unit. The NMR response in the UMCf-fg unit has a generally lower mean relaxation time and lack of mobile porosity as compared to the UMCf-cg units.

Representative logs from the western part of OU-2 (M-152 and PC-137D) are shown in Figures 5-26 and 5-27. The log for M-152 shows generally very fast relaxation times and high total porosities consistent with the boring log observations of silts and clays. The NMR estimate of hydraulic conductivity is too high by approximately an order of magnitude as compared to the slug test result. The log for PC-137D appears to indicate a sandier zone above 70 ft bgs, but this result may be biased by the high levels of noise in this portion of the log. Laboratory measurements of total and effective porosity are shown as point symbols on the log in the middle main panel. The correspondence between the NMR mobile and total water content and the laboratory measurements of effective and total porosity is good in this case.

Representative logs from the eastern part of OU-2 (ES-1, ES-30, and ES-13) are shown in Figures 5-28 through 5-30. The NMR responses confirm the field observations of tight soils in the UMCf in this area. The NMR estimates of hydraulic conductivity were reasonable for ES-1 and ES-30, but were too high for the very low conductivity silt and clay-rich soils at ES-13.

In general, the NMR logs were found to be a useful tool for confirming field observations of lithology and providing an estimate of porosity that is more representative of in-situ conditions than laboratory measurements. NMR logging has been used for decades in the petroleum industry to estimate the hydraulic properties of reservoirs, including total porosity (Coates et al. 1999). Below the water table, the NMR-measured water content is a good estimate of total porosity, which has been validated across a large range of geologic materials, including unconsolidated sediments (Keating and Falzone 2013; Behroozmand et al. 2017; Keating et al. 2020). Given the difficulty of obtaining undisturbed cores to test for porosity in the laboratory, the NMR porosity measurements are considered to be more representative of field conditions than the laboratory measurements. There are also many more NMR measurements available than laboratory measurements, and the NMR measurements were collected throughout the RI Study Area at many different depths. Since NMR data are consided to be more representative of undisturbed field conditions than laboratory measurements, the NMR data were used in the mass estimates. Thus, the average porosity values used in the contaminant mass estimates presented in the Annual Performance Reports since 2019 and in Section 9.7.3 are based on the average of the NMR water content measurements collected during the NERT RI.

While NMR provides a direct measurement of total porosity, the NMR method does not provide a direct measurement of effective porosity. During data processing, the total porosity measured by the NMR tool is partitioned into mobile and non-mobile porosity using a relaxation time cutoff that was developed from studies of oil reservoir sandstones. This relaxation time cutoff was selected to correspond to the lower limit of pore size in an oil reservoir that would allow fluid flow (Coates et al. 1999). In unconsolidated near-surface sediments such as those logged in the NERT RI Study Area, this cutoff used to define mobile porosity does not have a clear interpretation. Effective porosity is not defined by the size of the pores, which is measured by NMR; rather, it is defined as the portion of total void space of a porous material that is capable of transmitting a fluid (Gibb et al. 1984). Particle size, shape, and packing affect the connectivity of the pores and ability to allow water to flow. Further, fluids held on the surface of the grains within the pores by surface tension or molecular forces are immobile and do not participate in flow (Gibb et al. 1984). Regardless of their size, some pores are dead ends or not connected to the other pores. Since these pores do not participate in flow, they would not be included in effective porosity, but depending on their size could be included in the mobile porosity from NMR. For this reason, the mobile porosity estimates from RI-derived NMR data will not be used to characterize effective porosity, one of the parameters needed for groundwater modeling. Instead, and as discussed in Appendix E, effective porosity in the NERT groundwater model will be defined based on laboratory measurements, tracer test results, literature values, isotope studies, and model calibration.

As discussed in Appendix E, NMR is not an accurate method for determining hydraulic conductivities in very low conductivity sediments such as those found in the UMCf. As a result, the NMR-estimated hydraulic conductivities are not used in the RI.

5.6 Surface Water

The NERT RI Study Area is located in a very arid region with few natural surface water bodies; however, surface water is present in some areas of OU-1 and the surrounding area, primarily in surface water impoundments receiving process wastewater, lined artificial lakes, and within the COH Birding Ponds, which are associated with the City's municipal wastewater treatment plant. Surface water is also present on the ground surface and within retention basins following storm events.

During the 2011-2012 soil removal action, OU-1 was graded such that storm water would be retained on-site. Two retention basins with a connecting drainage channel were constructed to receive water during storm events: (1) the Central Retention Basin, located approximately 800 feet south (upgradient) of the IWF, and (2) the Northern Retention Basin, located approximately 300 feet north (downgradient) of the on-site groundwater barrier wall (Figure 1-4). The shallow channel located along the eastern side of the Site connects the two retention basins and conveys overflow from the Central Retention Basin into the Northern Retention Basin.

Surface runoff from on-site areas and a majority of water collected by the storm sewer network within the EMD-leased area is directed to the Central Retention Basin. Previously, the west end of the former Beta Ditch at the Site (the Beta Ditch Extension) continued to receive storm water drainage from the neighboring property to the west during major storm events. The former Beta Ditch Extension and contaminated soils were excavated in 2010. Given the current topography along the western property boundary, there is the potential for a small volume of storm water to enter OU-1 from the west through surface flow, which is collected in topographic depressions on the Site and/or in the Central Retention Basin. Surface runoff from north of the former Beta Ditch is generally directed to the Northern Retention Basin. The design capacities of the Central and Northern Retention Basins are approximately 1.3 and 1.2 million cubic feet, respectively (RCI 2010).

Surface water within OU-2 generally occurs infrequently as storm runoff in shallow washes and flows north toward the Las Vegas Wash; however, this will likely change due to rapid and ongoing development in the Eastside Sub Area. The only unlined, standing body of water within the Study Area is a small portion of the Birding Ponds within the COH WRF that are located within OU-3, but most are located west of the OU-3 boundary. Other artificial ponds or lakes within the Study Area, such as GW-11, process water ponds within the EMD leasehold (within OU-1), or the body of water within the Cadence master-planned community (within OU-2) are lined and therefore unlikely to result in local groundwater mounding or otherwise interact with the local water table.

Las Vegas Valley is drained by the Las Vegas Wash, a 12-mile-long channel located approximately 2.6 miles north of the OU-1, which flows into Lake Mead. Accounting for less than 2% of the water in Lake Mead, the water flowing through the Wash consists of urban runoff, shallow groundwater, storm water and treated wastewater from the Clark County Sanitation District, the COH, the City of Las Vegas, and treated discharge from NERT, TIMET, AMPAC. Prior to the development of Las Vegas Valley, the Las Vegas Wash was an ephemeral stream. Currently, the flow is perennial and composed almost entirely of effluent from wastewater treatment plants. This increase in flow caused significant erosion and downcutting of the Las Vegas Wash channel. A program of weir construction has been conducted by the Las Vegas Wash Coordinating Committee to address erosion and downcutting. The Pabco Road Weir and part of the Historic Lateral Weir were constructed in early 2000. Eleven more weirs were constructed between 2000 and the present. The Las Vegas Wash is located in the Downgradient Study Area of OU-3 and will be discussed in more detail within the forthcoming RI report for OU-3.

6. SCOPE OF THE REMEDIAL INVESTIGATION

This section presents the scope of the RI conducted in the NERT RI Study Area shown in Figure 6-1. The purpose of the RI is to investigate the nature and extent of contamination in OU-1 and within the downgradient plume in OU-2 and OU-3 to obtain data to support future risk assessments and FS evaluations and selection of the final remedy. This report focuses on the activities completed in OU-1 and OU-2.

Prior to the establishment of NERT, the area that now makes up OU-1, as well as portions of the downgradient area within OU-2 and OU-3, had been the subject of multiple environmental investigations as detailed in Setion 3 of this report. When NERT took title to the property, and consistent with the Interim Consent Agreement between the Trust and NDEP, NERT immediately began efforts to launch an RI/FS. Since its inception in 2014, the NERT RI evolved as new data was acquired.

As part of the initial RI/FS Work Plan for the NERT Site Study Area and associated downgradient plume to the north (ENVIRON 2014c), a data gap investigation was deemed necessary for areas that required further characterization to determine the nature and extent of COPCs in soil and groundwater. Beginning in 2014, data gaps were addressed in multiple phases of investigation, and as time progressed, new data gaps were addressed through discrete work plan modifications to the various phases of the investigation to streamline/accelerate the remedial process. Table 6-1 summarizes the dates of the various phases (including the work plan modifications) for the NERT RI field work.

As part of the RI/FS Work Plan (ENVIRON 2014c), a list of investigative COPCs was developed. These investigative COPCs were established to characterize the nature of contamination within OU-1, determine what contaminants had migrated off-site, and characterize the extent of contamination in soil and groundwater throughout the entire NERT RI Study Area. The initial phase of the RI (the Phase 1 RI), which included investigation of the NERT Site Study Area and NERT Off-Site Study Area, was completed and documented in the Technical Memorandum, Remedial Investigation Evaluation (Ramboll Environ 2016c). This memorandum identified additional data gaps that were identified after reviewing the Phase 1 RI data and included a Phase 2 RI work plan that was approved by NDEP in August 2016. Based on the results of the Phase 1 RI, the investigative COPCs were reduced as appropriate based on the extent of contamination determined at that time.

During the development of the Phase 2 RI, NDEP determined that the NERT RI Study Area should be expanded to include the Downgradient Study Area which was an extension of the RI that was already being conducted by the Trust. While funded by the Trust, this investigation was designed, implemented, and managed directly by NDEP and was documented in the series of work plans prepared in late 2015 and early 2016 (AECOM 2015, 2016a, 2016b). The investigative COPCs for the Downgradient Study Area were selected based on the environmental data available at that time. In 2017, and consistent with direction from NDEP, the Phase 3 RI Work Plan (Ramboll Environ 2017m) was developed to address select contaminants within the Eastside Study Area, including the Eastside and Northeast Sub-Areas. As discussed throughout this report, NERT is only responsible for perchlorate and chlorate impacts within the Eastside Sub-Area. Therefore, the NERT RI efforts have focused on perchlorate and chlorate in the Eastside Sub-Area. Chromium and hexavalent chromium were added to the NERT RI program investigative COPC list for the Northeast Sub-Area for consistency with the ongoing investigation within the Downgradient Study Area. Concurrent with the multiple phases of the RI, NERT also completed a source area investigation of soil and groundwater beneath the Unit 4 and 5 Buildings between 2015 and 2017 (Tetra Tech 2020).

In order to facilitate implementation of the RI and ultimately the final remedial action, the NERT RI Study Area was organized into three OUs (as described in Section 4). As such, NERT's reporting associated with the RI and subsequent FSs will be based on OUs. OU-1 and OU-2, the subject of this report, encompass the entirety of the NERT Site Study Area, the entirety of the NERT Eastside Sub-Area, and the portion of the NERT Off-Site Study Area located south of approximately Galleria Drive. OU-3, the subject of forthcoming reporting, encompasses the entirety of the Downgradient Study Area, the entirety of the Northeast Sub-Area, and the remaining portion of the NERT Off-Site Study Area located generally north of Galleria Drive.

The scope of the various elements of the RI located within OU-1 and OU-2 are presented in this section, with the investigation results presented in Sections 7 and 8. The complete scopes, various elements, and results of the RI located within OU-3 will be reported in the forthcoming RI Report for OU-3, although some aspects of the OU-3 investigation completed as part of the Phase 1 RI, Phase 2 RI, and Phase 3 RI are included in this section.

Investigations at the NERT RI Study Area associated with the Phase 1 RI, Phase 2 RI (inclusive of the Unit 4 and 5 Buildings Investigation), Phase 3 RI, Downgradient Study Area investigation, and all RI modifications discussed in this report were conducted in accordance with the procedures described in multiple documents that have been updated over the course of the RI, as required. Current versions of these documents are referenced herein. The RI/FS Work Plan includes a SAP, which comprises the Field Sampling Plan (FSP), Revision 1 (FSP; ENVIRON 2014d), the Quality Assurance Project Plan, Revision 6[59] (QAPP; Ramboll 2021a), the Health and Safety Plan, Revision 1 (HASP; Ramboll Environ 2017a), and the HASP Addendum for the Phase 3 RI (Ramboll Environ 2017q). Where appropriate, some activities (e.g., dust control, excavation work, etc.) were completed in accordance with the SMP that was current at the time (revised annually) (Ramboll 2018b; 2019i; 2020f).

6.1 Overview of the OU-1/OU-2 RI Field Investigations

The Phase 1, Phase 2, and Phase 3 RI field activities have been conducted within the NERT RI Study Area. This report specifically discusses results obtained in OU-1 and OU-2; however, many of the RI field activities have been implemented simultaneously and the history of the field program is complex. As such, some field activities referenced and documented in this report from the Phase 1, Phase 2, and Phase 3 field efforts include work completed in OU-3 (e.g., well construction and survey data). The results of the investigation in OU-3 will be presented in the RI Report for OU-3.

---

[59] The QAPP has been revised several times over the course of the RI. Previous versions of the document are as follows: QAPP, Revision 1 (ENVIRON 2014e); QAPP, Revision 2 (Ramboll Environ 2017l); QAPP, Revision 3 (Ramboll 2019c); QAPP, Revision 4 (Ramboll 2019h); and QAPP, Revision 5 (Ramboll 2020d). Much of the work described as part of the OU-1 and OU-2 RI was conducted under QAPP, Revisions 1 - 3.

Within OU-1, approximately 3,560 soil samples (3,170 analytical samples and 390 physical property samples), 830 groundwater samples, and 110 soil gas samples were collected as part of the RI. Within OU-2, approximately 1,030 soil samples (750 analytical samples and 280 physical property samples), 370 groundwater samples, and 130 soil gas samples were collected as part of the RI.

The Phase 1, Phase 2, and Phase 3 RI field investigations were conducted by Ramboll and the Unit 4 and 5 Buildings Investigation was conducted by Tetra Tech, both with the assistance of the key subcontractors described below. AECOM conducted investigative activities in OU-3, under contract with NDEP, which will be reported in the forthcoming RI Report for OU-3.

Drilling, monitoring well installation, and well development for the three phases of the RI and the Unit 4 and 5 Buildings Investigation was largely conducted by Cascade Drilling, LP (Cascade, formerly National Exploration Wells & Pumps). Some drilling and monitoring well installations during the Unit 4 and 5 Buildings Investigation were conducted by Walker-Hill Environmental, Inc. All soil borings and monitoring well installations were completed using rotary sonic drilling methods. Soil gas probe installations were completed by Cascade using direct push methods. Each soil boring was logged by a qualified geologist using the USCS. Underground Service Alert North One-Call System was notified to identify the location of public subsurface utilities prior to advancing the soil borings and well pilot borings. In addition, a private utility locator, Ground Penetrating Radar Systems, located and marked the traceable and identifiable private subsurface utilities in the work areas. Locations within the EMD leasehold were additionally located and cleared by a designated EMD (or Tronox for efforts before assignment of the Tronox lease) Engineering or Maintenance Supervisor. Hand auger or air knife utility clearance for all RI drilling locations was conducted by Cascade prior to commencing drilling. Surveying of the boring and well coordinates and elevations was conducted by Atkins North America, Inc., a Nevada Licensed Land Surveyor.

Soil and groundwater chemical analyses for the Phase 1-3 RIs were primarily conducted by Eurofins Environment Testing TestAmerica (Eurofins TestAmerica, formerly TestAmerica Laboratories, Inc.). Most samples were analyzed at Eurofins TestAmerica facilities located in Irvine, California; Sacramento, California; and St. Louis, Missouri. Eurofins TestAmerica also sent some samples to their facilities located in Denver, Colorado; Buffalo New York; and Phoenix, Arizona. Phase 1 RI soil gas samples were analyzed by McCampbell Analytical, Inc, located in Antioch, California. Phase 2 and 3 soil gas samples were analyzed by Eurofins TestAmerica in Irvine, California and Eurofins Air Toxics in Folsom, California, respectively. Some radionuclides were analyzed by ALS, located in Fort Collins, Colorado. Soil asbestos analyses were conducted by EMSL Analytical, Inc. located in Cinnaminson, New Jersey. Soil physical properties testing was conducted by PTS Laboratories located in Houston, Texas, and Core Laboratories LP located in Bakersfield, California. Data validation was performed by Laboratory Data Consultants (LDC) located in Carlsbad, California. These data have been validated in accordance with NDEP requirements.

Soil and groundwater chemical analyses for samples collected within the Unit 4 and 5 Buildings Investigation Area were conducted by Eurofins TestAmerica facilities located in Irvine and Sacramento, California, and Seattle, Washington. Geotechnical testing was conducted by Geotechnical & Environmental Services, Inc. and Silver State Analytical

Services located in Las Vegas, Nevada. Chemical sample data validation was conducted by Tetra Tech with the additional use of LDC Automated Data Review software.

Details of the Phase 1, Phase 2, and Phase 3 RI field investigation procedures are presented in Appendix A1. Aquifer testing procedures and results are presented in Appendix D, and the NMR downhole logging program is discussed in Appendix E. Soil physical properties testing results are provided in Appendix F. The complete analytical testing results are included in Appendices H, J, and K. Details of the Unit 4 and 5 Buildings investigation are presented in the Unit 4 and 5 Buildings Investigation Source Area Characterization Report ("Unit 4 and 5 Buildings Investigation Report"; Tetra Tech 2020), which was approved by NDEP on January 13, 2020.

6.2 Phase 1 RI

The Phase 1 RI data gap field investigation is complete. Phase 1 activities discussed in this report represent NERT's first data collection effort and were conducted between October 21, 2014 and May 10, 2015. Phase 1 RI activities included investigation of soil, soil gas, and groundwater data gaps in OU-1, OU-2, and OU-3 (within the NERT Site Study Area and the NERT Off-Site Study Area shown in Figure 6-1). As indicated previously, this report does not report analytical data associated with any sampling activities conducted in OU-3.

6.2.1 Data Gaps Addressed

As described in the Phase 1 Work Plan, areas within OU-1, OU-2, and OU-3 were identified that required additional investigation to determine the nature and extent of investigative COPCs in soil and groundwater within OU-1, and in groundwater and soil gas in OU-2 and OU-3 within the NERT Off-Site Study Area. Many of these areas within the NERT Site Study Area were previously identified by NDEP as areas requiring further study prior to the inception of the Trust. For purposes of additional soil characterization, four main areas were identified for collection of additional physical and chemical data from both shallow and deep soils. These areas included the AP-5 Pond area, the Leasehold Debris Pile, soil in the area between the Leasehold Debris Pile and AP-5 Pond, and the area west of the Mn-1 pond. As described in greater detail within Section 6.2.2, these additional data needs were addressed by the installation of shallow soil borings with soil samples collected continuously during drilling. One-time (grab) groundwater samples were collected from shallow groundwater using temporary well screens. Soil and groundwater samples were analyzed for investigative COPCs identified in the Phase 1 Work Plan. In addition to further characterization of the four abovementioned areas, additional data review and groundwater investigations were also conducted to address the following data gaps:

- Determination of background COPC concentrations;
- Revision of the original list of investigative COPCs;
- Evaluation of the vertical extent of COPC impacts in the Middle WBZ Muddy Creek Formation;
- The magnitude and extent of trespassing chemicals;
- The lateral and vertical extents of the downgradient plume;
- The extent of chloroform within the downgradient plume;

- The concentration of VOCs in soil gas at three locations in OU-2 where the highest concentrations of VOCs were detected in groundwater;
- Stream-aquifer interaction with the Las Vegas Wash;
- Collection of additional data to evaluate soils in ECAs; and
- Collection of additional groundwater analytical data in the area of the Unit 4, 5, and 6 Buildings. These data served as the basis for an additional investigation of soil and groundwater beneath the Unit 4 and 5 Buildings as discussed in Section 7.6.

6.2.2 Scope of Work

The Phase 1 RI data gap investigation was performed within each of the three OUs. Within OU-1, investigation occurred within eight areas (Areas 1 through 8), as shown in Figure 6-2. The eight investigation areas were defined in the FSP, Revision 1 to address data gaps within OU-1 (ENVIRON 2014d). Because the investigation within Area 1 could not be performed until after the decommissioning and removal of the AP-5 Pond, investigation of Area 1 was not performed as part of the Phase 1 RI, but instead implemented as part of the Phase 2 RI (as modified with Phase 2 RI Modification No. 15), as discussed in Section 6.3.2. In Areas 2 through 8, a total of approximately 450 environmental soil samples and 35 physical soil samples were collected from soil borings and test pits. Approximately 90 groundwater samples were collected from new monitoring wells, existing monitoring wells, and one-time grab samples. The locations of new and existing monitoring wells sampled in OU-1 are shown in Figure 6-3a. In addition to sampling performed in OU-1, investigation of groundwater impacts was performed throughout OU-2 and OU-3. The locations of new and existing monitoring wells sampled in OU-2 are shown in Figure 6-3b. Monitoring wells sampled within OU-3 along the Las Vegas Wash are shown in Figure 6-3c. The results obtained from sampling conducted in OU-3 will be presented in the forthcoming RI report for OU-3. The Phase 1 RI also included soil gas sampling at three locations in OU-2, as shown in Figure 6-4.

The RI data gap investigation consisted of the following:

OU-1:

- Fifty-six (56) soil borings with grab groundwater samples were completed in OU-1 and are shown in Figure 6-2 (RISB-9 through RISB-11, RISB-12A, RISB-12B, and RISB-13 through RISB-63; RISB-1 through RISB-5 were planned under this scope but drilled in 2018 after the decommissioning of the AP-5 Pond). Soil samples were collected at the surface, at intervals of five feet, and at any depth where field screening or observations indicated potential impacts, with the deepest sample collected at the capillary fringe above the groundwater table. A one-time groundwater sample was collected from each boring via a temporary PVC well casing. Soil and one-time groundwater samples were analyzed for:
    - Area 2 – chlorates and metals.
    - Area 4 – chlorates, metals, and VOCs.
    - Areas 5 and 6 – dioxins and furans and organochlorine pesticides (OCPs).

  - Areas 7 and 8 – chlorates, metals, hexavalent chromium, VOCs, TPH, and general chemistry parameters. In addition, selected soil samples were also analyzed for redox potential, TOC, pH, ferrous iron, ferric iron, chloride, nitrate, nitrite, sulfide, sulfate, calcium, potassium, and sodium.
- Three test pits (RIT-1, RIT-2, and RIT-3) were completed in the OU-1 Leasehold Debris Pile and are shown in Figure 6-2 (Area 3). Five grab soil samples were collected for analysis from each of the exploratory test pits to evaluate the presence of investigative COPCs and asbestos.
- Eight groundwater monitoring wells were installed in OU-1 and are shown in Figures 6-2 and 6-3a (M-161D, M-162D, M-186D, and M-189 through M-193).
- Slug tests were conducted at 23 wells in OU-1 (M-117, M-118, M-149 through M-154, M-156, M-161, M-161D, M-162, M-162D, M-181, M-186, M-186D, MC-MW-18, MC-MW-39, MC-MW-42, TR-2, TR-4, TR-7, and TR-9). Aquifer testing results are presented in Appendix D and these slug test locations are shown in Figures D-1d and D-1e.

OU-2:

- Nine groundwater monitoring wells were installed in OU-2 and are shown in Figure 6-3b (PC-134D, PC-137D, PC-151 through PC-154, and PC-158 through PC-160). Well PC-153 (shown in Figure 6-3b) was destroyed by construction activity in February 2017 and was decommissioned and replaced by well PC-153R in March 2017 (shown in Figure 6-6b). In addition, one soil sample was collected from off-site well pilot boring PC-152 based on field observations of discolored soil.
- Six soil gas sampling probes were installed at three locations in OU-2 (RISG-1, RISG-2, and RISG-3) with one shallow (5 feet) and one deeper (13 – 15 feet) soil gas probe at each location. These locations are shown in Figure 6-4. Soil gas samples were analyzed for VOCs using USEPA Method TO-15.

OU-3:

- Six groundwater monitoring wells were installed in OU-3 along the Las Vegas Wash and are shown in Figure 6-3c (PC-155A/B, PC-156A/B, and PC-157A/B).

Approximately 190 existing and new groundwater monitoring wells were sampled in OU-1, OU-2, and OU-3 during the Phase 1 RI. These well locations are shown in Figures 6-3a, 6-3b, and 6-3c.

The results of the Phase 1 investigation were presented in the RI Data Evaluation Technical Memorandum (Ramboll Environ 2016c) along with an evaluation of whether additional data were needed to complete the RI within the extent of the RI Study Area, as defined at the time. The technical memorandum provided a summary of the Phase 1 investigation results, identified additional data gaps to be addressed by a Phase 2 investigation, and presented the proposed scope of the Phase 2 investigation. The RI Data Evaluation Technical Memorandum was approved by NDEP on July 13, 2016 with comments for the administrative record. The Phase 1 RI results are further discussed along with the results of subsequent phases of the RI in Sections 7 and 8.

6.3 Phase 2 RI

The Phase 2 RI field investigation was conducted between February 2017 and April 2019. Consistent with the RI Data Evaluation Technical Memorandum, the Phase 2 RI activities included additional investigation to resolve new soil and groundwater data gaps identified within the NERT Site Study Area (in OU-1) and the NERT Off-Site Study Area (in both OU-2 and OU-3) shown in Figure 6-1. As indicated previously, the results of investigative activities in OU-3 are not discussed in this report.

6.3.1 Data Gaps Addressed

As part of the Phase 2 RI, the following tasks were completed to address data gaps outlined in the 2016 RI Data Evaluation Technical Memorandum (Ramboll Environ 2016c):

OU-1:

- Collection of additional groundwater data within the UMCf along the NERT Site Study Area boundary to document the vertical extent of contamination;
- Characterization of the Qal and UMCf between the IWF, barrier wall, and former injection trenches and the downgradient Site boundary to determine the vertical extent of contamination and estimate the contaminant mass contained within the geologic units in this area;
- Delineate the vertical extent of perchlorate in the UMCf upgradient of the IWF;
- Evaluation of investigative COPCs in shallow groundwater along the north side of Avenue F where shallow soil impacts were previously identified;
- Collection of additional soil and groundwater data in the area west and northwest of the GW-11 pond where the alluvium is unsaturated and few data are available;
- Evaluation of dioxins and furans in shallow groundwater to determine if these chemicals are present, which are present in soil above leaching criteria; and
- Delineation of VOCs within the Middle WBZ near the DNAPL plume along the western NERT Site Study Area boundary.

OU-2:

- Additional delineation of perchlorate mass and distribution of chloroform within the Qal and UMCf;
- Additional hydraulic characterization in the downgradient plume area outside of the paleochannels where perchlorate concentrations are highest; and
- Collection of additional concentration data for potential “tracer” chemicals such as chlorate and nitrate for plume quantification purposes.

OU-3:

- Evaluation of white salt deposits for potential perchlorate contamination observed in shallow soil within a low-lying area surrounding the former seep capture sump near the Las Vegas Wash.

6.3.2 Scope of Work

The scope of work for the Phase 2 RI investigation conducted to address the abovementioned data gaps is presented below. The initial planned Phase 2 RI scope of work was conducted between February 2017 and November 2017. The Phase 2 RI scope of work was modified through 15 Phase 2 RI modifications approved by NDEP as summarized below. Field activities associated with the Phase 2 RI modifications were completed concurrently with the initial planned Phase 2 RI scope of work and concluded in April 2019. Soil borings added as part of the Phase 2 RI are shown in Figures 6-5a (for OU-1), 6-5b (for OU-2), and 6-5c (for OU-3). Monitoring wells added as part of the Phase 2 RI are shown in Figures 6-6a (for OU-1), 6-6b (for OU-2), and 6-6e (for OU-3). Phase 2 RI soil gas sampling locations are shown in Figures 6-7a (for OU-1) and 6-7b (for OU-2).

OU-1 (Initial Scope). Investigation activities conducted within OU-1 included the advancement of soil borings, the collection of soil samples and associated one-time (grab) groundwater samples using temporary well screens, as well as the installation of monitoring wells. The vertical extent of COPCs in the low permeability UMCf was investigated using a combination of deep soil borings followed by well installations. In the northern area of OU-1, the initial planned soil borings were drilled to an approximate depth of 90 feet bgs and soil samples were collected at 10-foot intervals to provide perchlorate and other COPC data to support vertical delineation and mass estimates. In the central portion of OU-1, the focus of the initial planned Phase 2 RI was to characterize the presence and extent of perchlorate, VOCs, and other COPCs in the deeper Shallow WBZ and the Middle WBZ. In all, the initial Phase 2 RI scope of work within OU-1 included the following:

- Twenty-nine (29) soil borings, which were deeper than those advanced during the Phase 1 RI, were drilled in OU-1 and are shown in Figure 6-5a (RIDB-1 through RIDB-29). Soil samples were collected from the surface to 0.5 feet, 5 feet, and then at 10-foot intervals to 90 feet. Soil samples were analyzed for perchlorate, chlorate, total chromium, nitrate/nitrite, VOCs, and moisture content. Shallow soil samples (30 feet bgs and above) were also analyzed for SVOCs, PAHs, PCBs, dioxins and furans, OCPs, and radionuclides.
- Twenty-eight (28) additional RI soil borings, which are also shown in Figure 6-5a, were drilled in OU-1 (RI-1 through RI-28). Soil samples were collected from 5 feet, and then at 10-foot intervals to total depth (which was 130 or 150 feet bgs depending on the boring location). Soil samples were analyzed for perchlorate, chlorate, total chromium, nitrate/nitrite, VOCs, and moisture content. Shallow soil samples (30 feet bgs and above) were also analyzed for SVOCs, PAHs, PCBs, dioxins and furans, OCPs, and radionuclides.
- Fifty-eight (58) monitoring wells were installed within OU-1 and are shown in Figure 6-6a (M-5D, M-14D, M-21D, M-22D, M-36D, M-65D, M-66D, M-72D, M-81D, M-83D, M-125D, M-140D, and M-195 through M-240).

OU-2/OU-3 (Initial Scope). Shallow wells (including one temporary well) screened in the alluvium were installed to provide better delineation of the lateral extent of investigative COPCs in shallow groundwater. Deeper monitoring wells were also installed in the UMCf to improve NERT's understanding of the vertical extent of COPCs in groundwater. The vertical extent of perchlorate and other COPCs in the UMCf was also investigated by drilling and sampling 14 deep soil borings within the Shallow WBZ. The borings were advanced to an approximate depth of 90 feet bgs. These borings provided data to evaluate the vertical extent of COPCs in the UMCf, and the soil concentrations were also used to calculate a groundwater concentration based on the mass in the soil sample and the water content. In addition, shallow soil samples were collected at ten locations to assess potential perchlorate impacts in an area close to the Las Vegas Wash. In all, the initial Phase 2 RI scope of work for OU-2/OU-3 consisted of the following:

- Fourteen (14) soil borings were drilled in OU-2/OU-3 (PCDB-1 through PCDB-14). Soil borings within OU-2 are shown in Figure 6-5b. Soil borings within OU-3 are shown in Figure 6-5c. For soil borings PCDB-1, PCDB-2, and PCDB-3, per Phase 2 RI Modification No. 2 as discussed below, the borings were extended to a total depth of 150 feet bgs and soil samples were collected at 10-foot intervals from 50 feet bgs to total depth. For soil borings PCDB-4 through PCDB-14, soil samples were collected from 5 feet and then at 10-foot intervals to 90 feet, as initially planned. Soil samples were analyzed for perchlorate, chlorate, total chromium, nitrate, VOCs, and moisture content.
- Soil sampling was conducted at 10 locations in the vicinity of the SWF (SWF-01 through SWF-10). One surface soil sample and one shallow subsurface soil sample (approximately 0.5 to 1.0 feet) were collected at each location using a hand trowel. The samples were analyzed for perchlorate. The intended purpose of this scope of work was to evaluate white salt deposits observed within a low-lying area surrounding the former seep capture sump. At the time of sample collection, the seep capture area had recently been covered by a thick layer of soil produced during the construction of the diversion channel associated with the Sunrise Mountain Weir project by the SNWA. Surface soil sample locations are shown in Figure 6-5c.
- Forty (40) monitoring wells were installed in OU-2/OU-3 (PC-153R, PC-161 through PC-170, PC-170R, PC-171 through PC-187, PC-187R, and PC-188 through PC-197). Monitoring wells installed within OU-2 and OU-3 are shown in Figures 6-6b and 6-6e, respectively.

Phase 2 RI Scope of Work Modifications (OU-1, OU-2, and OU-3). As additional data gaps were identified, the initial Phase 2 RI scope of work described above was modified through 15 Phase 2 RI Modifications (Nos. 1 through 15) approved by NDEP (Ramboll Environ 2017b,c,d,e,f,g; Tetra Tech 2017b; Ramboll Environ 2017h,n; Ramboll 2018a,d,f,g,h,k). A summary of these modifications is provided below.

- Phase 2 RI Modification No. 1 (Ramboll Environ 2017b) added to the initial scope with the installation of five additional groundwater monitoring wells (M-242, M-243, M-244, M-245, and M-246) in OU-1 just west of the GW-11 Pond to better define VOC concentrations observed in soil samples collected from soil borings RIDB-6 and RIDB-7. The well locations are shown in Figure 6-6a.
- Phase 2 RI Modification No. 2 (Ramboll Environ 2017c) added to the initial scope by extending the depth of three of the initially planned soil borings near the SWF. The soil borings are shown in Figure 6-5c. Based on the discovery of perchlorate in the UMCf near the SWF, PCDB-1, PCDB-2, and PCDB-3 were extended to 150 ft bgs and

soil samples were collected at 10-ft intervals from 50 ft to 150 ft bgs and analyzed for perchlorate.

- Phase 2 RI Modification No. 3 (Ramboll Environ 2017d) added to the initial scope by incorporating additional surface water sampling locations in the Las Vegas Wash for perchlorate analyses at three transverse transects at existing USGS stream gage locations (sampling locations are not shown in figures; these will be presented in the forthcoming RI Report for OU-3).
- Phase 2 RI Modification No. 4 (Ramboll Environ 2017e) added to the initial scope by extending the total depth for the pilot borings for six initially planned monitoring wells within OU-1 (M-194 through M-199). These wells are shown in Figure 6-5a, with the exception of M-194 since the soil boring and well at this location could not be completed due to access limitations associated with underground and overhead utilities. The pilot borings were extended to 150 ft bgs (from the initially planned depth of 120 ft bgs) and samples were collected at 10-ft intervals to better delineate the vertical extent of perchlorate and other COPCs in the vicinity of the Unit 4, 5, and 6 Buildings.
- Phase 2 RI Modification No. 5 (Ramboll Environ 2017f) modified the initial scope by adjusting the well screen intervals for six initially planned monitoring wells within OU-1 (M-200, M-230, and M-235 through M-238), and an adjustment to the location of planned well M-234 based on lithology and COPC concentrations from pilot boring soil samples. These wells are shown in Figure 6-6a.
- Phase 2 RI Modification No. 6 (Ramboll Environ 2017g) added to the initial scope and included completion of a soil background study which included the drilling of five soil borings (RIBK-7, RIBK-8, RIBK-10, RIBK-12, and RIBK-13) west of OU-1. Soil samples were collected from the top of the UMCf and analyzed for a full suite of metals and radionuclides. The soil background study is described in the Soil Background Data Set Summary Report (Ramboll 2021d).
- Phase 2 RI Modification No. 7 (Tetra Tech 2017b) added to the initial scope by installation of two new groundwater monitoring wells (CTMW-07S and CTMW-07D) as part of the In-Situ Chromium Treatability Study Area within OU-1 based on observed elevated concentrations of COPCs in this area. These data have been included in the Treatability Study, rather than the RI, and these wells are not depicted in Figure 6-6a.
- Phase 2 RI Modification No. 8 (Ramboll Environ 2017h) added to the initial scope by adjusting the well screen intervals for initially planned monitoring wells within OU-1 (M-224, M-227, and M-228) based on lithology and COPC concentrations from pilot boring soil samples. These wells are shown in Figure 6-6a.
- Phase 2 RI Modification No. 9 (Ramboll Environ 2017n) added to the initial scope with the collection of groundwater samples for VOC analyses from 17 existing OU-1 groundwater monitoring wells (M-55, M-56, M-58, M-60, M-78, M-131, M-166, M-167, M-168, M-169, M-170, M-172, M-173, M-174, M-175, M-176, and M-177) in the vicinity of the IWF/barrier wall. These wells are shown in Figure 6-6a.
- Phase 2 RI Modification No. 10 (Ramboll 2018a) added to the initial scope by incorporating additional surface water sampling locations for perchlorate at three

locations, one sampling location at an existing USGS stream gauge station (LVW8.85) and new sampling locations at two existing Las Vegas Wash weirs (Sunrise Mountain Weir [LVW6.6] and Calico Ridge Weir [LVW4.75]) (sampling locations are not shown in figures; these will be presented in the forthcoming RI Report for OU-3).

- Phase 2 RI Modification No. 11 (Ramboll 2018d) added to the initial scope and included a soil gas sampling program which was conducted within the OU-1/OU-2 area to support the BHRA and in response to comments from NDEP on the 2016 Technical Memorandum. The scope of work included installation of soil gas sampling probes at 30 locations; 17 locations in OU-1 shown in Figure 6-7a (RISG-10 through RISG-26), and 13 locations in OU-2 shown in Figure 6-7b (RISG-1 through RISG-9 and RISG-27 through RISG-30). Soil gas samples were analyzed for VOCs using USEPA Method TO-15.
- Phase 2 RI Modification No. 12 (Ramboll 2018f) added to the initial scope and included a soil, soil gas, and groundwater sampling program conducted at Parcel E, located in the northwestern portion of OU-1. The scope of work included drilling at seven soil sample locations shown in Figure 6-5a (RISB-EJ-01, RISB-EJ-02, RISB-EJ-03, RISB-EJ-04, RISB-ER-01, RISB-ER-02, and RISB-ER-03), collection of groundwater samples from five existing monitoring wells shown in Figure 6-6a (MC-09R, MC-29, MC-94, MC-97, and MC-111), and the collection of soil gas samples for TO-15 VOC analysis at four locations shown in Figure 6-7a (RISG-31, RISG-32, RISG-33, and RISG-34).
- Phase 2 RI Modification No. 13 (Ramboll 2018g) added to the initial scope with the drilling of deep soil borings and installation of monitoring wells near the northern boundary of OU-1. Four 150-ft deep soil borings (RIDB-30 through RIDB-33) were first drilled along a transect north of the GW-11, WC-West, and WC-East Ponds and are shown in Figure 6-5a. Based on the evaluation of lithologic conditions and perchlorate analyses of soil samples from these borings, nine additional groundwater monitoring wells were installed along this northern transect (M-260 through M-268), which are shown in Figure 6-6a, to determine the horizontal extent of a permeable zone within the UMCf and the vertical extent of contamination in this area.
- Phase 2 RI Modification No. 14 (Ramboll 2018h) added to the initial scope by implementing changes to monthly surface water sampling at locations within the Las Vegas Wash as a result of the Historic Lateral Weir Expansion construction. This modification also added surface water sampling at surface water outfalls discharging from subdrains under the Chimera Golf Course and Tuscany neighborhood to the C-1 channel. These surface water sampling locations are not shown in figures; these will be presented in the forthcoming RI Report for OU-3.
- Phase 2 RI Modification No. 15 (Ramboll 2018k) added to the initial scope and included additional shallow soil borings, deeper soil borings, and monitoring wells that were installed in Phase 1 RI Area 1 (in the area of the former AP-5 Pond). The scope of work retained five of the initially planned shallow soil borings with one-time groundwater samples (RISB-1 through RISB-5), which are shown as part of the initial Phase 1 scope in Figure 6-2. The revised plan also included drilling three 150-ft deep borings (RIDB-34, RIDB-35, RIDB-36), which are shown in Figure 6-5a, and installing three groundwater monitoring wells (M-269, M-270, and M-271), which are shown in

Figure 6-6a. Approximately 107 soil samples were collected for chemical analysis. Groundwater samples were collected from the three new monitoring wells and the five one-time groundwater sample locations. This work was designed to delineate the vertical extent of contamination in this source area.

Following installation and development,[60] initial groundwater samples were collected from the new wells and analyzed for investigative COPCs beginning in May 2017 and a second comprehensive groundwater sampling event was conducted between September 28, 2017, and November 8, 2017. Groundwater samples were collected from a total of 156 wells, including the 63 Phase 2 RI wells installed in OU-1 and 37 Phase 2 RI wells (including one temporary well) installed within OU-2/OU-3. Monitoring well locations within OU-1 are shown in Figure 6-6a. Monitoring well locations within OU-2 and OU-3 are shown in Figures 6-6b and 6-6e, respectively. Analytical parameters for groundwater included perchlorate, chlorate, dissolved metals, VOCs, PCBs, radionuclides, major ions, and geochemical parameters. Focused groundwater sampling was also conducted at designated wells (dioxins and furans were analyzed in 10 wells and total cyanide was analyzed in one well, M-55).

The initial slug testing for the Phase 2 RI was conducted between September and October 2017. The initial Phase 2 RI included slug testing of 62 wells in OU-1 and 61 wells in OU-2. Slug testing was also conducted on new wells installed in OU-1 as part of Phase 2 RI Modification Nos. 13 and 15 bringing the total wells tested in OU-1 to approximately 73. Aquifer testing results are presented in Appendix D.

OU-2 (Parcel A/B). Because of activities associated with the property transaction of Sale Parcels A and B (Parcel A/B), significant modifications to existing and planned Phase 2 RI wells were made between August and December 2017 within the parcels. Figure 6-6c shows the Parcel A/B well network at the time of the Parcel A/B property transaction, and Figure 6-6d shows the final location of the monitoring network installed at the Parcel A/B property to accommodate redevelopment plans. Wells that were to be decommissioned were first sampled and the groundwater samples were analyzed for investigative COPCs prior to decommissioning. The following is a summary of well installation, well decommissioning, well relocation, well development, and groundwater testing/sampling activities that occurred on the Parcel A/B property:

- Nine Phase 2 RI wells (PC-170, PC-173 (temporary), PC-180 through PC-185, and PC-187) were installed between August 7 and 15, 2017.
- An initial round of groundwater sampling was conducted at Parcel A/B between August 22 and 24, 2017. A total of 21 existing wells were sampled, including five existing OSSM wells (H-49A, H-56A, H-58A, MC-MW-37, and MC-65) that were scheduled to be decommissioned and replaced, eight existing OSSM wells (H-48, MC-60, MC-61, MC-62, MC-63, MC-66, MC-MW-36, and MC-MW-38) that were scheduled to be decommissioned, five NERT-owned wells (M-44, M-152, M-156, PC-71, and PC-72) that were scheduled to be retained, and three NERT-owned wells (PC-37, PC-40,

---

[60] While not associated with a RI modification, four monitoring wells in the central portion of OU-1 (M-224, M-225, M-227, and M-228) were damaged beyond repair by high concentrations of organic chemicals in groundwater originating from the OSSM site. These wells were decommissioned and replaced in January 2018 with stainless steel monitoring wells M-224R, M-225R, M-227R, and M-228R.

and PC-73) that were scheduled to be decommissioned. The nine Phase 2 RI wells were not part of this initial Parcel A/B sampling and had not yet been developed at the time of sampling.

- Five replacement wells (H-49R, H-56R, H-58R, MC-MW-37R, and MC-65R) were installed along the boundary of the Parcel A/B property between August 27 and 30, 2017, to replace plugged and abandoned well locations previously installed by OSSM.
- An initial round of groundwater sampling was completed for the nine Phase 2 RI wells on September 11 and 12, 2017.
- Slug testing was conducted on the nine Phase 2 RI wells between September 19 and 23, 2017. Aquifer testing results are presented in Appendix D.
- A second round of groundwater sampling was conducted at Parcel A/B between October 25 and 27, 2017. This sampling event included the collection of 33 groundwater samples including 19 of the 21 wells sampled during the initial round of sampling (MC-60 was dry and M-156 had issues with the dedicated pump that prevented sample collection), the five OSSM replacement wells (H-49R, H-56R, H-58R, MC-65R, and MC-MW-37R), and the nine new Phase 2 RI wells (PC-170, PC-173 (temporary), PC-180, PC-181, PC-182, PC-183, PC-184, PC-185, and PC-187).
- The five replacement wells and the nine Phase 2 RI wells were surveyed by October 31, 2017.
- In late October and early November 2017, after completion of the second round of groundwater sampling, 13 OSSM wells (H-48, H-49A, H-56A, H-58A, MC-60, MC-61, MC-62, MC-63, MC-65, MC-66, MC-MW-36, MC-MW-37, and MC-MW-38) and two Trust-owned wells (PC-37 and PC-73) were decommissioned. On December 11, 2017, temporary Phase 2 RI monitoring well PC-173 was decommissioned.
- On October 25, 2017, and in connection with the sale of Parcel A/B to TRECO LLC (TRECO), the Trust was notified to decommission and if necessary, replace all monitoring wells identified as being further than 20 feet inside of the property boundary, except for artesian well TR-12. Five wells were identified as being outside the 20-foot buffer, including two OSSM-owned wells (MC-MW-37R and MC-65R), and three Trust-owned wells (PC-40, PC-170, and PC-187). The wells were decommissioned and replaced by Eagle Drilling (at the direction of TRECO) between November 27 and December 6, 2017. The new well designations are MC-MW-37R2, MC-65R2, PC-40R, PC-170R, and PC-187R.

Decommissioning of monitoring wells generally consisted of removing the surface completion components of the wells (concrete, surface protective casings, protective bollards), removing the well materials, and grouting the boreholes with neat cement from the bottom of the well/borehole to the surface with a tremie pipe per the requirements of NAC 534.420.

6.4 Phase 3 RI[61]

In 2016, NDEP directed the Trust to investigate the Eastside Sub-Area to evaluate the nature and extent of impacts in the subsurface due to the migration of COPCs from OU-1. As discussed earlier, this investigation was to be limited to perchlorate and chlorate ("Administratively Limited COPCs"). The scope of work for the Phase 3 RI was presented in the Phase 3 RI Work Plan, Revision 1 (Ramboll Environ 2017m). The Phase 3 RI Work Plan expanded the boundaries of the NERT RI, adding the Eastside Study Area to the existing NERT Site Study Area, the NERT Off-Site Study Area, and the Downgradient Study Area (collectively, "NERT RI Study Area") (see Figure 6-1). The Phase 3 RI Work Plan, Revision 1 was approved by NDEP on November 8, 2017.

The Eastside Study Area is located adjacent to the BMI Complex and includes approximately 2,527 acres of land located east of the NERT Site Study Area, immediately east of the NERT Off-Site Study Area, and immediately south (upgradient) of the Downgradient Study Area. The Eastside Study Area was further divided into two sub-areas:

- The Eastside Sub-Area is within OU-2, approximately 1,983 acres, and located east of Pabco Road, west of Lake Mead Parkway, and south of Galleria Drive. The majority of the Eastside Sub-Area was historically part of the BMI Common Areas as discussed in Section 2 of this report. While the Eastside Sub-Area is no longer associated with any operations within the BMI Complex, much of this area is rapidly being redeveloped, primarily for residential use, as part of a Master-Planned Community. This development is consistent with NDEP's NFA determinations. As of August 2022, approximately 50% of the master-planned community, much of which is within the Eastside Sub-Area, has been redeveloped. The southern portion of the Eastside Sub-Area is currently occupied by a number of commercial businesses.
- The Northeast Sub-Area is within OU-3, approximately 544 acres, and is located north of Galleria Drive and encompasses much of the area currently occupied by the Chimera Golf Club, Tuscany Village, and Josh Stevens Elementary School.

6.4.1 Data Gaps Addressed

Based on the comprehensive review of existing information regarding the Administratively Limited COPCs and an understanding of both the regulatory intent and past work in the Eastside Study Area (per NDEP's July 2016 directive), the initial objectives of the Phase 3 RI were to address the following data gaps:

- Identify the concentrations of Administratively Limited COPCs above leaching BCLs in unsaturated soil within the Eastside Sub-Area;[62]

---

[61] In 2014, NDEP determined that an investigation of the Downgradient Study Area (located within OU-3) would be performed by AECOM under contract with NDEP. The investigation of the Downgradient Study Area began in 2015. As the Downgradient Study Area is located within OU-3, results from these investigations will be presented in the forthcoming RI Report for OU-3.

[62] The potential presence of hexavalent chromium and other potential contaminants in groundwater within the Eastside Sub-Area will be investigated and remediated by BRC, if required by NDEP, pursuant to the terms of Administrative Order on Consent, Phase 3 (AOC3) (NDEP 2006).

- Identify the lateral and vertical distribution of COPCs in groundwater within the Shallow, Middle, and Deep WBZs within both the Eastside and Northeast Sub-Areas, as applicable; and
- Identify groundwater transport pathways within both the Eastside and Northeast Sub-Areas.

6.4.2 Scope of Work

The scope of work for the Phase 3 RI conducted to address the abovementioned data gaps is presented below. The initially planned Phase 3 RI scope of work, implemented between December 2017[63] and November 2018, was subsequently expanded to include 15 Phase 3 RI modifications. The scope of work for each of the Phase 3 RI modifications is summarized below. Sampling activities for the Phase 3 RI modifications conducted within OU-1 and OU-2 were completed between June 2018 and January 2020. Implementation of the Phase 3 RI modifications solely within OU-3 continued through October 2022. The OU-3 investigative activities are summarized below and will be detailed futher in the forthcoming RI Report for OU-3. Soil boring locations advanced as part of the Phase 3 RI are shown in Figures 6-8a (for OU-2) and 6-8b (for OU-3). Paleochannel transect boring locations are shown in Figure 6-9. Monitoring wells installed as part of the Phase 3 RI are shown in Figures 6-10a (for OU-2) and 6-10b (for OU-3). High-frequency surface water sampling locations are shown in Figure 6-11. Phase 3 RI soil gas sampling locations are shown in Figures 6-12a (for OU-1), 6-12b (for OU-2), and 6-12c (for OU-3).

OU-2/OU-3 (Initial Scope). The Phase 3 RI scope of work as detailed in the Phase 3 RI Work Plan included the following activities primarily designed to determine the extent of contamination throughout the Eastside Study Area:

- Eighteen (18) planned investigative soil borings were drilled in OU-2 (ESB-1 through ESB-18). Boring locations are shown in Figure 6-8a. The borings were advanced to a depth of 150 feet bgs. Soil samples were collected at 10 feet bgs and then at 10-foot intervals to the maximum depth of each boring. Four additional exploratory soil borings that are not associated with samples and are not shown in Figure 6-8a were drilled in OU-2 (ESB-1X, ES-2-PB1, ES-2-PB2, and ES-2-PB-3).
- Fifty-seven (57) exploratory soil borings were drilled at six separate transects located within the Eastside Sub-Area to evaluate the potential presence of paleochannels identified through previous geophysical investigations. Specifically, these included 11 soil borings at Transect A, nine soil borings at Transect B, nine soil borings at Transect C, eight soil borings at Transect E, 10 soil borings at Transect F, and 10 soil borings at Transect G. These transect locations are shown in Figure 6-9. Soil samples were collected for lithologic description and physical testing.
- Seven paleochannel exploratory soil borings were drilled in the Northeast Sub-Area at Transect D. This transect is also shown in Figure 6-9. Soil samples were collected for lithologic description and physical testing.

---

[63] Prior to the start of the Phase 3 RI, well inspections were performed as part of Phase 3 RI Modification No. 1 beginning in August 2017.

- Twenty-seven (27) monitoring wells were installed in OU-2 (ES-1 through ES-7, ES-8A, ES-8B, ES-9 through ES-13, ES-14A, ES-14B, ES-15 through ES-20, and ES-28 through ES-32). Well locations are shown in Figure 6-10a. Eight of these wells (ES-2, ES-6, ES-7, ES-12, ES-13, ES-20, ES-28, and ES-29) were subsequently decommissioned as part of property redevelopment activities; six of these wells (ES-2, ES-6, ES-7, ES-12, ES-13, and ES-28) are planned for relocation in 2023 as part of NERT's groundwater monitoring program (GWMP). The pilot borings for all but two of these wells were advanced to a depth of 120 feet bgs. The pilot borings for wells ES-19 and ES-20 were advanced to 200 feet. Soil samples were collected at 10 feet bgs and then at 10-foot intervals to the maximum depth of each boring.
- Eleven (11) monitoring wells were installed in OU-3 (ES-21A, ES-21B, ES-22A, ES-22B, ES-23A, ES-23B, ES-24, ES-25A, ES-25B, ES-26, and ES-27). Well locations are shown in Figure 6-10b. The pilot borings for these wells were advanced to a depth of 120 feet bgs. Soil samples were collected at 10 feet bgs and then at 10-foot intervals to the maximum depth of each boring.

Phase 3 RI Scope of Work Modifications (OU-1, OU-2, and OU-3). The Phase 3 RI scope of work was modified through 15 Phase 3 RI modifications (Nos. 1 through 15) approved by NDEP (Ramboll Environ 2017p; Ramboll 2018c,e,l,m, 2019b,d,e, 2020b,c,e, 2021c,g,k, 2022d). Many of the Phase 3 RI modifications (i.e., Phase 3 RI Modification Nos. 2, 4, 5, 6, 7, 8, 10, 11, 12, 13, 14, and 15) pertain solely to areas in OU-3, and the results obtained during these modifications will be discussed in the forthcoming RI Report for OU-3. A summary of the Phase 3 RI modifications is provided below.

- Phase 3 RI Modification No. 1 (Ramboll Environ 2017p) added to the initial scope by including a detailed inspection of existing wells in the Eastside Sub-Area.
- Phase 3 RI Modification No. 2 (Ramboll 2018c) added to the initial scope and included installation of nine wells (NERT5.91S1, NERT5.49S1, NERT5.11S1, NERT4.93S1, NERT4.71S1, NERT4.51S1, NERT4.38N1, NERT4.21N1, and NERT3.80S1) near the Las Vegas Wash within OU-3. The well pilot borings were drilled to 90 feet, or refusal, and Ramboll collected soil samples at 10-foot intervals for laboratory analysis of perchlorate, chlorate, total chromium, and moisture content. The pilot boring locations are shown in Figure 6-8b, and the well locations are shown in Figure 6-10b. The scope of work performed in OU-3, including the Downgradient Study Area, will be further described within the forthcoming RI Report for OU-3. Additionally, samples were collected at two subdrains that enter the C-1 channel north of the Tuscany neighborhood (not shown in figure) and seven groundwater monitoring wells on City of Henderson's landfill property, which are shown in Figure 6-10b. Planned monitoring well NERT3.65S1 was not installed because bedrock was encountered at a depth of 2 ft bgs.
- Phase 3 RI Modification No. 3 (Ramboll 2018e) added to the initial scope by including a program to conduct NMR logging, per NDEP's request, in numerous existing and new wells throughout OU-1, OU-2, and OU-3. The purpose of the NMR logging was to provide additional information on subsurface hydraulic properties to help identify potential continuous coarser-grained flow pathways, both within the saturated Qal and UMCf. The results of the NMR logging are discussed in Appendix E.

- Phase 3 RI Modification No. 4 (Ramboll 2018l) added to the initial scope and included four 200-ft deep soil borings (ESB-24, ESB-25, ESB-26, and ESB-27) drilled in OU-3 near the Phase 3 RI paleochannel investigation Transect D. These boring locations are shown in Figure 6-8b. Based on observations and analytical results from the deep soil borings, eight monitoring wells were installed along Transect D (ES-45 through ES-52), which are shown in Figure 6-10b.
- Phase 3 RI Modification No. 5 (Ramboll 2018m) added to the initial scope and included three 150-ft deep soil borings (PCDB-15, PCDB-16, and PCDB-17) and two groundwater monitoring wells (PC-198 and PC-199) installed in OU-3 near the SWF to better delineate the lateral and vertical extent of perchlorate and other NERT COPCs in deeper (i.e., greater than 50 ft bgs) UMCf soils. The boring locations are shown in Figure 6-8b and the well locations are shown in Figure 6-10b.
- Phase 3 RI Modification No. 6 (Ramboll 2019b) added to the initial scope and included installation of fourteen wells (NERT4.65N1, NERT4.64N1, NERT4.70N1, NERT4.71N1, NERT4.71S2, NERT4.64S1, NERT3.98S1, NERT3.63S1, NERT3.60S1, NERT3.58S1, NERT3.40S1, NERT3.35S1, NERT3.60N1, and NERT3.58N1) in OU-3 in the Downgradient Study Area. The pilot boring locations are shown in Figure 6-8b, and the monitoring well locations are shown in Figure 6-10b. Additionally, 11 2-inch diameter observation wells were installed to support planned aquifer testing. Work performed in OU-3 will be further described within the forthcoming RI Report for OU-3.
- Phase 3 RI Modification No. 7 (Ramboll 2019d) added to the initial scope and included soil gas probe installation and sampling at 17 locations in OU-3 (RISG-35 through RISG-51). These soil gas probe locations are shown in Figure 6-12c and were limited to locations west of Pabco Road. Two probes were installed at most locations, one at 5 feet bgs and the other at either 10 or 15 feet bgs. At two locations, RISG-35 and RISG-40, deeper soil gas probes were not installed due to the presence of shallow groundwater and shallow refusal, respectively. This modification also included the installation of three new groundwater monitoring wells (PC-200, PC-201, and PC-202) and the collection of groundwater samples from the three new wells and one existing piezometer (PZ-2S). These well locations are shown in Figure 6-10b.
- Phase 3 RI Modification No. 8 (Ramboll 2020b) added to the initial scope and included 1) the installation of 37 new groundwater monitoring wells primarily in OU-3;[64] 2) the drilling of twelve soil borings along two paleochannel investigation transects (Transects H and I) to define paleochannels identified through previous geophysical investigations; and 3) a comprehensive round of groundwater sampling from 268 new and existing groundwater monitoring wells to evaluate the current distribution of perchlorate and other COPCs in OU-3, as detailed further below.

  Nine groundwater monitoring wells (NERT6.21N1, NERT5.83N1, NERT5.26N1, NERT4.29N1, NERT4.29N2, NERT3.94N1, NERT-FM01A, NERT-FM01B, and NERT-FM02A) were installed at seven drilling locations on the north side of the Las Vegas Wash. Pilot borings (NERT3.94N, NERT4.29N, NERT5.26N, NERT5.83N, NERT6.21N, NERT-FM01, and NERT-FM02) were drilled at each of the seven locations with soil

---

[64] Two of the Phase 3 RI Modification No. 8 wells (ES-53 and ES-54) are located in OU-2.

samples collected at 10-foot intervals for chlorate and perchlorate analyses. On the south side of the Las Vegas Wash, 18 wells (NERT5.80S1, NERT5.80S2, NERT5.63S1, NERT5.63S2, NERT5.63S3, NERT5.20S1, NERT5.20S2, NERT5.20S3, ES-55A, ES-55B, ES-55C, ES-56A, ES-56B, ES-56C, ES-57A, ES-57B, ES-58A, and ES-58B) were installed at seven drilling locations. Pilot borings (ES-55, ES-56, ES-57, ES-58, NERT5.80S, NERT5.63S, and NERT5.20S) were drilled at each of the seven locations with soil samples collected at 10-foot intervals for chlorate and perchlorate analyses. Additionally, on the south side of the Las Vegas Wash, six wells (NERT2.60S2, NERT5.11S2, NERT5.49S2, NERT5.91S2, NERT5.91S3, and PC-157C) were installed adjacent to six existing monitoring wells to define perchlorate concentrations and vertical hydraulic gradients. Two deeper wells (PC-203 and PC-204) were installed adjacent to existing wells in the vicinity of the SWF to define perchlorate concentrations and vertical hydraulic gradients. In addition, two monitoring wells (ES-53 and ES-54) were installed along Galleria Drive within OU-2[65] between an approximate 4,000-foot gap in coverage near the OU-2/OU-3 boundary to define perchlorate concentrations and hydraulic conditions within this area. The locations of Phase 3 RI soil borings in OU-3 are shown in Figure 6-8b, and the locations of the monitoring wells are shown in Figure 6-10b.

Twelve soil borings were drilled along two paleochannel investigation transects (Transects H and I) as shown in Figure 6-9 to define paleochannels identified through previous geophysical investigations. Six soil borings were drilled at each transect; TB-H1 through TB-H6 at Trasect H, and TB-I1 thorugh TB-I6 at Trasect I. Two of the soil borings at each transect location (TB-H1, TB-H6, TB-I1, and TB-I2) were advanced to 90 ft bgs with soil samples collected at 10-foot intervals for chlorate and perchlorate analyses. The four additional soil borings at each transect were advanced to depths sufficient to visually identify the paleochannels.

To evaluate the current distribution of perchlorate and other COPCs in OU-3, a comprehensive round of groundwater samples was collected from 266 groundwater monitoring wells. The list of wells included the 37 new Phase 3 RI Modification No. 8 wells and 229 existing monitoring wells in OU-3. Note that six of the existing wells (ES-55A, ES-56A, NERT-FM01A, NERT-FM01B, NERT5.20S1, and PC-1) were dry and groundwater samples could not be collected. In addition, well M-15 located along Galleria Drive near the closed City of Henderson landfill was not located and appears to have been destroyed. As approved by NDEP, groundwater collected from wells located west of Pabco Road in the NERT Off-Site Study Area portion of OU-3 were analyzed for perchlorate, chlorate, chromium, and chloroform. Groundwater collected from wells located east of Pabco Road were analyzed for perchlorate, chlorate, and chromium. Note that the final analyte list for the comprehensive groundwater sampling event was modified by Phase 3 RI Modification No. 13, as described below. To characterize general groundwater chemistry in OU-3, all wells were tested for general chemistry and field parameters.

- Phase 3 RI Modification No. 9 (Ramboll 2019e) added to the initial scope and included soil gas probe installation and sampling at 12 locations in OU-1 (RISG-79 through RISG-90) and 27 locations in OU-2 (RISG-52 through RISG-78). Soil gas probe

---

[65] While these wells are located within OU-2, the data obtained from them will be evaluated and reported in the RI Report for OU-3 and are not included in Revision 1 of this report.

locations are shown in Figure 6-12a (for OU-1) and Figure 6-12b (for OU-2). Phase 3 RI Modification No. 9 also included collection of additional soil gas samples at the initial 34 soil gas probe locations previously installed as specified in Phase 2 RI Modification Nos. 11 and 12. Soil gas samples were analyzed for VOCs using USEPA TO-15 and TO-15 in selected ion monitoring (SIM) mode.

- Phase 3 RI Modification No. 10 (Ramboll 2020c) added to the initial scope by incorporating high-frequency surface water sampling in the Las Vegas Wash to characterize temporal variation in perchlorate, chlorate, and TDS concentrations and mass loading. Sampling locations are shown in Figure 6-11. Two sampling events were conducted, one in the summer and one in the winter. For each event, hourly sampling was conducted for 48 hours at 12 sampling locations situated at six key locations within the Las Vegas Wash using portable automated sampler technology. The sampling locations and samples included Duck Creek (LVW 7.2), Pabco Road (LVW 6.05), Historic Lateral (LVW 5.3N, LVW 5.3C, and LVW 5.3S), Homestead (LVW 4.2N, LVW 4.2C, and LVW 4.2S), Rainbow Gardens (LVW 3.5N, LVW 3.5C, and LVW 3.5S), and Northshore Road (LVW 0.55). Samples were collected using a programable peristaltic pump. Samples were analyzed for perchlorate, chlorate, and TDS. Work performed in connection with this RI modification and OU-3 in general will be further described within the forthcoming RI Report for OU-3.
- Phase 3 RI Modification No. 11 (Ramboll 2020e) added to the initial scope and included additional planned soil and groundwater characterization adjacent to and north of the SWF within OU-3. The scope of work included installation of additional soil borings and monitoring wells at three locations (total of five wells) located generally between the SWF and the Las Vegas Wash to evaluate the vertical extent of perchlorate. At each drilling location, a pilot soil boring was drilled to 90 ft bgs, and soil samples were collected at 10-foot intervals from 10 feet bgs to the total boring depth and analyzed for chlorate and perchlorate. The new Phase 3 RI Modification No. 11 wells (PC-94D, PC-205A, PC-205B, NERT5.98S1, and NERT5.98S2) were sampled consistent with the OU-3 comprehensive groundwater monitoring program previously described as part of Phase 3 RI Modification No. 8. The locations of Phase 3 RI soil borings in OU-3 are shown in Figure 6-8b, and the locations of the monitoring wells are shown in Figure 6-10b.
- Phase 3 RI Modification No. 12 (Ramboll 2021c) added to the initial scope by incorporating three existing OU-3 wells (PC-200, PC-201, and PC-202) into the comprehensive groundwater monitoring program previously described as part of Phase 3 RI Modification Nos. 8 and 11. These three wells were previously installed as part of Phase 3 RI Modification No. 7 (Ramboll 2019d). Note that during completion of the comprehensive groundwater sampling event, monitoring well PC-200 was dry and a sample could not be collected. Well locations are shown in Figure 6-10b. Work performed in connection with this RI Modification and OU-3 in general will be further described within the forthcoming RI Report for OU-3.
- Phase 3 RI Modification No. 13 (Ramboll 2021g) amended the Phase 3 RI Modification No. 8 scope of work by adding additional groundwater analytical parameters and soil sampling on the west side of Pabco Road to support the evaluation of the nature and extent of contamination in OU-3 and to inform the assessment of human health risks in OU-3 in the forthcoming OU-3 BHRA. Consistent with the approved Phase 3 RI

Modification No. 8, as previously described, groundwater samples collected from approximately 65 monitoring wells located west of Pabco Road were initially planned to be analyzed for perchlorate, chlorate, chromium, and chloroform, as well as general groundwater chemistry parameters and field parameters. Phase 3 RI Modification No. 13 added the following analytes that were detected in groundwater above their screening level in OU-2 to the analysis of groundwater samples collected from wells located west of Pabco Road: bromide, nitrate, nitrite, arsenic, boron, iron, magnesium, manganese, strontium, and vanadium. To ensure a comprehensive evaluation, the list of VOC analyses was expanded to include the full VOC analytical suite evaluated in OU-2.

Additionally, Phase 3 RI Modification No. 13 added nine targeted soil samples from three depth intervals (0 ft, 5 ft, and 9.5 ft bgs) at one boring location (the pilot boring PC-205) and two well locations (PC-205A and PC-205B) that were drilled and installed as part of Phase 3 RI Modification No. 11. These soil samples were analyzed for perchlorate, chlorate, nitrate, nitrite, arsenic, boron, chromium, iron, magnesium, manganese, strontium, vanadium, and VOCs. Results from these soil analyses will be used to support the evaluation of the nature and extent of contamination in OU-3 and to inform the assessment of human health risks in OU-3 in the forthcoming OU-3 BHRA. Sampling locations are shown in Figure 6-8b. Work performed in connection with this RI modification and OU-3 in general will be further described within the forthcoming RI Report for OU-3.

- Phase 3 RI Modification No. 14 (Ramboll 2021k) added to the Phase 3 RI Modification No. 8 scope of work with the installation and sampling of two shallow monitoring wells in the paleochannel near Transect I (NERT5.15S1 and NERT5.15S2) within OU-3. Additionally, Phase 3 RI Modification No. 14 included the slug testing of 16 shallow monitoring wells near the Las Vegas Wash (NERT3.94N1, NERT4.21N1, NERT4.29N1, NERT4.29N2, NERT4.64N1, NERT4.71N1, NERT5.15S1, NERT5.15S2, NERT5.26N1, NERT5.63S1, NERT5.63S2, NERT5.63S3, NERT5.80S1, NERT5.80S2, NERT5.83N1, and NERT5.21N1). The collection of this additional data was necessary to fully characterize perchlorate concentrations in groundwater within the Transect I paleochannel and provide additional hydraulic property data near the Las Vegas Wash. The locations of the monitoring wells are shown in Figure 6-10b. Work performed in connection with this RI modification and OU-3 in general will be further described within the forthcoming RI Report for OU-3.
- Phase 3 RI Modification No. 15 (Ramboll 2022d) added to the Phase 3 RI scope of work by incorporating a supplemental soil gas investigation to assess human health risk and represent a worst case or Reasonable Maximum Exposure (RME) condition in the OU-3 area west of Pabco Road and north of Galleria Drive. This included the installation of multi-level soil gas probes at two locations (RISG-91 and RISG-92) within the interior of the core NERT plume in this portion of OU-3 that originated in OU-1. Soil gas samples were then collected from the new locations and at 10 existing locations (RISG-35, RISG-36, RISG-37, RISG-38, RISG-39, RISG-40, RISG-42, RISG-43, RISG-44, and RISG-45) previously installed as part of Phase 3 RI Modification No. 7. Soil gas samples were analyzed for VOCs using USEPA Method TO-15. The soil gas probe locations are shown in Figure 6-12c. Work performed in connection with

this RI modification and OU-3 in general will be further described within the forthcoming RI Report for OU-3.

For the Phase 3 RI Scope of Work outlined above:

- Soil samples selected for physical parameter testing were tested for Atterberg Limits and/or grain size distribution, porosity, bulk density, and fractional organic carbon.
- Baseline sampling and analysis of the existing monitoring wells was conducted in the Eastside Sub-Area for the Administratively Limited COPCs and general water quality indicators. As previously described, baseline sampling of the existing monitoring wells in the Northeast Sub-Area included analyses for the Administratively Limited COPCs as well as chromium and hexavalent chromium. Due to large variances in COPC concentrations in groundwater from recent sampling events in comparison to prior sampling events, two rounds of comprehensive sampling were conducted to assess current groundwater conditions.

Focused hydraulic testing was performed during well development, including recovery testing (i.e., measuring well recovery following development activities), to begin to characterize local hydraulic conditions. More comprehensive slug testing was conducted at some newly installed wells following the completion of well development activities. Slug testing was conducted in association with the initial RI Phases 1, 2, and 3, the Unit 4 and 5 Buildings investigation, and during various pilot and treatability studies. In all, approximately 391 slug tests were completed between 2014 and 2019 to support the RI of OU-1 and OU-2. Aquifer testing results are presented in Appendix D.

NMR logging was conducted consistent with Phase 3 RI Modification No. 3. The modification proposed logging 155 well locations within OU-1, OU-2, and OU-3. Many of the wells selected for NMR logging were installed as part of the NERT RI (Phases 1, 2, and 3) and the Downgradient Study Area Investigation. Several previously existing wells were later added to supplement older boring log data, at the request of NDEP. In all, NMR logging was conducted in approximately 268 wells. Additional details are provided in Appendix E.

6.5 Summary of RI Field Investigations

As described above, the NERT RI Study Area has been expanded over time and includes the NERT Site Study Area (OU-1), NERT Off-Site Study Area (OU-2 and OU-3), Eastside Sub-Area (OU-2), Northeast Sub-Area (OU-3), and Downgradient Study Area (OU-3). Field activities for the RI associated with OU-1 and OU-2 are complete, and the RI results are the subject of the remaining sections of this report. Data collection to support the RI within OU-3 and the OU-3 human health and ecological risk assessments was completed in October 2022. All OU-3 RI data will be evaluated and presented within the forthcoming RI Report for OU-3.

7. RI RESULTS: OU-1

This section provides the RI results for soil and groundwater in OU-1. The physical and environmental setting of OU-1 is described in Section 5.0, and this section summarizes the identification of COPCs and the nature and extent of COPCs within OU-1. In Sections 7.1 and 7.2, respectively, results of soil and groundwater sampling during the RI investigations in OU-1 are evaluated to determine those constituents that exceed certain criteria indicating that they should be retained as either soil or groundwater COPCs. Section 7.3 provides a discussion regarding what constituents are retained as COPCs. The nature and extent of retained COPCs for soil and groundwater within OU-1 are discussed in Sections 7.4 and 7.5, respectively. Section 7.6 provides a discussion summarizing the Unit 4 and 5 Buildings investigation conducted on the EMD leasehold by Tetra Tech, which was fully presented in the Unit 4 and 5 Buildings Investigation Report (Tetra Tech 2020) and approved by NDEP on January 7, 2020.[66] The results of the OU-1 soil gas investigation are discussed in Section 7.7.

7.1 Identification of Soil COPCs

In this section, soil sampling results from RI investigations in OU-1 are evaluated to identify those constituents that will be retained as COPCs for soil. Soil COPCs are chemicals that exceed human health-based screening levels in shallow soil or have the potential to impact underlying groundwater due to leaching. Naturally occurring constituents are not considered COPCs unless they are found at concentrations significantly above naturally occurring background levels and appear to be indicative of an anthropogenic source. Common nutrients, salts, and infrequently detected chemicals (as discussed in Section 7.1.1) are also not considered COPCs.

7.1.1 Initial Soil COPC Screening

The first step in the soil COPCs identification process was to conduct a comparison of vadose zone soil concentrations in OU-1 to leaching-based soil screening levels (LSSLs). Vadose zone soil concentrations were also compared to the human health-based soil screening levels (HSSLs) if the HSSL was lower or no LSSL was available for the relevant COPC. LSSLs and HSSLs were derived using the methodology described in Appendix G, which is based on NDEP's User's Guide and Background Technical Document for NDEP BCLs for Human Health for the BMI Complex and Common Areas (NDEP 2023a). Consistent with this guidance, the LSSLs were developed assuming a conservative default dilution attenuation factor (DAF) of 1. The DAF is the ratio of leachate concentration to the concentration in groundwater at the receptor point. The HSSLs are based on conservative default assumptions for soil exposures by commercial or industrial workers.

Soil data collected from OU-1 used in the RI (referred to as the "RI Soil Data Set") includes approximately 500,000 analytical results from investigations in OU-1 over the period from 2006 to 2019. Included in the RI Soil Data Set are:

- Tronox Phase A, B, and Parcel Investigations (2006–2009);

---

[66] The Unit 4 and 5 Buildings Investigation Report was submitted on January 7, 2020, and is part of the administrative record.

- Sampling associated with the 2010–2011 NERT Soil Removal Action (Soil Removal Action);
- Sampling from the 2014–2019 NERT RI, including applicable RI modifications and the investigation of the Unit 4 and 5 Buildings; and
- Sampling from localized soil removal actions in 2016 and 2019.

Soil data associated with localized treatability studies in OU-1 and samples excavated through 2019 are not included in the RI Soil Data Set since they may not be representative of current conditions over the broader NERT RI Study Area, were not collected for the purpose of site characterization, or were not all validated to Stage 2B/4 consistent with data collected for the RI. Depths were re-adjusted in areas where soil was excavated during the Interim Removal Action but not backfilled to the pre-excavation grade. Specifically, sampling depths were revised to represent the depth below grade based on the elevation *after* completion of soil excavation. The complete RI Soil Data Set is presented in Appendix H.

The initial screening comparison was conducted for the RI Soil Data Set using the three following lithologic zones within the vadose zone:

- Upper 10 feet of soil (within the unsaturated alluvium);
- Unsaturated alluvium deeper than 10 ft bgs; and
- Unsaturated UMCf.

The initial screening comparison approach is consistent with the NDEP-approved BHRA Report for OU-1 Soils (Ramboll 2022b), which assumes potential human exposure is limited to the upper 10 feet of soil. Furthermore, this same distinction and methodology was utilized in the BRC Closure Plan for the BMI Common Areas (BRC 2007), which resulted in NFA determinations by NDEP for the upper 10 feet of soil. Tables 7-1a, 7-1b, and 7-1c present a statistical summary and comparison of all vadose zone soil results of the RI Soil Data Set to the LSSLs (with a DAF of 1) and HSSLs for these three lithologic zones. Consistent with the NDEP-approved RI/FS Work Plan (ENVIRON 2014c), the following constituents were eliminated as COPCs during this initial screening:

- Chemicals with no detected concentrations exceeding either the LSSL or HSSL were eliminated and are indicated with orange shaded rows;
- Chemicals which were detected in fewer than 5% of samples and do not have relevant screening levels were eliminated and are indicated with yellow shaded rows;
- The essential nutrients calcium, potassium, and sodium were eliminated and are indicated with blue shaded rows; and
- Due to a lack of toxicity data, and therefore LSSLs and HSSLs, the following macronutrients and salts were eliminated: silicon, sulfur, bicarbonate, carbonate, chloride, orthophosphate, and sulfate, as also indicated with blue shaded rows.

In addition to the above COPC exclusions, and also consistent with the NDEP-approved RI/FS Work Plan (ENVIRON 2014c), a modified evaluation of the following constituent groups or individual constituents was conducted during the initial screening as follows:

- While the radioisotopes of uranium were eliminated and are indicated with green shaded rows, the results for total uranium were evaluated, consistent with NDEP guidance (NDEP 2023a); and
- While petroleum hydrocarbon mixture analytes (e.g., gasoline range organics) were eliminated (green shading), indicator chemicals for petroleum hydrocarbon mixtures (i.e., benzene, toluene, ethylbenzene, and total xylenes, frequently referred to as BTEX; methyl tertiary butyl ether [MTBE]; and PAHs) were detected at the site, and sufficient data (over 20,000 analyses performed on OU-1 vadose zone soil samples) were collected for the indicator chemicals to evaluate their nature and extent of contamination. Therefore individual evaluations of indicator chemicals were used, consistent with NDEP guidance (NDEP 2023a).

If a chemical was not eliminated based on the initial screening, it was evaluated further in the secondary screening (presented in Section 7.1.2) before a decision was made regarding whether to exclude or retain that chemical as a soil COPC in OU-1. Chemicals are indicated with light yellow shaded rows in Tables 7-1a, 7-1b, and 7-1c if they exceeded the LSSL or HSSL, but had exceedances of the LSSL or HSSL in fewer than 10 samples, had a maximum exceedance of the LSSL or HSSL less than a factor of 20 higher than the lower screening level, and were detected in fewer than 5% of samples. These chemicals are highlighted because they would have been eliminated as COPCs according to the criteria in the NDEP-approved RI/FS Work Plan (ENVIRON 2014c); however, they were included in the secondary screening to evaluate potential areas of contamination.

The results of the initial soil COPC screening evaluation are presented in Tables 7-1a, 7-1b, and 7-1c. Based on the analysis and criteria outlined above, no compounds within the petroleum indicators chemical group were retained as potential COPCs in soil. All other chemical groups are discussed below.

7.1.1.1 Chlorates and General Chemistry

The following chlorates and general chemistry parameters were detected in soil at concentrations exceeding their respective LSSLs in one or more vadose zone lithologies: bromide, chlorate, nitrate (as NO_3), and perchlorate. As expected, given the operational history within OU-1, these parameters with the exception of bromide were detected in soil above their respective LSSLs in all three lithologic zones. Additionally, perchlorate was detected above the HSSL in the upper 10 feet of soil, and both perchlorate and chlorate were detected above their respective HSSLs in the alluvium below 10 feet. Therefore, perchlorate, chlorate, and nitrate (as NO_3) are initially retained as COPCs in soil and are subject to secondary screening. As shown in Table 7-1c, bromide was detected in unsaturated UMCf at concentrations above the LSSL and is also initially retained as a COPC in soil subject to secondary screening. Nitrate/nitrite (as N) does not have an LSSL or HSSL but is detected in all vadose zone lithologies at a frequency greater than 5% and is therefore also initially retained as a COPC in soil subject to secondary screening. The secondary screening of these constituents is discussed in Section 7.1.2.1.

7.1.1.2 Metals

The following metals were detected in soil at concentrations exceeding their respective LSSLs in one or more vadose zone lithologies: antimony, arsenic, barium, boron, cadmium, chromium (hexavalent), cobalt, copper, iron, lead, lithium, magnesium, manganese, mercury, molybdenum, nickel, niobium, selenium, silver, strontium, thallium, tungsten, uranium (total), and zirconium. Additionally, arsenic was detected at concentrations above the target remediation goal[67] in all three lithologies, hexavalent chromium was detected above its HSSL in soil deeper than 10 feet, and cobalt, lead, magnesium, manganese, and thallium were also detected above their HSSLs in the upper 10 feet of soil. Based on these results, these metals are initially retained as COPCs in soil and are subject to secondary screening. Palladium does not have an LSSL or HSSL but is detected in all vadose zone lithologies at a frequency greater than 5% and is therefore also initially retained as a COPC subject to secondary screening. The secondary screening of these constituents is discussed in Section 7.1.2.2.

7.1.1.3 Radionuclides

The following radionuclides were detected in soil at activities exceeding their respective LSSLs or HSSLs in one or more vadose zone lithologies: radium-226, radium-228, thorium-228, thorium-230, thorium-232, uranium-235, and uranium-238. Radium-226 and radium-228 do not have calculated LSSLs, but concentrations of these compounds exceed their respective HSSLs in all three lithologic units. Thorium-228 is above its LSSL and HSSL in all three lithologic units. Thorium-230 and thorium-232 are above their respective LSSLs in all three lithologic units and thorium-230 is above its HSSL in the unsaturated alluvium deeper than 10 feet. Uranium-235 and uranium-238 do not have LSSLs, but concentrations of uranium-235 exceeds its HSSL in unsaturated soil below 10 ft bgs and uranium-238 exceeds its HSSL in all three lithologic units. Based on these results, these radionuclides are initially retained as COPCs in soil and are subject to secondary screening. The secondary screening of these constituents is described in Section 7.1.2.3.

7.1.1.4 VOCs

The following VOCs were detected in soil at concentrations exceeding their respective LSSLs in one or more vadose zone lithologies: acetone, benzene, carbon tetrachloride, chlorobenzene, chloroform, 1,2-dichlorobenzene, 1,4-dichlorobenzene, 1,2-dichloroethane (1,2-DCA), 1,1-dichloroethene (1,1-DCE), methylene chloride, PCE, 1,2,3-trichlorobenzene, 1,2,4-trichlorobenzene, TCE, 1,2,3-trichloropropane, 1,2,4-trimethylbenzene, 1,3,5-trimethylbenzene, and tert butyl alcohol (TBA). Additionally, benzene was detected above the HSSL in the unsaturated UMCf, and chloroform was detected in soil at concentrations above the HSSL in the unsaturated alluvium deeper than 10 feet and the unsaturated UMCf. Based on these results, these VOCs are initially retained as COPCs in soil and are subject to secondary screening as described in Section 7.1.2.4.

---

[67] For arsenic, as discussed in Appendix G, there is no HSSL but instead a target remediation goal. A target remediation goal of 7.2 mg/kg was approved by NDEP on August 20, 2010 (NDEP 2010) in response to Tronox's August 13, 2010 errata to the Removal Action Work Plan (Northgate 2010h).

7.1.1.5 SVOCs

The following SVOCs were detected in soil at concentrations exceeding their respective LSSLs in one or more vadose zone lithologies: benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, carbazole, 2-chlorophenol, dibenz(a,h)anthracene, 1,4-dioxane, hexachlorobenzene, indeno(1,2,3-cd)pyrene, 1-methylnaphthalene, 2-methylnaphthalene, octachlorostyrene, and phenanthrene. The SVOCs carbazole, 2-chlorophenol, 1,4-dioxane, hexachlorobenzene and octachlorostyrene are discussed further in this section. The remaining compounds are PAHs and are discussed in Section 7.1.1.6.

Carbazole was only detected in the upper 10 feet of soil and did not exceed its HSSL. 2-Chlorophenol was only detected in the unsaturated alluvium deeper than 10 feet and did not exceed its HSSL. As shown in Tables 7-1a, 7-1b, and 7-1c, 1,4-dioxane was analyzed and reported as a VOC and SVOC; each of these results were analyzed to evaluate if 1,4-dioxane should be considered a soil COPC. 1,4-Dioxane was detected in soil deeper than 10 ft bgs and did not exceed its HSSL. Though each of these SVOCs were detected in very few samples, they are initially retained as COPCs in soil subject to secondary screening. As shown in Tables 7-1a, 7-1b, and 7-1c, hexachlorobenzene was analyzed and reported as an SVOC, a PAH, and as an OCP; each of these results were analyzed to evaluate if hexachlorobenzene should be considered a soil COPC. Hexachlorobenzene was detected in soil at concentrations above the LSSL and HSSL in the alluvium and was not detected above the LSSL or HSSL in the UMCf. Based on these results, hexachlorobenzene is initially retained as a COPC in soil subject to secondary screening. Octachlorostyrene does not have an LSSL or HSSL but was detected in the alluvium above and below 10 ft bgs at a frequency greater than 5% and is therefore also initially retained as a COPC in soil subject to secondary screening. The secondary screening for these constituents is described in Section 7.1.2.5.

7.1.1.6 PAHs

As shown in Tables 7-1a, 7-1b, and 7-1c, PAHs were analyzed and reported as SVOCs and as PAHs; each of these results were analyzed to evaluate if PAHs should be considered a soil COPC. The following PAHs were detected in soil at concentrations exceeding their respective LSSLs in the upper 10 feet of unsaturated alluvium: benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, dibenz(a,h)anthracene, indeno(1,2,3-cd)pyrene, 1-methylnaphthalene, 2-methylnaphthalene, and phenanthrene. Benzo(a)anthracene, benzo(b)fluoranthene, 1-methylnaphthalene, 2-methylnaphthalene, and phenanthrene were also detected above the LSSL in the unsaturated alluvium below 10 feet. Based on these results, these constituents are initially retained as COPCs in soil subject to secondary screening. The secondary screening for these constituents is described in Section 7.1.2.6.

7.1.1.7 PCBs

The following PCB mixtures were detected in soil at concentrations exceeding their respective LSSLs in the upper 10 feet of unsaturated alluvium: Aroclor-1248, Aroclor-1254, and Aroclor-1260. In addition, Aroclor-1260 was detected above the LSSL in the alluvium below 10 ft bgs. PCBs were not detected above LSSLs in the UMCf, and no PCBs exceeded HSSLs in any vadose zone lithology. Based on these results, these constituents are initially retained as COPCs in soil and are subject to secondary screening as described in Section 7.1.2.7.

7.1.1.8 Dioxins/Furans

All dioxin/furan congeners except for octachlorodibenzo-p-dioxin were detected in soil at concentrations above LSSLs and HSSLs in the alluvium both above and below 10 feet. Dioxins/furans were not detected above LSSLs or HSSLs in the UMCf. Based on these results, all the detected dioxin/furan congeners are initially retained as COPCs in soil and are subject to secondary screening as discussed in Section 7.1.2.8.

7.1.1.9 Organochlorine Pesticides

In addition to hexachlorobenzene as discussed in Section 7.1.1.5, the following OCPs were detected in soil at concentrations exceeding their respective LSSLs in the upper 10 feet of unsaturated alluvium: alpha-BHC, beta-BHC, gamma-BHC, 4,4'-dichlorodiphenyldichloroethylene (4,4’-DDE), 4,4'-dichlorodiphenyltrichloroethane (4,4’-DDT), and dieldrin. Alpha-BHC, beta-BHC, gamma-BHC, and dieldrin also had concentrations exceeding the LSSL in the alluvium at depths below 10 ft bgs. No OCPs were detected above LSSLs or HSSLs in the UMCf, and no OCPs exceeded HSSLs in any vadose zone lithology (with the exception of hexachlorobenzene as discussed in Section 7.1.1.5). Based on these results, these OCPs are initially retained as COPCs in soil and are subject to secondary screening as described in Section 7.1.2.9.

7.1.1.10 Organophosphorus Pesticides

The following OPPs were detected in soil at concentrations above the LSSL: dimethoate in the upper 10 feet of unsaturated alluvium and the unsaturated UMCf, and stirophos in the upper 10 feet of unsaturated alluvium. No OPPs exceeded HSSLs in any vadose zone lithology. Based on these results, these constituents are initially retained as COPCs in soil and are subject to secondary screening as described in Section 7.1.2.10.

7.1.1.11 Other Organics

Formaldehyde was detected above the LSSL (but below the HSSL) in the alluvium both above and below 10 feet. Based on this result, formaldehyde is initially retained as a COPC in soil and is subject to secondary screening as described in Section 7.1.2.11.

7.1.2 Secondary Soil COPC Screening

Based on the discussion above, constituents remaining as potential soil COPCs are shown in Table 7-2a. These remaining constituents are subjected to secondary screening as discussed in the following sections. Secondary screening criteria included:

- For naturally occurring constituents including metals and radionuclides, soil concentrations were compared to background concentrations;
- Soil concentrations were compared to site-specific LSSLs at an appropriate site-specific DAF (DAF of 1 or 20 as described below);
- Evaluating each constituent’s nature and extent (vertical and horizontal) in OU-1 soil (e.g., distribution and magnitude of soil concentrations above site-specific LSSLs, widespread distribution vs. localized occurrences, and/or distribution consistent with an anthropogenic source);
- Further evaluation of the relevant constituent’s detection frequency in each of the vadose zone depths and lithologies in OU-1; and

- Evaluating other chemical-specific and/or site-specific factors (e.g., contaminant mobility, indication that on-site impacts may be from an off-site source).

Figures supporting the secondary soil COPC evaluation are presented in this section of the report. These figures are important for determining if elevated concentrations of certain COPCs are localized in specific areas and depths of OU-1, and as such, could be indicative of the location of a prior release. As these figures are intended to best present the spatial distribution of COPCs, relevant criteria including the LSSL at a DAF of 1 and/or 20, the HSSL, approximate maximum background levels, and other appropriate levels have been included as color breaks in the figures depicting the horizontal extent of contamination; however, these criteria may be included as different colors for different constituents depending on the overall distribution of contamination relative to the criteria. Figures for constituents that are retained as COPCs for soil as a result of the secondary screening are presented in this section of the report and are discussed in greater detail in the nature and extent discussion in Section 7.4.

For the secondary screening, a site-specific DAF was developed to more realistically represent the effect of dilution-attenuation processes, which are physical, chemical, and biological processes that tend to reduce the eventual contaminant concentration at the receptor point (USEPA 1996). USEPA guidance indicates that a DAF of 1 is to be used at sites where little or no dilution or attenuation of soil leachate concentrations is expected, such as sites with shallow water tables, fractured media, karst topography, or source size greater than 30 acres (USEPA 1996). Within OU-1, groundwater is not shallow and fractured media or karst topography is not present. However, for perchlorate, chlorate, hexavalent chromium and chloroform, the soil source size in OU-1 is anticipated to be greater than 30 acres and therefore a DAF of 1 was used in the secondary soil COPC screening consistent with USEPA guidance (USEPA 1996).

Conversely, source sizes are anticipated to be relatively small for other COPCs in OU-1 and would warrant use of a DAF of greater than 1. As described in Appendix G, a site-specific evaluation using the groundwater fate and transport model indicated that the DAF within OU-1 could be as high as 70 for source areas of limited size (~2,500 ft^2). This is similar to the DAF of 66 used by TIMET for their portion of the Beta and Northwest Ditches (TIMET 2013). Therefore, although a higher DAF is likely more representative of site-specific conditions, to be conservative in the screening process, a DAF of 20 was chosen for all chemicals other than perchlorate, chlorate, hexavalent chromium, and chloroform. This is consistent with USEPA guidance that states that because of the uncertainty resulting from the wide variability in subsurface conditions that affect contaminant migration in groundwater, a default DAF of 20 is recommended as being protective for contaminated soil sources that are smaller than 0.5 acres in size.

7.1.2.1 Chlorates and General Chemistry

As noted in section 7.1.1.1, the following chlorate/general chemistry constituents were retained for secondary screening: bromide, perchlorate, chlorate, nitrate (as NO_3), and nitrate/nitrite (as N). The secondary screening of these constituents and final determinations whether to retain or exclude these constituents as COPCs for soil in OU-1 are discussed below.

Bromide

Bromide only slightly exceeds the LSSL at a DAF of 1 in the UMCf soil zone, but does not exceed the LSSL at a DAF of 1 in the unsaturated alluvium soil zones. Bromide concentrations in soil are also significantly less than the LSSL at the site-specific DAF of 20 in all lithologic zones (Tables 7-1a, 7-1b, and 7-1c). Based on these results, bromide is not retained as a COPC for soil in OU-1.

Perchlorate

Figure 7-1a shows the concentrations of perchlorate in soil versus depth. Figures 7-1b, 7-1c, and 7-1d show the extent of perchlorate concentrations across OU-1 in soil in the upper 10 feet, 10 to 30 ft bgs, and 30 to 50 ft bgs depth ranges, respectively. As these figures show, the elevated concentrations of perchlorate are widely distributed throughout OU-1 and most of these concentrations are significantly higher than the LSSL at a DAF of 1. Based on these results, perchlorate is retained as a COPC for soil in OU-1.

Chlorate

Figure 7-2a shows the concentrations of chlorate in soil versus depth. Figures 7-2b, 7-2c, and 7-2d show the extent of chlorate concentrations across OU-1 in soil in the upper 10 feet, 10 to 30 ft bgs, and 30 to 50 ft bgs depth ranges, respectively. As these figures show, the elevated concentrations of chlorate are widely distributed throughout OU-1 and many of these concentrations are significantly higher than the LSSL at a DAF of 1. Based on these results, chlorate is retained as a COPC for soil in OU-1.

Nitrate (as NO_3)

Figure 7-3a shows the concentrations of nitrate (as NO_3) in soil versus depth. Figures 7-3b, 7-3c, and 7-3d show the extent of nitrate (as NO_3) concentrations across OU-1 in soil in the upper 10 feet, 10 to 30 ft bgs, and 30 to 50 ft bgs depth ranges, respectively. As these figures show, the elevated concentrations of nitrate (as NO_3) are widely distributed throughout OU-1 and many of these concentrations are higher than the LSSL at a DAF of 1. Based on these results, nitrate (as NO_3) is retained as a COPC for soil in OU-1.

Nitrate/Nitrite (as N)

Nitrate/Nitrite (as N) is a calculated value reflecting the sum of nitrate and nitrite and does not have an LSSL or HSSL. Though nitrate/nitrite (as N) is deemed a complete data set, there are more data available for nitrate (as NO_3) than for nitrate/nitrite (as N). Because concentrations of nitrite in OU-1 are relatively low compared to nitrate, nitrate/nitrite (as N) concentrations are similar to nitrate (as NO_3) concentrations and therefore, nitrate/nitrite (as N) is not retained as a separate COPC for soil in OU-1.

Additional discussion of the nature and extent of the chlorates/general chemistry constituents retained as COPCs for soil in OU-1 (perchlorate, chlorate, and nitrate [as NO_3]) is presented in Section 7.4.1.

7.1.2.2 Metals

As noted in Section 7.1.1.2, the following metals were retained for secondary screening; antimony, arsenic, barium, boron, cadmium, chromium (hexavalent), cobalt, copper, iron, lead, lithium, magnesium, manganese, mercury, molybdenum, nickel, palladium, selenium, silver, strontium, thallium, tungsten, uranium (total), and zirconium. The secondary screening of these constituents and final determinations whether to retain or exclude these constituents as COPCs for soil in OU-1 are discussed below. As these are naturally occurring constituents, these metals are evaluated by comparing the results to established background concentrations in addition to evaluation of the horizontal and vertical distribution of metals in soil and how concentrations of metals compare to their respective LSSLs at a DAF of 20.

Soil Background Evaluation

The results of the soil background concentration study undertaken as part of the RI has been presented in the NDEP-approved Soil Background Data Set Summary Report (Ramboll 2021d). As described in detail in Appendix I, the RI Soil Data Set results for metals and radionuclides in the vadose zone were compared to relevant background data from the surrounding region to determine which metals and radionuclides in OU-1 are present in vadose zone soil at concentrations above naturally occurring levels in the region surrounding OU-1. Metals and radionuclides considered to be consistent with background are not likely related to an anthropogenic source (e.g., a spill or former operations) and were excluded as soil COPCs in OU-1. The full results of the statistical background evaluations are discussed in Appendix I, presented in Table I-2a and Table I-2b, and summarized in Table I-3. Statistical summaries of site and background data sets are presented in Tables I-1a through Tables I-1h. The background evaluation for metals is presented on an individual basis as part of the COPC selection process below, and the evaluation of radionuclides is presented on an individual basis in Section 7.1.2.3.

Evaluation of Metals Distribution in Soil

Metals with concentrations in soil in OU-1 that are higher than background soil concentrations as summarized in Table I-3 have been further evaluated to determine if these metals concentrations are indicative of an anthropogenic source. Concentrations of these metals in OU-1 soil were compared with each metal's LSSL at a DAF of 20 and the horizontal and vertical distribution of concentrations of each metal in soil was evaluated. As described below, the following metals were not retained as COPCs as part of secondary screening: cadmium, copper, iron, lithium, mercury, molybdenum, niobium, palladium, selenium, silver, strontium, thallium, tungsten, total uranium, and zirconium. The following presents the results of the secondary screening of metals which were retained as COPCs beyond the initial screening evaluation.

Antimony

Figure 7-4a shows the concentrations of antimony in soil versus depth. Figures 7-4b, 7-4c, and 7-4d show the extent of antimony concentrations across OU-1 in soil in the upper 10 feet, 10 to 30 ft bgs, and 30 to 50 ft bgs depth ranges, respectively. These figures show a pattern of elevated concentrations consistent with an anthropogenic source. Based on these results, antimony is retained as a COPC for soil in OU-1.

Arsenic

Figure 7-5a shows the concentrations of arsenic in soil versus depth. Figures 7-5b, 7-5c, and 7-5d show the extent of arsenic concentrations across OU-1 in soil in the upper 10 feet, 10 to 30 ft bgs, and 30 to 50 ft bgs depth ranges, respectively. Figures 7-5a and 7-5b show a pattern of elevated concentrations consistent with an anthropogenic source, though Figures

7-5c and 7-5d show patterns more consistent with a naturally occurring population as discussed in Appendix I. Based on these results, arsenic is retained as a COPC for soil in OU-1.

Barium

Figure 7-6a shows the concentrations of barium in soil versus depth. Figures 7-6b, 7-6c, and 7-6d show the extent of barium concentrations across OU-1 in soil in the upper 10 feet, 10 to 30 ft bgs, and 30 to 50 ft bgs depth ranges, respectively. As shown in Figure 7-6a, there are several samples that have concentrations of barium above maximum background concentrations. Seven of these samples exceed the LSSL at a DAF of 20 (1,640 milligrams per kilogram [mg/kg]). Based on these results, barium is retained as a COPC for soil in OU-1.

Boron

Figure 7-7a shows the concentrations of boron in soil versus depth. Figures 7-7b, 7-7c, and 7-7d show the extent of boron concentrations across OU-1 in soil in the upper 10 feet, 10 to 30 ft bgs, and 30 to 50 ft bgs depth ranges, respectively. These figures show a pattern of elevated concentrations consistent with an anthropogenic source. Based on these results, boron is retained as a COPC for soil in OU-1.

Cadmium

Cadmium had one sample with a soil concentration just slightly above the LSSL at a DAF of 20 (8 mg/kg) in the upper 10 feet of alluvium. However, cadmium was not detected in an adjacent soil sample. Figure 7-8a shows the concentrations of cadmium in soil versus depth. Figures 7-8b, 7-8c, and 7-8d show the extent of cadmium concentrations across OU-1 in soil in the upper 10 feet, 10 to 30 ft bgs, and 30 to 50 ft bgs depth ranges, respectively. These figures do not show clusters of high concentrations of cadmium indicative of an anthropogenic source. Based on these results, cadmium is not retained as a COPC for soil in OU-1.

Chromium (hexavalent)

Figure 7-9a shows the concentrations of hexavalent chromium in soil versus depth. Figures 7-9b, 7-9c, and 7-9d show the extent of hexavalent chromium concentrations across OU-1 in soil in the upper 10 feet, 10 to 30 ft bgs, and 30 to 50 ft bgs depth ranges, respectively. These figures show a pattern of elevated concentrations consistent with an anthropogenic source. Based on these results, hexavalent chromium is retained as a COPC for soil in OU-1.

Cobalt

Figure 7-10a shows the concentrations of cobalt in soil versus depth. Figures 7-10b, 7-10c, and 7-10d show the extent of cobalt concentrations across OU-1 in soil in the upper 10 feet, 10 to 30 ft bgs, and 30 to 50 ft bgs depth ranges, respectively. These figures show a pattern of elevated concentrations above background consistent with an anthropogenic source. Based on these results, cobalt is retained as a COPC for soil in OU-1.

Copper

Figure 7-11a shows the concentrations of copper in soil versus depth. Figures 7-11b, 7-11c, and 7-11d show the extent of copper concentrations across OU-1 in soil in the upper 10 feet, 10 to 30 ft bgs, and 30 to 50 ft bgs depth ranges, respectively. These figures do not show evidence of high concentrations of copper or widespread elevated concentrations that would be indicative of an anthropogenic source. In addition, concentrations are less than the LSSL at a DAF of 20 (916 mg/kg). Based on these results, copper is not retained as a COPC for soil in OU-1.

Iron

The mean concentration of iron is elevated above the LSSL at a DAF of 20 (11,780 mg/kg) but below the HSSL (100,000 mg/kg) in all three lithologic zones (Tables 7-1a, 7-1b, and 7-1c). However, as discussed in Appendix I and shown in Figures I-10a and I-10b and Tables I-2a and I-3, the concentrations of iron are consistent with background data in all vadose zone lithologies. Based on these results, iron is not retained as a COPC for soil in OU-1.

Lead

Figure 7-12a shows the concentrations of lead in soil versus depth. Figures 7-12b, 7-12c, and 7-12d show the extent of lead concentrations across OU-1 in soil in the upper 10 feet, 10 to 30 ft bgs, and 30 to 50 ft bgs depth ranges, respectively. As shown in Figure 7-12a, there are a significant number of samples that have concentrations of lead above maximum background concentrations. Lead is also elevated above the LSSL at a DAF of 20 (280 mg/kg) and above the HSSL (800 mg/kg). Based on these results, lead is retained as a COPC for soil in OU-1.

Lithium

Concentrations of lithium are below the LSSL at a DAF of 20 (400 mg/kg) in all three lithologic zones (Tables 7-1a, 7-1b, and 7-1c). In addition, as discussed in Appendix I and shown in Figure I-12 and Tables I-2a and I-3, the concentrations of lithium are consistent with background data in all vadose zone lithologies. Based on these results, lithium is not retained as a COPC for soil in OU-1.

Magnesium

Figure 7-13a shows the concentrations of magnesium in soil versus depth. Figures 7-13b, 7-13c, and 7-13d show the extent of magnesium concentrations across OU-1 in soil in the upper 10 feet, 10 to 30 ft bgs, and 30 to 50 ft bgs depth ranges, respectively. These figures show a pattern of elevated concentrations consistent with an anthropogenic source. Based on these results, magnesium is retained as a COPC for soil in OU-1.

Manganese

Figure 7-14a shows the concentrations of manganese in soil versus depth. Figures 7-14b, 7-14c, and 7-14d show the extent of manganese concentrations across OU-1 in soil in the upper 10 feet, 10 to 30 ft bgs, and 30 to 50 ft bgs depth ranges, respectively. These figures show a pattern of elevated concentrations consistent with an anthropogenic source. Based on these results, manganese is retained as a COPC for soil in OU-1.

Mercury

Figure 7-15a shows the concentrations of mercury in soil versus depth. Figures 7-15b, 7-15c, and 7-15d show the extent of mercury concentrations across OU-1 in soil in the upper 10 feet, 10 to 30 ft bgs, and 30 to 50 ft bgs depth ranges, respectively. These figures do not show evidence of widespread high concentrations of mercury indicative of an anthropogenic source and concentrations are less than the LSSL at a DAF of 20 (2.08 mg/kg). Based on these results, mercury is not retained as a COPC for soil in OU-1.

Molybdenum

The concentrations of molybdenum in soil compared to depth are shown in Figure 7-16a, which shows two soil samples with concentrations just slightly above the LSSL at a DAF of 20 (67.4 mg/kg) in the alluvium; however, the vertical and horizontal extent of these slightly elevated concentrations was limited as shown in Figures 7-16b, 7-16c, and 7-16d. These figures do not show evidence of widespread high concentrations of molybdenum indicative of an anthropogenic source. Based on these results, molybdenum is not retained as a COPC for soil in OU-1.

Nickel

Figure 7-17a shows the concentrations of nickel in soil versus depth. Figures 7-17b, 7-17c, and 7-17d show the extent of nickel concentrations across OU-1 in soil in the upper 10 feet, 10 to 30 ft bgs, and 30 to 50 ft bgs depth ranges, respectively. As shown in Figure 7-17a, there are three samples that have concentrations of nickel above maximum background concentrations and the LSSL at a DAF of 20 (140 mg/kg). Figures 7-17b, 7-17c, and 7-17d show a pattern of elevated results indicative of an anthropogenic source. Based on these results, nickel is retained as a COPC for soil in OU-1.

Niobium

Figure 7-18a shows the concentrations of niobium in soil versus depth. Figures 7-18b, 7-18c, and 7-18d show the extent of niobium concentrations across OU-1 in soil in the upper 10 feet, 10 to 30 ft bgs, and 30 to 50 ft bgs depth ranges, respectively. These figures do not show evidence of high concentrations of niobium indicative of an anthropogenic source and all detected concentrations are less than the LSSL at a DAF of 20 (23.4 mg/kg). Based on these results, niobium is not retained as a COPC for soil in OU-1.

Palladium

Palladium does not have an LSSL or HSSL, but was detected in all lithologic zones at a frequency greater than 5% (Tables 7-1a, 7-1b, and 7-1c). However, as discussed in Appendix I and shown in Figure I-19 and Tables I-2a and I-3, the concentrations of palladium are consistent with background data in all vadose zone lithologies. Based on these results, palladium is not retained as a COPC for soil in OU-1.

Selenium

Figure 7-19a shows the concentrations of selenium in soil versus depth. Figures 7-19b, 7-19c, and 7-19d show the extent of selenium concentrations across OU-1 in soil in the upper 10 feet, 10 to 30 ft bgs, and 30 to 50 ft bgs depth ranges, respectively. These figures do not show evidence of widespread or high concentrations of selenium indicative of an anthropogenic source and all detected concentrations are less than the LSSL at a DAF of 20 (6 mg/kg). Based on these results, selenium is not retained as a COPC for soil in OU-1.

Silver

Figure 7-20a shows the concentrations of silver in soil versus depth. Figures 7-20b, 7-20c, and 7-20d show the extent of silver concentrations across OU-1 in soil in the upper 10 feet, 10 to 30 ft bgs, and 30 to 50 ft bgs depth ranges, respectively. These figures do not show evidence of widespread or high concentrations of silver indicative of an anthropogenic source and concentrations are less than the LSSL at a DAF of 20 (28.4 mg/kg). Based on these results, silver is not retained as a COPC for soil in OU-1.

Strontium

Figure 7-21a shows the concentrations of strontium in soil versus depth. Figures 7-21b, 7-21c, and 7-21d show the extent of strontium concentrations across OU-1 in soil in the upper 10 feet, 10 to 30 ft bgs, and 30 to 50 ft bgs depth ranges, respectively. All strontium concentrations in soil samples are below the LSSL at a DAF of 20 (8,400 mg/kg). However, since concentrations of strontium above the LSSL at a DAF of 1 in soil between 10 and 30 ft bgs are distributed throughout OU-1 as shown in Figure 7-22c, strontium concentrations were examined further to confirm that the LSSL used was appropriate for this chemical. Over half of the exceedances of the LSSL at a DAF of 1 are below background levels and more than 95% of concentrations in the upper 10 feet of alluvium do not exceed the LSSL at a DAF of 1. Since strontium concentrations are below the LSSL at a DAF of 20 in all soil samples and based on the further analysis of strontium concentrations above the LSSL at a DAF of 1, strontium in OU-1 soil does not appear to be from an anthropogenic source. Based on these results, strontium is not retained as a COPC for soil in OU-1.

Thallium

Figure 7-22a shows the concentrations of thallium in soil versus depth. Figures 7-22b, 7-22c, and 7-22d show the extent of thallium concentrations across OU-1 in soil in the upper 10 feet, 10 to 30 ft bgs, and 30 to 50 ft bgs depth ranges, respectively. Thallium has two soil samples with concentrations above the LSSL at a DAF of 20 (8 mg/kg) in the upper 10 feet of alluvium; however, the extent of these elevated concentrations is limited both vertically and horizontally. These figures do not show evidence of widespread or high concentrations of thallium indicative of an anthropogenic source. Based on these results, thallium is not retained as a COPC for soil in OU-1.

Tungsten

Figure 7-23a shows the concentrations of tungsten in soil versus depth. Figures 7-23b, 7-23c, and 7-23d show the extent of tungsten concentrations across OU-1 in soil in the upper 10 feet, 10 to 30 ft bgs, and 30 to 50 ft bgs depth ranges, respectively. These figures do not show evidence of widespread or high concentrations of tungsten indicative of an anthropogenic source and concentrations are less than the LSSL at a DAF of 20 (80.2 mg/kg). Based on these results, tungsten is not retained as a COPC for soil in OU-1.

Uranium (Total)

Figure 7-24a shows the concentrations of total uranium in soil versus depth. Figures 7-24b, 7-24c, and 7-24d show the extent of total uranium concentrations across OU-1 in soil in the upper 10 feet, 10 to 30 ft bgs, and 30 to 50 ft bgs depth ranges, respectively. These figures do not show evidence of widespread or high concentrations of total uranium indicative of an anthropogenic source and concentrations are less than the LSSL at a DAF of 20 (270 mg/kg). Based on these results, total uranium is not retained as a COPC for soil in OU-1.

Zirconium

Concentrations of zirconium are below the LSSL at a DAF of 20 (96 mg/kg) in all three lithologic zones (Tables 7-1a, 7-1b, and 7-1c). In addition, as discussed in Appendix I and shown in Figure I-26 and Tables I-2a and I-3, the concentrations of zirconium are consistent with background data in all vadose zone lithologies. Based on these results, zirconium is not retained as a COPC for soil in OU-1.

Summary of Metals COPCs

As presented in Table 7-2a and based on the above discussion, the following metals are retained as COPCs for soil in OU-1: antimony, arsenic, barium, boron, hexavalent chromium, cobalt, lead, magnesium, manganese, and nickel. Additional discussion of the nature and extent of these COPCs in soil is presented in Section 7.4.2.

7.1.2.3 Radionuclides

As noted in Section 7.1.1.3, the following radionuclides were retained for secondary screening: radium-226, radium-228, thorium-228, thorium-230, thorium-232, uranium-235, and uranium-238. The radionuclides can be organized by decay chain. Of the radionuclides retained for secondary screening, the uranium-238 decay chain includes radium-226, thorium-230, and uranium-238. The thorium-232 decay chain includes radium-228, thorium-228, and thorium-232. Uranium-235 is not part of either decay chain, but is discussed with the uranium-238 decay chain. As shown in Appendix I, OU-1 data for both decay chains are in secular equilibrium. Analytical data demosntrate that uranium and uranium-238 decay chain radionuclide concentrations increase with depth across the study area and that the presence of the radionuclides is likely the result of naturally occurring processes. Their presence may be the result of several geologic processes including volcanism, variations in sediment source, and concentration due to depositional and geochemical processes. As discussed below, none of the radionuclides are retained as COPCs for soil in OU-1 based on the secondary screening.

Uranium-238 Decay Chain: Radium-226

Radium-226 does not have a calculated LSSL, but as shown in Figure 7-25a, nearly all measured radium-226 activities exceed its HSSL, including all data from the background data sets. The radium-226 activities in the upper 10 feet are consistent with background, but below 10 feet, activities are above background based on the statistical analysis in Appendix I (see Table I-3). However, the uranium-238 decay chain is in secular equilibrium in all vadose zone lithologies, and a visual analysis of the distribution of radium-226 activities in the deeper alluvium and UMCf does not depict any obvious contamination (see Figure I-29 in Appendix I), indicating that while the populations at the site may be higher than background, an anthropogenic source of high activities is unlikely. In addition, because activities of radium-226 in soil in the upper 10 feet are consistent with background and spills and/or releases from industrial operations would typically show impacts to soils in the upper 10 feet, it is unlikely that there are on-site anthropogenic sources of radium-226. Based on these results, radium-226 is not retained as a COPC for soil in OU-1.

Uranium-238 Decay Chain: Thorium-230

All measured thorium-230 activities exceed its LSSL at a DAF of 20, including all data from the background data sets, as depicted in Figure 7-25b. The thorium-230 activities in the upper 10 feet are consistent with background, but below 10 feet, activities are above background based on the statistical analysis in Appendix I (see Table I-3). However, the uranium-238 decay chain is in secular equilibrium in all vadose zone lithologies, and a visual analysis of the distribution of thorium-230 activities in the deeper alluvium and UMCf does not depict any obvious contamination (see Figure I-32 in Appendix I), indicating that while the populations at the site may be higher than background, an anthropogenic source of high activities is unlikely. In addition, because activities of thorium-230 in soil in the upper 10 feet are consistent with background and spills and/or releases from industrial operations would typically show impacts to soils in the upper 10 feet, it is unlikely that there are on-site anthropogenic sources of thorium-230. Based on these results, thorium-230 is not retained as a COPC for soil in OU-1.

Uranium-235

Uranium-235 does not have an LSSL, and approximately 1.9% of measured uranium-235 activities exceed its HSSL (with no exceedances in the upper 10 feet), as shown in Tables 7-1a, 7-1b, 7-1c, and Figure 7-25c. The uranium-235 activities in the upper 10 feet are consistent with background, but below 10 feet, activities are above background based on the statistical analysis in Appendix I (see Table I-3). However, there are no uranium-235 activites exceeding the HSSL in the upper 10 feet of soil, and a visual analysis of the distribution of uranium-235 activities in the deeper alluvium and UMCf does not depict any obvious contamination (see Figure I-33 in Appendix I), indicating that while the populations of uranium-235 activites at the Site may be higher than background, an anthropogenic source of high activities is unlikely. In addition, because activities of uranium-235 in soil in the upper 10 feet are consistent with background and spills and/or releases from industrial operations would typically show impacts to soils in the upper 10 feet, it is unlikely that there are on-site anthropogenic sources of uranium-235. Based on these results, uranium-235 is not retained as a COPC for soil in OU-1.

Uranium-238 Decay Chain: Uranium-238

Uranium-238 does not have an LSSL, and approximately 32% of measured uranium-238 activites exceed its HSSL (including 3.8% exceedances in the upper 10 feet), as shown in Tables 7-1a, 7-1b, 7-1c, and Figure 7-25d. The uranium-238 activities in the upper 10 feet are consistent with background, but below 10 feet, activities are above background based on the statistical analysis in Appendix I (see Table I-3). However, the uranium-238 decay chain is in secular equilibrium in all vadose zone lithologies, and a visual analysis of the distribution of uranium-238 activities in the deeper alluvium and UMCf does not depict any obvious contamination (see Figure I-34 in Appendix I), indicating that while the populations at the site may be higher than background, an anthropogenic source of high activities is unlikely. In addition, because activities of uranium-238 in soil in the upper 10 feet are consistent with background and spills and/or releases from industrial operations would typically show impacts to soils in the upper 10 feet, it is unlikely that there are on-site anthropogenic sources of uranium-238. Based on these results, uranium-238 is not retained as a COPC for soil in OU-1.

Uranium and Uranium-238 Decay Chain Summary

All uranium and uranium-238 decay chain radionuclide activities in the upper 10 feet are consistent with background, but below 10 feet, activities are above background based on the statistical analysis in Appendix I (see Table I-3). However, the uranium-238 decay chain is in secular equilibrium in all vadose zone lithologies, and a visual analysis of the distribution of uranium and uranium-238 decay chain radionuclide activities in the deeper alluvium and UMCf does not depict any obvious contamination, indicating that an anthropogenic source of high activities is unlikely. The likely explanation for the background exceedance of radionuclide activities in the uranium-238 decay chain at depth is therefore a natural variation in the concentration of uranium metal. Figure I-25 in Appendix I shows that the total uranium metal concentrations exceed background below 10 feet in a similar manner to the uranium-238 decay chain exceedances. While appropriately selected background data sets are reasonable approximations of naturally occurring concentrations at the site, geologic formations are naturally heterogeneous and variable in both random and systematic ways, and it is not possible to guarantee that any background data set will perfectly represent all naturally occurring concentrations at a given site.

Thorium-232 Decay Chain: Radium-228

Radium-228 does not have a calculated LSSL, but as shown in Figure 7-25e, all measured radium-228 activities exceed its HSSL, including all data from the background data sets. However, as discussed in Appendix I, the activities of radium-228 are consistent with background data in all vadose zone lithologies. Based on this evaluation, radium-228 is not retained as a COPC for soil in OU-1.

Thorium-232 Decay Chain: Thorium-228

Nearly all measured thorium-228 activities exceed its LSSL at a DAF of 20 and HSSL, including all data from the background data sets, as depicted in Figure 7-25f. However, as discussed in Appendix I, the activities of thorium-228 are consistent with background data in all vadose zone lithologies. Based on this evaluation, thorium-228 is not retained as a COPC for soil in OU-1.

Thorium-232 Decay Chain: Thorium-232

Nearly all measured thorium-232 activities exceed its LSSL at a DAF of 20, including all data from the background data sets, as depicted in Figure 7-25g. However, as discussed in Appendix I, the activities of thorium-232 are consistent with background data in all vadose zone lithologies. Based on this evaluation, thorium-232 is not retained as a COPC for soil in OU-1.

7.1.2.4 VOCs

As noted in Section 7.1.1.4, the following VOCs were retained for secondary screening: acetone, benzene, carbon tetrachloride, chlorobenzene, chloroform, 1,2-dichlorobenzene, 1,4-dichlorobenzene, 1,2-DCA, 1,1-DCE, methylene chloride, PCE, 1,2,3-trichlorobenzene, 1,2,4-trichlorobenzene, TCE, 1,2,3-trichloropropane, 1,2,4-trimethylbenzene, 1,3,5-trimethylbenzene, and TBA. As stated previously, with the exception of chloroform, the soil results for VOCs retained for secondary screening were compared to LSSLs using a conservative DAF of 20. Comparison of soil results for these VOCs to LSSLs using a DAF of 1 is included in the discussion below where necessary to provide additional insight and justification for decision making. As described in Section 7.1.2, because the soil source size for chloroform is anticipated to be larger than 30 acres, results were only compared to the LSSL using a DAF of 1 consistent with USEPA guidance on DAF selection (USEPA 1996). The secondary screening of these VOCs and final determinations whether to retain or exclude them as COPCs for soil in OU-1 are discussed below.

Acetone

Acetone was detected in soil above the LSSL at a DAF of 1 in the upper 10 feet of alluvium and UMCf at a small number of locations but below the LSSL at a DAF of 1 in the alluvium below 10 ft bgs. However, Tables 7-1a, 7-1b, and 7-1c show that acetone concentrations in soil are all well below the LSSL at a DAF of 20. Based on these results, acetone is not retained as a COPC for soil in OU-1.

Benzene

Figure 7-26a shows the concentrations of benzene in soil versus depth. Figures 7-26b, 7-26c, and 7-26d show the extent of benzene concentrations across OU-1 in soil in the upper 10 feet, 10 to 30 ft bgs, and 30 to 50 ft bgs depth ranges, respectively. As these figures show, there are many benzene concentrations below 20 ft bgs that are significantly above the LSSL at a DAF of 20 and the HSSL. Based on these results, benzene is retained as a COPC for soil in OU-1.

Carbon Tetrachloride

Figure 7-27a shows the concentrations of carbon tetrachloride in soil versus depth. Figures 7-27b, 7-27c, and 7-27d show the extent of carbon tetrachloride concentrations across OU-1 in soil in the upper 10 feet, 10 to 30 ft bgs, and 30 to 50 ft bgs depth ranges, respectively. As these figures show, there are a few spatially clustered carbon tetrachloride concentrations below 20 ft bgs that are significantly above the LSSL at a DAF of 20. Based on these results, carbon tetrachloride is retained as a COPC for soil in OU-1.

Chlorobenzene

Figure 7-28a shows the concentrations of chlorobenzene in soil versus depth. Figures 7-28b, 7-28c, and 7-28d show the extent of chlorobenzene concentrations across OU-1 in soil in the upper 10 feet, 10 to 30 ft bgs, and 30 to 50 ft bgs depth ranges, respectively. As these figures show, elevated concentrations of chlorobenzene are distributed throughout OU-1 and that there are a few spatially clustered chlorobenzene concentrations below 20 ft bgs that are significantly above the LSSL at a DAF of 20. Based on these results, chlorobenzene is retained as a COPC for soil in OU-1.

Chloroform

Figure 7-29a shows the concentrations of chloroform in soil versus depth. Figures 7-29b, 7-29c, and 7-29d show the extent of chloroform concentrations across OU-1 in soil in the upper 10 feet, 10 to 30 ft bgs, and 30 to 50 ft bgs depth ranges, respectively. As these figures show, the elevated concentrations of chloroform are widely distributed throughout OU-1 and that there are many chloroform concentrations below 20 ft bgs that are significantly above the LSSL at a DAF of 1 and the HSSL. Based on these results, chloroform is retained as a COPC for soil in OU-1.

1,2-Dichlorobenzene

1,2-Dichlorobenzene only slightly exceeds the LSSL at a DAF of 1 in the UMCf in a single sample, but does not exceed the LSSL at a DAF of 1 in the unsaturated alluvium. 1,2-Dichlorobenzene concentrations in soil are also significantly less than the LSSL at a DAF of 20 in all lithologic zones (Tables 7-1a, 7-1b, and 7-1c). Based on these results, 1,2-dichlorobenzene is not retained as a COPC for soil in OU-1.

1,4-Dichlorobenzene

1,4-Dichlorobenzene exceeds the LSSL at a DAF of 1 in the UMCf in two samples, but does not exceed the LSSL at a DAF of 1 in the unsaturated alluvium. The maximum concentration of 1,4-dichlorobenzene only slightly exceeds the LSSL at a DAF of 20 (Tables 7-1a, 7-1b, and 7-1c). Based on these results, 1,4-dichlorobenzene is not retained as a COPC for soil in OU-1.

1,2-Dichloroethane

1,2-DCA only slightly exceeds the LSSL at a DAF of 1 in the deeper unsaturated alluvium soil zone, but was not detected in the upper 10 feet or the UMCf soil zones. 1,2-DCA concentrations in soil are also significantly less than the LSSL at a DAF of 20 in the deeper unsaturated alluvium (Tables 7-1a, 7-1b, and 7-1c). Based on these results, 1,2-DCA is not retained as a COPC for soil in OU-1.

1,1-Dichloroethene

1,1-DCE slightly exceeds the LSSL at a DAF of 1 in the soil below 10 ft bgs but was not detected above the LSSL at a DAF of 1 in the upper 10 feet of alluvium. However, all detections of 1,1-DCE in the vadose zone were significantly below the LSSL at a DAF of 20 in the deeper alluvium and UMCf (Tables 7-1a, 7-1b, and 7-1c). Based on these results, 1,1-DCE is not retained as a COPC for soil in OU-1.

Methylene Chloride

Figure 7-30a shows the concentrations of methylene chloride in soil versus depth. Figures 7-30b, 7-30c, and 7-30d show the extent of methylene chloride concentrations across OU-1 in soil in the upper 10 feet, 10 to 30 ft bgs, and 30 to 50 ft bgs depth ranges, respectively. As these figures show, the elevated concentrations of methylene chloride are distributed throughout OU-1 and there are several methylene chloride concentrations above the LSSL at a DAF of 20. Based on these results, methylene chloride is retained as a COPC for soil in OU-1.

Tetrachloroethene

Figure 7-31a shows the concentrations of PCE in soil versus depth. Figures 7-31b, 7-31c, and 7-31d show the extent of PCE concentrations across OU-1 in soil in the upper 10 feet, 10 to 30 ft bgs, and 30 to 50 ft bgs depth ranges, respectively. As these figures show, there are a limited number of PCE concentrations above the LSSL at a DAF of 20 below 10 ft bgs observed in relatively isolated areas, and the mean of the detected concentrations is below the LSSL at a DAF of 20. Based on these results, PCE is not retained as a COPC for soil in OU-1.

1,2,3-Trichlorobenzene

1,2,3-Trichlorobenzene was detected in three samples above the LSSL at a DAF of 1 in soil below 10 ft bgs, and was not detected above the LSSL at a DAF of 1 in the upper 10 feet of alluvium. However, Table 7-1c shows that 1,2,3-trichlorobenzene concentrations in soil are all well below the LSSL at a DAF of 20 in the UMCf. Table 7-1b shows that the maximum concentration is above the LSSL at a DAF of 20 in the deeper alluvium; however, only two samples were above the LSSL at a DAF of 1 in the deeper alluvium and the mean concentration of the detections in the deeper alluvium is well below the LSSL at a DAF of 20. Based on these results, 1,2,3-trichlorobenzene is not retained as a COPC for soil in OU-1.

1,2,4-Trichlorobenzene

1,2,4-Trichlorobenzene was detected in one sample above the LSSL at a DAF of 1 in the alluvium below 10 ft bgs, and was not detected above the LSSL at a DAF of 1 in the upper 10 feet of alluvium or the UMCf. However, Tables 7-1a, 7-1b, and 7-1c show that 1,2,4-trichlorobenzene concentrations in soil are all well below the LSSL at a DAF of 20. Based on these results, 1,2,4-trichlorobenzene is not retained as a COPC for soil in OU-1.

Trichloroethene

Figure 7-32a shows the concentrations of TCE in soil versus depth. Figures 7-32b, 7-32c, and 7-32d show the extent of TCE concentrations across OU-1 in soil in the upper 10 feet, 10 to 30 ft bgs, and 30 to 50 ft bgs depth ranges, respectively. As these figures show, there are a limited number of TCE concentrations above the LSSL at a DAF of 20 below 10 ft bgs observed in relatively isolated areas, and the mean of the detected concentrations is less than the LSSL at a DAF of 20. below 10 ft bgs Based on these results, TCE is not retained as a COPC for soil in OU-1.

1,2,3-Trichloropropane

All detection limits for 1,2,3-Trichloropropane are above the LSSL at a DAF of 20. Figure 7-33a shows the concentrations of 1,2,3-trichloropropane in soil versus depth. Figures 7-33b, 7-33c, and 7-33d show the extent of 1,2,3-trichloropropane concentrations across OU-1 in soil in the upper 10 feet, 10 to 30 ft bgs, and 30 to 50 ft bgs depth ranges, respectively. As these figures show, a limited number of detections above the LSSL at a DAF of 20 are observed in relatively isolated areas. However, to be conservative with respect to the detection limits and the extremely low LSSL, 1,2,3-trichloropropane is retained as a COPC for soil in OU-1.

1,2,4-Trimethylbenzene

1,2,4-Trimethylbenzene was detected in one sample above the LSSL at a DAF of 1 in the alluvium below 10 ft bgs, and was not detected above the LSSL at a DAF of 1 in the upper 10 feet of alluvium or the UMCf. However, Tables 7-1a, 7-1b, and 7-1c show that 1,2,4-trimethylbenzene concentrations in soil are all well below the LSSL at a DAF of 20. Based on these results, 1,2,4-trimethylbenzene is not retained as a COPC for soil in OU-1.

1,3,5-Trimethylbenzene

1,3,5-Trimethylbenzene was detected in one sample above the LSSL at a DAF of 1 in the alluvium below 10 ft bgs, and was not detected above the LSSL at a DAF of 1 in the upper 10 feet of alluvium or the UMCf. However, Tables 7-1a, 7-1b, and 7-1c show that 1,3,5-

trimethylbenzene concentrations in soil are all well below the LSSL at a DAF of 20. Based on these results, 1,3,5-trimethylbenzene is not retained as a COPC for soil in OU-1.

tert Butyl Alcohol

TBA was detected in soil above the LSSL at a DAF of 1 in all vadose zone lithologies at a small number of locations. However, Tables 7-1a, 7-1b, and 7-1c show that TBA concentrations in soil are all well below the LSSL at a DAF of 20. Based on these results, TBA is not retained as a COPC for soil in OU-1.

Additional discussion of the nature and extent of the VOCs retained as COPCs for soil in OU-1 (benzene, carbon tetrachloride, chlorobenzene, chloroform, methylene chloride, and 1,2,3-trichloropropane) is presented in Section 7.4.3.

7.1.2.5 SVOCs

As noted in Section 7.1.1.5, the following SVOCs were retained for secondary screening: carbazole, 2-chlorophenol, 1,4-dioxane, hexachlorobenzene, and octachlorostyrene. The secondary screening of these SVOCs and final determinations whether to retain or exclude them as COPCs for soil in OU-1 are discussed below.

Carbazole

Carbazole was detected in soil above the LSSL at a DAF of 1 in the upper 10 feet of soil in two samples, but was not detected below 10 ft bgs. However, Tables 7-1a, 7-1b, and 7-1c show that carbazole concentrations in soil are all well below the LSSL at a DAF of 20. Based on these results, carbazole is not retained as a COPC for soil in OU-1.

2-Chlorophenol

2-Chlorophenol was detected in soil above the LSSL at a DAF of 1 in the alluvium below 10 ft bgs in a single sample, but was not detected in the upper 10 feet of soil or the UMCf. While Tables 7-1a, 7-1b, and 7-1c show that this one sample has a concentration above the LSSL at a DAF of 20, it is an isolated detection. Based on these results, 2-chlorophenol is not retained as a COPC for soil in OU-1.

1,4-Dioxane

Figure 7-34a shows the concentrations of 1,4-dioxane in soil versus depth. Figures 7-34b, 7-34c, and 7-34d show the extent of 1,4-dioxane concentrations across OU-1 in soil in the upper 10 feet, 10 to 30 ft bgs, and 30 to 50 ft bgs depth ranges, respectively. As these figures show, two detections above the LSSL at a DAF of 20 are observed in relatively isolated areas. In addition, many of the 1,4-dioxane detection limits are above the LSSL at a DAF of 20. To be conservative with respect to the detection limits and the low LSSL, 1,4-dioxane is retained as a COPC for soil in OU-1.

Hexachlorobenzene

Figure 7-35a shows the concentrations of hexachlorobenzene in soil versus depth. Figures 7-35b, 7-35c, and 7-35d show the extent of hexachlorobenzene concentrations across OU-1 in soil in the upper 10 feet, 10 to 30 ft bgs, and 30 to 50 ft bgs depth ranges, respectively. As these figures show, soil concentrations of hexachlorobenzene are above the LSSL at a DAF of 20 at depths primarily above 10 ft bgs. Many of these concentrations are significantly higher than the LSSLs. Figure 7-35b shows that hexachlorobenzene concentrations above the LSSL at a DAF of 20 in the upper 10 feet of soil are widely distributed throughout OU-1. Based on the results of this evaluation, hexachlorobenzene is retained as a COPC for soil in OU-1.

Octachlorostyrene

No LSSL could be estimated for octachlorostyrene as there is limited toxicity data available for this compound. Octachlorostyrene was detected at a relatively low frequency of 13.6% in the upper 10 feet of alluvium (Table 7-1a), 7.3% in the deeper alluvium (Table 7-1b), and less than 2% in the UMCf (Table 7-1c). Given the low detection frequency and the lack of toxicity data, octachlorostyrene is not retained as a COPC for soil in OU-1.

Additional discussion of the nature and extent of the SVOCs retained as COPCs for soil in OU-1 (1,4-dioxane and hexachlorobenzene) is presented in Section 7.4.4.

7.1.2.6 PAHs

As noted in Section 7.1.1.6, the following PAHs were retained for secondary screening: benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, dibenz(a,h)anthracene, indeno(1,2,3-cd)pyrene, 1-methylnaphthalene, 2-methylnaphthalene, and phenanthrene. The secondary screening of these PAHs and final determinations whether to retain or exclude them as COPCs for soil in OU-1 are discussed below.

1-Methylnaphthalene and 2-Methylnaphthalene

Figure 7-36a shows the concentrations of 1-methylnaphthalene in soil versus depth. Figures 7-36b, 7-36c, and 7-36d show the extent of 1-methylnaphthalene concentrations across OU-1 in soil in the upper 10 feet, 10 to 30 ft bgs, and 30 to 50 ft bgs depth ranges, respectively. Figure 7-37a shows the concentrations of 2-methylnaphthalene in soil versus depth. Figures 7-37b, 7-37c, and 7-37d show the extent of 2-methylnaphthalene concentrations across OU-1 in soil in the upper 10 feet, 10 to 30 ft bgs, and 30 to 50 ft bgs depth ranges, respectively. As these figures show, soil concentrations of 1-methylnaphthalene and 2-methylnaphthalene are above the LSSL at a DAF of 20, and the highest concentrations of 1-methylnaphthalene and 2-methlynaphthalene are spatially clustered. Based on these results, 1-methylnaphthalene and 2-methlynaphthalene are retained as COPCs for soil in OU-1.

Other PAHs

The remaining PAHs evaluated in the secondary screening all have soil concentrations at or below the LSSL at a DAF of 20: benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, dibenz(a,h)anthracene, indeno(1,2,3-cd)pyrene, and phenanthrene, as shown in Figures 7-38a through 7-38g, respectively. Based on these results, all the remaining PAHs are not retained as COPCs for soil in OU-1. These PAHs have a similar horizontal and vertical distribution in soil within OU-1. The vertical distribution of the individual PAHs is shown in Figures 7-38a through 7-38g. Because benzo(a)anthracene is detected at the highest concentration relative to its LSSL and is the most widely distributed chemical in this group, the horizontal extent of the Other PAHs in OU-1 is represented by benzo(a)anthracene, as shown in Figures 7-38h, 7-38i, and 7-38j for the upper 10 feet, 10 to 30 ft bgs, and 30 to 50 ft bgs depth ranges, respectively.

Additional discussion of the nature and extent of the PAHs retained as COPCs for soil in OU-1 (1-methylnaphthalene and 2-methlynaphthalene) is presented in Section 7.4.5.

7.1.2.7 PCBs

As noted in Section 7.1.1.7, the following PCBs were retained for secondary screening: Aroclor-1248, Aroclor-1254, and Aroclor-1260. Figure 7-39a shows the concentrations of Aroclor-1248 in soil versus depth. Figures 7-39b, 7-39c, and 7-39d show the extent of Aroclor-1248 concentrations across OU-1 in soil in the upper 10 feet, 10 to 30 ft bgs, and 30 to 50 ft bgs depth ranges, respectively. Figure 7-40a shows the concentrations of Aroclor-1254 in soil versus depth. Figures 7-40b, 7-40c, and 7-40d show the extent of Aroclor-1254 concentrations across OU-1 in soil in the upper 10 feet, 10 to 30 ft bgs, and 30 to 50 ft bgs depth ranges, respectively. Figure 7-41a shows the concentrations of Aroclor-1260 in soil versus depth. Figures 7-41b, 7-41c, and 7-41d show the extent of Aroclor-1260 concentrations across OU-1 in soil in the upper 10 feet, 10 to 30 ft bgs, and 30 to 50 ft bgs depth ranges, respectively. As these figures show, Aroclor-1248, Aroclor-1254, and Aroclor-1260 are not widely detected in OU-1, but are detected at concentrations that are significantly higher than their respective LSSLs at a DAF of 20 in the alluvium near the Unit Buildings. Based on these results, Aroclor-1248, Aroclor-1254, and Aroclor-1260 are retained as COPCs for soil in OU-1 and their nature and extent are discussed further in Section 7.4.6.

7.1.2.8 Dioxins/Furans

As noted in Section 7.1.1.8, all the dioxins/furans except octachlorodibenzo-p-dioxin (16 congeners) were retained for secondary screening. As all the congeners show a similar pattern of concentration and distribution in OU-1, the secondary screening of dioxins/furans is conducted based on the results for 2,3,4,7,8-pentachlorodibenzofuran, as discussed below.

Figure 7-42a shows the concentrations of 2,3,4,7,8-pentachlorodibenzofuran in soil versus depth. Figures 7-42b, 7-42c, and 7-42d show the extent of 2,3,4,7,8-pentachlorodibenzofuran concentrations across OU-1 in soil in the upper 10 feet, 10 to 30 ft bgs, and 30 to 50 ft bgs depth ranges, respectively. As these figures show, there are a significant number of 2,3,4,7,8-pentachlorodibenzofuran concentrations detected above the LSSL at a DAF of 20 in the upper 10 ft bgs and these elevated concentrations are widely distributed throughout OU-1. Based on this evaluation, all dioxin/furan congeners except octachlorodibenzo-p-dioxin (which was excluded as a COPC during the initial screening) are retained as COPCs for soil in OU-1 and their nature and extent are discussed further in Section 7.4.7.

7.1.2.9 Organochlorine Pesticides

As noted in Section 7.1.1.9, the following OCPs were retained for secondary screening: alpha-BHC, beta-BHC, gamma-BHC, 4,4′-DDE and 4,4′-DDT, and dieldrin. The secondary screening of these constituents and final determinations whether to retain or exclude these constituents as COPCs for soil in OU-1 are discussed below.

Alpha-BHC, Beta-BHC, and Gamma-BHC

Figure 7-43a shows the concentrations of alpha-BHC in soil versus depth. Figures 7-43b, 7-43c, and 7-43d show the extent of alpha-BHC concentrations across OU-1 in soil in the upper

10 feet, 10 to 30 ft bgs, and 30 to 50 ft bgs depth ranges, respectively. Figure 7-44a shows the concentrations of beta-BHC in soil versus depth. Figures 7-44b, 7-44c, and 7-44d show the extent of beta-BHC concentrations across OU-1 in soil in the upper 10 feet, 10 to 30 ft bgs, and 30 to 50 ft bgs depth ranges, respectively. Figure 7-45a shows the concentrations of gamma-BHC in soil versus depth. Figures 7-45b, 7-45c, and 7-45d show the extent of gamma-BHC concentrations across OU-1 in soil in the upper 10 feet, 10 to 30 ft bgs, and 30 to 50 ft bgs depth ranges, respectively. These figures show that beta-BHC is widely distributed in the alluvium and is detected in many samples at concentrations greater than the LSSL at a DAF of 20. The distributions of detected alpha-BHC and gamma-BHC are less widespread, but spatially clustered with the beta-BHC detections and are above their respective LSSLs at a DAF of 20. Based on these results, alpha-BHC, beta-BHC, and gamma-BHC are retained as COPCs for soil in OU-1.

4,4′-DDE and 4,4′-DDT

4,4′-DDE and 4,4′-DDT were detected in soil above the LSSL at a DAF of 1 in the upper 10 feet of soil in four samples and one sample, respectively, but were not detected above the LSSL at a DAF of 1 below 10 ft bgs. However, Tables 7-1a, 7-1b, and 7-1c show that 4,4′-DDE and 4,4′-DDT concentrations in soil are all well below their respective LSSLs at a DAF of 20. Based on these results, 4,4′-DDE and 4,4′-DDT are not retained as COPCs for soil in OU-1.

Dieldrin

Figure 7-46a shows the concentrations of dieldrin in soil versus depth. Figures 7-46b, 7-46c, and 7-46d show the extent of dieldrin concentrations across OU-1 in soil in the upper 10 feet, 10 to 30 ft bgs, and 30 to 50 ft bgs depth ranges, respectively. As these figures show, there are three dieldrin concentrations above the LSSL at a DAF of 20 from 0 to 30 ft bgs observed in isolated areas. Based on these results, dieldrin is not retained as a COPC for soil in OU-1.

Additional discussion of the nature and extent of the OCPs retained as COPCs for soil in OU-1 (alpha-BHC, beta-BHC, and gamma-BHC) is presented in Section 7.4.8.

7.1.2.10 Organophosphorus Pesticides

As noted in Section 7.1.1.10, the following OPPs were retained for secondary screening: dimethoate and stirophos. As shown in Tables 7-1a, 7-1b, and 7-1c, dimethoate was detected above the LSSL at a DAF of 1 in only four samples throughout the entire vadose zone, and stirophos was detected in only a single sample. The maximum detected concentrations of dimethoate are only slightly above the LSSL at a DAF of 1, and no soil concentrations of dimethoate are above the LSSL at a DAF of 20. The single detection of stirophos is also well below the LSSL at a DAF of 20. Based on these results, dimethoate and stirophos are not retained as COPCs for soil in OU-1.

7.1.2.11 Other Organics

As noted in Section 7.1.1.11, only formaldehyde was retained for secondary screening in this chemical group. Consistent with the NDEP-approved RI/FS Work Plan, the investigation of formaldehyde in soil was limited to seven samples collected from the unsaturated zone at two locations near the former Beta Ditch (associated with LOUs 38 and 54). Figure 7-47a shows the concentrations of formaldehyde in soil versus depth. Figures 7-47b, 7-47c and 7-47d show the extent of formaldehyde concentrations across OU-1 in soil in the upper 10 feet, 10 to 30 ft bgs, and 30 to 50 ft bgs, respectively. Figure 7-47d shows samples from the same two locations in the saturated zone, but these samples are not specifically discussed further as the soil COPC screening analysis is limited to the vadose zone. Formaldehyde was detected in all seven samples above the LSSL at a DAF of 20 (but below the HSSL), but all samples were flagged as estimated during data validation due to laboratory data quality issues. Five of the seven samples were qualified due to laboratory blank contamination and are below the practical quantitation limit, indicating that these detections could be due entirely to laboratory blank contamination. The remaining two detections were flagged as J+ (estimated concentration, positive bias), indicating that the true concentrations are expected to be lower. However, these concentrations could still represent an area of elevated concentration posing a risk to groundwater, so based on these results, formaldehyde is retained as a COPC for soil in OU-1. Additional discussion of the nature and extent of formaldehyde is presented in Section 7.4.9.

7.2 Identification of Groundwater COPCs

In this section, groundwater sampling results from RI investigations in OU-1 are evaluated to identify those constituents that will be retained as COPCs for groundwater. Groundwater COPCs are chemicals that exceed regulatory or human health-based screening levels in groundwater. Consistent with the NDEP-approved RI/FS Work Plan (ENVIRON 2014c), naturally occurring chemicals, such as metals, are not considered COPCs unless they are found at concentrations significantly above background. In addition, and similar to the identification of COPCs in soils, common nutrients, salts, and infrequently detected chemicals are also not considered COPCs consistent with NDEP guidance (NDEP 2023a).

7.2.1 Initial Groundwater COPC Screening

The first step in the groundwater COPC identification process was a comparison of groundwater concentrations in OU-1 to regulatory or health-based GWSLs. The GWSLs were tabulated using the hierarchy described in Appendix G (GWSLs are summarized in Table G-3). The GWSL selection hierarchy consists of the following:

1. Primary MCL (40 Code of Federal Regulations [CFR] 141).
2. MCLG (40 CFR 141), if goal is greater than zero.
3. PRG for perchlorate (USEPA 2009, 2008b).
4. NDEP BCL table (NDEP 2023a) for residential water.
5. USEPA RSL table for tap water (USEPA 2023).
6. Screening levels for dioxins were obtained by dividing the primary MCL of 2,3,7,8-TCDD by the congener toxic equivalency factor (TEF) (Van den Berg et al. 2006).

The OU-1 groundwater concentrations used in the screening (referred to as the “OU-1 Groundwater Data Set”) includes approximately 90,000 analytical results sampled between 2014 and 2019. Included in the OU-1 Groundwater Data Set are:

- Samples from the 2014–2019 RI, including applicable RI modifications and the investigation of the Unit 4 and 5 Buildings; and

- Sampling from the NERT groundwater monitoring program (2014–2018).

Groundwater data associated with localized treatability studies in OU-1 are not included in the data, consistent with the soil analytical data set, since these data may not be representative of current conditions over the broader NERT RI Study Area and were not collected for the purpose of site characterization. The complete OU-1 Groundwater Data Set is presented in Appendix J.

The initial screening evaluation for groundwater COPCs was conducted for the Shallow WBZ (0-90 ft bgs) and the Middle WBZ (90-300 ft bgs). Tables 7-3a and 7-3b present a statistical summary comparison of OU-1 groundwater concentrations from the Shallow and Middle WBZs with GWSLs, respectively. Consistent with the NDEP-approved RI/FS Work Plan (ENVIRON 2014c), the following constituents were eliminated during this initial screening:

- Chemicals with no detected concentrations exceeding the GWSL were eliminated and are indicated with orange shaded rows;
- Chemicals which were detected in fewer than 5% of samples and do not have relevant screening levels were eliminated and are indicated with yellow shaded rows;
- The essential nutrients calcium, potassium, and sodium were eliminated and are indicated with blue shaded rows; and
- Due to a lack of toxicity data and therefore GWSLs, the following macronutrients and salts were eliminated: silicon, sulfur, ammonia, bicarbonate, carbonate, chloride, orthophosphate, and sulfate, as also indicated with blue shaded rows. While ammonia does have a BCL, this screening level is based only on the toxicity of inhalation of ammonia gas in equilibrium with groundwater at high pH. As the pH of groundwater in OU-1 is generally neutral, the predominant species of ammonia in groundwater is the ammonium cation, which lacks toxicity data.

In addition to the above COPC exclusions, and also consistent with the NDEP-approved RI/FS Work Plan (ENVIRON 2014c), a modified evaluation of the following constituent groups or individual constituents was conducted during the initial screening as follows:

- While the radioisotopes of uranium were eliminated and are indicated with green shaded rows, the results for total uranium were evaluated, consistent with NDEP guidance (NDEP 2023a); and
- While petroleum hydrocarbon mixture analytes (e.g., gasoline range organics) were eliminated (green shading), indicator chemicals for petroleum hydrocarbon mixtures (i.e., benzene, toluene, ethylbenzene, and total xylenes, frequently referred to as BTEX; methyl tertiary butyl ether [MTBE]; and PAHs) were detected at the site, and sufficient data (over 4,000 analyses performed on OU-1 groundwater samples) were collected for the indicator chemicals to evaluate the nature and extent of contamination. Therefore individual evaluations of indicator chemicals were used, consistent with NDEP guidance (NDEP 2023a).

If a chemical was not eliminated based on the initial screening, it was evaluated further in the secondary screening (presented in Section 7.2.2) before a decision was made regarding whether to exclude or retain that chemical as a groundwater COPC in OU-1. Chemicals are indicated with light yellow shaded rows in Tables 7-3a and 7-3b if they exceeded the GWSL, but had exceedances of the GWSL in fewer than 10 samples, had a maximum exceedance of the GWSL less than a factor of 20 higher than the screening level, and were detected in fewer than 5% of samples. These chemicals are highlighted because they would have been eliminated as COPCs according to the criteria in the NDEP-approved RI/FS Work Plan (ENVIRON 2014c); however, they were included in the secondary screening to evaluate potential areas of contamination.

The results of the initial groundwater COPC screening evaluation are presented in Tables 7-3a and 7-3b. Based on the analysis and criteria outlined above, no compounds within the PAHs, dioxins/furans, OCPs, OPPs or petroleum indicators chemical groups were retained as potential groundwater COPCs in OU-1. All other chemical groups are discussed below.

7.2.1.1 Chlorates and General Chemistry

The following chlorate/general chemistry constituents were detected in groundwater from OU-1 at concentrations exceeding their respective GWSLs: bromide, chlorate, nitrate (as N), nitrate/nitrite (as N), nitrite (as N), and perchlorate. These chlorate/general chemistry constituents are initially retained as groundwater COPCs in OU-1 subject to secondary screening as described in Section 7.2.2.1.

7.2.1.2 Metals

The following metals were detected in groundwater from OU-1 at concentrations exceeding their respective GWSLs: arsenic, boron, chromium (total), chromium (hexavalent), iron, lead, magnesium, manganese, strontium, uranium (total), vanadium, and zirconium. These metals are initially retained as groundwater COPCs in OU-1, subject to secondary screening. Palladium does not have a GWSL but was detected at a frequency above 5% in the Shallow WBZ and is therefore also initially retained as a groundwater COPC in OU-1 subject to secondary screening. The secondary screening of these constituents is described in Section 7.2.2.2.

7.2.1.3 Radionuclides

The following radionuclide isotopes were detected in groundwater from OU-1 above their respective GWSLs: radium-226, radium-228, thorium-228, thorium-230, and thorium-232. Radium-226 and radium-228 do not have individual GWSLs in Tables 7-3a and 7-3b but are compared to a combined MCL for radium of 5 pCi/L (see Appendix G) per NDEP guidance (NDEP 2023a). These radionuclides are initially retained as groundwater COPCs in OU-1 subject to secondary screening as described in Section 7.2.2.3.

7.2.1.4 VOCs

The following VOCs were detected in groundwater from OU-1 above their respective GWSLs: benzene, bromodichloromethane, bromoform, carbon tetrachloride, chlorobenzene, chloroform, 1,2-dichlorobenzene, 1,3-dichlorobenzene, 1,4-dichlorobenzene, 1,1-dichloroethane (1,1-DCA), 1,2-DCA, 1,1-DCE, 1,4-dioxane, hexachlorobutadiene, methylene chloride, naphthalene, 1,1,2,2-tetrachloroethane, PCE, 1,2,4-trichlorobenzene, TCE, and 1,2,3-trichloropropane. Hexachlorobutadiene is also an SVOC and is discussed in Section 7.2.1.5. The remaining VOCs are initially retained as groundwater COPCs in OU-1 subject to secondary screening as described in Section 7.2.2.4.

7.2.1.5 SVOCs

Hexachlorobutadiene was detected in groundwater from OU-1 at a concentration above its GWSL. Hexachlorobutadiene is initially retained as a groundwater COPC in OU-1 subject to secondary screening as discussed in Section 7.2.2.5.

7.2.1.6 PCBs

Aroclor-1260 was detected in groundwater from OU-1 at a concentration above its GWSL. Aroclor-1260 is initially retained as a groundwater COPC in OU-1 subject to secondary screening as described in Section 7.2.2.6.

7.2.1.7 Other Organics

4-Chlorobenzenesulfonic acid (4-CBSA) and formaldehyde were detected in groundwater from OU-1 at concentrations above their respective GWSLs. These constituents are initially retained as groundwater COPCs in OU-1 subject to secondary screening as described in Section 7.2.2.7.

7.2.2 Secondary Groundwater COPC Screening

Based on the discussion above, constituents retained as potential groundwater COPCs in OU-1 are shown in Table 7-2a. These retained constituents are subject to secondary screening as discussed in the following sections. Secondary screening criteria are:

- Evaluating each constituent’s nature and extent in groundwater beneath OU-1 (e.g., distribution and magnitude of groundwater concentrations above GWSLs, widespread distribution vs. localized occurrences, and whether the distribution of each constituent is consistent with an anthropogenic source);
- Evaluating the relevant constituent’s detection frequency in each WBZ; and
- Evaluating other chemical-specific and/or site-specific factors (e.g., contaminant mobility and whether there is indication that on-site impacts may be from an off-site source).

Figures supporting the secondary groundwater COPC evaluation are presented in this section of the report. These figures are important for determining if elevated concentrations of certain COPCs are localized in specific areas and depths of OU-1, and as such, could be indicative of the location of a prior release. Figures for constituents that were retained as COPCs for groundwater in OU-1 as a result of the secondary screening are presented in this section of the report and are discussed in greater detail in the nature and extent discussion in Section 7.5.

In the context of discussing the presence of COPCs in groundwater, it is important to describe the relevant vertical depth intervals.

The Shallow WBZ has been defined by NDEP as the depth interval between 0–90 ft bgs. Within OU-1, the Shallow WBZ is composed of the saturated portions of the alluvium and the uppermost portion of the UMCf to depths of approximately 90 ft bgs. Historically, the alluvium was saturated below the northern portion of OU-1. However, recent groundwater elevations measured during the annual groundwater monitoring events show that except for a few small areas, the alluvium has become dewatered and first groundwater now occurs within the UMCf.

Many of the existing Shallow WBZ wells within OU-1 were installed to investigate groundwater conditions at and immediately below the water table, where shallow groundwater was most likely to be affected by historic facility operations. The majority of these shallow wells are screened in the depth interval between 0-55 ft bgs. As part of the Phase 2 RI, many of the new monitoring wells were installed in the deeper portion of the Shallow WBZ between approximate depths of 55-90 ft bgs. In order to distinguish differences between COPC concentrations in shallow groundwater near the water table and concentrations near the base of the Shallow WBZ, the figures illustrating chemical distributions show two Shallow WBZ depth intervals: Shallow WBZ (0-55 ft bgs); and the Shallow WBZ (55-90 ft bgs) within the UMCf.

For the Shallow WBZ (0-55 ft bgs), the 2005 CSM report (ENSR 2005) presented isoconcentration maps for chemicals in Site groundwater along with their known use areas within the Site. Historic isoconcentration maps were developed for perchlorate, specific conductance (showing chlorate use areas), chromium, and manganese based on groundwater data collected in 2003/2004. They provide a reference point for comparison with current concentrations. Therefore, isoconcentration maps for these COPCs and chloroform have been prepared based on the most recent data collected between 2015 and 2018 and are presented in this report to illustrate the current understanding of the distributions of these COPCs in OU-1 groundwater. For the remaining COPCs, colored dot maps are used to illustrate the concentration of COPCs in groundwater.

The Middle WBZ has been defined by NDEP as the depth interval between 90–300 ft bgs. At OU-1, the Middle WBZ is composed primarily of the UMCf-fg1 to depths of between approximately 220 to 260 ft bgs, depending on location. Below the southern and western part of OU-1, the UMCf-cg2 unit is present at depth beneath the fine-grained UMCf-fg1.

Based on the site geology/hydrogeology, the distribution of COPCs in groundwater is typically presented in a series of maps based on the following depth intervals:

- Shallow WBZ (0-55 ft bgs)
- Shallow WBZ (55-90 ft bgs)
- Middle WBZ (90-130 ft bgs)
- Middle WBZ (130-300 ft bgs)

7.2.2.1 Chlorates and General Chemistry

As noted in Section 7.2.1.1, the following chlorate/general chemistry constituents were retained for secondary screening: perchlorate, chlorate, bromide, nitrate (as N), nitrite (as N), and nitrate/nitrite (as N). The secondary screening of these constituents and final determinations whether to retain or exclude these constituents as COPCs for groundwater in OU-1 are discussed below.

Perchlorate

The distribution of perchlorate in groundwater in OU-1 is shown in multiple figures within this report, including Figure 7-48, Figures 7-49a and 7-49b, and Figures 7-50a through 7-50i. These figures indicate that perchlorate is widely distributed throughout OU-1 and is above its GWSL to depths of 175 ft bgs. Based on this evaluation perchlorate is retained as a COPC for groundwater in OU-1.

Chlorate

The distribution of chlorate in groundwater in OU-1 is shown in Figures 7-51a through 7-51j. These figures indicate that chlorate is widely distributed throughout OU-1 and is above its GWSL to depths of 130 ft bgs. Based on this evaluation chlorate is retained as a COPC for groundwater in OU-1.

Bromide

The distribution of bromide in groundwater in OU-1 is shown in Figures 7-52a through 7-52e. Figure 7-52b shows that bromide is widely distributed within the Shallow WBZ (0-55 ft bgs) throughout OU-1. Except for just a few locations, most of the shallow bromide concentrations are below its GWSL. Figure 7-52c indicates a similar pattern for bromide detections within the Shallow WBZ (55 to 90 ft bgs), but mostly in the northern portion of OU-1. Based on this widespread distribution, bromide is retained as a COPC for groundwater in OU-1.

Nitrate (as N), Nitrite (as N), and Nitrate/Nitrite (as N)

Nitrate (as N) and nitrite (as N) are detected in groundwater well above their respective GWSLs. Nitrate/nitrite (as N) is a calculated value reflecting the sum of nitrate and nitrite and has a more conservative GWSL than the sum of the individual GWSLs for nitrate (as N) and nitrite (as N). Evaluation of the distribution of nitrate (as N) and nitrite (as N) in groundwater in OU-1 is represented by the distribution of nitrate/nitrite (as N), as shown in Figures 7-53a through 7-53e. As these figures indicate, nitrate/nitrite (as N) is widely distributed in groundwater at multiple depths throughout OU-1 with some of the nitrate/nitrite (as N) concentrations, particularly in the Shallow WBZ (0 to 55 ft bgs), being significantly higher than the GWSL. Based on this evaluation, nitrate (as N) and nitrite (as N) are retained as COPCs for groundwater in OU-1, but the nature and extent of these constituents will be represented by the distribution of nitrate/nitrite (as N) in Section 7.5 due to the more conservative GWSL.

Additional discussion of the nature and extent of the chlorates/general chemistry constituents retained as groundwater COPCs in OU-1 is presented in Section 7.5.

7.2.2.2 Metals

As noted in section 7.2.1.2, the following metals were retained for secondary screening: arsenic, boron, chromium (total), hexavalent chromium, iron, lead, magnesium, manganese, palladium, strontium, uranium (total), vanadium, and zirconium. The secondary screening of these metals and final determinations whether to retain or exclude them as COPCs for groundwater in OU-1 are discussed below.

Arsenic

The distribution of arsenic in groundwater in OU-1 is shown in Figures 7-54a through 7-54e. As these figures indicate, arsenic is widely distributed in the Shallow and Middle WBZs within OU-1 with most concentrations generally above the GWSLs. Elevated levels of arsenic are also present in the upgradient wells at the south end of the site, indicating that naturally occurring background levels likely contribute to the elevated levels within OU-1. However, since arsenic is widely distributed in groundwater in OU-1 with many concentrations throughout OU-1 above that of the upgradient wells, arsenic is retained as a COPC for groundwater in OU-1.

Boron

The distribution of boron in groundwater in OU-1 is shown in Figures 7-55a through 7-55e. Figure 7-55b indicates that boron is frequently detected in the Shallow WBZ (0-55 ft bgs) in the central portion of OU-1. Elevated boron concentrations appear to occur near the Leach Plant, the Leasehold Debris Pile, downgradient of the AP Pond area, and downgradient of the IWF/barrier wall. These results are consistent with the operational history of the Site and boron is retained as a COPC for groundwater in OU-1.

Chromium (total) and Chromium (hexavalent)

A detailed analysis of hexavalent chromium to total chromium ratios was performed as part of the 2016 Groundwater Monitoring Optimization Plan (Ramboll Environ 2016a). The analysis found that the concentration of total chromium is generally equal to the concentration of hexavalent chromium within the NERT groundwater plume. With NDEP approval, analysis of hexavalent chromium in groundwater samples from monitoring wells was eliminated from NERT's on-going monitoring program in 2016 (NDEP 2016b). Therefore, total chromium and hexavalent chromium are not regarded as separate COPCs and interpretations of the lateral and vertical extent of chromium in groundwater will rely on total chromium data, as opposed to hexavalent chromium data.

The distribution of total chromium in groundwater in OU-1 is shown in multiple figures within this report, including Figure 7-56, Figures 7-57a and 7-57b, and Figures 7-58a through 7-58h. These figures indicate that chromium is widely distributed in the 0 to 130 ft bgs range throughout much of the eastern portion of OU-1 from the Unit Buildings to the northern OU-1 boundary and that most of the concentrations are significantly higher that the GWSL. These results are consistent with the operational history of the Site and chromium is retained as a COPC for groundwater in OU-1.

Iron

The distribution of iron in groundwater in OU-1 is shown in Figures 7-59a through 7-59e. As these figures indicate, iron was detected in groundwater above its GWSL in only one location: M-10 located upgradient of the Unit 4 and 5 Buildings. The single upgradient iron concentration exceeding the GWSL supports the conclusion that this exceedance is not the result of an anthropogenic source in OU-1. Based on this evaluation, iron is not retained as a COPC for groundwater in OU-1.

Lead

The distribution of lead in groundwater in OU-1 is shown in Figures 7-60a through 7-60e. As these figures indicate, lead was detected in groundwater above its GWSL in only two samples from the 0 to 55 ft bgs depth range: TR-6 and M-126 located near the western OU-1 boundary. These two samples are isolated from one another and exceed the GWSL of 0.015 mg/L by a very small margin: M-126 has a concentration equal to the GWSL at 0.015 mg/L, and TR-6 has an estimated concentration of 0.023 J mg/L.[68] The low frequency, isolation, and small magnitude of lead concentrations exceeding the GWSL supports the conclusion that the occurrence of lead in groundwater is not the result of an anthropogenic source in OU-1. Based on this evaluation, lead is not retained as a COPC for groundwater in OU-1.

Magnesium

The distribution of magnesium in groundwater in OU-1 is shown in Figures 7-61a through 7-61e. As Figures 7-61b and 7-61c indicate, magnesium is widely distributed throughout the Shallow WBZ (0-55 and 55-90 ft bgs) in OU-1 with a significant number of concentrations above the GWSL. In the Middle WBZ (90-130 ft bgs) concentrations of magnesium above the GWSL are isolated primarily to the area around the Unit 4 and 5 Buildings and the Leach Plant. These results are consistent with the operational history of the Site and magnesium is retained as a COPC for groundwater in OU-1.

Manganese

The distribution of manganese in groundwater in OU-1 is shown in multiple figures within this report, including Figure 7-62, Figures 7-63a and 7-63b, and Figures 7-64a through 7-64e. These figures indicate that the concentrations of manganese above the GWSL are only detected in the 0 to 55 ft bgs depth range, but there is a distinct pattern of occurrence of manganese that suggests an anthropogenic origin. These results are consistent with the operational history of the Site and manganese is retained as a COPC for groundwater in OU-1.

Palladium

Palladium was detected in the Shallow WBZ (0-55 ft bgs) in only two groundwater grab samples. Therefore, no figures have been prepared to illustrate the distribution of palladium in groundwater in OU-1. Both locations are near the Leasehold Debris Pile within the EMD leasehold. Palladium does not have a GWSL. Based on these limited detections and lack of a screening level, palladium is not retained as a COPC for groundwater in OU-1.

Strontium

The distribution of strontium in groundwater in OU-1 is shown in Figures 7-65a through 7-65e. As these figures indicate, strontium is widely distributed in each of the Shallow and Middle WBZ monitoring intervals throughout OU-1, being detected in 100% of the groundwater samples collected. Strontium concentrations in the 0 to 130 ft bgs depth range are above the GWSL in a large percentage of the samples with a distinct pattern of elevated concentrations occurring near the Unit 4 and 5 Buildings area and along the western

---

[68] A J flagged concentration is an estimated result. A J flagged concentration can also have a potential positive bias, which is denoted with a J+, or a potential negative bias, which is denoted with a J-.

boundary of OU-1 suggesting an anthropogenic origin. Based on this evaluation, strontium is retained as a COPC for groundwater in OU-1.

Uranium (Total)

The distribution of total uranium in groundwater in OU-1 is shown in Figures 7-66a through 7-66e. As these figures indicate, uranium (total) is widely distributed in each of the Shallow and Middle WBZ monitoring intervals throughout OU-1, being detected in 100% of the groundwater samples collected. Uranium (total) concentrations in the 0 to 55 ft bgs depth range are above the GWSL in a fairly large percentage of the samples. The distribution of elevated uranium (total) in the 0-55 ft bgs zone appears to generally extend from the Leach Plant northward and extends along the eastern and western portions of OU-1 to Warm Springs Road. The distribution of uranium (total) above the GWSL in shallow groundwater suggests that the elevated concentrations may result from anthropogenic sources in OU-1. Based on this evaluation, uranium (total) is retained as a COPC for groundwater in OU-1.

Vanadium

The distribution of vanadium in groundwater in OU-1 is shown in Figures 7-67a through 7-67e. As these figures indicate, vanadium was only detected above the GWSL in one sample north of the OSSM extraction well field, and there does not appear to be a distinct pattern of detections that would suggest an anthropogenic origin of vanadium. Based on this evaluation, vanadium is not retained as a COPC for groundwater in OU-1.

Zirconium

The distribution of zirconium in groundwater in OU-1 is shown in Figures 7-68a through 7-68e. While zirconium in groundwater has many detection limits above the GWSL, zirconium was only detected slightly above the GWSL in three grab groundwater samples within OU-1. These concentrations may not be representative of the concentration in the aquifer, but more indicative of the soil concentrations at these locations. There does not appear to be a distinct pattern of detections that would suggest an anthropogenic origin of zirconium. Based on this evaluation, zirconium is not retained as a COPC for groundwater in OU-1.

Additional discussion of the nature and extent of the metals retained as groundwater COPCs in OU-1 is presented in Section 7.5.

7.2.2.3 Radionuclides

As noted in Section 7.2.1.3, the following radionuclides were retained for secondary screening: radium-226, radium-228, thorium-228, thorium-230, and thorium-232. The secondary screening of these radionuclides and final determinations whether to retain or exclude them as COPCs for groundwater in OU-1 are discussed below.

Radium-226/228

The distribution of radium-226 and radium-228 (collectively referred to as radium due to the GWSL of 5 pCi/L for the sum of the two radionuclides) in groundwater in OU-1 is shown in Figures 7-69a through 7-69e. As these figures indicate, radium is widespread throughout OU-1, being detected in nearly every groundwater sample collected from each of the Shallow and Middle WBZ monitoring intervals. However, radium was detected above the GWSL in the Shallow WBZ (0 to 55 ft bgs) in only two locations. Due to the low frequency of detections above the GWSL, radium is not retained as a COPC for groundwater in OU-1.

Thorium-228/230

The distribution of thorium-228 and thorium-230 in groundwater in OU-1 are shown in Figures 7-70a through 7-70e and Figures 71a through 71e, respectively. As these figures indicate, thorium-228 and thorium-230 activities above the GWSL in groundwater are widespread in all Shallow and Middle WBZ monitoring intervals throughout OU-1. Based on this evaluation, thorium-228 and thorium-230 are retained as COPCs for groundwater in OU-1.

Thorium-232

The distribution of thorium-232 in groundwater in OU-1 is shown in Figures 7-72a through 7-72e. As these figures indicate, there are few thorium-232 activites above the GWSL in groundwater and the highest activites are observed in grab groundwater samples that may not be representative of the activity in the aquifer, but more indicative of the soil activities at these locations. Based on this evaluation, thorium-232 is not retained as a COPC for groundwater in OU-1.

Additional discussion of the nature and extent of the radionuclides retained as COPCs for groundwater in OU-1 is presented in Section 7.5.

7.2.2.4 VOCs

As noted in Section 7.2.1.4, the following VOCs were retained for secondary screening: benzene, bromodichloromethane, bromoform, carbon tetrachloride, chlorobenzene, chloroform, 1,2-dichlorobenzene, 1,3-dichlorobenzene, 1,4-dichlorobenzene, 1,1-DCA, 1,2-DCA, 1,1-DCE, 1,4-dioxane, methylene chloride, naphthalene, 1,1,2,2-tetrachloroethane, PCE, 1,2,4-trichlorobenzene, TCE, and 1,2,3-trichloropropane. The relative mobility of these constituents is presented in Figure 7-73. The secondary screening of these constituents and final determinations whether to retain or exclude these constituents as COPCs for groundwater in OU-1 are discussed below.

Benzene

The distribution of benzene in groundwater in OU-1 is shown in Figures 7-74a through 7-74e. These figures indicate that benzene was detected at concentrations significantly above the GWSL in the 0 to 130 ft bgs depth range at wells located primarily along the western boundary of OU-1. Benzene was not detected below a depth of 130 ft bgs. Based on this evaluation, benzene is retained as a COPC for groundwater in OU-1.

Bromodichloromethane

The distribution of bromodichloromethane in groundwater in OU-1 is shown in Figures 7-75a through 7-75e. These figures indicate that bromodichloromethane was detected at concentrations significantly above the GWSL in the Shallow Zone (0-55 and 55-90 ft bgs) and Middle WBZ (90-130 ft bgs) depth intervals at wells located primarily in the central portion of OU-1. The highest concentrations occur in the 55 to 90 ft bgs depth range in the vicinity of the former AP ponds. Bromodichloromethane was not detected below a depth of

130 ft bgs, though all detection limits are above the GWSL. Based on this evaluation, bromodichloromethane is retained as a COPC for groundwater in OU-1.

Bromoform

The distribution of bromoform in groundwater in OU-1 is shown in Figures 7-76a through 7-76e. These figures indicate that bromoform was detected at concentrations above the GWSL in the 0 to 130 ft bgs depth range at wells located primarily in the central portion of OU-1. The highest concentrations occur in the 55 to 130 ft bgs depth range in the vicinity of the AP ponds and the Leach Plant. Bromoform was not detected below a depth of 130 ft bgs. Based on this evaluation, bromoform is retained as a COPC for groundwater in OU-1.

Carbon Tetrachloride

The distribution of carbon tetrachloride in groundwater in OU-1 is shown in Figures 7-77a through 7-77e. These figures indicate that carbon tetrachloride was detected at concentrations above the GWSL in the 0 to 130 ft bgs depth range at wells located throughout OU-1. The highest concentrations are along the western boundary of OU-1. Carbon tetrachloride was not detected below a depth of 130 ft bgs. Based on this evaluation, carbon tetrachloride is retained as a COPC for groundwater in OU-1.

Chlorobenzene

The distribution of chlorobenzene in groundwater in OU-1 is shown in Figures 7-78a through 7-78e. These figures indicate that chlorobenzene was detected at concentrations above the GWSL in the 0 to 130 ft bgs depth range at wells located throughout OU-1. The highest concentrations are along the western boundary of OU-1. Chlorobenzene was not detected below a depth of 130 ft bgs. Based on this evaluation, chlorobenzene is retained as a COPC for groundwater in OU-1.

Chloroform

The distribution of chloroform in groundwater in OU-1 is shown in Figures 7-79a through 7-79h. These figures indicate that chloroform was detected at concentrations above the GWSL in the 0 to 130 ft bgs depth range at wells located throughout OU-1. The highest concentrations are along the western boundary of OU-1 and in the vicinity of the Unit 4 and 5 Buildings. Chloroform was not detected above the GWSL below a depth of 130 ft bgs. Based on this evaluation, chloroform is retained as a COPC for groundwater in OU-1.

1,2-Dichlorobenzene, 1,3-Dichlorobenzene, and 1,4-Dichlorobenzene

The distribution of 1,2-dichlorobenzene, 1,3-dichlorobenzene, and 1,4-dichlorobenzene in groundwater in OU-1 are shown in Figures 7-80a through 7-80e, 7-81a through 7-81e, and 7-82a through 7-82e, respectively. These figures indicate that all dichlorobenzenes were detected at concentrations above the GWSL in the 0 to 130 ft bgs depth range at wells located throughout OU-1. The highest concentrations are along the western boundary of OU-1. The dichlorobenzenes were not detected below a depth of 130 ft bgs. Based on this evaluation, 1,2-dichlorobenzene, 1,3-dichlorobenzene, and 1,4-dichlorobenzene are retained as COPCs for groundwater in OU-1.

1,1-Dichloroethane and 1,2-Dichloroethane

The distribution of 1,1-DCA and 1,2-DCA in groundwater in OU-1 are shown in Figures 7-83a through 7-83e, and 7-84a through 7-84e, respectively. These figures indicate that 1,1-DCA and 1,2-DCA were detected at concentrations above the GWSL in the 0 to 90 ft bgs depth range at wells located along the western boundary in the northern portion of OU-1. 1,1-DCA and 1,2-DCA were not detected at concentrations above the GWSL below 90 feet. Based on this evaluation, 1,1-DCA and 1,2-DCA are retained as COPCs for groundwater in OU-1.

1,1-Dichloroethene

The distribution of 1,1-DCE in groundwater in OU-1 is shown in Figures 7-85a through 7-85e. These figures indicate that while 1,1-DCE was detected at concentrations above the GWSL in the 0 to 55 ft bgs depth range at wells located throughout the central portion of OU-1, 1,1-DCE was not detected at concentrations above the GWSL below 55 feet. Based on this evaluation, 1,1-DCE is retained as a COPC for groundwater in OU-1.

1,4-Dioxane

The distribution of 1,4-dioxane in groundwater in OU-1 is shown in Figures 7-86a through 7-86e. These figures indicate that while 1,4-dioxane was detected at concentrations above the GWSL in the 0 to 130 ft bgs depth range at wells located throughout OU-1, 1,4-dioxane was not detected below a depth of 130 ft bgs, though all detection limits are above the GWSL. Based on this evaluation, 1,4-dioxane is retained as a COPC for groundwater in OU-1.

Methylene Chloride

The distribution of methylene chloride in groundwater in OU-1 is shown in Figures 7-87a through 7-87e. These figures indicate that while methylene chloride was detected above the GWSL relatively infrequently in the 0 to 55 ft bgs depth range, generally along the western boundary of OU-1, methylene chloride was not detected above the GWSL below 55 feet. Based on this evaluation, methylene chloride is retained as a COPC for groundwater in OU-1.

Naphthalene

The distribution of naphthalene in groundwater in OU-1 is shown in Figures 7-88a through 7-88e. All detection limits of naphthalene are above the GWSL. However, these figures indicate that naphthalene was detected in only two wells in the Shallow WBZ, and these detections are not spatially correlated with significantly elevated detection limits. Naphthalene was also detected in grab groundwater samples from the Unit 4 and 5 Buildings Investigation which are not shown given the scale of the figures. However, naphthalene was not detected in the surrounding wells, indicating that the detections of naphthalene are likely not representative of the concentration in the aquifer, but more indicative of the soil concentrations around the Unit 4 and 5 Buildings. Based on this evaluation, naphthalene is not retained as a COPC for groundwater in OU-1.

1,1,2,2-Tetrachloroethane

The distribution of 1,1,2,2-tetrachloroethane in groundwater in OU-1 is shown in Figures 7-89a through 7-89e. All detection limits of 1,1,2,2-Tetrachloroethane are above the GWSL, though it was detected in only one well in the Shallow WBZ and not detected in the Middle WBZ. However, the single detection is significantly above the screening level and spatially correlated with significantly elevated detection limits along the western edge of OU-1. Based on this evaluation, 1,1,2,2-tetrachloroethane is retained as a COPC for groundwater in OU-1.

Tetrachloroethene

The distribution of PCE in groundwater in OU-1 is shown in Figures 7-90a through 7-90e. These figures indicate that while PCE was detected infrequently in OU-1 in the 0 to 55 ft bgs depth range, and only above the GWSL in one well located along the western OU-1 boundary, PCE was not detected below 55 feet. However, the detections of PCE appear to be concentrated around the Leasehold Debris Pile, the IWF/barrier wall, and the former injection trenches suggesting an anthropogenic source of PCE within OU-1. Based on this evaluation, PCE is retained as a COPC for groundwater in OU-1.

1,2,4-Trichlorobenzene

The distribution of 1,2,4-trichlorobenzene in groundwater in OU-1 is shown in Figures 7-91a through 7-91e. 1,2,4-Trichlorobenzene was detected in one well (MC-29) above the GWSL (Table 7-3a); however, Figure 7-91b shows that the most recent sample from this well is a non-detect with a detection limit only slightly above the GWSL. Based on this evaluation, 1,2,4-trichlorobenzene is not retained as a COPC for groundwater in OU-1.

Trichloroethene

The distribution of TCE in groundwater in OU-1 is shown in Figures 7-92a through 7-92e. These figures indicate that while TCE was detected above the GWSL in the 0 to 55 ft bgs depth range throughout OU-1, TCE was not detected above the GWSL below 55 feet. The highest concentrations occur in the central portion of OU-1 and along the western boundary of OU-1. Based on this evaluation, TCE is retained as a COPC for groundwater in OU-1.

1,2,3-Trichloropropane

The distribution of 1,2,3-trichloropropane in groundwater in OU-1 is shown in Figures 7-93a through 7-93e. All detection limits of 1,2,3-Trichloropropane are above the GWSL. These figures indicate that 1,2,3-trichloropropane was detected above the GWSL in all Shallow and Middle WBZ monitoring intervals throughout OU-1. Based on this evaluation, 1,2,3-trichloropropane is retained as a COPC for groundwater in OU-1.

1,2,4-Trimethylbenzene

The distribution of 1,2,4-trimethylbenzene in groundwater in OU-1 is shown in Figures 7-94a through 7-94e. 1,2,4-Trimethylbenzene was detected slightly above the GWSL in a single sample from one well, and groundwater samples from two wells had detection limits slightly above the GWSL, as shown in Figures 7-94b and 7-94c. However, each of these samples are spatially isolated from each other, surrounded by samples with non-detected concentrations and detection limits below the GWSL. Based on this evaluation, 1,2,4-trimethylbenzene is not retained as a COPC for groundwater in OU-1.

Additional discussion of the nature and extent of the VOCs retained as groundwater COPCs in OU-1 is presented in Section 7.5.

7.2.2.5 SVOCs

As noted in Section 7.2.1.5, the following SVOC was retained for secondary screening: hexachlorobutadiene. The secondary screening of hexachlorobutadiene and a final determination whether to retain or exclude it as a COPC for groundwater in OU-1 is discussed below.

Hexachlorobutadiene

The distribution of hexachlorobutadiene in groundwater in OU-1 is shown in Figures 7-95a through 7-95e. All detection limits of hexachlorobutadiene are above the GWSL, though most of the detection limits are only slightly above the GWSL. As these figures indicate, hexachlorobutadiene was detected in only one groundwater sample from a well (M-66) screened within the Shallow WBZ (0-55 ft bgs) in the most recent sampling event, and was not detected below 55 feet. Hexachlorobutadiene is not associated with historical activities in OU-1 and the highest detection limits are likely not reflective of elevated levels of hexachlorobutadiene, but due to matrix interferences from VOCs in the trespassing OSSM plume. Based on this evaluation, hexachlorobutadiene is not retained as a COPC for groundwater in OU-1.

7.2.2.6 PCBs

As noted in Section 7.2.1.6, the following PCB was retained for secondary screening: Aroclor-1260. The secondary screening of Aroclor-1260 and a final determination whether to retain or exclude it as a COPC for groundwater in OU-1 is discussed below.

Aroclor-1260

Aroclor-1260 was detected in the Shallow WBZ (0-55 ft bgs) in only one groundwater grab sample located near the Leasehold Debris Pile within the EMD leasehold (RISB-12). Therefore, no figures have been prepared to illustrate the distribution of Aroclor-1260 in groundwater in OU-1. While this detection was significantly above the GWSL, Aroclor-1260 was also detected in soil at the same location below the LSSL at a DAF of 20. The groundwater grab sample may therefore not be representative of the concentration in the aquifer, but more indicative of the soil concentration at that location. Based on these results, Aroclor-1260 is not retained as a COPC for groundwater in OU-1.

7.2.2.7 Other Organics

As noted in Section 7.2.1.7, the following other organic constituents were retained for secondary screening: 4-chlorobenzenesulfonic acid and formaldehyde. The secondary screening of these constituents and final determinations whether to retain or exclude these constituents as COPCs for groundwater in OU-1 are discussed below.

4-Chlorobenzenesulfonic Acid

The distribution of 4-CBSA in groundwater in OU-1 is shown in Figures 7-96a through 7-96e. As these figures and Table 7-3a indicate, 4-CBSA was only detected in four samples (including one field duplicate) collected from three locations along the western OU-1 boundary in the Shallow WBZ (0-55 ft bgs). One detection was at a concentration significantly higher than the GWSL. 4-CBSA was not analyzed in the 55-90 ft bgs depth range of the Shallow WBZ or the 90-130 ft bgs range of the Middle WBZ and was not detected in the 130-300 ft bgs range of the Middle WBZ. Because the 4-CBSA detections in the 0-55 ft bgs depth range are spatially correlated and one detection is significantly higher than the GWSL, 4-CBSA is retained as a COPC for groundwater in OU-1. Additional discussion of the nature and extent of 4-CBSA in groundwater in OU-1 is presented in Section 7.5.

Formaldehyde

The distribution of formaldehyde in groundwater in OU-1 is shown in Figures 7-97a through 7-97e. As these figures indicate, formaldehyde was only detected in four samples collected from around the Unit 4 Building from the 90-130 ft bgs depth range. However, formaldehyde was detected at concentrations significantly higher than the GWSL in all four samples. Formaldehyde was not analyzed in the 0-55 ft bgs depth range of the Shallow WBZ. Formaldehyde was analyzed, but not detected in the deeper portion of the Shallow WBZ (55-90 ft bgs) or the deeper portion of the Middle WBZ (130-300 ft bgs). Because the formaldehyde detections in the 90-130 ft bgs depth range are significantly higher than the GWSL, formaldehyde is retained as a COPC for groundwater in OU-1. Additional discussion of the nature and extent of formaldehyde in groundwater in OU-1 is presented in Section 7.5.

7.3 Summary of Soil and Groundwater COPCs

Based on the initial and secondary screening of soil and groundwater data in the OU-1 RI Data Sets presented above, the COPCs for soil and groundwater in OU-1 are summarized in Table 7-2b. Due to the frequency of COPCs primarily detected adjacent to the east and west borders of OU-1, Table 7-2c presents a summary of the COPCs in OU-1 and indicates whether these chemicals are also identified as COPCs at the adjacent TIMET and OSSM sites. A discussion of sources for trespassing COPCs can be found in Section 9.4.5 of this report. Finally, it should be noted that the COPCs discussed herein differ from that of OU-2, which will be discussed later in Section 8 of this report, and OU-3, which will be discussed in the forthcoming OU-3 RI report.

7.4 Nature and Extent of COPCs in Soil in OU-1

A discussion of the horizontal and vertical extent of retained COPCs in vadose zone soil in OU-1 is presented below. The distribution of chemicals in vadose zone soil in OU-1 is generally discussed in 20-ft bgs intervals below the upper 10 ft of soil and relative to the OU-1 boundaries and major OU-1 features. Some figures in this section show the location of soil samples above LSSLs or HSSLs and where they are located relative to ECAs established on the NERT Site. ECAs are areas of OU-1 with known soil contamination not removed during the 2010-2011 Soil Removal Action, areas adjacent to building footprints which may be impacted by lead or asbestos from building construction materials, and areas of potentially contaminated soils which have not been characterized due to the presence of structures or other obstructions (e.g., underneath site buildings).

7.4.1 Chlorates and General Chemistry

As noted in Section 7.1.2.1, the following chlorate/general chemistry constituents were retained as COPCs for soil in OU-1: perchlorate, chlorate, and nitrate (as NO_3). The nature and extent of these constituents in soil is discussed below.

Perchlorate

Figure 7-1a shows the concentration of perchlorate in soil versus sample depth. This figure indicates that perchlorate is elevated at concentrations above the LSSL at a DAF of 1 and HSSL at all depths (up to 50 ft bgs) throughout OU-1. Figures 7-1b, 7-1c and 7-1d show the extent of perchlorate in soil across OU-1 in the upper 10 feet, 10 to 30 ft bgs, and 30 to 50 ft bgs depth ranges, respectively. The highest concentrations of perchlorate in unsaturated soil are located near the Unit 4 Building, in the central portion of OU-1 between the Lhoist facility and the former Beta ditch, beneath and downgradient of the former AP Ponds area, and near the Former Recharge Trench Area. Additional discussion of the nature and extent of contamination at the Unit 4 Building is provided in Section 7.6 and in the Unit 4 and 5 Buildings Investigation Report. This distribution pattern is consistent with historical perchlorate production operation between approximately 1945 and the mid-1990s (see Figures 2-3, 2-4, and 2-5a). With respect to groundwater, perchlorate is considered a COPC and additional discussion of its nature and extent is presented in Section 7.5.

Chlorate

Figure 7-2a shows the concentration of chlorate in soil versus sample depth. This figure indicates that chlorate is elevated at concentrations above the LSSL at a DAF of 1 but below the HSSL at all depths (up to 50 ft bgs) throughout OU-1 with the exception of two samples between 20 and 30 feet bgs that exceed the HSSL. Figures 7-2b, 7-2c and 7-2d show the extent of chlorate in soil across OU-1 in the upper 10 feet, 10 to 30 ft bgs, and 30 to 50 ft bgs depth ranges, respectively. Similar to perchlorate, the highest concentrations of chlorate in unsaturated soil are located near the Unit 4 Building, in the central portion of OU-1 between the Lhoist facility and the former Beta ditch, beneath and downgradient of the former AP Ponds area, and near the Former Recharge Trench Area. This distribution pattern is consistent with historical chlorate production operation between approximately 1945 and the mid-1990s (see Figures 2-3, 2-4, and 2-5a). With respect to groundwater, chlorate is considered a COPC and additional discussion of its nature and extent is presented in Section 7.5.

Nitrate (as NO_3)

Figure 7-3a shows the concentration of nitrate in soil versus sample depth. This figure indicates that nitrate is elevated at concentrations above the LSSL at a DAF of 1 but below the HSSL at all depths (up to 50 ft bgs) throughout OU-1. Figures 7-3b, 7-3c, and 7-3d show the extent of nitrate in soil across OU-1 in the upper 10 feet, 10 to 30 ft bgs, and 30 to 50 ft bgs depth ranges, respectively. Elevated concentrations of nitrate are widely distributed throughout OU-1, with the most consistent grouping of high concentrations of nitrate occurring in the central portion of OU-1. This distribution pattern is consistent with historical ammonia perchlorate production near the former Beta Ditch between 1951 and the late 1990s (see Figures 2-3, 2-4, and 2-5a). With respect to groundwater, nitrate is considered a COPC and additional discussion of its nature and extent is presented in Section 7.5.

7.4.2 Metals

As noted in Section 7.1.2.2, the following metals were retained as final COPCs for soil in OU-1: antimony, arsenic, barium, boron, hexavalent chromium, cobalt, lead, magnesium, manganese and nickel. The nature and extent of these metals in soil is discussed below.

Antimony

Figure 7-4a shows that antimony concentrations were elevated above the LSSL at a DAF of 20 in three shallow soil samples. Figures 7-4b, 7-4c, and 7-4d show the extent of antimony in soil in OU-1 in the upper 10 feet, 10 to 30 feet, and 30 to 50 ft bgs depth ranges, respectively. The extent of elevated antimony concentrations is very limited. All three elevated antimony concentrations are shown in Figure 7-4b. One sample with elevated antimony is from shallow soil at the western boundary of OU-1 and is within an ECA. A second sample is located in the area of the former P-1, P-2, and P-3 Ponds. Historically, this area was occupied by diesel ASTs, which were operated between the 1940s until the mid-1990s (Figures 2-2, 2-3, 2-4, 2-5a). A third sample is located in the Leach Plant area, which was historically used for manganese production operations. The elevated antimony concentrations in the Leach Plant area and the area south of the P-1, P-2, and P-3 Ponds are limited in horizontal and vertical extent and are present in ECAs. With respect to groundwater, however, antimony was excluded as a COPC in the initial screening process (Section 7.2.1.2, Tables 7-3a and 7-3b).

Arsenic

Figure 7-5a shows that arsenic concentrations are elevated above the target remediation goal[69] of 7.2 mg/kg as well as the LSSL at a DAF of 20 across all depths in the vadose zone in OU-1. However, in the UMCf, the arsenic concentrations are consistent with background and the elevated concentrations in the alluvium below 10 ft bgs appear to be part of a population consistent with the concentrations in the UMCf (see Section I.2.3 and Table I-3 in Appendix I as well as Figures 7-5a, 7-5c, and 7-5d). Figure 7-5b shows that the elevated concentrations of arsenic in the upper 10 feet are primarily focused in the area of the former P-1, P-2, and P-3 Ponds, although isolated elevated concentrations are also observed near the Unit 2 Building, the former Beta Ditch, and the western OU-1 boundary. These isolated elevated concentrations outside the area of the former P-1, P-2, and P-3 Ponds are all located within ECAs, and it is unlikely that the isolated elevated concentrations on the western OU-1 boundary extend beyond OU-1 given the small area of contamination within OU-1 (as indicated by the numerous adjacent samples where arsenic was below the target remediation goal). In the area of the former P-1, P-2, and P-3 Ponds, all but one of the soil samples with arsenic concentrations above the target remediation goal are located in ECAs. With respect to groundwater, arsenic is considered a COPC and additional discussion of its nature and extent in groundwater is presented in Section 7.5.

Barium

Figures 7-6a and 7-6b show the vertical and areal extent (0-10 feet) of barium in soil in OU-1, respectively. As shown in Figure 7-6a, only four of these samples (in the upper 10 feet) exceed the LSSL at a DAF of 20. The remaining three samples (collected at depths below 10 ft bgs) slightly exceed the LSSL at a DAF of 20. Based on the fact that barium has not been detected in groundwater above background and has been screened out as a COPC in groundwater, the barium concentrations in soils below 10 ft bgs do not represent a significant leaching concern (Tables 7-3a, 7-3b). Figure 7-6b shows that the locations with exceedances of the LSSL at a DAF of 20 in the upper 10 feet are isolated in extent and

---

[69] As discussed in Appendix G, although the LSSL for arsenic is 1 mg/kg, a target remediation goal of 7.2 mg/kg for the top ten feet of soil was approved by NDEP on August 20, 2010 (NDEP 2010) in response to Tronox's August 13, 2010 errata to the Removal Action Work Plan (Northgate 2010h).

located in the Leach Plant area, the area of the former P-1, P-2, and P-3 Ponds, on the western boundary of OU-1, and in the former Ammonium Perchlorate manufacturing area (AP Area). The isolated exceedance on the western boundary of OU-1 is located in an ECA and is co-located with the arsenic exceedance mentioned above. It is therefore unlikely that this exceedance extends beyond the boundary of OU-1. Elevated barium concentrations in soil are also located in ECAs in the Leach Plant and in the area south of the former P-1, P-2, and P-3 Ponds. With respect to groundwater, however, barium was excluded as a COPC in the initial screening process (Section 7.2.1.2, Tables 7-3a and 7-3b).

Boron

Figure 7-7a shows that boron concentrations exceed the LSSL at a DAF of 20 in 6 soil samples in the upper 15 feet of alluvium in OU-1. Figures 7-7b, 7-7c, and 7-7d show that these elevated concentrations are primarily located in the vicinity of C-1 Pond Area (which has previously been identified as a potential source area for boron in groundwater and received wastewaters including boron plant neutralization solutions). With respect to groundwater, boron is considered a COPC and additional discussion of its nature and extent in groundwater is presented in Section 7.5.

Chromium (hexavalent)

Figure 7-9a shows that concentrations of hexavalent chromium in soil exceed the LSSL at a DAF of 20 and the HSSL in many samples in soil within the upper 40 ft bgs in OU-1. Figures 7-9b, 7-9c, and 7-9d show that these elevated concentrations are primarily located in the vicinity of the Unit 4 Building, where hexavalent chromium was used in perchlorate production, and near the former P-1, P-2, and P-3 Ponds, which received process wastes containing hexavalent chromium from chlorate and perchlorate production. While these ponds were lined, the lining was replaced on several occasions between the mid-1970s and mid-1980s due to leaks and liner failures (Kleinfelder 1993; ENVIRON 2011). Additional discussion of the nature and extent of contamination at the Unit 4 Building is provided in Section 7.6 and in the Unit 4 and 5 Buildings Investigation Report. Some soil samples with hexavalent chromium concentrations above the LSSL at a DAF of 20 are located outside of ECAs in the area of the former P-1, P-2, and P-3 Ponds. With respect to groundwater, hexavalent chromium is considered a COPC and additional discussion of its nature and extent in groundwater is presented in Section 7.5.

Cobalt

Figure 7-10a shows that cobalt concentrations in soil exceed the LSSL at a DAF of 20 in many samples across the entire vadose zone in OU-1 and the HSSL in one sample. The frequency of elevated cobalt concentrations in soil is greatest in the upper 10 ft bgs, then tapers off significantly between 10 feet and 50 ft bgs. It is also important to note that the LSSL at a DAF of 20 (9.06 mg/kg) is below the maximum background concentration (16 – 17 mg/kg) for cobalt in soil in the surrounding area. In addition, as discussed in Appendix I, cobalt concentrations are consistent with background concentrations in soil at depths below 10 feet. Figures 7-10b and 7-10c show that the highest cobalt concentrations are primarily located in the upper 10 feet of soil in the vicinity of the Leach Plant and near the former P-1, P-2, and P-3 Ponds. These areas are coincident with the extent of manganese tailing and leach bed operations during the 1950s and 1960s, as shown in Figure 2-4. These areas are adjacent to the eastern boundary of OU-1 and are therefore not completely delineated as

NERT did not have access to TIMET property; however, because the areas of contamination are coincident with the manganese tailing and leach bed operations which were located entirely on OU-1, it is unlikely that contamination extends beyond the boundary of OU-1. The one sample with a cobalt concentration above the HSSL is located in an ECA. In addition to being above the LSSL at a DAF of 20, cobalt concentrations in soil are significantly above background concentrations in these areas. With respect to groundwater, however, cobalt was excluded as a COPC in the initial screening process (Section 7.2.1.2, Tables 7-3a and 7-3b).

Lead

Figure 7-12a shows the vertical extent of lead in soil in OU-1. This figure shows that lead concentrations exceed the LSSL at a DAF of 20 in five samples and the HSSL in three samples. Figure 7-12b shows that lead exceeds the LSSL at a DAF of 20 in the area of the former P-1, P-2, and P-3 Ponds and on the western boundary of OU-1. The isolated exceedance on the western boundary of OU-1 is located in an ECA and is co-located with the arsenic exceedance mentioned above. It is therefore unlikely that this exceedance extends beyond the boundary of OU-1. Elevated lead concentrations in soil are located in ECAs in the area of the former P-1, P-2, and P-3 Ponds. While historical documentation generally identifies the ASTs as used for diesel storage, it is possible they were used to store other fuels, such as leaded gasoline. With respect to groundwater, however, lead was excluded as a COPC in the secondary screening process as discussed in Section 7.2.2.2.

Magnesium

Figure 7-13a shows that magnesium concentrations in soil exceed the LSSL at a DAF of 20 in many samples and the HSSL in only 11 samples within the OU-1 vadose zone. Figures 7-13b, 7-13c, and 7-13d show the distribution of magnesium across different depth intervals in OU-1. Magnesium impacts in soil are widely distributed throughout OU-1. A review of Figures 7-13a, 7-13b, 7-13c, and 7-13d shows that magnesium concentrations in soil generally increase with increasing depth. As discussed in Section 2, the Unit Buildings were originally constructed for production of magnesium metal in the early 1940s (Figure 2-2), and the Trade Effluent Ponds were used for process wastewater disposal during the same period. With respect to groundwater, magnesium is considered a COPC and additional discussion of its nature and extent in groundwater is presented in section 7.5.

Manganese

Figure 7-14a shows that manganese soil concentrations exceed the LSSL at a DAF of 20 in many samples and the HSSL in only twelve soil samples in the OU-1 vadose zone. Figures 7-14b, 7-14c, and 7-14d show the distribution of manganese across different depth intervals in OU-1, and that manganese concentrations in soil are generally elevated in the vicinity of the Unit 4 and 5 Buildings, the Leach Plant area, and areas of current and former ponds, including in the area of the former P-1, P-2, and P-3 Ponds, north of the former AP-6 pond, and around the former pond Mn-1 and current pond Mn-2. As shown in Figure 2-5a, much of this area has been used for manganese production (manganese dioxide and high-purity manganese metal) since the early 1950s (Figure 2-1). As shown in Figures 2-4, 2-5a, and 2-6, on-Site activities have included manganese tailings storage, leach bed and leach plant operation, and electroplating. While elevated concentrations are adjacent to the eastern boundary of OU-1 in the Leach Plant area and are therefore not completely delineated since

NERT did not have access to TIMET property, because the area of these elevated concentrations is coincident with operations that were located entirely on OU-1, it is unlikely that these elevated concentrations extend beyond the boundary of OU-1. Manganese concentrations in soil generally decrease with increasing depth. With respect to groundwater, manganese is considered a COPC and additional discussion of its nature and extent in groundwater is presented in section 7.5.

Nickel

Figure 7-17a and 7-17b show that nickel has two samples that exceed 20 times the LSSL in the upper 10 feet of soil in the Leach Plant area. One of the two elevated nickel concentrations in soil is located in an ECA in the Leach Plant area. With respect to groundwater, however, nickel was excluded as a COPC in the initial screening process (Section 7.2.1.2, Tables 7-3a and 7-3b).

7.4.3 VOCs

As noted in Section 7.1.2.4, the following VOCs were retained as COPCs for soil in OU-1: benzene, carbon tetrachloride, chlorobenzene, chloroform, methylene chloride, and 1,2,3-trichloropropane. The discussion below focuses on the nature and extent of VOCs in soil within the vadose zone in OU-1. Soil gas samples have also been collected from the vadose zone in OU-1 and a discussion and preliminary screening of soil gas results is presented below in Section 7.7.

Benzene

Figure 7-26a shows that benzene soil concentrations exceed the LSSL at a DAF of 1 at all depths, exceed the LSSL at a DAF of 20 in depths greater than 20 ft bgs in OU-1, and exceed the HSSL in depths greater than approximately 30 ft bgs. Benzene concentrations in soil generally increase with increasing depth with very few elevated concentrations detected in the 0 – 10 foot depth interval. Figures 7-26b, 7-26c, and 7-26d show that these elevated concentrations are primarily located at depths greater than 30 feet at the western OU-1 boundary with the OSSM site and are indicative of the trespassing OSSM groundwater plume given the fact that they are co-located with elevated concentrations of benzene in groundwater as discussed in Section 7.5.2.4. The trespassing OSSM groundwater plume is detailed further in Section 7.5.1.4. With respect to groundwater, benzene is considered a COPC and additional discussion of its nature and extent in groundwater is presented in Section 7.5.

Carbon Tetrachloride

Figure 7-27a shows that carbon tetrachloride soil concentrations exceed the LSSL at a DAF of 1 at depths greater than 15 ft bgs in OU-1, exceed the LSSL at a DAF of 20 in depths greater than 20 ft bgs, and do not exceed the HSSL. Carbon tetrachloride concentrations in soil generally increase with increasing depth with very few elevated concentrations detected in the 0 – 10 foot depth interval. Figures 7-27b, 7-27c, and 7-27d show that these elevated concentrations are primarily located at depths greater than 30 feet at the western OU-1 boundary with the OSSM site and are indicative of the trespassing OSSM groundwater plume given the fact that they are co-located with elevated concentrations of carbon tetrachloride in groundwater as discussed in Section 7.5.2.4, with additional concentrations above the LSSL at a DAF of 1 but below the LSSL at a DAF of 20 near the former Recharge Trench

Area. The trespassing OSSM groundwater plume is detailed further in Section 7.5.1.4. With respect to groundwater, carbon tetrachloride is considered a COPC and additional discussion of its nature and extent in groundwater is presented in Section 7.5.

Chlorobenzene

Figure 7-28a shows that chlorobenzene soil concentrations exceed the LSSL at a DAF of 1 and the LSSL at a DAF of 20 in depths greater than 15 ft bgs in OU-1, and exceed the HSSL in depths greater than approximately 25 ft bgs. Chlorobenzene concentrations in soil generally increase with increasing depth with very few elevated concentrations detected in the 0 – 10 foot depth interval. Figures 7-28b, 7-28c, and 7-28d show that these elevated concentrations are primarily located at depths greater than 20 feet at the western OU-1 boundary with the OSSM site and are indicative of the trespassing OSSM groundwater plume given the fact that they are co-located with elevated concentrations of chlorobenzene in groundwater as discussed in Section 7.5.2.4. The trespassing OSSM groundwater plume is detailed further in Section 7.5.1.4. With respect to groundwater, chlorobenzene is considered a COPC and additional discussion of its nature and extent in groundwater is presented in Section 7.5.

Chloroform

Figure 7-29a shows that chloroform soil concentrations exceed the LSSL at a DAF of 1 at all depths, exceed the LSSL at a DAF of 20 in depths greater than 15 ft bgs in OU-1, and exceed the HSSL in depths greater than approximately 20 ft bgs. Chloroform concentrations in soil generally increase with increasing depth. Figures 7-29b, 7-29c, and 7-29d show that these elevated concentrations are primarily located in the vicinity of the Unit 4 Building and downgradient area as well as at depths greater than 20 feet at the western OU-1 boundary with the OSSM site. The highest concentrations of chloroform occur in the 30 to 50 ft bgs depth range along the western boundary of OU-1 and are indicative of the trespassing OSSM groundwater plume given the fact that they are co-located with elevated concentrations of chloroform in groundwater as discussed in Section 7.5.1.4. The trespassing OSSM groundwater plume is also detailed further in Section 7.5.1.4. Additional discussion of the nature and extent of contamination at the Unit 4 Building is provided in Section 7.6 and in the Unit 4 and 5 Buildings Investigation Report. With respect to groundwater, chloroform is considered a COPC and additional discussion of its nature and extent in groundwater is presented in Section 7.5.

Methylene Chloride

Tables 7-1a, 7-1b, and 7-1c and Figure 7-30a show that the detection frequency for methylene chloride in soil samples is low: 17.9% in the upper 10 feet, 10.4% in the alluvium below 10 ft bgs, and 6.1% in the UMCf. In addition, Figures 7-30b, 7-30c, and 7-30d show that methylene chloride concentrations in soil that are above the LSSL at a DAF of 1 are widely distributed across OU-1, including in Parcel RZ-A near the southern boundary of OU-1, which has no documented history of significant industrial operations. The extent of methylene chloride concentrations above the LSSL at a DAF of 20 is very limited across OU-1 and with depth. Methylene chloride is also a common laboratory chemical and often a lab contaminant in environmental samples. Given the low detection frequency, the presence of methylene chloride in soil in upgradient Parcel RZ-A and the fact that elevated concentrations in soil are very limited in distribution across OU-1 with no specific pattern tied to historical operations in OU-1, it is unlikely there is a specific source/release of methylene chloride in OU-1. With respect to groundwater, methylene chloride is considered a COPC and additional discussion of its nature and extent in groundwater is presented in Section 7.5.

1,2,3-Trichloropropane

All detection limits of 1,2,3-trichloropropane are above the LSSL at a DAF of 20 by approximately two orders of magnitude or more, as shown by Figure 7-33a. All vadose zone detection limits are below the HSSL. The five detected 1,2,3-trichloropropane soil concentrations exceed the LSSL at a DAF of 20 in depths greater than 25 ft bgs in OU-1 but do not exceed the HSSL. Figures 7-33b, 7-33c, and 7-33d show that these elevated concentrations are primarily located in the vicinity of the Unit 1 and Unit 2 Buildings with an isolated detection in the area of the former P-1, P-2, and P-3 Ponds. With respect to groundwater, 1,2,3-trichloropropane is considered a COPC and additional discussion of its nature and extent in groundwater is presented in Section 7.5.

7.4.4 SVOCs

As noted in Section 7.1.2.5, the following SVOCs were retained as COPCs for soil in OU-1: 1,4-dioxane and hexachlorobenzene. The nature and extent of these SVOCs in soil is discussed below.

1,4-Dioxane

Many detection limits of 1,4-dioxane are above the LSSL at a DAF of 20, though all detection limits are below the HSSL, as shown by Figure 7-34a. 1,4-Dioxane was detected in soil at concentrations above the LSSL at a DAF of 20 but below the HSSL in two samples at approximately 10 and 40 ft bgs. Figures 7-34b, 7-34c, and 7-34d show that these two detected concentrations are located adjacent to and south of the Unit 2 Building. With respect to groundwater, 1,4-dioxane is considered a COPC and additional discussion of its nature and extent in groundwater is presented in Section 7.5.

Hexachlorobenzene

Figure 7-35a shows that hexachlorobenzene was detected in soil at concentrations above the LSSL at a DAF of 20 in the upper 10 ft bgs in OU-1. Concentrations of hexachlorobenzene are detected above the HSSL in numerous samples to a depth of approximately 25 ft bgs, with concentrations decreasing with depth. Although the hexachlorobenzene detections above the LSSL at a DAF of 1 are quite widespread in soil across OU-1, Figure 7-35b shows that the highest concentrations of hexachlorobenzene are located in the area of the former Trade Effluent Ponds, specifically around the former Recharge Trenches. Several isolated samples near the former Beta Ditch also exceed the LSSL at a DAF of 20. Although the majority of the hexachlorobenzene soil concentrations above the LSSL at a DAF of 20 are located in ECAs, there are some elevated concentrations in soil outside of ECAs around the former Recharge Trenches. With respect to groundwater, however, hexachlorobenzene was excluded as a COPC in the initial screening process (Section 7.2.1.5, Tables 7-3a and 7-3b).

7.4.5 PAHs

As noted in Section 7.1.2.6, the following PAHs were retained as COPCs for soil in OU-1: 1-methylnaphthalene and 2-methlynaphthalene. The nature and extent of these PAHs in soil is discussed below.

1-Methylnaphthalene and 2-Methlynaphthalene

Figures 7-36a and 7-37a show that detected concentrations of 1-methylnaphthalene and 2-methylnaphthalene, respectively, are less than the LSSL at a DAF of 20 at depths below 10 feet, though detection limits of 1-methylnaphthalene are above the LSSL at a DAF of 20 at depths below 20 ft bgs. Soil concentrations of 1-methylnaphthalene and 2-methylnaphthalene decrease significantly with depth. 1-methylnaphthalene has a low detection frequency (5.9%) in the upper 10 feet of soil and is only detected above the LSSL at a DAF of 1 at a frequency greater than 5% in the upper 10 feet. The horizontal extent of 1-methylnaphthalene and 2-methlynaphthalene in the upper 10 feet of soil are shown in Figures 7-36b and 7-37b, respectively. These figures show that the elevated concentrations of 1-methylnaphthalene and 2-methlynaphthalene are isolated to the area of the former P-1, P-2, and P-3 Ponds. With respect to groundwater, however, 1-methylnaphthalene and 2-methylnaphthalene were excluded as COPCs in the initial screening process (Section 7.2.1, Tables 7-3a and 7-3b).

7.4.6 PCBs

As noted in Section 7.1.2.7, the following PCBs were retained as COPCs for soil in OU-1: Aroclor-1248, Aroclor-1254, and Aroclor-1260. The nature and extent of these PCBs in soil is discussed below.

Aroclor-1248

Figure 7-39a shows that Aroclor-1248 was detected in soil at concentrations above the LSSL at a DAF of 20 in two samples within the upper 10 feet within OU-1 and not detected in soil below 10 ft bgs, though many detection limits are above the LSSL at a DAF of 20. As shown in Figure 7-39b, the two detections above the LSSL at a DAF of 20 were north and south of the Unit 2 Building, though both elevated concentrations are outside the ECAs surrounding the Unit Buildings. As shown in Figure 2-5a, the area north of the Unit 2 Building was historically used for PCB storage beginning in the late 1970s. With respect to groundwater, however, Aroclor-1248 was excluded as a COPC in the initial screening process (Section 7.2.1.6, Tables 7-3a and 7-3b).

Aroclor-1254

Figure 7-40a shows that Aroclor-1254 was detected in soil at concentrations above the LSSL at a DAF of 20 in three samples within the upper 10 feet within OU-1 and not detected in soil below 10 ft bgs, though some detection limits are above the LSSL at a DAF of 20. As shown in Figure 7-40b, one detection above the LSSL at a DAF of 20 was adjacent to the Unit 4 Building, and two were north of the Unit 1 Building. The elevated concentration adjacent to the Unit 4 Building is within an ECA, though the two elevated concentrations north of the Unit 1 Building are outside the ECAs surrounding the Unit Buildings. As shown in Figure 2-5a, the area north of the Unit 2 Building was historically used for PCB storage beginning in the late 1970s and a PCB transformer spill occurred south of the Unit 5 Building in the early 1990s. With respect to groundwater, however, Aroclor-1254 was excluded as a COPC in the initial screening process (Section 7.2.1.6, Tables 7-3a and 7-3b).

Aroclor-1260

Figure 7-41a shows that Aroclor-1260 was detected in soil at concentrations above the LSSL at a DAF of 20 in five samples within the upper 10 feet within OU-1 and in only two samples in the alluvium below 10 ft bgs. As shown in Figure 7-41b, the detections above the LSSL at a DAF of 20 were primarily near the Unit Buildings. The elevated concentrations are within ECAs surrounding the Unit Buildings. As shown in Figure 2-5a, the area north of the Unit 2 Building was historically used for PCB storage beginning in the late 1970s and a PCB transformer spill occurred south of the Unit 5 Building in the early 1990s. With respect to groundwater, however, Aroclor-1260 was excluded as a COPC in the secondary screening process as discussed in Section 7.2.2.6.

7.4.7 Dioxins/Furans

As noted in Section 7.1.2.8, all the detected dioxin/furan congeners except octachlorodibenzo-p-dioxin were retained as COPCs for soil in OU-1. The nature and extent of dioxins/furans (as depicted by 2,3,4,7,8-Pentachlorodibenzofuran as a representative example) in soil is discussed below.

Dioxins/Furans

As shown in Figure 7-42a, dioxins/furans were detected in numerous soil samples at concentrations above LSSLs in the upper 15 feet of alluvium.[70] Figures 7-42b and 7-42c show that elevated concentrations were detected in soil in the northern end of OU-1 in the area of the former Trade Effluent Ponds. Specifically, elevated concentrations are seen near the former Recharge Trench Area. Excavation in 2019 has removed impacted soil that had been sampled and contained elevated concentrations of dioxins near the current GW-11 pond. Due to the excavation, these samples are not shown in these figures. This excavation is described in more detail in the Report of Soil Removal Action, Dioxin Soil Removal Area letter report (Ramboll 2020a). Localized elevated detections are also observed near the former Beta Ditch and just north of the Unit 2 Building. Many but not all of the detections of 2,3,4,7,8-Pentachlorodibenzofuran with soil concentrations greater than the LSSL at a DAF of 20 in the former Recharge Trench/Trade Effluent Ponds Area are located in ECAs. With respect to groundwater, however, all dioxins/furans were excluded as COPCs in the initial screening process (Section 7.2.1, Tables 7-3a and 7-3b).

7.4.8 Organochlorine Pesticides

As noted in Section 7.1.2.9, the following OCPs were retained as COPCs for soil in OU-1: alpha-BHC, beta-BHC, and gamma-BHC. The nature and extent of these OCPs in soil is discussed below.

Alpha-BHC

As shown in Figure 7-43a, alpha-BHC had concentrations exceeding the LSSL at a DAF of 20 in three samples within the unsaturated alluvium at depths between 10 and 20 ft bgs. Two of these samples were at the same location in a field duplicate pair. Figure 7-43c shows that the two locations with alpha-BHC detections above the LSSL at a DAF of 20 are near the western boundary near the OSSM site and north of the Unit 2 Building. Alpha-BHC is considered a COPC at the OSSM site and its presence in soil in OU-1 is likely related to historical discharges from the OSSM site given the absence of historical alpha-BHC

---

[70] No HSSLs exist for individual dioxins or furans, so one is not shown in Figure 7-42a. A site-specific HSSL of 2,700 pg/g is used for the total toxicity equivalence of all the dioxins/furans.

production activities within OU-1. With respect to groundwater, alpha-BHC was excluded as a COPC in the initial screening process (Section 7.2.1, Tables 7-3a and 7-3b).

Beta-BHC

As shown in Figure 7-44a, beta-BHC had concentrations exceeding the LSSL at a DAF of 20 in the unsaturated alluvium at depths above and below 10 ft bgs. Beta-BHC was not detected above the LSSL at a DAF of 20 in the unsaturated UMCf. Beta-BHC soil concentrations decrease with increasing depth. Figures 7-44b and 7-44c show that beta-BHC detections above the LSSL at a DAF of 20 are widely distributed in soil throughout OU-1. The highest concentrations of beta-BHC in soil are near the former Beta Ditch, the former Recharge Trench/Trade Effluent Ponds Area, and the western boundary near the OSSM site. Beta-BHC is considered a COPC at the OSSM site and its presence in soil in OU-1 is likely related to historical discharges from the OSSM site given the absence of historical beta-BHC production activities within OU-1. With respect to groundwater, beta-BHC was excluded as a COPC in the initial screening process (Section 7.2.1, Tables 7-3a and 7-3b).

Gamma-BHC

As shown in Figure 7-45a, gamma-BHC had concentrations exceeding the LSSL at a DAF of 20 in the unsaturated alluvium at depths above and below 10 ft bgs. Figures 7-45b and 7-45c show that gamma-BHC detections above the LSSL at a DAF of 20 are located near the western boundary near the OSSM site. Gamma-BHC is considered a COPC at the OSSM site and its presence in soil in OU-1 is likely related to historical discharges from the OSSM site given the absence of historical gamma-BHC production activites within OU-1. With respect to groundwater, gamma-BHC was excluded as a COPC in the initial screening process (Section 7.2.1, Tables 7-3a and 7-3b).

7.4.9 Other Organics

As noted in Section 7.1.2.11, formaldehyde is the only other organic constituent retained as a COPC for soil in OU-1. The nature and extent of formaldehyde in soil is discussed below.

Formaldehyde

As shown in Figure 7-47a and discussed in Section 7.1.2.11, formaldehyde was detected above the LSSL at a DAF of 20 and below the HSSL in all seven samples collected in the vadose zone. Figures 7-47b, 7-47c, and 7-47d show the two locations where all of these samples were collected. These locations are in the vicinity of the laboratory constructed in 1980 (Kleinfelder 1993) formerly used for quality assurance testing of products produced at the ammonium perchlorate plant. The laboratory used dilute formaldehyde as part of chemical testing, with the rinse water discharged to a septic tank. Limited quantities of formaldehyde would have been used in laboratory operations and only rinse water containing formaldehyde would have been released to the subsurface. Formaldehyde soil impact would thus be limited in magnitude and extent. With respect to groundwater, formaldehyde is considered a COPC and additional discussion of its nature and extent in groundwater is presented in Section 7.5.

7.5 Nature and Extent of COPCs in Groundwater in OU-1

This section presents a discussion of the horizontal and vertical extent of COPCs in groundwater within OU-1. For ease of discussion, and for the remainder of this report, COPCs have been divided into two categories, Primary COPCs and Other COPCs. Primary COPCs were identified based on use in historic or current manufacturing operations, as well as widespread presence and mobility in groundwater as evidenced by the RI groundwater data and prior groundwater monitoring program results. These Primary COPCs are limited to:

- Perchlorate
- Chlorate
- Chromium (hexavalent)
- Chloroform

The second category of COPCs, Other COPCs, includes all other groundwater constituents retained through the above analysis:

General Chemistry	Bromide
	Nitrate/nitrite
Metals	Arsenic
	Boron
	Magnesium
	Manganese
	Strontium
	Uranium (total)
Radionuclides	Thorium-228
	Thorium-230
VOCs	Benzene
	Bromodichloromethane
	Bromoform
	Carbon tetrachloride
	Chlorobenzene
	1,2-Dichlorobenzene
	1,3-Dichlorobenzene
	1,4-Dichlorobenzene
	1,1-DCA
	1,2-DCA
	1,1-DCE
	1,4-Dioxane
	Methylene chloride
	1,1,2,2-Tetrachloroethane

	PCE
	TCE
	1,2,3-Trichloropropane
Other Organics	4-Chlorobenzenesulfonic acid
	Formaldehyde

A summary of the analytical results for the Primary COPCs and Other COPCs in the OU-1 Groundwater Data Set is presented in Tables 7-4, 7-5, and 7-6. Table 7-4 presents the results for Primary COPCs,[71] Table 7-5 presents the results for all VOC COPCs, and Table 7-6 presents the results for all Other COPCs (excluding VOCs). The complete groundwater analytical results of the OU-1 Groundwater Data Set are presented in Appendix J.

As described earlier in Section 7.2.2, the distribution of COPCs in groundwater in OU-1 is presented in a series of maps based on the following depth intervals:

- Shallow WBZ (0-55 ft bgs)
- Shallow WBZ (55-90 ft bgs)
- Middle WBZ (90-130 ft bgs)
- Middle WBZ (130-300 ft bgs)

7.5.1 OU-1 Groundwater Primary COPCs

7.5.1.1 Perchlorate

Based on the wide distribution of perchlorate throughout the Shallow WBZ (0-55 ft bgs and 55-90 ft bgs) and its high concentrations, this constituent is considered a Primary COPC. The distribution of perchlorate in Site groundwater based on data from May 2004 is shown along with perchlorate source areas in Figure 7-48. The groundwater perchlorate results from 2015 to 2018 are presented in Figure 7-49a with additional detail areas shown in Figure 7-49b.

In May 2004, the highest perchlorate concentrations (above 1,000 mg/L) extended from the area downgradient (north) of the Unit 4 Building to the IWF/barrier wall. Perchlorate was also present at similar concentrations in the area between the barrier wall and the former injection trenches, which were operational at that time, at concentrations of 1,400 mg/L and 1,700 mg/L in wells M-71 and M-72, respectively. In contrast, from 2015 to 2018, the perchlorate concentrations above 1,000 mg/L were limited to a smaller area extending from the former Beta Ditch to the IWF/barrier wall (up to 2,500 mg/L at RISB-18). Perchlorate continued to be present at these concentrations between the barrier wall and the former injection trenches with concentrations of 1,200 mg/L in wells M-71 and M-72. These results indicate that perchlorate concentrations in wells located in the area between the Unit Buildings and the former Beta Ditch have generally decreased by an order of magnitude since 2004. For example, groundwater collected from well M-12A (located north of the Unit 4 Building) in May 2004 contained perchlorate at a concentration of 1,100 mg/L. Groundwater collected from M-12A in 2018 indicated that the perchlorate concentration had

---

[71] Results for Total VOCs are also included in Table 7-4 to aid in interpretation of chloroform analytical results.

decreased to 140 mg/L. Similarly, perchlorate concentrations in groundwater at well M-31A (located on the north side of the Leach Plant) decreased from 2,100 mg/L in May 2004 to 320 mg/L by 2018. Groundwater samples collected from other wells in this area of the Site exhibited similar decreases in perchlorate concentrations over this time period.

The vertical extent of perchlorate in OU-1 is shown in Figure 7-50a where perchlorate concentrations are plotted against mid-screen depths. To illustrate the lateral and vertical extent of perchlorate in OU-1, perchlorate concentrations in two depth intervals in the Shallow WBZ (0-55 ft bgs and 55-90 ft bgs) and three depth intervals in the Middle WBZ (90-130 ft bgs, 130-175 ft bgs, and 175-300 ft bgs) are shown in Figures 7-50b through 7-50h. The figures for the deeper intervals incorporate data from groundwater monitoring wells supplemented by saturated soil sample results from the deep soil borings installed as part of the Phase 2 RI. The saturated soil sample results in mg/kg may be biased low compared to a calculated equivalent groundwater concentration. However, since porosity and bulk density (terms in the calculation equation) are not available for these samples, the saturated soil sample results are considered representative and used to inform the placement of contour lines in the figures. The lateral extent of perchlorate is shown at these five separate depth intervals, and the vertical extent of perchlorate is depicted in subsurface cross-section M-M’ presented in Figure 7-50i.

Shallow WBZ (0-55 ft bgs)

As discussed in Section 5.5.2, the alluvium has become largely unsaturated in OU-1 and first groundwater now typically occurs in the fine-grained soils of the UMCf-fg1, except near the southern Site boundary where the UMCf-cg1 unit underlies the alluvium. As can be seen in Figure 7-50b, the area of the highest concentrations in the Shallow WBZ (0-55 ft bgs) depth interval is generally in the eastern half of the Site and extends north from the Unit 4 and 5 Buildings to the Site boundary and into OU-2. The highest concentrations in shallow groundwater are found in the northern part of the Site in the area between the former Beta Ditch and the IWF/barrier wall. Other former source areas that affect the perchlorate distribution in shallow groundwater in this area (e.g., the former AP plant operation area, former AP ponds, and the area around the IWF and the former Recharge Trench Area) are shown in Figures 7-48 and 7-49a. The lateral extent of perchlorate above the GWSL of 0.015 mg/L is defined west of OU-1 on the OSSM property, but the lateral extent east of OU-1 is eventually defined using 0.4 mg/L established by NDEP in their Up-Gradient Groundwater Review (NDEP 2016a) (rather than the GWSL given the presence of low levels of perchlorate from unknown upgradient sources). Accordingly, the perchlorate concentration at the southern end of OU-1 in well M-120 is also defined using the upgradient concentration of 0.4 mg/L. Perchlorate is above this upgradient level in well M-121 indicating that other unidentified sources of perchlorate have impacted groundwater upgradient (south) of OU-1.

Shallow WBZ (55-90 ft bgs)

Perchlorate concentrations in the 55-90 feet depth of the Shallow WBZ are shown in Figure 7-50c, with a detail of the central portion of OU-1 presented in Figure 7-50d. Overall, the perchlorate concentrations are lower than in the Shallow WBZ (0-55 ft bgs) wells. The highest concentrations in this depth interval are generally co-located with the areas of highest concentrations in the Shallow WBZ (0-55 ft bgs) depth interval. The lateral extent of perchlorate above the GWSL of 0.015 mg/L is defined on the eastern and western sides of the Site and can be reasonably inferred south of the Unit Buildings based on data from wells and borings in that area.

Middle WBZ (90-130 ft bgs)

Perchlorate concentrations in the 90-130 feet depth of the Middle WBZ are shown in Figure 7-50e, with a detail of the Unit Building area presented in Figure 7-50f. The distribution of perchlorate at this depth interval is distinctly different compared to the distributions in the Shallow WBZ (0-55 ft bgs and 55-90 ft bgs). The highest concentrations (above 1,000 mg/L) are found beneath the Unit 4 Building and extend north-northeast for a distance of approximately 900 feet. The perchlorate (and other chemicals associated with historic releases at the Unit 4 Building) migrated downward through the alluvium and UMCf silty sands/sandy silts that occur in this area of the Site and accumulated at the base of a sandy silt layer and the top portion of the underlying silty clay soils. The highest concentrations were found between depths of approximately 90-110 ft bgs. The sandy silt is underlain by low permeability clayey silt and silty clay soil that impedes the downward migration of the perchlorate. Instead, the perchlorate-impacted groundwater migrated laterally, first toward the north-northeast for a distance of approximately 1,800 feet to where the sandy silt layer transitions laterally into finer-grained silt and clayey silt. The decrease in permeability associated with this lateral facies change has the effect of deflecting groundwater flow toward the east. Based on the available data, the area of perchlorate-impacted groundwater above the BCL extends for a distance of approximately 2,500 feet northeast of the Unit 4 Building.

At the Site, the extent of the perchlorate migrating from the vicinity of the Unit 4 Building is defined to the south, west, and north by groundwater data from wells and deep soil boring samples. To the east, the extent of the perchlorate is inferred based on samples collected from three multi-port wells located at the TIMET site. Samples were collected from the multi-port well screens following their installation in 2008; however, they have since been decommissioned and were unable to be sampled by NERT or in connection with the NERT RI.

In contrast, perchlorate concentrations are generally below 1 mg/L in the northern part of the Site except in the area between the IWF/barrier wall and the northern OU-1 boundary. At many sampled locations, perchlorate was either not detected or detected concentrations which were slightly above the GWSL of 0.015 mg/L.

The difference between the depth of perchlorate impacted groundwater in the southern and northern areas of OU-1 can be seen in Figure 7-50i, Subsurface Cross-Section M-M’.

Middle WBZ (130-175 ft bgs)

Perchlorate concentrations in the 130-175 feet depth of the Middle WBZ are shown in Figure 7-50g. Concentrations in the wells located at and near the Unit 4 Building and to the north range from 0.81 to 8.6 J mg/L, with one higher concentration at well M-195 (72 J+ mg/L). In other areas of the Site, perchlorate is either not detected or concentrations are slightly above the GWSL of 0.015 mg/L. The presence of fine-grained silt and clay soils at this depth limits the rate of lateral migration toward the north-northeast. As discussed in Section 4.5.3, investigations of the Middle WBZ within OU-1 indicate a vertical upward gradient between the Middle and Shallow Zones that generally increases with depth. Along with the presence of fine-grained silt and clay soils at this depth, this upward gradient has and most likely will continue to reduce the potential for further downward migration of perchlorate.

Middle WBZ (175-300 ft bgs)

Perchlorate concentrations in the 175-300 feet depth of the Middle WBZ are shown in Figure 7-50h. The wells in this depth interval located along the western side of OU-1 and at the adjacent OSSM site are screened in the UMCf-cg2. Historically, perchlorate has not been detected, or has been detected at very low concentrations below the GWSL of 0.015 mg/L at this depth interval throughout OU-1. NERT well TR-9 located on the southwest Site boundary appears to be affected by groundwater impacts from the former AMPAC site to the west. Well TR-9 has shown an increasing perchlorate concentration trend since 2015, and the 2018 concentration of 0.13 mg/L is now above the GWSL. Similarly, OSSM wells DMC-MW-26 and DMC-MW-27R appear to be affected by groundwater impacts from the former AMPAC site. As indicated in Figures 7-50b through 7-50h, perchlorate originating from NERT source areas is not present near this deeper perchlorate plume. Additionally, groundwater flow would drive perchlorate northward from NERT's source areas, not to the southwest.

7.5.1.2 Chlorate

The distribution of chlorate based on groundwater sampling results obtained between 2015 to 2018 is shown in Figure 7-51a, with additional detail areas shown in Figure 7-51b. The current distribution of chlorate in Site groundwater is similar to perchlorate and as such, is considered a Primary COPC. Chlorate concentrations between 500 and 1,000 mg/L extend from the Unit 4 Building to beyond the IWF/barrier wall. The highest chlorate concentrations (above 2,500 mg/L) are found in the area between the former Beta Ditch and the IWF/barrier wall. In the area between the barrier wall and the former injection trenches chlorate is present at concentrations above 2,500 mg/L in monitoring well M-72 (3,300 mg/L) and above 1,000 mg/L in several wells including M-70, M-71, M-80, and M-73 with concentrations ranging from 1,300 mg/L to 1,900 mg/L.

The vertical extent of chlorate in OU-1 is shown in Figure 7-51c where chlorate concentrations are plotted against mid-screen depths. To illustrate the lateral and vertical extent of chlorate in OU-1, chlorate concentrations in two depth intervals in the Shallow WBZ (0-55 ft bgs and 55-90 ft bgs) and three depth intervals in the Middle WBZ (90-130 ft bgs, 130-175 ft bgs, and 175-300 ft bgs) are shown in Figures 7-51d through 7-51j. The figures for the deeper intervals incorporate data from groundwater monitoring wells supplemented by saturated soil sample results from the deep soil borings installed as part of the Phase 2 RI. The saturated soil sample results in mg/kg may be biased low relative to groundwater sampled at the same location and depth. However, the saturated soil sample results are considered sufficiently representative to inform the placement of contour lines in the figures. The lateral extent of chlorate shown at these five separate depth intervals is discussed below.

Shallow WBZ (0-55 ft bgs)

As can be seen in Figure 7-51d, the area of the highest concentrations in the Shallow WBZ (0-55 ft bgs) depth interval is generally in the eastern half of OU-1 and extends north from the Unit 4 and 5 Buildings to the Site boundary and into OU-2. The highest concentrations in shallow groundwater are found in the northern part of the Site in the area between the former Beta Ditch and the IWF/barrier wall. Other former source areas that affect the chlorate distribution in shallow groundwater in this area (e.g., the former P-1, P-2, P-3, and S-1 ponds (see Figure 2-5a), and the area around the IWF and the inactive Recharge Trench Area) are shown in Figure 7-51a. The lateral extent of chlorate above the GWSL of 1.0 mg/L is defined on the western side of OU-1 and can be reasonably inferred on the southern side based on data from wells and borings in that area. On the southern end of OU-1, the chlorate concentration in groundwater adjacent to wells M-103 and M-120 is below the GWSL. In the absence of chlorate data at the TIMET site, the lateral extent of chlorate above the GWSL to the east can be reasonably inferred based on the perchlorate 1 mg/L contour (see Figure 7-50b) since these two chemicals have equivalent levels of mobility (e.g., solubility, sorption potential) and were released from sources on OU-1 at concentrations with similar orders of magnitude.

Shallow WBZ (55-90 ft bgs)

Chlorate concentrations in the lower depth interval of the Shallow WBZ (55-90 ft bgs) are shown in Figure 7-51e, with a detail of the central portion of OU-1 presented in Figure 7-51f. Overall, the chlorate concentrations are lower than in the Shallow WBZ (0-55 ft bgs) depth interval wells. The highest concentrations in this depth interval are generally co-located with the areas of highest concentrations in the Shallow WBZ (0-55 ft bgs) interval. The highest concentrations occur below and north of the former P-1 and P-3 Ponds and below the inactive recharge trenches north of the barrier wall. The lateral extent of chlorate above the GWSL of 1.0 mg/L is defined on the western side of the Site and can be reasonably inferred south of the Unit Buildings based on data from wells and borings in that area. On the eastern side of OU-1, chlorate data in groundwater is not available on the TIMET site. Therefore, the position of the 1.0 mg/L contour to the east of OU-1 for chlorate was inferred based on the 1.0 mg/L contour for perchlorate (see Figure 7-50c) since the two chemicals have equivalent levels of mobility (e.g., solubility, sorption potential) and were released from sources on OU-1 at concentrations with similar orders of magnitude.

Middle WBZ (90-130 ft bgs)

Chlorate concentrations in the 90-130 feet depth of the Middle WBZ are presented in Figure 7-51g, with a detail of the Unit Building area presented in Figure 7-51h. Chlorate was detected in 30 of the 42 wells sampled within the Middle WBZ (90-130 ft bgs). Chlorate concentrations were above the GWSL of 1.0 mg/L in groundwater at 24 of these 30 wells. As shown in Figures 7-51g and 7-51h, groundwater with the highest chlorate concentrations (greater than 100 mg/L) extends from the vicinity of the Unit 4 Building northeast to well M-200 located near the eastern Site boundary, a distribution pattern very similar to perchlorate in this depth interval. Similar to perchlorate, the highest chlorate concentrations were found in wells located adjacent to the Unit 4 Building, below the Unit 4 Building basement, and northeast of the Unit 4 Building. This area of chlorate-impacted groundwater is within the perchlorate groundwater plume footprint at this depth (see Figure 7-50e). These similar distribution patterns are consistent with historic operations and releases from the Unit 4 Building and its vicinity.

Similar to perchlorate, chlorate concentrations are generally below 1.0 mg/L in the northern part of the Site, except in the area between the IWF/barrier wall and the northern OU-1 boundary. At many sampled locations, chlorate was either not detected or detected concentrations which were slightly above the GWSL of 1.0 mg/L.

Middle WBZ (130-175 ft bgs)

Chlorate concentrations in the 130-175 feet depth of the Middle WBZ are shown in Figure 7-51i. In this depth interval, chlorate was detected above the GWSL in four of the 17 wells sampled, with groundwater concentrations ranging between 2.1 to 17 mg/L. These four wells are all located at and near the Unit 4 Building and to the north. The two wells with the highest concentrations are located adjacent to the Unit 4 Building (M-250, 14 mg/L) and below the Unit 4 Building basement (M-252, 17 mg/L). Chlorate concentrations above the GWSL in groundwater at two wells located northeast of the Unit 4 Building were lower (M-257, 4.0 mg/L; M-186D, 2.1 mg/L). In other areas of OU-1, chlorate is either not detected or concentrations are below the GWSL of 1.0 mg/L.

Middle WBZ (175-300 ft bgs)

Chlorate concentrations in the 175-300 feet depth of the Middle WBZ are shown in Figure 7-51j. In this depth interval, chlorate was not detected in groundwater in six of the eight wells sampled within OU-1. In one well (TR-9), the concentration of 0.054 mg/L was below the GWSL of 1.0 mg/L. In well M-154 located in the northern part of the Site, chlorate was reported at a concentration of 4.8 mg/L in May 2018, which is above the GWSL. However, this result appears anomalous since the chlorate result for this well was <0.010 mg/L in May 2017 and 0.0046 J mg/L in May 2019.

7.5.1.3 Chromium (Hexavalent)

Chromium (hexavalent) is also widely distributed in the Shallow WBZ (0-55 ft bgs and 55-90 ft bgs) with relatively high concentrations in groundwater making it a Primary COPC. The dissolved chromium present in groundwater is hexavalent chromium. As a result, and as previously discussed in Section 7.2.2.2, groundwater analytical results for total chromium are equivalent to results for hexavalent chromium. Accordingly, this groundwater COPC is often referred to as chromium instead of hexavalent chromium throughout this report. The distribution of chromium in Site groundwater based on data from May 2004 is shown in Figure 7-56 along with source areas. Similar to perchlorate, in May 2004 the highest chromium concentrations (above 10 mg/L or 10,000 µg/L) extended from the area downgradient (north) of the Unit 4 Building to the IWF/barrier wall, and into the area between the barrier wall and the former injection trenches. The highest concentration was 55 mg/L (55,000 µg/L) in well M-50, which has since been decommissioned.

The results for Shallow WBZ (0-55 ft bgs) depth interval wells from 2015 to 2018 are presented in Figure 7-57a, with additional detail shown in Figure 7-57b. Please note that NERT currently reports chromium in units of µg/L, as opposed to mg/L as shown in historical figures such as Figure 7-56. Similar to perchlorate, the highest chromium concentrations (above 20,000 µg/L) are limited to the area between the former Beta Ditch and the IWF/barrier wall with up to 25,000 µg/L detected in extraction well I-T. Chromium concentrations in six wells immediately north of the barrier wall are lower, with concentrations ranging from 1,200 µg/L in well M-140 to 11,000 µg/L in well M-72.

In comparison to the data reported in 2004 (see Figure 7-56), chromium concentrations in Shallow WBZ (0-55 ft bgs) depth interval wells located between the Unit Buildings and the former Beta Ditch have generally decreased. For example, in May 2004 the chromium concentration was 18,000 µg/L in both wells M-12A and M-31A. From 2015 to 2018, the chromium concentrations in M-12A and M-31A decreased to 5,600 µg/L and 1,700 µg/L, respectively.

The vertical extent of chromium in OU-1 is shown in Figure 7-58a where chromium concentrations are plotted against mid-screen depths. To illustrate the lateral and vertical extent of chromium in OU-1, chromium concentrations in two depth intervals in the Shallow WBZ (0-55 ft bgs and 55-90 ft bgs) and three depth intervals in the Middle WBZ (90-130 ft bgs, 130-175 ft bgs, and 175-300 ft bgs) are shown in Figures 7-58b through 7-58h.

Shallow WBZ (0-55 ft bgs)

As can be seen in Figure 7-58b, the area of the highest chromium concentrations in the Shallow WBZ (0-55 ft bgs) depth interval is generally in the eastern half of OU-1 and extends north from the Unit 4 and 5 Buildings to the OU-1 boundary and into OU-2. The highest concentrations in shallow groundwater are found in the northern part of the Site in the area between the former Beta Ditch and the IWF/barrier wall. Other former source areas that affect the chlorate distribution in shallow groundwater in this area (e.g., the former P-1, P-2, P-3, and S-1 ponds (see Figure 2-5a), and the area around the IWF and the inactive Recharge Trench Area) are shown in Figure 7-57a. The lateral extent of chromium above the GWSL of 100 µg/L is defined on the western and southern sides of OU-1. Chromium above the GWSL is present along the eastern OU-1 boundary and within the adjacent TIMET site. The eastern extent of chromium above the GWSL is defined by data from the TIMET wells.

Shallow WBZ (55-90 ft bgs)

Chromium concentrations in the lower depth interval of the Shallow WBZ (55-90 ft bgs) are shown in Figure 7-58c, with a detail of the central portion of OU-1 presented in Figure 7-58d. In general, chromium is detected in the same areas where it is present in the Shallow WBZ (0-55 ft bgs) depth interval wells, but at lower concentrations. Where detected, chromium concentrations ranged from 5.3 µg/L to 6,000 µg/L with many samples containing chromium in excess of its GWSL (100 µg/L).

Middle WBZ (90-130 ft bgs)

Chromium concentrations in the 90-130 feet depth of the Middle WBZ are presented in Figure 7-58e, with a detail of the Unit Building area presented in Figure 7-58f. Chromium was detected in groundwater in 41 of the 42 wells sampled within the Middle WBZ (90-130 ft bgs). Chromium concentrations were above the GWSL of 100 µg/L in 15 of these 41 wells. As shown in Figure 7-58e, these 15 locations extend from the vicinity of the Unit 4 Building northeast to well M-200 located near the eastern Site boundary, a distribution pattern very similar to perchlorate and chlorate in this depth interval. Similar to perchlorate and chlorate, the highest chromium concentrations were found in wells located adjacent to the Unit 4 Building, below the Unit 4 Building basement, and northeast of the Unit 4 Building. The area of chromium-impacted groundwater is within the perchlorate groundwater plume footprint at this depth (see Figure 7-50e). These similar distribution patterns are consistent with historic operations and releases from the Unit 4 Building and vicinity.

Middle WBZ (130-175 ft bgs)

Chromium concentrations in the 130-175 feet depth of the Middle WBZ are shown in Figure 7-58g. Within OU-1, chromium concentrations were below the GWSL of 100 µg/L in all 17 monitoring wells sampled.

Middle WBZ (175-300 ft bgs)

Chromium concentrations in the 175-300 feet depth of the Middle WBZ are shown in Figure 7-58h. Within OU-1, chromium concentrations were below the GWSL of 100 µg/L in all 8 monitoring wells sampled and in a one-time sample collected at a depth of 242 feet within the footprint of the Unit 4 Building.

7.5.1.4 Chloroform

As discussed earlier in this section, chloroform is the most widespread VOC detected in OU-1. While the Unit 4 and 5 Buildings have been identified as a source of chloroform within the NERT Site, the area of highest chloroform concentrations is associated with a trespassing VOC plume identified at the adjacent OSSM site (OSSM plume). This OSSM plume is the subject of on-going remedial action that has been implemented by OSSM with NDEP oversight. The OSSM plume encroaches onto OU-1 across its western boundary and includes free-phase DNAPL at depths of 100-120 ft bgs as well as dissolved phase VOCs in the Shallow and Middle WBZs (Geosyntec 2019). Figure 7-98 illustrates the mobility of the primary OSSM DNAPL constituents relative to other common organics. Of the VOCs detected in the DNAPL, represented by red dots in Figure 7-98, chloroform is the most persistent and soluble (and mobile), and it represents the most prevalent VOC found in the dissolved phase in OU-1 and adjacent areas. As indicated by the blue arrow, mobility increases toward the right (higher water solubility) and toward the top (lower octanol-water partition coefficient) of the graph. Of the OSSM DNAPL constituents, chloroform's combination of relatively high water solubility and low octanol-water partition coefficient make it the most mobile of the DNAPL constituents, as indicated by its position at the upper right side of the graph. Due to these characteristics, chloroform is a Primary COPC. As shown in Figure 7-79b, there is very clear separation between the trespassing OSSM plume and the chloroform plume originating from the Unit 4 and 5 Buildings as illustrated by the 10 to 70 µg/L contour interval that trends north-south and is located north of the Unit 2 Building which effectively shows a division between the chloroform plumes originating from each of the OSSM and NERT sites. There is also a chloroform plume originating on the TIMET site that is also separated from the plume originating from the Unit 4 and 5 Buildings by an area of lower concentration chloroform (represented by the north-south trending 10 to 70 µg/L contour interval located north of the Unit 6 Building). The results for chloroform, as well as the clear delineations between the various chloroform plumes, are discussed in this section.

There have been two comprehensive groundwater sampling events that provide data to evaluate chloroform distribution in shallow groundwater. In 2008-2009, groundwater sampling was conducted by Tronox for an extensive suite of constituents, including chloroform and other VOCs, as part of the Phase A and Phase B Site investigations. Other BMI complex wells were also sampled by OSSM, TIMET, and BRC for VOCs in 2008-2009. Most of the shallow wells sampled were screened at or below the groundwater table. At the time of the 2008-2009 sampling, the first groundwater occurred in the saturated alluvium within OU-1 and the adjacent OSSM and TIMET sites, and the shallow groundwater flow conditions were generally similar across the BMI Complex. Since that time, the alluvium has become largely unsaturated in OU-1 and first groundwater now occurs in the fine-grained soils of the UMCf-fg1 (except near the southern Site boundary where the UMCf-cg1 unit underlies the alluvium). The alluvium remains saturated to the west at the OSSM site, where the alluvium-filled paleochannels are deeper than at NERT. Since the alluvium-filled paleochannels at the NERT Site are now largely dry, they no longer serve as preferential pathways for groundwater flow. As the hydraulic conductivity of the UMCf-fg1 is lower than in the alluvium, the current shallow groundwater flow rate within OU-1 is generally lower than at the adjacent OSSM site.

A second more comprehensive sampling for VOCs includes the NERT soil and groundwater sampling results from the Phase 1 and 2 RI conducted during the period from October 2014 through March 2019, and the NERT and OSSM groundwater monitoring results from annual sampling events conducted during this same period. As discussed in Section 5, the Phase 2 RI included installation of deeper wells and soil borings to better delineate the vertical extent of COPC impacts in the saturated fine-grained UMCf soils. To illustrate the vertical extent of chloroform in OU-1, chloroform concentrations are plotted against mid-screen depths in Figure 7-79a. Chloroform distribution maps based on the Phase 1 and Phase 2 RI investigations results and the annual groundwater monitoring results are presented in Figures 7-79b through 7-79h and are discussed below. Since there are fewer wells in the deeper groundwater zones, the distribution maps for the deeper intervals incorporate data from groundwater monitoring wells and saturated soil sample results from the deep soil borings installed as part of the Phase 2 RI. The soil sample results in µg/kg may be biased low compared to a calculated equivalent groundwater concentration, but they provide qualitative information helpful for evaluating the extent of chloroform-impacted groundwater. Table 7-5 presents the groundwater results for VOCs, and soil boring sample results are included in Appendix H.

Shallow WBZ (0-55 ft bgs)

The distribution of chloroform in the Shallow WBZ (0-55 ft bgs) depth interval is shown in Figure 7-79b, with a detail of the IWF area presented in Figure 7-79c for clarity. The highest chloroform concentrations at the OSSM site are within the 10,000 µg/L concentration contour and clearly encroach across the western OU-1 boundary in the vicinity of the former Beta Ditch. Historically, as detailed earlier in this report, process wastewater from the OSSM site was conveyed through the former unlined Beta Ditch to the ponds in the BMI Common Area east of Pabco Road. In groundwater samples from three wells located on the OSSM site, chloroform concentrations were higher than 10,000 µg/L in the 2017 and 2018 annual sampling events, ranging from 21,000 µg/L in well AA-MW-25 to 93,000 µg/L in well MW-2. As indicated previously, the OSSM plume can be easily distinguished from the plume originating from the Unit 4 and 5 Buildings by the 10 to 70 µg/L contour interval located north of the Unit 2 Building (Figure 7-79b). The OSSM and NERT chloroform plumes begin to commingle in the vicinity of the WC-West and WC-East Ponds located in the northern portion of OU-1.

Along the western NERT Site boundary, where chloroform is trespassing onto OU-1, chloroform concentrations in groundwater were 15,000 µg/L in the sample from well MW-123, 16,000 µg/L in the sample from well M-125, and 19,000 µg/L in the sample from well M-126. As part of the Phase 2 RI, existing well M-160 located northeast of well M-126 and adjacent to the south side of the GW-11 Pond was sampled; the chloroform result was 4,300 µg/L. On the north side of the GW-11 Pond, existing shallow well M-98 screened from 19 to 29 ft bgs in alluvium is dry. A deeper Shallow WBZ (0-55 ft bgs) depth interval well, M-206, has been installed adjacent to M-98. M-206 is screened from 30 to 50 ft bgs in the UMCf; the chloroform concentration in groundwater was 790 µg/L. Further north, the chloroform concentration in groundwater at well M-23 (located near Warm Springs Road) was 730 µg/L. This linear progression north-northeast from 19,000 µg/L at well M-126 to 4,300 µg/L at M-160 to 790 µg/L at M-206 to 720 µg/L at well M-23 indicates that chloroform originates at the OSSM site, trespasses onto OU-1, and then migrates northward across OU-1 in the saturated UMCf between the OSSM and IWF extraction systems to at least Warm Springs Road (the OU-1/OU-2 boundary). The direction of chloroform migration appears to be largely controlled by both geometry of the preferential pathways located within the UMCf and secondarily by the direction of groundwater flow.

In other areas of the NERT Site, chloroform concentrations are two to three orders of magnitude lower than concentrations found at the OSSM site and migrating into OU-1 from the OSSM site. The highest chloroform concentrations were identified in the vicinity of the former Beta Ditch, likely associated with the use of the Beta Ditch by both OSSM and operations within OU-1, ranging from 810 µg/L in groundwater at well M-65 to 1,400 µg/L in groundwater at well M-22A. In contrast, the chloroform concentrations in the vicinity of the Unit 4 and 5 Buildings in shallow groundwater were found in the range of 13 µg/L at well M-192 to 310 µg/L at well M-12A.

Based on the direction of groundwater flow and the distribution of other Primary COPCs unique to the Unit 4 and 5 Buildings source area (chlorate and chromium), the Unit 4 and 5 Buildings chloroform plume above the GWSL does not migrate west of wells M-97, M-76, M-37, and M-79 and is within the IWF capture zone (i.e., chloroform in groundwater that originated at the Unit 4 and 5 Buildings migrates northward and continues to be extracted and treated by the NERT GWETS). The western boundary of the Unit 4 and 5 Buildings chloroform plume is consistent with the western boundaries of the chlorate and chromium plumes illustrated in Figures 7-51a and 7-57a, respectively. This correlation is not as apparent with the perchlorate plume since there were multiple perchlorate manufacturing and waste handling areas across OU-1, which resulted in its wider distribution in the subsurface.

Within the TIMET site north of the former Unit 7 Building and Unit 8 Building, chloroform was detected at concentrations up to 450 µg/L (well J2D4) and 530 µg/L (well CLD4-R). These wells are located south (upgradient) of the former Beta Ditch. Along the northern TIMET site boundary, chloroform concentrations range from 1,400 µg/L in well TIMETMW-7 to 0.24J µg/L in well TIMETMW-8. Similar to the delineation between the OSSM and NERT chloroform plumes there is an area of lower chloroform concentrations located north of the Unit 6 Building represented by the 10 to 70 µg/L contour interval that delineates the extent of both plumes. However, north of the Mn-2 Pond, it appears that the NERT and TIMET plumes commingle. Given that the direction of groundwater flow in the shallow zone is to the north (Figure 5-16a) and the shape of the chloroform plume (Figure 7-79b) is elongated in a north-south orientation, it is reasonable to conclude that there is a third source of chloroform on the TIMET site north of the Unit 8 Building. The orientation of the perchlorate, chlorate, and chromium plumes (Figures 7-50b, 7-51d, and 7-58b, respectively) originating from the

Unit 4 and 5 Buildings support the interpretation that the NERT and TIMET plumes are distinctly separate as those COPCs drop rapidly in concentration easterly from the property boundary instead of increasing again as chloroform does. The distribution of perchlorate, chlorate, chromium, and chloroform in shallow groundwater on the TIMET site are discussed in greater detail in Section 9.6.2.

Shallow WBZ (55-90 ft bgs)

Chloroform concentrations in the Shallow WBZ (55-90 ft bgs) depth interval are shown in Figure 7-79d. There is only one OSSM well in (PW-1, 40,000 J+ µg/L) and one BRC well (MCF-BW-08, 120 µg/L) located at the southern boundary of the BMI CAMU delineating the western edge of the OSSM plume at this depth interval. Due to the absence of data between these two wells, isoconcentration contours depicting chloroform at the OSSM site are inferred based on its presence in groundwater above and below this depth interval. Concentrations above 10,000 µg/L in groundwater at newly installed wells and borings along the western OU-1 boundary indicate chloroform is also trespassing onto the NERT Site in the UMCf within this depth interval. Groundwater concentrations ranged from 15,000 µg/L in groundwater well M-224R (screened from 60-80 ft bgs) to 25,000 µg/L in groundwater at well M-125D (screened from 60-70 ft bgs). Similar to the Shallow WBZ (0-55 ft bgs) depth interval, chloroform was also detected in groundwater at the two wells located south (M-159, 2,300 µg/L) and north (M-263, 420 µg/L) of the GW-11 Pond. Similar to the Shallow WBZ (0-55 ft bgs) interval, a north-south trending zone of lower chloroform concentrations north of the Unit 2 Building delineate the OSSM and NERT plumes as illustrated in Figure 7-79b. This delineation is also supported by the shape of the chlorate and chromium plumes originating from the Unit 4 and 5 Buildings source area.

Along the eastern OU-1 boundary, chloroform was detected at concentrations above 1,000 µg/L in groundwater at well M-182 and at the TIMET multiport well screen CMT-202, which was sampled in 2008. In groundwater at the 8 wells located near the Unit 4 and 5 Buildings, chloroform concentrations were at least an order of magnitude lower, ranging from 2.4 µg/L to 130 µg/L.

Middle WBZ (90-130 ft bgs)

Chloroform concentrations in the 90-130 feet depth of the Middle WBZ are presented in Figure 7-79e, with a detail of the Unit Building area presented in Figure 7-79f for clarity. At the OSSM site and partially within OU-1, wells completed in the Middle WBZ are sampled for VOCs as part of the OSSM groundwater monitoring program. Also at the OSSM site and within OU-1, Montrose has conducted an investigation of DNAPL that was detected in eight wells screened between depths of 90-120 ft bgs. The former unlined Beta Ditch has been identified as a significant transport pathway for contamination that historically impacted the Shallow WBZ as discussed above. However, the effect of the former Beta Ditch on contaminant migration in OU-1 appears to be limited to the Shallow WBZ. As shown in Figure 7-79e, free-phase (mobile) DNAPL has been found in well MC-MW-12 at the OSSM site and in well MC-MW-18 located in OU-1, and residual DNAPL was identified in six other wells. The DNAPL contains several VOCs (primarily benzene, chlorobenzene, dichlorobenzenes, carbon tetrachloride, and chloroform), pesticides, and herbicides. Figure 7-73 illustrates the relative mobility of these VOCs in groundwater. Of the VOCs, chloroform has the highest solubility and lowest affinity to adsorb to soils (octanol-water partition coefficient). In addition, chloroform is resistant to biodegradation. Therefore, chloroform is more mobile in groundwater than the other primary VOCs constituting the OSSM DNAPL. This is evident in Figure 7-79e, where two source areas are depicted for the chloroform migrating into OU-1. As described in OSSM's Revised DNAPL Investigation Summary Report (AECOM 2014), two DNAPL source areas are present at the OSSM site:

1) the northern residual DNAPL area / mobile DNAPL area situated north of the former Montrose chemical manufacturing plant in the vicinity of OSSM wells MC-MW-10, MC-MW-12, and MC-MW-43, from which chloroform and other DNAPL VOCs have migrated approximately 1,000 feet northeast to NERT well M-225R and OSSM well MC-MW-39 located in OU-1 south of the former Beta Ditch; and
2) the southern residual DNAPL area situated at the north end of the Montrose Closed Ponds in the vicinity of OSSM wells CP-02 and MC-MW-09, from which chloroform and other soluble DNAPL VOCs have migrated approximately 1,400 feet northeast beyond the identified residual DNAPL area to NERT well M-235, located west of Lhoist.

Chloroform was also found in groundwater beneath, and downgradient of, the Unit 4 Building in samples collected from wells screened between approximate depths of 90-115 ft bgs. This is the only source area within OU-1 that is associated with historical operations at the NERT Site. The highest concentrations (up to 8,300 µg/L in well M-251-100) were found beneath the Unit 4 Building and extend north-northeast for a distance of approximately 1,600 feet, a distribution pattern similar to perchlorate and chromium at this depth (see Figure 7-50e and 7-58e, respectively). This indicates chloroform migrated downward beneath the Unit 4 Building along with perchlorate and other Primary COPCs found at this depth interval. It should be noted that the highest chloroform concentration beneath the Unit 4 Building is one order of magnitude lower than the highest concentrations at the OSSM site, which range between 28,000 µg/L and 57,000 µg/L in this depth interval.

Middle WBZ (130-175 ft bgs)

Chloroform concentrations in the 130-175 feet depth of the Middle WBZ are shown in Figure 7-79g. Within OU-1 in this depth interval, chloroform is either not detected in groundwater or concentrations are below the GWSL of 70 µg/L. As discussed in Section 5.5.2.5, investigations of the Middle WBZ within OU-1 indicate a vertical upward gradient between the Middle and Shallow Zones that generally increases with depth. Along with the presence of fine-grained silt and clay soils at this depth, this upward gradient would reduce the potential for further downward migration of chloroform, as evidenced by the very low and non-detect concentrations in all the samples collected throughout this depth interval.

Middle WBZ (175-300 ft bgs)

Chloroform concentrations in the 175-300 feet depth of the Middle WBZ are shown in Figure 7-79h. The wells in this depth interval along the western side of the NERT Site and at the adjacent OSSM site are screened in the UMCf-cg2. Chloroform was either not detected in groundwater at this depth interval or was detected at very low concentrations below the GWSL of 70 µg/L. As discussed in Section 5.5.2.2, the UMCf-cg2 is confined, as indicated by the artesian groundwater elevations consistently measured in these wells and the associated upward gradient. The absence of chloroform except at very low concentrations in only a few wells is consistent with the hydraulic separation indicated by the artesian groundwater conditions in the UMCF-cg2.

Summary

In summary, three areas of elevated concentrations of chloroform in groundwater have been identified in and adjacent to OU-1 – one at the western property boundary associated with the OSSM site, one in the central portion of OU-1 associated with historical operations in the Unit 4 and 5 Buildings, and one on the TIMET site north of the Unit 8 Building. The most significant concentrations of chloroform are associated with the OSSM site and its plume that trespasses onto OU-1 along its western border. There are two distinct significant sources of chloroform on the OSSM site and both result in trespassing plumes onto OU-1. The highest chloroform concentrations (up to 43,000 µg/L) and the greatest number of other VOCs are in the area of OU-1 affected by the trespassing OSSM plume. A second area of elevated chloroform concentrations is central to OU-1 in the vicinity of the former unlined Beta Ditch and originating from the Unit 4 and 5 Buildings source area. Relatively high chloroform concentrations (up to 2,200 µg/L) were found in shallow groundwater downgradient of the former Beta Ditch along with other VOCs at low concentrations below GWSLs. In the Unit 4 and 5 Buildings source area, chloroform concentrations were relatively low in the Shallow WBZ, increasing to relatively high concentrations (up to 8,300 µg/L) in the depth interval of 90-115 ft bgs. Within this depth interval, chloroform appeared to migrate northeast in a distribution pattern similar to perchlorate and other Primary COPCs released from the Unit 4 Building. However, as noted previously, the highest chloroform concentration beneath the Unit 4 Building is one order of magnitude lower than the highest concentrations at the OSSM site in this depth interval. The third area of elevated chloroform is located on the TIMET site and originates from TIMET's former operations north of the former Unit 7 and 8 Buildings. The shape of the perchlorate and chromium plumes strongly support the delineation of each of the chloroform plumes as these Primary COPCs are unique to the Unit 4 and 5 Buildings source area. The migration of chloroform into OU-2 from these areas of elevated chloroform is discussed in Section 8 of this report. Section 9 provides additional clarification regarding the migration pathways from each chloroform source area and the relative extent of impact within OU-2.

7.5.2 OU-1 Groundwater Other COPCs

7.5.2.1 General Chemistry

Bromide

Bromide concentrations with depth are shown in Figure 7-52a. Bromide detections in groundwater within OU-1 in the Shallow WBZ (0-55 ft bgs) and the Shallow WBZ (55-90 ft bgs) are presented in Figures 7-52b and 7-52c, respectively. Given the lower frequency of detection, color-coded maps are used to illustrate the location of elevated constituent concentrations in both Shallow WBZ depth intervals. As shown in Figure 7-52b, bromide was detected in groundwater at 71 locations in the Shallow WBZ (0-55 ft bgs). Concentrations were all below the GWSL of 13.3 mg/L with two exceptions: groundwater at shallow well M-125 (29 mg/L) and at shallow well M-205 (39 mg/L). As shown in Figure 7-52c, bromide was detected in 27 wells screened in the Shallow WBZ (55-90 ft bgs). Concentrations were all below the GWSL of 13.3 mg/L except at two wells: M-269 (23 J mg/L) located within the footprint of the former AP-5 Pond and M-5D (42 mg/L) located near the western property boundary.

In the Middle WBZ, bromide was either not detected, or the detected concentrations were below the GWSL of 13.3 mg/L. Bromide detections in groundwater within the Middle WBZ

(90-130 ft bgs) and the Middle WBZ (130-300 ft bgs) are illustrated in Figures 7-52d and 7-52e, respectively.

Nitrate/Nitrite (as N)

Nitrate/Nitrite (as N) concentrations with depth are shown in Figure 7-53a. Nitrate/Nitrite (as N) detections in groundwater within OU-1 in the Shallow WBZ (0-55 ft bgs) and the Shallow WBZ (55-90 ft bgs) are presented in Figures 7-53b and 7-53c, respectively. As shown in Figure 7-53a, nitrate/nitrite (as N) was detected at 104 locations in the Shallow WBZ (0-55 ft bgs). Concentrations were above the GWSL of 10 mg/L at 42 of these locations, ranging from 10 J mg/L to 170 J mg/L. The highest concentrations are present in the northeastern portion of OU-1 in the area north of the former Beta Ditch and the IWF, extending to the northern Site boundary. As shown in Figure 7-53c, nitrate/nitrite (as N) was detected in 36 wells screened in the Shallow WBZ (55-90 ft bgs). In general, nitrate/nitrite is detected in the same area where it is present in the Shallow WBZ (0-55 ft bgs) interval wells, but at lower concentrations. Only six groundwater wells had concentrations above the GWSL, ranging from 11 mg/L to 29 mg/L, as illustrated by the yellow and red well symbols in the figure.

Nitrate/nitrite (as N) was detected in groundwater at all of the 31 wells sampled for this inorganic compound in the Middle WBZ (90-130 ft bgs) and in groundwater at the 18 wells sampled in the Middle WBZ (130-300 ft bgs). In the Middle WBZ (90-130 ft bgs), nitrate/nitrite (as N) concentrations were below the GWSL of 10 mg/L in groundwater at 29 of the 31 wells sampled. As shown in Figure 7-53d, nitrate/nitrite (as N) was detected above the GWSL in groundwater at two wells located downgradient of the Unit 4 and 5 Buildings in the Leach Plant area, wells M-195 (15 mg/L) and M-199 (12 mg/L).

In the Middle WBZ (130-300 ft bgs), nitrate/nitrite (as N) concentrations were all below the GWSL of 10 mg/L in groundwater at the 18 wells sampled, ranging between 0.65-2.5 mg/L. The well locations and sample results are presented in Figure 7-53e.

7.5.2.2 Metals

Arsenic

Arsenic concentrations with depth are shown in Figure 7-54a. Arsenic detections in groundwater within OU-1 in the Shallow WBZ (0-55 ft bgs) and the Shallow WBZ (55-90 ft bgs) are presented in Figures 7-54b and 7-54c, respectively. As shown in Figure 7-54b, arsenic was detected in groundwater at all of the locations in the Shallow WBZ (0-55 ft bgs). Concentrations above the GWSL of 0.010 mg/L were detected in all of these samples and ranged from 0.011 mg/L in well M-10 to 0.46 mg/L in well M-12A. Many of these concentrations are also above the 0.059 mg/L 90th percentile upgradient level demonstrated by NDEP in their Up-Gradient Groundwater Review (NDEP 2016a). Separated from the widespread elevated arsenic concentrations in the rest of OU-1, arsenic concentrations above this upgradient level were also found in groundwater located in the northwestern portion of OU-1, with concentrations ranging from 0.069 mg/L in well MC-93 to 0.37 mg/L in well M-5A. These elevated arsenic levels appear to be related to the OSSM site located west of the

NERT Site.[72] As shown in Figure 7-54c, arsenic was detected in groundwater at all but two of the wells screened in the Shallow WBZ (55-90 ft bgs). Where detected, concentrations ranged from 0.011 mg/L in well M-269 to 0.13 mg/L in well M-255-60, all above the GWSL of 0.010 mg/L.

Arsenic concentrations above the upgradient level demonstrated by NDEP in their Up-Gradient Groundwater Review (NDEP 2016a) are widely distributed in the Shallow WBZ (0-55 ft bgs), including in upgradient wells M-120 (0.17 mg/L) and M-121 (0.1 mg/L). Arsenic concentrations generally decrease with depth and within the Shallow WBZ (55-90 ft bgs) are generally consistent with the upgradient level demonstrated by NDEP with the exception of the maximum concentration of 0.13 mg/L in groundwater at well M-255-60.

Arsenic was detected in groundwater at 33 of the 38 wells sampled in the Middle WBZ (90-130 ft bgs). As shown in Figure 7-54d, arsenic concentrations were above the GWSL in groundwater at 30 wells across the Site. Concentrations above the GWSL ranged from 0.014 mg/L in groundwater at well M-204 near the northern Site boundary to 0.044 mg/L in groundwater at well M-181 near the eastern Site boundary. Concentrations were detected but below the GWSL in groundwater at three wells located northeast of the Unit 4 Building (M-195, M-196, M-199), and arsenic was not detected in five wells located near the Unit 4 Building.

In the Middle WBZ (130-300 ft bgs), arsenic was detected at concentrations above the GWSL of 0.01 mg/L in groundwater at all of the 25 wells sampled, including wells near the Unit 4 Building. As shown in Figure 7-54e, concentrations ranged from 0.010 mg/L in groundwater at well M-250 near the Unit 4 Building to 0.053 mg/L in groundwater at well M-118 located at the southern (upgradient) Site boundary.

The widespread distribution of arsenic in groundwater throughout the Middle WBZ within a relatively small concentration range, including the two Middle WBZ wells at the southern (upgradient) property boundary, suggests that the arsenic concentrations detected in groundwater in the Middle WBZ in OU-1 are naturally occurring and not related to anthropogenic activities at the Site. The mean arsenic concentrations in the Middle WBZ in OU-1 are consistent with the upgradient level demonstrated by NDEP in their Up-Gradient Groundwater Review (NDEP 2016a).

Boron

Boron concentrations with depth are shown in Figure 7-55a. The boron results from 2015 to 2018 for the Shallow WBZ (0-55 ft bgs) depth interval wells are presented in Figure 7-55b. Boron was detected in groundwater at concentrations above the GWSL of 6.67 mg/L in wells and one-time groundwater grab samples located between the Leach Plant and the IWF/barrier wall. The highest concentration (21 mg/L) was detected in a one-time groundwater sample from soil boring RISB-14 near the eastern edge of the IWF/barrier wall (see Figure 7-49b). Boron was detected above the GWSL at wells M-72 and M-73 located on the downgradient side of the IWF/barrier wall at concentrations of 12 mg/L and 14 J mg/L,

---

[72] Although not shown in Figure 7-54b, elevated arsenic concentrations in the Shallow WBZ on the OSSM site are presented in the OSSM 2013 Comprehensive Groundwater Data Evaluation Report (Hargis 2013) and the OSSM RAS (Geosyntec 2019).

respectively. Boron concentrations were below the GWSL in other wells located downgradient of the barrier wall.

Figure 7-55c presents boron concentrations in the Shallow WBZ (55-90 ft bgs). Boron was detected in all the wells sampled at concentrations below the GWSL of 6.67 mg/L with one exception. Boron was detected above the GWSL, at a concentration of 11 mg/L, in groundwater at well M-269 located within the footprint of the former AP-5 Pond.

Boron was detected in groundwater at all the Middle WBZ wells sampled. Except for groundwater at one well (M-199), the detected concentrations were all below the GWSL of 6.67 mg/L. Boron was detected in groundwater at well M-199 (6.7 mg/L), at a concentration only slightly above the GWSL. Boron detections in the Middle WBZ (90-130 ft bgs) and the Middle WBZ (130-300 ft bgs) are illustrated in Figures 7-55d and 7-55e, respectively.

Magnesium

Magnesium concentrations with depth are shown in Figure 7-61a. Magnesium detections in groundwater within OU-1 in the Shallow WBZ (0-55 ft bgs) and the Shallow WBZ (55-90 ft bgs) are presented in Figures 7-61b and 7-61c, respectively. As shown in Figure 7-61b, magnesium was detected in groundwater at 139 locations in the Shallow WBZ (0-55 ft bgs). Of these, magnesium concentrations in 72 locations were above the GWSL of 189 mg/L. In the eastern portion of OU-1, magnesium concentrations above the GWSL extend from the Leach Plant to and just beyond the IWF/barrier wall. In the western portion of OU-1, the highest magnesium concentrations were found in groundwater at 10 wells located along the western property boundary (up to 960 mg/L in well TR-6). In this area, magnesium concentrations above the GWSL extend along the western OU-1 boundary from west of the Lhoist facility north to the OSSM extraction/treatment system and Warm Springs Road. These elevated magnesium levels appear to be related to the OSSM site located west of the NERT Site.[73] As shown in Figure 7-61c, magnesium was detected in groundwater at 46 wells screened within the Shallow WBZ (55-90 ft bgs). Of these, magnesium concentrations were above the GWSL of 189 mg/L at 14 wells. The highest concentrations were found in wells in the vicinity of the former Beta Ditch and in wells near the western Site boundary.

Magnesium was detected in groundwater at all 38 wells screened within the Middle WBZ (90-130 ft bgs) and in groundwater at all 25 wells screened within the Middle WBZ (130-300 ft bgs).

In the Middle WBZ (90-130 ft bgs), magnesium concentrations were below the GWSL of 189 mg/L in groundwater at 31 of the 38 wells sampled. Magnesium concentrations were above the GWSL in groundwater at seven wells. As shown in Figure 7-61d, these seven wells are located at and near the Unit 4 Building and extend northeast to well M-199 located near the north side of the EMD Leach Plant, a distribution pattern very similar to perchlorate, chlorate, and chromium in this depth interval. Similar to perchlorate, chlorate, and chromium, the highest magnesium concentrations were found in groundwater at wells

---

[73] Although not shown in Figure 7-61b, elevated magnesium concentrations in the Shallow WBZ on the OSSM site are presented in the OSSM 2013 Comprehensive Groundwater Data Evaluation Report (Hargis 2013) and the distribution of magnesium in the Shallow WBZ is illustrated using arsenic as a representative constituent in the OSSM RAS (Geosyntec 2019).

located adjacent to the Unit 4 Building, below the Unit 4 Building basement, and northeast of the Unit 4 Building. The area of magnesium-impacted groundwater is within the perchlorate groundwater plume footprint at this depth (see Figure 7-50e). These similar distribution patterns are consistent with historic operations and releases from the Unit 4 Building area.

In the Middle WBZ (130-300 ft bgs), magnesium concentrations were all below the GWSL of 189 mg/L in the 25 wells sampled, ranging between 13-24 mg/L. The well locations and sample results are presented in Figure 7-61e.

Manganese

The distribution of manganese in Site groundwater based on May 2003 data is shown along with potential source areas in Figure 7-62. As the figure shows, in May 2003 the highest manganese concentrations were detected in the area downgradient of the Unit 6 Building and the Leach Plant where manganese ore and tailings were once managed. The groundwater concentrations in that area ranged from 2.1 mg/L to 13 mg/L (at wells M-33 and M-32, respectively) with one higher concentration of 440 mg/L at well M-29 located in the basement of the Unit 6 Building (well M-29 is currently inaccessible).

The manganese results from 2015 to 2018 for the Shallow WBZ (0-55 ft bgs) depth interval wells are presented in Figure 7-63a with additional detail shown in Figure 7-63b. In 2015, the highest manganese concentrations were encountered in wells and grab groundwater samples from borings located in the immediate vicinity of the Leach Plant. However, manganese concentrations in this area are significantly lower than they were in 2003, ranging from 1.3 in groundwater at well M-77 to 3.2 mg/L in the grab sample from soil boring RISB-60. In groundwater at well M-32 the manganese concentration has decreased from 13 mg/L in 2003 to 0.25 mg/L by 2018. Manganese was not detected downgradient of the barrier wall at concentrations above the GWSL of 0.801 mg/L. In the western portion of OU-1, manganese concentrations above the GWSL extend along the western OU-1 boundary from just north of the former Beta Ditch north to the OSSM extraction/treatment system and Warm Springs Road. These elevated manganese levels appear to be related to the OSSM site located west of the NERT Site.[74]

Manganese concentrations with depth are shown in Figure 7-64a. Figure 7-64c presents manganese concentrations in the Shallow WBZ (55-90 ft bgs). In general, manganese is detected in the same areas where it is present in the Shallow WBZ (0-55 ft bgs) depth interval wells; however, all concentrations were below the manganese GWSL (0.801 mg/L). Where detected, manganese concentrations ranged from 0.015 J mg/L to 0.77 mg/L.

In the Middle WBZ, manganese was either not detected, or the detected concentrations were all below the GWSL of 0.801 mg/L. The manganese detections in groundwater at six wells in the Middle WBZ (90-130 ft bgs) and at two wells in the Middle WBZ (130-300 ft bgs) are illustrated in Figures 7-64d and 7-64e, respectively.

---

[74] Although not shown in Figure 7-63a, elevated manganese concentrations in the Shallow WBZ on the OSSM site are presented in the OSSM 2013 Comprehensive Groundwater Data Evaluation Report (Hargis 2013) and the distribution of manganese in the Shallow WBZ is illustrated using arsenic as a representative constituent in the OSSM RAS (Geosyntec 2019).

Strontium

Strontium concentrations with depth are shown in Figure 7-65a. Strontium detections in groundwater within OU-1 in the Shallow WBZ (0-55 ft bgs) and the Shallow WBZ (55-90 ft bgs) are presented in Figures 7-65b and 7-65c, respectively. As shown in Figure 7-65b, strontium was detected above the GWSL of 20 mg/L in groundwater at 15 monitoring wells screened in the in the Shallow WBZ (0-55 ft bgs) at concentrations ranging from 20 to 53 mg/L. These monitoring wells are located along the western boundary of OU-1 from west of the Lhoist facility to just north of the OSSM groundwater extraction/treatment system. Strontium was also detected in the Shallow WBZ (0-55 ft bgs) in groundwater at four wells located in the vicinity of the IWF (both upgradient and downgradient) in the northeastern portion of OU-1. These locations are M-36D (25 mg/L), M-66 (21 mg/L), M-72 (26 mg/L), and M-73 (20 mg/L). As shown in Figure 7-65c, strontium was detected at concentrations above the GWSL in groundwater at six OU-1 wells in the Shallow WBZ (55-90 ft bgs). These include groundwater at wells M-227R (49 mg/L), M-224R (22 mg/L), M-125D (25 mg/L), and M-5D (21 mg/L) located along the western boundary of OU-1. Strontium was also detected above the GWSL in groundwater at two 55 to 90-foot deep wells located in the central portion of OU-1; M-269 (20 mg/L) and M-182 (26 mg/L). These wells are generally in the vicinity of the AP-5, AP-6, and Mn-1 Ponds.

Strontium was detected in groundwater at all 42 wells screened within the Middle WBZ (90-130 ft bgs) and in groundwater at all 22 wells screened within the Middle WBZ (130-300 ft bgs). In the Middle WBZ (90-130 ft bgs), strontium concentrations were below the GWSL of 20 mg/L in groundwater at 34 of the 38 wells sampled. As shown in Figure 7-65d, strontium concentrations were above the GWSL in groundwater at three wells located at and near the Unit 4 Building and in groundwater at well M-199 located near the north side of the Leach Plant, a distribution pattern very similar to perchlorate in this depth interval. Similar to perchlorate and other Primary COPCs, the highest strontium concentrations were found in wells located adjacent to the Unit 4 Building (M-249-100), below the Unit 4 Building basement (M-251-100), and northeast of the Unit 4 Building (M-256-100). The area of strontium-impacted groundwater is within the perchlorate groundwater plume footprint at this depth (see Figure 7-50e). These similar distribution patterns are consistent with historic operations and releases from the Unit 4 Building area.

In the Middle WBZ (130-300 ft bgs), strontium concentrations were all below the GWSL of 20 mg/L in groundwater at the 25 wells sampled, ranging between 0.70-2.0 mg/L. The well locations and sample results are presented in Figure 7-65e.

Uranium (Total)

Uranium (total) concentrations with depth are shown in Figure 7-66a. Uranium (total) detections in groundwater within OU-1 in the Shallow WBZ (0-55 ft bgs) and the Shallow WBZ (55-90 ft bgs) are presented in Figures 7-66b and 7-66c, respectively. As shown in Figure 7-66b, uranium (total) was detected in groundwater at all the wells sampled in the Shallow WBZ (0-55 ft bgs). Concentrations were above the GWSL of 0.03 mg/L at 50 of 104 locations sampled (~50%). Many concentrations were just slightly above the GWSL with concentrations generally ranging from 0.031 mg/L to 0.080 mg/L. Concentrations at three locations were above 0.1 mg/L. The distribution of total uranium above the GWSL in shallow groundwater appears to generally extend from the Leach Plant north to the Mn Pond area, as well as throughout the portion of OU-1 north of the former Beta Ditch. As shown in Figure 7-66c, uranium (total) was detected in groundwater at all 46 wells sampled in the Shallow WBZ (55-90 ft bgs). Concentrations were all below the GWSL of 0.03 mg/L.

Uranium (total) was detected in groundwater at all the Middle WBZ wells sampled; however, the detected concentrations were all below the GWSL of 0.03 mg/L. The total uranium concentrations in the Middle WBZ (90-130 ft bgs) and the Middle WBZ (130-300 ft bgs) are illustrated in Figures 7-66d and 7-66e, respectively.

7.5.2.3 Radionuclides

Thorium-228/230

Thorium-228 and thorium-230 activites with depth are shown in Figures 7-70a and 7-71a, respectively. Thorium-228 and thorium-230 activities in groundwater within OU-1 in the Shallow WBZ (0-55 ft bgs) are presented in Figures 7-70b and 7-71b, respectively. Thorium-228 and thorium-230 activities in groundwater within OU-1 in the Shallow WBZ (55-90 ft bgs) are presented in Figures 7-70c and 7-71c, respectively. As shown in Figures 7-70b and 7-71b, thorium-228 and thorium-230 are widespread in groundwater within the Shallow WBZ (0-55 ft bgs) throughout OU-1. Approximately 80% of the thorium-228 activities were above the GWSL of 0.14 pCi/L, and all of the thorium-230 activities were above the GWSL of 0.05 pCi/L. High activities of thorium-228 and thorium-230 are generally located near the Unit 5 and 6 Buildings, south of the former P1, P2, and P3 Ponds and south of the former Beta Ditch, and near the Leasehold Debris Pile. Thorium-230 also has high activities in the northwest area of OU-1 near the OSSM extraction well field. As shown in Figure 7-70c and 7-71c, in the Shallow WBZ (55-90 ft bgs), thorium-228 activities were above the GWSL in approximately 70% of samples, and thorium-230 activities were above the GWSL in all 14 wells sampled. The highest activities were located just north of the IWF/barrier wall.

Thorium-228 and thorium-230 activities in groundwater within OU-1 in the Middle WBZ (90-130 ft bgs) are presented in Figures 7-70d and 7-71d, respectively. Thorium-228 and thorium-230 activities in groundwater within OU-1 in the Middle WBZ (130-300 ft bgs) are presented in Figures 7-70e and 7-71e, respectively.

In the Middle WBZ (90-130 ft bgs), the highest thorium-228 and thorium-230 concentrations were in four wells located near the Unit 4 Building: M-249-100 (1.11 and 1.49 pCi/L), M-251-100 (1.49 and 0.594 pCi/L), M-255-100 (1.05 and 1.84 pCi/L) and M-256-100 (1.37 and 1.06 pCi/L). In the Middle WBZ (130-300 ft bgs), thorium-228 activities exceeded the GWSL in 7 of the 25 wells sampled, and the thorium-230 activities exceeded the GWSL in 24 of the 25 wells sampled including the upgradient Site boundary wells M-117 and M-118. However, the lack of particularly high activities of thorium-228 and the widespread distribution of thorium-230 in groundwater at this depth within a relatively small activity range, including in the two Middle WBZ wells at the southern (upgradient) property boundary, suggests that thorium-228 and thorium-230 activities in the Middle WBZ (130-300 ft bgs) are not related to anthropogenic activities in OU-1.

7.5.2.4 Other VOCs

As discussed above, chloroform is the most widespread VOC detected in groundwater in OU-1. While there is an area of elevated chloroform concentration in the central portion of OU-1 associated with the former unlined Beta Ditch and the Unit 4 and 5 Buildings, the area of highest concentrations and greatest number of other VOCs is associated with the trespassing OSSM plume, including both the dissolved plume and DNAPL. In addition to chloroform, VOCs that are detected in the DNAPL and are also found in the dissolved phase include benzene, carbon tetrachloride, chlorobenzene, 1,2-dichlorobenzene, 1,3-dichlorobenzene, and 1,4-dichlorobenzene. Methylene chloride, 1,1-DCA, 1,2-DCA, 1,1,2,2-tetrachloroethane, 1,4-dioxane, 1,2,3-trichloropropane, and PCE were not detected in the OSSM DNAPL or in OSSM's investigations of the dissolved phase plume, but have very high detection limits in groundwater samples collected within the dissolved plume and DNAPL. Given the location of the detected concentrations, methylene chloride, 1,1,-DCA, 1,2-DCA, 1,1,2,2-tetrachloroethane, and PCE appear to be associated with the trespassing OSSM plume, and 1,4-dioxane and 1,2,3-trichloropropane appear to be in part associated with the trespassing OSSM plume and in part associated with other sources within OU-1. These VOCs associated with the trespassing OSSM plume have been detected in groundwater near the western OU-1 boundary at concentrations up to 190,000 µg/L and were found to extend approximately 1,000 feet into the western portion of OU-1. In comparison, these VOCs are detected at concentrations up to 140 µg/L north of the former unlined Beta Ditch and in the vicinity of the Unit 4 and 5 Buildings. Unlike chloroform, which extends further into and eventually migrates to the north of OU-1, the concentrations of these additional VOCs decrease rapidly with distance due to their lower solubility, lower persistence, and high affinity to adsorb to soils. However, there are also detectable concentrations of VOCs in groundwater that do not appear to be associated with the OSSM trespassing plume, including bromodichloromethane, bromoform, 1,1-DCE, and TCE. The nature and extent of chloroform was discussed above in Section 7.5.1.4, and the nature and extent of all VOCs other than chloroform (which includes VOCs associated with both the OSSM and NERT sites) are discussed below.

Benzene

Detected concentrations of benzene in groundwater in OU-1 are depicted in Figures 7-74a through 7-74e. These figures show that benzene was detected at concentrations that are significantly higher than its GWSL along the western OU-1/OSSM boundary in the upper three groundwater monitoring zones extending from 0 to 130 ft bgs. Similar to other VOCs associated with the trespassing OSSM plume, the elevated benzene concentrations extend from south of the former Beta Ditch just west of the Lhoist facility northward to the OU-1/OU-2 boundary near the OSSM treatment system. Benzene was not detected in groundwater deeper than 130 ft bgs. Benzene is a COPC that is unique to the OSSM site and trespasses onto OU-1. Benzene has not migrated as far eastward as chloroform due to its relative mobility in the subsurface as compared to chloroform (Figure 7-73).

Bromodichloromethane

Detected concentrations of bromodichloromethane in groundwater in OU-1 are depicted in Figures 7-75a through 7-75e. Figure 7-75b shows that bromodichloromethane was detected at concentrations that are higher than its GWSL in a limited number of samples near the Unit 4 Building and along a paleochannel to the OU-1/OU-2 boundary in the Shallow WBZ (0-55 ft bgs). Figure 7-75c shows the highest concentrations of bromodichloromethane observed in the vicinity of the AP ponds in the Shallow WBZ (55-90 ft bgs). Figure 7-75d shows two isolated detections of bromodichloromethane above the GWSL in the Middle WBZ (90-130 ft bgs). Bromodichloromethane was not detected in groundwater deeper than 130 ft bgs.

Bromoform

Detected concentrations of bromoform in groundwater in OU-1 are depicted in Figures 7-76a through 7-76e. These figures show that bromoform was detected at concentrations that are higher than its GWSL at only one isolated location in the Shallow WBZ (0-55 ft bgs), Shallow WBZ (55-90 ft bgs), and Middle WBZ (90-130 ft bgs). These three locations are also horizontally isolated from each other. Bromoform was not detected in groundwater deeper than 130 ft bgs.

Carbon Tetrachloride

Detected concentrations of carbon tetrachloride in groundwater in OU-1 are depicted in Figures 7-77a through 7-77e. These figures show that detected concentrations of carbon tetrachloride in the upper 90 ft bgs extend from along the OU-1/OSSM boundary south of the former Beta Ditch and just west of the Lhoist facility northeastward to the IWF/barrier wall. Similar to other VOCs associated with the trespassing OSSM plume, the highest concentrations above the GWSL are generally isolated to the area closest to the OU-1/OSSM boundary. In the 0-55 ft bgs zone, carbon tetrachloride concentrations that are below the GWSL also extend from the former Recharge Trench Area northward toward the OU-1/OU-2 boundary. Figure 7-77d shows that carbon tetrachloride was detected in the Middle WBZ (90-130 ft bgs) in an area extending from the Unit 2 and 3 Buildings northwestward to just south of the former Beta Ditch near the OU-1/OSSM boundary. This area near the OU-1/OSSM boundary is where the highest carbon tetrachloride concentrations are found; wells M-225R and M-228R with concentrations of 1,700 µg/L and 1,800 µg/L, respectively. Carbon tetrachloride was not detected in groundwater deeper than 130 ft bgs.

Chlorobenzene

Detected concentrations of chlorobenzene in groundwater in OU-1 are depicted in Figures 7-78a through 7-78e. These figures show that chlorobenzene was detected at concentrations that are significantly higher than its GWSL along the western OU-1/OSSM boundary in the upper three groundwater monitoring zones (0 to 130 ft bgs). Similar to other VOCs associated with the trespassing OSSM plume, the elevated chlorobenzene concentrations extend from south of the former Beta Ditch just west of the Lhoist facility northward to the OU-1/OU-2 boundary near the OSSM treatment system. Chlorobenzene was not detected in groundwater deeper than 130 ft bgs. Chlorobenzene is a COPC that is largely unique to the OSSM site and trespasses onto OU-1. Chlorobenzene has not migrated as far eastward as chloroform due to its relative mobility in the subsurface as compared to chloroform (Figure 7-73).

1,2-Dichlorobenzene

Detected concentrations of 1,2-dichlorobenzene in groundwater in OU-1 are depicted in Figures 7-80a through 7-80e. Figures 7-80b, 7-80c, and 7-80d show that 1,2-dichlorobenzene was detected at concentrations significantly higher than its GWSL along the western OU-1/OSSM boundary in the upper three groundwater monitoring zones (0 to 130 ft bgs). Similar to other VOCs associated with the trespassing OSSM plume, the elevated 1,2-dichlorobenzene concentrations extend from south of the former Beta Ditch just west of the Lhoist facility northward to the OU-1/OU-2 boundary near the OSSM treatment system. 1,2-dichlorobenzene has not migrated as far eastward as chloroform, another OSSM COPC, due to its relative mobility in the subsurface as compared to chloroform (Figure 7-73). Additionally, Figure 7-80b shows three other distinct areas of 1,2-dichlorobenene detections in shallow groundwater that are below the GWSL that do not appear to be associated with the OSSM plume. These areas include the Leasehold Debris Pile, the western two-thirds of the IWF/barrier wall, and the area surrounding and downgradient of the former Recharge Trench Area. 1,2-Dichlorobenzene was not detected in groundwater deeper than 130 ft bgs.

1,3-Dichlorobenzene

Detected concentrations of 1,3-dichlorobenzene in groundwater in OU-1 are depicted in Figures 7-81a through 7-81e. Figures 7-81b, 7-81c, and 7-81d show that 1,3-dichlorobenzene was detected along the western OU-1/OSSM boundary in the upper three groundwater monitoring zones (0 to 130 ft bgs). 1,3-dichlorobenzene present along the western portion of OU-1 is associated with the OSSM site and trespasses onto OU-1. 1,3-dichlorobenzene has not migrated as far eastward as chloroform, another OSSM COPC, due to its relative mobility in the subsurface as compared to chloroform (Figure 7-73). Only a few of the detected concentrations of 1,3-dichlorobenze are above the GWSL. The detected 1,3-dichlorobenzene concentrations in the Shallow WBZ (0-55 ft bgs) extend from south of the former Beta Ditch just west of the Lhoist facility northward to the OU-1/OU-2 boundary near the OSSM treatment system. Between the depths of 55 and 130 ft bgs there are just a few elevated concentrations of 1,3-dichlorobenzene along the western OU-1 boundary south of the former Beta Ditch. 1,3-Dichlorobenzene was not detected in groundwater deeper than 130 ft bgs.

1,4-Dichlorobenzene

Detected concentrations of 1,4-dichlorobenzene in groundwater in OU-1 are depicted in Figures 7-82a through 7-82e. Figures 7-82b, 7-82c, and 7-82d show that 1,4-dichlorobenzene was detected along the western OU-1/OSSM boundary in the upper three groundwater monitoring zones (0 to 130 ft bgs). 1,4-dichlorobenzene present along the western portion of OU-1 is associated with the OSSM site and trespasses onto OU-1. 1,4-dichlorobenzene has not migrated as far eastward as chloroform, another OSSM COPC, due to its relative mobility in the subsurface as compared to chloroform (Figure 7-73). Only a few of the detected concentrations of 1,4-dichlorobenzene are above the GWSL. The detected 1,4-dichlorobenzene concentrations in the Shallow WBZ (0-55 ft bgs) extend from south of the former Beta Ditch just west of the Lhoist facility northward to the OU-1/OU-2 boundary near the OSSM treatment system. Between the depths of 55 and 130 ft bgs there are just a few elevated concentrations of 1,4-dichlorobenzene along the western OU-1 boundary south of the former Beta Ditch. Additionally, Figure 7-82b shows three other distinct areas of 1,4-dichlorobenzene detections in shallow groundwater that are below the GWSL that do not appear to be associated with the OSSM plume. The areas that are not associated with the OSSM plume include the Leasehold Debris Pile, the western two-thirds of the IWF/barrier wall, and the area surrounding and downgradient of the Recharge Trench Area. 1,4-Dichlorobenzene was not detected in groundwater deeper than 130 ft bgs.

1,1-Dichloroethane

Detected concentrations of 1,1-DCA in groundwater in OU-1 are depicted in Figures 7-83a through 7-83e. As these figures show, 1,1-DCA is detected in the upper 90 feet of the Shallow WBZ in the northwest portion of OU-1 extending from just west of the GW-11 Pond to the OU-1/OU-2 boundary just north of the OSSM groundwater treatment system. The higher concentrations occur along the OU-1/OSSM boundary and appear to be associated with the trespassing OSSM plume. 1,1-DCA is generally not detected below the depth of 90 ft bgs.

1,2-Dichloroethane

Detected concentrations of 1,2-DCA in groundwater in OU-1 are depicted in Figures 7-84a through 7-84e. As these figures show, 1,2-DCA is detected in the upper 90 feet of the Shallow WBZ in the northwest portion of OU-1 extending from just west of the GW-11 Pond to the OU-1/OU-2 boundary just north of the OSSM groundwater treatment system. The higher concentrations occur along the OU-1/OSSM boundary and appear to be associated with the trespassing OSSM plume. 1,2-DCA is generally not detected below the depth of 90 ft bgs.

1,1-Dichloroethene

Detected concentrations of 1,1-DCE in groundwater in OU-1 are depicted in Figures 7-85a through 7-85e. As Figure 7-85b shows, and dissimilar from previous VOCs discussed in this section, 1,1-DCE was detected in the Shallow WBZ (0-55 ft bgs) originating in and extending from the WAPA property (Terracon 2017) south of the Unit 1 and 2 Buildings northward to the west side of the IWF/barrier wall. The higher concentrations appear to occur along the north-south trending paleochannel, with the highest concentration occurring just west of the Lhoist facility. 1,1-DCE was detected in only two samples below the depth of 55 ft bgs at relatively low concentrations below the GWSL.

1,4-Dioxane

Detected concentrations of 1,4-dioxane in groundwater in OU-1 are depicted in Figures 7-86a through 7-86e. As Figure 7-86b shows, 1,4-dioxane is widely distributed in the Shallow WBZ (0-55 ft bgs) throughout the central portion of OU-1 at concentrations generally less than ten times the GWSL. The highest concentrations of 1,4-dioxane appear to occur along the north-south trending paleochannel extending from south of the Unit 1 and 2 Buildings to the western side of the IWF/barrier wall (where the number of GWSL exceedances is greatest). A second area of elevated 1,4-dioxane in shallow groundwater occurs along the western boundary of OU-1 extending from just west of the GW-11 Pond northward to the OU-1/OU-2 boundary just north of the OSSM treatment system. This second area of elevated 1,4-dioxane appears to be related to the trespassing OSSM plume. Only a few isolated detections of 1,4-dioxane just slightly above the GWSL occur between 55 and 130 ft bgs, and 1,4-dioxane was not detected below 130 ft bgs.

Methylene Chloride

Detected concentrations of methylene chloride in groundwater in OU-1 are depicted in Figures 7-87a through 7-87e. As Figure 7-87b shows, methylene chloride is not widely distributed throughout OU-1 in the Shallow WBZ (0-55 ft bgs). There are only a few isolated locations where methylene chloride was slightly above the GWSL. However, there is one shallow groundwater location with a methylene chloride concentration that was significantly higher than the 5 µg/L GWSL; M-125 with a concentration of 390 J µg/L. Well M-125 is located near the western OU-1 site boundary immediately north of the former Beta Ditch, within the trespassing OSSM plume and spatially correlated with significantly elevated detection limits of methylene chloride and other VOCs in groundwater samples, indicating that methylene chloride is associated with the trespassing OSSM plume. Methylene chloride was not detected in groundwater above the GWSL deeper than 55 ft bgs.

1,1,2,2-Tetrachloroethane

Detected concentrations of 1,1,2,2-tetrachloroethane in groundwater in OU-1 are depicted in Figures 7-89a through 7-89e. As Figure 7-89a shows, and as discussed in Section 7.2.2.4, all detection limits of 1,1,2,2-tetrachloroethane are above the GWSL. However, as there is no operational history within OU-1 associated with 1,1,2,2-tetrachloroethane, it would likely only be found with other VOCs, resulting in increased detection limits. Even though all detection limits are above the GWSL, 1,1,2,2-tetrachloroethane is therefore unlikely to be present over much of OU-1 as most wells have standard or minimally elevated detection limits (0.25 – 2.5 µg/L). As Figure 7-89b shows, there is one shallow groundwater location with a detected 1,1,2,2-tetrachloroethane concentration that was significantly higher than the 0.0775 µg/L GWSL; M-126 with a concentration of 54 J µg/L. Well M-126 is located near the western OU-1 site boundary north of the former Beta Ditch within the trespassing OSSM plume, with a concentration that is spatially correlated with highly elevated 1,1,2,2-tetrachloroethane detection limits in samples from wells M-125 (<50 µg/L) and M-123 (<100 µg/L), indicating that elevated levels of 1,1,2,2-tetrachloroethane are associated with the trespassing OSSM plume. 1,1,2,2-Tetrachloroethane was not detected in groundwater above the GWSL deeper than 55 ft bgs.

Tetrachloroethene

Detected concentrations of PCE in groundwater in OU-1 are depicted in Figures 7-90a through 7-90e. As Figure 7-90b shows, PCE was generally detected in isolated locations throughout OU-1 at concentrations below its GWSL. A discernible pattern of these low concentrations appears to be concentrated around the Leasehold Debris Pile on the eastern boundary of OU-1 and adjacent to the IWF. Only one PCE detection was slightly above the 5 µg/L GWSL; well TR-6 at 7.6 J µg/L along the western boundary of OU-1. In addition, groundwater samples collected from wells within the trespassing OSSM plume have significantly elevated dectection levels of PCE. The exceedance observed at well TR-6 may therefore be associated with the trespassing OSSM plume. PCE was not detected in groundwater in OU-1 deeper than 55 ft bgs.

Trichloroethene

Detected concentrations of TCE in groundwater in OU-1 are depicted in Figures 7-92a through 7-92e. As Figure 7-92b shows, TCE was detected in the Shallow WBZ (0-55 ft bgs) originating in and extending from the WAPA property (Terracon 2017) south of the Unit 1 and 2 Buildings northward to the west side of the IWF/barrier wall.[75] The higher

---

[75] NDEP issued an NFA for WAPA's property in 2018 following an Industrial Risk Assessment (Terracon 2017). As part of the risk assessment, TCE and 1,1-DCE were found above action levels in groundwater, but an NFA was issued based on a number of factors including current land and groundwater use and the results of the risk assessment (NDEP 2018). An Environmental Covenant was also recorded for the WAPA property.

concentrations above the GWSL appear to occur along the north-south trending paleochannel, with the highest concentrations occurring just west of the Lhoist facility. A second area of detectable TCE occurs along the western boundary of OU-1 extending from just west of the GW-11 Pond northward to the OU-1/OU-2 boundary just north of the OSSM treatment system. The highest concentrations in this second grouping are located on the OU-1/OSSM boundary and appear to be associated with the trespassing OSSM plume. TCE was not detected above the GWSL at depths greater than 55 ft bgs.

1,2,3-Trichloropropane

Detected concentrations of 1,2,3-trichloropropane in groundwater in OU-1 are depicted in Figures 7-93a through 7-93e. As Figures 7-93b and 7-93c show, where detected, 1,2,3-trichloropropane concentrations are all above the GWSL. All detection limits of 1,2,3-trichloropropane are also above the GWSL. The elevated concentrations are widespread, occurring around the Unit 4 Building, in the central portion of OU-1 along the paleochannel south of the former P1, P2, and P3 Ponds, around the entire length of the IWF/barrier wall, around the Recharge Trench Area, and then northward to the OU-1/OU-2 boundary. Significantly elevated detection limits are also present along the western boundary of OU-1 south of the GW-11 Pond close to the highest detected concentrations, indicating that 1,2,3-trichloropropane is also likely associated with the trespassing OSSM plume. As Figure 7-93d shows, elevated concentrations above the GWSL occur in the Middle WBZ (90 to 130 ft bgs) in an area that encompasses the Unit 3, 4, and 5 Buildings, the Leach Plant, and an isolated location just to the west of the Lhoist facility. Figure 7-93e shows that only two detections of 1,2,3-trichloropropane occur in the Middle WBZ (130-300 ft bgs), with the highest concentration occurring just north of the Unit 4 and 5 Buildings.

7.5.2.5 Other Organics

4-Chlorobenzenesulfonic Acid

Detected concentrations of 4-CBSA in groundwater in OU-1 are depicted in Figures 7-96a through 7-96e. As these figures indicate, 4-CBSA was only detected in four samples collected from three locations along the western OU-1 boundary in the Shallow WBZ (0-55 ft bgs). One detection was at a concentration significantly higher than the GWSL. 4-CBSA was not analyzed in the 55-90 ft bgs depth range of the Shallow WBZ or the 90-130 ft bgs range of the Middle WBZ and was not detected in the 130-300 ft bgs range of the Middle WBZ. 4-CBSA has a limited sampling extent because the concentrations of 4-CBSA were below GWSLs at the time the sampling plans were designed. However, the elevated level of 4-CBSA appears to be related to the OSSM site located west of the NERT Site.[76]

Formaldehyde

Formaldehyde was not sampled for in the Shallow WBZ (0-55 ft bgs). As shown in Figure 7-97a, all detection limits of formaldehyde are above the GWSL. Formaldehyde detections in OU-1 in the Shallow WBZ (55-90 ft bgs), Middle WBZ (90-130 ft bgs) and the Middle WBZ (130-300 ft bgs) are provided in Figures 7-97c, 7-97d, and 7-97e, respectively. As these figures show, formaldehyde was sampled for in seven wells in each monitoring zone, but

---

[76] Although not shown in Figure 7-96b, elevated 4-CBSA concentrations in the Shallow WBZ on the OSSM site are presented in the OSSM 2013 Comprehensive Groundwater Data Evaluation Report (Hargis 2013) and the OSSM RAS (Geosyntec 2019).

only detected in four samples collected from around the Unit 4 and 5 Buildings from the 90-130 ft bgs monitoring zone. These detections were significantly above the GWSL of 0.387 µg/L. However, formaldehyde was not detected in groundwater in the Shallow WBZ (55-90 ft bgs) or in the Middle WBZ below 130 ft bgs.

7.6 Summary of the Unit 4 and 5 Buildings Source Characterization

Prior to performance of the NERT RI, soil and shallow groundwater investigation data collected in and downgradient of the area near the Unit 4 and 5 Buildings indicated that it was a potential perchlorate and hexavalent chromium source to the underlying soil and groundwater (ENVIRON 2014c). Accordingly, the Trust directed Tetra Tech to prepare the Unit 4 and 5 Buildings Investigation Work Plan (Tetra Tech 2015) and implement it as part of the NERT RI with a focused objective to determine the nature of contamination in this area and the vertical extent of impacted soil and groundwater underneath the Unit 4 and 5 Buildings. This source characterization investigation was designed to identify the nature and vertical extent of contamination in the Unit 4 and 5 Buildings area such that source control and containment remedial alternatives can be considered in the forthcoming FS. Since data collected as part of the RI demonstrates that perchlorate, chlorate, chromium, and chloroform concentrations extended downgradient of this source area and beyond the boundary of OU-1, the lateral extent of contamination is discussed in Sections 7.4, 7.5, and 8 of this RI Report.

Investigation of the Unit 4 and 5 Buildings was conducted by Tetra Tech in three field mobilizations between October 2015 and December 2017. The results of this phased investigation are provided in the Unit 4 and 5 Buildings Investigation Report which was approved by NDEP on January 13, 2020 (Tetra Tech 2020). As outlined in the Unit 4 and 5 Buildings Investigation Work Plan (Tetra Tech 2015), the specific goals of the investigation included the following:

- Collect sufficient soil and groundwater data to provide scale-appropriate data density for characterization of the nature and extent of perchlorate, hexavalent chromium, and other contaminants in the vadose zone and shallow groundwater within the investigation area defined in the Unit 4 and 5 Buildings Investigation Work Plan ("the Unit 4 and 5 Buildings Investigation Area").
- Estimate the mass of perchlorate and hexavalent chromium in the vadose zone and shallow groundwater in the Unit 4 and 5 Buildings Investigation Area.
- Evaluate potential migration pathways and the velocity of perchlorate and hexavalent chromium migration in shallow groundwater in the Unit 4 and 5 Buildings Investigation Area.
- Evaluate the potential contribution of perchlorate and hexavalent chromium in the Unit 4 and 5 Buildings Investigation Area to the previously identified Site-wide shallow groundwater plume.

A brief summary of the investigation and investigation results is provided below as understanding of the nature and vertical extent of contamination in this significant source area is critical to understanding the distribution of NERT COPCs in OU-1 and thoughout the NERT RI Study Area. Figure 7-99a shows the originally planned boring transect locations.

Figures 7-99b and 7-99c show the locations of the borings and monitoring wells installed during investigation of the Unit 4 and 5 Buildings. In addition to perchlorate and hexavalent chromium, several other COPCs were identified in soil and groundwater above their respective BCLs or other screening criteria. The presence of perchlorate, chlorate, chromium, hexavalent chromium, chloroform, TDS, and nitrate in the environment are related to releases during former operations at the Unit 4 and 5 Buildings. With respect to chloroform, this investigation and the RI confirmed that the Unit 4 and 5 Buildings are the only other source of chloroform contamination in OU-1 separate and apart from OSSM's trespassing plume in the western portions of OU-1.

7.6.1 Implementation of the Unit 4 and 5 Buildings Investigation

The investigation of the Unit 4 and 5 Buildings was implemented in three field mobilizations. The first field mobilization was performed prior to the demolition of the Unit 4 Building cell floor, with demolition activities completed between the first and second mobilizations. Demolition of much of the Unit 4 Building was required to facilitate basement access for the drill rigs. The first mobilization commenced on October 20, 2015, and included advancing four borings near the four exterior corners of the Unit 4 Building cell floor and collecting soil samples and discrete-depth groundwater samples from each borehole. The boring locations, which are shown in Figure 7-99b, were positioned along two of the five planned transects shown in Figure 7-99a. The first field mobilization concluded on December 7, 2015.

The second field mobilization commenced on June 28, 2016, following NDEP concurrence with the scope of work and approach proposed in the First Mobilization Technical Memorandum (Tetra Tech 2016a). The second field mobilization included the advancement of the remaining 47 borings along the five planned east/west transects and collecting soil samples and discrete-depth groundwater samples from each borehole. In addition to these borings, three borings were placed around an identified sump located along the southwest side of the Unit 4 Building basement; eight additional borings were field-placed based on the presence of cracks, sumps, and observations following the demolition of the Unit 4 Building cell floor; four step-out borings to 90 ft bgs were added to delineate the extent of COPCs within the Unit 4 and 5 Buildings Investigation Area; and seven deeper step-down borings ranging in depth from 150 to 250 ft bgs were advanced to define the vertical extent of contamination at this source area. As shown in Figures 7-99b and 7-99c, a total of 69 borings were advanced and one monitoring well was installed within the Unit 4 and 5 Buildings Investigation Area during the second field mobilization, which concluded on January 3, 2017.

The third field mobilization commenced on August 8, 2017, following NDEP concurrence with the scope of work and approach proposed in the Second Mobilization Technical Memorandum (Tetra Tech 2017a). The third mobilization included advancement of four angled borings (shown in Figure 7-99b) and the installation of 20 monitoring wells (shown in Figure 7-99c) within the Unit 4 and 5 Buildings Investigation Area. The angled borings were advanced from outside of the Unit 5 Building and angled at 45 degrees to collect soil and discrete-depth groundwater samples from underneath the building, an area of active operations, to assess whether the Unit 5 Building was a potential uncharacterized source of contaminants to groundwater.

Monitoring wells installed during the third mobilization were designed to verify the results obtained from discrete-depth groundwater samples collected from temporary wells and to provide ongoing groundwater monitoring points in the Unit 4 and 5 Buildings Investigation Area. At the time the Unit 4 and 5 Buildings Investigation Work Plan (Tetra Tech 2015) was prepared, it was thought that the greatest COPC concentrations were limited to the Shallow WBZ based on previous data collected from the area, and the monitoring wells were proposed to be advanced and constructed at a maximum depth of 90 ft bgs. However, results from the second and third mobilizations demonstrated that the greatest COPC concentrations in groundwater are observed in the Middle WBZ (deeper than 90 ft bgs) below and downgradient of the Unit 4 Building. For that reason, the depth of the monitoring wells was increased from 90 ft bgs to 150 ft bgs with screens at intervals of 60 to 70 ft bgs, 100 to 110 ft bgs, and 140 to 150 ft bgs. The third mobilization field activities were completed on December 21, 2017.

7.6.2 Results of the Unit 4 and 5 Buildings Investigation

The investigation of the Unit 4 and 5 Buildings area examined a suite of COPCs, which are fully presented within the NDEP-approved Unit 4 and 5 Buildings Investigation Report (Tetra Tech 2020). This section discusses contaminant distribution of the four Primary COPCs in soil (Section 7.6.2.1) and groundwater (Section 7.6.2.2). Aquifer testing conducted as part of the Unit 4 and 5 Buildings investigation is summarized in Section 7.6.2.3.

7.6.2.1 Primary COPC Contaminant Distribution in Soil

Perchlorate was observed throughout the Unit 4 and 5 Buildings Investigation Area in both the alluvium and the UMCf at concentrations that exceeded the LSSL[77] of 0.0155 mg/kg. Perchlorate was present above the HSSL for soil at two points in the upper 10 feet of the Unit 4 and 5 Buildings Investigation Area, in borehole U4U5-59 at 10 ft bgs and in borehole U4U5-60 at 5 ft bgs. Perchlorate was below the HSSL throughout the upper 10 feet of the remainder of the Unit 4 and 5 Buildings Investigation Area. Within the alluvium, the greatest perchlorate concentrations were observed within the vadose zone immediately east and west of the Unit 4 Building, as well as immediately east of the Unit 5 Building, at depths of approximately 20-30 ft bgs (up to 25,000 mg/kg at 20 ft bgs in boring U4U5-62, which is located in the very southeast corner of the Unit 4 Building footprint). For comparison, perchlorate concentrations in this depth interval within the remainder of OU-1 are generally between 1 mg/kg to 5,000 mg/kg. Perchlorate concentrations decreased below the alluvium, ranging from approximately 0.12 mg/kg to 210 mg/kg at 60 ft bgs within the upper, coarse-grained interval of the UMCf. Below this lower concentration interval, perchlorate concentrations increased with depth within the UMCf, with the highest perchlorate concentrations in soil present directly below and west of the Unit 4 Building at a depth of approximately 95 ft bgs (up to 29,000 mg/kg at 93 ft bgs in the pilot boring for well M-252, which is located within the northern portion of the Unit 4 Building footprint). Elevated concentrations were also observed approximately 200 feet north of the former Unit 4 Building chlorinator structure within the UMCf. Perchlorate concentrations are generally below 10 mg/kg in soil below a depth of 125 ft bgs in the UMCf.

---

[77] The Unit 4 and 5 Buildings Investigation Report refers to NDEP BCLs instead of LSSLs, HSSLs, and GWSLs. These are generally numerically identical and do not impact conclusions where they differ.

The distribution of chlorate in soil is generally similar to the distribution of perchlorate with concentrations exceeding the LSSL of 1.03 mg/kg for chlorate throughout the Unit 4 and 5 Buildings Investigation Area. Within the alluvium, the highest chlorate concentrations were observed within the vadose zone to the west and beneath the Unit 4 Building, as well as beneath the east side of the Unit 5 Building, at depths of approximately 20-30 ft bgs (up to 74,000 mg/kg at 25 ft bgs in the pilot boring for well M-191, which is located west of the Unit 4 Building). For comparison, chlorate concentrations within this depth interval within the remainder of OU-1 are generally between 1 mg/kg to 5,000 mg/kg. Chlorate concentrations decrease below the alluvium within the course-grained interval of the UMCf. Below this interval of lower concentrations, chlorate concentrations within the UMCf increase with depth, with the highest chlorate concentrations in soil present immediately west and beneath the Unit 4 Building at depths of approximately 90-105 ft bgs (up to 35,000 mg/kg at 103 ft bgs in the pilot boring for well M-250, which is located west of the Unit 4 Building). Chlorate concentrations are also elevated approximately 200 feet north of the former Unit 4 Building chlorinator structure within the UMCf. Chlorate concentrations generally decrease to less than 10 mg/kg in soil below a depth of approximately 125 ft bgs in the UMCf.

As expected, the distribution of hexavalent chromium in soil is similar to the distribution of perchlorate and chlorate with hexavalent chromium concentrations observed in both the alluvium and the UMCf exceeding the LSSL of 2 mg/kg throughout the Unit 4 and 5 Buildings Investigation Area. Hexavalent chromium was present above the HSSL in the upper 10 feet of soil within 12 borings throughout the Unit 4 and 5 Buildings Investigation Area. Soil samples from borings with HSSL exceedances are located primarily in and adjacent to the Unit 4 Building basement, with the exception of boring U4U5-15, located north of the Unit 5 Building. The greatest hexavalent chromium concentrations in the alluvium were observed immediately east and west of the Unit 4 Building within the vadose zone, from approximately 10 to 35 ft bgs (up to 380 mg/kg at 17.5 ft bgs in boring U4U5-21, which is located within the northwest side of the footprint for the Unit 4 Building). For comparison, hexavalent chromium concentrations in this depth interval within the remainder of OU-1 are generally less than 30 mg/kg. Below the alluvium, within the upper coarse-grained interval of the UMCf, concentrations of hexavalent chromium were lower, ranging from approximately 0.21 to 2.8 mg/kg at a depth of 60 ft bgs. Below this interval, concentrations increase with depth within the UMCf, reaching the greatest hexavalent chromium concentrations in the UMCf at depths of approximately 90-110 ft bgs along the west side and beneath the Unit 4 Building (up to 62 mg/kg at 110 ft bgs in boring U4U5-31, which is located in the center of the Unit 4 Building footprint). Elevated hexavalent chromium concentrations were also observed approximately 200 feet north of the Unit 4 Building chlorinator structure within the UMCf. Hexavalent chromium concentrations are generally less than 1 mg/kg in soil below a depth of 125 ft bgs in the UMCf.

Concentrations of chloroform in soil exceed the LSSL of 30 µg/kg throughout the Unit 4 and 5 Buildings Investigation Area. However, and consistent with the analysis in Section 7.5.1.4 above, the distribution of chloroform is different than perchlorate, chlorate, and hexavalent chromium. Within the alluvium, the greatest concentrations of chloroform were observed within the vadose zone to the east and west of the Unit 4 Building, as well as beneath the Unit 4 Building, (up to 1,000 µg/kg at 27.5 ft bgs in boring U4U5-21, which is located within the northwest side of the Unit 4 Building footprint). These concentrations are not unusual across the central and eastern portions of OU-1, where chloroform concentrations generally range between <1 µg/kg and 1,000 µg/kg within the 20-40 foot depth interval, with the exception of the west side of OU-1 where concentrations are higher due to the trespassing OSSM plume. Chloroform concentrations generally decrease below the alluvium within the upper, coarse-grained interval of the UMCf. Below this lower concentration interval, chloroform concentrations increased with depth within the UMCf, with the highest chloroform concentrations found beneath and west to northwest of the Unit 4 Building (up to 5,800 µg/kg at 93 ft bgs in the pilot boring for well M-252, which is on the north side within the Unit 4 Building footprint). Elevated concentrations of chloroform were also observed approximately 200 feet north of the former Unit 4 Building chlorinator structure within the UMCf. Chloroform concentrations are generally below 5 µg/kg in soil below a depth of approximately 125 ft bgs in the UMCf. While the Unit 4 and 5 buildings are the only source area for chloroform within OU-1, the chloroform concentrations are significantly less than found in the OSSM trespassing plume as discussed in Section 7.4.3.

7.6.2.2 Primary COPC Contaminant Distribution in Groundwater

Perchlorate exceeded the GWSL of 0.015 mg/L throughout most of the Unit 4 and 5 Buildings Investigation Area. Based on one-time discrete-depth sampling results, perchlorate was detected in groundwater within the alluvium (0-35 ft bgs)[78] at concentrations as high as 2,900 mg/L (boring U4U5-66 at 30 ft bgs) and in the upper saturated interval of the UMCf (35-75 ft bgs) at concentrations as high as 3,500 mg/L (boring U4U5-64 at 58.5 ft bgs). For comparison, concentrations of perchlorate greater than 1,000 mg/L are also present in the Shallow WBZ near the IWF, immediately downgradient of the former AP ponds. The highest perchlorate concentrations in groundwater were observed directly below and downgradient of the Unit 4 Building in the lower saturated interval of the UMCf between 75-125 ft bgs (up to 6,700 J- mg/L at 102 ft bgs in boring U4U5-64, which is located in the northeast corner of the Unit 4 Building footprint). Perchlorate concentrations decreased below 125 ft bgs within the UMCf, where perchlorate was detected at concentrations no greater than 570 mg/L. The perchlorate concentration detected in the discrete-depth sample collected from 240 ft bgs was non-detect. Although a limited number of discrete-depth groundwater samples were collected below the Unit 5 Building, the results indicate a similar distribution pattern, but at concentrations of perchlorate approximately an order of magnitude lower. In general, perchlorate concentrations in the 21 new and 7 existing monitoring wells within the Unit 4 and 5 Buildings Investigation Area were lower than the discrete-depth groundwater sample results from similar depth intervals. Overall monitoring well concentrations ranged from 0.0086 mg/L to 6,600 mg/L, with the highest perchlorate concentration in well M-256-100 (screened from 100-110 ft bgs), located northeast of the Unit 4 Building. Directly beneath the Unit 4 Building basement, the highest perchlorate concentration was 4,600 mg/L in groundwater at well M-251-100 (screened from 93-103 ft bgs).

The distribution of chlorate in groundwater based on the one-time discrete-depth sampling results is similar to the distribution of perchlorate in groundwater with chlorate concentrations exceeding the GWSL of 1.0 mg/L throughout the Unit 4 and 5 Buildings Investigation Area. Based on one-time discrete-depth sampling results, chlorate was

---

[78] The groundwater depth intervals defined within Section 7.6.2.2 are slightly different from the nomenclature and depth intervals used in the remainder of the RI report, but are consistent with those used in the Unit 4 and 5 Buildings Investigation Report (Tetra Tech 2020) and are helpful in defining areas of higher and lower concentration within the Unit 4 and 5 Buildings Investigation Area.

detected in groundwater within the alluvium (0-35 ft bgs), as well as the upper saturated interval of the UMCf (35-75 ft bgs), at concentrations as high as 3,200 mg/L within each interval (boring U4U5-66 at 30 ft bgs and boring U4U5-6 at 66 ft bgs). For comparison, chlorate concentrations of greater than 2,500 mg/L are also present near the IWF, immediately downgradient of the former AP ponds. The highest concentrations of chlorate were detected between 75-125 ft bgs in the lower saturated interval of the UMCf. Chlorate concentrations up to 32,000 mg/L were detected in well M-251-100 (screened from 92-102 ft bgs), located directly beneath the Unit 4 Building basement. Chlorate concentrations decreased below 125 ft bgs within the UMCf where chlorate was detected at concentrations no greater than 500 mg/L (boring U4U5-74 at 130 ft bgs). As with perchlorate, the sampling results for chlorate below the Unit 5 Building indicate a similar distribution pattern between the alluvium, upper saturated interval of the UMCf, and lower UMCf interval, but at concentrations of chlorate approximately an order of magnitude lower than beneath the Unit 4 Building.

The distribution of hexavalent chromium in groundwater based on the one-time discrete-depth sampling results is similar to the distribution of perchlorate and chlorate in groundwater with concentrations of hexavalent chromium exceeding the GWSL of 100 µg/L at most locations. Based on one-time discrete sampling results, hexavalent chromium was detected in groundwater within the alluvium (0-35 ft bgs) at concentrations as high as 12,000 µg/L (boring U4U5-66 at 30 ft bgs) and the upper saturated interval of the UMCf (35-75 ft bgs) at concentrations as high as 42,000 µg/L (U4U5-20 at 42.5 ft bgs). For comparison, concentrations of hexavalent chromium in groundwater within OU-1 greater than 20,000 µg/L are also present in the Shallow WBZ (0-55 ft bgs) near the IWF, immediately downgradient of the former AP ponds. As was observed with perchlorate and chlorate, the greatest concentrations of hexavalent chromium within the Unit 4 and 5 Buildings Investigation Area were generally observed below and downgradient of the Unit 4 Building within the lower saturated interval of the UMCf between approximately 80 to 125 ft bgs. Based on one-time discrete sampling results, hexavalent chromium concentrations of up to 110,000 µg/L (boring U4U5-22 at 82 ft bgs) were detected in the lower saturated interval of the UMCf (75-125 ft bgs). Similar to the observed groundwater perchlorate distribution with depth, hexavalent chromium concentrations generally decrease with depth below approximately 125 ft bgs. A slight increase in hexavalent chromium concentrations was noted in groundwater samples collected from a depth of 150 ft bgs from the angled borings beneath the Unit 5 Building, although concentrations were below 500 µg/L.

Chloroform concentrations in groundwater exceeded the GWSL of 70 µg/L throughout the Unit 4 and 5 Buildings Investigation Area. Based on one-time discrete-depth sampling results, chloroform was detected in groundwater within the alluvium (0-35 ft bs) at concentrations as high as 1,600 µg/L (boring U4U5-29 at 32.5 ft bgs), as well as the upper saturated interval of the UMCf (35-75 ft bgs) at concentrations as high as 550 µg/L (boring U4U5-7 at 67.5 ft bgs). Chloroform concentrations detected in the one-time discrete-depth samples were generally higher than concentrations found in permanent wells, where concentrations of chloroform during the same time period were between 2.4 µg/L and 130 µg/L in wells with screened intervals between 60-70 ft bgs. For comparison, chloroform concentrations in groundwater in the Shallow WBZ (0-55 ft bgs) within OU-1 are also greater than 1,000 µg/L immediately upgradient of the IWF and along the western property boundary with the OSSM site. The highest chloroform concentrations in groundwater were observed directly below and immediately north of the Unit 4 Building in the lower saturated interval of the UMCf. Chloroform concentrations as high as 8,300 µg/L were measured in well M-251-100 (screened from 92-102 ft bgs), which is located within the footprint of the Unit 4 Building and screened in the lower saturated interval of the UMCf. Chloroform concentrations beneath the Unit 5 Building followed a similar pattern with the highest concentrations generally within the lower saturated interval of the UMCf (75-125 ft bgs) at concentrations as high as 440 µg/L (boring U4U5-77 at 110 ft bgs). Chloroform was detected above the BCL of 0.219 µg/L, but below the GWSL, as deep as 242 feet bgs. Based on the description of this source area associated with historical operations in the Unit 4 and 5 Buildings, it is clear that this is a distinct source area separate from the trespassing OSSM plume and the TIMET source area north of the Unit 8 Building. While the Unit 4 and 5 Buildings are the only source area for chloroform within OU-1, the chloroform concentrations are significantly less than found in the OSSM trespassing plume as discussed in Section 7.5.1.4.

7.6.2.3 Aquifer Test Results from the Unit 4 and 5 Buildings Investigation

Aquifer testing was also conducted as part of the Unit 4 and 5 Buildings investigation. A total of 10 slug tests were conducted to determine hydraulic parameters laterally and vertically within the UMCf in the investigation area. The hydraulic conductivity values ranged from 0.005 ft/day at monitoring well M-253-100 to 0.57 ft/day at monitoring well M-253-60. Hydraulic conductivity values for the intervals of the UMCf where the monitoring wells are screened are within the typical range for clay, silt, and silty sand.

In addition to the 10 slug tests performed, three low flow specific capacity tests were conducted to corroborate the hydraulic parameters determined by slug tests and calculate specific capacity. The tests were conducted at monitoring wells M-251-60, M-251-100, and M-252 located within the Unit 4 Building footprint where elevated perchlorate, chlorate, hexavalent chromium, and chloroform concentrations were observed. The hydraulic conductivity values ranged from 3.2 x 10-6 cm/sec (0.009 ft/day) at monitoring well M-252 to 2.9 x 10-5 cm/sec (0.081 ft/day) at monitoring well M-251-100. The hydraulic conductivity values obtained from the specific capacity testing at M-251-60, M-251-100, and M-252 were consistent with the slug test results. These values are within typical ranges of clay, silt, and silty sand.

7.7 Summary of OU-1 Soil Gas Results

As discussed earlier in Sections 6.3.2 and 6.4.2, two rounds of soil gas sampling were conducted in OU-1 associated with the NERT RI. The first round of sampling occurred in March 2019 at 21 locations (RISG-10 through RISG-26, and RISG-31 through RISG-34). The second round of sampling occurred between November 2019 and January 2020, and included resampling at the original 21 locations in addition to sampling at 12 new locations (RISG-79 through RISG-90). Soil gas samples were collected from depths of 5 feet bgs and between 12 to 15 feet bgs at each location with the exception of RISG-31 and the four locations within the Unit 4 Building (RISG-16 through RISG-19). A deeper probe could not be installed at RISG-31 due to shallow groundwater conditions. The samples within the Unit 4 Building were collected at a depth of 5 feet below the basement floor, which is approximately 13 ft bgs. Soil gas samples were analyzed for VOCs using EPA Method TO-15. The soil gas sampling results for VOCs detected at least once during the RI soil gas sampling program are shown in Tables 7-7a and 7-7b. As stated in Section 7.5.1, chloroform is the most widely distributed VOC detected in groundwater with OU-1. As such, chloroform is also the most widely distributed VOC in soil gas within OU-1. Soil gas sample locations and results for chloroform (the VOC with the most widespread distribution in soil gas) from the second sampling event are shown relative to the chloroform concentrations in groundwater in Figures 7-100a and 7-100b. Additional details on the sampling procedures are provided in Appendix A1. The complete OU-1 RI soil gas data set is presented in Appendix K.

As discussed in more detail in Section 3.2, the only prior investigation of soil gas within OU-1 occurred in 2008 as part of the Phase B investigation by Tronox. Analytical results for samples collected during the 2008 soil gas survey were presented in a Data Validation Summary Report (ENSR 2008g) that was submitted to NDEP on October 13, 2008, and approved by NDEP on October 20, 2008. No actions with respect to soil gas were required by NDEP immediately following this investigation. Given that the data are over ten years old and numerous remedial activities have been ongoing in OU-1 since then, only the 2019-2020 soil gas results collected as part of the OU-1 RI are discussed below.

The RI soil gas results presented in Tables 7-7a and 7-7b are compared to site-specific, health-based SGSLs.[79] Detected concentrations or detection limits above the SGSL are highlighted in yellow. As described in more detail in Appendix G, the OU-1 SGSLs represent the concentration of a chemical in soil gas that is protective of human health considering the vapor intrusion to indoor air exposure pathway and assuming industrial/commercial land use.

Chloroform was the only VOC in OU-1 detected above SGSLs, and it was detected at all sample locations and depths across OU-1 during the sampling events conducted in 2019-2020. As shown in Figures 7-100a and 7-100b, the highest soil gas concentrations for chloroform were located next to the Unit 4 Building and over the portion of the DNAPL plume which trespasses from the OSSM site onto the western side of OU-1. Except for three locations (RISG-79, RISG-80, and RISG-86), chloroform concentrations in soil gas increased with depth indicating that the source of chloroform in soil gas is attributable to chloroform in groundwater rather than a shallow vadose zone source associated with a surface spill. In general, there were no discernible or significant trends regarding differences in chloroform concentrations from locations sampled in March 2019 and November 2019 through January 2020. Chloroform concentrations at RISG-10 did decrease substantially (from 850,000 to 92,000 µg/m^3 at 15 feet bgs) between March and November 2019, while at RISG-18 chloroform concentrations increased (from 12,000 to 72,000 µg/m^3 at 13 feet bgs).

In addition to chloroform, the following VOCs were detected at elevated concentrations below SGSLs in OU-1: TCE, carbon tetrachloride, and PCE. As discussed above, TCE is not considered a COPC in soil within OU-1, but carbon tetrachloride is considered a COPC in soil and both compounds are considered COPCs in groundwater largely due to carbon

---

[79] On March 31, 2020, NERT submitted the soil gas data to NDEP. NDEP replied to this submittal on January 28, 2021, requesting submittal of a Baseline Health Risk Assessment for OU-1 and OU-2 soil gas and groundwater. NERT submitted the OU-1 Soil Gas and Groundwater Baseline Health Risk Assessment to NDEP on September 29, 2021, and NDEP provided comments on March 9, 2022. NERT submitted a response to comments on June 24, 2022, and NDEP provided further comments on November 3, 2022. The OU-1 Soil Gas and Groundwater Baseline Health Risk Assessment Revision 1 was submitted on November 3, 2023 and approved by NDEP on January 2, 2024.

tetrachloride and TCE groundwater contamination that trespasses from the OSSM and WAPA sites onto OU-1, respectively. This is demonstrated by that fact that the highest concentrations of carbon tetrachloride in soil gas were located along the western OU-1 boundary where VOCs in groundwater trespass from the OSSM site onto OU-1. TCE was also detected at relatively low concentrations in soil gas across OU-1, with the highest TCE concentrations being detected at RISG-82 and RISG-22, in the central portion of OU-1; these locations correlate with the locations of higher concentrations of TCE in groundwater migrating from the WAPA site (see Section 7.2.2.4). The highest concentrations of PCE were located in the Unit 4 Building basement but at concentrations well below the SGSL and not spatially correlated with the detection of PCE in groundwater above the GWSL within OU-1.

While the above discussion presented details regarding nature and extent of chemicals exceeding screening levels in soil gas within OU-1 and a discussion of potential sources is included in Section 9 of this report, assessment of the potential human health risks from the VOCs detected in soil gas at OU-1 is presented in the OU-1 Soil Gas and Groundwater Baseline Health Risk Assessment Report.

8. RI RESULTS: OU-2

This section presents the results of the RI conducted in OU-2. As discussed earlier in this report, the NERT RI Study Area is composed of three OUs with OU-2 and OU-3 containing multiple sub-areas. In addition, each of the OUs can contain different COPCs and will be further evaluated independently through subsequent risk assessments and feasibility studies. As shown in Figure 8-1, OU-2 includes two sub-areas: the NERT Off-Site Study Area located west of Pabco Road, and the Eastside Sub-Area located east of Pabco Road. As explained previously in this report, Pabco Road demarcates the investigatory and clean-up obligations of NERT resulting from the AOC between NDEP and BRC and thus discrete sets of COPCs have been assigned to the areas east and west of the road.

The NERT Phase 1 and Phase 2 RI investigations began in the NERT Off-Site Study Area in late 2014 before the establishment of the NERT Operable Units. In July 2016, NDEP directed NERT to expand its RI Study Area and investigate HLCs in "areas to the northeast of the Site, known as the BMI Common Areas due to migration of hazardous substances released at the Henderson Property [Site] prior to the Effective Date of the Trust" (NDEP 2016c). According to the Interim Consent Agreement, HLCs "shall mean the presence or release, prior to or on the Effective Date, of hazardous substances (including without limitation perchlorate and chlorate compounds) in or into the environment at, on or below any portion of the Henderson Property, including the presence in any environmental media of such released hazardous substances as a result of migration from any portion of the Henderson Property, whether before or after the Effective Date" (NDEP 2011a). For the purposes of the RI, and consistent with the abovementioned AOC, HLCs within the Eastside Sub-Area are referred to as "Administratively Limited COPCs" and are limited to perchlorate and chlorate. Accordingly, the RI in this area is limited to perchlorate and chlorate impacts to the subsurface, including soil (below 10 ft bgs) and groundwater. BRC, under NDEP oversight, is responsible for environmental impacts associated with other constituents within the Eastside Sub-Area.

The physical and environmental setting of OU-2 is described in Section 5.0, and this section summarizes the identification of COPCs and the nature and extent of COPCs. The remainder of this section is organized as follows: Section 8.1 provides the results of the evaluation of RI soil analytical data from OU-2 to determine those constituents that exceed certain screening criteria for soil indicating that they should be retained as COPCs, and Section 8.2 includes a discussion of vadose zone soil impacts from perchlorate and chlorate at depths below 10 feet in the Eastside Sub-Area. Section 8.3 provides the results of the evaluation of RI groundwater analytical data in OU-2 to determine those constituents that exceed certain screening criteria for groundwater indicating that they should be retained as COPCs, and based on this analysis, the COPCs for OU-2 are presented in Section 8.4. Section 8.5 provides a discussion of the nature and extent of OU-2 COPCs in groundwater in the NERT Off-Site Study Area and Eastside Sub-Area. The results of the 2015-2019 OU-2 soil gas investigation are discussed in Section 8.6.

8.1 Identification of Soil COPCs

In the NERT Off-Site Study Area, which is located in OU-2 immediately downgradient of OU-1 west of Pabco Road and extends into OU-3, the mechanism by which Site-related contaminants migrated to this area was by groundwater. Since vadose zone soil was not directly impacted by historical Site operations, evaluation of soil COPCs (and their nature and extent) was not performed in the NERT Off-Site Study Area consistent with the NDEP-approved RI/FS Work Plan (ENVIRON 2014c). There is a potential for soluble constituents such as perchlorate and hexavalent chromium to become trapped in the capillary fringe as groundwater levels decline due to groundwater extraction, changes in areas and amounts of surface water recharge, or naturally from drought. These trapped COPCs represent a potential secondary source of groundwater contamination with the potential to continue to contribute mass to the groundwater for an extended period of time.

In the Eastside Sub-Area, which is within OU-2 immediately east of the NERT Off-Site Study Area and separated by Pabco Road, historical operations included the operation of unlined wastewater disposal ponds for the BMI Complex between 1943[80] and 1976, as described in Section 2 of this report. Both vadose zone soil and groundwater were impacted by the Administratively Limited COPCs (i.e., perchlorate and chlorate) that migrated via the former Beta Ditch to the former unlined ponds in the Eastside Sub-Area.[81] As discussed above, BRC, under NDEP oversight, is responsible for environmental impacts associated with other constituents within the Eastside Sub-Area. Soil and groundwater COPCs have therefore been administratively limited in the Eastside Sub-Area to perchlorate and chlorate. Furthermore, and consistent with the NFAs granted to BRC in much of the former BMI Common Areas, and the NERT Phase 3 RI Work Plan (Ramboll Environ 2017m), perchlorate and chlorate impacts to vadose zone soil were only investigated at depths below 10 ft bgs to the water table and soil COPCs are only defined for this depth interval in the Eastside Sub-Area.

8.2 Nature and Extent of COPCs in Soil, Eastside Sub-Area

This section presents a discussion of the nature and horizontal/vertical extent of the Administratively Limited COPCs in vadose zone soil below 10 feet within the OU-2 Eastside Sub-Area component of OU-2 east of Pabco Road.

Perchlorate and chlorate concentrations in vadose zone soil below 10 feet are presented in Figure 8-2. Based on the current depth of groundwater (generally below 45 ft bgs), the soil sample results from depths of 10, 20, 30, and 40 feet are shown in data boxes included in the figure for each boring. For borings ES-28 and ES-29 located in the southern part of the Eastside Sub-Area where the groundwater table is deeper, the soil results from 50 ft bgs are also shown.

As previously described in Section 7, the soil results are compared to the LSSLs developed for the NERT Site (see Appendix G). The LSSL for perchlorate is 0.0155 mg/kg, and the LSSL for chlorate is 1.03 mg/kg. The boring locations shown in Figure 8-2 are color-coded to show perchlorate and/or chlorate concentrations above the LSSL.

As shown in Figure 8-2, perchlorate concentrations above the LSSL of 0.0155 mg/kg were found in nearly all the boring locations (designated by a color-coded sample location symbol). In general, the highest concentrations are found in the western part of the

---

[80] The BMI wastewater ponds began receiving wastewater via the Beta Ditch in approximately 1943 (under the ownership of the US Government) and were operated by Basic Management from 1952 until 1976.

[81] The potential presence of hexavalent chromium and other potential contaminants in groundwater within the Eastside Sub-Area will be investigated and remediated by BRC, if required by NDEP, pursuant to the terms of Administrative Order on Consent, Phase 3 (AOC3) (NDEP 2006).

Eastside Sub-Area beneath the area previously occupied by the former ditches and unlined wastewater ponds. Perchlorate concentrations above the LSSL ranged from 0.028 J- mg/kg (boring ES-1 located near the southwest boundary) to 18 mg/kg (boring ES-12 near the northern OU-2/OU-3 boundary within the former surface seep area).

Chlorate concentrations above the LSSL of 1.03 mg/kg are also shown in the data boxes in Figure 8-2. With the exception of seven borings, the chlorate and perchlorate concentrations above the LSSL are co-located. Chlorate concentrations above the LSSL ranged from 1.1 mg/kg (in borings ESB-3, ESB-11, and ESB-12) to 34 mg/kg (in boring ES-6), with one higher concentration of 140 mg/kg in boring ESB-8 at a depth of 10 ft bgs. The distribution of perchlorate and chlorate in the deeper vadose zone soil is consistent with historical operations in the Eastside Sub-Area and with the distributions of perchlorate and chlorate in underlying shallow groundwater, as discussed in Section 8.3.2.1. In general, the areas of investigation by NERT were situated primarily in the currently undeveloped portions of the Eastside Sub-Area.

8.3 Identification of Groundwater COPCs

In this section, groundwater sampling analytical results are evaluated to identify constituents that will be retained as COPCs for groundwater in OU-2. As discussed above, for the Eastside Sub-Area, the groundwater COPCs have been administratively limited to perchlorate and chlorate. As such, the COPC screening process described in this section only refers to the NERT Off-Site Study Area of OU-2, with the exception of perchlorate and chlorate. The screening of perchlorate and chlorate applies to the entirety of OU-2 groundwater.

The following section focuses on the identification of groundwater COPCs in OU-2. As previously presented in Section 7.2, groundwater COPCs are chemicals that exceed regulatory or human health-based screening levels in groundwater. Consistent with the NDEP-approved RI/FS Work Plan (ENVIRON 2014c), naturally occurring chemicals, such as metals, are not considered COPCs unless they are found at concentrations significantly above background. In addition, and similar to the identification of COPCs in soils, common nutrients, salts, and infrequently detected chemicals are also not considered COPCs consistent with NDEP guidance (NDEP 2023a).

8.3.1 Initial Groundwater COPC Screening

The first step in the groundwater COPC identification process was an initial screening conducted by comparing groundwater concentrations in OU-2 to regulatory or health-based GWSLs. Selection of the GWSLs was completed following the hierarchy described in Appendix G (GWSLs are summarized in Table G-3). The GWSL selection hierarchy consisted of the following:

1. Primary MCL (40 CFR 141).
2. MCLG (40 CFR 141), if goal is greater than zero.
3. PRG for perchlorate (USEPA 2009, 2008b).
4. NDEP BCL table (NDEP 2023a) for residential water.
5. USEPA RSL table for tap water (USEPA 2023).

The OU-2 groundwater concentrations used in the screening (referred to as the "OU-2 Groundwater Data Set") includes approximately 30,000 analytical results obtained between 2014 and 2019. Included in the OU-2 Groundwater Data Set are:

- Samples from the 2014-2019 RI, including applicable RI modifications;
- Samples from the Phase 1 downgradient investigation conducted by AECOM in 2016; and
- Samples from the NERT groundwater monitoring program (2014–2018).

As with the OU-1 Groundwater Data Set, groundwater data associated with localized treatability studies in OU-2 are not included in the data set, since data may not be representative of current conditions within the broader NERT RI Study Area and were not collected for the purpose of site characterization. The complete OU-2 Groundwater Data Set is presented in Appendix J.

Whereas the analytes selected for the OU-2 RI groundwater sampling program east of Pabco Road are reflective of the Administratively Limited COPCs, the analytes selected west of Pabco Road were developed based on reviews of previous investigations and were presented in the RI Data Evaluation Tech Memo which was approved by NDEP (Ramboll Environ 2016c). Therefore, while the analyte list east of Pabco Road was fixed, the list of analytes west of Pabco Road is slightly different from the list of analytes in the OU-1 Groundwater Data Set based on data review. Specifically, and relevant to the OU-1 groundwater COPCs (Table 7-2b), OU-2 groundwater samples were not analyzed for radionuclides (including total uranium), SVOCs, PAHs, dioxins, pesticides, TPH and formaldehyde. These chemicals were excluded in the OU-2 RI due to the fact that they are not very mobile in groundwater, not widely distributed in OU-1 groundwater, and were either not detected in groundwater at OU-1 boundary wells or are not related to known previous operations at the NERT Site.

Tables 8-1a, 8-1b, and 8-1c present a statistical summary and comparison of all OU-2 groundwater data used in the COPC screening process for the following depth intervals, which are also defined in greater detail in the paragraphs that follow:

- Shallow WBZ (0-40 ft bgs)
- Shallow WBZ (~40-90 ft bgs)
- Middle WBZ (90-300 ft bgs)

The Shallow WBZ has been defined by NDEP as the depth interval between 0-90 ft bgs. In order to distinguish differences between COPC concentrations in shallow groundwater near the water table and concentrations near the base of the Shallow WBZ, the figures illustrating the nature and extent of COPCs show two Shallow WBZ depth intervals: the Shallow WBZ (0-40 ft bgs), and the Shallow WBZ (~40-90 ft bgs), which consists of saturated fine-grained UMCf-fg1 in the lower portion of the Shallow WBZ. Due to differences in the current hydrogeologic conditions in the NERT Off-Site Study Area and Eastside Sub-Area components of OU-2, the depth intervals represented by these figures vary slightly in the two sub-areas as described below.

In OU-2, the Shallow WBZ is composed of the saturated portions of the alluvium and the uppermost portion of the UMCf to a depth of 90 ft bgs. Historically, the alluvium was saturated throughout OU-2. Recent groundwater elevations measured during the 2018-2021 annual groundwater monitoring events show that, except for a few small areas, the alluvium remains saturated in the NERT Off-Site Study Area component of OU-2 west of Pabco Road. However, recent groundwater elevations show that in the Eastside Sub-Area component of OU-2 east of Pabco Road, much of the alluvium has become dewatered, and first groundwater now occurs within the UMCf. The current extent of saturated alluvium in OU-2 is illustrated in Figure 8-3. A discussion of the extent of the saturated alluvium is presented in Section 5.5.2.

Many of the existing wells predating the NERT RI in the NERT Off-Site Study Area component of OU-2 west of Pabco Road were installed to investigate groundwater conditions at and immediately below the water table, where shallow groundwater was most likely to be affected by chemicals migrating from OU-1 in the saturated alluvium. The majority of these older shallow wells are screened in the depth interval between 0-40 ft bgs. As part of the NERT RI, many of the new monitoring wells were installed in the Shallow WBZ between approximate depths of 40-90 ft bgs to investigate the vertical extent of COPCs in the saturated UMCf.

In the Eastside Sub-Area component of OU-2 east of Pabco Road, and as discussed above, the alluvium has become dewatered except in the southwestern portion and northwest corner of the Sub-Area. In addition, the depth to groundwater ranges between approximately 40 to 50 ft bgs. As a result, the water table is deeper than in the NERT Off-Site Study Area and the Shallow WBZ is divided into two depth intervals in the Eastside Sub-Area component of OU-2 east of Pabco Road: the Shallow WBZ (0-55 ft bgs) and the Shallow WBZ (~55-90 ft bgs). Except in the southwestern portion of the Eastside Sub-Area, both of these Shallow WBZ intervals consist predominantly of the low conductivity UMCf-fg1. This concept, which will be discussed in greater detail in Section 9.1.2, is important because groundwater flow in the UMCf is very slow compared to flow in the alluvium, minimizing the migration in the UMCf.

The Middle WBZ has been defined by NDEP as the depth interval between 90-300 ft bgs. Both at OU-1 and in the NERT Off-Site Study Area component of OU-2 west of Pabco Road, the Middle WBZ is composed primarily of the UMCf-fg1 to depths between approximately 220 to 260 ft bgs, depending on location. Below the southwestern portion of the NERT Off-Site Study Area, the UMCf-cg2 unit is present at depth beneath the fine-grained UMCf-fg1. In the Eastside Sub-Area component of OU-2 east of Pabco Road, the Middle WBZ is composed entirely of the UMCf-fg1.

The Deep WBZ has been defined by NDEP as the depth interval below 300 ft bgs. This water bearing zone was only investigated in the Eastside Sub-Area as contamination in the NERT Off-Site Study Area west of Pabco Road does not extend below the Middle WBZ. All Deep WBZ wells predate the NERT RI in the Eastside Sub-Area and are screened in the UMCf-fg1.

Tables 8-1a, 8-1b, and 8-1c present a statistical summary comparison of OU-1 groundwater concentrations from the Shallow WBZ (0-40 ft bgs), the Shallow WBZ (~40-90 ft bgs), and the Middle WBZ with GWSLs, respectively. Similar to the approach for COPC screening in OU-1, but solely related to COPC screening in the NERT Off-Site Study Area component of OU-2 west of Pabco Road with the exception of perchlorate and chlorate, and consistent with the NDEP-approved RI/FS Work Plan (ENVIRON 2014c), the following constituents were eliminated as COPCs during this initial screening:

- Chemicals with no detected concentrations exceeding the GWSL were eliminated and are indicated with orange shaded rows;
- Chemicals which were detected in fewer than 5% of samples and do not have relevant screening levels were eliminated and are indicated with yellow shaded rows;
- Consistent with NDEP guidance (NDEP 2023a), the essential nutrients calcium, potassium, and sodium were eliminated and are indicated with blue shaded rows; and
- Due to a lack of toxicity data and therefore GWSLs, the following macronutrients and salts were eliminated: ammonia, bicarbonate, carbonate, chloride, orthophosphate, and sulfate, as also indicated with blue shaded rows. While ammonia does have a BCL, this screening level is based only on the toxicity of inhalation of ammonia gas in equilibrium with groundwater at high pH. At the pH of groundwater in OU-2 (generally neutral), the predominant species of ammonia in groundwater is the ammonium cation, which lacks toxicity data.

If a chemical was not eliminated based on the initial screening, it was evaluated further in the secondary screening (presented in Section 8.3.2) before a decision was made regarding whether to exclude or retain that chemical as a groundwater COPC in OU-2. Chemicals are indicated with light yellow shaded rows in Tables 8-1a, 8-1b, and 8-1c if they exceeded the GWSL, but had exceedances of the GWSL in fewer than 10 samples, had a maximum exceedance of the GWSL less than a factor of 20 higher than the screening level, and were detected in fewer than 5% of samples. These chemicals are highlighted because they would have been eliminated as COPCs according to the criteria in the NDEP-approved RI/FS Work Plan (ENVIRON 2014c); however, they were included in the secondary screening to evaluate potential areas of contamination. Due to the fact that the screening of chemicals other than perchlorate and chlorate only applies to the NERT Off-Site Study Area component of OU-2 west of Pabco Road, the results of this initial screening process are generally limited to a discussion related to that area, and are discussed in the following sections.

8.3.1.1 Chlorates and General Chemistry

The following chlorates and general chemistry parameters were detected in groundwater above their GWSLs in the Shallow WBZ (0-40 ft bgs and ~40-90 ft bgs): bromide, chlorate, nitrate (as N), nitrite (as N), nitrate/nitrite (as N), and perchlorate. Only perchlorate and chlorate were detected above the GWSL in the Middle WBZ. Based on these results, bromide, nitrate (as N), nitrite (as N), and nitrate/nitrite (as N) are initially retained as groundwater COPCs in the NERT Off-Site Study Area component of OU-2 west of Pabco Road and are subject to secondary screening as described in Section 8.3.2.1. Chlorate and perchlorate are retained for all of OU-2 and are subject to secondary screening as described in Section 8.3.2.1.

8.3.1.2 Metals

The following metals were detected in groundwater above their GWSLs in the Shallow WBZ (0-40 ft bgs and ~40-90 ft bgs): arsenic, boron, chromium (total), chromium (hexavalent), iron (Shallow WBZ [0-40 ft bgs] only), magnesium, manganese (Shallow WBZ [0-40 ft bgs] only), strontium (Shallow WBZ [0-40 ft bgs] only), and vanadium (Shallow WBZ [0-40 ft bgs] only). Only arsenic and hexavalent chromium were detected above their respective GWSLs in samples from the Middle WBZ. Based on these results, all of the above metals are initially retained as groundwater COPCs in the NERT Off-Site Study Area component of OU-2 west of Pabco Road and are subject to secondary screening as described in Section 8.3.2.2.

8.3.1.3 VOCs

The following VOCs were detected in groundwater above their GWSLs in the Shallow WBZ (0-40 ft bgs and ~40-90 ft bgs): benzene, bromodichloromethane, bromoform (Shallow WBZ [0-40 ft bgs] only), carbon tetrachloride, chlorobenzene, chloroform, 1,1-DCA, 1,4-dioxane, hexachlorobutadiene (Shallow WBZ [0-40 ft bgs] only), methylene chloride, naphthalene (Shallow WBZ [~40-90 ft bgs] only), PCE (Shallow WBZ [0-40 ft bgs] only), TCE (Shallow WBZ [0-40 ft bgs] only), and 1,2,3-trichloropropane. VOCs were not detected above GWSLs in the Middle WBZ. Based on these results, all of the above listed VOCs are initially retained as groundwater COPCs in the NERT Off-Site Study Area component of OU-2 west of Pabco Road and are subject to secondary screening as described in Section 8.3.2.3.

8.3.2 Secondary Groundwater COPC Screening

Based on the discussion above, constituents remaining as potential groundwater COPCs in OU-2 from the initial screening, including the Administratively Limited COPCs, are shown in Table 8-2. These remaining constituents are subjected to secondary screening as discussed in the following sections. Secondary screening criteria included:

- Evaluating each constituent’s nature and extent in groundwater beneath OU-2 (e.g., distribution and magnitude of groundwater concentrations above GWSLs; widespread distribution vs. localized occurrences; distribution consistent with an anthropogenic source; clear evidence that the constituent migrated from OU-1);
- Further evaluation of the relevant constituent’s detection frequency in each WBZ; and
- Evaluating other chemical-specific and/or site-specific factors (e.g., contaminant mobility; indication that impacts may be from other sources other than migration from OU-1).

The results of the secondary screening of groundwater COPCs for OU-2 are discussed in the following sections. If a constituent is retained during this secondary screening process, then the extent of contamination will be described in Section 8.5.

8.3.2.1 Chlorates and General Chemistry

As noted in Section 8.3.1.1, the following chlorate/general chemistry constituents were retained for secondary screening: perchlorate, chlorate, bromide, nitrate (as N), and nitrate/nitrite (as N). The secondary screening of these constituents and determinations whether to retain or exclude these constituents as COPCs for groundwater in OU-2 are discussed below. As shown in Tables 7-2b and 8-2, nitrite was identified as a COPC in OU-1 groundwater. However, in OU-2 nitrite was not retained as a COPC because with respect to sampling conducted in the NERT Off-Site Study Area component of OU-2 west of Pabco Road, it was detected at a frequency of less than 5% in the Shallow WBZ (0-40 ft bgs) and it was detected below the GWSL in both the Shallow WBZ (~40-90 ft bgs) and the Middle WBZ.

Perchlorate

The distribution of perchlorate in groundwater in OU-2 is shown in multiple figures within this report, including Figures 8-4a through 8-4e. These figures show that perchlorate is widely distributed throughout OU-2 and is above its GWSL to depths of 177 ft bgs. Based on this evaluation, and because perchlorate is an Administratively Limited COPC, perchlorate is retained as a COPC for groundwater throughout the entirety of OU-2, and its extent will be discussed in greater detail in Section 8.5.

Chlorate

The distribution of chlorate in groundwater in OU-2 is shown in Figures 8-5a through 8-5e. These figures show that chlorate is widely distributed throughout OU-2 and is above its GWSL to depths of 110 ft bgs. Based on this evaluation, and because chlorate is an Administratively Limited COPC, chlorate is retained as a COPC for groundwater throughout the entirety of OU-2, and its extent will be discussed in greater detail in Section 8.5.

Bromide

The distribution of bromide in the Shallow WBZ in the NERT Off-Site Study Area component of OU-2 west of Pabco Road is shown in Figures 8-6a, 8-6b, and 8-6c. As these figures show, bromide is not widely distributed in either shallow groundwater depth interval. As shown in Figure 8-6a, bromide was also not detected above the GWSL in the Middle WBZ. Where detected, the bromide concentrations were only slightly above the GWSL. One apparent isolated outlier occurs in the southwest corner of OU-2 (in shallow groundwater at well H-49R at a concentration of 220 mg/L). However, this detection is isolated in horizontal extent. In nearby downgradient wells bromide is not detected or detected at concentrations just slightly above the detection limit. Although bromide is a COPC in groundwater in OU-1, its extent in OU-2 is limited and the data suggests that bromide originating in OU-1 has not migrated off-site as indicated by the absence of its detection in groundwater south of well H-49R. Therefore, bromide is not retained as a COPC for groundwater in OU-2.

Nitrate (as N), Nitrite (as N), and Nitrate/Nitrite (as N)

Consistent with the methodology discussed earlier related to OU-1, nitrate/nitrite (as N) in OU-2 is a calculated value reflecting the sum of nitrate and nitrite and has a more conservative GWSL than the sum of the individual GWSLs for nitrate (as N) and nitrite (as N). Evaluation of the distribution of nitrate (as N) and nitrite (as N) in groundwater in the NERT Off-Site Study Area component of OU-2 west of Pabco Road is represented by the distribution of nitrate/nitrite (as N) in the Shallow WBZ as shown in Figures 8-7a, 8-7b, and

8-7c. Nitrate/nitrite (as N) was not detected above the GWSL in the Middle WBZ. As Figure 8-7b shows, nitrate/nitrite (as N) is widely distributed in shallow groundwater, and some concentrations are significantly higher than the GWSL. Based on this evaluation, nitrate/nitrite (as N) is retained as a COPC for groundwater in the NERT Off-Site Study Area component of OU-2 west of Pabco Road.

8.3.2.2 Metals

As noted in Section 8.3.1.2, the following metals were retained for secondary screening: arsenic, boron, chromium (total) and hexavalent chromium, iron, magnesium, manganese, strontium, and vanadium. The secondary screening of these metals and final determinations whether to retain or exclude them as COPCs for groundwater in the NERT Off-Site Study Area component of OU-2 west of Pabco Road are discussed below.

Arsenic

The distribution of arsenic in the Shallow WBZ in the NERT Off-Site Study Area component of OU-2 west of Pabco Road is shown in Figures 8-8a, 8-8b, and 8-8c. Evaluation of the distribution and extent of arsenic in these figures indicates that it is widely distributed in the Shallow WBZ with most concentrations slightly above the GWSL. Based on this evaluation, arsenic is retained as a COPC for groundwater in the NERT Off-Site Study Area component of OU-2 west of Pabco Road.

Boron

The distribution of boron in the Shallow WBZ in the NERT Off-Site Study Area component of OU-2 west of Pabco Road is shown in Figures 8-9a, 8-9b, and 8-9c. As shown in Figure 8-9a, boron was not detected above the GWSL in the Middle WBZ. Evaluation of the distribution and extent of boron in these figures indicates that it is widely distributed in the Shallow WBZ with a significant number of concentrations slightly above the GWSL. Based on this evaluation, boron is retained as a COPC for groundwater in the NERT Off-Site Study Area component of OU-2 west of Pabco Road.

Chromium (total) and Chromium (hexavalent)

As previously discussed in Section 7, detailed analysis of hexavalent chromium to total chromium ratios was performed as part of the 2016 Groundwater Monitoring Optimization Plan (Ramboll Environ 2016a). The results of the analysis indicated that the concentration of total chromium is generally equal to the concentration of hexavalent chromium within the NERT groundwater plume. With NDEP approval, hexavalent chromium was generally eliminated from NERT's on-going monitoring program in 2016. Therefore, total chromium and hexavalent chromium are not regarded as separate COPCs and interpretations of the lateral and vertical extent of chromium in groundwater will rely on total chromium data (rather than hexavalent chromium data).

The distribution of total chromium in the Shallow WBZ in the NERT Off-Site Study Area component of OU-2 west of Pabco Road is shown in Figures 8-10a, 8-10b, and 8-10c. As summarized in Table 8-1c and shown in Figure 8-10a, total chromium was not detected above the GWSL in the Middle WBZ (although hexavalent chromium was detected above the GWSL). Figures 8-10b and 8-10c show that total chromium is widely distributed in the Shallow WBZ. Most of the concentrations are above the GWSL, a distribution consistent with migration in shallow groundwater from upgradient operational areas in OU-1. Based on this evaluation, chromium is retained as a COPC for groundwater in the NERT Off-Site Study Area component of OU-2 west of Pabco Road.

Iron

The distribution of iron in the Shallow WBZ in the NERT Off-Site Study Area component of OU-2 west of Pabco Road is shown in Figures 8-11a, 8-11b, and 8-11c. As shown in Figure 8-11a, iron was not detected in the Middle WBZ. Evaluation of the distribution and extent of iron in these figures indicates that it is not widely distributed in groundwater and the detected concentrations are generally well below the GWSL. One outlier was detected in shallow groundwater in the southwest corner of OU-2; the sample collected from well H-48 had a concentration of 3,900 mg/L. Well H-48 is an older well that is constructed of iron casing. In addition, iron concentrations were not detected in wells adjacent to Well H-48. Furthermore, as previously discussed in Section 7, iron is not considered a COPC in groundwater in OU-1. As such, iron is not retained as a COPC for groundwater in OU-2.

Magnesium

The distribution of magnesium in the Shallow WBZ in the NERT Off-Site Study Area component of OU-2 west of Pabco Road is shown in Figures 8-12a, 8-12b, and 8-12c. as shown in Figure 8-12a, magnesium was not detected above the GWSL in the Middle WBZ. As these figures show, magnesium is widely distributed throughout the Shallow WBZ with many concentrations above the GWSL. Based on this evaluation, magnesium is retained as a COPC for groundwater in the NERT Off-Site Study Area component of OU-2 west of Pabco Road.

Manganese

The distribution of manganese in the Shallow WBZ in the NERT Off-Site Study Area component of OU-2 west of Pabco Road is shown in Figures 8-13a, 8-13b, and 8-13c. As shown in Figure 8-13b, manganese is widely distributed in the Shallow WBZ (0-40 ft bgs) interval with many concentrations above the GWSL. Manganese was not detected above the GWSL in the Shallow WBZ (~40-90 ft bgs) interval (Figure 8-13c), and it was not detected in the Middle WBZ (Figure 8-13a). Given its wide distribution in the Shallow WBZ (0-40 ft bgs) interval, manganese is retained as a COPC for groundwater in the NERT Off-Site Study Area component of OU-2 west of Pabco Road.

Strontium

The distribution of strontium in the Shallow WBZ in the NERT Off-Site Study Area component of OU-2 west of Pabco Road is shown in Figures 8-14a, 8-14b, and 8-14c. Strontium was not detected above the GWSL in the Shallow WBZ (~40-90 ft bgs) interval (Figure 8-14c) or the Middle WBZ (Figure 8-14a). Evaluation of the distribution and extent of strontium in Figure 8-14b indicates that it is widely distributed in the Shallow WBZ (0-40 ft bgs) interval in the upgradient portion of the NERT Off-Site Study Area, but at generally low concentrations. A few locations in the southern part of OU-2 have concentrations that are slightly above the GWSL (the maximum concentration detected was 28 mg/L versus a GWSL of 20 mg/L). However, these slightly elevated concentrations do not appear to be reflective of contamination that is migrating from OU-1 (where strontium is a COPC) or from any other anthropogenic source, as strontium is not found above the GWSL in wells adjacent to the

OU-1/OU-2 boundary. Concentrations in the more northerly part of OU-2 (downgradient wells) are all below the GWSL. Strontium is therefore not retained as a COPC for groundwater in OU-2.

Vanadium

The distribution of vanadium in the Shallow WBZ in the NERT Off-Site Study Area component of OU-2 west of Pabco Road is shown in Figures 8-15a, 8-15b, and 8-15c. Vanadium was not detected above the GWSL in the Shallow WBZ (~40-90 ft bgs) interval (Figure 8-15c) or the Middle WBZ (Figure 8-15a). As shown in Figure 8-15b, vanadium is widely distributed throughout the NERT Off-Site Study Area component of OU-2 west of Pabco Road in the Shallow WBZ (0-40 ft bgs) interval, but at generally low concentrations with just a few concentrations that are above the GWSL. Furthermore, as previously discussed in Section 7, vanadium is not considered a COPC in groundwater in OU-1. As such, vanadium is not retained as a COPC for groundwater in OU-2.

8.3.2.3 VOCs

As noted in Section 8.3.1.3, the following VOCs were retained for secondary screening: benzene, bromodichloromethane, bromoform, carbon tetrachloride, chlorobenzene, chloroform, 1,1-DCA, 1,4-dioxane, hexachlorobutadiene, methylene chloride, naphthalene, PCE, TCE, and 1,2,3-trichloropropane. The secondary screening of these VOCs and final determinations whether to retain or exclude them as groundwater COPCs in the NERT Off-Site Study Area component of OU-2 west of Pabco Road are discussed below. As shown in Tables 7-2b and 8-2, several additional VOCs were identified as COPCs in OU-1 groundwater:1,2-dichlorobenzene, 1,3-dichlorobenzene, 1,4-dichlorobenzene, 1,2-DCA,1,1-DCE, and 1,1,2,2-tetrachloroethane. However, in OU-2 west of Pabco Road, these VOCs were not retained as COPCs in groundwater because they were not detected above GWSLs in the Shallow WBZ (0-40 ft bgs) interval, Shallow WBZ (~40-90 ft bgs) interval, and the Middle WBZ. The remaining VOCs are discussed below.

Benzene

The distribution of benzene in the Shallow WBZ in the NERT Off-Site Study Area component of OU-2 west of Pabco Road is shown in Figures 8-16a, 8-16b, and 8-16c. These figures show that benzene was not detected above the GWSL in the Shallow WBZ (0-40 ft bgs) interval at the time of most recent sampling (Figure 8-16b), though a slight exceedance of the GWSL was observed in the initial sampling of PC-173 (Table 8-1a). However, benzene was detected at concentrations significantly above the GWSL in the Shallow WBZ (~40-90 ft bgs) interval (Figure 8-16c). As shown in Figure 8-16a, Benzene was not detected in the Middle WBZ. Since benzene concentration are significantly above GWSLs in the Shallow WBZ (~40-90 ft bgs) interval at the southwest corner of OU-2, benzene is retained as a COPC for groundwater in the NERT Off-Site Study Area component of OU-2 west of Pabco Road.

Bromodichloromethane

The distribution of bromodichloromethane in the Shallow WBZ in the NERT Off-Site Study Area component of OU-2 west of Pabco Road is shown in Figures 8-17a, 8-17b, and 8-17c. As shown in Figure 8-17a, Bromodichloromethane was not detected in the Middle WBZ. Evaluation of the distribution and extent of bromodichloromethane indicates that it is not widely distributed in the Shallow WBZ; however, a few concentrations were above the GWSL.

The highest concentrations in groundwater were limited to one location (PC-187/PC-187R), which is in the upgradient portion of OU-2 and downgradient of a GWSL exceedance in OU-1 (see Figure 7-75b). Although bromodichloromethane is a COPC in OU-1 groundwater, it is also important to note that bromodichloromethane is a trihalomethane and TTHMs are found in municipal water provided by the City of Henderson that is used for irrigation in landscaped areas throughout OU-2 (COH 2020). Since bromodichloromethane was detected significantly above the GWSL it is retained as a COPC for groundwater in the NERT Off-Site Study Area component of OU-2 west of Pabco Road.

Bromoform

The distribution of bromoform in the Shallow WBZ in the NERT Off-Site Study Area component of OU-2 west of Pabco Road is shown in Figures 8-18a, 8-18b. and 8-18c. As shown in Figure 8-18a and Table 8-1c, bromoform was not detected in the Middle WBZ. As shown in Tables 8-1a and 8-1b, bromoform was relatively infrequently detected in the Shallow WBZ (0-40 ft bgs) interval (in only 8 of 234 samples) and in the Shallow WBZ (~40-90 ft bgs) interval (in only 4 of 59 samples). Only one location has concentrations elevated slightly above the GWSL (PC-187/PC-187R). Although bromoform is a COPC in groundwater in OU-1, it is not found above the GWSL in groundwater adjacent to the OU-1/OU-2 boundary. In addition, given its low detection frequency and limited extent in OU-2, bromoform is not retained as a COPC for groundwater in OU-2.

Carbon Tetrachloride

The distribution of carbon tetrachloride in the Shallow WBZ in the NERT Off-Site Study Area component of OU-2 west of Pabco Road is shown in Figures 8-19a, 8-19b, and 8-19c. As shown in Figure 8-19a, carbon tetrachloride was not detected in the Middle WBZ. Evaluation of the distribution and extent of carbon tetrachloride indicates that it is not widely distributed in the Shallow WBZ. The highest concentrations in groundwater are slightly above the GWSL (PC-187/PC-187R) and are isolated in extent, but are downgradient of a GWSL exceedance in OU-1 (see Figure 7-77b). Since carbon tetrachloride is detected in OU-2 groundwater above the GWSL at a location downgradient of a GWSL exceedance in OU-1 it is retained as a COPC for groundwater in the NERT Off-Site Study Area component of OU-2 west of Pabco Road.

Chlorobenzene

The distribution of chlorobenzene in the Shallow WBZ in NERT Off-Site Study Area component of OU-2 west of Pabco Road is shown in Figures 8-20a, 8-20b, and 8-20c. As shown in Figure 8-20a, chlorobenzene was not detected in the Middle WBZ. Since chlorobenzene concentrations are above the GWSL throughout the Shallow WBZ in the southwest corner of OU-2, chlorobenzene is retained as a COPC for groundwater in the NERT Off-Site Study Area component of OU-2 west of Pabco Road.

Chloroform

The distribution of chloroform in the Shallow WBZ in the NERT Off-Site Study Area component of OU-2 west of Pabco Road is shown in Figures 8-21a, 8-21b, and 8-21c. As shown in Figure 8-21a, chloroform was not detected in the Middle WBZ. These figures show that chloroform is widely distributed and is above its GWSL to depths of 90 ft bgs. As a result, chloroform is retained as a COPC for groundwater in the NERT Off-Site Study Area component of OU-2 west of Pabco Road.

1,1-Dichloroethane

The distribution of 1,1-DCA in the Shallow WBZ in the NERT Off-Site Study Area component of OU-2 west of Pabco Road is shown in Figures 8-22a, 8-22b, and 8-22c. As shown in Figure 8-22a, 1,1-DCA was not detected in the Middle WBZ. These figures show that 1,1-DCA is widely distributed in shallow groundwater along the western side of this area. In general, the 1,1-DCA concentrations above the GWSL are in the Shallow WBZ in the southwest corner of OU-2. As a result, 1,1-DCA is retained as a COPC for groundwater in the NERT Off-Site Study Area component of OU-2 west of Pabco Road.

1,4-Dioxane

The distribution of 1,4-dioxane in the Shallow WBZ in the NERT Off-Site Study Area component of OU-2 west of Pabco Road is shown in Figures 8-23a, 8-23b, and 8-23c. As shown in Figure 8-23a, 1,4-dioxane was not detected in the Middle WBZ, though all detection limits are above the GWSL. These figures show that 1,4-dioxane is widely distributed and is above its GWSL in the Shallow WBZ. Based on this evaluation, 1,4-dioxane is retained as a COPC for groundwater in the NERT Off-Site Study Area component of OU-2 west of Pabco Road.

Hexachlorobutadiene

All detection limits of hexachlorobutadiene are above the GWSL, as shown in Tables 8-1a, 8-1b, and 8-1c. However, even the highest detection limits in OU-2 are not significantly above the GWSL as they are in OU-1. As these tables indicate, hexachlorobutadiene was detected in groundwater at only one groundwater well (M-48A; north of Warm Springs Road) screened within the Shallow WBZ and was not detected in the Middle WBZ. This detection was only slightly above the GWSL. Hexachlorobutadiene is not associated with historical activities in OU-1, was not retained as a COPC for groundwater in OU-1, and is not found above the GWSL in groundwater just south of the OU-1/OU-2 boundary (Figure 7-95b and Figure 7-95c). Based on this evaluation, hexachlorobutadiene is not retained as a COPC for groundwater in OU-2.

Methylene Chloride

The distribution of methylene chloride in the Shallow WBZ in the NERT Off-Site Study Area component of OU-2 west of Pabco Road is shown in Figures 8-24a, 8-24b, and 8-24c. As shown in Figure 8-24a, methylene chloride was not detected above the GWSL in the Middle WBZ. Methylene chloride was relatively infrequently detected in the Shallow WBZ (0-40 ft bgs) interval (in only 20 of 234 samples) and in the Shallow WBZ Shallow WBZ (~40-90 ft bgs) interval (in only 12 of 59 samples). These detections are relatively isolated in extent and only two are elevated slightly above the GWSL. Although methylene chloride is a COPC in groundwater in OU-1, it is not found above the GWSL in wells adjacent to the OU-1/OU-2 boundary. In addition, given its low detection frequency and limited extent in OU-2, methylene chloride is not retained as a COPC for groundwater in OU-2.

Naphthalene

All detection limits of naphthalene are above the GWSL, as shown in Tables 8-1a, 8-1b, and 8-1c. However, even the highest detection limits in OU-2 are not significantly above the GWSL as they are in OU-1. As these tables indicate, naphthalene was detected in groundwater at only one groundwater well (MC-MW-36; north of the OSSM well field) screened within the Shallow WBZ and was not detected in the Middle WBZ. This detection was only slightly above the GWSL. Naphthalene was not retained as a COPC for groundwater in OU-1 and is not found above the GWSL in groundwater just south of the OU-1/OU-2 boundary (Figure 7-88b and Figure 7-88c). Based on this evaluation, naphthalene is not retained as a COPC for groundwater in OU-2.

Tetrachloroethene

The distribution of PCE in the Shallow WBZ in the NERT Off-Site Study Area component of OU-2 west of Pabco Road is shown in Figures 8-25a, 8-25b, and 8-25c. Figure 8-25b shows that in the Shallow WBZ (0-40 ft bgs) interval, PCE was detected above the GWSL at several locations. PCE was not detected at concentrations above the GWSL in the Shallow WBZ (~40-90 ft bgs) interval (Figure 8-25c) and was not detected in the Middle WBZ (Figure 8-25a). Given that there are several detections above the GWSL in the Shallow WBZ (0-40 ft bgs) interval, PCE is retained as a COPC for groundwater in the NERT Off-Site Study Area component of OU-2 west of Pabco Road.

Trichloroethene

The distribution of TCE in the Shallow WBZ in the NERT Off-Site Study Area component of OU-2 west of Pabco Road is shown in Figures 8-26a, 8-26b, and 8-26c. These figures show that TCE was detected at concentrations above the GWSL only in the Shallow WBZ (0-40 ft bgs) interval (Figure 8-26b), was not detected at concentrations above the GWSL in the Shallow WBZ (~40-90 ft bgs) interval (Figure 8-26c), and was not detected in the Middle WBZ (Figure 8-26a). Although widely detected in the Shallow WBZ (0-40 ft bgs) interval, TCE was detected at only two locations above the GWSL. Based on the low number of detected concentrations above the GWSL and the fact that TCE is not found above the GWSL in groundwater adjacent to the OU-1/OU-2 boundary, TCE is not retained as a COPC for groundwater in OU-2.

1,2,3-Trichloropropane

The distribution of 1,2,3-trichloropropane in the Shallow WBZ in the NERT Off-Site Study Area component of OU-2 west of Pabco Road is shown in Figures 8-27a, 8-27b, and 8-27c. As shown in Figure 8-27a, 1,2,3-trichloropropane was not detected in the Middle WBZ, though all detection limits are above the GWSL. These figures show that 1,2,3-trichloropropane is widely detected throughout the Shallow WBZ (0-40 ft bgs) interval and is above its GWSL in both the Shallow WBZ (0-40 ft bgs) interval and the Shallow WBZ (~40-90 ft bgs) interval. As a result, 1,2,3-trichloropropane is retained as a COPC for groundwater in the NERT Off-Site Study Area component of OU-2 west of Pabco Road.

8.4 Summary of OU-2 COPCs

Based on the initial and secondary screening of groundwater data in the OU-2 Groundwater Data Set, the COPCs for OU-2 groundwater and soil below 10 ft bgs in the Eastside Sub-Area component of OU-2 east of Pabco Road are presented in Table 8-2. The COPCs for groundwater in OU-1 are also shown in Table 8-2 for reference. Table 8-2 presents the COPCs for OU-2 based on the analyses presented in the prior sections, compares the COPCs for groundwater in OU-2 to the COPCs for groundwater in OU-1, and further depicts that all COPCs for groundwater in OU-2 are also COPCs for groundwater in OU-1. A total of 17 COPCs were retained for OU-2 groundwater in comparison to the 34 COPCs retained in OU-1 groundwater.

8.5 Nature and Extent of COPCs in Groundwater

This section presents a discussion of the nature and extent of retained COPCs in groundwater within OU-2. As discussed above, COPCs for groundwater in OU-2 were identified through the initial and secondary screening process. As discussed previously, the groundwater COPCs applicable to the Eastside Study Area are administratively limited to chlorate and perchlorate.

Using a similar approach to the evaluation conducted in OU-1, COPCs for groundwater in OU-2 have been divided into two categories, Primary COPCs and Other COPCs, with Primary COPCs being identified by their widespread presence and mobility in groundwater. The OU-2 COPCs in groundwater are as follows:

- Primary COPCs
    - Perchlorate (throughout OU-2);
    - Chlorate (throughout OU-2);
    - Chromium (hexavalent – limited to the NERT Off-Site Study Area component of OU-2 west of Pabco Road); and
    - Chloroform (limited to the NERT Off-Site Study Area component of OU-2 west of Pabco Road).
- Other COPCs (all limited to the NERT Off-Site Study Area component of OU-2 west of Pabco Road)
    - Nitrate/nitrite;
    - Arsenic, boron, magnesium, and manganese; and
    - Benzene, bromodichloromethane, carbon tetrachloride, chlorobenzene, 1,1-DCA, 1,4-dioxane, PCE, and 1,2,3-trichloropropane.

A summary of the analytical results for all the COPCs in the wells sampled as part of the OU-2 RI is presented in Tables 8-3a and 8-3b. The complete groundwater analytical results are presented in Appendix J.

8.5.1 OU-2 Groundwater Primary COPCs

As discussed above, perchlorate, chlorate, chloroform, and chromium have been identified as OU-2 Primary COPCs in groundwater, with the latter two only applicable to the NERT Off-Site Study Area component of OU-2 west of Pabco Road. The nature and extent of NERT Primary COPCs in OU-2 groundwater is discussed below.

8.5.1.1 Perchlorate

Based on the wide distribution of elevated concentrations of perchlorate in groundwater throughout OU-2, this constituent is considered a Primary COPC. To illustrate the lateral and vertical extent of perchlorate in groundwater within OU-2, perchlorate concentrations in four depth intervals are shown in a series of figures. Overall, the depth to groundwater is shallower in OU-2 than in OU-1. In addition, as described in Section 8.3.1, the depth to first groundwater in OU-2 varies between the NERT Off-Site Study Area west of Pabco Road and the Eastside Sub-Area east of Pabco Road. As a result, the depth intervals for the wells grouped in the Shallow WBZ (~40-90 ft bgs) interval vary slightly depending on the localized conditions. Perchlorate concentrations in the shallow groundwater (water table interval) are shown in Figure 8-4b with a detail map of the NERT Off-Site Study Area component of OU-2 west of Pabco Road presented in Figure 8-28a. Figure 8-4c shows perchlorate concentrations in the Shallow WBZ (~40-90 ft bgs) interval with a detail of the NERT Off-Site Study Area component of OU-2 west of Pabco Road presented in Figure 8-28b. Figures 8-4d and 8-4e show perchlorate concentrations in the Middle WBZ and Deep WBZ, respectively. The vertical extent of perchlorate is depicted on south-north subsurface cross-section L-L’ and on the east-west subsurface cross-sections K-K’, K’-K” and K”-K’’’ transects along the northern OU-2/OU-3 boundary, which are presented in Figures 8-29a through 8-29d. A complete set of full-scale subsurface cross-sections within OU-2 is presented in Appendix C. The nature and extent of perchlorate in these depth intervals is discussed below. Based on the results presented, the horizontal and vertical extent of contamination has been adequately delineated throughout the entirety of OU-2. In addition, the commingling of the AMPAC plume within OU-2 near the AWF at the OU-2/OU-3 boundary is well understood and is discussed below and in Section 9.5.1.1.

Shallow WBZ (0-40 ft bgs)

Perchlorate concentrations in the Shallow WBZ (0-40 ft bgs) depth interval in OU-2 are shown in Figure 8-4b along with the current extent of saturated alluvium. As shown in Figure 8-4b, the perchlorate plume originating from OU-1 and extending north through OU-2 is separate from a second perchlorate plume to the west, which originates from the former AMPAC site. The two separate plumes become partly commingled west of the AWF near the northwestern OU-2/OU-3 boundary.

West of Pabco Road, much of the alluvium remains saturated. As discussed in Section 5.4.2, 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 underlying 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 hydraulic conductivity than the adjacent, well-graded deposits. A major paleochannel system (up to 60 feet deep) is located roughly parallel to the western OU-2 boundary and extends from Warm Springs Road north to the OU-2/OU-3 boundary. A second smaller paleochannel extends from south to north in the eastern part of the NERT Off-Site Study Area component of OU-2, roughly parallel to Pabco Road. The two paleochannels are intercepted by the AWF which has operated nearly continuously since 2002 along Galleria Drive near the northern OU-2 boundary. The presence of these two high-conductivity paleochannels in close relative proximity near the northern OU-2 boundary made this the preferred location for an extraction well field. The perchlorate extracted at the AWF represents approximately 40% of the perchlorate captured by the GWETS.

A map showing perchlorate in the NERT Off-Site Study Area component of OU-2 west of Pabco Road is presented in Figure 8-28a. As shown in Figure 8-28a, the area of highest concentrations within the NERT Off-Site Study Area generally extends from the southern OU-2 boundary near Warm Springs Road north to the AWF along Galleria Drive. The highest perchlorate concentrations are found in the area between the east and west paleochannels, where the saturated alluvium is thinner and there is less groundwater flow to flush perchlorate from the alluvium over time. As shown in Figure 8-28a, perchlorate concentrations in groundwater in the southwest portion of OU-2 (north of Warm Springs Road) range from 580 mg/L at well PC-73 to 120 mg/L at wells M-48A and PC-65. Well PC-187, which was sampled before it was decommissioned, and its replacement well, PC-187R, are located along a paleochannel that extends into OU-2 from OU-1. Perchlorate concentrations in groundwater from these two wells were 980 J- and 1,200 mg/L, the highest in the NERT Off-Site Study Area (and all of OU-2).

Figure 8-28a also shows that perchlorate concentrations in groundwater along the northern OU-2 boundary are one to two orders of magnitude lower, ranging from 16 mg/L in well ARP-4A to 41 mg/L in well ARP-2A. As can be seen in Figure 8-28a, perchlorate from the AMPAC plume to the west becomes partly commingled with the NERT plume near the western end of the AWF (also depicted in Figure 8-4b). Consequentially, this commingling of the AMPAC plume with the NERT plume contributes to the perchlorate migrating in shallow groundwater from OU-2 immediately north of the AWF into OU-3. As discussed within Endeavour's 2017 Shallow Zone Capture Assessment, most perchlorate mass from the AMPAC plume is captured by a series of Endeavour-operated extraction wells along Galleria Drive, which are separate from NERT's extraction well system (Geosyntec 2017). As expected, the report also finds that NERT's extraction wells (within both the AWF and SWF) capture a portion of the east side of the AMPAC plume (Geosyntec 2017).

As discussed throughout this section, the alluvium has become dewatered east of Pabco Road except in the southwest part of the Eastside Sub-Area. As a result, the perchlorate in the shallow water table wells occurs primarily in the UMCf-fg1, and the paleochannels identified in the alluvium do not affect groundwater flow and transport of perchlorate from the Eastside Sub-Area since they are largely dry. Perchlorate concentrations above the GWSL of 0.015 mg/L are widely distributed in shallow groundwater throughout the Eastside Sub-Area. As illustrated by the 1 mg/L contour shown in Figure 8-4b, the highest concentrations within the Eastside Sub-Area are generally found in the area north of the former Beta Ditch and former unlined wastewater ponds ranging from 1.0 mg/L to 19 mg/L. These elevated concentrations are consistent with the historical industrial use in this area. Perchlorate concentrations along the northern OU-2 boundary with OU-3 range from 0.76 mg/L to 17 mg/L except in the northeast corner of the Eastside Sub-Area where perchlorate concentrations are below the BCL (wells DBMW-17, DBMW-18, and BEC-12). This area is outside the area occupied by the former ponds. Although the perchlorate concentrations along much of the southeastern boundary of OU-2 (along Lake Mead Parkway) are still above the GWSL, they are below its upgradient concentration as identified by NDEP (NDEP 2016a). As such, additional investigation upgradient of the southeastern boundary of OU-2 is not necessary.

Shallow WBZ (~40-90 ft bgs)

Perchlorate concentrations in the Shallow WBZ (~40-90 ft bgs) depth interval in OU-2 are shown in Figure 8-4c, and the distribution of perchlorate in the NERT Off-Site Study Area component of OU-2 west of Pabco Road is presented in Figure 8-28b. These figures illustrate perchlorate concentrations in the UMCf-fg1 and in the Shallow WBZ. The data have been contoured to the perchlorate GWSL of 0.015 mg/L, as shown with a brown dashed line in the figure. As discussed previously, in the NERT Off-Site Study Area component of OU-2, the 20 wells completed in the Shallow WBZ (~40-90 ft bgs) depth interval are all screened in the UMCf-fg1. Data are also available from three wells that were sampled before being decommissioned. As shown in Figures 8-4c and 8-28b, the distribution of perchlorate at concentrations greater than 1 mg/L is generally consistent with the distribution in the Shallow WBZ (0-40 ft bgs) wells, but overall concentrations are lower. Perchlorate concentrations range from 100 mg/L in well PC-188 near the southern boundary at Warm Springs Road to below 10 mg/L at the northern boundary of OU-2 near the AWF. The highest perchlorate concentration was detected in well PC-193 (360 mg/L).

In the Eastside Sub-Area, the depth to the water table is greater. Accordingly, Figure 8-4c represents perchlorate concentrations for wells screened within a depth interval of approximately 55-90 ft bgs. The 18 wells completed in this depth interval are all screened in the UMCf-fg1. Similar to the NERT Off-Site Study Area, the distribution of perchlorate at concentrations greater than 1 mg/L in the Eastside Sub-Area is generally consistent with the distribution in the Shallow WBZ (0-40 ft bgs) interval wells, but overall concentrations are lower. The highest perchlorate concentration within the Eastside Sub-Area was detected in groundwater at well ES-4 (23 mg/L) located near the former Beta Ditch. Along the northern OU-2/OU-3 boundary, perchlorate concentrations in groundwater range from 4.0 mg/L on the western side to 0.0011 J mg/L on the eastern side.

Similar to the Shallow WBZ (0-40 ft bgs) interval, the NERT perchlorate plume is bounded to the west by the AMPAC plume and the east/southeast at the OU boundary (along Lake Mead Parkway). Although the perchlorate concentrations along much of the southeastern boundary of OU-2 are still above the GWSL, they are below its upgradient concentration as identified by NDEP (NDEP 2016a). Accordingly, additional investigation upgradient of the southeastern boundary of OU-2 is not necessary.

Middle WBZ (90-300 ft bgs)

Figure 8-4d provides an overview of OU-2 showing perchlorate detections in the Middle WBZ (90-300 ft bgs). In the NERT Off-Site Study Area component of OU-2 west of Pabco Road, three wells are screened in the Middle WBZ. Perchlorate was detected in well M-152, screened from 125-145 ft bgs, at a concentration of 0.13 mg/L, which is above the GWSL of 0.015 mg/L. Perchlorate was not detected in well M-156 screened from 175-195 ft bgs. In well TR-12 screened from 272-292 ft bgs, perchlorate was detected at a concentration of 0.012 mg/L, below the GWSL.

In the Eastside Sub-Area component of OU-2 east of Pabco Road, two of the 16 Middle WBZ wells could not be sampled in 2018 because they had been paved over and/or abandoned during area re-development. For these two wells (MCF-02B and MCF-12C), the most recent groundwater data from 2009 are shown. Perchlorate was not detected in four of the 16 wells, although the detection limit for the sample collected from well MCF-24B was higher than the perchlorate GWSL of 0.015 mg/L due to matrix interference from naturally occurring salts in the samples. In samples collected from two other wells (ES-10 and MCF-02B), the perchlorate concentrations were below the GWSL. The highest perchlorate concentrations were detected in groundwater samples collected from wells ES-1 (45 mg/L), ES-8B (3.5 mg/L), and ES-13 (7.6 mg/L). These three wells are screened in the upper Middle WBZ in the 90 and 110 ft bgs depth interval. Concentrations in the other seven Middle WBZ wells were below 1 mg/L, ranging from 0.016 J+ mg/L to 0.65 mg/L.

Deep WBZ (>300 ft bgs)

Perchlorate concentrations in the Deep WBZ are shown in Figure 8-4e. Eight of the 17 Deep WBZ wells could not be sampled in 2018 because they had been paved over and/or abandoned during area redevelopment. For these eight wells, the most recent data from 2009 are shown. At least one well (MCF-19A) has been decommissioned. Perchlorate was not detected in 15 of the 17 wells sampled, although in five wells the detection limit was higher than the perchlorate GWSL of 0.015 mg/L due to matrix interference from naturally occurring salts in the samples. At the two wells where perchlorate was detected, the perchlorate concentrations were 2.8 mg/L at well MCF-24A and 0.51 J mg/L at well MCF-02A (sampled in 2009). Given that perchlorate was only detected at two locations above detection limits (with one location just above the upgradient level), the relatively low permeability of the UMCf, and the upward gradient between the Deep, Middle, and Shallow WBZs, NERT concludes that the vertical extent of contamination has been adequately delineated.

Vertical Extent of Perchlorate in OU-2

The difference between the depth of perchlorate impacted groundwater in the southern and northern areas of the NERT Off-Site Study Area component of OU-2 can be seen in Figure 8-29a, Subsurface Cross-Section L-L’. Based on the perchlorate concentrations in well M-152, perchlorate is detected above the GWSL to depths of 145 feet in the southern area near the OU-1/OU-2 boundary. The depth of perchlorate above the GWSL decreases to less than 90 ft bgs in the northern area near the OU-2/OU-3 boundary. Subsurface Cross-Section K-K’ shown in Figure 8-29b further illustrates the vertical extent of perchlorate and other Primary COPCs in groundwater north of the AWF along the OU-2/OU-3 boundary. Similar to the data shown in L-L’, perchlorate concentrations in groundwater above the GWSL are limited to the Shallow WBZ (i.e., above a depth of 90 ft bgs).

The vertical extent of perchlorate in groundwater along the Eastside Sub-Area northern boundary is illustrated in subsurface cross-sections K’-K” and K”-K’’’, which are presented in Figures 8-29c and 8-29d, respectively. As shown in these cross-sections, perchlorate concentrations above the GWSL extend to depths of 110 ft bgs at several locations along the OU-2/OU-3 boundary. At the eastern end of OU-2/OU-3 boundary, perchlorate was also detected in groundwater above the GWSL in a deeper sandy silt lens between 157-177 ft bgs (see Figure 8-29d).

8.5.1.2 Chlorate

Similar to its distribution in OU-1, the current distribution of chlorate in OU-2 groundwater is generally similar to perchlorate, and as such, it is considered a Primary COPC. To illustrate the lateral and vertical extent of chlorate in groundwater within the NERT Off-Site Study Area component of OU-2 west of Pabco Road, chlorate concentrations in four depth intervals are shown in a series of figures. Chlorate concentrations in the Shallow WBZ (0-40 ft bgs) interval are shown in Figures 8-5b with a detail map of the NERT Off-Site Study Area component of OU-2 presented in Figure 8-30. The shape and highest concentrations within the chlorate plume depicted in Figure 8-5b is very similar to the perchlorate plume depicted in Figure 8-4b, and this similarity is discussed in further detail in Section 9.5.1.4. Figure 8-5c shows chlorate concentrations in the Shallow WBZ (~40-90 ft bgs) interval. Figures 8-5d and 8-5e show chlorate concentrations in the Middle WBZ and Deep WBZ, respectively. Based on the results presented, the horizontal and vertical extent of contamination has been adequately delineated throughout OU-2. With respect to the commingling AMPAC plume as discussed earlier, chlorate in the AMPAC plume is also commingling with the NERT chlorate plume. However, chlorate concentrations in the AMPAC plume are significantly lower than concentrations in the NERT plume.

Shallow WBZ (0-40 ft bgs)

The distribution of chlorate in OU-2 based on groundwater sampling results obtained between 2015 to 2018 is shown in Figure 8-5b with the additional detail in the NERT Off-Site Study Area component of OU-2 west of Pabco Road shown in Figure 8-30.

As shown in Figures 8-5b and 8-30, in the NERT Off-Site Study Area component of OU-2, chlorate concentrations between 100 and 500 mg/L extend from the OU-1 boundary with OU-2 north to the AWF and the OU-2 boundary with OU-3. The highest concentrations (above 500 mg/L) are found in the southern area closest to OU-1. In this area, chlorate is present at 1,100 J mg/L in well PC-187 and above 500 mg/L in several wells including M-44, M-94, PC-73, PC-54, PC-65, and PC-187R with concentrations ranging from 540 mg/L to 870 mg/L.

As shown in Figure 8-5b, chlorate concentrations above the GWSL of 1 mg/L are generally detected in groundwater located in the central and northern portions of the Eastside Sub-Area (i.e., in the area previously occupied by the former ditches and unlined wastewater ponds). Chlorate concentrations in groundwater above the GWSL in the Eastside Sub-Area interior range from 2.4 mg/L (well AA-01) to 160 mg/L (well AA-09). Along the northern OU-2 boundary, chlorate concentrations in groundwater range from 81 mg/L in well DBMW-5 on the western side to 1.5 mg/L in well DBMW-15 on the eastern side of the boundary. In the southern (upgradient) and eastern side of the Eastside Sub-Area along Lake Mead Parkway, chlorate is either not detected or concentrations are below the GWSL and defines the eastern extent of perchlorate migration. As discussed in Section 8.5.1.1 and shown in Figures 8-4b and 8-28a, perchlorate from the AMPAC plume becomes partly commingled with perchlorate from the NERT plume near the western end of the AWF. Chlorate is also present in the AMPAC plume and trespasses into OU-2 above the GWSL of 1 mg/L, though the chlorate concentrations in the AMPAC plume are significantly lower than those in the NERT plume. This is because chlorate was only generated as a byproduct of perchlorate production at the AMPAC site, whereas chlorate was produced as a product for sale at the NERT Site. Figures 8-5b and 8-30 show a pattern of low chlorate concentrations (<10 mg/L) in the AMPAC plume commingling with high chlorate concentrations of the NERT plume, similar to the pattern observed in the perchlorate plumes. The lower chlorate concentration of the AMPAC plume is an important characteristic to distinguish the NERT and AMPAC plumes and will be discussed in the forthcoming RI Report for OU-3.

Shallow WBZ (~40-90 ft bgs)

Figure 8-5c presents chlorate concentrations in the Shallow WBZ (~40-90 ft bgs) depth interval. As discussed previously, in the NERT Off-Site Study Area component of OU-2, the 20 wells completed in this depth interval are all screened in the UMCf-fg1. Data are also available from three wells that were sampled before being decommissioned. In general, chlorate is detected in the same areas where it is present in the Shallow WBZ (0-40 ft bgs) interval wells. Where detected, chlorate concentrations ranged from 0.13 mg/L to 770 mg/L. In most cases, chlorate concentrations in this depth interval exceed its GWSL of 1 mg/L.

In the Eastside Sub-Area where the depth to the water table is greater, Figure 8-5c represents chlorate concentrations for wells screened at depths between 55-90 ft bgs. The 18 wells completed in this depth interval are all screened in the UMCf-fg1. Chlorate concentrations were below the GWSL in six of the 18 wells. Similar to the distribution in shallow groundwater, the area where chlorate concentrations are above the GWSL is in the Eastside Sub-Area interior. Concentrations in this area range from 3.0 mg/L (well MCF-01B) to 220 mg/L (well ES-4). Five wells are located along, or close to, the northern OU-2/OU-3 boundary. Chlorate concentrations were detected above the GWSL in three of these boundary wells, ranging 1.6 mg/L to 5.3 mg/L.

Middle WBZ (90-300 ft bgs)

Figure 8-5d provides an overview of OU-2 showing chlorate detections in the Middle WBZ (90-300 ft bgs). In the NERT Off-Site Study Area component of OU-2 west of Pabco Road, three wells are screened in the Middle WBZ. Chlorate was detected in well M-152, screened from 125-145 ft bgs, at a concentration of 0.082 mg/L, which is below the GWSL of 1 mg/L. Chlorate was not detected in two deeper wells (M-156 screened from 175-195 ft bgs, and TR-12 screened from 272-292 ft bgs).

In the Eastside Sub-Area component of OU-2 east of Pabco Road, two of the 16 Middle WBZ wells could not be sampled in 2018 due to access or other constraints. One older well (LG013) has been decommissioned. Chlorate was either not detected or concentrations were below the GWSL of 1 mg/L in 11 of the 14 wells sampled in 2018. Chlorate concentrations above the GWSL were detected in wells ES-1 (48 mg/L), ES-8B (6.1 mg/L), and ES-13 (11 mg/L). These are the same three Middle WBZ wells where the highest perchlorate concentrations were detected.

Deep WBZ (>300 ft bgs)

Chlorate concentrations in the Deep WBZ are shown in Figure 8-5e. Eight of the 17 Deep WBZ wells could not be sampled in 2018 due to access or other constraints. At least one well (MCF-19A) has been decommissioned. Chlorate was not detected above the GWSL of 1 mg/L in any of the nine wells sampled in 2018.

8.5.1.3 Chromium (Hexavalent)

As previously indicated, this Primary COPC is only applicable to the NERT Off-Site Study Area component of OU-2 west of Pabco Road. Additionally, the collection of groundwater samples from the Deep WBZ in the Off-Site Study Area component of OU-2 was not required as the vertical extent of contamination is defined within the Shallow WBZ.

Shallow WBZ (0-40 ft bgs)

Chromium is widely distributed in the Shallow WBZ (0-40 ft bgs) depth interval with relatively high concentrations in groundwater making it a Primary COPC in groundwater.[82] Results for wells in the Shallow WBZ (0-40 ft bgs) interval from 2015 to 2018 are presented in units of µg/L in Figure 8-10b. Similar to perchlorate, the area of highest chromium concentrations (above 100 µg/L) within the NERT Off-Site Study Area component of OU-2 generally extends from the southern OU-2 boundary near Warm Springs Road north to the AWF at Galleria Drive. As indicated throughout this report, the shape and highest concentrations within the chromium plume in general, and as depicted in Figure 8-10b, is very similar to the perchlorate and chlorate plumes depicted in Figures 8-4b and 8-5b. Similar to perchlorate and chlorate, the highest chromium concentrations are found in the area between the east and west paleochannels, where the saturated alluvium is thinner and there is less groundwater flow. As shown in Figure 8-10b, within this area, chromium concentrations decrease by an order of magnitude between the southern (upgradient) and northern (downgradient) OU-2 boundaries, ranging from 2,000 µg/L in southern well M-48 to 200 µg/L in well ARP-6B at the OU-2/OU-3 boundary.

Shallow WBZ (~40-90 ft bgs)

Figure 8-10c illustrates chromium concentrations in the UMCf-fg1 in the Shallow WBZ (~40-90 ft bgs) depth interval. As shown in Figure 8-10c, the distribution of chromium at concentrations greater than the GWSL of 100 µg/L is generally consistent with the distribution in the Shallow WBZ (0-40 ft bgs) depth interval, but overall concentrations are lower. Chromium concentrations above the GWSL range in from 210 µg/L in groundwater at well PC-188 to 720 µg/L in groundwater at well PC-179. Chromium was not detected at concentrations above the GWSL in the vicinity of the AWF, and chromium was not detected (ND<2.5 µg/L) in wells PC-195, PC-196, and PC-197 located near the northern OU-2 boundary with OU-3.

Middle WBZ (90-300 ft bgs)

Chromium was not detected at concentrations above the GWSL in Middle WBZ wells M-152, M-156, and TR-12.

Deep WBZ (>300 ft bgs)

As indicated previously, groundwater samples were not collected from the Deep WBZ in the NERT Off-Site Study Area component of OU-2 as the vertical extent of contamination by chromium above the GWSL is defined within the Shallow WBZ.

8.5.1.4 Chloroform

As previously indicated, this Primary COPC is only applicable to the NERT Off-Site Study Area component of OU-2 west of Pabco Road. Additionally, the collection of groundwater samples from the Deep WBZ in the NERT Off-Site Study Area component of OU-2 was not required as the vertical extent of contamination is defined within the Shallow WBZ.

---

[82] As discussed in Section 7.5.1.3, this Primary COPC is often referred to as chromium instead of hexavalent chromium.

Shallow WBZ (0-40 ft bgs)

The distribution of chloroform in the Shallow WBZ (0-40 ft bgs) depth interval in the NERT Off-Site Study Area is shown in Figure 8-21b. Chloroform was detected in nearly all wells sampled in the Shallow WBZ (0-40 ft bgs) interval, but the majority of detected concentrations were well below the GWSL of 70 µg/L. Chloroform concentrations above the GWSL were found in roughly the eastern third of the NERT Off-Site Study Area component of OU-2. This eastern portion of the NERT Off-Site Study Area component of OU-2 is situated downgradient of the TIMET site and is bounded by Warm Springs Road on the south, Pabco Road on the east, and approximately the eastern half of the AWF to the north. Within this part of the NERT Off-Site Study Area, chloroform concentrations ranged from 650 µg/L in groundwater at well PC-187 near Warm Springs Road to 97 µg/L in groundwater at well PC-36 near the AWF. Just north of the AWF, chloroform concentrations in groundwater at wells ARP-6B and ARP-7 located near the OU-2 boundary with OU-3 were 330 µg/L and 310 µg/L, respectively. Of particular note, however, unlike the perchlorate, chlorate, and chromium plumes which, as discussed throughout this report, share the same general alignment, the chloroform plume has a different shape and the highest concentrations are not coincident with the highest concentrations of the other Primary COPCs, strongly indicating that a source other than OU-1 is contributing chloroform to groundwater.

Shallow WBZ (~40-90 ft bgs)

Figure 8-21c shows the distribution of chloroform in the UMCf-fg1 in the Shallow WBZ (~40-90 ft bgs) depth interval. Chloroform was detected at concentrations above the GWSL in groundwater at four of the 26 wells sampled: PC-179 (190 µg/L), PC-188 (420 µg/L), PC-189 (180 µg/L), and PC-193 (280 µg/L). Most of these concentrations are found in the southern portion of the NERT Off-Site Study Area. Most chloroform was either not detected or concentrations were below the GWSL in the vicinity of the AWF and the northern OU-2 boundary with OU-3.

Middle WBZ (90-300 ft bgs)

Chloroform was not detected (<0.25 µg/L) in groundwater within the Middle WBZ at wells M-152, M-156, and TR-12.

Deep WBZ (>300 ft bgs)

As indicated previously, groundwater samples were not collected from the Deep WBZ in the NERT Off-Site Study Area component of OU-2 as the vertical extent of contamination by chloroform is defined within the Shallow WBZ.

Summary

Based on the distribution of chloroform in OU-2, and as discussed throughout this report, there are multiple sources of chloroform migrating north of Warm Springs Road. As discussed in Section 7.5.1.4, three sources come from OU-1 groundwater that have migrated into OU-2: the trespassing OSSM contaminant plume, the Unit 4 and 5 Buildings, and the former Beta Ditch. Additionally, chloroform migrated from the TIMET site into OU-2. As shown in Figure 8-21b, chloroform is generally present at concentrations below the GWSL in OU-2 shallow groundwater directly downgradient of the OSSM site and the OSSM well field, indicating that the OSSM well field is effectively capturing chloroform from the western lobe of the OSSM plume. However, chloroform trespassing onto OU-1 is migrating in an uncontrolled manner in between the OSSM well field and the NERT GWETS. In addition to OU-1, chloroform concentrations above 1,000 µg/L are present in groundwater at the northern TIMET site boundary in the vicinity of, and downgradient of, the TIMET extraction well field and barrier wall (Figure 8-3) recently installed in 2014, which also migrate into OU-2. Migration of chloroform from the TIMET site has had a larger impact on the geometry of the chloroform plume in OU-2 given that the TIMET extraction system only began operation in 2014 while the OSSM well field and the NERT GWETS began operation in the 1980s (Figures 7-79b and 8-21b). This is discussed in greater detail in Section 9.

8.5.2 OU-2 Groundwater Other COPCs

As presented in Section 8.3, a COPC screening process was conducted for groundwater in the NERT Off-Site Study Area component of OU-2 west of Pabco Road. The nature and extent of Primary COPCs in this area is discussed above in Section 8.5.1. The nature and extent of Other COPCs in this portion of the NERT Off-Site Study Area is discussed below.

8.5.2.1 Nitrate/Nitrite (as N)

Nitrate/Nitrite (as N) concentrations with depth are shown in Figure 8-7a. Concentrations of nitrate/nitrite (as N) in the Shallow WBZ (0-40 ft bgs) depth interval and in the Shallow WBZ (~40-90 ft bgs) depth interval in the NERT Off-Site Study Area component of OU-2 west of Pabco Road are shown in Figures 8-7b and 8-7c, respectively. As shown in Figure 8-7b, nitrate/nitrite (as N) is widely distributed in shallow groundwater in the Shallow WBZ (0-40 ft bgs) depth interval. The current distribution of nitrate/nitrite (as N) in this depth interval is generally similar to perchlorate. Concentrations above the GWSL of 10 mg/L ranged from 12 mg/L (well PC-50) to 180 mg/L (temporary well PC-173).

As shown in Figure 8-7c, nitrate/nitrite (as N) was detected at concentrations above the GWSL in four wells screened in the UMCf-fg1 in the Shallow WBZ (~40-90 ft bgs) interval. Concentrations ranged from 16 mg/L (PC-193) to 59 mg/L (PC-183).

Nitrate/nitrite (as N) was not detected above its GWSL in Middle WBZ wells M-152, M-156, and TR-12 (Table 8-1c and Appendix J).

As indicated previously, groundwater samples were not collected from the Deep WBZ in the NERT Off-Site Study Area component of OU-2 as the vertical extent of nitrate/nitrite contamination above the GWSL is defined within the Shallow WBZ.

8.5.2.2 Arsenic

Arsenic concentrations with depth are shown in Figure 8-8a. Arsenic concentrations in groundwater in the Shallow WBZ (0-40 ft bgs) depth interval and the Shallow WBZ (~40-90 ft bgs) depth interval in the NERT Off-Site Study Area component of OU-2 west of Pabco Road are presented in Figures 8-8b and 8-8c, respectively. As shown in Figure 8-8b, arsenic was detected in groundwater in all wells screened in the Shallow WBZ (0-40 ft bgs) interval with one exception (H-48). Concentrations above the GWSL of 0.010 mg/L were detected in all of these samples and ranged from 0.027 mg/L in well PC-187 to 0.26 mg/L in well PC-71. This concentration range in the NERT Off-Site Study Area is generally similar to the arsenic concentrations in shallow groundwater in OU-1, which ranged from 0.011 mg/L to 0.13 mg/L (see Section 7.5.2.2). Many of the highest arsenic concentrations are found in groundwater at wells along the western NERT Off-Site Study Area boundary, which appear to be related to the OSSM site west of OU-1.

As shown in Figure 8-8c, arsenic concentrations in the UMCf in the Shallow WBZ (~40-90 ft bgs) interval were above the GWSL of 0.010 mg/L in all 26 wells sampled. In 19 wells, concentrations were below the 90th percentile upgradient level of 0.059 mg/L established by NDEP (NDEP 2016a), ranging from 0.016 mg/L to 0.046 mg/L. In seven wells, arsenic concentrations ranged from 0.064 mg/L to 0.13 mg/L.

In groundwater at Middle WBZ well M-152, arsenic was detected at a concentration of 0.047 mg/L, which is above the GWSL of 0.010 mg/L but below the upgradient level of 0.059 mg/L established by NDEP (Table 8-1c and Appendix J). Due to a malfunction with the sampling pump, a sample could not be collected from Middle WBZ well M-156 for arsenic (and other metals) analysis, as described in Section 6.3.2. Additionally the NDEP-approved RI work plan did not include collecting groundwater samples from well TR-12.

As indicated previously, groundwater samples were not collected from the Deep WBZ in the NERT Off-Site Study Area component of OU-2 as the vertical extent of arsenic contamination above the established upgradient level is likely defined within the Shallow WBZ. There is some uncertainty in the definition of vertical extent because arsenic concentrations range up to 0.12 mg/L in the northern portion of OU-2 in the UMCf and there are limited data in the Middle WBZ within OU-2. However, there are no arsenic concentrations above the established upgradient level in either OU-1 or OU-2 in the Middle WBZ. Any contamination originating in OU-1 and migrating into OU-2 would travel horizontally northward and encounter upward vertical gradients, limiting the possibility of contamination below the Shallow WBZ in the northern portion of OU-2.

8.5.2.3 Boron

Boron concentrations with depth are shown in Figure 8-9a. Concentrations of boron in the Shallow WBZ (0-40 ft bgs) depth interval and the Shallow WBZ (~40-90 ft bgs) depth interval in the NERT Off-Site Study Area component of OU-2 west of Pabco Road are shown in Figures 8-9b and 8-9c, respectively. As shown in Figure 8-9b, boron was detected in all the wells sampled in the Shallow WBZ (0-40 ft bgs) interval; however, most of the detected concentrations are below the GWSL of 6.67 mg/L. Concentrations above the GWSL are generally co-located with the area of perchlorate-impacted groundwater in the Shallow WBZ (0-40 ft bgs) interval (see Figure 8-28a) but confined to 12 wells located in the southern part of the NERT Off-Site Study Area (i.e., immediately downgradient of OU-1). In this area, boron concentrations ranged from 13 mg/L in groundwater at well PC-187R located near the OU-1/OU-2 boundary, decreasing to 6.7 mg/L in groundwater at well PC 66 located approximately 2,000 feet north.

Figure 8-9c shows the distribution of boron in the UMCf-fg1 in the Shallow WBZ (~40-90 ft bgs) interval. Boron was detected in all 26 wells sampled. Boron concentrations were above the GWSL in groundwater at two wells in the southern portion of the NERT Off-Site Study Area, PC-180 (8.1 mg/L) and PC-183 (9.1 mg/L). In the other 24 wells, concentrations were all below the GWSL of 6.67 mg/L.

In Middle WBZ well M-152, boron was detected at a concentration of 0.79 mg/L, which is below the GWSL of 6.67 mg/L (Table 8-1c and Appendix J). As discussed previously, samples were not collected from Middle WBZ wells M-156 and TR-12 for boron analysis.

As indicated previously, groundwater samples were not collected from the Deep WBZ in the NERT Off-Site Study Area component of OU-2 as the vertical extent of boron contamination above the GWSL is defined within the Shallow WBZ.

8.5.2.4 Magnesium

Magnesium concentrations with depth are shown in Figure 8-12a. Concentrations of magnesium in groundwater collected from the Shallow WBZ (0-40 ft bgs) depth interval and the Shallow WBZ (~40-90 ft bgs) depth interval in the NERT Off-Site Study Area component of OU-2 west of Pabco Road are shown in Figures 8-12b and 8-12c, respectively. As shown in Figure 8-12b, magnesium is widely distributed in the Shallow WBZ (0-40 ft bgs) interval throughout the NERT Off-Site Study Area. The majority of the magnesium concentrations above the GWSL of 189 mg/L are found in groundwater at wells along the western NERT Off-Site Study Area boundary, where concentrations range from 210 mg/L to 470 mg/L. As described in Section 7.5.2.2, in OU-1 the highest magnesium concentrations were found in groundwater at 10 wells located along the western OU-1 boundary extending to Warm Springs Road (northern OU-1 boundary). These elevated magnesium concentrations in the western side of both OU-1 and the NERT Off-Site Study Area appear to be related to the OSSM site located west of OU-1. In the NERT Off-Site Study Area, magnesium concentrations above the GWSL were also found in 10 wells located near the eastern boundary. Magnesium concentrations were generally below the GWSL in groundwater at wells located in the central part of the NERT Off-Site Study Area.

Figure 8-12c shows the distribution of magnesium in the UMCf-fg1 in the Shallow WBZ (~40-90 ft bgs) interval. Magnesium was detected in all 24 wells sampled. Magnesium concentrations were above the GWSL of 189 mg/L in groundwater at 10 wells; concentrations ranged from 190 mg/L to 380 mg/L.

In groundwater at Middle WBZ well M-152, magnesium was detected at a concentration of 16 mg/L, which is below the GWSL (Table 8-1c and Appendix J). As discussed previously, samples were not collected from Middle WBZ wells M-156 and TR-12 for magnesium analysis.

As indicated previously, groundwater samples were not collected from the Deep WBZ in the NERT Off-Site Study Area component of OU-2 as the vertical extent of magnesium contamination above the GWSL is defined within the Shallow WBZ.

8.5.2.5 Manganese

Manganese concentrations with depth are shown in Figure 8-13a. Concentrations of manganese in the Shallow WBZ (0-40 ft bgs) depth interval and the Shallow WBZ (~40-90 ft bgs) depth interval in the NERT Off-Site Study Area component of OU-2 west of Pabco Road are shown in Figures 8-13b and 8-13c, respectively. As shown in Figure 8-13a, manganese is only detected in the Shallow WBZ (0-40 ft bgs) interval in the western portion of the NERT Off-Site Study Area. Manganese concentrations above the GWSL of 0.801 mg/L extend from the western third of the OU-1/OU-2 boundary at Parcel A/B north along the western paleochannel system to Sunset Road. These elevated manganese concentrations in the western side of both OU-1 (see Section 7.5.2.2) and the NERT Off-Site Study Area appear to be related to an the OSSM site located west of OU-1. Concentrations of manganese above the GWSL in groundwater range from 0.83 mg/L (PC-165) to 3.6 mg/L (PC-40), with one higher concentration of 200 mg/L in groundwater at well H-48.

Figure 8-13c shows the distribution of manganese in the UMCf-fg1 in the Shallow WBZ (~40-90 ft bgs) interval. Manganese was not detected in 10 of the 24 wells sampled. Where detected, manganese concentrations were all below the GWSL of 0.801 mg/L.

Manganese was not detected (<0.015 mg/L) in groundwater within the Middle WBZ at well M-152 (Table 8-1c and Appendix J). As discussed previously, samples were not collected from Middle WBZ wells M-156 and TR-12 for manganese analysis.

As indicated previously, groundwater samples were not collected from the Deep WBZ in the NERT Off-Site Study Area component of OU-2 as the vertical extent of manganese contamination is defined within the Shallow WBZ.

8.5.2.6 VOCs

Benzene

Benzene concentrations with depth are shown in Figure 8-16a. The distribution of benzene in the Shallow WBZ (0-40 ft bgs) depth interval and the Shallow WBZ (~40-90 ft bgs) depth interval in the NERT Off-Site Study Area component of OU-2 west of Pabco Road are shown in Figures 8-16b and 8-16c, respectively. As shown in Figure 8-16b, benzene was detected only in groundwater at wells in the Shallow WBZ (0-40 ft bgs) interval located in the southwestern part of the NERT Off-Site Study Area, downgradient of the OSSM site and the OSSM well field, with concentrations at the time of most recent sampling below the GWSL of 5 µg/L. As shown in Figure 8-16c, benzene was detected in the UMCf-fg1 in the Shallow WBZ (~40-90 ft bgs) interval at concentrations above the GWSL in groundwater at three wells located close to Warm Springs Road and in groundwater at one well along Sunset Road (PC-194). The benzene concentrations above the GWSL ranged from 11 µg/L to 120 µg/L.

Benzene was not detected (<0.25 µg/L) in groundwater at Middle WBZ wells M-152, M-156, and TR-12 (Table 8-1c and Appendix J).

As indicated previously, groundwater samples were not collected from the Deep WBZ in the NERT Off-Site Study Area component of OU-2 as the vertical extent of benzene contamination is defined within the Shallow WBZ.

Based on the distribution of benzene in groundwater within OU-1 (as discussed in Section 7.5.2.4), the direction of groundwater flow, the absence of this COPC in groundwater along the central/eastern portion of the OU-1/OU-2 boundary, and evaluation of OU-2 data, the benzene in the southwestern corner of OU-2 is associated with OSSM's contaminant plume.

Bromodichloromethane

Bromodichloromethane concentrations with depth are shown in Figure 8-17a. The distribution of bromodichloromethane in the Shallow WBZ (0-40 ft bgs) depth interval and the Shallow WBZ (~40-90 ft bgs) depth interval in the NERT Off-Site Study Area component of OU-2 west of Pabco Road are shown in Figures 8-17b and 8-17c, respectively. As shown in Figure 8-17b, bromodichloromethane was detected above the GWSL in groundwater at wells in the Shallow WBZ (0-40 ft bgs) interval located in the southern part of the NERT Off-Site Study Area, downgradient of the eastern OU-1 boundary and extending along the paleochannel system, with concentrations at the time of most recent sampling up to 1.7 µg/L. An isolated detection of bromodichloromethane above the GWSL was also observed in the northeastern part of the NERT Off-Site Study Area component of OU-2 at PC-126 (0.86 µg/L). As shown in Figure 8-17c, bromodichloromethane was detected in the UMCf-fg1 in the Shallow WBZ (~40-90 ft bgs) interval at concentrations above the GWSL in groundwater at three wells located in the southern part of the NERT Off-Site Study Area, downgradient of OU-1. The bromodichloromethane concentrations above the GWSL in this depth interval ranged from 0.28 µg/L to 0.54 µg/L.

Bromodichloromethane was not detected (<0.25 µg/L) in groundwater at Middle WBZ wells M-152, M-156, and TR-12 (Table 8-1c and Appendix J).

As indicated previously, groundwater samples were not collected from the Deep WBZ in the NERT Off-Site Study Area component of OU-2 as the vertical extent of bromodichloromethane contamination is defined within the Shallow WBZ.

Carbon Tetrachloride

Carbon tetrachloride concentrations with depth are shown in Figure 8-19a. The distribution of carbon tetrachloride in the Shallow WBZ (0-40 ft bgs) depth interval and the Shallow WBZ (~40-90 ft bgs) depth interval in the NERT Off-Site Study Area component of OU-2 west of Pabco Road are shown in Figures 8-19b and 8-19c, respectively. As shown in Figure 8-19b, carbon tetrachloride was detected in groundwater at wells in the Shallow WBZ (0-40 ft bgs) interval located in the southern part of the NERT Off-Site Study Area, downgradient of the eastern OU-1 boundary and extending along the paleochannel system, as well as along the eastern portion of the NERT Off-Site Study Area along the paleochannel to the boundary of OU-2 with OU-3, with concentrations at the time of most recent sampling generally below the GWSL of 5 µg/L. GWSL exceedances were observed in PC-187 and PC-187R in the southern portion of the NERT Off-Site Study Area, and PC-126 in the northeastern portion of the NERT Off-Site Study Area component of OU-2. As shown in Figure 8-19c, carbon tetrachloride was detected in the UMCf-fg1 in the Shallow WBZ (~40-90 ft bgs) interval at concentrations above the GWSL in groundwater at PC-188, located close to Warm Springs Road (8.6 µg/L).

Carbon tetrachloride was not detected (<0.25 µg/L) in groundwater at Middle WBZ wells M-152, M-156, and TR-12 (Table 8-1c and Appendix J).

As indicated previously, groundwater samples were not collected from the Deep WBZ in the NERT Off-Site Study Area component of OU-2 as the vertical extent of carbon tetrachloride contamination is defined within the Shallow WBZ.

Chlorobenzene

Chlorobenzene concentrations with depth are shown in Figure 8-20a. The distribution of chlorobenzene in the Shallow WBZ (0-40 ft bgs) depth interval and the Shallow WBZ (~40-90 ft bgs) depth interval in the NERT Off-Site Study Area component of OU-2 west of Pabco

Road are shown in Figures 8-20b and 8-20c, respectively. As shown in Figure 8-20b, chlorobenzene was detected at concentrations above the GWSL of 100 µg/L in groundwater at four wells in the Shallow WBZ (0-40 ft bgs) interval located in the southwestern part of the NERT Off-Site Study Area, downgradient of the OSSM site and the OSSM well field. Concentrations ranged from 150 µg/L (well MC-62) to 320 µg/L (well H-49A).

As shown in Figure 8-20c, chlorobenzene was detected the UMCf-fg1 in the Shallow WBZ (~40-90 ft bgs) interval at a concentration above the GWSL in groundwater at one well also located in the Parcel A/B area close to Warm Springs Road. The chlorobenzene concentration in groundwater at OSSM well MC-MW-38 was 200 µg/L. Chlorobenzene was detected at concentrations below the GWSL in groundwater at eight wells located along the western side of the NERT Off-Site Study Area, i.e., wells screened in the UMCf below the paleochannel system in the alluvium that extends from the OSSM well field to the AWF (shown in Figure 8-20b). Chlorobenzene was not detected (<0.25 µg/L) in groundwater at the other 17 wells sampled.

Chlorobenzene was not detected (<0.25 µg/L) in groundwater at Middle WBZ wells M-152, M-156, and TR-12 (Table 8-1c and Appendix J).

As indicated previously, groundwater samples were not collected from the Deep WBZ in the NERT Off-Site Study Area component of OU-2 as the vertical extent of chlorobenzene contamination is defined within the Shallow WBZ.

Based on the distribution of chlorobenzene in groundwater within OU-1 (as discussed in Section 7.5.2.4), the direction of groundwater flow, the absence of this COPC in groundwater along the central/eastern portion of the OU-1/OU-2 boundary, and evaluation of OU-2 data, the chlorobenzene in the southwestern corner of OU-2 is associated with OSSM’s contaminant plume.

1,1-Dichloroethane

1,1-DCA concentrations with depth are shown in Figure 8-22a. The distribution of 1,1-DCA in the Shallow WBZ (0-40 ft bgs) depth interval and the Shallow WBZ (~40-90 ft bgs) depth interval in the NERT Off-Site Study Area component of OU-2 west of Pabco Road are shown in Figures 8-22b and 8-22c, respectively. As shown in Figure 8-22b, 1,1-DCA was detected at concentrations above the GWSL of 2.79 µg/L in groundwater at 12 groundwater wells located in the Shallow WBZ (0-40 ft bgs) interval along the western side of the NERT Off-Site Study Area. Nine of these wells are located downgradient of the OSSM site and the OSSM well field, where 1,1-DCA concentrations above the GWSL ranged from 2.9 µg/L to 22 µg/L, and all are located along the western side of the NERT Off-Site Study Area.

As shown in Figure 8-22c, 1,1-DCA was also detected in the UMCf-fg1 in the Shallow WBZ (~40-90 ft bgs) interval at a concentration above the GWSL in groundwater at three wells located in the southwest corner of OU-2 close to Warm Springs Road. The 1,1-DCA concentrations ranged from 2.9 µg/L to 5.4 µg/L in wells MC-MW-36, MC-MW-37R, and MC-MW-38.

1,1-DCA was not detected (<0.25 µg/L) in groundwater at Middle WBZ wells M-152, M-156, and TR-12 (Table 8-1c and Appendix J).

As indicated previously, groundwater samples were not collected from the Deep WBZ in the NERT Off-Site Study Area component of OU-2 as the vertical extent of 1,1-DCA contamination is defined within the Shallow WBZ.

Based on the distribution of 1,1-DCA in groundwater within OU-1 (as discussed in Section 7.5.2.4), the direction of groundwater flow, the absence of this COPC in groundwater along the central/eastern portion of the OU-1/OU-2 boundary, and evaluation of OU-2 data, the 1,1-DCA in the southwest corner of OU-2 is associated with OSSM's contaminant plume.

1,4-Dioxane

1,4-Dioxane concentrations with depth are shown in Figure 8-23a. The distribution of 1,4-dioxane in the Shallow WBZ (0-40 ft bgs) depth interval and the Shallow WBZ (~40-90 ft bgs) depth interval in the NERT Off-Site Study Area component of OU-2 west of Pabco Road are shown in Figures 8-23b and 8-23c, respectively. As shown in Figure 8-23b, the majority of the 1,4-dioxane concentrations above the GWSL of 0.46 µg/L are found in groundwater at wells in the Shallow WBZ (0-40 ft bgs) interval along the western NERT Off-Site Study Area boundary, where concentrations range from 0.50 J µg/L to 4.2 µg/L. 1,4-dioxane concentrations above the GWSL were also found in groundwater at 18 wells located near the eastern boundary. In this area, concentrations ranged from 0.52 J µg/L to 4.0 µg/L, with one higher value in groundwater at well PC-67 (23 µg/L). In general, 1,4-dioxane was not detected in groundwater at wells located in the central part of the NERT Off-Site Study Area.

As shown in Figure 8-23c, 1,4-dioxane was detected in the UMCf-fg1 in the Shallow WBZ (~40-90 ft bgs) interval at concentrations above the GWSL in groundwater at three wells located in the Parcel A/B area close to Warm Springs Road and in groundwater at one well along Sunset Road (PC-176). The 1,4-dioxane concentrations above the GWSL ranged from 0.51 J µg/L to 1.3 J µg/L.

1,4-Dioxane was not detected (<0.50 µg/L) in groundwater at Middle WBZ wells M-152, M-156, and TR-12 (Table 8-1c and Appendix J).

As indicated previously, groundwater samples were not collected from the Deep WBZ in the NERT Off-Site Study Area component of OU-2 as the vertical extent of 1,4-dioxane contamination is defined within the Shallow WBZ.

Based on the distribution of 1,4-dioxane in groundwater described above, the 1,4-dioxane in OU-2 appears to be associated with OSSM, TIMET, and NERT.

Tetrachloroethene

PCE concentrations with depth are shown in Figure 8-25a. The distribution of PCE in the Shallow WBZ (0-40 ft bgs) depth interval and the Shallow WBZ (~40-90 ft bgs) depth interval in the NERT Off-Site Study Area component of OU-2 west of Pabco Road are shown in Figures 8-25b and 8-25c, respectively. As shown in Figure 8-25b, PCE is widely distributed in the Shallow WBZ (0-40 ft bgs) interval throughout the NERT Off-Site Study Area in concentrations below the GWSL of 5 µg/L, detected in 50% of the groundwater samples. However, PCE concentrations above the GWSL of 5 µg/L were found in groundwater at only six wells located in the eastern side of the NERT Off-Site Study Area downgradient of the TIMET site. PCE concentrations above the GWSL ranged from 5.2 µg/L (at wells PC-169 and PC-172D) to 68 µg/L (at well PC-21A located near the southern boundary). Although PCE was detected and is a COPC in OU-1, it was not detected above the GWSL in the northern portion of OU-1. As such, the presence of PCE in OU-2 is unlikely to be associated with a release in OU-1. However, as shown in Table 7-2c, PCE has been identified as a groundwater SRC at the TIMET site.

As shown in Figure 8-25c, PCE was not detected above the GWSL in the UMCf-fg1 in the Shallow WBZ (~40-90 ft bgs) interval in the NERT Off-Site Study Area component of OU-2.

PCE was also not detected (<0.25 µg/L) in groundwater at Middle WBZ wells M-152, M-156, and TR-12 (Table 8-1c and Appendix J).

As indicated previously, groundwater samples were not collected from the Deep WBZ in the NERT Off-Site Study Area component of OU-2 as the vertical extent of PCE contamination is defined within the Shallow WBZ.

Since the PCE concentrations above the GWSL in OU-2 are found in wells located in the eastern portion of the NERT Off-Site Study Area downgradient of the TIMET site, and the concentrations of PCE in groundwater along the central/eastern portion of the OU-1/OU-2 boundary are below the GWSL, the PCE concentrations above the GWSL in OU-2 groundwater are associated with the TIMET site.

1,2,3-Trichloropropane

1,2,3-Trichloropropane concentrations with depth are shown in Figure 8-27a. The distribution of 1,2,3-trichloropropane in the Shallow WBZ (0-40 ft bgs) depth interval and the Shallow WBZ (~40-90 ft bgs) depth interval in the NERT Off-Site Study Area component of OU-2 west of Pabco Road are shown in Figures 8-27b and 8-27c, respectively. As shown in Figure 8-27b, the concentrations of 1,2,3-trichloropropane above the GWSL of 0.000835 µg/L in the Shallow WBZ (0-40 ft bgs) interval ranged from 0.0026 J µg/L to 0.50 µg/L.

As shown in Figure 8-27c, 1,2,3-trichloropropane was detected at concentrations above the GWSL in groundwater at 13 of the 26 wells sampled in the UMCf-fg1 in the Shallow WBZ (~40-90 ft bgs) interval. Concentrations above the GWSL ranged from 0.0025 J µg/L to 0.27 µg/L.

1,2,3-Trichloropropane was not detected (<0.0025 µg/L) in groundwater at Middle WBZ wells M-152, M-156, and TR-12 (Table 8-1c and Appendix J).

As indicated previously, groundwater samples were not collected from the Deep WBZ in the NERT Off-Site Study Area component of OU-2 as the vertical extent of 1,2,3-trichloropropane contamination is defined within the Shallow WBZ.

Based on the distribution of 1,2,3-trichloropropane in groundwater described above, the 1,2,3-trichloropropane in OU-2 appears to be associated with OSSM, TIMET, and NERT.

8.5.3 Summary of Extent of COPCs in OU-2 Groundwater

Based on the data presented in the previous sections it is clear that in some cases COPCs detected in groundwater above GWSLs within OU-2 originated from the OSSM or TIMET sites. In some cases, the data indicates that the COPCs originate from multiple sites within the BMI Complex.

The following OU-2 groundwater COPCs originate from OU-1:

- Chromium
- Nitrate
- Boron
- Bromodichloromethane

The following OU-2 groundwater COPCs originate from OSSM:

- Benzene
- Chlorobenzene
- 1,1-DCA
- Manganese

The following OU-2 groundwater COPC appears to originate from TIMET:

- PCE

The following OU-2 groundwater COPCs appear to originate from multiple sources:

- Perchlorate (AMPAC and NERT)
- Chlorate (AMPAC and NERT)
- Chloroform (OSSM, NERT, and TIMET)
- Carbon Tetrachloride (OSSM and NERT)
- 1,4-Dioxane (OSSM, NERT, and TIMET)
- 1,2,3-Trichloropropane (OSSM, NERT, and TIMET)
- Arsenic (OSSM and NERT)
- Magnesium (OSSM and NERT)

This will be discussed in greater detail in Section 9.

8.6 Summary of OU-2 Soil Gas Results

As part of the NERT RI, three rounds of soil gas sampling were conducted in OU-2. The first round of sampling occurred in 2015 as part of the Phase 1 RI. This investigation included the installation of soil gas sampling probes at three locations in OU-2 (RISG-1, RISG-2, and RISG-3). The second round of sampling occurred in March 2019 associated with the Phase 3 RI, including samples collected from 13 locations (RISG-1 through RISG-9, RISG-27 through RISG-30). During the third round of sampling, also associated with the Phase 3 RI, which occurred between November 2019 and January 2020, soil gas samples were collected from the 13 locations sampled in the previous round, as well as 27 new locations (RISG-52 through RISG-78). Soil gas samples were analyzed for VOCs using EPA Method TO-15 and were collected from depths of 5 feet and between 10 to 15 feet bgs depending on the depth to groundwater. Samples from the deeper probes at RISG-8 and RISG-9 could not be collected in either the second or third sampling rounds because the probes contained groundwater. The soil gas sampling results for VOCs detected at least once during the RI soil gas sampling program are shown in Tables 8-4a through 8-4d. Sample locations and soil gas results for chloroform (the most highly concentrated and widely detected VOC in soil gas) are shown relative to the chloroform concentrations in groundwater in Figures 8-31a and 8-31b. Additional details on the sampling procedures are provided in Appendix A1. The complete OU-2 soil gas data set is presented in Appendix K.

The RI soil gas results presented in Tables 8-4a through 8-4d are compared to site-specific, health-based SGSLs.[83] Detected concentrations or detection limits above the SGSL are highlighted in yellow. As described in more detail in Appendix G, the OU-2 SGSLs represent the concentration of a chemical in soil gas that is protective of human health considering the vapor intrusion to indoor air exposure pathway and assuming industrial/commercial land use (Tables 8-4a and 8-4b) or residential land use (Tables 8-4c and 8-4d). Detected concentrations from soil gas locations in areas zoned residential are compared to residential SGSLs, and detected concentrations from locations in areas zoned industrial/commercial are compared to industrial/commercial SGSLs.

In the commercial/industrial land use areas located near the northern and southern boundaries of the NERT Off-Site Study Area component of OU-2 west of Pabco Road, chloroform was the only VOC detected in soil gas above the SGSL. The chloroform concentrations that are above the SGSL in the area zoned for commercial/industrial use include RISG-2 and RISG-3 at 5 feet bgs only in 2015, RISG-6 at only 5 feet bgs in 2019, and RISG-56 at 5 and 15 feet bgs in 2019 (Tables 8-4a and 8-4b). In the residential land use area located towards the interior of the NERT Off-Site Study Area, chloroform and bromodichloromethane are the only VOCs detected in soil gas above SGSLs (Table 8-4c). Chloroform concentrations are above the SGSL at 17 locations and bromodichloromethane concentrations are above the SGSL in one location (RISG-74) at both depths sampled. Chloroform and bromodichloromethane are trihalomethanes and a by-product of chlorination of municipal water for domestic use. Though bromodichloromethane is a COPC in OU-1 and OU-2 groundwater, this SGSL exceedance is not co-located with the GWSL exceedances in OU-2 groundwater. Because of the isolated location and since bromodichloromethane is not identified as a COPC on the OSSM or TIMET sites and does not originate from OU-1, its presence in soil gas above the SGSL in this isolated residential location may be related to municipal water distribution by the City of Henderson and its use for irrigation in landscaped areas throughout OU-2.

The highest soil gas concentrations for chloroform are located in areas where the chloroform concentration in groundwater ranges from 63 μg/L near RISG-5 to 610 μg/L near RISG-1, as shown in Figures 8-31a and 8-31b. In general, chloroform concentrations in soil gas

---

[83] On March 31, 2020 NERT submitted the soil gas data to NDEP. NDEP replied to this submittal on January 28, 2021 requesting submittal of a Baseline Health Risk Assessment for OU-1 and OU-2 soil gas and groundwater. NERT submitted the OU-2 Soil Gas and Groundwater Baseline Health Risk Assessment to NDEP on July 23, 2021, and NDEP provided comments on October 13, 2022. The OU-2 Soil Gas and Groundwater Baseline Health Risk Assessment Revision 1 was submitted on September 15, 2023 and approved by NDEP on November 27, 2023.

increase with depth indicating that the source of chloroform in soil gas is attributable to chloroform in groundwater rather than a vadose zone source associated with a surface spill.

The trend in soil gas concentrations between 2015 and 2019 was evaluated at the three sampling locations (RISG-1, RISG-2, and RISG-3) where data is available in all three sampling rounds. Chloroform concentrations in soil gas at RISG-2 and RISG-3 have decreased since 2015 (Tables 8-4a and 8-4b). However, at RISG-1, chloroform concentrations in soil gas have remained relatively stable (especially at the 5 foot depth interval) with a slight increase at the 15 foot depth interval (Tables 8-4c and 8-4d). The sample collected from this depth interval in March 2019 showed a decrease in chloroform from the 2015 sample but then increased again as shown in the November 2019 sample results. Nevertheless, the concentrations of chloroform from March 2015 to November 2019 are relatively similar.

In addition to chloroform and bromodichloromethane, the following VOCs were detected in soil gas at elevated concentrations below SGSLs in OU-2: TCE, carbon tetrachloride, and PCE. In OU-2, carbon tetrachloride and PCE have been identified as COPCs in groundwater. As discussed previously within Sections 7 and 8, carbon tetrachloride is one of the trespassing VOCs from the OSSM site that has and continues to migrate via groundwater into the southwest corner of OU-2, and PCE has migrated in groundwater from the TIMET site directly into the southeast corner of OU-2. The soil gas concentrations of TCE and carbon tetrachloride are generally lower in OU-2 than in OU-1. However, the PCE concentrations measured in the most recent sampling events at RISG-3 in March and November 2019, located in OU-2 just downgradient of the TIMET site, are higher than any of the locations in OU-1.

While the above discussion presented details regarding nature and extent of chemicals exceeding screening levels in soil gas within OU-2 and a discussion of potential sources is included in Section 9 of this report, a site-specific assessment of the potential human health risks from the VOCs detected in soil gas at OU-2 is presented in the BHRA Report for OU-2 Soil Gas and Groundwater, Revision 1 (Ramboll 2023c), which was approved by NDEP on November 27, 2023.

9. CONCEPTUAL SITE MODEL

This section presents the CSM for OU-1 and OU-2. CSMs describe contaminant sources and migration and transformation pathways, as well as the human and ecological receptors potentially exposed to those contaminants. The purpose of the CSM is to distill extensive environmental data and knowledge in order to clearly describe where contamination came from (sources), where it has gone or is going (migration pathways), and how it might change over time (transformation pathways), to help ensure that remediation decisions are effective and protective of human health and the environment (receptors).

This CSM considers sources of contamination in OU-1 and sources outside of the NERT RI Study Area that are migrating or have migrated into OU-1 or OU-2. This includes COPCs in OU-1 that are trespassing chemicals originating from the OSSM site, as well as COPCs in OU-2 that have migrated from the OSSM, TIMET, and former AMPAC sites. Contamination originating outside of the NERT RI Study Area is included in the CSM because it must be considered when making remediation decisions; however, as indicated previously, NERT is only responsible for remediating HLCs that pose an unacceptable risk to human health and the environment. NDEP has stated that it will work with other responsible parties to address in their FSs and remediation plans any COPCs that are trespassing onto the NERT site.

The focus of the CSM is on the previously-defined Primary COPCs (perchlorate, chlorate, hexavalent chromium, and chloroform). Focusing on the Primary COPCs is appropriate since these constituents are the most widely distributed COPCs in the environment and highlight the location and extent of migration pathways.

The description of the CSM in Section 9 is organized as follows:

- Overview of the CSM (Section 9.1);
- Physical features of the Site (Section 9.2);
- Chemical and physical characteristics of COPCs (Section 9.3);
- Contaminant sources throughout the Site’s history (OU-1 sources are described within Section 9.4 and OU-2 sources are described within Section 9.5);
- Nature and extent of these COPCs in different environmental media (Section 9.6);
- GWETS performance and mass remaining in soil and groundwater (Section 9.7); and
- Human and ecological receptors (Section 9.8).

While this CSM focuses primarily on OU-1 and OU-2, in the forthcoming RI Report for OU-3 the CSM will be updated with more detail for OU-3, including downgradient receptors.

9.1 Overview of the CSM

A CSM was first developed for the area now designated as OU-1 in 2005 based on the information available at that time (ENSR 2005). The 2005 CSM presented detailed information on the LOU source areas identified by NDEP (see Section 3.2), including information on products made, years of production, approximate waste volumes, and actions taken to date. Available analytical results for each LOU were summarized and Site-related chemicals 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 at that time.

The CSM was updated in 2014 during development of the RI/FS Work Plan (ENVIRON 2014c). Between 2005 and 2014, the Site was the subject of additional field investigations and soil removal actions were implemented (see Sections 3.2 and 3.3). The 2014 CSM provided a refined, but still preliminary, identification of sources, release mechanisms, exposure media, exposure routes, and receptors based on the then current understanding of on-site and off-site environmental conditions. At that time, the RI Study Area consisted of the NERT Site Study Area and NERT Off-Site Study Area. As noted in the RI/FS Work Plan, the CSM was intended to be revised, as appropriate, based on the further evaluation of available on-site and off-site characterization data and additional environmental data collected during the RI. The CSM in this report presents an update inclusive of all the RI data collected in OU-1 and OU-2 and relevant data from OU-3 collected prior to 2020. The CSM will be updated again at the completion of the OU-3 RI and presented in the forthcoming RI Report for OU-3.

As described in the previous sections, there has been a long and complex history of industrial activity within and surrounding the NERT RI Study Area involving various operating entities, resulting in contamination over a large area with differing physical conditions. The objective of the CSM is to integrate the information previously presented into a concise description of the most significant sources, migration and transformation pathways, and receptors. The CSM will inform the human health and ecological risk assessments and the forthcoming FS for OU-1 and OU-2. Environmental investigations of the NERT RI Study Area have been on-going for over 20 years resulting in a comprehensive understanding of the CSM in OU-1 and OU-2, which will support the FS and the selection of a final remedy.

9.1.1 Schematic of the CSM

The key features of the CSM are illustrated schematically in Figures 9-1, 9-2a and 9-2b. Figure 9-1 shows the entire NERT RI Study Area from OU-1 on the south through OU-2 and OU-3 to the Las Vegas Wash on the north. Figure 9-2a presents a cutaway below the eastern portions of OU-2 and OU-3, and Figure 9-2b presents a similar cutaway extending from OU-1 to the Las Vegas Wash. To illustrate the differences between the western and eastern portions of the NERT RI Study Area (delineated by Pabco Road), separate figures representing each portion have been prepared and are discussed in the following sections.

West Side CSM

Figure 9-2b illustrates the west side of the NERT RI Study Area, which is generally west of Pabco Road. The west side includes the OU-1 source areas, groundwater migration pathways, the three groundwater extraction well fields associated with the NERT GWETS, the one groundwater extraction well field associated with the OSSM GWETS, and potential receptors in the portion of OU-2 and OU-3 west of Pabco Road. As historical releases occurred in the various production areas within OU-1, COPCs impacted soil first and then migrated downwards until groundwater was encountered. After reaching groundwater, the downward migration of COPCs continued during historical production periods as a result of wastewater infiltration and the sinking of high-density brines that occurred beneath the Unit 4 Building. The vertical migration of COPCs was eventually impeded by the fine-grained sediments of the UMCf, present at approximately 130 ft bgs within the production areas of

OU-1. Once reaching the fine-grained UMCf, however, COPCs began slowly diffusing into the UMCf, a process which continued over the approximately 50-year period of perchlorate and chlorate production.

COPCs also migrated northward through horizontal groundwater flow, with the fastest and most significant migration occurring in the paleochannels within the alluvium and coarse-grained UMCf. Slower migration would have occurred within the upper portion of the fine-grained UMCf where COPCs were present. Within OU-1, horizontal migration of COPCs within the UMCf-fg1 would have been facilitated by the presence of anastomosing stream deposits identified within this geologic unit as described in Section 5.4.2. Within OU-2, horizontal migration within the UMCf-fg1 would have occurred at a significantly slower rate due to the absence of abundant anastomosing stream deposits and a reduction in grain size of the few stream channel sediments identified within this geologic unit. As can be seen in the cutaway side of the diagram (Figure 9-2b), the relative groundwater concentrations are highest below OU-1 as indicated by the red color and decrease with distance from OU-1 beneath OU-2, where groundwater is intercepted by the AWF. The groundwater concentrations decrease further beneath OU-3 as indicated by the color progression from orange to yellow, and then to blue (lowest concentrations) beyond the SWF adjacent to the Las Vegas Wash, reflecting the control of the core NERT plume (i.e., COPCs that migrated via groundwater from OU-1) located west of Pabco Road by the SWF. As indicated via multiple lines of evidence in the 2021 Annual Groundwater Monitoring and GWETS Performance Report, the GWETS captures 100% of any Primary COPCs currently migrating from the various source areas within OU-1 (Ramboll 2022a). These lines of evidence include a capture zone evaluation, monitoring well concentration trends, and well field capture efficiency estimates. In addition, tracer testing conducted as part of the AWF Capture Evaluation and Matrix Diffusion Study confirmed that the core NERT plume is captured by the AWF (Appendix B of this report). As a result, there is no longer any discharge of perchlorate from the core NERT plume (i.e., perchlorate and chlorate that originates from groundwater migrating from OU-1), with the exception of perchlorate diffusing upwards from the UMCf north of the SWF.

East Side CSM

Figure 9-2a illustrates the east side of the NERT RI Study Area, which is generally east of Pabco Road including the Eastside Sub-Area (the former BMI Common Area) and various residential communities. Generally speaking, COPCs migrated to this area from OU-1 through the former Beta Ditch and into the Upper BMI Ponds, which were used during historical manufacturing (see Section 2.3.2). After migrating to the Eastside Sub-Area in OU-2 via the Beta Ditch (and ultimately the Upper BMI Ponds), the COPCs seeped into the ground through the unlined Upper BMI Ponds impacting soil and groundwater in a manner similar to what occurred in OU-1. Similar to off-site migration from OU-1, COPCs in groundwater within the Eastside Sub-Area migrated northward from OU-2 into OU-3 and eventually to the Las Vegas Wash, with the fastest and most significant migration occurring in the paleochannels within the alluvium.

Following the cessation of discharges to the former pond system within the Eastside Sub-Area in the mid-1970s, the alluvium has become dewatered, which is a significant difference from the portion of OU-2 shown in the West Side CSM in Figure 9-2b. The cutaway shown in the East Side CSM illustrates these differing conditions along a transect extending from within the Eastside Sub-Area of OU-2, through various residential communities, to the Las

Vegas Wash. As depicted in the figures, as indicated by the orange color, groundwater concentrations are generally lower in the East Side CSM (east of Pabco Road) versus concentrations in the West Side CSM (west of Pabco Road). Another notable difference is the absence of groundwater extraction wells or other mitigation measures within the footprint of the East Side CSM. Thus, COPCs in groundwater will migrate northward to the Las Vegas Wash in an uncontrolled manner. While additional information about the distribution of COPCs in OU-1 and OU-2 is provided in Sections 7 and 8 of this report, respectively, the importance of the abovementioned differences in each of the CSM illustrations is discussed later in this section.

9.1.2 Summary of Groundwater Conditions

As discussed throughout this report, the alluvium has become dewatered throughout most of OU-1, and first groundwater now occurs in the low permeability UMCf. Only a few thin sandy units are present in the UMCf, predominantly in the southern part of the NERT RI Study Area. These preferential flow pathways are, however, limited in lateral extent and, due to its low permeability, contaminants migrate very slowly through the UMCf. Since OU-1 is located closer to the mountains, the upper portion of the UMCf-fg1 unit tends to have zones of sandy silt/silty fine-grained sand as well as a greater number of thin, discontinuous layers of silty sand than is observed in the downgradient off-site areas farther from the mountains and more toward the interior of the depositional basin (i.e., in OU-2 and OU-3). Figure 9-3 persents a south to north subsurface cross-section from OU-1 to the Las Vegas Wash showing perchlorate concentrations with depth. As illustrated in Figure 9-3, the deeper, thinly bedded, discontinuous silty sand units within the UMCf are below the vertical extent of perchlorate as defined by the NDEP BCL of 0.015 mg/L. Therefore, even if some of these units were interconnected, they would not serve as site-related contaminant migration pathways. In addition, discontinuous sand units are rarely encountered in the UMCf in the northern portion of OU-2 and OU-3. Within OU-2, the UMCf-fg1 deposits become very fine-grained with abundant gypsum deposits, reflecting the saline mudflat depositional environment characteristic of the basin interior.

Within OU-2, the alluvium remains saturated in the area west of Pabco Road. In general, the perchlorate concentrations decrease with depth and distance from OU-1. Figure 9-3 illustrates the horizontal and vertical extent of perchlorate in the alluvium and the UMCf between the Unit 4 and 5 Buildings source area to the Las Vegas Wash. As indicated in the 2021 Annual Groundwater Monitoring and GWETS Performance Report (Ramboll 2022a), COPCs migrating via groundwater from OU-1 are completely captured by the AWF and SWF. However, significant mass remains in the saturated UMCf south (upgradient) of the AWF (see Section 9.6.4). As a result, slow upward migration due to the combination of an upward hydraulic gradient and matrix diffusion from the UMCf into the alluvium will be a significant factor affecting the long-term persistence of perchlorate (and other COPCs) in OU-2 groundwater. In OU-3, perchlorate concentrations decrease to below 1 mg/L on the downgradient side of the SWF, indicating control of the NERT plume west of Pabco Road by the GWETS.

In the East Side CSM area of OU-2, the alluvium has become dewatered across much of the central and eastern portions with first groundwater now occurring in the UMCf. This is important because groundwater flow (and COPC migration) occurs at a much lower rate in the UMCf than in the alluvium. As noted above, contaminants migrate very slowly though the UMCf, leading to long-term persistence of COPCs in groundwater in the eastern side of OU-2. As previously discussed, unlike groundwater represented by the West Side CSM where COPCs migrating from OU-1 are captured by the NERT GWETS, there are no groundwater extraction or other mitigation measures in place to address COPCs in groundwater represented by the East Side CSM.

The conditions in OU-3 will be evaluated in more detail in the forthcoming RI Report for OU-3.

9.1.3 Summary of Groundwater Contamination

As shown in Table 9-1, the majority of the COPCs identified in OU-1 soil above LSSLs do not impact OU-1 groundwater above GWSLs. Specifically, 31 of the 46 COPCs identified in OU-1 soil above LSSLs do not impact groundwater above GWSLs, and therefore do not appear to pose a long-term threat to groundwater quality. Figure 9-4 presents the COPCs in groundwater for each of the investigative areas within OU-1 and OU-2. The primary off-site migration pathway from OU-1 to the NERT Off-Site Study Area portion of OU-2 west of Pabco Road is via groundwater, whereas the off-site migration pathway from OU-1 to the Eastside Sub-Area component of OU-2 east of Pabco Road was via the Beta Ditch. There are fewer than half the number of groundwater COPCs in the western portion of OU-2 than in OU-1. In the eastern portion of OU-2, since the COPCs are administratively limited to perchlorate and chlorate, the CSM is also limited to these chemicals. As such, any COPCs other than perchlorate and chlorate that migrate northward from OU-2 east of Pabco Road into OU-3 will not be addressed by NERT.

As presented in Sections 7.5.1 and 8.5.1, perchlorate and chlorate are the most widespread contaminants in groundwater and the distribution of other COPCs in groundwater which are attributed to OU-1 generally occur within the footprint of the perchlorate plume. Therefore, for purposes of discussing the extent of contamination in groundwater, the following discussion will focus on perchlorate but also applies to the distribution of chlorate, chromium, and other COPCs which are attributed to OU-1. The extent of perchlorate in shallow groundwater is illustrated in Figure 9-5a, which shows the perchlorate plume, and Figure 9-5b, which shows the perchlorate plume along with the extent of saturated alluvium. The migration of perchlorate and other COPCs will be much faster in areas where the alluvium is saturated than where the alluvium is unsaturated.

As discussed previously, the perchlorate plume in the West Side CSM was the result of off-site migration from OU-1 via groundwater into OU-2, whereas the plume in the East Side CSM was the result of migration via the Beta Ditch and infiltration into groundwater through the former pond system. The historical migration of perchlorate from OU-1 to the Las Vegas Wash that was depicted in the West Side CSM has been eliminated by operation of the GWETS. As indicated in the 2021 Annual Groundwater Monitoring and GWETS Performance Report, the GWETS captures 100% of any Primary COPCs currently migrating from the various source areas within OU-1 (Ramboll 2022a). As a result, there is no longer any discharge of perchlorate from the core NERT plume (i.e., perchlorate that originates from groundwater migrating from OU-1), with the exception of perchlorate diffusing upwards from the UMCf north of the SWF. Conversely, the perchlorate plume that is represented in the East Side CSM, which is primarily the result of historic migration via the Beta Ditch to the historical pond system, continues to migrate into the Las Vegas Wash and then into Lake

Mead and the Colorado River, as the GWETS was not designed to capture this groundwater contamination.

The vertical extent of perchlorate in groundwater is shown in Figure 9-3, which presents a south–north subsurface cross-section along the axis of the NERT plume migrating via groundwater from OU-1 within the West Side CSM. As indicated previously, this portion of the NERT plume is completely captured by the ongoing operation of the GWETS. As discussed in Sections 7.4.1 and 9.3.1, the Unit 4 Building was a major source of perchlorate and other chemicals released at OU-1. The location of the Unit 4 Building is shown in the left side of Figure 9-3. Historically, higher water levels from wastewater discharges and density-driven flow likely contributed to the downward migration of the highest perchlorate concentrations to depths of 90-120 feet bgs. See Section 5.5.2.5 for additional discussion of density-driven flow. Perchlorate in groundwater above the GWSL extends to a depth of approximately 150 feet bgs beneath the Unit 4 Building.

In contrast, in the northern part of the Site between the former Beta Ditch and the IWF/barrier wall, the highest perchlorate concentrations are in shallow groundwater above a depth of 90 feet bgs, with perchlorate concentrations above the GWSL extending to depths of 145 feet bgs. In this part of OU-1, separate sources related to other former operational areas (such as the AP Plant area and associated ponds, and the area around the IWF and the former recharge trenches) released perchlorate to soil and shallow groundwater.

Within OU-2, the vertical extent of the highest perchlorate concentrations is generally less than 100 feet bgs. Under current conditions, geologic controls and the naturally upward vertical hydraulic gradient impede any further downward migration of perchlorate in OU-1 and OU-2. In addition, the capture zone of the AWF extends vertically to a depth greater than the extent of contamination within the western portion of OU-2, which inhibits any future downgradient and downward vertical migration of COPCs (Ramboll 2022a). However, the UMCf serves as a long-term, ongoing source to contamination in the alluvium.

In contrast to the perchlorate and chlorate plumes, the extent of the hexavalent chromium plume within the NERT RI Study Area has been limited due to remediation activities begun in 1987 and natural attenuation mechanisms. As a result, hexavalent chromium impacts in groundwater have not extended to the Las Vegas Wash in the NERT RI Study Area or to Lake Mead. Similar to the impact of hexavalent chromium, VOCs originating from OU-1 have impacted groundwater in the NERT RI Study Area, but the plumes do not extend to the Las Vegas Wash. As indicated in Section 8.5, VOCs detected in groundwater within OU-2 at concentrations above screening levels originate not only from OU-1 but also from the OSSM and TIMET sites within the BMI Complex. With respect to VOCs in groundwater, an evaluation of volatilization from shallow groundwater into soil gas and any resultant potential vapor intrusion risk is presented in the BHRA Reports for soil gas and groundwater in OU-1 and OU-2 (see Section 9.8).

9.2 Physical Features of the Site

The movement and distribution of contaminants throughout the NERT RI Study Area are impacted by its physical features. As discussed in Section 5.0, key physical characteristics of the site that strongly influence contaminant transport, transformation, and fate include topography, climate, surface water hydrology, and geology and hydrogeology. In addition, land use and natural habitats are important features for the identification of human health and ecological receptors that may be affected by site-related contaminants in the environment. While this report focuses on OU-1 and OU-2, this section describes the physical features of the entire NERT RI Study Area.

9.2.1 Topography, Climate, Land Use, and Natural Habitats

Topography. Topography at the NERT RI Study Area is gently sloping to the north with little ground surface relief. Elevations across OU-1 range from 1,700 to 1,874 ft msl. The land surface across the Site generally slopes toward the north at a gradient of approximately 0.02 ft/ft. The NERT Site is over 300 feet higher in elevation than the Las Vegas Wash, which is located approximately 2.5 miles to the north (downgradient) in OU-3. Developed portions of the Site have been modified over time by grading to accommodate construction activities, and further modifications were made during the 2010-2011 Soil Removal Action (ENVIRON 2012a). In the Eastside Sub-Area within OU-2 east of Pabco Road, the ground surface is being graded and reconfigured as part of the development of a master-planned community.

Climate. As detailed in Section 5.2, the climate of the Las Vegas Valley is arid with mild winters and dry hot summers. Precipitation generally occurs during two periods, December through March, and July through September. Winter storms typically produce low intensity rainfall over a large area, while summer storms typically produce high intensity rainfall over a smaller area for a short duration, and 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 mph; however, velocities in excess of 50 mph are not atypical when weather fronts move through the area. During these windy events, soil at the ground surface can become airborne and may travel several miles. Flooding and intense wind events characteristic of the area may contribute to the transport of contaminants via overland runoff and dust entrainment, respectively.

Land Use. The NERT RI Study Area and surroundings are primarily mixed commercial/light industrial and residential use areas (Figure 5-1). OU-1 is located in an industrial area and is the only land owned by NERT, while portions of the NERT Off-Site Area and Eastside Sub-Area within OU-2 are primarily a mixture of residential and commercial land use areas with some light industrial operations. The Eastside Sub-Area is being actively redeveloped into a master-planned community. Over the next decade, it is anticipated that as many as 13,250 planned residences, as well as parks, schools, and retail stores, will be constructed within much of the remaining vacant areas of the Eastside Sub-Area (LandWell 2019).

Natural Habitats. As described in Section 5.3 and shown in Figure 5-2, the ecosystem type in this region of southern Nevada is Mojave Desert scrub (Clark County Department of Comprehensive Planning 2000). Other ecosystems in the vicinity include Salt Desert scrub and creosote bursage.

9.2.2 Surface Water

As explained in Section 5.6, the NERT RI Study Area is located in a very arid region with few natural surface water bodies. However, surface water is present in some areas of the NERT RI Study Area, primarily in surface water impoundments receiving process wastewater, lined artificial lakes, and in the COH Birding Ponds, which are associated with the City's municipal wastewater treatment plant. Surface water is also present on the ground surface and within retention basins following storm events.

During the 2011-2012 soil removal action, OU-1 was graded such that storm water would be retained within OU-1. Two retention basins were constructed to receive water during storm events. As shown in Figure 1-4, a shallow drainage channel located along the eastern side of the Site connects the two retention basins and conveys overflow from the Central Retention Basin into the Northern Retention Basin. These surface water containment features were designed to retain storm water on-site.

Surface water within OU-2 generally occurs infrequently as storm runoff in shallow washes and flows north toward the Las Vegas Wash; however, this will likely change due to rapid and ongoing development, particularly in the Eastside Sub-Area within OU-2 east of Pabco Road. A small portion of the unlined Bird Viewing Ponds within the COH WRF are located within OU-3. The Las Vegas Wash is located along the northern boundary of OU-3. Additional discussion on these features and how they affect the CSM will be presented in the OU-3 RI Report.

9.2.3 Geology/Hydrogeology

Key features of the geology and hydrogeology of the NERT RI Study Area that affect groundwater flow and associated COPC migration are summarized in this section. Additional details are provided in Sections 5.4 and 5.5 of this report.

9.2.3.1 Geology

The NERT RI Study Area 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 in the north to Railroad Pass to 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 Mountains and River Mountains to the south and southeast; and the Spring Mountains to the west. Within the Las Vegas Valley, eroded Tertiary and Quaternary sedimentary and volcanic rocks comprise the unconsolidated basin deposits, which can be over 5,000 feet thick (Plume 1989). 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 valley fill deposits consist of a relatively thin series of Quaternary alluvium deposits over a thick unit of older Tertiary Muddy Creek Formation sediments. The NERT RI Study Area is situated near the southeast edge of the Las Vegas Valley hydrologic basin between the McCullough Mountains to the south and the River Mountains to the east, in an area where the total basin fill reaches thicknesses between 3,000 to 4,000 feet (see Figure 5-3). The north-south trending ridge of the McCullough Mountains forms a local divide between the sources of the sediment accumulated near the NERT RI Study Area. On the northwest side of the ridge, the overall direction of both surface water runoff and groundwater flow is north-northeast. The larger valley area from the Spring Mountains to the west contributes a greater volume of higher energy surface water runoff flow and associated coarser-grained sediment transport than the relatively small sub-basin between the McCullough and River

Mountains southeast of the Site. In the smaller sub-basin, the overall surface water runoff and groundwater flow direction is toward the northwest. In general, this smaller sub-basin contributes finer-grained sediments to the basin fill due to the lower quantity of surface water runoff.

Both the alluvial deposits and the Muddy Creek Formation sediments in the Site vicinity reflect the valley sub-basin geography described above. The following paragraphs describe these major geologic units within the NERT RI Study Area.

Quaternary Alluvium. The surface of the NERT RI Study Area is primarily alluvium that slopes northward toward the 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. The thickness of the alluvial deposits within the NERT RI Study Area ranges from less than 1 foot near the Las Vegas Wash to more than 50 feet at the southern end of OU-1.

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 underlying 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 hydraulic conductivity than the adjacent, well-graded deposits. In general, these paleochannels trend northeast. Where the alluvium is saturated, the paleochannels serve as preferential groundwater flow and contaminant migration pathways. Groundwater flow within the paleochannels is significantly greater than within the finer-grained sediments of the alluvium and UMCf. The deepest and best developed paleochannel system is located west of OU-1 and extends across the western side of OU-2 and OU-3 to the Las Vegas Wash. The OSSM, AWF, and SWF extraction wells all span this paleochannel system, which is as deep as 50-60 feet in places within OU-2. In the central and eastern portions of OU-2, the paleochannels tend to be smaller, reflecting the relatively smaller and lower energy water flow from the upgradient sub-basin between the McCullough and River Mountains southeast of the NERT RI Study Area.

Transitional (or reworked) Muddy Creek Formation. Where present (primarily in OU-1), the xMCf is encountered at the base of the alluvium. The xMCf 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 a mixture of alluvium and reworked, disturbed fine-grained sediments.

Muddy Creek Formation. The Muddy Creek Formation of Tertiary 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. Within the NERT RI Study Area, the Muddy Creek Formation does not crop out but instead subcrops beneath a veneer of Qal sediments. Subsurface investigation in the NERT RI Study Area has been focused on characterization of the alluvium and the Muddy Creek Formation to depths of up to 300-400 feet. Therefore, the Muddy Creek Formation has been informally termed the Upper Muddy Creek Formation (UMCf) in this area. Similar to the paleochannels discussed above, the presence and nature of the UMCf deposits is a key component of the CSM for the NERT RI Study Area.

At the time of deposition, Las Vegas Valley was a closed inland basin, forming a terminal playa in the Lake Mead region drainage network (Faulds et al. 2016). A generalized sedimentation model (or facies model) modified for the NERT RI Study Area that illustrates the depositional environments for sediments and evaporites within the arid closed inland basin is shown in Figure 5-5. The proximal portions of the fan, adjacent to the mountains, are steeply graded with a main channel carrying coarse-grained sediments which is often entrenched in the fan. As the sediments are transported by surface water runoff from the surrounding mountains towards the basin interior, surface slopes decrease reducing the stream competency resulting in coarsergrained sediments being deposited near the toe of the slope and finer grained sediments being deposited with increasing distance from the mountains. Coarse-grained alluvial fan aprons along the mountain front transition to finer-grained sand flats, then mudflats, and finally to saline lacustrine/mudflat deposits in the basin interior. The saline mudflats in the basin interior are characterized by abundant gypsum and other evaporite salt deposits. Sediments in the sand flat and siliciclastic mudflat environments are often characterized by carbonate caliche deposits. During the period of basin fill (typically many thousands to millions of years), the shoreline of the interior playa lake and the transitions between the surrounding mudflats and alluvial fans have expanded and receded in response to variations in rainfall and storm events over that period of geologic time. This has resulted in extensive interfingering of these deposits at depth within the basin.

OU-1 is located near the McCullough Mountains that form the edge of the depositional basin in this area. Beneath the NERT Site, the Muddy Creek Formation is composed of a thick unit of fine-grained sediments of clay and silt (the first fine-grained facies [UMCf-fg1]) interbedded with at least two thinner units of coarse-grained sediments of sand, silt, and gravel (the first coarse-grained facies [UMCf-cg1] and second coarse-grained facies [UMCf-cg2]). The UMCf-cg1 occurs at the southern Site boundary and transitions laterally into fine-grained sediments toward the north, roughly beneath the Unit Buildings. The deeper coarse-grained UMCf-cg2 is found below the western side of OU-1 and extends north as far as the southwestern corner of OU-2. Since the Site is located closer to the mountains, the upper portion of the UMCf-fg1 unit tends to have zones of sandy silt/silty fine-grained sand as well as a greater number of thin, discontinuous layers of silty sand than is observed in the downgradient off-site areas farther from the mountains and more toward the interior of the depositional basin (i.e., in OU-2 and OU-3).

Figure 9-3 persents a south to north subsurface cross-section from OU-1 to the Las Vegas Wash showing perchlorate concentrations with depth. As illustrated in Figure 9-3, the deeper, thinly bedded, discontinuous silty sand units within the UMCf are below the vertical extent of perchlorate as defined by the NDEP BCL of 0.015 mg/L. Therefore, even if some of these units were interconnected, they would not serve as site-related contaminant migration pathways. In addition discontinuous sand units are rarely encountered in the UMCf in the northern portion of OU-2 and OU-3. Within OU-2, the UMCf-fg1 deposits become very fine-grained with abundant gypsum deposits, reflecting the saline mudflat depositional environment characteristic of the basin interior. As discussed in Sections 9.5.3 and 9.6.1, the lower permeability UMCf is the unit in which most of the contaminant mass is stored. A key component of the CSM is that COPCs present in the UMCf slowly migrate downgradient and upwards into the overlying alluvium where it is saturated.

9.2.3.2 Hydrogeology

As previously discussed, NDEP has defined the Shallow WBZ, Middle WBZ, and the Deep WBZ as the three WBZs present in the BMI Complex, as described in the Hydrogeologic and Lithologic Nomenclature Unification guidance document (NDEP 2009a). The Shallow WBZ is defined by the first occurrence of groundwater in either the Qal, xMCf, or the UMCf where the xMCf is missing, is unconfined to partially confined, and is considered the "water table aquifer". The Middle WBZ extends from approximately 90 to 300 ft bgs. The Deep WBZ is defined as the contiguous WBZ that is generally encountered between 300 to 400 ft bgs. Environmental investigations within the NERT RI Study Area have historically focused on the Shallow WBZ, although recent investigations, including this RI, have included a number of Middle WBZ wells to improve vertical delineation of hydrogeology and chemical constituent distribution. Understanding the interaction of groundwater between the deeper WBZs and shallow groundwater is an important feature of the CSM in understanding the groundwater flow pathways between the BMI Complex sites and the Las Vegas Wash.

Shallow WBZ. Within OU-1, first groundwater is generally encountered between 30 and 45 feet bgs and tends to be deepest in the southern portion of the NERT Site. Within OU-2, groundwater is generally encountered between 20 and 60 feet bgs, becoming shallower to the north. Within OU-3, groundwater is generally encountered between 5 and 35 feet bgs, becoming shallower to the north and occurring near the ground surface at the Las Vegas Wash. Within OU-1, the alluvium was previously saturated below the northern portion of the NERT Site. However, as shown in Figure 9-5b, recent groundwater elevations measured during annual groundwater monitoring events show that, except for a few small areas, the alluvium has become dewatered and first groundwater now occurs within the UMCf. Similarly, there are significant areas within the Eastside Study Area component of OU-2 east of Pabco Road where the alluvium is dewatered. Within OU-3, the alluvium is generally saturated. Groundwater conditions within OU-3 will be discussed in the forthcoming OU-3 RI Report.

The hydraulic gradient, which typically parallels the topographical gradient, causes groundwater within the saturated alluvium to flow from OU-1 to OU-2 and continuing toward the Wash within OU-3. This flow pattern may be modified locally by features such as subsurface paleochannels, operation of the NERT GWETS and neighboring extraction systems (shown in Figure 3-1), storm water retention basins, and artificial groundwater mounds and depressions. As shown in Figure 5-16a, the flow direction of the potentiometric surface generally mimics the ground surface (north-northeast with minor variations). Figure 5-16a also shows the extent of the saturated alluvium and the locations of the paleochannels that influence groundwater flow pathways in the saturated alluvium. Stream-deposited sands and gravels were laid down within paleochannels eroded into the surface of the underlying Muddy Creek Formation during infrequent historic flood runoff periods. The channel fill deposits vary in thickness and are typically narrow and generally linear. These generally uniform sand and gravel deposits exhibit higher transmissivity than the adjacent, well-graded alluvial deposits. When located below the water table, these paleochannels play a significant role in contaminant migration from OU-1 to the Las Vegas Wash.

The transmissivity of the alluvial sands and gravels is generally quite high, particularly within paleochannels and closer to the Las Vegas Wash. The transmissivity of the underlying UMCf, which is generally finer-grained, is significantly lower. Based on the Phase 6 groundwater flow model for the NERT RI Study Area (Ramboll 2019g), the estimated average groundwater velocity within the alluvium in the area between the northern NERT Site boundary and the AWF (located near the OU-2/OU-3 boundary) ranges from 1,900 to 3,700 ft/yr. In the area between the AWF and the SWF (within OU-3), the estimated average groundwater velocity ranges from 2,600 to 5,700 ft/yr. These groundwater velocities within the alluvium, estimated using the groundwater model, are equivalent to travel times of 2.9-5.7 years from the NERT Site boundary to the AWF, and 0.8-1.8 years from the AWF to the SWF. Both the horizontal and vertical hydraulic conductivities of the UMCf are one or more orders of magnitude less than those of the alluvium. Thus, groundwater flow rates in the Shallow WBZ are substantially higher within the alluvium (where it is saturated) than within the UMCf. The highest flow rates occur within paleochannels in the alluvium where the saturated thickness is greatest. The general north-northeast flow direction transports groundwater and dissolved contaminants toward the Las Vegas Wash.

Middle WBZ. Within OU-1, the sediments within the Middle WBZ consist predominantly of the UMCf-fg1. To better characterize hydraulic properties in the Middle WBZ UMCf fine-grained unit, slug tests were conducted in all the NERT wells screened in this unit. The slug testing results are presented in Appendix D. The hydraulic conductivities for the 16 wells screened in silt were very low, ranging from 0.00093 ft/day (3.3×10^{-7} cm/sec) to 0.084 ft/day (3.0×10^{-5} cm/sec). For five wells screened in sandy silt intervals, the hydraulic conductivities were higher, ranging from 0.22 ft/day (7.8×10^{-5} cm/sec) to 0.69 ft/day (2.4×10^{-4} cm/sec).

Within OU-1, 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 OU-1 by five deep wells (TR-1, TR-5, TR-7, TR-9, and TR-11) and by well TR-12 below the southwestern portion of OU-2. The UMCf-cg2 unit is confined, as indicated by artesian groundwater elevations consistently measured in these wells. The hydraulic conductivities calculated based on slug tests in wells TR-7 and TR-9 were 1.2 ft/day (4.2×10^{-4} cm/sec) and 2.9 ft/day (1.0×10^{-3} cm/sec), respectively. Within OU-1, the range of average groundwater velocities in this unit from the groundwater model range from 80 to 90 ft/year.

Deep WBZ. The Deep WBZ has been defined by NDEP as the depth interval below 300 feet bgs. Eighteen existing monitoring wells were installed by BRC in the Deep WBZ in the Eastside Sub-Area, which is composed of the UMCf-fg1. Hydraulic properties in the Deep WBZ UMCf-fg1 are likely similar to the results for the Middle WBZ wells screened in the UMCf-fg1 silt described above.

Vertical Gradients. Investigations of the Middle WBZ within OU-1/OU-2 indicate, with a few exceptions, a vertical upward gradient exists between the Middle and Shallow WBZs that generally increases with depth. In the area immediately downgradient of the IWF, vertical head differences between Middle and Shallow WBZ wells ranged from 5 to 26 feet during second quarter 2018 with calculated vertical gradients ranging between 0.05 and 0.2 ft/ft in the upward direction. Near the IWF, upward vertical gradients were generally more prominent near the western and central portions of the barrier wall. At the AWF, two wells were installed as part of the Phase 1 RI that are screened deeper within the shallow WBZ, PC-134D and PC-137D, to depths of 90 feet. During second quarter 2018, the vertical head differences measured between PC-134D and PC-137D and corresponding wells screened within the alluvium were 6.0 and 2.8 feet, respectively, with upward vertical gradients of 0.1 and 0.05 ft/ft. The upward vertical gradient between the Middle and Shallow WBZs limits the extent of downward migration of the COPCs in groundwater and enhances the upward migration of COPCs currently in the UMCf into overlying alluvium over time. A key component of the CSM is that COPCs present in the UMCf slowly migrate upwards via matrix diffusion into the overlying alluvium where it is saturated. As a result, groundwater concentrations in the alluvium will decline relatively slowly over extended periods of time, even in areas where remediation of the higher permeability alluvium is in progress.

9.3 Chemicals of Potential Concern

As described in Section 3, the NERT RI Study Area has been the subject of numerous regulatory actions and environmental investigations since the early 1970s. Investigation activities conducted as part of the NERT RI were designed to fill data gaps within the NERT RI Study Area to fully characterize the nature and extent of contamination.

9.3.1 Chemical Screening

Results of the OU-1 and OU-2 COPC screening are presented in Sections 7 and 8 of this RI Report, respectively. The procedures for selecting COPCs within the NERT RI Study Area were consistent with methods presented within the RI/FS Work Plan (ENVIRON 2014c) and consistent with USEPA guidance on conducting an RI/FS under CERCLA (USEPA 1988). Following NDEP approval of the risk assessments for OU-1 and OU-2, a more refined list of chemicals of concern (COC) will be established for use in the FS for OU-1 and OU-2. Table 9-1 summarizes retained COPCs within the various RI Study Areas and media.

As discussed throughout this report, the NERT Primary COPCs in soil and groundwater of OU-1 and OU-2 (within the NERT Off-Site Study Area west of Pabco Road) are perchlorate, chlorate, chromium, and chloroform. In OU-2 (within the Eastside Sub-Area east of Pabco Road), the Primary COPCs are administratively limited to perchlorate and chlorate.

In OU-1, Other COPCs in soil and groundwater as identified in Section 7 are grouped into the following chemical classes:

- General Chemistry
- Metals
- Radionuclides (groundwater only)
- VOCs
- SVOCs (soil only)
- PAHs (soil only)
- Dioxins and Furans (soil only)
- PCBs (soil only)

- Organochlorine Pesticides (soil only)
- Other Organics

In OU-2 (within the NERT Off-Site Study Area west of Pabco Road), Other COPCs in groundwater as identified in Section 8 are grouped into the following chemical classes:

- General Chemistry
- Metals
- VOCs

In OU-2 (within the Eastside Sub-Area of Pabco Road), no additional COPCs other than the administratively-limited subset of perchlorate and chlorate have been evaluated in soil or groundwater.

9.3.2 Migration Pathways

The major contaminant sources include the former OU-1 production areas (e.g., the Unit 4 and 5 Buildings, former P and S Ponds, and AP Production Area), other sites within the BMI Complex adjacent to OU-1, and former industrial wastewater management features generally located in the Eastside Sub-Area component of OU-2, including unlined ponds (e.g., the unlined Upper BMI Ponds) and conveyances (e.g., the former unlined Beta Ditch). The use of these source features generally spanned the early 1940s to the mid-1970s and are detailed in Tables 2-1, 2-2, and 2-3. As described in Sections 2.3.2 and 2.4.1, the Beta Ditch and Upper BMI Ponds were in use from 1943 to the mid-1970s, but there is limited information about the quantities of wastewater discharged. Given that the Beta Ditch and Upper BMI Ponds were unlined, during periods of use there would have been increased recharge to groundwater and relatively rapid downgradient migration of dissolved COPCs through the saturated alluvium.

The Primary COPCs that have resulted from the historical operations within the NERT Study Area (perchlorate, chlorate, hexavalent chromium, and chloroform) are very soluble and mobile chemicals that generally migrated from their sources in a dissolved phase associated with historical wastewater discharges, migrated in unlined ditches, and released to the subsurface environment. The subsurface migration of dissolved-phase COPCs has been historically (and is currently) associated with groundwater flow. Figures 9-1, 9-2a, and 9-2b, presented earlier in this section, present the CSM which depicts the direction of groundwater flow and COPC migration from various points adjacent to the various source areas. In addition to dissolved-phase migration, the very high concentrations of perchlorate, chlorate, and other COPCs that were historically present as a brine beneath the Unit 4 Building would have migrated downward into the UMCf through density-driven flow. Similarly, the DNAPL from the adjacent OSSM site also migrated into OU-1 via preferential pathways within the UMCf through density-driven flow.

As discussed throughout this section, releases to the subsurface within the BMI Complex first impacted the alluvium, which was saturated during manufacturing operations prior to 1980. As releases continued, COPCs simultaneously migrated downgradient from the complex and downward into the UMCf. Within OU-1, the Primary COPCs that migrated into the UMCf also then started to migrate downgradient within the UMCf through preferential pathways (coarse-grained sediments) and represent significant secondary sources that will slowly migrate upwards into the alluvium for extended periods of time throughout the entirety of the NERT RI Study Area. In the past, when releases of COPCs were occurring directly into the subsurface and wastewaters were being discharged to unlined ditches and ponds within OU-1, concentrations of the Primary COPCs migrated into the UMCf due to a combination of downward hydraulic gradients, matrix diffusion, and density-driven flow beneath source areas with very high concentrations of TDS (i.e., the Unit 4 Building).

Under current conditions, the COPCs in the UMCf are generally migrating back into the alluvium due to the natural upward gradient and through matrix diffusion. As reported in the 2021 Annual Groundwater Monitoring and GWETS Performance Report (Ramboll 2022a), the perchlorate mass flux migrating upward from the deeper UMCf to the alluvium or shallower UMCf (where the alluvium is unsaturated) within OU-1 and OU-2 was approximately 786 pounds per day (lbs/d) based on May 2021 data. As will be discussed in Section 9.7, the mass of perchlorate currently within the UMCf is much larger than in the alluvium. Where the UMCf has lower hydraulic conductivity, the migration of COPCs from the UMCf to the alluvium is expected to persist, causing concentrations in the alluvium to remain above regulatory levels as it migrates north toward the Las Vegas Wash for extended periods of time (i.e., hundreds of years), even given the ongoing mass removal of the current GWETS.

For the Primary COPCs, another secondary source includes COPCs present in vadose zone soils that will slowly leach downward to groundwater. As described in Section 9.7, the mass of perchlorate in vadose zone soils in OU-1 and the Eastside Sub-Area is significant, representing a potential on-going source of COPCs in groundwater for many years.

Most of the soil COPCs in OU-1, aside from the Primary COPCs, metals, and VOCs, were not found above GWSLs in OU-1 groundwater. This indicates that the mobility of these Other COPCs is limited and leaching from soil to groundwater is not a major migration pathway. This is expected because chemicals that are SVOCs, PAHs, PCBs, and dioxins/furans have low mobility as a result of their low solubility (limiting water pathway transport), low volatility (limiting air pathway transport), and high soil-water partition coefficients (high affinity to sorb to soil).

Due to their high volatility, VOCs can migrate from the subsurface upwards into ambient and indoor air. As discussed in Section 7.7 (for OU-1) and Section 8.6 (for OU-2), soil gas sampling was conducted during the RI to support the evaluation of vapor intrusion. Soil gas concentrations generally increased with depth indicating that VOCs present in soil gas are from groundwater rather than a source in the vadose zone. This potential exposure pathway is evaluated in the BHRA Reports for soil gas and groundwater in OU-1 and OU-2 (Ramboll 2023c, 2023d).

In summary, COPCs present in the UMCf are slowly migrating upwards into the saturated alluvium, a process that will continue for a long time. In addition, COPCs in the vadose zone can migrate downwards to the water table. Once in the alluvium, COPC migration is much more rapid and towards the Las Vegas Wash. Stream-deposited sands and gravels were laid down within paleochannels eroded into the surface of the underlying UMCf during infrequent historic flood runoff periods. When located below the water table, these paleochannels play a significant role in contaminant migration from OU-1 to the Las Vegas Wash. In OU-2 west of Pabco Road, COPCs are captured by the NERT GWETS before reaching the Las Vegas Wash. However, in OU-2 east of Pabco Road, COPC migration via groundwater to the Las Vegas Wash is currently uncontrolled since the GWETS was not designed to capture COPCs east of Pabco Road.

9.3.3 Chemical Transformation and Fate

There are various transformation processes, including physical, biological and chemical processes, which can act on chemicals in the natural environment and influence their migration and ultimate fate. As such, consideration of these processes and their effects on existing contamination sources, COPC migration, and possible influences regarding future remedial alternatives, are important in the development of the CSM. A summary of the transformation processes that could substantively impact the Primary COPCs in OU-1 and OU-2 is provided below.

As mentioned previously, perchlorate and chlorate are highly soluble compounds that do not sorb strongly to soil and, thus, tend to be extremely mobile in groundwater. This characteristic is demonstrated by the lateral and vertical extent of contamination by these two COPCs in groundwater throughout the entire NERT RI Study Area. Neither compound will tend to undergo transformation in the environment except under certain specific conditions, namely, biological degradation in a highly negative redox environment. This condition is generally not expected to occur under the natural geochemical conditions within the NERT RI Study Area. However, in the presence of a carbon substrate, biological activity in the subsurface can be sufficiently stimulated such that residual dissolved oxygen and other electron acceptors (e.g., nitrate) can be depleted creating the negative redox environment conducive to perchlorate or chlorate degradation. This represents what could potentially be a viable remedial alternative to consider for certain areas of the NERT RI Study Area and treatability studies are currently being conducted to better understand the conditions under which perchlorate and chlorate can be degraded.

VOCs, such as chloroform, can sorb to soils which influences the magnitude and extent of their migration in the environment (see Section 9.5.3) causing them to behave differently than the inorganic Primary COPCs. The COPCs that are VOCs can also undergo biological reductive dehalogenation under a highly negative (anaerobic) redox environment. However, because the natural geochemical conditions in the NERT RI Study Area do not favor microbial reductive dehalogenation (groundwater is generally aerobic), it is not anticipated that such processes will substantively influence the migration and fate of the VOCs within OU-1 or OU-2.

Metals do not degrade, which means they are naturally persistent in the environment. Radionuclides can decay into other elements, but eventually decay into stable species which are persistent in the environment. Both metals and radionuclides are sensitive to reduction and oxidation (redox) reactions that can change their valence, species (the form in which a dissolved metal or radionuclide is present in solution), and net ionic charge. The redox state strongly influences the transport behavior of the species in the environment and determines whether it will be present as an immobile solid or bound phase in soil or as a mobile dissolved phase in groundwater.

One of the Primary COPCs is the metal chromium, which exists in two main oxidation states in the environment: trivalent chromium [Cr(III)] and hexavalent chromium [Cr(VI)]. Trivalent chromium is both significantly less mobile and less toxic as compared to hexavalent chromium. Total chromium analytical results are a measurement of the sum of chromium concentrations in both states. Hexavalent chromium is very soluble and its adsorption on aquifer minerals is limited. In contrast, trivalent chromium tends to form insoluble precipitates under slightly acidic and neutral conditions, limiting both the concentration and mobility of Cr(III) in groundwater. As a result, total chromium analytical results in groundwater are mostly measuring dissolved Cr(VI), while total chromium analytical results in soil are measuring both Cr(III) and Cr(VI) in both sorbed and dissolved phases. Hexavalent chromium can convert to trivalent chromium under reducing conditions with a slightly alkaline pH, rendering it immobile and nontoxic.

9.3.4 Chemical Mobility and Persistence

Each contaminant's tendency for mobility and persistence is a function of site-specific characteristics and its chemical properties, including:

- Solubility,
- Tendency to transform,
- Tendency of organic compounds to degrade, and
- Chemical affinity for soils, organic matter, or air (usually described by a partition coefficient).

Table 9-2 lists the COPC chemical classes and their relative solubility, volatility, and soil-water partition coefficient (K_d). Chemicals that are volatile can migrate from the subsurface to ambient and indoor air. As a result, the BHRAs for soil gas and groundwater in OU-1 and OU-2 evaluate the risk of vapor intrusion from VOCs, such as chloroform. In general, chemicals with higher water solubilities (indicated as dark blue in Table 9-2) and lower K_d values (light green) tend to have greater mobility in soil and groundwater. Perchlorate and chlorate have very high solubilities and K_d values close to zero indicating they are extremely mobile in soil and groundwater. VOCs, such as chloroform, are still very mobile in soil and groundwater, but sorption to organic matter means they migrate more slowly in soil and groundwater. Chemicals with lower water solubilities (light blue) and higher K_d values (dark green) have a higher potential to remain sorbed to soil, restricting their mobility in soil and groundwater. This explains why SVOCs, PAHs, PCBs, and dioxins/furans within OU-1 are generally present in vadose zone soils and not groundwater.

As mentioned in Section 9.3.3.2, an important issue affecting the persistence of contamination in groundwater is the effect of matrix diffusion, in which slow upward migration from the UMCf causes concentrations in the higher permeability alluvium to remain above regulatory levels for a long period of time regardless of any remediation occurring in the shallower zones. Matrix diffusion will continue to be a significant factor relating to the persistence of the Primary COPCs of perchlorate, chlorate, chromium, and chloroform that have impacted the UMCf within and downgradient of OU-1. The lower permeability UMCf is the unit in which most of the contaminant mass is stored, as shown by the mass estimates for perchlorate and chromium provided in Section 9.6.1. As a result of matrix diffusion, groundwater concentrations of perchlorate and chromium have been declining relatively slowly, even though remediation of the higher permeability alluvium in the areas west of Pabco Road has been in progress for over 20 years.

The density of a contaminant plume may contribute to the direction of transport if dissolved concentrations are high enough. In the NERT RI Study Area, density-driven flow likely contributed to the downward transport of dissolved contaminants in OU-1 during historical periods when TDS concentrations were significantly higher than they are currently. Density-driven flow would have caused downward movement through coarser-grained units until downward movement was impeded by finer-grained units. Transport would then occur laterally following the slope of the top of the finer-grained unit. Based on the configuration of the perchlorate plume originating from the Unit 4 and 5 Buildings at 90-130 ft bgs (see Figure 7-50e), a finer-grained unit controlling the historical density-driven flow is present at the base of this depth interval that is dipping to the northeast. A similar plume configuration at this depth interval is observed for chromium, chlorate, and chloroform. The lithologic data is not sufficiently detailed to allow this finer-grained unit to be accurately mapped since density-driven flow can be influenced by small changes in hydraulic properties that are not apparent on boring logs. The mapping of the finer-grained unit is not necessary since the migration path is clearly delineated by the consistent configuration of the four plumes (perchlorate, chlorate, chloroform, and chromium). Under current conditions, however, data has demonstrated that continued, downward density-driven flow is negligible and upward migration due to matrix diffusion and the upward hydraulic gradient is currently the dominant transport mechanism.

A very similar situation of density-driven flow occurred with the DNAPL released on the OSSM site that has migrated and continues to migrate onto OU-1. Based on the configuration of the chloroform plume originating from the OSSM site at 90-130 ft bgs (see Figure 7-79e), a similar finer-grained unit is present at the base of this depth interval that caused the DNAPL to migrate to the north-northeast onto OU-1 from the OSSM site. Free product continues to be removed by OSSM from monitoring wells MC-MW-12, located on the OSSM site, and MC-MW-18, located on OU-1 (de maximis 2022b), indicating that DNAPL migration from the OSSM site onto OU-1 is still occurring. As noted previously, the lithologic data is not sufficiently detailed to allow the slope of this finer-grained unit to be accurately mapped. Since the migration path is clearly delineated by the configuration of the chloroform plume, it is not necessary to map the finer-grained unit in detail. Additional discussion of trespassing chemical migration is provided in Section 9.4.5.

9.4 Sources of Contamination within OU-1

Section 2.0 of this report describes in detail the land use history of the NERT RI Study Area, with a focus on OU-1 and OU-2. This section provides an abridged summary of historical detail for OU-1 to serve as a basis for the West Side CSM generally encompassing the NERT RI Study Area west of Pabco Road.

The BMI Complex, which includes the NERT Site, was initially developed by the US Government (under the Defense Plant Corporation) as a magnesium metal manufacturing facility during World War II. Facility construction began in 1941 under a contract with Basic Magnesium. The facility consisted of ten identical Unit Buildings, six of which (the Unit 1 through 6 Buildings) are within the boundaries of OU-1 (the NERT Site Study Area), with the remainder (the Unit 7 through 10 Buildings)[84] within the boundaries of the TIMET site. Chlorine, which was used in the magnesium manufacturing process, was supplied via pipeline to the Unit Buildings from a chlorine plant located to the west (within what is currently the OSSM site). The first production operations for magnesium metal began on August 31, 1942. Approximately 82,500 tons of magnesium metal were produced by Basic Magnesium within the entire BMI Complex (the Unit 1 through 10 Buildings) between 1942 and 1944 (Table 2-1 and Figure 2-1). The plant was operated from August 31, 1942 until November 15, 1944 in support of the war effort. Wastewater management features were established during this period, including a series of unlined ditches leading to infiltration/evaporation ponds located north and east of the current BMI Complex.

After World War II, the Basic Magnesium facility was repurposed, leased, and eventually sold to several chemical manufacturers. The portion that includes OU-1 (the Unit 1 through 6 Buildings) was operated as a perchlorate and chlorate manufacturing facility beginning in 1945, with the later addition of manganese dioxide (1951), elemental boron (1973), and boron trichloride (1973) operations in addition to several other chemical products.

To the west of OU-1, chlorine production, which began in 1942, continued on the current OSSM site. Beginning in the 1950s, pesticides were produced on the OSSM site. Until the 1970s, the wastes from the off-site production processes of chlorine and pesticides flowed to unlined ponds on the OSSM site and to several ditches, notably the Western Ditch and Beta Ditch, through which the wastes ultimately migrated to the BMI Ponds. While the Western Ditch did not travel through OU-1, the Beta Ditch Extension, which originated on the OSSM site and then connected with the Beta Ditch, ran west to east and bisected the entirety of OU-1 exiting on the east side. While on OU-1, the Beta Ditch received wastewater discharges from OU-1 operations. To the east of OU-1 at the Unit 7 through 10 Buildings, TIMET produced magnesium (the Unit 7 and 10 Buildings) beginning in the 1950s for use in the production of titanium tetrachloride (the Unit 8 Building). Wastewater from TIMET operations discharged to the Beta Ditch present on its site. Discharges to the unlined Beta Ditch continued until the 1970s. The Beta Ditch, which is a key element of the transport and migration of chemicals from multiple sources, received wastes from OSSM operations to the west of OU-1, various operations within OU-1, and TIMET operations to the east of OU-1 before eventually migrating to unlined ponds within the Eastside Sub-Area.

Historic source areas were identified and described within the LOU document issued in 1994 (NDEP 1994b).[85] The sources include areas that are currently used by EMD for chemical production (e.g., the Unit 4 and 5 Buildings), areas that are no longer active (e.g., the former AP Plant and associated facilities), and/or where near surface soil contamination has been addressed (e.g., former surface water impoundments and ponds that have been closed). Following the comprehensive investigation of on-site source areas during the NERT RI, the following areas have been identified as the major sources of contamination in OU-1,

---

[84] TIMET demolished the majority of Unit Building 7 between 2015 and 2016.

[85] NDEP identified 69 source areas referred to as LOUs in their document, most of which were located within OU-1 (NDEP 1994 a,b). Subsequently, an additional potential source area, the former U.S. Vanadium site, was identified during planning for the Phase B 2008 investigation (NDEP 2011c). Although not formally designated as a LOU, the U.S. Vanadium site is commonly referred to as LOU 70.

both originating on-site and off-site (i.e., trespassing chemicals). The major sources of contamination within OU-1 are illustrated in Figure 9-6.

9.4.1 Unit 4 and 5 Buildings

As previously stated, the Unit 4 and 5 Buildings were used for multiple purposes, including the production of magnesium, chlorates and perchlorates. Reported historical releases included process chemicals leaking to soil through cracks in the basements of the Unit 4 and 5 Buildings (LOUs 43 and 61) (NDEP 1994b). Sumps in the concrete basements collected process liquor, spillage, and wash water associated with production. Between October 2015 and December 2017, investigation of the Unit 4 and 5 Buildings was conducted in accordance with the approved Unit 4 and 5 Buildings Investigation Work Plan (Tetra Tech 2015). The objective of this investigation was to determine the nature of contamination and the vertical extent of impacted soil and groundwater underneath the Unit 4 and 5 Buildings. In addition to perchlorate and hexavalent chromium, several other COPCs were identified in soil and groundwater above their respective LSSLs, GWSLs, or other screening criteria. These other COPCs included chlorate, chloroform, and nitrate. In addition, elevated TDS concentrations were observed.

The results of this phased investigation were provided in the Unit 4 and 5 Buildings Investigation Report (Tetra Tech 2020). A summary of the investigation and results was presented in Section 7.6, and Figures 7-99b and 7-99c show the locations of the 77 borings and 21 monitoring wells installed during the investigation of the Unit 4 and 5 Buildings, respectively.

Perchlorate was found to be the most widespread of these COPCs in both soil and groundwater. To assist with vertical delineation, soil samples were collected both in the vadose zone and in saturated soil below the water table along with discrete-depth groundwater samples. Perchlorate concentrations in groundwater exceeded the GWSL of 0.015 mg/L throughout most of the Unit 4 and 5 Buildings Investigation Area. The highest perchlorate concentrations in groundwater were observed directly below and downgradient of the Unit 4 Building in the UMCf (up to 6,600 mg/L). Based on the depth-discrete sampling results, the highest concentrations of perchlorate were detected in the UMCf within a depth interval between 75 and 125 feet bgs. The perchlorate concentrations decreased at depths below 125 feet. In the deepest discrete-depth sample collected from 240 feet bgs, the perchlorate result was non-detect.

The lateral extent of the perchlorate and other COPCs found in the Unit 4 and 5 Buildings source area groundwater was evaluated as part of the OU-1 RI and detailed in Section 7.6.2. Perchlorate (and other chemicals associated with releases at the Unit 4 and 5 Buildings) migrated downward through the alluvium and UMCf silty sands/sandy silts that occur in this area of OU-1 and accumulated at the base of a sandy silt layer and the top portion of the underlying silty clay soils at an approximate depth of 110 feet bgs. In addition to dissolved-phase migration, the very high concentrations of perchlorate, chlorate, and other COPCs historically present as a brine beneath the Unit 4 Building would have migrated downward into the UMCF through density-driven flow. Perchlorate concentrations (above 1,000 mg/L) found beneath the Unit 4 Building, as described earlier in this document, extend north-northeast for a distance of approximately 900 feet. Northeast of the Unit 4 Building, the highest concentrations were generally found between depths of approximately 90-110 feet bgs. The sandy silt layer described above is underlain by low permeability clayey silt and silty clay soil that impedes the downward migration of perchlorate. As shown in Figure 7-50e, the perchlorate-impacted groundwater migrated laterally, first toward the north-northeast within a depth interval of 90 to 130 feet bgs, for a distance of approximately 1,800 feet to where the sandy silt layer transitions laterally into finer-grained silt and clayey silt. The decrease in permeability associated with this lateral transition has the effect of deflecting groundwater flow toward the east. As such, the plume geometry is oriented in the southwest-northeast direction as opposed to the north-south orientation characteristic of the Primary COPCs in the Shallow WBZ. Based on the available data, the area of perchlorate-impacted groundwater above the GWSL extends for a distance of approximately 2,500 feet northeast of the Unit 4 Building within the 90-130 feet depth interval (see Figure 7-50e).

The distribution of Primary COPCs besides perchlorate is similar to perchlorate in that the highest concentrations were found in wells located adjacent to the Unit 4 Building, below the Unit 4 Building basement, and northeast of the Unit 4 Building between approximate depths of 90-110 feet. The lateral extent of groundwater impacted by the other Primary COPCs is within the perchlorate groundwater plume footprint at this depth (see Figure 7-50e). These similar distribution patterns are consistent because they originate from the same source area (Unit 4 and 5 Buildings) and are subject to the same hydrogeologic conditions.

Specifically with respect to the primary COPC chloroform, the highest concentrations in groundwater beneath and downgradient of the Unit 4 Building were found in samples collected from wells screened between approximate depths of 90-115 ft bgs. The highest concentrations (up to 8,300 µg/L in well M-251-100) were found beneath the Unit 4 Building and extend north-northeast for a distance of approximately 1,600 feet, a distribution pattern similar to perchlorate at this depth (see Figures 7-50e and 7-79e). This indicates chloroform migrated downward beneath the Unit 4 Building along with perchlorate and other Primary COPCs found at this depth interval.

As indicated in Section 7, the Primary COPCs migrated downward then downgradient of the Unit 4 and 5 Buildings. The direction of COPC migration is dictated by the direction of groundwater flow and the geometry of the geologic units that serve as the preferential pathways. Within the upper 90 feet of the subsurface, the COPCs migrate northward. However, within the depth interval of 90 to 130 feet bgs, COPC migration is controlled by the geometry of the geologic unit serving as the preferential pathway (and the surrounding fine grain sediments) which deflects flow to the northeast (Figures 7-50e [perchlorate], 7-51g [chlorate], 7-58e [chromium], and 7-79e [chloroform]). Groundwater monitoring of the depth interval of 130 to 175 feet bgs indicates that COPCs are migrating northward of the Unit 4 and 5 Buildings for a limited distance and do not migrate into OU-2 at this depth interval (Figures 7-50g [perchlorate], 7-51i [chlorate], 7-58g [chromium], and 7-79g [chloroform]).

9.4.2 Former Beta Ditch

The Beta Ditch was an unlined ditch that carried wastewater from the BMI Complex to the Upper BMI Ponds from 1943 until the mid-1970s.[86] As previously discussed, this feature

---

[86] The Beta Ditch within OU-1 was excavated in 2010-2011 (ENVIRON 2012a) and 2013 (ENVIRON 2014d). Portions of the Beta Ditch within the TIMET site were primarily excavated in 2013 (GEI 2013).

started on the OSSM site to the west, crossed OU-1 onto the TIMET site, then continued to the system of disposal ponds within the Eastside Sub-Area. The Upper BMI Ponds were constructed in this area during the early 1940s to provide additional discharge capacity beyond that of the original on-site Trade Effluent Ponds within OU-1. From 1943 to 1944, process wastewater from magnesium production within OU-1 migrated to the Upper BMI Ponds via the Beta Ditch. From 1945 until the mid-1970s, process effluents from the chlorate-, perchlorate-, and boron-related production processes within OU-1, as well as effluents associated with historical tenants within OU-1 and process effluents from chlorine- and pesticide-related production processes at the OSSM site and titanium tetrachloride-related production processes at the TIMET site, commingled within and migrated to the Upper BMI Ponds via the Beta Ditch.

Discharges to the Beta Ditch would have included perchlorate, chlorate, chloroform, and chromium associated with former production processes in OU-1. In addition, chloroform discharges to the Beta Ditch would have occurred from the OSSM and TIMET sites, because chloroform is known to be a waste by-product of the chemical production processes occurring at both the OSSM and TIMET sites (Converse 1993; Weston 1993; USEPA 2007; US Patent Office 1957). Carbon tetrachloride, which readily degrades to chloroform, was also a waste by-product at the OSSM site and TIMET site.

For approximately 35 years, percolation of wastewater from the unlined Beta Ditch resulted in contamination of underlying soil and shallow groundwater related to former operations in OU-1 and from other BMI Complex users of the ditch, including the OSSM and TIMET sites. With respect to the segments of the ditch system west of OU-1, this use of the ditches by OSSM, or other entities operating within the present day OSSM site, represented a historical source of contaminants to OU-1 environmental media unrelated to former OU-1 operations (Geraghty & Miller 1993). Additional information on their past operations is provided in Section 2. Since the Beta Ditch was unlined, discharges to the Beta Ditch migrating eastward to the Eastside Sub-Area would have impacted groundwater beneath the Beta Ditch, and COPCs in groundwater resulting from the percolation of wastewater would have migrated downgradient.

In the early 1970s, under the federal NPDES program, the BMI Complex companies curtailed waste discharges to the Beta Ditch and the Upper and Lower BMI Ponds (Geraghty & Miller 1993). Kerr-McGee achieved zero-discharge status in 1976, at which time process effluents were sent to on-site lined surface impoundments. As a result, process waste discharges from all parties to the Beta Ditch ceased in 1976 when all companies operating within the BMI Complex achieved zero discharge status.

Within OU-1, the inactive Beta Ditch and underlying soil were excavated in 2010-2011 as part of a soil removal action and concurrent construction of the Central Retention Basin. In the area north (downgradient) of the Beta Ditch, between the Beta Ditch and the IWF/barrier wall, the RI sampling results show an extensive area of residual soil and groundwater contamination related at least in part to infiltration from the former unlined ditch which was not addressed through the soil removal action. Groundwater is impacted by perchlorate (up to 1,900 mg/L) and chloroform (up to 1,400 µg/L) to a depth of approximately 70 feet bgs in this area. Other COPCs found in groundwater within the same depth interval in this area of the Site include chlorate (up to 4,400 mg/L), magnesium (up to 520 mg/L), nitrate/nitrite (up to 70 mg/L), strontium (up to 25 mg/L), chromium (up to 23 mg/L), bromide (up to 7.5 mg/L), and boron (up to 5.8 mg/L). These groundwater results are consistent with the West Site CSM (i.e., the NERT RI Study Area west of Pabco Road), which identified the Beta Ditch as a significant source of COPCs in OU-1.

9.4.3 Former AP Plant and Associated Facilities

The AP Plant and associated waste containment ponds and other facilities were located in the southern half of OU-1, south of the former Beta Ditch, and in the area between the Beta Ditch and the IWF/barrier wall. The area occupied by the former AP Plant facilities is shown in Figures 2-4 and 2-5a. The RI results and concurrent AP Area Down and Up Flushing Treatability Study (Tetra Tech 2018) investigations in this area showed elevated concentrations of perchlorate and other COPCs in soil above LSSLs and in groundwater above GWSLs to depths of at least 60-70 feet bgs. Beginning in early 2018, eight wells installed for the treatability study continued operating (as directed by NDEP as part of the GWETS) in an area where perchlorate concentrations ranged from 99 mg/L to 1,600 mg/L. Additional elevated COPCs detected in groundwater included chlorate (up to 2,100 mg/L), magnesium (up to 370 mg/L), nitrate/nitrite (up to 130 mg/L), bromide (up to 23 mg/L), strontium (up to 20 mg/L), boron (up to 11 mg/L), and chromium (up to 6 mg/L). Closure of the nearby former AP-5 Pond was completed in September 2018 (Tetra Tech 2019b). Following the pond closure, RI results showed perchlorate concentrations above 1 mg/L in underlying groundwater to a depth of approximately 85 feet, and perchlorate above the GWSL was found to extend to a depth of approximately 145 feet. The highest concentration of perchlorate in groundwater at this location was 950 mg/L between 60 and 70 feet bgs. At a depth interval of 90 to 100 feet bgs, perchlorate in groundwater at this location was 0.6 mg/L.

9.4.4 Features North of the IWF/Barrier Wall

As discussed in Section 7 of this report, COPCs were also found in soil and groundwater at concentrations above their respective LSSLs and GWSLs in the area north of the IWF/barrier wall and near the north (i.e., downgradient) boundary of OU-1. The major sources of contamination in this area of OU-1 are listed below.

Former Trade Effluent Ponds. Between 1942 and 1944, process wastewater generated by industrial operations within OU-1 and the BMI Complex was discharged via the Distribution Flume following treatment in the wastewater acid neutralization plant to the Trade Effluent Ponds (partially located outside of OU-1), the original wastewater disposal ponds that were used prior to construction of the Upper and Lower BMI Ponds (Kleinfelder 1993). Details regarding Trade Effluent Pond usage after 1944 were not reported (Kleinfelder 1993). The locations of these former unlined ponds are shown in Figure 2-9. As shown in Figure 2-5a, the GW-11 and WC ponds, which are currently in operation, are located where some of the former Trade Effluent Ponds were located and the northern berms of these in-service ponds appear to have been originally constructed from the former Trade Effluent Ponds. Soil characterization data from the GW-11 and WC pond berms indicates the presence of select COPCs above LSSLs in the pond berms. As such, these COPCs have impacted groundwater quality within OU-1 and ultimately migrate off-site into OU-2.

Former IWF Recharge Trenches. Between mid-1987 and 1998, treated groundwater from the IWF was conveyed to two shallow recharge trenches north of the barrier wall (see

Section 3.2). At that time, the extracted groundwater from the IWF was treated only for chromium and then reinjected into the ground. Data indicates that this activity may have contributed to the high concentrations of perchlorate, chlorate, and chloroform found in groundwater north of the barrier wall observed today. Following the discovery of perchlorate in groundwater, stabilized Lake Mead water was used to recharge groundwater downgradient of the IWF from 1998 until September 2010, when the recharge trenches ceased operation prior to soil removal activities at the Site. The Primary COPCs are detected in groundwater in this area of OU-1 north of the barrier wall at the following concentrations: perchlorate up to 1,200 mg/L, chlorate up to 3,300 mg/L, chromium up to 11,000 µg/L, and chloroform up to 740 µg/L. In general, the highest concentrations occur within the Shallow WBZ to a depth of 70-75 ft bgs. Perchlorate concentrations above the GWSL of 0.015 mg/L extend to depths of 90 ft bgs along the northern OU-1 boundary and to depths of 145-150 ft bgs near the northeastern portion of the northern OU-1 boundary.

9.4.5 Trespassing Chemicals

As discussed above within Sections 2.2 and 9.4, historical chemical production processes occurred at the adjacent facilities both to the east (TIMET) and west (OSSM) of OU-1. These processes resulted in releases of chemicals that caused contamination of soil, soil gas, and groundwater. As indicated previously, COPCs and DNAPL from the OSSM site are migrating into OU-1, and COPCs released at the Unit 4 and 5 Buildings are migrating into the TIMET site.

9.4.5.1 Trespass From OSSM Site to OU-1

Based on the evaluation in Section 7.5, the following 17 groundwater COPCs have been identified along the western boundary of OU-1 as originating on the OSSM site: arsenic, magnesium, manganese, chloroform, benzene, chlorobenzene, 1,2-, 1,3- and 1,4-dichlorobenzene, carbon tetrachloride, 1,1-dichloroethane (1,1-DCA), 1,2-dichloroethane (1,2-DCA), 1,4-dioxane, 1,1,2,2-tetrachloroethane, 1,2,3-trichloropropane, methylene chloride, and tetrachloroethene (PCE). Since chloroform is the most significant trespassing chemical in terms of its mobility in the subsurface and also one of the Primary COPCs, the discussion of trespassing chemicals from the OSSM site focuses on this chemical. As described in Section 2.2.1, there were several chemical production processes used on the OSSM site that generated chloroform. Unlike chloroform, other trespassing chemicals primarily associated with the OSSM DNAPL (i.e., benzene, chlorobenzene, dichlorobenzenes, and carbon tetrachloride) were not reportedly used or generated as byproducts in the industrial processes that occurred in OU-1, except for de minimis use of chlorobenzene and dichlorobenzene by Hardesty (Kleinfelder 1993). These 16 other major trespassing chemicals were directly used in or were byproducts of pesticide production on the OSSM site. Thus, their presence in groundwater in the western portion of OU-1 is a result of trespassing contaminants from the OSSM site.

This trespassing VOC plume and DNAPL is referred to as the OSSM plume. This plume is the subject of on-going remedial action (i.e., operation of the OSSM GWETS and DNAPL recovery) that has been implemented by OSSM under NDEP oversight. As detailed in Section 7, the OSSM plume encroaches into OU-1 across its western boundary for a distance of approximately 1,000 feet. It includes DNAPL at depths of 100-120 feet bgs, as well as dissolved-phase VOCs in the Shallow and Middle WBZs (Geosyntec 2019). Of the VOCs detected in the DNAPL, chloroform is the most persistent and soluble (i.e., mobile), and represents the most prevalent VOC found in the dissolved phase in OU-1. Chloroform is detected at concentrations up to 19,000 µg/L in samples from Shallow WBZ wells within OU-1 impacted by the OSSM plume. For comparision, the highest chloroform concentration in the vicinity of the Unit 4 and 5 Buildings source area in the Shallow WBZ was 310 µg/L.

Based on data collected by NERT and OSSM, trespassing chemicals from the OSSM site have migrated onto OU-1 through three main mechanisms: 1) migration from the OSSM site as DNAPL (and associated dissolved VOCs) in the Middle WBZ, 2) migration from the OSSM site via wastewater containing dissolved VOCs and metals flowing in the Beta Ditch, and 3) migration from the OSSM site via groundwater containing dissolved VOCs and metals flowing in the Shallow WBZ. The first mechanism of DNAPL migration continues to occur. The second and third mechanisms would have mainly occurred prior to the mid-1970s when the Beta Ditch was in use and the disposal of wastewater into the ponds on the OSSM site would have caused groundwater mounding in the Shallow WBZ, resulting in groundwater flow and migration of dissolved VOCs and metals from the OSSM site onto OU-1. VOCs may also have migrated in the vapor phase within the unsaturated zone. Based on the observation that the highest groundwater concentrations of chloroform along the western boundary of OU-1 are present in the Middle WBZ (90-130 ft bgs) where DNAPL has been observed, DNAPL migration is the dominant migration mechanism. The vertical extent of the OSSM plume does not extend beyond a depth of 130 ft bgs as illustrated in the chloroform plume maps in the Shallow WBZ (0-55 ft bgs), Shallow WBZ (55-90 ft bgs), and Middle WBZ (90-130 ft bgs) shown in Figures 7-79b, 7-79d, and 7-79e, respectively.

Similar to the situation at the Unit 4 and 5 Buildings, the geometry of a finer-grained geologic unit within the UMCf near the base of the 90-130 ft bgs interval along the western property boundary caused the DNAPL released from source areas on the OSSM site to migrate in a northeast direction into OU-1. Figure 9-7 shows the southwest-northeast orientation of the OSSM plume in this depth interval. As shown in the figure, cross-section O-O’ runs along the axis of the trespassing OSSM plume. The geology along this cross-section is shown in Figure 9-8a, and the chloroform concentrations overlain on the cross section are shown in Figure 9-8b. Similar to OU-1, the southern part of the OSSM site is near the mountain sources of sediment deposited in the UMCf. As can be seen in Figure 9-8a, above a depth of approximately 130 feet, the UMCf is characterized by silty sand units that become thinner and discontinuous toward the north, consistent with the Distal Alluvial Fan FA and the Sheet Sands FA discussed in Section 5.4.3.

As illustrated in Figure 9-8b, chloroform appears to migrate through the UMCf following a series of discontinuous silty sand units that create downward “stair step” pathways, consistent with a common DNAPL migration pathway through hetereogeneous fine-grained depoists with discontinuous sandy lenses. Mobile DNAPL has accumulated in a 4-5 feet thick silty sand unit that extends from well MC-MW-12 at the OSSM site to MC-MW-18 at the NERT site, and pinches out to the north and east. This thin silty sand unit is underlain by fine-grained silt and clayey silt, which limits the continued downward DNAPL migration below approximately 130 feet bgs. Although the available lithologic data in this area is not sufficiently detailed to allow the slope of the finer-grained unit controlling the direction of the DNAPL migration to be accurately mapped, the migration pathway is clearly delineated by the configuration of the OSSM plume.

Investigations by OSSM have indicated that the OSSM DNAPL is present in eight wells screened between depths of 90-120 ft bgs. Free-phase (mobile) DNAPL has been found in well MC-MW-12 at the OSSM site and in well MC-MW-18 located in OU-1, and residual DNAPL was identified in six other OSSM wells. As shown in Figure 7-79e, residual or mobile DNAPL is present over an area of approximately 53 acres in the Middle WBZ between 90 and 130 ft bgs, including approximately 7 acres of residual or mobile DNAPL present within OU-1. Within the area of mobile DNAPL between wells MC-MW-12 and MC-MW-18, migration of DNAPL will continue from the OSSM site to the northeast onto OU-1 for the foreseeable future until residual saturation is reached through DNAPL removal or spreading. The OSSM DNAPL contains a mixture of VOCs – primarily benzene, chlorobenzene, dichlorobenzenes, carbon tetrachloride, chloroform, pesticides, and herbicides. Chloroform has been reported up to a concentration of 43,000 µg/L in a groundwater sample collected from OSSM well MC-MW-18 located on the NERT Site, but within the trespassing portion of the DNAPL from the OSSM site (see Figure 7-79e).

This DNAPL has served and continues to serve as a long-term source of groundwater and soil gas contamination in OU-1 and OU-2. As shown in Figure 9-8c, there are multiple transport pathways from the OSSM trespassing DNAPL source zone. The DNAPL itself is still mobile within the 90-130 ft bgs zone shown in Figure 7-79e. It will continue migrating laterally to the northeast until reaching residual saturation. The residual DNAPL is no longer mobile, but groundwater flowing through or near the DNAPL will dissolve chloroform and other VOCs from the DNAPL, acting as a long-term source to the dissolved-phase OSSM plume. Unless the DNAPL is removed, dissolved chloroform will remain in groundwater within OU-1. Under the influence of the upward gradient, the dissolved contaminants will migrate into the Shallow WBZ. A portion of the OSSM plume will continue to slowly migrate northward within the Shallow WBZ passing from OU-1 into OU-2. This migration is slow because the alluvium is currently unsaturated within most of OU-1, so groundwater migration only takes place in the fine-grained UMCf.

When groundwater levels were higher historically, the migration of chloroform and other other COPCs into OU-2 would have also occurred through the alluvium. Due to its higher conductivity, the migration of chloroform in the alluvium would have been much faster. While this alluvium migration was occurring, the chloroform and other VOCs in the alluvium would have diffused downwards into the UMCf. Both historically and under current conditions, the dissolved-phase contaminants below the DNAPL will migrate deeper into the UMCf through diffusion. In addition, chloroform and other VOCs will volatilize from the water table of the OSSM plume and migrate upwards into soil gas towards the ground surface.

Throughout most of OU-1, the OSSM chloroform plume is distinct from the NERT chloroform plume. Figures 7-79b through 7-79h display the two chloroform plumes within OU-1: the trespassing plume from OSSM within the western half of OU-1 and the plume originating at the Unit 4 and 5 Buildings within the eastern half of OU-1. As shown in these figures, the two plumes are clearly discernable with an area of lower chloroform concentrations present north of the Unit 2 and 3 Buildings separating both plumes. The separation between the two plumes is also illustrated in the east-west cross sections C-C’ and D-D’ shown in Plates C-3c and C-4c in Appendix C.

To support this interpretation, NERT completed a particle tracking evaluation of water table conditions using a revised version of the Phase 6 groundwater model. The results of this evaluation are shown in Figure 9-9a, which documents the groundwater flow direction at the water table. This evaluation not only considers groundwater elevation data across OU-1 but also the geometry of geologic units and aquifer properties such as hydraulic conductivity. Based on this evaluation it is clear that chloroform at the Unit 4 and 5 Buildings is not the source of chloroform contamination within the western half of OU-1. Additionally, the particle tracking evaluation is consistent with the depiction of the chloroform plume in the Shallow WBZ (0-55 ft bgs) shown in Figure 7-79b, including the migration of the trespassing plume into OU-1 and further migration off-site into OU-2 without being captured by OSSM's groundwater extraction system.

A similar particle tracking evaluation for the Middle WBZ (90-130 ft bgs) is shown in Figure 9-9b. Within this depth interval, the groundwater flow direction is more to the northeast as compared to the Shallow WBZ. Under current conditions, the flow direction is being pulled to the north by the pumping at the OSSM GWETS. Prior to the operation of the OSSM GWETS, the flow direction would have been more to the northeast and aligned with the axis of the OSSM trespassing plume. The particle tracking evaluation shows that groundwater from the chloroform plume in the Middle WBZ first moves northeast and then moves upward into the Shallow WBZ in the northern portion of OU-1 due to the upward gradient and the pinching out of the silty-sand unit in the Middle WBZ. Within the Shallow WBZ, the particle tracking evaluation shows that groundwater flow is in a direction consistent with the configuration of the chloroform plume in the Shallow WBZ (0-55 ft bgs) shown in Figure 7-79b, including the migration into OU-2 without being captured by OSSM's groundwater extraction system.

The horizontal mass flux of chloroform across the NERT-OSSM property boundary for the Middle WBZ (90-130 ft) was estimated based on available data. The horizontal groundwater gradient was calculated using the potentiometric surface map for the Middle WBZ (90-130 ft bgs) shown in Figure 5-17a. Using the hydraulic conductivity for this unit from the Phase 6 groundwater model, the normal component of groundwater flow across the property boundary was estimated. Chloroform concentrations along the boundary were estimated using the plume map for this depth interval shown in Figure 7-79e. The estimated horizontal mass flux of chloroform dissolved in groundwater is 0.7 lb/day. Additional migration across the property boundary is also occurring due to DNAPL migration, but this has not been estimated due to the lack of data on the levels of DNAPL saturation.

9.4.5.2 Trespass From OU-1 to TIMET Site

As indicated in Section 7.5.1, COPCs identified at the Unit 4 and 5 Buildings source area are migrating northeastward at a depth interval of 90 to 130 ft bgs. As a result, the Primary COPCs (perchlorate, chlorate, chromium, and chloroform) are migrating from OU-1 onto the TIMET site. Figures 7-50e, 7-58e, and 7-79e display the horizontal extent of Primary COPC migration within this depth interval based on perchlorate, hexavalent chromium, and chloroform data collected by TIMET in 2008 (TIMET did not analyze these samples for chlorate). As shown in Figure 9-7, cross-section N-N' is oriented along the axis of the trespassing plume, with the geology and vertical extents of chloroform, perchlorate, and chromium along the cross-section shown in Figures 9-10a, 9-10b, 9-10c, and 9-10d.

Given that there is an upward gradient, it is expected that these COPCs are also slowly migrating upward toward the water table within the TIMET site. As such, the concentrations in the 90-to-130 ft depth interval should be higher than the concentrations in groundwater at the water table within the TIMET site for all NERT COPCs. Earlier in this report it has been documented that while perchlorate, chlorate, and chromium are unique to former operations in OU-1, chloroform can be associated with former operations at the OSSM site, OU-1, and the TIMET site.

TIMET evaluated conditions in the UMCf based on multi-port samples collected at five borehole locations in 2008 and 2009 and summarized their findings in a May 2020 report (TIMET 2020a). As indicated in their report and illustrated in Figures 9-10c and 9-10d, perchlorate and chromium concentrations between 90 to 130 ft bgs were one to two orders of magnitude higher than at the water table. This overall decreasing upward concentration gradient is consistent with what would be expected if the source of NERT Primary COPCs within the TIMET site were this deep trespassing plume. However, unlike the other NERT Primary COPCs, chloroform does not display the same concentration gradient. Chloroform concentrations in the 90-to-130 ft depth interval are up to two orders of magnitude lower than in groundwater at the water table (Figure 9-10b). As such, chloroform migrating from the Unit 4 and 5 Buildings source area cannot be solely responsible for the higher concentrations of chloroform in groundwater at the water table within the TIMET site. Thus, there must be other chloroform sources within the TIMET site that are directly impacting shallow groundwater.

This interpretation of COPC migration from the Unit 4 and 5 Buildings source area was confirmed with a particle tracking evaluation based on a revised version of the Phase 6 groundwater model. As shown in Figure 9-9c, groundwater originating just north of the Unit 4 and 5 Buildings within the Middle WBZ (90-130 ft bgs) flows to the northeast along the axis of the chloroform plume within this depth interval. Consistent with the chloroform distribution in the cross section shown in Figure 9-10b, the groundwater from the Unit 4 and 5 Buildings remains within the Middle WBZ (90-130 ft bgs) passing beneath the elevated chloroform concentrations near the water table. Thus, the particle tracking evaluation confirms that there must be other chloroform sources on the TIMET site that are impacting shallow groundwater.

In addition, the particle tracking evaluation shown in Figure 9-9c indicates that the chloroform plume trespassing onto the TIMET site passes beneath the TIMET extraction system and migrates into OU-2. Although not shown in Figure 9-9c, the particles moving into OU-2 are ultimately captured by the NERT GWETS at the AWF or SWF. This is confirmed by the capture zone figure for the Middle WBZ in the 2021 Annual Groundwater Monitoring and GWETS Performance Report, which indicates that groundwater throughout the TIMET site is captured by the TIMET GWETS, the NERT AWF, or the NERT SWF (Figure 10b, Ramboll 2022a). As described below, the TSE was designed to treat NERT COPCs that are captured by the TIMET extraction system.

The horizontal mass fluxes of perchlorate, chlorate, chromium, and chloroform across the NERT-TIMET property boundary for the Middle WBZ (90-130 ft) were estimated based on available data. The horizontal groundwater gradient was calculated using the potentiometric surface map of groundwater for the Middle WBZ (90-130 ft bgs) shown in Figure 5-17a.

Using the hydraulic conductivity for this unit from the Phase 6 groundwater model, the normal component of groundwater flow across the property boundary was estimated. The plume maps from Section 7.5 were used to estimate the concentrations used to calculate the horizontal flux across the NERT-TIMET boundary. The estimated horizontal mass fluxes are 4.1, 20.0, 0.03, and 0.005 lb/day for perchlorate, chlorate, chromium, and chloroform, respectively. To calculate the vertical mass flux of each constituent from the deeper interval up into the 0-55 ft depth interval on the TIMET property, the measured vertical gradient at M-148A/M-186 was used (Table 5-1). The estimated vertical mass fluxes on the TIMET property are 5.4, 19.2, 0.06, and 0.004 lb/day for perchlorate, chlorate, chromium, and chloroform, respectively.

As directed by NDEP, the TSE was constructed in 2022 through early 2023 to remove perchlorate, chlorate, and chromium from groundwater that migrates from the NERT Site and is captured by TIMET's GWETS. The captured groundwater is initially treated by TIMET for VOCs using an air stripper. The groundwater treated by TIMET is then pumped to the TSE located on the NERT Site via an underground 8-inch diameter, high density polyethylene pipe, where it is treated for perchlorate, chlorate, and chromium. The TSE accommodates up to 100 gpm of flow from TIMET. The treated groundwater is returned to TIMET for injection into TIMET's recharge trenches, which are regulated by TIMET's UIC permit.

9.4.6 Summary of Sources of Groundwater Contamination in OU-1

In summary, groundwater contamination in OU-1 related to releases from historical operations included the following significant sources:

- Historical operations in the Unit 4 and 5 Buildings;
- Use of the former unlined Beta Ditch from 1943 to the mid-1970s;
- Historical operations at the former AP Plant and associated facilities; and
- Features north of the IWF/barrier wall (e.g., the former Trade Effluent Ponds and recharge trenches).

A summary of the sources within OU-1 of perchlorate, chlorate, and chromium are shown in Figures 9-11a, 9-11b, and 9-11c. In addition, trespassing VOCs and metals from the OSSM plume have impacted and continue to impact groundwater in OU-1.

Based on the data presented above and in Section 7, the following COPCs are detected in groundwater near the OU-1/OU-2 boundary and continue to migrate into OU-2 via the groundwater pathway:

- Primary COPCs (perchlorate, chlorate, chromium, and chloroform); and
- Other COPCs (nitrates, arsenic, boron, magnesium, manganese, bromodichloromethane, carbon tetrachloride, 1,4-dioxane, and 1,2,3-trichloropropane).

A contaminant plume originating on the OSSM site continues to trespass into OU-1 adversely impacting groundwater quality. These trespassing COPCs, particularly chloroform, migrate through OU-1 and into OU-2 without being captured by the OSSM or NERT groundwater extraction systems, as illustrated in Figure 7-79b and Figures 9-9a and 9-9b. While particle tracking results shown in Figure 9-9a indicate that some of the trespassing plume within the alluvium is captured and ultimately treated by the OSSM GWETS (shown in Figure 3-1), the great majority of what has migrated into OU-1 continues uncaptured and eventually exits OU-1 into OU-2. While the DNAPL trespassing into OU-1 from the OSSM site is not migrating into OU-2, an approximately 7-acre area of OSSM's DNAPL is present within the 90-130 ft bgs depth interval within OU-1 and will continue to serve as a long-term uncontrolled source of contamination to groundwater in the Shallow and Middle WBZs that will continue to migrate into OU-2. NDEP has stated that it will work with OSSM and other responsible parties to address in their FSs and remediation plans any COPCs that are trespassing onto the NERT site.

9.5 Sources of Contamination Impacting OU-2

As discussed throughout this report, OU-2 is immediately downgradient of OU-1 and is approximately 2.5 miles wide from west to east. Also as discussed, Pabco Road effectively demarcates the investigatory and cleanup obligations of NERT resulting from the AOC between NDEP and BRC, and thus discrete sets of COPCs have been assigned to the areas east and west of Pabco Road. Furthermore, and due to substantial differences in historical land use and source areas in OU-2 east of Pabco Road, separate CSMs have been established (i.e., East Side and West Side CSMs). Ultimately, contaminants in groundwater on both sides of Pabco Road discharge into the Las Vegas Wash; however, contaminants in the Eastside Sub-Area migrated to this area via the Beta Ditch and may have originated from any of the properties within the BMI Complex. In order to determine the migration path of COPCs from the various source areas to the Las Vegas Wash, a particle tracking analysis was completed. The West Side CSM is composed of OU-1 and the NERT Off-Site Study Area component of OU-2 west of Pabco Road and the East Side CSM is composed of the Eastside Sub-Area component within OU-2 east of Pabco Road. As such, these areas are discussed separately below.

9.5.1 Sources of Contamination West of Pabco Road (NERT Off-Site Study Area)

As depicted in the West Side CSM (Figure 9-2b), property in the NERT Off-Site Study Area component of OU-2 has been used for residential or commercial purposes unrelated to the historic and current operations of the BMI Complex inclusive of OU-1. Although a comprehensive survey of the history of each property in this area has not been done, the area is currently occupied by casinos, gas stations, retail stores, auto dealerships, auto wreckers, a large data center, and a wide variety of other small businesses. While some of these operations could result in localized soil or groundwater contamination, none of the identified operations are likely to have significantly contributed to the wide-spread distribution of COPCs within OU-2. Further, COPC concentration gradients clearly indicate that properties in OU-2 do not have an observable impact on groundwater quality.

Since there are no identifiable sources of Site-related contamination within the portion of the NERT Off-Site Study Area in OU-2, the groundwater contamination present within this area resulted from migration in groundwater from upgradient sources (including OU-1). In addition, COPC migration in groundwater associated with releases that occurred during the early years of manufacturing within OU-1 and adjacent properties within the BMI Complex has resulted in residual contamination in the UMCf, which acts as an on-going source of contamination to the overlying alluvium via slow upward matrix diffusion (discussed further in Sections 9.5.1.3 and 9.5.2.1).

9.5.1.1 Migration in Groundwater from Upgradient Sites

Within the NERT Off-Site Study Area component of OU-2 west of Pabco Road, the primary source of the contamination in groundwater is the migration of COPCs in groundwater from upgradient sites: OU-1, the OSSM site, and the TIMET site. In addition, the perchlorate plume originating from the former AMPAC site is commingling with the NERT perchlorate plume in the northwest corner of OU-2. The locations of the upgradient site investigation areas are shown in Figure 1-3b. Since contamination originates from upgradient sources, the highest concentrations of COPCs in OU-2 groundwater are found in the southern part of this area adjacent to Warm Springs Road. Of the Primary COPCs, only chromium contamination in groundwater resulted from releases exclusively from OU-1. Perchlorate and chlorate contamination in groundwater resulted from releases from both OU-1 and the former AMPAC site. Chloroform (and other VOC) contamination within OU-2 originated from multiple sites within the BMI Complex, including the OSSM site, OU-1, and the TIMET site.

Unlike the other Primary COPCs, a significant portion of the chloroform plume present in OU-2 groundwater does not originate from operations in OU-1. Groundwater extraction systems installed at the OSSM site, OU-1, and the TIMET site have mitigated migration of multiple contaminants into OU-2, including chloroform, but have not eliminated them. As illustrated in Figures 7-79b (for OU-1) and 8-21b (for OU-2), the OSSM trespassing plume migrates across OU-1 and into OU-2 without being captured by the OSSM or NERT groundwater extraction systems. In addition to the trespassing plume, the OSSM DNAPL poses a long-term source to groundwater contamination in the Shallow and Middle WBZs of OU-1 and OU-2. Given when the extraction systems were installed at each property (1983 for OSSM, 1987 for NERT, and 2014 for TIMET), uncontrolled COPCs, including chloroform, have been migrating from the TIMET site for approximately 30 years longer than from the OSSM site and OU-1.

The following subsections discuss the nature of contamination migrating from each of the upgradient sites.

<u>OU-1</u>. A limited number of groundwater COPCs present in OU-1 groundwater have migrated downgradient into the NERT Off-Site Study Area component of OU-2 (perchlorate, chlorate, chromium, chloroform, nitrates, arsenic, boron, magnesium, bromodichloromethane, carbon tetrachloride, 1,4-dioxane, and 1,2,3-trichloropropane). The Primary COPCs, perchlorate (up to 1,200 mg/L), chlorate (up to 1,100 mg/L), chromium (up to 2,000 µg/L), and chloroform (up to 650 µg/L), are present in OU-2 groundwater west of Pabco Road. As indicated in Sections 7.5.1.4 and 9.4.5, chloroform migrating from OU-1 originates from multiple source areas including former manufacturing operations within OU-1 and OSSM’s trespassing DNAPL and groundwater plume. As described in Section 9.4.5, OSSM’s trespassing plume is clearly discernable from chloroform associated with former manufacturing operations in OU-1 (Figures 7-79b through 7-79h). Similar to OU-1, the COPC arsenic is widely distributed in OU-2 groundwater within a relatively small concentration range, but some of the highest concentrations just downgradient of the OU-1 boundary may be due to migration from OU-1.

OSSM site. The OSSM site is located west of OU-1 and is the source of a groundwater plume that encroaches into OU-1 before ultimately exiting into OU-2, as previously discussed. While a GWETS that began operation in 1983 just north of the OSSM site mitigates the VOCs in the western lobe/component of their plume, some of the contamination present in the southwest corner of OU-2 likely migrated from the OSSM site prior to the installation of OSSM's GWETS. However, as indicated previously, chloroform associated with OSSM's plume trespassing into OU-1 largely migrates off-site into OU-2 without being captured by OSSM's GWETS. Downgradient (north) of the OSSM site and its groundwater extraction and treatment system, the COPCs above GWSLs currently found in OU-2 groundwater include six VOCs (chloroform up to 650 µg/L, benzene up to 120 µg/L, chlorobenzene up to 320 µg/L, 1,1-DCA up to 22 µg/L, 1,4-dioxane up to 4.2 µg/L, and 1,2,3-trichloropropane detections up to 0.13 µg/L and detection limits up to 0.40 µg/L). In addition, groundwater in this area contains three metals COPCs (arsenic up to 0.26 mg/L, magnesium up to 470 mg/L, and manganese up to 200 mg/L) as well as elevated TDS (up to 15,000 mg/L) related to releases from the OSSM site.

TIMET site. COPCs in groundwater originating from the TIMET site located east of OU-1 that have migrated downgradient directly to OU-2 include chloroform and PCE. TIMET began producing titanium metal ingots within the BMI Complex in the early 1950s and has also produced titanium tetrachloride, titanium sponge, and titanium fines. TIMET continues to produce titanium products at their facility to the current day.

A bentonite-slurry barrier wall and GWETS were installed in 2014 along the northern boundary of the TIMET site to capture and treat groundwater contaminated by VOCs to mitigate continued off-site migration of VOC COPCs. Chloroform and PCE are the two VOCs detected above GWSLs in the treatment plant influent (GEI 2020b). In 2023, NERT completed construction of the TSE which removes NERT's trespassing perchlorate, chlorate, and chromium from groundwater extracted on the TIMET site prior to reinjection. The treated groundwater is reinjected into the ground just downgradient of the barrier wall following treatment. Prior to the installation of the barrier wall and groundwater extraction and treatment system in 2014, COPCs in groundwater would have migrated off-site into OU-2 as illustrated in Figures 7-79b and 8-21b.

While concentrations have been on the decline, presumably due to the operation of the TIMET GWETS, chloroform and PCE are currently present in groundwater above GWSLs at the northern TIMET site boundary which is immediately upgradient from OU-2 (GEI 2022b). As a result of COPC migration prior to the installation of the barrier wall and groundwater extraction and treatment system in 2014, chloroform (up to 110 µg/L), 1,4-dioxane (up to 23 µg/L), 1,2,3-trichloropropane (detected concentrations up to 0.088 µg/L and detection limits up to 4.0 µg/L), PCE (up to 68 µg/L), and TDS (up to 11,000 mg/L) are detected in groundwater in OU-2 north of Warm Springs Road and the TIMET site. NERT's particle tracking evaluation indicates that VOCs detected in the eastern portion of the Offsite Study Area of OU-2 originated from the TIMET site. The contamination in this portion of OU-2 is unrelated to COPCs that have migrated or are migrating from OU-1. In particular, as indicated in Section 9.4.5, chloroform migrating from the Unit 4 and 5 Buildings source area cannot be solely responsible for the higher concentrations of chloroform in groundwater at the water table within the TIMET site.

Former AMPAC site. In addition to the groundwater contamination sources from upgradient sites as described above, a separate perchlorate plume associated with the former AMPAC site located approximately 1.5 miles west of OU-1 has commingled with the NERT perchlorate plume near the AWF in OU-2 (Geosyntec 2017). The AMPAC plant began production of ammonium perchlorate in 1958 and operated until the facility experienced a catastrophic explosion on May 4, 1988 (Broadbent 1998). As shown in Figure 9-5a, the AMPAC plume is generally located to the west of the NERT plume but becomes commingled with the NERT plume within OU-2 in the vicinity of the AWF (Geosyntec 2017). A portion of the AMPAC perchlorate plume is captured in both the AWF and SWF and ultimately treated in NERT's GWETS (Geosyntec 2017). The AMPAC plume also is present within the western part of OU-3 north of the COH Birding Ponds, where the plume discharges perchlorate to the Las Vegas Wash (Geosyntec 2017). Chlorate is also present in the AMPAC plume as a byproduct of perchlorate production. Similar to perchlorate, chlorate trespasses into OU-2 and becomes commingled with the NERT plume in the vicinity of the AWF. While a limited discussion of the commingling and delineation of the NERT and AMPAC perchlorate plumes in OU-2 is presented in Section 8.5.1, greater detail will be provided in the forthcoming RI Report for OU-3.

9.5.1.2 Former Ditches

Two former unlined ditches located along the boundaries of the NERT Off-Site Study Area component of OU-2 west of Pabco Road may have contributed contaminants to groundwater when they were operating between 1945 and 1985 (see Figure 2-9).

Alpha Ditch. The former Alpha Ditch, which is described in greater detail within Section 2.4.1, was likely used to convey primarily storm drainage and non-contact cooling water to the Las Vegas Wash and, possibly, the Lower BMI ponds (Geraghty and Miller 1993). The Alpha Ditch was located along Pabco Road, which now serves as the boundary between the NERT Off-Site Study Area and the Eastside Sub-Area components of OU-2. The Alpha Ditch was constructed in approximately 1943 and was used until 1985, when it was replaced by the Pittman By-Pass pipeline, an underground pipeline still in use exclusively by TIMET.

Northwest Ditch. The former Northwest Ditch was located along Warm Springs Road, which now forms the boundary between OU-1 and the NERT Off-Site Study Area component of OU-2. The Northwest Ditch was constructed in the early 1940s to convey process effluent to the Lower BMI Ponds (located mostly in OU-3). After extending northwest through what is now the TIMET site, effluent and storm water were conveyed along the northern boundary of OU-1 before joining a natural drainage channel, located west of the NERT RI Study Area, leading to the Lower BMI Ponds (Geraghty & Miller 1993).

The Alpha and Northwest Ditches were unlined ditches that may have contributed contaminants to groundwater in OU-2 during any period in which they were used prior to 1985 to convey process effluents or stormwater containing COPCs. Although there is limited groundwater monitoring data available during their periods of use prior to 1985, the potential impacts to groundwater quality in OU-2 do not appear to be significant.

9.5.1.3 Residual Contamination in the UMCf

As summarized in Section 9.0 and discussed throughout in this report, an important issue affecting the persistence of contamination in groundwater is the effect of matrix diffusion, in which slow upward migration from the UMCf causes concentrations in the higher permeability alluvium to remain above regulatory levels for a long period of time. Matrix diffusion will be significant for the Primary COPCs that have impacted the UMCf first in OU-1 and then migrating within the UMCf to OU-2, including perchlorate, chromium, and chloroform. The lower permeability UMCf is the unit in which most of the contaminant mass is currently stored, as shown by the mass estimates for perchlorate and chromium provided in Section 9.7.3. This mass in the UMCf slowly migrates upwards into the alluvium. As a result of this continual source of contamination, groundwater concentrations of perchlorate and chromium in the NERT Off-Site Study Area component of OU-2 have been declining relatively slowly, even though active remediation of the alluvium has been in progress for over 20 years. In other words, residual contamination in the UMCf acts as an ongoing source to shallower groundwater within this area of OU-2, which will continue until the concentrations of COPCs in the UMCf decline below GWSLs.

9.5.1.4 Origin of COPCs in OU-2

Given that there are multiple sources of perchlorate and chloroform impacts in groundwater within OU-2, NERT has completed an evaluation to determine from which sites the COPCs likely originated. For this evaluation, NERT considered particle tracking results conducted using the Phase 6 groundwater model and plume geometry for COPCs with a similar potential to migrate in groundwater. The results of the particle tracking evaluation in the alluvium and UMCf in the Shallow WBZ are shown in Figures 9-12a and 9-12b, respectively.

This particle tracking evaluation was conducted using the NERT Phase 6 groundwater model, which provides an accurate representation of groundwater flow and COPC migration since it considers hydraulic head, geologic unit geometry, hydraulic properties, and the effect of extraction wells and barrier walls. As discussed below, particles were released immediately downgradient of the Unit Buildings extending from the OSSM site property boundary on the west to the TIMET site on the east, along the northern boundary of the BMI Complex, within the Eastside Sub-Area (where the alluvium is saturated), and north of the Eastside Area (where the alluvium is unsaturated). The model simulation was conducted using current pumping rates of the OSSM, NERT, TIMET, and AMPAC GWETS (pumping well locations are shown in Figure 3-1), but general flow directions are reflective of conditions once the Upper BMI Ponds and Southern RIBs stopped operating in the mid-1970s and 2002, respectively. In Figures 9-12a and 9-12b, the particle tracks have been color coded based on their point of release as indicated below:

- Black – particles released at the northwest corner of OU-1 downgradient of the OSSM site indicate the path that historical COPCs would have migrated in groundwater prior to the installation of the OSSM GWETS in 1983. As indicated in Figures 9-12a and 9-12b, COPCs that escaped the OSSM site before the startup of their GWETS would have moved north-northeast along the western boundary of OU-2. Any residual COPCs in groundwater would be captured by the AWF. Prior to the installation of the AWF, COPCs would have continued to migrate northward and eventually be captured by the SWF. Prior to the installation of the SWF, COPCs would have continued to migrate northward and discharged into the Las Vegas Wash.
- Orange – particles released to the immediate west and just north of the Unit 1 and 2 Buildings within OU-1 indicate the direction of groundwater flow and COPC migration

within the western portion of OU-1, including OSSM's trespassing plume. As indicated in Figures 9-12a and 9-12b, COPCs associated with the OSSM trespassing plume (which are the predominant COPCs in this area) would migrate northward across OU-1 and into the NERT Off-Site Study Area component of OU-2 west of Pabco Road. After moving north of Warm Springs Road, COPC movement is heavily influenced by a paleochannel (which is located below the water table) resulting in a shift in direction to the northwest and then to the northeast. Ultimately, any COPCs traveling along these flow paths will be captured by the AWF. Prior to the installation of the AWF, COPCs would have continued to migrate northward and eventually be captured by the SWF. Prior to the installation of the SWF, COPCs would have continued to migrate northward and discharged into the Las Vegas Wash.

- Green – particles released just north of the Unit 3 through 6 Buildings within OU-1 (light green) and along the eastern portion of the northern OU-1 boundary (dark green) indicate the direction of groundwater flow and COPC migration within the western portion of OU-1, including the Unit 4 and 5 Buildings source area, former P and S Ponds, former AP manufacturing area, and eastern-most former Trade Effluent Ponds.[87] Residual COPCs released from the Unit 4 and 5 Buildings source area, former P and S Ponds, and former AP manufacturing areas would all be captured by the IWF. However, any COPCs that had migrated north of the IWF prior to its operation would continue to migrate northward into OU-2. As indicated in Figures 9-12a and 9-12b, groundwater flow and COPC migration shifts to the northwest and then back to the northeast in the southern portion of the NERT Off-Site Study Area component of OU-2. Ultimately, any COPCs traveling along these flow paths will be captured by the AWF. Prior to the installation of the AWF, COPCs would have continued to migrate northward and eventually be captured by the SWF. Prior to the installation of the SWF, COPCs would have continued to migrate northward and discharged into the Las Vegas Wash.
- Pink – particles released just north of the TIMET barrier wall and groundwater extraction system indicate the direction of groundwater flow and COPC migration from the TIMET site. COPCs that migrated from the TIMET site prior to installation of their barrier wall and GWETS would have migrated northward through the eastern portion of the NERT Off-Site Study Area component of OU-2. As indicated in Figures 9-12a and 9-12b, COPCs migrating in groundwater from the eastern-most portion of the TIMET site would migrate northeast into the Eastside Sub-Area component of OU-2 east of Pabco Road and eventually move northwest back into the NERT Off-Site Study Area component of OU-2 west of Pabco Road. Ultimately, any COPCs traveling along these flow paths will be captured by the NERT AWF. Prior to the installation of the AWF, COPCs would have continued to migrate northward and eventually be captured by the SWF. Prior to the installation of the SWF, COPCs would have continued to migrate northward and discharge into the Las Vegas Wash.
- Blue – particles released within and just north of the Eastside Sub-Area indicate the direction of groundwater flow and COPC migration across this area ranges from slightly northwest to north. Groundwater flow and COPC migration within the western-most portion of the Eastside Sub-Area component of OU-2 would move

---

[87] No light green particle tracks are shown in Figure 9-12a originating from the north of the Unit 3 through 6 Buildings because the alluvium is dewatered in this area.

briefly northwest into the NERT Off-Site Study Area component of OU-2 and eventually be captured by the SWF. Prior to the installation of the SWF, COPCs would have continued to migrate northward and discharge into the Las Vegas Wash. Groundwater flow and COPC migration move northward from the central and eastern portions of the Eastside Sub-Area and ultimately discharge into the Las Vegas Wash as there is not a groundwater remediation system in place to contain COPCs.

In addition to particle tracking, the shapes of the perchlorate, chlorate, chromium, and chloroform plumes were examined and compared. The southern portion of the NERT Off-Site Study Area component of OU-2 west of Pabco Road is largely not impacted by the perchlorate plume originating from the AMPAC site so the footprint of the perchlorate, chlorate, and chromium plumes all originate within the eastern portion of OU-1. However, three separate chloroform plumes are visible in Figures 8-21b and 8-21c originating from OU-1 and the neighboring OSSM and TIMET sites. Figure 9-12c displays the perchlorate, chlorate, chromium, and chloroform plumes side-by-side. These constituents were chosen because perchlorate, chlorate, and chromium in groundwater in the southern portion of OU-2 are only associated with OU-1, while chloroform is present at the OSSM, NERT, and TIMET sites. Close inspection of each plume map indicates the following:

- The NERT perchlorate plume has a distinctive shape based on the location of the source areas, the direction of groundwater flow, and the influence that paleochannels have had on contaminant migration. The primary sources of perchlorate contamination are the Unit 4 and 5 Buildings source area, former P and S Ponds, and former AP manufacturing area.
- The NERT chlorate plume also has a distinctive shape (nearly identical to the perchlorate plume) based on the location of the source areas, the direction of groundwater flow, and the influence that paleochannels have had on contaminant migration. The primary sources of chlorate contamination are the Unit 4 and 5 Buildings source area and former P and S Ponds.
- The NERT chromium plume also has a distinctive shape (nearly identical to the perchlorate and chlorate plumes) based on the location of the source areas, the direction of groundwater flow, and the influence that paleochannels have had on contaminant migration. The primary sources of chromium contamination are the Unit 4 and 5 Buildings source area and former P and S Ponds.
- The chloroform plume has a shape that is significantly different than the perchlorate, chlorate, and chromium plumes, indicating that the chloroform plume has a different set of sources than the other three plumes. The highest concentrations of chloroform in OU-2 are not downgradient of the sources of perchlorate, chlorate, and chromium. Rather, as shown in Figures 9-12a and 9-12b, the highest concentrations in OU-2 are found along the particle tracks originating from the OSSM trespassing plume (orange particle tracks) and from the TIMET site (pink particle tracks).

9.5.1.5 Summary of the Sources of Groundwater Contamination in OU-2 West of Pabco Road

In summary, the sources of groundwater contamination in OU-2 west of Pabco Road are as follows:

- *Migration of groundwater from OU-1 into OU-2*. As discussed in Section 9.4, the sources of the COPCs in OU-1 groundwater related to releases from historic operations include the Unit 4 and 5 Buildings, the former P and S Ponds, the former unlined Beta Ditch, the former AP Plant and associated facilities, and features north of the IWF/barrier wall (e.g., the former Trade Effluent Ponds and recharge trenches). This includes trespassing VOCs from the OSSM plume which have impacted groundwater in OU-1.
- *Migration of contaminants from the OSSM site, across OU-1 and into OU-2*. The highest concentrations of chloroform in groundwater within OU-2 are located downgradient of OSSM's trespassing plume (which migrates across OU-1 into OU-2) and the TIMET site. Particle tracking and plume geometry evaluations indicate that the OSSM trespassing plume and sources within the TIMET site are the primary sources of the chloroform plume in OU-2.
- *Migration of contaminants directly downgradient from the OSSM site into OU-2*. VOCs including chloroform and elevated TDS originating from the OSSM site are detected in OU-2 groundwater in the area downgradient of the OSSM site and OSSM extraction wells. Migration of COPCs off-site north of the OSSM site was mitigated after the installation of their groundwater extraction and treatment system. However, legacy COPCs appear to remain in groundwater downgradient of the OSSM extraction wells. As previously discussed, some of this contamination may be associated with OSSM's trespassing plume (the eastern lobe/component).
- *Migration of contaminants directly from the TIMET Site into OU-2*. PCE, chloroform, and elevated TDS are detected in OU-2 groundwater in the area downgradient of the TIMET site and TIMET extraction wells, which is immediately upgradient of OU-2.
- *Commingling with the AMPAC perchlorate plume*. The AMPAC perchlorate plume located to the west of the NERT plume has become commingled with the NERT plume within OU-2 in the vicinity of the AWF.
- *Upward migration*. Residual contamination in the UMCf has been and will continue to be an ongoing source to shallower groundwater within OU-2 via upward migration due to matrix diffusion and the upward gradient. Upward migration will be significant for the Primary COPCs that have impacted the UMCf first in OU-1 and then migrated within the UMCf to OU-2, including perchlorate, chlorate, chromium, and chloroform. The mass of these COPCs in the UMCf will continue to slowly migrate upwards into the alluvium for an extended period of time.

9.5.2 Sources of Contamination in OU-2 East of Pabco Road (Eastside Sub-Area)

As discussed in Section 2.0, the portion of the BMI Complex located east of Pabco Road was historically referred to as the Eastside Area or the BMI Common Areas. The BMI Common Areas contained a network of unlined ditches, canals, flumes, and unlined ponds developed during World War II that were used for the management of industrial process wastewater and other aqueous byproducts from the BMI Complex manufacturing facilities, inclusive of the former operations associated with OU-1. The aqueous waste reportedly contained a variable mix of BMI Complex facility-related contaminants including perchlorate, metals, VOCs, TDS, and various other contaminants that migrated from the BMI Complex through the Beta Ditch.

Figure 2-9 depicts the historical unlined wastewater ponds and associated ditches operated in the Eastside Sub-Area beginning in 1943 through the mid-1970s. Historical records and aerial photographs indicate that only the southern-most eight rows were used (BRC 2007), corresponding to approximately 50% of the total area of the Upper BMI Ponds. Beginning in 2006, BRC conducted soil and groundwater investigations and remediation activities (completed in 2014), which served as the basis for NDEP granting NFA determinations on the majority of the parcels comprising the Eastside Sub-Area within OU-2. NDEP's NFA determinations were restricted to the upper 10 feet of the soil horizon consistent with proposed future land uses (BRC 2014).

As discussed in Section 8.0 and detailed in the Phase 3 RI Work Plan, the NERT COPCs investigated by NERT in the Eastside Sub-Area component of OU-2 east of Pabco Road are administratively limited to perchlorate and chlorate in soil deeper than 10 feet and in groundwater. As a result of the limited scope of the NERT RI in this area, the East Side CSM does not consider the contamination from chemicals other than perchlorate and chlorate. The following sections discuss the sources of perchlorate and chlorate in the Eastside Sub-Area component of OU-2.

9.5.2.1 Residual Contamination in Shallow Groundwater and the UMCf

During the period of operation of the unlined Upper BMI Ponds and the associated unlined ditches (e.g., the former Beta Ditch), perchlorate and chlorate migrated into soil and groundwater in the Eastside Sub-Area. As shown in Figure 9-5a, the perchlorate plume in the Shallow WBZ within the Eastside Sub-Area of OU-2 is divided into three lobes with less contaminated areas between the lobes. This configuration appears to have been caused by historical wastewater disposal practices, which was evaluated by overlaying the shallow perchlorate plume in figures showing the historical wastewater features. Figure 9-13a shows historical wastewater features established before 1975, and Figure 9-13b shows historical wastewater features established after 1975. The three lobes of the perchlorate plume in the Eastside Sub-Area are labeled on Figures 9-13a and 9-13b as Lobe A, Lobe B, and Lobe C.

As shown in Figure 9-13a, historical records and aerial photographs indicate that the Henderson Sewage Treatment Plant (HSTP2) was in operation throughout the period that the Upper BMI Ponds were in operation (1943 to mid-1970s). During its operation, the HSTP2 discharged treated municipal sewage effluent that would not have contained perchlorate to unlined ponds south of the Beta Ditch. Infiltration of this effluent would have created a mound of clean groundwater in the area of the Beta Ditch downgradient of the HSTP2. This mound would have reduced or eliminated infiltration of perchlorate-impacted wastewater from the Beta Ditch and Upper BMI Ponds in this area. In addition, the clean groundwater discharged from HSTP2 would have flushed out the perchlorate plume between Lobes A and B in the central and northern portion of the Upper BMI Ponds. Thus, this discharge from HSTP2 appears to be the cause of the gap in the perchlorate plume between Lobe A and Lobe B shown on Figure 9-13a. Further flushing of this area by clean municipal sewage effluent from the Southern RIBs occurred from 1992-2002, as shown in Figure 9-13b. Any infiltration of discharges from the TIMET spray wheel and surface impoundments would not have contained perchlorate and may have flushed the area further.

The source of perchlorate for Lobe B was infiltration of wastewater from the Beta Ditch. The source of perchlorate for Lobe C is likely the preferential infiltration of wastewater into the eastern ends of the ponds. This preferential infiltration likely occurred because the ponds would have been graded so that they sloped away from the Beta Ditch. An examination of LANDSAT images from early 1970s confirmed that ponding occurred preferentially into the southeast corner of the Upper BMI Ponds, just upgradient of Lobe C shown on Figure 9-13a. Thus, it is likely that the source of perchlorate for Lobe C was the preferential infiltration of perchlorate-impacted wastewater into the southeastern portion of the Upper BMI Ponds.

The OU-2 RI results show that both perchlorate and chlorate remain at concentrations above GWSLs in both shallow groundwater and in the saturated UMCf to a depth of approximately 110 feet bgs within the Eastside Sub-Area, including groundwater located along the northern OU-2 boundary. Although much of the alluvium has become dewatered in the Eastside Sub-Area, the alluvium remains saturated in OU-3. Matrix diffusion (i.e., slow upward migration) of the mass stored in the low permeability UMCf into shallow groundwater will cause concentrations in the higher permeability alluvium in OU-3 to remain above regulatory levels for a long period of time. As described in Section 9.5.1.4, Figures 9-12a and 9-12b display the direction of groundwater flow and COPC migration (represented by blue lines) within the Eastside Sub-Area. As shown in these figures, the perchlorate and chlorate currently present in both shallow groundwater and in the UMCf will continue to migrate north from the Eastside Sub-Area into OU-3, toward the Las Vegas Wash.

9.5.2.2 Residual Contamination in Vadose Zone Soils Below 10 Feet Resulting from Former Pond Usage

Perchlorate and chlorate concentrations in vadose zone soils below 10 feet were investigated at 14 boring locations installed during the Phase 3 RI. Perchlorate concentrations above its LSSL of 0.0155 mg/kg and chlorate concentrations above its LSSL of 1.03 mg/kg were found in nearly all the boring locations. In general, the highest concentrations were found in the western part of the Eastside Sub-Area beneath the area previously occupied by the former ditches and unlined wastewater ponds. The perchlorate results are generally consistent with previous soil sampling conducted by BRC at approximately 740 boring locations with samples at or below 10 feet bgs. Perchlorate was detected above the LSSL in soil samples below 10 feet in approximately 80% of these locations. Depending on the amount of surface water infiltration, the residual contamination in the deeper vadose zone soil represents a continuing source of perchlorate and chlorate to underlying shallow groundwater in the Eastside Sub-Area.

9.5.2.3 Summary of Sources of Contamination in OU-2 East of Pabco Road

In summary, the primary sources of perchlorate and chlorate in OU-2 East of Pabco Road are as follows:

- Residual contamination in shallow groundwater within the alluvium (where saturated) and the UMCf. Perchlorate and chlorate currently present in both shallow groundwater and the UMCf will continue to migrate north from the Eastside Sub-Area into OU-3, toward the Las Vegas Wash.
- Residual contamination in the vadose zone soils. Perchlorate and chlorate present in vadose zone soils below 10 feet in the Eastside Sub-Area represents a continuing source to underlying groundwater.

9.6 Nature and Extent of COPCs

This section presents a summary of the nature and extent of COPCs described in Section 7 (for OU-1) and Section 8 (for OU-2). The COPCs for soil and groundwater in OU-1 and OU-2 are presented in Table 9-1. The lateral and vertical extent of these COPCs compared to LSSLs and GWSLs is discussed in Sections 7 and 8. Naturally occurring inorganic compounds in soil have been evaluated compared to the background concentrations identified in the Soil Background Data Set Summary Report (Ramboll 2021d). For chloroform and other VOCs in groundwater, an evaluation of volatilization from shallow groundwater into soil gas and potential vapor intrusion risk is presented in the BHRA Reports for soil gas and groundwater in OU-1 and OU-2 (see Section 9.8).

9.6.1 Soil and Groundwater COPCs

In OU-1, the soil COPCs shown in Table 9-1 are associated primarily with historical operations at the NERT Site. OU-1 groundwater COPCs associated with historical operations at the NERT Site include the four Primary COPCs (perchlorate, chlorate, chromium, chloroform) and Other COPCs. The COPC arsenic is widely distributed within a relatively small concentration range, but some of the highest concentrations are associated with operations in OU-1 as well as a trespassing plume from the OSSM site to the west. Similarly, high concentrations of magnesium and manganese are associated with operations in OU-1 as well as the trespassing OSSM plume. Fourteen of the eighteen VOCs identified as COPCs in OU-1 groundwater are associated with the trespassing OSSM plume. In addition to the Primary COPC chloroform, the other VOCs associated with the trespassing OSSM plume are benzene, chlorobenzene, 1,2-, 1,3- and 1,4-dichlorobenzene, carbon tetrachloride, 1,1-DCA, 1,2-DCA, 1,4-dioxane, 1,2,3-trichloropropane, 1,1,2,2-tetrachloroethane, methylene chloride, and PCE. The VOCs found in groundwater in other areas of OU-1 include bromodichloromethane, bromoform, TCE, and 1,1-DCE. Chloroform was the only chemical detected above screening levels in OU-1 soil gas.

A limited number of groundwater COPCs present in OU-1 groundwater have migrated downgradient from OU-1 into the NERT Off-Site Study Area portion of OU-2 west of Pabco Road (perchlorate, chlorate, chromium, chloroform, nitrates, arsenic, boron, magnesium, bromodichloromethane, carbon tetrachloride, 1,4-dioxane, and 1,2,3-trichloropropane). Similar to OU-1, the COPC arsenic is widely distributed in OU-2 groundwater within a relatively small concentration range, but some of the highest concentrations are either associated with the trespassing OSSM plume or are migrating from OU-1. The trespassing COPCs from the OSSM site that have migrated via groundwater into OU-2 are arsenic, magnesium, manganese, chloroform, carbon tetrachloride, benzene, chlorobenzene, 1,1-DCA, 1,4-dioxane, and 1,2,3-trichloropropane. COPCs in groundwater from the TIMET site located east of OU-1 that have migrated downgradient directly to OU-2 include chloroform, 1,4-dioxane, 1,2,3-trichloropropane, and PCE. COPCs in groundwater from the AMPAC site located to the west of the OSSM site that have migrated downgradient directly to OU-2 include perchlorate and chlorate. Chloroform was the only chemical in soil gas with widespread detections above screening levels in OU-2 in both commercial/industrial and residential land use areas. Bromodichloromethane was also detected in soil gas above screening levels at one residential land use area location within OU-2. A more detailed summary of the trespassing COPCs in OU-1 and OU-2, including chloroform, is presented above in Section 9.4.5.

In the Eastside Sub-Area component of OU-2, the soil (below a depth of 10 feet) and groundwater COPCs associated with NERT are administratively limited to perchlorate and chlorate.

9.6.2 Extent of Primary COPCs

Figures 9-14a through 9-17d illustrate the lateral and vertical extent of the four Primary COPCs (perchlorate, chlorate, chromium, and chloroform) in groundwater. The figures also indicate the locations of the extraction wells associated with the OSSM, NERT, and TIMET GWETSs.

Perchlorate. As shown in Figures 9-14a through 9-14d, the areas with perchlorate in groundwater above 0.5 mg/L extend throughout OU-1 and OU-2, but the areas with perchlorate above 10 mg/L are limited to OU-1 and the portion of OU-2 west of Pabco Road. Concentrations of perchlorate above 500 mg/L are present within OU-1 below the Unit 4 Building and the AP Area, both of which are upgradient of the IWF and barrier wall. The extent of perchlorate is well defined in the figures presented in Section 7 (Figures 7-50a though 7-50i) and Section 8 (Figures 8-4a through 8-4e, and 8-29a through 8-29d). Figure 9-14a uses a higher cutoff than the GWSL for illustration purposes. However, the extent of perchlorate contamination in groundwater is bounded to the west by the AMPAC plume (partially visible in this figure set to the west of OU-2, commingling with NERT perchlorate in the vicinity of the AWF, and migrating north into OU-3), to the south by Lake Mead Parkway (concentrations are below the upgradient level), and to the east by Galleria Drive (just east of the Tuscany Village community). The extent of perchlorate north of the Las Vegas Wash is still under investigation and will be defined in the RI Report for OU-3.

Chlorate. As discussed earlier in this section, the geometry of the COPC plumes which are attributed to OU-1 operations are very similar. As such, the distribution of chlorate shown in Figures 9-15a through 9-15d is similar to perchlorate. The areas with concentrations above the chlorate GWSL of 1 mg/L are widespread through OU-1 and OU-2, but the areas with concentrations above 10 mg/L are generally limited to OU-1 and the western portion of OU-2. The extent of chlorate in groundwater is very similar to perchlorate and also well defined as shown in the figures presented in Section 7 (Figures 7-51a though 7-51j) and Section 8 (Figures 8-5a through 8-5e). The extent of contamination of chlorate is defined at the same boundaries as described above for perchlorate. In addition, low levels of chlorate within the AMPAC plume are partially visible in Figures 9-15a and 9-15b.

Chromium. As discussed earlier in this section, the geometry of the COPC plumes which are attributed to OU-1 operations are very similar. As such, the distribution of chromium shown in Figures 9-16a through 9-16d is similar to both perchlorate and chlorate. The areas with chromium concentrations above the GWSL of 0.1 mg/L are located within OU-1 and the western portion of OU-2. Chromium contamination in groundwater is not as extensive as perchlorate and chlorate as illustrated in the figures presented in Section 7 (Figures 7-57a though 7-58h) and Section 8 (Figures 8-10a through 8-10c). As such, the extent of contamination has been well defined throughout OU-1 and OU-2.

Chloroform. As discussed earlier in this section, the geometry of the COPC plumes which are attributed to OU-1 operations are very similar. When compared to perchlorate, chlorate and chromium, the geometry of the chloroform plume is different due to its source largely attributable to the neighboring OSSM and TIMET sites. As shown in Figures 9-17a through 9-17d, the area with chloroform concentrations above the GWSL of 0.07 mg/L is generally limited to OU-1 and the eastern portion NERT Off-Site Study area component of OU-2 (downgradient of the TIMET site), with smaller areas within the western portion of the Eastside Sub-Area component of OU-2. As indicated in Section 8, and unlike perchlorate, chlorate, and chromium, the extent of chloroform in groundwater is influenced by the chloroform contamination originating from the OSSM site, OU-1 (the Unit 4 and 5 Buildings), and the TIMET site. The areas with the highest chloroform concentrations above 1 mg/L are located in the western portion of OU-1 and associated with the trespassing plume from the OSSM site. Figure 9-12c illustrates how the shape of the chloroform plume within OU-2 is different than the other Primary COPCs indicating that chloroform within OU-2 originated from a different source than the other Primary COPCs. Furthermore, the highest chloroform concentrations within OU-2 are located downgradient of the TIMET site. Based on the plume shape and the fact that OSSM and NERT’s GWETS have been in place since the 1980s, the current extent of chloroform in groundwater in OU-2 is largely the result of uncontrolled migration of chloroform in groundwater from the TIMET site prior to 2014, when their barrier wall and GWETS became fully operational.

In summary, the extent of the four Primary COPCs is well defined within OU-1 and OU-2 as described in Sections 7 and 8. Figures 9-14a through 9-17d also clearly illustrate that the highest concentrations of the Primary COPCs originating from OU-1 are captured by the three NERT groundwater extraction well fields (IWF, AWF, and SWF). However, COPCs presently located within most of the Eastside Sub-Area component of OU-2 will continue to migrate northward, eventually discharging to the Las Vegas Wash. As additional data is collected in OU-3, these figures will be updated and presented in the forthcoming RI Report for OU-3.

9.7 GWETS Performance and Mass Remaining in Soil and Groundwater

As discussed throughout this report, the current NERT GWETS was designed as a removal action that targets the core NERT plume of perchlorate and hexavalent chromium located within OU-1 and the portions of OU-2 and OU-3 west of Pabco Road. Details on the operational efficiency and potential approaches to optimize the NERT GWETS for the final remedy are not discussed in this RI Report. It is assumed that the NERT GWETS will remain in operation largely as-is until the NERT final remedy is selected. As such, information about the GWETS is provided in this section only to support the CSM. The current performance of the GWETS is summarized in this section.

9.7.1 Plume Capture

As reported in the 2021 Annual Groundwater Monitoring and GWETS Performance Report, the GWETS captures 100% of any Primary COPCs currently migrating from the various source areas within OU-1 (Ramboll 2022a). As a result, there is no longer any discharge of perchlorate from the core NERT plume (i.e., perchlorate and chlorate that originates from groundwater migrating from OU-1), with the exception of perchlorate diffusing upwards from the UMCf north of the SWF. In contrast, the perchlorate plume located in OU-2 and OU-3 east of Pabco Road is mostly outside of the capture zone of the GWETS as originally designed and therefore migrates uncontrolled to the Las Vegas Wash. This uncontrolled discharge to the Las Vegas Wash in OU-3 is outside the scope of this report and will be discussed in the forthcoming OU-3 RI Report.

With respect to the core NERT plume, and as shown in Figures 9-14a through 9-17d, the highest concentrations of Primary COPCs are generally located upgradient of the IWF and AWF extraction wells. As described in Section 3.3.3, the current NERT GWETS includes three groundwater extraction well fields, including the IWF, the AWF, and the SWF, as well as eight AP Area extraction wells located approximately 300 feet south of the IWF just west of the former AP-5 Pond. The extraction well locations are shown in Figure 3-2. The IWF, which currently contains 27 active extraction wells, coupled with the on-site barrier wall provides capture of the highest concentrations of perchlorate and chromium and significantly reduces the amount of perchlorate and chromium in downgradient groundwater. The off-site AWF, located in OU-2 approximately 8,200 feet downgradient of the IWF, consists of eight active extraction wells and captures moderate concentrations of both perchlorate and chromium (in comparison to groundwater captured by the IWF), but operates at higher extraction rates than the IWF, resulting in significant contributions to overall perchlorate mass removal from the environment and mitigation of perchlorate migration in groundwater. The SWF, located in close proximity to the Las Vegas Wash, includes nine extraction wells and operates at the highest extraction rate of the three well fields, but captures groundwater containing significantly lower perchlorate concentrations.

9.7.2 Mass Removal

As reported in the 2021 Annual Groundwater Monitoring and GWETS Performance Report, approximately 1.0 tons of total chromium and 150 tons of perchlorate were removed from groundwater by the GWETS between July 2020 and June 2021 (Ramboll 2022a). Chlorate removed from groundwater by the GWETS over this period was approximately 343 tons. Since July 2004 shortly after the GWETS inception, the total mass removed has been approximately 27 tons of total chromium, 5,400 tons of perchlorate, and 10,450 tons of chlorate.

The trends in average perchlorate and hexavalent chromium concentrations in the extraction well fields between 2004 and 2019 are shown in Figures 9-18a and 9-18b. While overall concentrations have decreased during this time period, the persistence of contamination in shallow groundwater is affected by the continued upward migration due to matrix diffusion and upward flow, as previously discussed throughout this report, in which slow upward migration from the saturated UMCf causes concentrations in the higher permeability alluvium to remain above regulatory levels for extended periods of time. The most recent, and most comprehensive, estimate of the remaining contaminant mass is discussed in the next section.

9.7.3 Mass Remaining in Soil and Groundwater

The mass of perchlorate and chromium remaining in soil and groundwater was most recently estimated in the 2021 Annual Groundwater Monitoring and GWETS Performance Report (Ramboll 2022a). The mass estimate was performed using the methodology described in the Performance Metrics Technical Memorandum (Ramboll Environ 2017k), and first applied for the mass estimate presented in the 2018 Annual Remedial Performance Report (Ramboll 2018j). The mass estimates presented in this section, which are unchanged from the 2021 Annual Groundwater Monitoring and GWETS Performance Report, incorporates all relevant data and, with respect to OU-1 and OU-2, should be considered final for the purposes of the RI and the forthcoming FS for OU-1.[88]

The mass estimate method involved using kriging interpolation to estimate the spatial distribution of chemical concentrations over a uniform grid for each lithological interval, resulting in a concentration grid. The elevations of the ground surface, water table, and the alluvium-UMCf contact were used to generate a grid of values representing the vertical extent of impact for each lithological interval, resulting in a thickness grid. The concentration and thickness grids were combined to generate a grid of chemical mass, taking into account the soil physical properties and partitioning between phases. The cells of the mass grid were summed over the relevant boundaries to produce total mass estimates in tons. A mass balance approach was used to update the mass estimate in groundwater using simulated mass fluxes across the OU boundaries estimated using the Phase 6 groundwater model in conjunction with measured mass removals in the GWETS and measured mass loading in the Las Vegas Wash.

A standard linear uncertainty assessment was conducted to quantify the relative uncertainty in the total mass estimates by chemical, OU, and zone. The major sources of uncertainty in the mass estimate calculations include: uncertainty in soil properties due to heterogeneity and measurement error; uncertainty in chemical concentrations due to heterogeneity of contaminant distribution and measurement error; uncertainty regarding the elevation of the alluvium-UMCf contact, the position of the water table, and the total depth of contamination in the UMCf; uncertainty associated with the interpolation procedures used to predict concentrations on a grid from point measurements; and uncertainty associated with the selection of the hexavalent chromium partitioning coefficient.

While this section discussing the NERT CSM has focused on the NERT Primary COPCs, the mass estimate calculations performed have been limited to perchlorate and chromium as directed by NDEP. Consistent with prior reporting, the mass estimate boundary for chromium includes the entirety of OU-1 but is limited in OU-2 and OU-3 to the area west of Pabco Road.[89,90] Tables 9-3a and 9-3b and Figures 9-19a and 9-19b (identical to the same figures included with the 2021 Annual Groundwater Monitoring and GWETS Performance Report) present perchlorate and hexavalent chromium mass estimates, respectively, by OU (OU-1, OU-2, and OU-3) and by hydrogeologic unit (vadose zone, saturated alluvium, and saturated UMCf). As presented in the 2021 Annual Groundwater Monitoring and GWETS Performance Report, contaminant masses estimated to remain in the NERT RI Study Area are 3,998 to 5,756 tons of perchlorate and 61.3 to 156.7 tons of hexavalent chromium. The range in masses represents the 95% confidence limits based on a formal uncertainty

---

[88] Includes perchlorate and hexavalent chromium mass within the entire NERT RI Study Area, including both the vadose and saturated zones; however, the mass estimate does not include perchlorate mass associated with the AMPAC plume where it is not commingled with the NERT plume.

[89] For the sole purpose of the mass estimate, the boundary of OU-1 has been extended to include adjacent areas where perchlorate and chromium originating from OU-1 may have migrated (Mass Estimate Extension Area), as described in Appendix A of the 2021 Annual Groundwater Monitoring and GWETS Performance Report (Ramboll 2022a).

[90] The potential presence of hexavalent chromium and other potential contaminants in groundwater within the Eastside Sub-Area will be investigated and remediated by BRC, if required by NDEP, pursuant to the terms of Administrative Order on Consent, Phase 3 (AOC3; NDEP 2006).

analysis, which was documented in the 2021 Annual Groundwater Monitoring and GWETS Performance Report (Ramboll 2022a).

Table 9-3a. Perchlorate Mass by Hydrogeologic Unit and OU (tons)

Unit	OU-1	OU-2	OU-3	Total by Unit
Vadose Zone	890±130	344±40	64±10	**1,298±180**
Saturated Alluvium	34±3	348±60	53±6	**435±69**
Saturated UMCf	1,284±200	1,712±400	148±30	**3,144±630**
Total by OU	**2,208±333**	**2,404±500**	**265±46**	**4,877±879**

Table 9-3b. Hexavalent Chromium Mass by Hydrogeologic Unit and OU (tons)

Unit	OU-1	OU-2	OU-3	Total by Unit
Vadose Zone	13.0±2.0	7.1±2.4	0.4±0.1	**20.5±4.5**
Saturated Alluvium	3.1±1.4	5.3±2.6	0.4±0.2	**8.8±4.2**
Saturated UMCf	72.1±35	7.8±3.6	0.6±0.4	**80.5±39.0**
Total by OU	**88.2±38.4**	**20.2±8.6**	**1.4±0.7**	**109.8±47.7**

As discussed throughout this report, upward migration through matrix diffusion and upward flow is a significant element of the East Side and West Side CSMs. As shown in Table 9-3a above, most of the perchlorate mass in the NERT RI Study Area is present in the saturated UMCf within OU-1, OU-2, and OU-3. As shown in Table 9-3b, most of the hexavalent chromium mass exists in the saturated UMCf within OU-1. This further demonstrates the importance of understanding matrix diffusion and upward flow, as roughly 64% of the total estimated perchlorate mass and 73% of total estimated hexavalent chromium mass remains in the UMCf and is subject to continued upward migration, thus acting as an ongoing source to shallow groundwater.

As presented in the 2021 Annual Groundwater Monitoring and GWETS Performance Report, approximately 300,090 pounds (around 150 tons) of perchlorate and 2,008 pounds (around 1 ton) of chromium were captured and removed from groundwater during the annual reporting period by the GWETS. The perchlorate annual mass removal rate is equivalent to 3.1% of the mass of perchlorate remaining in soil and groundwater of the NERT RI Study Area, and the chromium annual mass removal rate is equivalent to 0.9% of the mass of chromium remaining in soil and groundwater of the NERT RI Study Area.

The mass estimates are provided to support the development of these CSMs and to provide a basis for the evaluation of alternative remedies in the forthcoming FS. As described above, the uncertainty of the mass estimates has been evaluated using standard methods. The levels of uncertainty were found to be acceptable given the purpose of the mass estimates. The mass estimates will next be updated in the RI Report for OU-3 and will incorporate additional RI data collected through 2022. As a result, the estimates for OU-3 may change more significantly from the current estimates based on the new data, while the estimates for OU-1 and OU-2 are not likely to change (except as a result of mass removal). The final mass estimates for OU-3 will be presented in the OU-3 RI or the 2022 Annual Groundwater Monitoring and GWETS Performance Report, depending on project timing.

9.8 Receptors and Exposure Pathways

As discussed in Section 9.0, the final element of the CSM is a thorough understanding of potential exposure pathways by which human and ecological receptors could be exposed to contamination. Human receptors include residents, commercial workers, and industrial workers that live and/or work in the NERT RI Study Area, and ecological receptors include plants, animals, and other organisms present in the NERT RI Study Area. Exposure pathways describe how contamination potentially migrates from a source area through an environmental media (e.g., soil, soil gas, groundwater) and then causes exposure to a receptor through the possible routes of exposure (e.g., inhalation, ingestion, and contact with skin). This information plays a crucial role in the CERCLA process, particularly when performing risk assessments, which quantifies the potential health risks to human and ecological receptors associated with COPCs present in the environment.

The remainder of the discussion in this section represents a refinement of the CSM presented in the RI/FS Workplan (ENVIRON 2014c) based on information collected during the RI and the ongoing groundwater monitoring program, changes in land use, and other relevant information.

The development of the CSM includes an evaluation of whether exposure pathways are complete or incomplete for each potential receptor. Incomplete pathways do not have the potential to actually cause exposure to receptors. Only complete exposure pathways will be evaluated quantitatively in NERT's risk assessments. For an exposure pathway to be complete, all of the following elements must exist (USEPA 1989):

- Source and mechanism for chemical release
- Environmental transport medium (i.e., air, water, soil)
- Point of potential contact with the exposure medium (e.g., indoor air, outdoor air, soil)
- Route of exposure (e.g., inhalation, ingestion, dermal contact)

The identification of potential human receptors with complete exposure pathways is based on the following land use scenarios: commercial, industrial, and residential. Based on these land uses, exposure pathways were evaluated for the following human receptors in OU-1 and OU-2:

- Construction worker (OU-1 and OU-2)

- Outdoor commercial/industrial worker (OU-1 and OU-2)
- Indoor commercial/industrial worker (OU-1 and OU-2)
- Visitor/trespasser (OU-1)
- Child and adult resident (OU-2)

Exposure pathways in OU-1 and OU-2 were evaluated for the following ecological receptors:

- Terrestrial invertebrates
- Terrestrial plants
- Birds and mammals

Figures 9-20a through 9-20d present charts summarizing the CSMs for OU-1 and OU-2 and identifying the pathways that are potentially complete based on current and future land uses. As discussed elsewhere in this report, various risk assessments are being performed to evaluate potential risks for the complete exposure pathways for human and ecological receptors in OU-1 and OU-2 that will be submitted subsequent to this report. A discussion of the scope of these risk assessments and further discussion of the complete exposure pathways for human and ecological receptors in OU-1 and OU-2 are presented below. The CSM for OU-3 will be summarized in the forthcoming RI Report for OU-3 with the risk assessments for OU-3 following the RI Report.

9.8.1 OU-1 Potential Exposure Populations and Pathways

The land use in OU-1 will likely be restricted to industrial and/or commercial purposes through a land use covenant. Accordingly, and as shown in Figure 9-20a, the potentially exposed OU-1 populations in the CSM include construction workers, outdoor commercial/industrial workers, indoor commercial/industrial workers, and visitors/trespassers.

OU-1 Soil Exposure

Based on the source and release mechanisms presented in the CSM, the following receptor populations and exposure routes are identified as complete for quantitative evaluation in the soil BHRA Study Area for OU-1 as shown in Figure 9-20a:

- Construction workers
  - *Incidental soil ingestion*
  - *Dermal contact with soil*
  - *Inhalation of airborne soil particulates or vapor*
  - *External exposure from soil (radionuclides only)*
- Outdoor commercial/industrial workers
  - *Incidental soil ingestion*
  - *Dermal contact with soil*
  - *Inhalation of airborne soil particulates or vapor*

    - *External exposure from soil (radionuclides only)*
- Indoor commercial/industrial workers
    - *Incidental soil ingestion*
    - *Inhalation of airborne dust particulates or vapor*
    - *External exposure from soil (radionuclides only)*

Commercial/industrial workers are assumed to have direct contact with shallow soils (0 to 2 feet bgs) when minimum soil excavation occurs that could bring subsurface soil to the surface, or with surface and subsurface soils (0–10 feet bgs) when soils from depths of up to 10 feet bgs could be brought to the surface during excavation or other activities.

The Soil BHRA also includes a qualitative evaluation of exposure pathways for visitors or trespassers to OU-1 (Ramboll 2022b).

<u>OU-1 Soil Gas and Groundwater Exposure</u>

Based on the source and release mechanisms presented in the CSM, the following receptor populations and exposure pathways have been identified as complete for quantitative evaluation in the soil gas and groundwater BHRA for OU-1 (Figure 9-20a):

- Construction workers
    - *Inhalation of vapors migrating from soil gas/groundwater to trench air*
- Outdoor commercial/industrial workers
    - *Inhalation of vapors migrating from soil gas/groundwater to outdoor air*
- Indoor commercial/industrial workers
    - *Inhalation of vapors migrating from soil gas/groundwater to indoor air*

Construction workers in OU-1 are conservatively assumed to be exposed to vapors migrating from soil gas/groundwater while standing in a 10-feet deep trench in the unsaturated zone, placing them closer to the potential sources. Exposure to VOCs in outdoor air were not quantitatively evaluated for construction workers and indoor commercial/industrial workers because it was expected to be much lower than the exposure to VOCs in trench air and indoor air.

A qualitative evaluation of exposure pathways for visitors or trespassers to VOCs in OU-1 is included in the BHRA Report for OU-1 Soil Gas and Groundwater, Revision 1 (Ramboll 2023d).

Exposure via domestic use of groundwater are not considered a complete exposure pathway in OU-1, because groundwater in OU-1 is not and will not be used as a domestic water supply. Incidental ingestion of and dermal contact with groundwater during short-term construction activities are also not considered complete exposure pathways due to the groundwater depth being greater than 10 feet bgs.

Potential exposures to surface water (i.e., runoff) by on-site populations are only evaluated qualitatively in the BHRA Report for OU-1 Soil Gas and Groundwater since such exposures would be intermittent and of short duration or regulated under an Occupational Safety and Health Administration (OSHA) program.

9.8.2 OU-2 Potential Exposure Populations and Pathways

The current and future land use in the NERT Off-Site Study Area in OU-2 is mixed commercial/light industrial and residential use. Accordingly, the potentially exposed populations in OU-2 west of Pabco Road in the CSM include construction workers, outdoor commercial/industrial workers, indoor commercial/industrial workers, and residents. In the Eastside Sub-Area component of OU-2 east of Pabco Road, risk assessments have already been performed by BRC resulting in the determination by NDEP that no further action is needed to address risks to residents, commercial/industrial workers, and construction workers. NERT COPCs in the Eastside Sub-Area are administratively limited to perchlorate and chlorate in soil (greater than 10 ft bgs) and groundwater. Thus, there are no complete exposure pathways within the Eastside Sub-Area to be evaluated by NERT in the BHRA for OU-2.

Based on the source and release mechanisms presented in the CSM, the following exposure pathways are identified as complete for quantitative evaluation in the soil gas and groundwater BHRA for the NERT Off-Site Study Area in OU-2 west of Pabco Road (Figure 9-20b):

- Construction workers[91]
    - *Inhalation* of *vapors migrating from soil gas/groundwater to air within a construction trench*
- Indoor commercial/industrial workers
    - *Inhalation of vapors migrating* from *soil gas/groundwater to indoor air*
- Residents
    - *Inhalation of vapors migrating from soil gas/groundwater to indoor air*

As in OU-1, construction workers in OU-2 are conservatively assumed to be exposed to vapors migrating from soil gas/groundwater while standing in a 10-feet deep trench in the unsaturated zone, placing them closer to the potential sources. Exposure to VOCs in outdoor air are not quantitatively evaluated for construction workers, indoor commercial/industrial workers, and residents because it is expected to be much lower than the exposure to VOCs in trench air (construction workers) and indoor air (residents and commercial/industrial workers).

As in OU-1, exposure via domestic use of groundwater are not evaluated in OU-2 because groundwater is not and will not be used as a domestic water supply. Incidental ingestion of and dermal contact with groundwater during short-term construction activities are not

---

[91] Potential exposures through direct contact with groundwater in the limited areas with groundwater shallower than 10 ft bgs are semi-quantitatively discussed as part of the uncertainty analysis in the OU-2 BHRA Report (Ramboll 2023b).

considered complete exposure pathways in most areas in OU-2 because the depth to groundwater is greater than 10 feet bgs. In the limited area of OU-2 near monitoring wells PC-161 and PC-162 where groundwater is shallower than 10 ft bgs, significant health risks are not expected to occur through direct contact with groundwater due to the small size of the area and the low concentrations of COPCs. Therefore, the health risks associated with this pathway are semi-quantitatively discussed as part of the uncertainty analysis in the OU-2 BHRA Report, Revision 1 (Ramboll 2023c).

9.8.3 OU-1/OU-2 Ecological Exposure Receptors and Pathways

In the ecological risk assessments (ERAs), ecologically relevant media typically include surface water, sediment (i.e., the upper six inches), and surface soil (i.e., generally the upper foot of the soil column) where the majority of biological activity occurs. Groundwater becomes relevant in the ERA at the groundwater-surface water transition zone or interface (USEPA 2008a). There are no natural surface water features within OU-1. The only surface water present in OU-1 is in permitted ponds; therefore, exposure to surface water is not considered a complete pathway for ecological receptors in OU-1. Surface soils are the only ecologically relevant exposure media, and the only complete exposure pathways to ecological receptors are via surface soil (Figure 9-20c).

Based on the source and release mechanisms presented in the CSM, the relevant and representative receptor populations and complete exposure pathways that have been evaluated in the Refined SLERA Report for OU-1 (Ramboll 2023e) are as follows (Figure 9-20c):

- Terrestrial Invertebrates
    - *Bioaccumulation*
    - *Direct contact to soil*
- Terrestrial Plant Communities
    - *Bioaccumulation*
    - *Direct contact to soil*
    - *Root uptake*
- Terrestrial Birds and Mammals
    - *Bioaccumulation*
    - *Ingestion (incidental ingestion of soil and ingestion of food items)*

The analysis for special status species (including federally listed threatened and endangered species) is performed on an individual level, as even a single individual comprises a larger percentage of those populations at risk. Multiple site reconnaissance surveys revealed no critical habitat at OU-1 and no records of special status species present at or in the immediate vicinity of OU-1 (CCDCP 2000, 2003).

The CSM for ecological receptors in OU-2 is similar to that of OU-1 (Figure 9-20c). Based on the source and release mechanisms presented in the CSM, the relevant and representative receptor populations and complete exposure pathways that have been evaluated in the Refined SLERA Report for OU-2 (Ramboll 2023f) are as follows:

- Terrestrial Invertebrates
    - *Bioaccumulation*
    - *Direct contact to soil*
- Terrestrial Plant Communities
    - *Bioaccumulation*
    - *Direct contact to soil*
    - *Root uptake*
- Terrestrial Birds and Mammals
    - *Bioaccumulation*
    - *Ingestion (incidental ingestion of soil and ingestion of food items)*

Based on the highly developed residential and commercial land uses in OU-2, it is important to point out that many areas within OU-2 are considered to be inaccessible or highly unlikely to attract wildlife. These areas were not considered in the SLERA as there is no complete exposure pathway from source to receptor at these locations (e.g., most of the residential areas at OU-2). Based on the observations made during an April 2018 site reconnaissance, residential areas do not contain a significant number of ecologically attractive features that would entice wildlife to preferentially forage or nest there as most of these areas are covered by buildings and pavement. Due to the presence of the Las Vegas Wash, there are more ecological receptors and ecologically attractive features within OU-3, which will be discussed in the forthcoming RI Report for OU-3 and the Baseline Ecological Risk Assessment (BERA) Report for OU-3.

9.9 Summary

In summary, the CSM presented herein links environmental data and knowledge to clearly describe contaminant sources, migration pathways and transformation pathways of the NERT RI Study Area in light of its complex industrial history. This synthesis will inform remediation decisions to be made in the forthcoming FS for OU-1 and OU-2 to adequately mitigate sources, migration pathways, and/or receptors' exposure pathways. Populations and environmental receptors that have the potential to be exposed to constituents present in OU-1 and OU-2 have been identified. Potentially exposed populations and exposure pathways have been evaluated in the OU-1/OU-2 BHRAs (Ramboll 2022b, 2023c, 2023d), and potentially exposed ecological receptors have been evaluated in the OU-1/OU-2 SLERAs (Ramboll 2023e, 2023f). A similar trio of documents (RI Report, risk assessments, and an FS) will subsequently be prepared for OU-3 to complete the CERCLA process prior to final remedy selection.

The key features of the CSM are illustrated schematically in Figures 9-1, 9-2a and 9-2b. Figure 9-1 shows the entire NERT RI Study Area from OU-1 on the south through OU-2 and OU-3 to the Las Vegas Wash on the north. Figure 9-2a presents a cutaway below the eastern portions of OU-2 and OU-3 (i.e., the East Side CSM), and Figure 9-2b presents a similar cutaway extending from OU-1 and the NERT Off-Site Study Area to the Las Vegas Wash generally aligned with Pabco Road (i.e., the West Side CSM).

With respect to OU-1 and the portions of OU-2 and OU-3 west of Pabco Road, the groundwater migration pathways from OU-1 discussed in this CSM are illustrated in Figure 9-2b, which also shows the three NERT groundwater extraction well fields and potential receptors in the NERT Off-Site Study Area west of Pabco Road. As illustrated in the cutaway side of the diagram, the alluvium has become dewatered beneath OU-1 but remains saturated in OU-2 and OU-3. The relative groundwater concentrations are highest below OU-1 as indicated by the red color and decrease with distance from OU-1 beneath OU-2, where groundwater is intercepted by the AWF. The groundwater concentrations decrease further beneath OU-3 as indicated by the color progression from orange to yellow, and then to blue (lowest concentrations) beyond the SWF adjacent to the Las Vegas Wash, reflecting the control of the core NERT plume (i.e., NERT contamination originating at OU-1 and west of Pabco Road) by the GWETS.

A fundamental complexity of the NERT CSM is the presence of a continuing contaminant source through upward migration of chemicals from the UMCf into shallow groundwater as it flows from OU-1 to the Las Vegas Wash. The current mass estimate indicates that 66% of the total mass of perchlorate and 73% of the total mass of chromium are sequestered in the lower conductivity UMCf, which will continue to be slowly released into shallow groundwater over a long period.

With respect to portions of OU-2 and OU-3 east of Pabco Road, Figure 9-2a illustrates similar features in these areas. This component of the CSM shares the same complexity of contaminant upward migration; however, it differs in three key ways. First, the alluvium has become largely dewatered beneath OU-2 and, as indicated by the orange color, groundwater concentrations in the saturated UMCf are lower than concentrations beneath OU-1. Second is the current absence of groundwater extraction wells or other mitigation measures between the OU-2 Eastside source area and the Las Vegas Wash which results in the uncontrolled migration of COPCs from OU-2 into OU-3 and eventually north to the Las Vegas Wash. Finally, the only contaminants evaluated by NERT in the Eastside Sub Area are perchlorate and chlorate, as BRC is responsible for addressing all other COPCs to the extent required by NDEP. As a result, the CSM for the portion of OU-2 east of Pabco Road is limited to perchlorate and chlorate.

As discussed throughout this report, COPCs (including chloroform) from the neighboring OSSM site have been identified as trespassing into OU-1, and the contamination continues to migrate across OU-1 and into OU-2. The geometry of the chloroform plume is consistent with the particle tracking analysis presented in Figures 9-9a, 9-12a, and 9-12b. Both of these lines of evidence demonstrate that chloroform from OSSM's trespassing plume is not fully captured by their GWETS and migrates in an uncontrolled manner into OU-2. COPCs related to the TIMET site have also been identified in OU-2 and continue to migrate northward across OU-2. The chloroform plume migrating from the Unit 4 and 5 Buildings source area trespasses on the TIMET site at a depth interval of 90 to 130 feet bgs and the Primary COPCs are moving upwards into the Shallow WBZ. However, the concentration gradient of chloroform indicates that the Unit 4 and 5 Buildings source area cannot be solely responsible for the higher concentrations of chloroform in groundwater at the water table within the TIMET site. As such, other source area(s) must be contributing to chloroform contamination on the TIMET site. As indicated previously in this section, the current extent of chloroform in groundwater in OU-2 is largely the result of its uncontrolled migration from the TIMET site prior to 2014, when its barrier wall and GWETS became fully operational. This conclusion is based on the shape of the chloroform plume and the particle tracking analysis presented in Figures 9-12a and 9-12b.

Perchlorate and chlorate from the AMPAC plume enter OU-2 from the west near the AWF and the OU-3 boundary, commingle with the perchlorate and chlorate from the NERT plume, and extend north into OU-3. The AMPAC plume is chemically distinguishable from the NERT plume and the delineation between the two plumes will be discussed in more detail in the forthcoming RI Report for OU-3.

10. SUMMARY OF CONCLUSIONS

This RI Report for OU-1 and OU-2 was prepared to define the nature and extent of contamination within OU-1 and OU-2 of the NERT RI Study Area, consistent with CERCLA and in accordance with the Interim Consent Agreement between NDEP and the Trust (NDEP 2011a). As stated in RI/FS guidance (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." While this report presents the results of the investigation of OU-1 and OU-2, the results of the investigation of OU-3 will be presented in a separate and forthcoming RI Report for OU-3. In addition to presenting the nature and extent of contamination within OU-3, the RI Report for OU-3 will present an updated CSM based on additional data collected during the OU-3 investigation, as well as updated mass estimates for perchlorate and chromium in OU-3.

The nature and extent of contamination documented in the RI Reports, in conjunction with the risk assessments (BHRA for soil in OU-1, BHRA for soil gas and groundwater in OU-1, Refined SLERA for OU-1, BHRA for soil gas and groundwater in OU-2, Refined SLERA for OU-2, BHRA for OU-3, and BERA for OU-3) will be used to support the evaluation of remedial action alternatives in each of the two planned NERT FS documents.[92] Following approval of the FS documents, plans will be prepared summarizing the proposed remedial action alternatives, which will be made available for public comment. After the close of the public comment periods, NDEP will review and respond to public comments, and RODs will be issued identifying the selected remedial action alternatives representing the final remedy.

10.1 Scope of the RI

This report documents the findings of investigations conducted to determine the nature and extent of COPCs in OU-1 and OU-2 related to historical industrial activities within OU-1. Since the historical operations within and immediately adjacent to OU-1 all contributed to current day contamination within OU-1, OU-2, and OU-3, this report also presents relevant off-site data and relates it to NERT's obligations consistent with CERCLA and the abovementioned Interim Consent Agreement. The RI was conducted to address the following objectives for OU-1 and OU-2:

- Collect geologic and hydrogeologic data necessary to characterize the environmental setting of the NERT RI Study Area including the collection of subsurface soil and groundwater samples, the completion of aquifer testing, and NMR logging.
- Identify a comprehensive list of COPCs that exceed screening levels and should be evaluated in greater detail in the baseline human health risk assessments, the ecological risk assessments, and the forthcoming FS, if present at levels that pose an unacceptable risk to the target receptor.
- Identify and characterize the primary sources of the COPCs related to historical activities within OU-1, such as the Unit 4 and 5 Buildings.

---

[92] It is anticipated that one FS report will be prepared for OU-1 and OU-2 and a second FS report will be prepared for OU-3. The forthcoming RI Report for OU-3 will also be used to support the evaluation of remedial action alternatives in OU-3.

- Identify and characterize the sources of the COPCs related to historical activities immediately adjacent to OU-1, to the extent such activity affects OU-1 and OU-2 due to trespass or migration.
- Complete the lateral and vertical delineation of COPCs, including trespassing COPCs within OU-1.
- Characterize the COPCs migrating via groundwater from OU-1 into the NERT Off-Site Study Area component of OU-2 west of Pabco Road.
- Complete the lateral and vertical delineation of COPCs within the NERT Off-Site Study Area component of OU-2 west of Pabco Road, including COPCs migrating from areas other than OU-1 into OU-2, but limited only to perchlorate and chlorate in the Eastside Sub-Area component of OU-2 east of Pabco Road.
- Update the Conceptual Site Model with data acquired during the RI related to geologic and hydrogeologic conditions, identification of migration pathways and COPC concentrations, land use, and exposure pathways.
- Characterize groundwater migration pathways in order to support the BHRAs, the SLERAs, and evaluation of remedial alternatives in the upcoming FS.
- Obtain soil gas data to support the evaluation of volatilization from shallow groundwater into soil gas and any resultant potential vapor intrusion risk that is presented in the BHRAs for soil gas and groundwater in OU-1 and OU-2.

As described in Section 3.2, significant investigations were implemented within OU-1 and OU-2 prior to the Trust's ownership of the NERT Site. These investigations were conducted by Kerr-McGee from 1981 through 2005. After taking ownership of the facility from Kerr-McGee in 2005, Tronox conducted investigations until February 2011, when the Trust took title to the NERT Site as part of the confirmation of Tronox's bankruptcy. Additional investigations within the NERT RI Study Area and vicinity were also conducted by other parties associated with the BMI Complex.

Since the creation of the Trust in February 2011, approximately 192 monitoring wells have been installed, 380 boreholes were advanced, and soil gas probes have been installed at 73 locations within OU-1 and OU-2 for the RI. These new locations, in addition to previously existing locations sampled for the RI, yielded approximately 5,988 investigative environmental samples. Specifically, results of the following investigations are included in this report:

1. The Phase 1 RI, as described in the RI/FS Work Plan (ENVIRON 2014c);
2. The investigation of soil and groundwater beneath the Unit 4 and 5 Buildings within OU-1, as described in the Unit 4 and 5 Buildings Investigation Work Plan (Tetra Tech 2015); the results of this investigation are presented within the Unit 4 and 5 Buildings Investigation Report (Tetra Tech 2020);
3. The Phase 2 RI, as described in the Technical Memorandum for the Remedial Investigation Data Evaluation (Ramboll Environ 2016c) and 15 Phase 2 RI modifications approved by NDEP (Ramboll Environ 2017b,c,d,e,f,g,h,n; Tetra Tech 2017b; Ramboll 2018a,d,f,g,h,k); and

4. The Phase 3 RI, as described in the Phase 3 RI Work Plan (Ramboll Environ 2017m) and three of the 15 Phase 3 RI modifications (Phase 3 RI Modification Nos 1, 3, and 9) approved by NDEP that related to OU-1 and OU-2 (Ramboll Environ 2017p; Ramboll 2018e, 2019e).[93]

Evaluation of these data, in addition to the substantial environmental data set collected prior to the Trust's inception, are discussed in detail within Sections 7 and 8 of this report. Results of the investigation of the Downgradient Study Area within OU-3 (AECOM 2016a, 2016b) and the results of the Phase 3 RI within OU-3 are briefly discussed, but are not the focus of this report and will be extensively discussed in the forthcoming RI Report for OU-3, which is anticipated to be submitted to NDEP under separate cover in late 2023.

Potentially exposed populations and exposure pathways are evaluated in the OU-1 and OU-2 BHRAs (Ramboll 2022b, 2023c, 2023d), and potentially exposed ecological receptors are evaluated in the OU-1 and OU-2 SLERAs (Ramboll 2023e, 2023f).

The RI scope of work implemented has defined the nature and extent of contamination within OU-1 and OU-2 and all of the objectives listed above have been accomplished. As such, all of the identified data gaps have been resolved and NERT considers the RI for OU-1 and OU-2 complete.

10.2 Hydrogeology of the NERT RI Study Area

Under current conditions, the major migration pathway for the Primary COPCs is via groundwater migration from source areas towards the Las Vegas Wash. A key objective of the RI has been to more completely characterize these groundwater migration pathways in order to support the evaluation of remedial alternatives in the upcoming FSs.

Hydrogeologic investigations conducted during the RI characterizing significant groundwater migration pathways include:

Mapping of Paleochannels and Saturated Alluvium. Mapping of the paleochannels and current extent of saturated alluvium has been completed to characterize where groundwater transport is occurring in the high conductivity alluvium. The alluvium within paleochannels tends to have the highest hydraulic conductivity and largest saturated thickness. Thus, the paleochannels represent the most significant groundwater migration pathways. Within OU-1, the alluvium was historically saturated below the northern portion of the OU, while in the southern portion of OU-1 the first groundwater occurred in the UMCf. However, except for a few small areas, the alluvium, including paleochannels, has become dewatered and the first groundwater encountered now occurs within the underlying UMCf across OU-1. Similarly, there are significant areas within the eastern portion of OU-2 where the alluvium is dewatered.

Detailed Characterization of the UMCf. The UMCf of Tertiary age occurs in the Las Vegas Valley as valley-fill deposits that are coarse-grained near the mountain fronts and become

---

[93] The RI Report for OU-1 and OU-2 includes data from the initial Phase 3 RI, including three Phase 3 RI modifications with field investigations conducted through January 2020. Results from remaining Phase 3 RI modifications with field investigations conducted through October 2022 which pertain solely to areas in OU-3 will be discussed in the forthcoming RI Report for OU-3.

progressively finer-grained toward the center of the valley. Coarse-grained alluvial fan aprons along the mountain front transition to finer-grained sand flats, then mud flats, and finally to saline lacustrine/mudflat deposits in the basin interior. The saline mudflats in the basin interior are characterized by abundant gypsum and other evaporite salt deposits. Sediments in the sand flat and dry mudflat environments are often characterized by carbonate caliche deposits. Within the NERT RI Study Area, only a few thin sandy units were found in the UMCf, predominantly in OU-1. Since the NERT Site Study Area (OU-1) is located closer to the mountains, the upper portion of the UMCf tends to have zones of sandy silt/silty fine sand as well as a greater number of thin layers of silty sand than is observed in the downgradient off-site areas farther from the mountains and more toward the interior of the depositional basin (i.e., in OU-2 and OU-3). As described in Section 5.4.2, these thin preferential flow pathways are likely associated with anastomosing streams. As indicated in cross sections G-G′ to K′′-K′′′ within Appendix C, the number of observed silty sand units within the UMCf significantly decreases and transitions into fine-grained low permeability sediments toward the north. Due to its low permeability, contaminants migrate very slowly through the UMCf.

Aquifer Testing. The hydraulic conductivity of the alluvium and UMCf has been sufficiently characterized through aquifer testing in wells throughout OU-1 and OU-2. Particularly within paleochannels and closer to the Las Vegas Wash, the hydraulic conductivity of the alluvial sands and gravels is generally quite high. The hydraulic conductivity of the underlying UMCf, which is generally finer-grained, is significantly lower. The estimated average groundwater velocity within the alluvium in the area between the northern OU-1 boundary and the AWF (located near the OU-2/OU-3 boundary) ranges from 1,900 to 3,700 ft/yr, equivalent to travel times of 2.9-5.7 years. In the area between the AWF and the SWF (within OU-3), the estimated average groundwater velocity within the alluvium ranges from 2,600 to 5,700 ft/yr, equivalent to a travel time of 0.8-1.8 years. These velocity estimates were developed using the NERT groundwater model. Both the horizontal and vertical hydraulic conductivities of the UMCf are one or more orders of magnitude less than those of the alluvium. The estimated average groundwater velocity within the fine-grained UMCf ranges from 4 to 40 ft/yr in the area between the northern OU-1 boundary and the AWF, and ranges from 0.5 to 30 ft/yr between the AWF and the SWF. Thus, groundwater flow rates in the Shallow WBZ are substantially higher within the alluvium (where it is saturated) than within the UMCf. The highest flow rates occur within paleochannels in the alluvium where the saturated thickness is greatest.

NMR Logging. NMR logging has been conducted in approximately 268 wells within the NERT RI Study Area. In general, the NMR logs were found to be a useful tool for confirming field observations of lithology and providing an estimate of porosity that is potentially more representative of in-situ conditions than laboratory measurements. The porosities measured using NMR were incorporated into the residual mass estimates for perchlorate and hexavalent chromium in the NERT RI Study Area. However, NMR was determined to not be an accurate method for determining hydraulic conductivities in very low conductivity sediments such as those found in the UMCf or for determing effective porosity values for use in the groundwater model.

Vertical Gradients. Investigations of the Middle WBZ within OU-1/OU-2 indicate, with a few exceptions, a vertical upward gradient between the Middle and Shallow WBZs that generally increases with depth. The average gradient observed in the 25 well clusters between the Middle and Shallow WBZs with an upward vertical gradient was approximately 0.19 ft/ft. The upward vertical gradient between the Middle and Shallow WBZs limits the extent of downward migration of the COPCs in groundwater and enhances the upward diffusion of COPCs currently in the UMCf into overlying alluvium over time. These vertical gradients are a significant finding of the RI and a critical component of the CSM, since the upward gradient is a major mechanism that will cause contaminant mass in the UMCf to act as a source to shallow groundwater for the foreseeable future.

10.3 Summary of COPCs for OU-1 and OU-2

The COPCs for soil and groundwater in OU-1 and OU-2 were developed based on the initial and secondary screening processes described in Section 7 (OU-1) and Section 8 (OU-2). In OU-1, initial and secondary screening of COPCs was applied to both vadose zone soil and groundwater. In the NERT Off-Site Study Area component of OU-2 west of Pabco Road, the primary mechanism by which Site-related contaminants migrated to this area has been by groundwater transport. Since vadose zone soil in the NERT Off-Site Study Area was not directly impacted by historical operations within the NERT Site Study Area, the screening for COPCs was limited to groundwater. In the Eastside Sub-Area component of OU-2 east of Pabco Road, and consistent with the Phase 3 RI Work Plan (Ramboll Environ 2017m), the COPCs are administratively limited to perchlorate and chlorate. As previously discussed in this report, Pabco Road demarcates the investigatory and cleanup obligations of NERT resulting from the AOC between NDEP and BRC. Thus, discrete sets of COPCs have been assigned to the areas east and west of Pabco Road.

The COPCs for both OU-1 and OU-2 were presented in Table 9-1 and are summarized below.

- The four NERT Primary COPCs (perchlorate, chlorate, chromium, and chloroform) are the most widespread of all COPCs identified in OU-1 and extend northward to the Las Vegas Wash. However, only perchlorate and chlorate have been detected above GWSLs in groundwater within OU-3. These COPCs are in soil and groundwater in OU-1 and groundwater in the NERT Off-Site Study Area component of OU-2 west of Pabco Road. In the Eastside Sub-Area component of OU-2 east of Pabco Road, the NERT Primary COPCs in soil and groundwater are administratively limited to perchlorate and chlorate.
- In OU-1, Other COPCs in soil and groundwater were identified from the following chemical classes: general chemistry, metals, radionuclides (groundwater only), VOCs, SVOCs (soil only), PAHs (soil only), dioxins and furans (soil only), PCBs (soil only), OCPs (soil only), and other organics. Out of 46 soil COPCs in OU-1, 44 are associated with historical operations in OU-1, and two are solely associated with trespassing groundwater from the OSSM site to the west of OU-1. Out of 34 groundwater COPCs in OU-1, there are 10 COPCs that are solely associated with trespassing groundwater from the OSSM site and 7 COPCs (including the Primary COPC chloroform) that are associated with trespassing groundwater from the OSSM site as well as sources within OU-1.
- In OU-2 (within the NERT Off-Site Study Area west of Pabco Road), Other COPCs in groundwater were identified from the following chemical classes: general chemistry, metals, and VOCs. Of the 17 total groundwater COPCs, 12 have migrated in

groundwater from OU-1. Six of these 12 COPCs and an additional 4 COPCs have migrated in groundwater from the OSSM site (across OU-1 and into OU-2). Three of these 12 COPCs and one additional COPC have migrated in groundwater from the TIMET site. Two of these 12 COPCs (perchlorate and chlorate) have migrated in groundwater from the former AMPAC site. In the Eastside Sub-Area component of OU-2 east of Pabco Road, no additional COPCs have been defined due to the administratively limited COPC set.

10.4 OU-1 Nature and Extent of Contamination

The CSM presented a summary of the sources of contamination within OU-1. Following the comprehensive investigation of OU-1 source areas during the RI, the areas that have been identified as the primary sources of contamination in OU-1 include: the Unit 4 and 5 Buildings, the former Beta Ditch, the former AP Plant and associated facilities, the former P and S Ponds, and features north of the IWF/barrier wall (the former Trade Effluent Ponds and the former recharge trenches). Details regarding these features can be found in Sections 2.1 and 9.4. In addition, groundwater in the western portion of OU-1 has been impacted by trespassing chemicals from the adjacent OSSM site, as discussed in Sections 7 and 9.

Subsequent to soil removal activities conducted in 2010-2011, during which an estimated 567,770 cubic yards of contaminated soil was removed from OU-1 and disposed off-site (see Section 3.2), additional soil removal actions have been conducted within OU-1 concurrent with the RI, including excavation and off-site disposal of soil at the eastern end of the former Beta Ditch (ENVIRON 2012a), dioxin contaminated soil near the GW-11 Pond (Ramboll 2020a), and closure of the former AP-5 Pond (Tetra Tech 2019b).

10.4.1 OU-1 Vadose Zone Soil

The OU-1 vadose zone soil has been thoroughly characterized through implementation of the RI. Based on the data previously presented in this RI Report, NERT concludes the following regarding the investigation of OU-1 vadose zone soil:

- OU-1 vadose zone soil has been characterized and all previously identified data gaps have been addressed. The details of the soil COPC screening process and a comprehensive discussion of the presence and extent of soil COPCs above LSSLs and HSSLs are presented in Section 7.
- The majority of the COPCs identified in OU-1 soil above LSSLs have not migrated into OU-1 groundwater at concentrations above GWSLs. Only perchlorate, chlorate, hexavalent chromium, chloroform, nitrates, arsenic, boron, magnesium, manganese, methylene chloride, and beta-BHC have been determined to have impacted groundwater quality such that the GWSLs have been exceeded in OU-1.

Based on the data presented in Section 7, no data gaps or additional investigation are needed, and the investigation of soil within OU-1 is considered complete.

10.4.2 OU-1 Groundwater

OU-1 groundwater has also been thoroughly characterized through implementation of the RI. Based on the data previously presented in this RI Report, NERT concludes the following regarding the investigation of OU-1 groundwater:

- The alluvium has become dewatered throughout almost all of OU-1, and first groundwater now primarily occurs in the low permeability UMCf. Only a few thin sandy units were found in the UMCf, predominantly in the southern part of OU-1. These preferential flow pathways are, however, limited in lateral extent and, due to its low permeability, contaminants migrate very slowly through the UMCf.
- The lateral extent of both the Primary COPCs (perchlorate, chlorate, chromium, and chloroform) and Other COPCs in OU-1 groundwater has been defined. Perchlorate and chlorate are the most widespread contaminants in groundwater within OU-1 and the distribution of Other COPCs in groundwater which are attributed to OU-1 generally occur within the footprint of the perchlorate and chlorate plumes.
- The vertical extent of both the Primary and Other COPCs in OU-1 groundwater has been defined. In OU-1, the Unit 4 and 5 Buildings were found to be a significant source of perchlorate and Other COPCs historically released within the NERT Site Study Area, with higher groundwater levels from wastewater infiltration and density-driven flow likely contributing to the downward migration of the highest perchlorate concentrations to depths of 90-120 feet bgs. Perchlorate in groundwater above the GWSL extends to a depth of approximately 175 feet bgs beneath the Unit 4 Building. In contrast, the highest perchlorate concentrations are in shallow groundwater above a depth of 90 feet bgs in the northern part of OU-1 between the former Beta Ditch and the IWF. In this area, separate sources related to other operational areas (such as the AP Plant area and associated ponds, and the former recharge trenches) historically released perchlorate and other COPCs to soil and shallow groundwater.
- In addition to the chloroform attributed to the trespassing OSSM plume, chloroform was also found in groundwater beneath and downgradient of the Unit 4 Building in samples collected from wells screened between approximate depths of 90-115 ft bgs. The highest concentrations of chloroform originating from historical manufacturing activities within OU-1 (up to 8,300 µg/L in well M-251-100) were found beneath the Unit 4 Building and extend north-northeast for a distance of approximately 1,600 feet, a distribution pattern similar to perchlorate at this depth. In comparison, the highest concentrations of chloroform within the OSSM plume are up to approximately 7 times greater than the highest concentration documented at the Unit 4 and 5 Buildings. This suggests chloroform migrated downward beneath the Unit 4 Building along with perchlorate and other Primary COPCs found at this depth interval.

No data gaps for groundwater in OU-1 were identified and, as such, no additional investigation is needed to delineate the extent of contamination in groundwater in OU-1. Contaminants trespassing into OU-1 are discussed in detail in Sections 7 and 9 of this report and summarized below in Section 10.4.4.

10.4.3 OU-1 Soil Gas

Through the NERT RI, two rounds of soil gas sampling were conducted in OU-1. Chloroform was the only VOC in OU-1 detected in soil gas above screening levels, and it was detected at all sample locations and depths across OU-1 during the RI sampling events. The highest soil gas concentrations for chloroform are attributed to two sources, with one located next to the Unit 4 Building and the second over the portion of the DNAPL plume which trespasses from the OSSM site into the western portion of OU-1. In general, chloroform concentrations in soil gas increased with depth indicating that the source of chloroform in soil gas in both instances is chloroform in groundwater or DNAPL, rather than a shallow vadose zone source. In addition, the DNAPL associated with the OSSM trespassing plume is also a source of other elevated COPCs in soil gas and will continue to be until the DNAPL is remediated.

Three additional VOCs (TCE, carbon tetrachloride, and PCE) were detected at elevated concentrations but below screening levels in OU-1 soil gas. TCE is not considered a COPC in soil within OU-1, but carbon tetrachloride is considered a COPC in soil and both compounds are considered COPCs in groundwater largely due to carbon tetrachloride and TCE groundwater contamination that trespasses from the OSSM and WAPA sites onto OU-1, respectively. The highest concentrations of carbon tetrachloride in soil gas were located along the western portion of OU-1 within the footprint of the OSSM trespass. TCE was detected at relatively low concentrations in soil gas across OU-1, with the highest TCE concentrations detected in the central portion of OU-1, correlated with the locations of higher concentrations of TCE in groundwater originating in and migrating from the WAPA property. The highest concentrations of PCE were located in the Unit 4 Building basement but at concentrations well below the SGSL and not spatially correlated with the detection of PCE in groundwater above the GWSL within OU-1.

For chloroform and other VOCs in groundwater, an evaluation of volatilization from shallow groundwater into soil gas and any resultant potential vapor intrusion risk is presented in the BHRA Report for OU-1 Soil Gas and Groundwater, Revision 1 (Ramboll 2023d).

10.4.4 OU-1 Trespassing Contaminants

As indicated previously, groundwater contaminants have migrated into OU-1 from the OSSM site in shallow groundwater and via DNAPL migration in the Middle WBZ. In addition, OSSM historically discharged wastewater to the unlined Beta Ditch which allowed contaminants to seep into the subsurface within OU-1. As a result, the following 17 COPCs have been identified along the western boundary of OU-1 as originating on the OSSM site: arsenic, magnesium, manganese, chloroform, benzene, chlorobenzene, 1,2-, 1,3- and 1,4-dichlorobenzene, carbon tetrachloride, 1,1-DCA, 1,2-DCA, 1,4-dioxane, 1,1,2,2-tetrachloroethane, 1,2,3-trichloropropane, methylene chloride, and PCE. The OSSM groundwater plume associated with the trespassing DNAPL encroaches into OU-1 across its western boundary for a distance of at least 1,000 feet, migrates across OU-1, and a large portion of it ultimately migrates off-site into OU-2. This trespassing plume includes free-phase VOCs (DNAPL) at depths of 100-120 feet bgs as well as dissolved phase VOCs in the Shallow and Middle WBZs. Of the VOCs detected in the DNAPL, chloroform is the most persistent and soluble (i.e., mobile), and represents the most prevalent VOC found in the dissolved phase in OU-1 and adjacent areas. Chloroform is detected at concentrations up to 25,000 µg/L in NERT Shallow WBZ wells impacted by the OSSM plume, and up to 43,000 µg/L in OU-1 Middle WBZ wells impacted by the OSSM plume, whereas chloroform concentrations at the Unit 4 and 5 Buildings source area were identified up to 8,300 µg/L.

10.4.5 OU-1 Contaminants Trespassing Onto TIMET

As indicated in Section 7.5.1, groundwater contaminants are migrating northeastward from the Unit 4 and 5 Buildings source area at a depth interval of 90 to 130 feet bgs. As a result, the Primary COPCs (perchlorate, chlorate, chromium, and chloroform) are migrating from OU-1 onto the TIMET site. Figures 7-50e, 7-58e, and 7-79e display the extent of Primary COPC migration within this depth interval based on perchlorate, hexavalent chromium, and chloroform data collected by TIMET in 2008 (TIMET did not analyze these samples for chlorate). Given that there is an upward gradient, it is expected that these COPCs are slowly migrating upward to the water table within the TIMET site. As such, the concentrations in the 90 to 130 foot depth interval should be higher than the concentrations in groundwater at the water table within the TIMET site for all NERT COPCs. As indicated in TIMET's Upper Muddy Creek Formation Groundwater Evaluation Report (TIMET 2020a), perchlorate and chromium concentrations between 90 to 130 feet bgs were one to two orders of magnitude higher than at the water table. This overall decreasing upward concentration gradient is consistent with what would be expected if the source of NERT Primary COPCs within the TIMET site are from this deep trespassing plume. However, chloroform does not display the same concentration gradient. Chloroform concentrations in the 90 to 130 foot depth interval are up to two orders of magnitude lower than in groundwater at the water table. As such, chloroform migrating from the Unit 4 and 5 Buildings source area cannot be solely responsible for the higher concentrations of chloroform in groundwater at the water table within the TIMET site. The data indicate that there must be other chloroform sources within the TIMET site that are directly impacting shallow groundwater.

As directed by NDEP, the TSE was constructed in 2022 through early 2023 to remove perchlorate, chlorate, and chromium from groundwater that migrates from the NERT Site and is captured by TIMET's GWETS.

10.5 OU-2 Nature and Extent of Contamination

OU-2 is divided into two distinct areas that are discussed separately: the NERT Off-Site Study Area component of OU-2 west of Pabco Road and the Eastside Sub-Area component of OU-2 east of Pabco Road. Key findings are summarized below.

10.5.1 Sources of Contamination within OU-2 West of Pabco Road (NERT Off-Site Study Area)

As described in the CSM in Section 9, land use in the NERT Off-Site Study Area component of OU-2 west of Pabco Road has been used for residential or commercial purposes unrelated to operation of OU-1 or the BMI Complex. Therefore, there are no primary sources of Site-related contamination within OU-2 west of Pabco Road. The groundwater contamination in this area has resulted from migration of contaminants in groundwater from upgradient sources and possibly from the infiltration of contaminants from wastewater that migrated through former ditches bordering the area while in operation. In addition, residual contamination that has and continues to migrate downgradient in the UMCf represents a long-term secondary source to shallow groundwater in this area of OU-2.

Migration in Groundwater from Upgradient Sites

In OU-2 west of Pabco Road, a primary source of the contamination in groundwater has been the migration of COPCs in groundwater from upgradient sites, including OU-1, the OSSM site, the TIMET site, and the former AMPAC site. The highest concentrations of COPCs in OU-2 groundwater downgradient of these sites are found in the southern (upgradient) portion of OU-2, north of Warm Springs Road, as described below.

- NERT Site Study Area/OU-1. The Primary COPCs in OU-2 groundwater resulting from releases that occurred in OU-1 are perchlorate (up to 1,200 mg/L), chlorate (up to 1,100 mg/L), chromium (up to 2,000 µg/L), and chloroform (up to 650 µg/L). In addition, nitrates, arsenic, boron, magnesium, bromodichloromethane, carbon tetrachloride, 1,4-dioxane, and 1,2,3-trichloropropane present in groundwater within OU-2 originated from releases in OU-1. The history and descriptions of source areas within OU-1 are discussed in Section 9.4.
- OSSM site. The OSSM site is located immediately west of OU-1 and is the source of a groundwater plume that encroaches into OU-1, and a large portion of this plume eventually migrates off-site into OU-2 without being captured by either the OSSM or NERT GWETS. Downgradient (north) of the OSSM site and its GWETS, the COPCs above GWSLs currently found in OU-2 groundwater associated with releases on the OSSM site are arsenic, magnesium, manganese, 1,1-DCA, 1,2,3-trichloropropane, 1,4-dioxane, benzene, chlorobenzene, carbon tetrachloride, and chloroform. In addition, groundwater in this area contains elevated TDS (up to 15,000 mg/L) related to releases from the OSSM site. As described in Section 9, particle tracking supports the conclusion that the trespassing OSSM plume largely migrates offsite into OU-2 without being captured by the OSSM or NERT GWETS.
- TIMET site. COPCs from the TIMET site, located immediately east of OU-1, have also migrated downgradient directly to OU-2. Chloroform and PCE are present in groundwater above GWSLs at the northern TIMET site boundary, as indicated by their presence in both monitoring wells and the treatment plant influent (Tetra Tech EMI 2005; GEI 2020b). As indicated previously, chloroform trespassing onto the TIMET site at the 90 to 130 foot bgs depth interval from OU-1 is contributing to chloroform concentrations in TIMET shallow groundwater. However, the chloroform concentrations in the OU-1 deep plume are up to two orders of magnitude less than found in shallow groundwater on the TIMET site indicating that additional chloroform sources within the TIMET site are directly impacting shallow groundwater quality. Directly downgradient of the TIMET site, chloroform and PCE are detected above their GWSLs in OU-2 groundwater north of Warm Springs Road. In addition, groundwater directly downgradient of the TIMET site is impacted by 1,4-dioxane (up to 23 µg/L), 1,2,3-trichloropropane (detected concentrations up to 0.088 µg/L and detection limits up to 4.0 µg/L) and elevated TDS (up to 11,000 mg/L). As such, releases from the TIMET site have also contributed to elevated VOC contamination in OU-2, particularly prior to the operation of their GWETS.
- Former AMPAC site. In addition to the groundwater contamination sources from the upgradient sites within the BMI Complex, a separate perchlorate plume associated with the former AMPAC site located approximately 1.5 miles west of OU-1 has commingled with the NERT perchlorate plume near NERT's AWF in OU-2. AMPAC's

plume also is present within the western part of OU-3 and discharges perchlorate to the Las Vegas Wash in this area. AMPAC's plume also contains chlorate that trespasses into OU-2 and OU-3. Additional information regarding delineation of the AMPAC and NERT perchlorate plumes will be presented in the forthcoming RI Report for OU-3.

Sufficient data have been collected in the RI to determine the origins of the various contaminants in OU-2 groundwater west of Pabco Road and no additional data collection is necessary. As indicated in Figure 9-12c, the shape of the perchlorate, chlorate, and hexavalent chromium plumes are nearly identical as these COPCs all originate from the same source areas, with the Unit 4 and 5 Buildings being the most significant source area. The Unit 4 and 5 Buildings source area is also the only source area associated with historical operations in OU-1 that contains chloroform. However, the shape of the chloroform plume within OU-2 is significantly different than perchlorate, chlorate, and chromium plumes, indicating that other sources on the OSSM and TIMET sites have impacted groundwater quality in OU-2. This conclusion is also supported by particle tracking that has been performed using NERT's Phase 6 groundwater flow model.

Residual Contamination in the UMCf

Another primary source of contamination to shallow groundwater throughout each of the three NERT OUs is the effect of matrix diffusion, in which slow upward migration of contaminants from the UMCf causes concentrations in the higher permeability alluvium to remain above regulatory levels for a long period of time. Matrix diffusion is and will continue to be a primary source of contamination to shallow groundwater. Primary COPCs (perchlorate, chlorate, chromium, and chloroform) that have impacted the UMCf first in OU-1 and then migrated within the UMCf into OU-2 will migrate upwards into the alluvium. The lower permeability UMCf across all of the NERT OUs is the unit in which most of the contaminant mass originating from OU-1 is stored, as shown by the mass estimates for perchlorate and chromium presented in Section 9.7.3. This mass in the UMCf slowly migrates upwards into the alluvium. As a result, groundwater concentrations of perchlorate and chromium in the alluvium have been declining relatively slowly, even though active remediation of the higher permeability alluvium has been in progress for over 20 years.

10.5.2 Sources of Contamination within OU-2 East of Pabco Road (Eastside Sub-Area)

The portion of OU-2 located east of Pabco Road was historically referred to as the Eastside Area or BMI Common Areas. For purposes of the NERT RI, this area is referred to as the Eastside Sub-Area. The BMI Common Areas contained a network of unlined ditches, flumes, and unlined ponds developed during the mid-1940s that were used for industrial process wastewater and other aqueous byproducts from the BMI Complex manufacturing facilities. The Upper BMI Ponds began operating in approximately 1943 through the mid-1970s. Contaminants in wastewater generated within OU-1 migrated to the Eastside Sub-Area via the Beta Ditch.

The COPCs investigated by NERT in the Eastside Sub-Area are administratively limited to perchlorate and chlorate in soil deeper than 10 feet and in groundwater. BRC, under NDEP oversight, is responsible for the remediation of other constituents within the Eastside Sub-Area. BRC has obtained NFA determinations for the upper 10 feet of the soil horizon throughout most of the Eastside Sub-Area. The major sources of perchlorate and chlorate in the Eastside Sub-Area are residual contamination in vadose zone soils below 10 feet, and residual contamination in shallow groundwater (primarily found in the UMCf, as the alluvium is largely dewatered).

10.5.3 OU-2 Vadose Zone Soil

Within the Eastside Sub-Area, perchlorate and chlorate concentrations in vadose zone soils below 10 feet were investigated during the RI. Perchlorate concentrations above its LSSL of 0.0155 mg/kg and chlorate concentrations above its LSSL of 1.03 mg/kg were found in soil samples from nearly all of the Eastside Sub-Area boring locations. In general, the highest concentrations were found in the western part of the Eastside Sub-Area beneath the area previously occupied by the former ditches and unlined wastewater ponds. The perchlorate results are generally consistent with previous soil sampling conducted by BRC at approximately 740 boring locations. Perchlorate was detected above the LSSL in soil samples below 10 feet in approximately 80% of the borings sampled by BRC. The residual contamination in the deeper vadose zone soil represents a potential continuing source of perchlorate and chlorate to underlying shallow groundwater in the Eastside Sub-Area.

No data gaps for soil in OU-2 east of Pabco Road were identified and no additional investigation is needed, and as such, the investigation of soil within the Eastside Sub-Area is considered complete.

10.5.4 OU-2 Groundwater

OU-2 groundwater has been thoroughly characterized through implementation of the RI. The extent of contamination in groundwater (including perchlorate and chlorate, the most widespread of all COPCs) has been delineated within OU-2. Based on the data previously presented in the RI Report, NERT concludes the following regarding the investigation of OU-2 groundwater:

- The lateral extent of perchlorate and other COPCs in OU-2 groundwater has been defined. Perchlorate and chlorate are the most widespread contaminants in groundwater within OU-2. The distribution of other COPCs in groundwater are related to their presence in groundwater at upgradient sites and subsequent migration into OU-2, as discussed above. The extent of NERT's perchlorate contamination is bounded to the west by the AMPAC plume and delineated to the south/southeast at Lake Mead Parkway where concentrations are below the upgradient concentration adopted by NDEP (NDEP 2016a), and to the east at Galleria Drive (east of the Tuscany Village community) within OU-3 where the concentrations are below the GWSL.
- The vertical extent of perchlorate and other COPCs in OU-2 groundwater has also been defined and does not extend into the Deep WBZ.
- There is a difference between the depth of perchlorate-impacted groundwater in the southern (upgradient) and northern (downgradient) areas of OU-2 west of Pabco Road. Perchlorate is detected above the GWSL to depths of 145 feet in the southern area near the OU-1/OU-2 boundary, whereas the depth of perchlorate above the GWSL decreases to less than 90 feet bgs in the northern area near the OU-2/OU-3 boundary. North of the AWF along the OU-2/OU-3 boundary, perchlorate

concentrations in groundwater above the GWSL are limited to the Shallow WBZ (i.e., above a depth of 90 feet bgs).

- Along most of the Eastside Sub-Area northern boundary, perchlorate concentrations above the GWSL extend to depths of 110 feet bgs at several locations. At the eastern end of the OU-2/OU-3 boundary along Galleria Drive, perchlorate was also detected in groundwater above the GWSL in a deeper sandy silt lens between 157-177 feet bgs.
- Within OU-2 west of Pabco Road, the alluvium remains saturated. In general, the perchlorate concentrations decrease with distance from OU-1 and with depth. Perchlorate in the alluvium is captured by NERT through its operation of the AWF near Galleria Drive at the boundary of OU-2 and OU-3. However, significant mass remains in the saturated UMCf south (upgradient) of the AWF. As a result, slow upward migration due to the combination of an upward hydraulic gradient and matrix diffusion from the UMCf into the alluvium will be a significant factor affecting the long-term persistence of perchlorate (and other COPCs) in OU-2 groundwater.
- Within OU-2 east of Pabco Road, the alluvium has become dewatered across much of the central and eastern portions of the Eastside Sub-Area, and in this part of the Sub-Area, first groundwater now occurs in the UMCf. As noted above, contaminants migrate very slowly though the UMCf, leading to long-term persistence of COPCs in groundwater in the eastern portion of OU-2.
- During the period of operation of the unlined Upper BMI Ponds and the associated unlined ditches (e.g., the former Beta Ditch), COPCs including perchlorate and chlorate migrated into soil and groundwater in the Eastside Sub-Area, and then subsequently migrated north into OU-3 via groundwater. Although much of the alluvium has become dewatered in the Eastside Sub-Area, the alluvium remains saturated in OU-3. The potential for matrix diffusion (i.e., slow upward migration) of the mass stored in the low permeability UMCf into shallow groundwater in OU-3 will be evaluated in the forthcoming RI Report for OU-3. The slow upward migration of the mass stored in the low permeability UMCf within OU-2 will serve as a secondary long-term source of perchlorate and chlorate and cause concentrations of these COPCs in the higher permeability alluvium in OU-3 to remain above regulatory levels for a long period of time.
- NERT's particle tracking evaluation indicates that COPCs originating in OU-1 do not migrate into the Eastside Sub-Area east of Pabco Road via groundwater. This evaluation also determined that COPCs migrating from the Eastside Sub-Area migrate northward into OU-3 and largely discharge into the Las Vegas Wash. The SWF does capture some of the COPCs that migrate from the Eastside Sub-Area into OU-3.

No data gaps were identified for groundwater in OU-2 and, as such, no additional investigation is needed to delineate the extent of contamination in groundwater in OU-2.

10.5.5 OU-2 Soil Gas

As part of the RI, three rounds of soil gas sampling were conducted in OU-2 west of Pabco Road. Due to the administratively limited COPC set, soil gas was not sampled in OU-2 east of Pabco Road. In the commercial/industrial land use areas of OU-2 west of Pabco Road, chloroform was the only VOC detected in soil gas above screening levels. In the residential land use area, chloroform and bromodichloromethane are the only VOCs detected in soil gas above screening levels. Chloroform and bromodichloromethane are trihalomethanes and a by-product of chlorination of municipal water for domestic use. Though bromodichloromethane is a COPC in soil in OU-1 and OU-2 groundwater, its single isolated presence above the SGSL in soil gas is not co-located with the GWSL exceedances in OU-2 groundwater. Since bromodichloromethane is not identified as a COPC on the OSSM or TIMET sites and does not originate from OU-1, its presence in soil gas above the SGSL in this isolated residential location may be related to municipal water distribution and use. In general, chloroform concentrations in soil gas increase with depth indicating that the source of chloroform in soil gas is attributable to chloroform in groundwater rather than a vadose zone source.

Similar to OU-1, three additional VOCs (TCE, carbon tetrachloride, and PCE) were detected in soil gas in OU-2 west of Pabco Road at elevated concentrations but below screening levels. In this area of OU-2, carbon tetrachloride and PCE have been identified as COPCs in groundwater. Carbon tetrachloride is one of the trespassing VOCs from the OSSM site that has and continues to migrate via groundwater into OU-2 through OU-1, and PCE has migrated in groundwater from the TIMET site directly into OU-2. The soil gas concentrations of carbon tetrachloride and TCE are generally lower in OU-2 than in OU-1. However, the PCE concentrations measured in the most recent sampling events in March and November 2019 at RISG-3, located in OU-2 just downgradient of the TIMET site, are higher than any of the locations in OU-1.

For chloroform and other VOCs in groundwater, an evaluation of volatilization from shallow groundwater into soil gas and any resultant potential vapor intrusion risk is presented in the BHRA Report for OU-2 Soil Gas and Groundwater, Revision 1 (Ramboll 2023c).

10.6 Conclusions

Based on the data presented throughout this RI Report for OU-1 and OU-2, NERT has reached the following conclusions:

- The alluvium has become largely dewatered throughout OU-1, and first groundwater now occurs in the low permeability UMCf. Only a few sandy units were found in the UMCf, predominantly in the southern part of the NERT RI Study Area. However, these preferential pathways are limited in lateral extent, and due to its low permeability, contaminants migrate very slowly through the UMCf.
- Within the NERT Off-Site Study Area component of OU-2 west of Pabco Road, the alluvium remains saturated. In general, COPC concentrations decrease with distance from OU-1 and with depth. COPCs in the alluvium are captured by the AWF near Galleria Drive at the boundary of OU-2 and OU-3.
- Within the Eastside Sub-Area component of OU-2 east of Pabco Road, the alluvium has become dewatered across much of the central and eastern portions of the Sub-Area, and in this part of the Sub-Area, first groundwater now occurs in the UMCf. As noted above, contaminants migrate very slowly though the UMCf, leading to long-term persistence of COPCs in groundwater in the eastern portion of OU-2.

- The NERT GWETS, largely constructed in 2002 with the installation of the SWF, prevents any migration of COPCs from OU-1 to the Las Vegas Wash west of Pabco Road. As discussed in Section 9 of this report, the GWETS captures all of the COPCs within OU-1 and any contamination migrating via groundwater from OU-1 into OU-2. Conversely, there are no groundwater extraction or other mitigation measures in place between the Eastside Sub-Area within OU-2 and the Las Vegas Wash. This uncontrolled migration represents the bulk of the perchlorate flux into the Las Vegas Wash. The forthcoming RI Report for OU-3 will extensively discuss the migration of perchlorate and other COPCs from OU-2 into OU-3 and their discharge to the Las Vegas Wash.
- The majority of the COPCs identified in OU-1 soil above LSSLs do not impact OU-1 groundwater at levels above GWSLs. The primary off-site migration pathway from OU-1 to OU-2 west of Pabco Road (NERT Off-Site Study Area) is via groundwater. Groundwater COPCs in this area of OU-2 are more limited than in OU-1.
- Based on their widespread distribution in groundwater, perchlorate, chlorate, hexavalent chromium, and chloroform have been defined as Primary COPCs within OU-1 and OU-2. The lateral extent of the Primary COPCs in OU-1 and OU-2 groundwater has been defined:
    - Perchlorate is the most widespread contaminant in groundwater within the NERT RI Study Area and the distributions of other NERT COPCs in groundwater which are attributed to OU-1 generally occur within the footprint of the perchlorate plume. Perchlorate has migrated from OU-1 to the Las Vegas Wash, which flows into Lake Mead and then to the Colorado River. The western, southern, and eastern boundaries of the perchlorate plume have been delineated.
    - The distribution of chlorate in groundwater is generally similar to perchlorate, and chlorate also extends from OU-1 to the Las Vegas Wash. The western, southern, and eastern boundaries of the chlorate plume have been delineated.
    - Although hexavalent chromium has also impacted groundwater within the NERT RI Study Area, the extent of its impact has been limited (relative to perchlorate and chlorate), partly through the construction and operation of the GWETS and natural attenuation mechanisms. Consequently, hexavalent chromium impacts in Site groundwater have not extended to the Las Vegas Wash and Lake Mead. The extent of hexavalent chromium in groundwater has been delineated within the NERT RI Study Area.
    - Chloroform and other VOCs have impacted groundwater in OU-1 and OU-2, but the plumes do not extend to the Las Vegas Wash. The extent of chloroform and Other VOCs in groundwater has been delineated within the NERT RI Study Area.
- The vertical extent of the Primary COPCs in OU-1 and OU-2 has been defined:
    - In OU-1, the Unit 4 and 5 Buildings were confirmed to be a major source of perchlorate, chlorate, hexavalent chromium, chloroform, and other chemicals released within the NERT Site Study Area. Historically, higher groundwater levels due to wastewater infiltration and density-driven flow likely contributed

  to the downward migration of the highest concentrations of the Primary COPCs to depths of 90-120 feet bgs. Perchlorate in groundwater above the GWSL extends to a depth of approximately 150 feet bgs beneath the Unit 4 Building.

  - In contrast, in the northern part of OU-1 between the former Beta Ditch and the IWF/barrier wall, the highest concentrations of Primary COPCs are in shallow groundwater above a depth of 90 feet bgs. In this area, separate sources related to other operational areas, such as the AP Plant area and associated ponds, the former P and S Ponds, and the area around the IWF and the former recharge trenches, released perchlorate to soil and shallow groundwater.
  - In OU-2, the vertical extent of Primary COPCs ranges from a maximum depth of 145 ft bgs in the southern area near the OU-1/OU-2 boundary to less than 90 ft bgs in the area north of the AWF near the OU-2/OU-3 boundary.

- Significant mass remains in the saturated UMCf south (upgradient) of the AWF. As a result, slow upward migration due to the combination of an upward hydraulic gradient and matrix diffusion from the UMCf into the alluvium will be a significant factor affecting the long-term persistence of perchlorate (and other COPCs) in OU-2 groundwater. Matrix diffusion from the UMCf, as a current and future source of mass flux of COPCs to the alluvium, is a critical component of the CSM that will be evaluated during the FS.
- COPCs trespassing into or migrating to OU-1 and OU-2 for which NERT is not responsible have been defined:
  - <u>Trespassing OSSM Plume migrating across OU-1 and into OU-2</u>. As described earlier, a groundwater VOC plume and DNAPL trespass into OU-1. The groundwater plume largely migrates northeastward between OSSM's groundwater extraction system and NERT's GWETS and migrates into OU-2 in an uncontrolled manner. DNAPL in OU-1 originating from the OSSM site will serve as a long-term source of groundwater contamination in OU-1.
  - <u>Historical conveyances/ditches from OSSM</u>. Historical wastewater discharges by OSSM to ditches and conveyances have resulted in contamination within OU-1.
  - <u>TIMET Plume migrating directly into OU-2</u>. Prior to the installation of TIMET's slurry wall and groundwater extraction system, chloroform and PCE in groundwater at the TIMET site migrated northward into OU-2. Given that the OSSM and NERT groundwater extraction and treatment systems were constructed much earlier than TIMET's, chloroform has migrated from the TIMET site in an uncontrolled manner for approximately 30 years longer than from the OSSM and NERT sites. While COPCs from the Unit 4 and 5 Buildings source area are migrating into the TIMET site at the 90 to 130 foot depth interval from OU-1, the concentration of chloroform in this deep plume are up to two orders of magnitude less than found in shallow groundwater on the TIMET site. This indicates that there are additional chloroform sources on the TIMET site that are directly impacting groundwater quality in the Shallow WBZ.

    - AMPAC Plume migrating into OU-2. The separate perchlorate plume associated with the former AMPAC site located approximately 1.5 miles west of OU-1 has commingled with the NERT perchlorate plume near the AWF in OU-2.

10.7 Next Steps

Based on the RI results for OU-1 and OU-2, the nature and extent of contamination associated with both OUs has been defined and no data gaps or additional investigation are required to complete the RI. Characterization of subsurface conditions and the nature and extent of COPCs is sufficient to support evaluations of human health and ecological risk, as well as remedial technologies and remedial alternatives to be developed as part of a FS for OU-1 and OU-2. In addition, sufficient knowledge has been gained regarding non-NERT sources of contamination that have impacted groundwater quality in OU-1 and OU-2; thus, the NERT FS will be limited to what is NERT's responsibility to the extent technically feasible.

While this RI Report presented limited information with respect to OU-3, the conditions in OU-3 will be further evaluated in greater detail in the forthcoming RI Report for OU-3. In addition to presenting the nature and extent of contamination within OU-3, the RI Report for OU-3 will present an updated NERT CSM, building upon what was presented herein, including an evaluation of contaminant migration through OU-3, COPC discharge to the Las Vegas Wash, and COPC mass estimates based on additional data collected during the OU-3 investigation. Concurrent with preparation of this RI Report, NERT has advanced its efforts related to human health and ecological risk assessments, and has continued its development of a groundwater flow and transport model and associated hydrostratigraphic characterization covering all three OUs.

The various risk assessments associated with OU-1 and OU-2 were submitted in 2021 subsequent to Revision 0 of this RI Report (except for the BHRA for OU-1 Soils). The BHRA for OU-1 Soils, Revision 2 was submitted to NDEP on May 6, 2022 (Ramboll 2022b) and approved on June 2, 2022. NDEP provided comments on Revision 0 of the various risk assessments for OU-1 and OU-2 in 2022. Revisions to these risk assessments associated with OU-1 and OU-2 were submitted in 2023 as follows: The Refined SLERA Report for OU-1, Revision 1 was submitted to NDEP on April 20, 2023; the Refined SLERA Report for OU-1, Revision 2 was submitted to NDEP on December 18, 2023 (Ramboll 2023e) and approved by NDEP on February 1, 2024; the Refined SLERA Report for OU-2, Revision 1 was submitted to NDEP on May 18, 2023; the Refined SLERA Report for OU-2, Revision 2 was submitted to NDEP on December 20, 2023 (Ramboll 2023f) and approved by NDEP on February 1, 2024; the Soil Gas and Groundwater BHRA Report for OU-2, Revision 1 was submitted on September 15, 2023 (Ramboll 2023c) and approved by NDEP on November 27, 2023; and the Soil Gas and Groundwater BHRA Report for OU-1, Revision 1 was submitted on November 3, 2023 (Ramboll 2023d) and approved by NDEP on January 2, 2024.

NERT will utilize the information from the RIs, the risk assessments, the groundwater flow and transport model, and the pilot and treatability studies to conduct the Feasibility Studies for all three OUs, which will provide the basis for selecting the final remedy for the entirety of the NERT RI Study Area. Specifically, the forthcoming FS Report for OU-1 and OU-2 and subsequent FS Report for OU-3 will evaluate the applicable remedial technologies and assemble a number of remedial action alternatives designed to meet the approved RAOs for the NERT RI Study Area. Following approval of the Feasibility Studies, plans will be prepared summarizing the proposed remedial action alternatives, which will be made available for public comment. After the close of the public comment periods, NDEP will review and respond to public comments, and RODs will be issued identifying the selected remedial action alternatives representing the final remedy.

11. REFERENCES

AECOM (AECOM Inc.). 2008. Revised Phase B Site Investigation Work Plan for Areas I, II, III and IV; Tronox, LLC Facility; Henderson, Nevada. December 18. Approved by NDEP on January 16, 2009.

AECOM. 2014. Revised DNAPL Investigation Summary Report, Montrose Chemical Corporation of California, Environmental Conditions Investigation; Henderson, Nevada. May 15.

AECOM. 2015. Work Plan (#2015-140) for Initial Sampling of Groundwater - NERT Remedial Investigation, Downgradient Study Area; Henderson, Nevada. December 30. Approved by NDEP on January 8, 2016. Amendment 1 issued March 25, 2016.

AECOM. 2016a. Groundwater Sampling Plan, NERT Remedial Investigation - Downgradient Study Area; Nevada Environmental Response Trust Site; Henderson, Nevada. February 29.

AECOM. 2016b. Surface Water Sampling Plan, NERT Remedial Investigation - Downgradient Study Area; Nevada Environmental Response Trust Site; Henderson, Nevada. April 4.

AECOM/Northgate (AECOM Inc. and Northgate Environmental Management, Inc.). 2009. Revised Phase B Quality Assurance Project Plan, Revision 2; Tronox, LLC Facility; Henderson, Nevada. July 23. Approved by NDEP on January 16, 2009.

AMPAC (American Pacific Corporation). 2007. Report on the One Year Performance and Operations Optimization Program of the Endeavour In Situ Bioremediation (ISB) System for Perchlorate in Groundwater at the Athens Rd/Galleria Dr Area in Henderson, Nevada. August 23.

AMPAC. 2012. Closeout Summary of the Perchlorate In Situ Bioremediation System; American Pacific Corporation; Henderson, Nevada. August 20.

Bell, J.W. and E.I. Smith. 1980. Geologic Map of the Henderson Quadrangle, Nevada. Nevada Bureau of Mines and Geology, Map 67.

Basic Magnesium (Basic Magnesium Inc.). 1944. As-Built Drawings for Water Effluent and Service: Substructures Metals Plant No. 1 Composite Plan (No. R-485), Substructures East Half of Chlorine Plant Composite Plan (No. R-495), and Area Around Permanent Laboratory Composite Plan (No. R-511).

Behroozmand, Ahmad A., Rosemary Knight, Mike Müller-Petke, Esben Auken, Adrian A. S. Barfod, Ty P. A. Ferré, Troels N. Vilhelmsen, Carole D. Johnson, and Anders V. Christiansen. 2017. "Successful Sampling Strategy Advances Laboratory Studies of NMR Logging in Unconsolidated Aquifers." Geophysical Research Letters 44 (21): 11,021-11,029. https://doi.org/10.1002/2017GL074999.

Boggs, S. 2001. Principles of Sedimentology and Stratigraphy, 3rd ed. Prentice Hall, Upper Saddle River, New Jersey.

BRC (Basic Remediation Company). 2007. BRC Closure Plan, Revision 1; BMI Common Areas; Clark County, Nevada. May. Approved by NDEP on July 16, 2007.

BRC. 2014. Human Health Risk Assessment and Closure Report for the Eastside Main Sub-Area, BMI Common Areas (Eastside); Clark County, Nevada. June. Approved by NDEP on July 22, 2015.

BRC. 2017. 2016 CAMU Long-Term Groundwater Monitoring Report; BRC Corrective Action Management Unit (CAMU) Area; Clark County, Nevada. January.

BRC. 2022. Sampling and Analysis Plan (SAP) for Groundwater, BMI Common Areas (Eastside with Western Hook and Open Space parcels), Clark County, Nevada. November 16.

BRC. 2023. Quarterly Progress Report. April 15.

Broadbent (Broadbent & Associates, Inc.). 1998. Hydrogeologic Investigation of Perchlorate in Ground Water at the Former PEPCON Plant; Henderson, Nevada. May.

Broadbent. 2021. Chloroform Report, Black Mountain Industrial Complex, Henderson, Nevada. December 23.

CalEPA (California Environmental Protection Agency). 2015. Public Health Goal for Perchlorate in Drinking Water. February.

CCDCP (Clark County Department of Comprehensive Planning). 2000. Clark County Multiple Species Habitat Conservation Plan and Environmental Impact Statement for Issuance of a Permit to Allow Incidental Take of 79 Species in Clark County, Nevada; Appendix A: Ecosystem Analyses. September.

CCDCP. 2003. Species Account Manual. November. https://www.clarkcountynv.gov/airquality/dcp/Documents/Library/dcp%20reports/2003/20031100_MSHCPSpeciesAcctManual.pdf

Chemstar (Chemstar Lime Company). 1993. Phase I Environmental Conditions Assessment Report; Henderson, Nevada, Facility. April 15.

City of Henderson (COH). 2020. 2020 Water Quality Report. https://www.cityofhenderson.com/docs/default-source/utility-services-docs/water-quality/2020-water-quality-report.pdf?sfvrsn=2

Coates, G. R., Xiao, L., & Prammer, M. G. (1999). NMR logging: Principles and applications. Houston: Haliburton Energy Services.

Collinson, J.D. 1969. The sedimentology of the Grindslow shales and the Kinderscout grit: a deltaic complex in the Namurian of northern England. *Journal of Sedimentary Petrology* 39: 194–221.

Converse (Converse Environmental Consultants Southwest, Inc.). 1993. Phase I Environmental Conditions Assessment for Former Montrose Chemical Corporation Facility; Henderson, Nevada. April.

Daniel B. Stephens & Associates, Inc (DBS&A). 2019. Shallow Groundwater Conceptual Site Model and Remedial Alternatives Study (CSM/RAS) Report; BMI Common Area (Eastside); Clark County, Nevada. Prepared for Basic Remediation Company (BRC). August 2. Approved by NDEP on January 20, 2021.

DBS&A. 2020. Shallow Groundwater Conceptual Site Model Report; Western Hook Area; BMI Eastside Common Areas; Henderson, Nevada. Prepared for Basic Remediation Company (BRC). December 4.

DBS&A. 2023. Shallow Groundwater Conceptual Site Model Report [Revision 1]; Western Hook Area; BMI Eastside Common Areas; Henderson, Nevada. Prepared for Basic Remediation Company (BRC). May 30.

de maximis (de maximis, inc.). 2019. Quarterly Progress Report – First Quarter 2019, Environmental Conditions Investigation Program; Former Montrose Facility, ID# H-000540; Henderson, Nevada. April 17.

de maximis. 2022a. Semi-Annual Operations Report; Groundwater Treatment System; Henderson, Nevada; July – December 2021. March 31.

de maximis. 2022b. Quarterly DNAPL Data Report – Third Quarter 2022; Montrose Site, Henderson, Nevada. December 6.

Endeavour (Endeavour LLC). 2018. BISC Semi-Annual/Annual Monitoring and Performance Report, Revision 1; January 1 to June 30, 2018, Perchlorate Bioremediation Systems; Endeavour LLC; Henderson, Nevada. September 14. Approved by NDEP on September 17, 2018.

ENSR (ENSR International). 1997. Kerr-McGee Chemical Corporation, Phase II Environmental Conditions Assessment Located at Kerr-McGee Chemical Corporation; Henderson, Nevada. August. Approved by NDEP on June 10, 1998.

ENSR. 2001. Supplemental Phase II Environmental Conditions Assessment. April 1.

ENSR. 2005. Conceptual Site Model; Kerr-McGee Facility; Henderson, Nevada. February.

ENSR. 2006. Phase A Source Area Investigation Work Plan; Tronox LLC Facility; Henderson, Nevada. September. Conditionally approved by NDEP on October 26, 2006.

ENSR. 2007a. Addendum to the Phase A Source Area Investigation Work Plan; Tronox, LLC Facility; Henderson, Nevada. May. Approved by NDEP on May 7, 2007.

ENSR. 2007b. Phase A Source Area Investigation Results Report; Tronox, LLC Facility; Henderson, Nevada. September. Approved by NDEP on November 30, 2007.

ENSR. 2007c. Upgradient Investigation Results; Tronox, LLC Facility; Henderson, Nevada. September.

ENSR. 2008a. Phase B Source Area Investigation, Soil Gas Survey Work Plan; Tronox, LLC Facility; Henderson, Nevada. March. Approved by NDEP on March 26, 2008.

ENSR. 2008b. Phase B Source Area Investigation Work Plan, Area I (Northern LOUs); Tronox LLC Facility; Henderson, Nevada. April. Conditionally approved by NDEP on May 6, 2008.

ENSR. 2008c. Phase B Source Area Investigation Work Plan, Area II (Central LOUs); Tronox LLC Facility; Henderson, Nevada. May. Conditionally approved by NDEP on July 21, 2008.

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

ENSR. 2008e. Phase B Source Area Investigation Work Plan, Area III (Eastern LOUs); Tronox LLC Facility; Henderson, Nevada. June. Conditionally approved by NDEP on July 21, 2008.

ENSR. 2008f. Annual Remedial Performance Report for Chromium and Perchlorate, July 2007 through June 2008; Tronox, LLC Facility; Henderson, Nevada. August 25.

ENSR. 2008g. Revised Data Validation Summary Report Phase B Source Area Investigation Soil Gas Survey; Tronox, LLC Facility; Henderson, Nevada. October. Approved by NDEP on October 20, 2008.

ENSR/AECOM (ENSR International and AECOM Inc.). 2007. Semi-Annual Performance Report Chromium and Perchlorate, July - December 2006; Tronox, LLC Facility; Henderson, Nevada. February 26.

ENSR/AECOM. 2008. Summary of Available Data for LOU; Various Packets Spanning LOU 1 to LOU 66.

Envirogen (Envirogen Technologies Inc.). 2016. 100% Design Drawings for IX Treatment System; Nevada Environmental Response Trust; Henderson, Nevada. August 19. Approved by NDEP on August 30, 2016.

ENVIRON (ENVIRON International Corporation). 2011. Phase I Environmental Site Assessment of Tronox LLC; Clark County, Nevada. January.

ENVIRON. 2012a. Interim Soil Removal Action Completion Report, August 2010 - November 2011; Nevada Environmental Response Trust; Henderson, Nevada. September 28. Approved by NDEP on December 17, 2012.

ENVIRON. 2012b. Remedial Investigation Feasibility Study Work Plan; Nevada Environmental Response Trust Site; Henderson, Nevada. December 17. NDEP commented June 27, 2013. Second revision submitted June 19, 2014.

ENVIRON. 2014a. Semi-Annual Remedial Performance Report for Chromium and Perchlorate, July - December 2013; Nevada Environmental Response Trust Site; Henderson, Nevada. February 28.

ENVIRON. 2014b. Excavation of Beta Ditch at NERT-TIMET Property Line; Nevada Environmental Response Trust Site; Henderson, Nevada. March 31.

ENVIRON. 2014c. Remedial Investigation and Feasibility Study Work Plan, Revision 2; Nevada Environmental Response Trust Site; Henderson, Nevada. June 19. Approved by NDEP on July 2, 2014.

ENVIRON. 2014d. Field Sampling Plan, Revision 1; Nevada Environmental Response Trust Site; Henderson, Nevada. July 18. Approved by NDEP on August 1, 2014.

ENVIRON. 2014e. Quality Assurance Project Plan, Revision 1; Nevada Environmental Response Trust Site; Henderson, Nevada. July 18. Approved by NDEP on August 1, 2014.

ENVIRON. 2014f. Annual Remedial Performance Report for Chromium and Perchlorate, July 2013 - June 2014; Nevada Environmental Response Trust Site; Henderson, Nevada. October 31. Approved by NDEP on December 26, 2014.

ENVIRON. 2015. 2013 GWETS Optimization Project Report; Nevada Environmental Response Trust Site; Henderson, Nevada. April 30. (As provided as Attachment A to ENVIRON. 2015. Semi-Annual Remedial Performance Report for Chromium and Perchlorate, July - December 2014; Nevada Environmental Response Trust Site; Henderson, Nevada. April 30. Approved by NDEP on May 20, 2015).

ERM (ERM-West Inc.). 1996. Draft Environmental Conditions Investigation Report; BMI Common Areas; Henderson, Nevada. August.

ERM. 1997. Environmental Characterization Report, BMI Exclusion Areas 3, 4A, 4B, 5/6; Henderson, Nevada. April. Approved by NDEP on September 30, 1997.

Faulds, J.E., C. Schreiber, V. Langenheim, N.H. Hinz, T. Shaw, M.T. Heizler, M.E. Perkins, M. El Tabakh, and M.J. Kunk. 2016. Paleogeographic implications of late Miocene Lacustrine and nonmarine evaporite deposits in the Lake Mead region: immediate precursors to the Colorado River. *Geosphere* 12: 721–767. March 24. https://doi.org/10.1130/GES01143.1.

GEI (GEI Consultants Inc.). 2013. Removal Action Completion Report; BMI Beta Ditch/Northwestern Ditches Located on the Titanium Metals Corporation Plant Site; BMI Common Areas, Clark County, Nevada. November 22. Approved by NDEP on June 5, 2014.

GEI. 2015. Conceptual Site Model; Titanium Metals Corporation; Henderson, Nevada Facility; NDEP Facility ID # 000537. September 30.

GEI. 2019a. 2018 Annual Groundwater Monitoring Report; Titanium Metals Corporation; Henderson, Nevada. May 3. Approved by NDEP on November 18, 2019.

GEI. 2019b. Groundwater Extraction and Treatment System Operations, Maintenance & Performance Report – 1st Quarter 2019; Titanium Metals Corporation; Henderson, Nevada. May.

GEI. 2020a. 2019 Annual Groundwater Monitoring Report; Titanium Metals Corporation, Henderson, Nevada. April 30. Approved by NDEP on September 15, 2020.

GEI. 2020b. Groundwater Extraction and Treatment System Operations, Maintenance & Performance Report; Quarterly Report – 2nd Quarter 2020; Titanium Metals Corporation; Henderson, NV. August.

GEI. 2022a. Quarterly Status Report for the Third Quarter of 2022 (Q3-22); Titanium Metals Corporation; Henderson, NV Facility, Facility ID #H000537. October 15.

GEI. 2022b. 2021 Annual Groundwater Monitoring Report; Titanium Metals Corporation, Henderson, Nevada. December 22. Under NDEP review.

Geosyntec (Geosyntec Consultants). 2008. Phase I Construction Quality Assurance Report; Basic Remediation Company; Corrective Action Management Unit; Henderson, Nevada. September.

Geosyntec. 2010. CAMU Partial Final Closure Construction Quality Assurance Report, Phase IIIA & Portion of Phase II, Basic Remediation Company; Corrective Action Management Unit; Henderson, Nevada. April.

Geosyntec. 2015. CAMU Final Closure Construction Quality Assurance Report, Phase V; Basic Remediation Company; Corrective Action Management Unit; Henderson, Nevada. April.

Geosyntec. 2017. Memorandum: Shallow Zone Capture Assessment – Revision 1; Endeavour, Henderson, NV. March 23.

Geosyntec. 2019. Groundwater Remedial Alternatives Study; Former Stauffer and Montrose Facilities; Henderson, Nevada. June.

Geraghty & Miller (Geraghty & Miller Inc.). 1993. Phase I Environmental Conditions Assessment for The Basic Management, Inc. Industrial Complex; Clark County, Nevada. April 14.

Gibb, James P., Michael J. Barcelona, Joseph D. Ritchey, and Mary H. LeFaivre. 1984. Effective Porosity of Geologic Materials First Annual Report; Illinois State Water Survey Contract Report 351. September.

Hargis (Hargis + Associates, Inc.). 2008. Conceptual Site Model – Former Montrose and Stauffer Facilities and Downgradient Areas to Las Vegas Wash, Henderson, Nevada. July 25.

Hargis. 2013. 2013 Comprehensive Groundwater Data Evaluation Report, Former Montrose and Stauffer Facilities and Current Olin Facility, Henderson, Nevada. October 18.

Hargis. 2020. Demonstration of the Fate and Transport of Trespass Site Related Chemicals, Former Montrose and Stauffer Facilities and Current Olin Facility, Henderson, Nevada. May 8.

Keating, Kristina, and Samuel Falzone. 2013. “Relating Nuclear Magnetic Resonance Relaxation Time Distributions to Void-Size Distributions for Unconsolidated Sand Packs.” Geophysics 78 (6): D461–72. https://doi.org/10.1190/geo2012-0461.1.

Keating, Kristina, David O. Walsh, and Elliot Grunewald. 2020. “The Effect of Magnetic Susceptibility and Magnetic Field Strength on Porosity Estimates Determined from Low-Field Nuclear Magnetic Resonance.” Journal of Applied Geophysics 179 (August): 104096. https://doi.org/10.1016/j.jappgeo.2020.104096.

Kerr-McGee (Kerr-McGee Chemical Corporation). 1984. Groundwater Monitoring, KMCC; Henderson, Nevada Facility. February 1.

Kerr-McGee. 1985. Geohydrological Investigation; Kerr-McGee Chemical Corporation; Henderson Facility. July.

Kerr-McGee. 1987. Chromium Mitigation Program Performance Report; Kerr-McGee Chemical Corporation; Henderson, Nevada. November 18.

Kerr-McGee. 1996a. Phase II Work Plan. October. Approved by NDEP on February 4, 1997.

Kerr-McGee. 1996b. KMCC Phase II Written Response to Letter of Understanding. October 2.

Kerr-McGee. 1998. Phase II Groundwater Perchlorate Investigation Report. July 15.

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

Kerr-McGee. 2003. Quarterly Performance Report, Perchlorate Recovery System, January - March 2003; Kerr-McGee Chemical LLC; Henderson, Nevada. April 28.

Kleinfelder (Kleinfelder Inc,). 1993. Environmental Conditions Assessment; Kerr-McGee Chemical Corporation; Henderson, Nevada. April.

Landsberg, Arne et al. 1985. Formation of Chlorinated Carbon Products during Carbochlorination Reactions. Metalurgical Transactions B. Volume 16B. December. pp. 847-849.

LandWell (The LandWell Company). 2019. Cadence Development Media Kit. https://cadencenv.com/wp-content/uploads/2017/02/2016-Media-Kit.pdf. Accessed August 14, 2019.

Laubusch, Edmund J. 1959. Standards of Purity for Liquid Chlorine. Journal of the American Water Works Association. pp. 742-748.

Law Engineering (Law Engineering Inc.). 1993. Final Report of Phase 1 Environmental Conditions Assessment; Titanium Metals Corporation (TIMET); Henderson, Nevada. April 15.

Middleton, G.V. 1978. Facies. In Fairbridge, R.W. and J. Bourgeois (eds.), Encyclopedia of Sedimentology. Dowden, Hutchinson and Ross, Stroudsburg, Pennsylvania, pp. 323–325.

NDEP (Nevada Division of Environmental Protection). 1983. Consent Order between NDEP, Stauffer, and Montrose. April 4th.

NDEP. 1986. Consent Order between NDEP and Kerr-McGee. September 9.

NDEP. 1989. Visual Site Inspection and Familiarization of Kerr-McGee, Montrose, and Stauffer Facilities at Henderson, Nevada. October 20.

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

NDEP. 1994a. Phase II Letter of Understanding between NDEP and the Henderson Industrial Site Steering Committee (HISSC). August 15.

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

NDEP. 1996a. Consent Agreement, Montrose Chemical Corporation of California Phase II Environmental Conditions Investigation. June 28.

NDEP. 1996b. Consent Agreement, Pioneer Chlor Alkali Company, Inc. and Stauffer Management Company Phase II Environmental Conditions Investigation. June 28.

NDEP. 1996c. Consent Agreement, Titanium Metals Corporation Phase II Environmental Conditions Investigation. June 28.

NDEP. 1996d. Consent Agreement, Kerr-McGee Phase II Environmental Conditions Investigation. August 1.

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

NDEP. 1999b. Memorandum: BMI Center, Gates 8 & 9 (Exclusion Areas 5 & 6). August 9.

NDEP. 1999c. Memorandum: No Further Action Determination for Parcel 9 North. September 27.

NDEP. 1999d. The BMI et al. Liability Transfer and Assumption Agreement. December 30.

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

NDEP. 2001b. Remediation of Soils and Sediments in the Upper and Lower Ponds at the BMI Complex; Henderson, Nevada. November 2.

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. 2006. Settlement Agreement and Administrative Order on Consent: BMI Common Areas, Phase 3 (AOC3). February.

NDEP. 2007. Phase A Report and Phase B Work Plan Meeting Minutes, Tronox. July 18.

NDEP. 2008a. NDEP Response to: Phase B Source Area Investigation - Soil Gas Survey Work Plan; Tronox, LLC; Henderson, Nevada. March 26.

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

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

NDEP. 2009b. Letter to Tronox, LLC Re: Enforcement Action for Failure to Complete Approved Site Remediation Activities, and Show Cause Meeting; Tronox, LLC (Tronox); NDEP Facility ID No. 8-000539; Henderson, Nevada. December 14.

NDEP. 2010. Letter to Tronox, LLC Re: Response to: Errata to: Removal Action Work Plan for Phase B Soil Remediation of Remediation Zones RZ-B through RZ-E; Dated: August 13, 2010. August 20.

NDEP. 2011a. Interim Consent Agreement, Nevada Environmental Response Trust. February 14.

NDEP. 2011b. No Further Action Determination – Mohawk Sub-Area, BMI Common Areas (Eastside Site), Clark County, Nevada, Portions of APN Nos. 179-05-501-002, 179-05-301-004 and 179-05-502-001, NDEP Facility ID: H-000688. March 8.

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

NDEP. 2012. Memorandum: Enforcement Action Requiring Site Remediation Activities and Show Cause Meeting; Titanium Metals Corporation (TIMET); Henderson, Nevada. December 12.

NDEP. 2013a. No Further Action Determination – Galleria North of ROW Sub-Area, BMI Common Areas (Eastside Site), Clark County, Nevada, APNs 179-05-301-005, and 179-06-301-004, NDEP Facility ID: H-000688. March 11.

NDEP. 2013b. No Further Action Determination – Phase I Development Sub-Area, BMI Common Areas (Eastside Site), Clark County, Nevada, Portions of APNs 179-05-301-004, 179-05-401-001, 179-06-301-004, and 179-07-501-009, NDEP Facility ID: H-000688. March 27.

NDEP. 2013c. No Further Action Determination – Galleria Drive Right of Way, BMI Common Areas (Eastside Site), Clark County, Nevada, Portions of APNs 179-05-301-004, 179-05-301-004, 179-05-401-001, 179-06-301-004, and 179-07-501-009, NDEP Facility ID: H-000688. July 31.

NDEP. 2013d. No Further Action Determination – Southern RIBS Sub-Area, BMI Common Areas (Eastside Site), Clark County, Nevada, Portions of APNs 160-31-401-003, 160-31-801-003, 160-31-801-002, 179-05-301-004, NDEP Facility ID: H-000688. December 9.

NDEP. 2015a. Letter to NERT Re: Requirements for Continued Optimization of GWETS System. January 7.

NDEP. 2015b. No Further Action Determination – Eastside Main Sub-Area. BMI Common Areas (Eastside Site), Clark County, Nevada, APNs 179-06-501-003, 179-06-301-004, 179-07-501-012, 160-31-401-005, NDEP Facility ID: H-000688. January 22.

NDEP. 2015c. No Further Action Determination – Western Hook-Open Space Sub-Area, BMI Common Areas (Eastside Site), Clark County, Nevada, APNs 160-31-401-003, 160-31-101-002, 161-31-101-003, 161-36-101-002, NDEP Facility ID: H-000688. June 17.

NDEP. 2015d. No Further Action Determination – APN 178-11-501-007, BMI Common Areas, Clark County, Nevada, APN 178-11-501-007, NDEP Facility ID: H-000688. July 22.

NDEP. 2015e. No Further Action Determination – Western Hook-Development Sub-Area, BMI Common Areas (Eastside Site), Clark County, Nevada, APNs 161-36-201-005, 161-36-101-002, 161-36-301-001, 161-36-301-003, NDEP Facility ID: H-000688. September 28.

NDEP. 2015f. No Further Action Determination – Parcel 9 South Commercial Sub-Area, BMI Common Areas (Eastside Site), Clark County, Nevada, APN 178-12-601-010, NDEP Facility ID: H-000688. September 29.

NDEP. 2015g. No Further Action Determination – Triangle Commercial Sub-Area, BMI Common Areas (Eastside Site), Clark County, Nevada, APNs 179-07-201-006, 179-07-101-005, 179-07-299-002, 179-07-199-001, Portions of APNs 179-06-501-003, 179-07-201-008, NDEP Facility ID: H-000688. September 29.

NDEP. 2015h. Letter RE: NDEP Facility ID# H0005337 (TIMET); Nevada Division of Environmental Protection Response To: Conceptual Site Model; Dated and Received: September 30, 2015. December 9.

NDEP. 2015i. Letter Re: Nevada Division of Environmental Protection (NDEP) Response to: Annual Remedial Performance Report for Chromium and Perchlorate; Nevada Environmental Response Trust Site; Henderson, Nevada; Dated: October 30, 2015. December 30.

NDEP. 2016a. Draft Up-Gradient Groundwater Quality Technical Memorandum for TDS, Arsenic and Perchlorate. January 21.

NDEP. 2016b. Letter to NERT Re: Response to: 2016 Groundwater Monitoring Optimization Plan. June 24.

NDEP. 2016c. Nevada Division of Environmental Protection (NDEP) Response to: Technical Memorandum Remedial Investigation Data Evaluation; Dated: May 2, 2016; Tronox LLC (TRX) Facility; Nevada Environmental Response Trust (Trust) Property; NDEP Facility ID: H-000539. July 13.

NDEP. 2016d. Letter Re: Nevada Division of Environmental Protection (NDEP) Response to: Annual Remedial Performance Report for Chromium and Perchlorate; Dated: October 31, 2016. December 6.

NDEP. 2017a. NDEP Response to: Phase 5 Transient Groundwater Flow Model, Response to Comments; Nevada Environmental Response Trust; Henderson, Nevada. June 26.

NDEP. 2017b. Memorandum: CAMU Groundwater Request for Clarification; NDEP Facility ID: H-00068 (BRC). November 8.

NDEP. 2018. Letter Re: NDEP Facility ID #H-000855 (WAPA); Industrial Risk Assessment – Exemption Closure Report, and associated Appendices A, B, C & D; Basic Substation; Transformer Maintenance Area and Yard 1; Henderson, Clark County, Nevada; Dated: February 10, 2017. August 29.

NDEP. 2019. Letter Re: Nevada Division of Environmental Protection (NDEP) Response to: Barrier Wall Integrity Evaluation, Revision 1; Date November 21, 2019. December 23.

NDEP. 2020a. Letter Re: Nevada Division of Environmental Protection (NDEP) Response to: Phase 6 Groundwater Flow and Transport Model; Dated November 27, 2019. July 22.

NDEP. 2020b. Letter Re: NDEP Facility ID: H-000536 (Olin Stauffer Syngenta Site) and H-000540 (Montrose Site) NERT Groundwater Data, January 7.

NDEP. 2021a. Letter Re: Shallow Groundwater Conceptual Site Model and Remedial Alternatives Study Report; BMI Eastside Common Areas, Clark County, Henderson, Nevada, Dated: March 14, 2019; Response to Nevada Division of Environmental Protection Comments Shallow Groundwater Conceptual Site Model and Remedial Alternatives Study; BMI Common Areas, Clark County, Henderson, Nevada, Dated: June 6, 2019. January 20.

NDEP. 2021b. Letter Re: Shallow Groundwater Conceptual Site Model Report, Western Hook Development Area; BMI Eastside Common Areas, Clark County, Henderson, Nevada, Dated: December 4, 2020. March 23.

NDEP. 2021c. Letter Re: Nevada Division of Environmental Protection (NDEP) Response to: Soil Background Dataset Summary Report, Revision 2, Dated: March 24, 2021. April 12.

NDEP. 2022a. Letter Re: Nevada Division of Environmental Protection (NDEP) Response to: *Remedial Investigation Report for OU-1 and OU-2,* Dated: July 9, 2021. February 9.

NDEP. 2022b. Letter Re: Nevada Division of Environmental Protection (NDEP) Response to: *Response to NDEP Comments on the Remedial Investigation Report for OU-1 and OU-2*; Dated: June 9, 2022. August 31.

NDEPa. 2023. User's Guide and Background Technical Document for NDEP Basic Comparison Levels (BCLs) for Human Health for the BMI Complex and Common Areas, Revision 16. June.

NDEP. 2023b. Letter Re: Nevada Division of Environmental Protection (NDEP) Response to: *Remedial Investigation Report for OU-1 and OU-2, Revision 1* and Associated Response to NDEP Comments, Dated: August 15, 2023. December 21.

NDEP. 2024. Letter Re: Nevada Division of Environmental Protection (NDEP) Response to: *Remedial Investigation Report for OU-1 and OU-2, Revision 1* and Associated Response to NDEP Comments, Dated: August 15, 2023. January 11.

NDWR (Nevada Division of Water Resources). 2021. Groundwater Pumpage Inventory for Calendar Year 2021. http://water.nv.gov/PumpageInventoryFiles.aspx.

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

Nevada Environmental Response Trust Agreement. 2011. By and among Tronox Incorporated, Tronox LLC, Tronox Finance Corp., Tronox Holdings, Inc., Tronox Luxembourg S.AR.L., Tronox Pigments (Savannah), Inc., Tronox Worldwide, LLC, Southwestern Refining Company, Inc., Transworld Drilling Company, Triangle Refineries, Inc., Triple S, Inc., Triple S Environmental Management Corporation, Triple S Minerals Resources Corporation, Triple S Refining Corporation, and Cimarron Corporation. As settlors, Le Petomane XXVII, Inc. not individually but solely in its representative capacity as Nevada Trustee, and The United States of America and the State of Nevada as beneficiaries. February 14.

NOAA (National Oceanic and Atmospheric Administration). 2021. Climate Data Online: Las Vegas Weather Station # USW00023169. Data from January 1980 to December 2020. https://www.ncdc.noaa.gov/cdo-web/. Accessed July 13, 2021.

Northgate (Northgate Environmental Management Inc.). 2009a. Memorandum: Scope for Additional Sampling - Phase B Investigation, Area I. November 19. Approved by NDEP on November 24, 2009.

Northgate. 2009b. Memorandum: Scope for Additional Sampling - Phase B Investigation, Area II. December 11. Approved by NDEP on December 11, 2009.

Northgate. 2010a. Revised Data Validation Summary Report, Phase B Investigation Area I Soil; Tronox, LLC; Henderson, Nevada. January 15. Approved by NDEP on January 20, 2010.

Northgate. 2010b. Data Validation Summary Report, Phase B Investigation Area II Soil; Tronox, LLC; Henderson, Nevada. February 12. Approved by NDEP on February 18, 2010.

Northgate. 2010c. Data Validation Summary Report, Phase B Investigation Area III Soil; Tronox, LLC; Henderson, Nevada. February 18. Approved by NDEP on March 17, 2010.

Northgate. 2010d. Data Validation Summary Report, Phase B Investigation Area I, II, III, IV Groundwater; Tronox, LLC; Henderson, Nevada. February 25.

Northgate. 2010e. Revised Data Validation Summary Report, Phase B Investigation Area IV Soil; Tronox, LLC; Henderson, Nevada. March 19. Approved by NDEP on March 29, 2010.

Northgate. 2010f. Interim Groundwater Capture Zone Evaluation and Vertical Delineation Report; Tronox LLC; Henderson, Nevada. March 23. ENVIRON resubmitted the NERT Site groundwater model on February 21, 2013. Approved by NDEP on April 4, 2013.

Northgate. 2010g. Capture Zone Evaluation Work Plan; Tronox, LLC; Henderson, Nevada. May 13. Approved by NDEP on May 24, 2010.

Northgate. 2010h. Removal Action Work Plan for Phase B Soil Remediation of Remediation Zones RZ-B through RZ-E; Tronox, LLC; Henderson, Nevada. May 28. Revised June 22 and Errata submitted August 13. Approved by NDEP on Errata August 20, 2010. NDEP commented November 8, 2010.

Northgate. 2010i. Spring 2010 Indoor Air Quality Sampling and Analysis Report; Tronox, LLC; Henderson, Nevada. September 22. Approved by NDEP on November 1, 2010.

Northgate. 2010j. Site-Wide Soil Gas Human Health Risk Assessment; Tronox, LLC; Henderson, Nevada. November 22.

Northgate. 2010k. Capture Zone Evaluation Report; Tronox LLC; Henderson, Nevada. December 10. ENVIRON resubmitted the NERT Site groundwater model on February 21, 2013. Approved by NDEP on April 4, 2013.

Northgate. 2011. December 2010 Indoor Air Quality Sampling and Analysis Report; Tronox, LLC; Henderson, Nevada. February 3. Approved by NDEP on March 21, 2011.

Northgate. 2013. Manganese Tailings Pile Removal Technical Memorandum; Nevada Environmental Response Trust Site; Henderson, Nevada. April 5. Approved by NDEP on February 21, 2013.

Olin (Olin Corporation). 2019. First Quarter 2019 Quarterly Progress Report, Former Stauffer Chemical Company Facility (“Site”); NDEP Facility ID: H-000536; Pioneer/Stauffer; Henderson, Nevada. April 17.

OSSM Companies. 2021. Letter to the Nevada Environmental Response Trust re: OSSM-NERT October 13, 2020 Meeting and NERT’s Remedial Investigation Report. March 24.

Pavelko, M.T. 2000. Ground-Water and Aquifer-System-Compaction Data from the Lorenzi Site; Las Vegas, Nevada; 1994-99. United States Geological Survey Open File Report 00-362.

Plume, R.W. 1989. Ground-Water Conditions in Las Vegas Valley; Clark County, Nevada; Part 1, Hydrogeologic Framework. United States Geological Survey Water-Supply Paper 2320-A.

Ramboll Environ (Ramboll Environ US Corporation). 2015a. Refined Screening Level Ecological Risk Assessment Work Plan, Revision 2; Nevada Environmental Response Trust Site; Henderson, Nevada. July 6. Approved by NDEP on August 14, 2015.

Ramboll Environ. 2015b. Annual Remedial Performance Memorandum for Chromium and Perchlorate, July 2014 - June 2015; Nevada Environmental Response Trust Site; Henderson, Nevada. October 31. Approved by NDEP on December 30, 2015.

Ramboll Environ. 2016a. 2016 Groundwater Monitoring Optimization Plan; Nevada Environmental Response Trust Site; Henderson, Nevada. April 29. Approved by NDEP on June 24, 2016.

Ramboll Environ. 2016b. Semi-Annual Remedial Performance Memorandum for Chromium and Perchlorate, July - December 2015; Nevada Environmental Response Trust Site; Henderson, Nevada. April 29. Approved by NDEP on June 1, 2016.

Ramboll Environ. 2016c. Technical Memorandum: Remedial Investigation Data Evaluation; Nevada Environmental Response Trust Site; Henderson, Nevada. May 2. Initial NDEP comment letter issued on July 13, 2016. Ramboll Environ provided a response to comments (RTC) letter on August 12, 2016. Approved by NDEP on August 23, 2016.

Ramboll Environ. 2016d. Phase 5 Transient Groundwater Flow Model; Nevada Environmental Response Trust Site; Henderson, Nevada. November 15. Approved by NDEP on June 26, 2017.

Ramboll Environ, 2017a. Health and Safety Plan, Remedial Investigation and General Site Activities, Revision 1; Nevada Environmental Response Trust Site; Henderson, Nevada. February.

Ramboll Environ. 2017b. Phase 2 RI Modification No. 1; Nevada Environmental Response Trust Site; Henderson, Nevada. April 27. Approved by NDEP on May 1, 2017.

Ramboll Environ. 2017c. Phase 2 RI Modification No. 2; Nevada Environmental Response Trust Site; Henderson, Nevada. May 2. Approved by NDEP on May 5, 2017.

Ramboll Environ. 2017d. Phase 2 RI Modification No. 3; Nevada Environmental Response Trust Site; Henderson, Nevada. June 7. Approved by NDEP on June 9, 2017.

Ramboll Environ. 2017e. Phase 2 RI Modification No. 4; Nevada Environmental Response Trust Site; Henderson, Nevada. June 8. Approved by NDEP on June 8, 2017.

Ramboll Environ. 2017f. Phase 2 RI Modification No. 5; Nevada Environmental Response Trust Site; Henderson, Nevada. June 22. Approved by NDEP on June 26, 2017.

Ramboll Environ. 2017g. Phase 2 RI Modification No. 6: Soil Background Concentration Study Work Plan; Nevada Environmental Response Trust Site; Henderson, Nevada. July 17. Approved by NDEP on October 16, 2017.

Ramboll Environ. 2017h. Phase 2 RI Modification No. 8; Nevada Environmental Response Trust Site; Henderson, Nevada. August 24. Approved by NDEP on August 25, 2017.

Ramboll Environ. 2017i. Barrier Wall Integrity Field Evaluation Work Plan; Nevada Environmental Response Trust Site; Henderson, Nevada. September 7. Approved by NDEP on October 3, 2017.

Ramboll Environ. 2017j. Athens Road Well Field Capture Evaluation and Matrix Diffusion Study Work Plan; Nevada Environmental Response Trust Site; Henderson, Nevada. September 22. Approved by NDEP on October 3, 2017.

Ramboll Environ. 2017k. RI Study Area Mass Estimate and Expanded Performance Metrics Technical Approach Technical Memorandum; Nevada Environmental Response Trust Site; Henderson, Nevada. October 5. Approved by NDEP on October 19, 2017.

Ramboll Environ. 2017l. Quality Assurance Project Plan, Revision 2; Nevada Environmental Response Trust Site; Henderson, Nevada. October 26. NDEP approved November 8, 2017.

Ramboll Environ. 2017m. RI/FS Work Plan Addendum: Phase 3 Remedial Investigation, Revision 1; Nevada Environmental Response Trust Site; Henderson, Nevada. October 27. Approved by NDEP on November 8, 2017.

Ramboll Environ. 2017n. Phase 2 RI Modification No. 9; Nevada Environmental Response Trust Site; Henderson, Nevada. November 1. Approved by NDEP on November 3, 2017.

Ramboll Environ. 2017o. Interim Report: Identification of COPCs and Decision Units for OU-1 Soils, Revision 1. November 15. Approved by NDEP on December 27, 2017.

Ramboll Environ. 2017p. Phase 3 RI Modification No. 1: Results of Well Inspections, Additional Proposed Wells, and All Wells Database Update for the Eastside Sub-Area; Nevada Environmental Response Trust Site; Henderson, Nevada. December 8. Approved by NDEP on December 11, 2017.

Ramboll Environ. 2017q. HASP Addendum, Phase 3 RI, Off-Site Investigative Properties; Nevada Environmental Response Trust Site; Henderson, Nevada. December.

Ramboll (Ramboll US Corporation). 2018a. Phase 2 RI Modification No. 10; Nevada Environmental Response Trust Site; Henderson, Nevada. March 1. Approved by NDEP on May 2, 2018.

Ramboll. 2018b. Site Management Plan, Revision 4; Nevada Environmental Response Trust Site; Henderson, Nevada. March 26. Approved by NDEP on March 29, 2018.

Ramboll. 2018c. Phase 3 RI Modification No. 2; Nevada Environmental Response Trust Site; Henderson, Nevada. April 10. Approved by NDEP on April 12, 2018.

Ramboll. 2018d. Phase 2 RI Modification No. 11: Recommended Soil Gas Sampling Locations; Nevada Environmental Response Trust Site; Henderson, Nevada. May 23. Approved by NDEP on June 21, 2018.

Ramboll. 2018e. Phase 3 RI Modification No. 3; Nevada Environmental Response Trust Site; Henderson, Nevada. May 29. Approved by NDEP on June 8, 2018.

Ramboll. 2018f. Phase 2 RI Modification No. 12: Recommended Soil, Soil Gas and Groundwater Sampling in Parcel E; Nevada Environmental Response Trust Site; Henderson, Nevada. July 17. Approved by NDEP on July 19, 2018.

Ramboll. 2018g. Phase 2 RI Modification No. 13; Nevada Environmental Response Trust Site; Henderson, Nevada. August 8. Approved by NDEP on August 14, 2018.

Ramboll. 2018h. Phase 2 RI Modification No. 14; Nevada Environmental Response Trust Site; Henderson, Nevada. September 11. Approved by NDEP on September 12, 2018.

Ramboll. 2018i. Screening Level Ecological Risk Assessment Work Plan for Operable Unit 2, Revision 1; Nevada Environmental Response Trust Site; Henderson, Nevada. September 25. Approved by NDEP on October 30, 2018.

Ramboll. 2018j. Annual Remedial Performance Report for Chromium and Perchlorate, July 2017 - June 2018; Nevada Environmental Response Trust Site; Henderson, Nevada. November 9. Approved by NDEP on January 18, 2019.

Ramboll. 2018k. Phase 2 RI Modification No. 15; Nevada Environmental Response Trust Site; Henderson, Nevada. November 14. Approved by NDEP on November 15, 2018.

Ramboll. 2018l. Phase 3 RI Modification No. 4: Transect D Area Drilling; Nevada Environmental Response Trust Site; Henderson, Nevada. November 14. Approved by NDEP on November 15, 2018.

Ramboll. 2018m. Phase 3 RI Modification No. 5: Seep Well Field Area Drilling; Nevada Environmental Response Trust Site; Henderson, Nevada. November 13. Approved by NDEP on November 16, 2018.

Ramboll. 2018n. Baseline Health Risk Assessment Work Plan for OU-1 and OU-2 Soil Gas and Groundwater, Revision 1; Nevada Environmental Response Trust Site; Henderson, Nevada. December 19. Approved by NDEP on January 24, 2019.

Ramboll. 2019a. Soil Excavation Work Plan, SMP-Required Notifications and Contingency Plan, Dioxin Soil Remediation Area; Nevada Environmental Response Trust Site; Henderson, Nevada. January 7. Approved by NDEP on January 14, 2019.

Ramboll. 2019b. Phase 3 RI Modification No. 6; Nevada Environmental Response Trust Site; Henderson, Nevada. February 22. Approved by NDEP on March 1, 2019.

Ramboll. 2019c. Quality Assurance Project Plan, Revision 3; Nevada Environmental Response Trust Site; Henderson, Nevada. April 8. Approved by NDEP on April 17, 2019.

Ramboll. 2019d. Phase 3 RI Modification No. 7: Recommended Soil Gas and Groundwater Sampling Locations in Operable Unit 3; Nevada Environmental Response Trust Site; Henderson, Nevada. May 17. Approved by NDEP on May 31, 2019.

Ramboll. 2019e. Phase 3 RI Modification No. 9: Proposed Soil Gas Sampling in OU-1 and OU-2; Nevada Environmental Response Trust Site; Henderson, Nevada. October 7. Approved by NDEP on October 14, 2019.

Ramboll. 2019f. Barrier Wall Integrity Evaluation Report, Revision 1; Nevada Environmental Response Trust Site; Henderson, Nevada. November 21. Approved by NDEP on December 23, 2019.

Ramboll. 2019g. Phase 6 Groundwater Flow and Perchlorate Fate & Transport Model; Nevada Environmental Response Trust; Henderson, Nevada. November 27.

Ramboll. 2019h. Quality Assurance Project Plan, Revision 4; Nevada Environmental Response Trust Site; Henderson, Nevada. December 31. NDEP approved February 20, 2020 with amended pages to address comments noted for the Administrative Record submitted March 12, 2020.

Ramboll. 2019i. Site Management Plan, Revision 5; Nevada Environmental Response Trust Site; Henderson, Nevada. December 31. Submitted to NDEP for review January 9, 2020. Approved by NDEP on January 21, 2020.

Ramboll. 2020a. Report of Soil Removal Action, Dioxin Soil Remediation Area; Nevada Environmental Response Trust Site; Henderson, Nevada. January 31. Approved by NDEP on March 16, 2020.

Ramboll. 2020b. Phase 3 RI Modification No. 8, Revision 1; Nevada Environmental Response Trust Site; Henderson, Nevada. March 19. Approved by NDEP on March 20, 2020.

Ramboll. 2020c. Phase 3 RI Modification No. 10; Nevada Environmental Response Trust Site; Henderson, Nevada. April 30. Approved by NDEP on May 11, 2020.

Ramboll. 2020d. Quality Assurance Project Plan, Revision 5; Nevada Environmental Response Trust Site; Henderson, Nevada. July 16. Approved by NDEP on July 29, 2020.

Ramboll. 2020e. Phase 3 RI Modification No. 11; Nevada Environmental Response Trust Site; Henderson, Nevada. October 21. Approved by NDEP on October 28, 2020.

Ramboll (Ramboll US Consulting, Inc.). 2020f. Site Management Plan, Revision 6; Nevada Environmental Response Trust; Henderson, Nevada. December 23, 2020. Approved by NDEP on January 26, 2021.

Ramboll. 2021a. Quality Assurance Project Plan, Revision 6; Nevada Environmental Response Trust Site; Henderson, Nevada. February 24. Approved by NDEP on March 11, 2021.

Ramboll. 2021b. Annual Groundwater Monitoring and GWETS Performance Report, July 2019 - June 2020 Performance Period; Nevada Environmental Response Trust Site; Henderson, Nevada. February 26. Approved by NDEP on May 6, 2021.

Ramboll. 2021c. Phase 3 Remedial Investigation Modification No. 12; Nevada Environmental Response Trust Site; Henderson, Nevada. March 9. Approved by NDEP on March 10, 2021.

Ramboll. 2021d. Soil Background Data Set Summary Report, Revision 2; Nevada Environmental Response Trust Site; Henderson, Nevada. March 24. Approved by NDEP on April 12, 2021.

Ramboll. 2021e. Remedial Investigation Report for OU-1 and OU-2; Nevada Environmental Response Trust Site; Henderson, Nevada. July 9. NDEP comments received February 9, 2022.

Ramboll. 2021f. Baseline Health Risk Assessment Report for OU-2 Soil Gas and Groundwater; Nevada Environmental Response Trust Site; Henderson, Nevada. July 23. NDEP comments received on October 13, 2022.

Ramboll. 2021g. Phase 3 Remedial Investigation Modification No. 13; Nevada Environmental Response Trust Site; Henderson, Nevada. August 25. Approved by NDEP on September 1, 2021.

Ramboll. 2021h. Las Vegas Wash ZVI-Enhanced Bioremediation Treatability Study Work Plan Addendum; Nevada Environmental Response Trust Site; Henderson, Nevada. September 29. Approved by NDEP on November 10, 2021.

Ramboll. 2021i. Baseline Health Risk Assessment Report for OU-1 Soil Gas and Groundwater; Nevada Environmental Response Trust Site; Henderson, Nevada. September 29. NDEP comments received on March 9, 2022.

Ramboll. 2021j. BHRA Work Plan for OU-1 and OU-2 Soil Gas and Groundwater Modification #1 (Revision 1); Nevada Environmental Response Trust Site; Henderson, Nevada. October 29. Approved by NDEP on November 10, 2021.

Ramboll. 2021k. Phase 3 Remedial Investigation Modification No. 14; Nevada Environmental Response Trust Site; Henderson, Nevada. December 6. Approved by NDEP on December 8, 2021.

Ramboll. 2022a. Annual Groundwater Monitoring and GWETS Performance Report, July 2020 - June 2021 Performance Period; Nevada Environmental Response Trust Site; Henderson, Nevada. May 27. Approved by NDEP on July 27, 2022.

Ramboll. 2022b. Baseline Health Risk Assessment Report for OU-1 Soils, Revision 2; Nevada Environmental Response Trust Site; Henderson, Nevada. May 6. Approved by NDEP on June 2, 2022.

Ramboll. 2022c. Response to NDEP Comments on the Remedial Investigation Report for OU-1 and OU-2, Nevada Environmental Response Trust Site; Henderson, Nevada. June 9. NDEP responded on August 31, 2022.

Ramboll. 2022d. Phase 3 Remedial Investigation Modification No. 15; Nevada Environmental Response Trust Site; Henderson, Nevada. August 2. Approved by NDEP on August 9, 2022.

Ramboll. 2022e. Semi-Annual Groundwater Monitoring and GWETS Performance Memorandum, July-December 2021 Performance Period; Nevada Environmental Response Trust Site; Henderson, Nevada. August 17. Approved by NDEP on September 14, 2022.

Ramboll. 2022f. OU-1 and OU-2 Soil Gas and Groundwater Modification #1 Technical Memorandum, Nevada Environmental Response Trust Site; Henderson, Nevada. August 29. NDEP comments received on October 13, 2022.

Ramboll. 2023a. Site Management Plan, Revision 8; Nevada Environmental Response Trust; Henderson, Nevada. January 27, 2023. Approved by NDEP on February 1, 2023.

Ramboll. 2023b. Remedial Investigation Report for OU-1 and OU-2, Revision 1; Nevada Environmental Response Trust Site; Henderson, Nevada. August 15. NDEP comments received December 21, 2023 and January 11, 2024.

Ramboll Americas Engineering Solutions, Inc. (Ramboll). 2023c. Baseline Health Risk Assessment Report for OU-2 Soil Gas and Groundwater, Revision 1; Nevada Environmental Response Trust Site; Henderson, Nevada. September 15. Approved by NDEP on November 27, 2023.

Ramboll. 2023d. Baseline Health Risk Assessment Report for OU-1 Soil Gas and Groundwater, Revision 1; Nevada Environmental Response Trust Site; Henderson, Nevada. November 3. Approved by NDEP on January 2, 2024.

Ramboll. 2023e. Refined Screening-Level Ecological Risk Assessment for Operable Unit 1, Revision 2; Nevada Environmental Response Trust; Henderson, Nevada. December 18. Approved by NDEP on February 1, 2024.

Ramboll. 2023f. Refined Screening-Level Ecological Risk Assessment for Operable Unit 2, Revision 2; Nevada Environmental Response Trust; Henderson, Nevada. December 20. Approved by NDEP on February 1, 2024.

Ramsey, R.H. 1943. Magnesium, production at the world’s largest plant. *Chemical and Metallurgical Engineering* 50(10): 98–101,115.

RCI (RCI Engineering). 2010. Technical Drainage Study for Tronox Soil Remediation Treatment Basins; Las Vegas, Nevada. October.

Rust, B.R. 1978. A Classification of Alluvial Channel Systems. *Fluvial Sedimentology*, August.

Schumacher, J.C. 1999. History of Establishing a Source of Potassium and Ammonium Perchlorates for Use in Solid Propellant Rockets 35th AIAA/ASME/SAE/ASEE Joint Propulsion Conference and Exhibit, Los Angeles, California. AIAA Paper 99-2926. June.

Shevenell, L. 1996. Statewide Potential Evapotranspiration Maps for Nevada. Nevada Bureau of Mines and Geology, Report 48, p. 32.

Smith, N.D., T.A. Cross, J.P. Dufficy, and S.R. Clough. 1989. Anatomy of an Avulsion. *Sedimentology*, Volume 36.

Stauffer Chemical Company (Stauffer). 1984. Quarterly Progress Report for the Henderson Groundwater Project for the Second Quarter 1984. June 15.

Terracon (Terracon Consultants Inc.). 2017. Revised Industrial Risk Assessment - Exemption Closure Request, Basic Substation Transformer Maintenance Area & Yard 1; Henderson, Clark County, Nevada. February 10.

Tetra Tech EMI (Tetra Tech EM Inc.). 2005. Potential Source Areas Technical Memorandum, Revision 1; Titanium Metals Corporation Facility; Henderson, Nevada, July 5.

Tetra Tech (Tetra Tech Inc.). 2015. Unit 4 and 5 Buildings Investigation Work Plan; Nevada Environmental Response Trust Site; Henderson, Nevada. March 30. Approved by NDEP on April 13, 2015.

Tetra Tech. 2016a. Unit 4 and 5 Buildings Investigation First Mobilization. May 6.

Tetra Tech. 2016b. AP-5 Pond Closure Plan; Nevada Environmental Response Trust Site; Henderson, Nevada. November 17.

Tetra Tech. 2017a. Unit 4 and 5 Buildings Investigation Second Mobilization. May 4.

Tetra Tech. 2017b. Phase 2 RI Modification No. 7; Nevada Environmental Response Trust Site; Henderson, Nevada. July 26. Approved by NDEP on July 27, 2017.

Tetra Tech. 2018. AP Area Down and Up Flushing Treatability Study Results Report; Nevada Environmental Response Trust Site; Henderson, Nevada. December 21. Approved by NDEP on January 18, 2019.

Tetra Tech. 2019a. Galleria Drive Bioremediation Treatability Study Work Plan Addendum; Nevada Environmental Response Trust Site; Henderson, Nevada. March 29.

Tetra Tech. 2019b. AP-5 Pond Closure Report; Groundwater Discharge Permit NEV2001515; Nevada Environmental Response Trust Site; Henderson, Nevada. June 24.

Tetra Tech. 2020. Unit 4 and 5 Buildings Investigation Source Area Characterization Report, Revised; Nevada Environmental Response Trust Site; Henderson, Nevada. January 7. Approved by NDEP on January 13, 2020.

TIMET (Titanium Metals Corporation). 2007. Conceptual Site Model, Titatanium Metals Corporation Facility, Henderson, NV. April 25.

TIMET. 2008. Remedial Alternatives Study, First Water-Bearing Zone, Titatanium Metals Corporation, Henderson, NV. September 15.

TIMET. 2013. Calculation of Leaching-Based Site-Specific Levels, BMI Beta Ditch/Northwestern Ditches Located on the Titanium Metals Corporation Plant Site. May 16.

TIMET. 2014. Groundwater Extraction and Treatment System, Operations, Maintenance and Performance Report; Quarterly Report (July 1, 2014 – September 30, 2014). November 2014.

TIMET. 2020a. Upper Muddy Creek Formation Report; Titanium Metals Corporation; Henderson, Nevada. May 2020. Approved by NDEP on January 6, 2021.

TIMET. 2020b. Letter dated July 28, 2020 re: upcoming mass layoffs. https://cms.detr.nv.gov/Content/Media/20014_WARN_200729_Timet.pdf. Accessed February 18, 2021.

USDOI (United States Department of the Interior). 2022. Press Release: Interior Department Announces Actions to Protect Colorado River System, Sets 2023 Operating Conditions for Lake Powell and Lake Mead. https://www.doi.gov/pressreleases/interior-department-announces-actions-protect-colorado-river-system-sets-2023. August 16.

USEPA (United States Environmental Protection Agency). 1980. NPDES Compliance Monitoring Report; Permittee: Kerr-McGee Chemical Corporation, Oklahoma City, Oklahoma; Facility: Kerr-McGee Chemical Corporation, Henderson, NV; Permit No.: NV0000078. June 19.

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

USEPA. 1989. Risk Assessment Guidance for Superfund: Volume I—Human Health Evaluation Manual (Part A). Interim Final. Office of Emergency and Remedial Response, Washington, D.C. U.S. EPA/540/1-89/002. December.

USEPA. 1993. Wildlife Exposure Factors Handbook. December. Office of Research and Development. EPA/600/R-93/187. https://cfpub.epa.gov/ncea/risk/recordisplay.cfm?deid=2799.

USEPA. 1996. Soil Screening Guidance: Technical Background Document, 2nd edition. May.

USEPA. 2007. Resource Conservation and Recovery Act (RCRA) & Toxic Substances Control Act (TSCA) Compliance Investigation; Titanium Metals Corporation; Henderson, Nevada. February.

USEPA. 2008a. ECO Update/Ground Water Forum Issue Paper. Evaluating Ground-Water/Surface-Water Transition Zones in Ecological Risk Assessments. EPA-540-R-06-07. July.

USEPA. 2008b. Interim Drinking Water Health Advisory for Perchlorate, EPA 822-R-08-025. December.

USEPA. 2009. Memorandum: Revised Assessment Guidance for Perchlorate. January 8.

USEPA. 2017. Best Practices for Environmental Site Management: A Practical Guide for Applying Environmental Sequence Stratigraphy to Improve Conceptual Site Models. September. EPA/600/R-17/293.

USEPA. 2023. Regional Screening Levels (RSL) for Chemical Contaminants at Superfund Sites. May.

USFWS (United States Fish and Wildlife Service). 2014. Endangered Species. http://www.fws.gov/endangered/what-we-do/critical-habitats-faq.html. Accessed October 1, 2014.

USGS (United States Geological Survey). 1989. Changes in Water Levels and Water Quality in Shallow Ground Water, Pittman-Henderson Area, Clark County, Nevada, Resulting from Diversion of Industrial Cooling Water from Ditch to Pipeline in 1985. Water-Resources Investigations Report 89-4093.

USGS. 1999. Las Vegas, Nevada, Gambling with Water in the Desert. US Geological Survey Circular 1182.

USGS. 2000. Water Use and Associated Effects on Ground-Water Levels, Las Vegas Valley and Vicinity, Clark County Nevada, 1980-1995. Prepared in cooperation with Nevada Division of Water Resources and Las Vegas Valley Water District. US Geological Survey Water-Resources Information Report 35.

USGS. 2010. Section 6. Conceptual Understanding and Groundwater Quality of the Basin-Fill Aquifer in Las Vegas Valley, Nevada. US Geological Survey Professional Paper 1781. December 17.

US Patent Office (United States Patent Office). 1950. US Patent No. 2,512,973 to J. C. Schumacher. June 27.

US Patent Office. 1957. US Patent No. 2,890,000 to Titanium Metals Corporation. January 31.

University of Nevada Las Vegas (UNLV) Batista, Jacimaria R., Penny S. Amy, Lambis Papelis, Yi-Tung Chen, and Richard Unz. 2003 The Fate and Transport of Perchlorate in a Contaminated Site in the Las Vegas Valley. March.

Van den Berg, M., L.S. Birnbaum, M. Denison, M. De Vito, W. Farland, M. Feeley, H. Fiedler, H. Hakansson, A. Hanberg, L. Haws, M. Rose, S. Safe, D. Schrenk, C. Tohyama, A.

Tritscher, J. Tuomisto, M. Tysklind, N. Walker, and R.E. Peterson. 2006. Review: the 2005 World Health Organization reevaluation of human and mammalian toxic equivalency factors for dioxins and dioxin-like compounds. *Toxicological Sciences* 93(2): 223–241. https://doi.org/10.1093/toxsci/kfl055.

Van Wagoner, J.C., R.M. Mitchum, L.M. Campion, and V.D. Rahmanian. 1990. Siliciclastic Sequence Stratigraphy in Well Logs, Cores, and Outcrops. AAPG Methods in Exploration Series, Book 7. American Association of Petroleum Geologists, pp. 1–55.

Wendt, H. et al. 1990. Chlorine corrosion of graphites and technical carbons – I. Reaction with gaseous chlorine at elevated temperatures. Werkstoffe und Korrosion. 41. Pp. 457-463.

Westergard, R.D. 1969. In the Matter of Application 21635 Filed by Basic Management, Inc., to Appropriate Effluent from the City of Henderson Sewage Disposal Plant and Pittman Underdrain, Clark County, Nevada. July 31.

Weston. 1993. Phase I Environmental Conditions Assessment Report; Pioneer Chlor-Alkali Plant; Stauffer Chemical Company; Henderson, Nevada. March 22.

Wright, Lucas. “192 employees impacted by mass layoffs at Henderson TIMET plant,” last updated July 31, 2020. https://www.8newsnow.com/news/local-news/192-employees-impacted-by-mass-layoffs-at-henderson-timet-plant/