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Data Gap Investigation Plan – Phase I Groundwater Monitoring Well Installation

NERT Remedial Investigation – Downgradient Study Area
Nevada Environmental Response Trust Site
Henderson, Nevada

Final

Data Gap Investigation Plan – Phase I Groundwater Monitoring Well Installation, Revision 0

Nevada Environmental Response Trust
Remedial Investigation – Downgradient Study Area, 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.

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List of Acronyms

%	percent
BMI	Basin Management Inc.
BRC	Basic Remediation Company
BOR	U.S. Bureau of Reclamation
cfs	cubic feet per second
CSM	conceptual site model
DGIP	Data Gap Investigation Plan
Downgradient Study Area	NERT RI Downgradient Study Area
DQO	data quality objective
EA	Environmental Assessment
EB	equipment blank
EPA	United States Environmental Protection Agency
FB	field blank
FD	field duplicate
FGD	Field Guidance Document
FONSI	Finding of No Significant Impact
GWETS	Groundwater Extraction and Treatment System
HASP	Health and Safety Plan
ID	identification number
IDW	investigation-derived waste
LCS	laboratory control sample
LCSD	laboratory control sample duplicate
LVW	Las Vegas Wash
mg/l	milligram(s) per liter
mL/min	milliliter(s) per minute
MS/MSD	matrix spike/matrix spike duplicate
NDEP	Nevada Division of Environmental Protection
NEPA	National Environmental Policy Act
NERT	Nevada Environmental Response Trust
NERT Site	on-site portion of the NERT RI Downgradient Study Area
±	plus or minus
PPE	personal protective equipment
QA	quality assurance
QAPP	Quality Assurance Project Plan
QC	quality control
RI	Remedial Investigation
RM	river mile
RPD	relative percent difference
SNWA	Southern Nevada Water Authority

SOP	standard operating procedure
µg/L	microgram(s) per liter
UMCf	Upper Muddy Creek formation
USGS	United States Geological Survey

1.0 Introduction

This Data Gap Investigation Plan (DGIP) describes the locations, procedures and methods for the installation of the initial (Phase I) groundwater wells along the Las Vegas Wash (LVW) in support of the Nevada Environmental Response Trust (NERT) Remedial Investigation (RI) Downgradient Study Area in Henderson, Nevada (herein referred to as the Downgradient Study Area or Project) (**Figure 1**). This DGIP was developed at the direction of the Nevada Division of Environmental Protection (NDEP) and describes the rationale, procedures and methods for the proposed installation and development of groundwater wells, and the collection of groundwater data from these wells. The DGIP was modified to respond to comments received from stakeholders via email on April 19, 2017. For reference the responses to the comments are provided in **Appendix A**.

The overall objective of the investigation of the Downgradient Study Area is to identify subsurface pathways downgradient and cross-gradient of the NERT RI Study Area through which perchlorate-impacted groundwater is entering the LVW. The objective of installing new wells is to address specific data gaps identified based on historic data and recent groundwater monitoring data collected in April 2016 as well as LVW surface water data collected in May 2016. Data collected from these Phase I wells and data collected from transducers that will be installed in existing wells along the LVW will be used to refine the conceptual site model (CSM), and to identify areas of potential perchlorate flux to the LVW. The procedures and rationale for the installation of the transducers were presented in a separate work plan titled, *Data Gap Investigation Plan – Transducer Installation and Monitoring* (AECOM 2016a). Environmental assessment investigations performed within the downgradient area will be coordinated with other ongoing environmental investigations in the area and on adjacent properties.

The Phase I well locations are determined based on the results of the April 2016 groundwater sampling event (AECOM 2016b), during which groundwater samples were collected from 61 wells throughout the Downgradient Study Area and the May 2016 surface water sampling (AECOM 2016c) event, during which 14 surface water samples were collected from the LVW (including 7 tributary samples and 3 seep samples collected along the LVW). The 2016 groundwater well and surface water sampling locations are shown on **Figure 2**. In addition, historical data and recommendations presented in the *Technical Memorandum, Data Gap Evaluation Regional Groundwater Investigation* (Environ 2015) and the *NERT Regional Groundwater Data Gap Technical Memorandum* (Broadbent 2015) were considered when identifying the investigation areas along the LVW. Under this Phase I DGIP ten wells will be installed. In conjunction with sampling and analysis of groundwater from these and other nearby wells, additional LVW surface water data will be collected in early 2017 to assist in identification of additional wells to be installed. In addition, a Geophysical Pilot Test is currently underway that may lead to geophysical surveys aimed at further characterizing the alluvium/Upper Muddy Creek formation (UMCf) contact in the Downgradient Study Area. The geophysical data will also be used to assist in the identification of where additional wells should be installed. A work plan for the next phase (Phase II) will be prepared to install and sample the next group of wells. During Phase II, additional investigations, such as aquifer and tracer testing may be performed on select existing Phase I and/or Phase II wells to provide further understanding of perchlorate pathways and approximate flux to the LVW.

The activities in this DGIP will be conducted in conformance with the Quality Assurance Project Plan (QAPP) (AECOM 2016d) and the site-specific Health and Safety Plan (HASP) (AECOM 2016e). Data collected under this DGIP will be reported in a technical memorandum which will in turn be used by NERT during the preparation of the RI Report.

1.1 Data Gap Investigation Plan Organization

This document includes the following sections, which are summarized as follows:

- Section 1.0 provides an introduction, including the overall objectives and scope of the DGIP.

- Section 2.0 presents the CSM.
- Section 3.0 discusses the data quality objectives (DQOs) for the sampling and analyses.
- Section 4.0 describes the monitoring well installation, sampling objectives and locations for the DGIP and describes the sampling types, locations, and frequency along with pre-field and field activities to be conducted.
- Section 5.0 details the sampling procedures and equipment to be used during the investigation.
- Section 6.0 describes sample designations, sample handling, and analytical methods to be conducted as part of the investigation.
- Section 7.0 describes the schedule and report preparation that will document the results of this assessment.
- Section 8.0 provides references to sources of information used in the preparation of this DGIP.

1.2 Definitions and Key Terms

The following terms are used in this DGIP and are defined here for consistency.

Groundwater discharge: approximate location where groundwater is entering the surface, either on land or under water. The groundwater may or may not contain perchlorate.

Groundwater flux: measurement of the amount of groundwater discharging per unit of time (for example, gallons per minute or cubic feet per second [cfs]).

Perchlorate discharge: approximate location where groundwater containing perchlorate is discharging to the surface, either on land or under water.

Perchlorate flux: the amount of perchlorate transported in water per unit of time (e.g., pounds per day).

Seep: an area of slow discharge of groundwater on land or into a body of water.

Spring: a discrete place where groundwater actively discharges on land or into a body of water. In contrast to seeps, springs often create small rivulets on the ground surface, and may be visible underwater as sand boils or areas of reduced cloudiness.

Sump: a manmade collection structure used to manage surface water runoff.

2.0 Conceptual Site Model

Before development of the Las Vegas area, the LVW was an ephermal natural stream in southern Nevada. In the past decades, the LVW has experienced large increases in water flow due to increases in wastewater discharge related to development in the Las Vegas Valley, providing the LVW with a relatively steady year-round water flow. The increased flow rates, combined with flooding during major storm events, cause erosion of the LVW channel. Erosion control weirs have been and are continuing to be constructed, to slow down the water velocities through major portions of the LVW. Groundwater infiltrating into the LVW via seeps and springs is known to be contaminated with dissolved chemicals related to industrial operations in the Las Vegas Valley, including perchlorate, chlorate, and chromium. It should be noted that these chemicals are only a limited subset of the chemical impacts encountered at the Basic Management Inc. (BMI) Industrial Sites. The paths by which the contaminated groundwater enters the LVW and introduce contamination to the surface waters are not well understood. The following section provides a description of the CSM of the LVW and known and suspected inputs.

2.1 Regional Hydrology and Water Usage

The headwaters of the LVW are located in the northern part of the Las Vegas Valley near Fossil Ridge in the Las Vegas Range. The LVW flows to the southwest around Gass Peak then turns to the southeast flowing toward Tule Springs Ranch and North Las Vegas. Tule Springs was one of the larger springs in the valley (Rafferty 1984). The LVW then runs south-southeast along the eastern edge of the valley before turning east toward its exit from the valley near the City of Henderson, joining with the Colorado River in Lake Mead approximately 5 miles to the northeast. As the point of discharge from the valley, the LVW picks up flow from all other intermittent and perennial streams draining the basin, including Las Vegas Creek which drains another area of significant historical spring discharge (Las Vegas Springs and Big Springs).

In the early 1900s, the water demands of the growing population in the area began to overwhelm the natural rate of groundwater recharge, and a number of large, flowing artesian wells were drilled in the valley floor (Pavelko et al, 1999). Flow from those wells represented a significant increase in groundwater discharge within the basin, causing increased surface water flows and water-level declines in aquifers. As a result, water levels in parts of the valley dropped by as much as 300 feet and resulted in land subsidence due to compaction of aquifer materials.

Following the construction of the Hoover Dam on the Colorado River, Lake Mead began to supply water to the Las Vegas Valley and today represents approximately 90 percent (%) of the water supply (Las Vegas Valley Water District 2016). The streamflow characteristics of the LVW have changed considerably through the years as natural contributions from large springs have dried up and treated wastewater discharge from the growing population has increased (**Figure 3**).

Figure 4 presents a map and schematic representation of the LVW across the Downgradient Study Area, including known major inflow and outflows by river mile (RM) as measured from the historic high water level mark on Lake Mead. **Figure 4** shows the location and average flow (based on up to 10 years of discharge data; 2006–2015), where available, for United States Geological Survey (USGS) water level gages in the general study area, including gages on the LVW, one on Duck Creek, and the C-1 Channel. **Figure 4** also shows the 2016 perchlorate concentrations in surface water and in groundwater monitoring wells adjacent to the LVW.

The USGS has operated a long-term stream gaging station downstream of Las Vegas since 1958 (LVW at Pabco Road near Henderson, Nevada; gage 09419700) (**Figure 4**). From 1958 through 1967, the average annual flow at the Pabco Road station was 21.8 cfs. The rate of flow grew steadily through much of the period of record at Pabco Road (**Figure 3**) and has stabilized at approximately 300 cfs since 2005 (average annual flow of 296 cfs from 2006 to 2015).

The USGS also operates a long-term gaging station near the point of exit for the LVW from the valley (above Three Kids Wash; gage 09419753) (**Figure 4**). Between 2006 and 2015, the average annual flow at the downstream station was 302 cfs, or only 6 cfs (2.0%) higher than at the Pabco Road gaging station. While that apparent increase is within the uncertainty of streamflow measurements (generally accepted to be within plus or minus (±) 5% of true streamflow), some additional flow inputs have been observed over the 2.5-mile distance between the two stations. Those inputs, including stormflow and groundwater discharge (springs and seepage areas), are balanced to some degree by losses to evapotranspiration (**Figure 4**).

2.2 Anthropogenic Sources of Discharge to the LVW

Discharges from the four major wastewater treatment plants in the valley represent the vast majority of flow in the LVW (Clark County Water Reclamation District, City of Las Vegas Water Pollution and Control Facility, City of Henderson Water Reclamation Facilities, and City of North Las Vegas Water Reclamation Facility). Outfalls from groundwater treatment plants (NERT, American Pacific Corporation [Endeavour], and TIMET) join the channel conveying treated wastewater from the City of Henderson, entering the LVW above Pabco Weir (indicated as combined treated wastewater inflow on **Figure 4**). The remaining flow in the LVW comes from Duck Creek and the C-1 channel, as well as non-point sources including urban and stormwater runoff and shallow groundwater discharge. It is expected that portions of the LVW are below the groundwater table and, therefore, receive groundwater discharge. Other parts of the LVW are above the groundwater, which cause infiltration (loss) of the surface water. This condition is dynamic and changes depending on a wide variety of variables including, but not limited to, increases in flow rates from the wastewater treatment plants due to increased land development, diurnal fluctuations in wastewater flows, and seasonal fluctuations of the groundwater table.

The treatment plants contribute a relatively steady daily supply of water to the LVW throughout the year. The outfalls discharge continuously but at a predictably cyclic rate. That cycling causes a diurnal flow pattern similar to a tidal pattern, with daily high and daily low flows. Unless disrupted by rain storm events, daily high flows are on the order of 100% higher than the daily low. However, the constant daily discharge represents the vast majority of flow in the LVW, and the natural, seasonal variability in streamflow has largely been eliminated. On average, streamflow tends to be somewhat higher from October through March (290 to 340 cfs) and lower from April through September (260 to 310 cfs) (USGS 2016).

Along with the general increase in background flow in the LVW through the years, there has also been an increase in the magnitude of stormwater runoff draining into the LVW. Fifty years ago, the annual peak flow at Pabco Road was on the order of 300 cfs (median value of 280 cfs from 1957 to 1967), or similar to the current average annual flow (298 cfs). More recently, annual peak flows are on the order of 4,500 cfs (median value of 4,350 cfs from 2005 to 2015) (USGS 2016).

In an effort to protect the channel from the erosive forces of higher flows, a series of erosion control structures (weirs) have been constructed to slow the water velocities in the LVW. Where erosional forces have been allowed to run their course, the stream channel within the Downgradient Study Area is generally 40 feet or less in width. Near some of the weirs, the width increases to 300 feet or more.

The channel materials consist of loose, unconsolidated sediments that have been shifted and sorted by the energy of the flowing water. Most of the underlying material is alluvium that consists of both fine-grained materials (silts and clays) and courser materials (sands and gravels). As the water carries those deposits downstream, sand and gravel are deposited in areas with higher velocity, providing a more solid streambed. Where streamflow slows down in natural pools and behind some of the weir structures, silts and clays are deposited, creating a soft bottom. The Horse Springs Formation is present in the southern streambank east of Calico Ridge Weir, and the Thumb Formation is present on the northern and southern streambanks between the Lower Narrows and Three Kids Weirs.

2.3 Known Sources of Perchlorate

The former Kerr McGee/Tronox site (NERT Site) (**Figure 1**) has been the location of industrial operations since 1942 when it was developed by the U.S. government as a magnesium plant to support World War II operations. Following the war, this area continued to be used for industrial activities, including production of perchlorate, boron, and manganese compounds. Former industrial and waste management activities conducted at the NERT On-Site Study Area, as well as those conducted at adjacent properties, resulted in contamination of environmental media, including soil, groundwater, and surface water. Since 1979, the NERT Site has been the subject of numerous investigations and removal actions. Soil removal actions were conducted in 2010 and 2011 from the NERT Site to minimize potential health risks from impacted soil. Additional soil removal was performed in 2013 when the eastern end of the Beta Ditch was excavated. The soil removal activities and post-removal conditions are described in detail in the Revised Interim Soil Removal Action Completion Report (ENVIRON 2012). On-site and Off-site groundwater removal actions include the installation of the groundwater extraction-and-treatment system, designed to capture and treat perchlorate and hexavalent chromium in shallow groundwater. Please refer to the Annual Remedial Performance Report for Chromium and Perchlorate by Ramboll Environ dated October 31, 2016 for additional information on the groundwater impacts and perchlorate mass entering LVW (Ramboll Environ, 2016).

In the spring of 1999, Southern Nevada Water Authority (SNWA) hydrologists discovered a seep (“the original seep”) discharging to the LVW at approximately 400 gallons per minute. The location of the sump collecting water from the original seep is shown on **Figure 2** as location KM-S. Perchlorate concentrations in the seep exceeded 100,000 micrograms per liter (µg/L) in 1999. The results of the seep samples indicated that a significant mass flux of perchlorate was entering the LVW; Kerr McGee subsequently implemented a capture system at the seep in November 1999 to reduce the migration of perchlorate to the LVW (ENSR International 2005). The operation of the Seep Capture System has contained and treated a substantial mass of perchlorate that otherwise would have entered the LVW.

In an effort to locate additional potential inputs of perchlorate to the LVW, Kerr McGee conducted a groundwater, surface water and seep sample field program in 2000 near and in the LVW (**Figure 5**). Samples were collected from seep locations in April 2000 before the installation of the weirs. After the installation of the weirs, some of the seeps were submerged below the water surface of the LVW. **Table 1** is a list of existing and proposed weirs in and near the Downgradient Study Area, and includes the year the weir was completed. Concentrations of perchlorate reported in the 2000 sampling were up to 57,000 µg/L (location KM-70; approximately RM 6). The perchlorate concentrations in the seeps from the 2000 seep sampling were highest near the original seep discovered by SNWA; upstream concentrations were either non-detect or very low (31 µg/L at KM-58; near the Duck Creek confluence). Downstream seep concentrations dropped from KM-70 with distance downstream to KM-53 (321 µg/L; approximately RM 5), but increased at KM-91 (2,100 µg/L; approximately RM 4.7). Concentrations in the seeps again decreased with distance downstream from KM-91 to KM-66 where the concentration was 460 µg/L. The concentration of perchlorate then increased at KM-67 to 2,100 µg/L. No samples were collected downstream of KM-67 during this sampling event (Kerr McGee, 2001).

2.4 Recent Perchlorate Patterns in Surface Water and Groundwater

2.4.1 Seep and Surface Water Sampling Results (May 2016)

To support the Downgradient Study Area investigation, seep and surface water samples were collected from several locations in and near the LVW in May 2016. As part of that sampling program, a sample was collected from the sump immediately downgradient of the seep discovered by SNWA in 1999 (labelled KM-S in **Figure 2**). The capture system that was subsequently implemented has significantly reduced both the perchlorate concentration and volume of groundwater discharging at the location. The 2016 sample had a perchlorate concentration of 85 µg/L, three orders of magnitude lower than samples collected in 1999. The seep is currently reported to be active only seasonally, with the small volume of flow terminating a short distance downstream in a topographic low where it seeps back into the ground and/or is evaporated into the air upgradient of its historic confluence with the LVW. The seep was active during the May 2016 sampling, with discharge through the sump visible (AECOM 2016a).

During the May 2016 sampling program, an attempt was made to locate the seeps from the 2000 sampling event. Seeps that were successfully located, accessible, and flowing were subsequently sampled. It is surmised that weir construction, onshore riparian zone restoration, flooding and vegetative growth during intervening years, and the ongoing regional drought conditions may have affected the occurrence and, if present, the flow from the previously identified seeps. Because the installation of the weirs likely changed the seep locations, attempts were made to relocate the seeps and, if possible, sample them. Of the 18 historic seep locations, only three (KM-45, KM-67 and KM-71) could be located in the field. All other historic seeps may have been buried by weir and bank construction, submerged by the expanded stream channel and associated sediments, temporarily dried up under the ongoing drought conditions, or obscured by dense vegetation. Of the three located seeps, two (KM-67 and KM-71) were sampled. KM-45 was identified as a pit located near the Pabco Road Weir. The pit was dry and, therefore, not sampled. The concentrations of perchlorate in the two sampled seeps were lower in 2016 than in 2000. At KM-71, the perchlorate concentration in 2016 (1.4 J µg/L) was substantially lower than in 2000 (3,400 µg/L). In 2000, KM-71 was located downgradient of the proposed location of the Sunrise Mountain Weir. The seep was located in 2016 immediately upstream of this location in a backwater channel. At KM-67, located near the Three Kids Weir, the perchlorate concentration in 2016 (1,500 µg/L) was slightly lower than in 2000 (2,100 µg/L). Construction of Three Kids Weir was completed in July 2015. A riprap weir referred to as a “Demonstration Weir” was constructed near this location in 1999. The Demonstration Weir was relocated and rebuilt in 2007 and was eventually dismantled in 2013 and replaced by the Three Kids Weir (Las Vegas Wash Coordination Committee, 2016). Although a weir was in place in this location during both the 2000 and 2016 sampling events, it is not clear to what extent, if any, each weir affected the stream flow and sample results during the 2000 and 2016 sampling events.

The results of the seep sampling conducted by Kerr McGee in 2000 and by AECOM in May 2016 indicate that there may be perchlorate discharge to the LVW, particularly in the area near Three Kids Weir. During the May 2016 sampling event, in addition to the three seep samples, surface water grab samples were collected from 14 locations in the LVW and 6 locations in tributary or side streams. These locations ranged from the upstream portion of the Downgradient Study Area (LW7.2) downstream to LW3.1, located out of the Study Area. The perchlorate concentrations from these samples are provided in **Figure 6**. While the daily flows may have influenced the concentration of perchlorate (i.e., the daily higher flows may dilute perchlorate in the LVW), there appears to be reaches along the LVW where perchlorate concentrations show an increase. The first increase in perchlorate concentrations appears near the NERT RI Off-Site Study Area and the Pabco Road Weir. Concentrations increase again near the Proposed Historic Lateral Weir Expansion, where the C-1 channel enters the LVW. While the 2000 seep data (**Figure 5**) do not show a potential seep point source, concentrations in the surface water from May 2016 are slightly higher in this reach (19 to 23 µg/L) than upstream (8.3 µg/L), but are similar to that near Pabco Road Weir (15 to 17 µg/L in the LVW channel). Downstream of Lower Narrows Weir, concentrations increase to 44 µg/L, and remain high through the rest of the sampled reach of the LVW (51 µg/L at the most downstream location). The seep KM-67 may account for some of the increase in perchlorate concentrations from the Three Kids Weir and downstream. However, upstream near Lower Narrows Weir, the only other potential source measured is the seep KM-91 (2,100 µg/L in 2000). This seep (KM-91) could not be located in May 2016 (AECOM, 2016c).

2.4.2 Groundwater Sampling Results (April 2016)

In April 2016 groundwater was collected from 61 wells in the downgradient study area to provide information to evaluate where groundwater with high concentrations of perchlorate was present. The results of this study are presented on **Figure 6** and discussed in more detail in the Groundwater Sampling Technical Memorandum (AECOM 2016b). Perchlorate was detected above the detection limit in groundwater from 49 wells. As shown on **Figure 6**, the highest perchlorate concentration was detected at 9,000 micrograms per liter (µg/L) in well DBMW-1 located in the south-central portion of the Downgradient Study Area. Perchlorate concentrations above the Basic Comparison Level of 18 µg/L were detected in groundwater from 44 wells. In general, the highest concentrations were detected along the southern boundary and central portion of the Downgradient Study Area.

Perchlorate was also detected in four wells on the north side of the LVW from east of the Pabco Road Weir to the eastern boundary of the Downgradient Study Area (**Figure 6**). The highest concentration of perchlorate (1,500 µg/L) on the north side of LVW was detected just east of the Lower Narrow Weir in well LNDMW2 (**Figure 6**).

The results of the April 2016 groundwater sampling further indicate that there are five monitoring wells within 500 feet of the LVW where groundwater concentrations are 1,000 µg/l or higher (COH2B1, MW-13, LNDMW-1, LNDMW-2, and WMW3.5S). Four of these wells are on the south side of the LVW and one well, LNDMW-2, is on the north side. The areas near these wells may include pathways for potential flux of perchlorate to the LVW. Because the wells are hundreds to over 1,000 feet apart and, as stated above, nearby wells exhibit significantly different concentrations, the perchlorate plume is relatively heterogeneous with respect to concentration. This heterogeneity is further complicated by the composition of the alluvium, the composition of the bedrock formations (UMCf, Horse Spring and Thumb formations), and the presence of faulting (GES, 2003). Based on the data obtained to date, groundwater near the LVW interacts with surface water in a highly complex manner.

2.5 Groundwater Data Gaps

The reaches where perchlorate is entering the LVW can be grossly defined, but additional data are required to understand where the groundwater impacted with perchlorate enters the LVW. As shown by the April 2016 groundwater data discussed in Section 2.4.2, concentrations of perchlorate in groundwater vary considerably between wells and additional data are needed to identify the areas where remedial actions could be taken to prevent perchlorate flux to the LVW. The contributing effect of paleochannels on perchlorate flux to the LVW is not well understood. Several studies have been conducted to identify the locations of paleochannels (BRC, 2007; Northgate, 2010; and Krish 2015). It appears that the paleochannels have been flushed of high concentrations of perchlorate and that the surrounding lower permeable sediments continue to gradually discharge perchlorate. As presented in the Broadbent memorandum dated April 17, 2015, numerous consultants participated in identifying data gaps that, once filled, would assist NDEP in identifying areas where perchlorate flux enters the LVW (Broadbent 2015). Specific data gaps regarding the installation of monitoring wells were identified by these consultants and AECOM, and are reflected in this Phase I DGIP for the installation of new groundwater monitoring wells. A Phase II DGIP investigation will follow this investigation and will include additional wells, pumping tests and other investigations as needed. The April 2016 groundwater sampling event provided valuable data regarding the concentration of perchlorate, and other constituents in the Downgradient Study Area. These data, coupled with the May 2016 surface water and seep sampling data, have been used to identify specific areas where additional monitoring wells will provide needed data to focus efforts to intercept perchlorate before it enters the LVW. During the initial phase (Phase I) of the groundwater data-gap investigation, ten wells will be installed. Data collected from these wells will be evaluated to identify where the next set (Phase II) of monitoring wells are needed to address the following data gaps. The Table below identifies the data gaps and whether the gap will be addressed in Phase I or Phase II.

Data Gaps	Investigation Phase/Description
1) Where are the high concentration (1,000 µg/L or higher) perchlorate-impacted groundwater plumes along the north and south sides of the LVW?	Phase I Investigation includes installation and sampling of 10 additional groundwater monitoring wells combined with sampling of 19 existing wells. If the 1,000 µg/L or higher perchlorate limits are not defined, further definition of these high concentration areas will be performed under the Phase II investigation.
2) Why are there noticeable differences in perchlorate concentrations in groundwater over relatively short distances?	Phase I and Phase II Investigations. Phase II will take into consideration the Phase I data and available upgradient data from the NERT RI Off-site Study Area and the NERT RI Eastside Study Area.
3) How deep are the high concentration perchlorate-impacted groundwater	Phase II Investigation

	Data Gaps	Investigation Phase/Description
	plumes?	
4)	Do the high-concentration perchlorate plumes follow distinct water-bearing zones within the alluvium or bedrock formations?	Phase I Investigation, full-scale geophysical investigation followed by Phase II Investigation.
5)	Where does faulting affect the movement of high-concentration perchlorate-impacted groundwater?	Full-scale geophysical investigation followed by Phase II Investigation.
6)	Along the LVW, does groundwater flow generally in the same direction as the surface water?	Phase I Investigation
7)	Where does impacted groundwater discharge to the LVW?	Surface water investigation (currently in progress), Phase I Investigation with refinement in Phase II Investigation.
8)	Where is the groundwater/surface water interface and how far is it from the LVW?	Surface water investigation (currently in progress), water level data gap investigation (transducers to be installed in early March 2017), Phase I Investigation with refinement in Phase II Investigation.
9)	Is there an area of known or suspected perchlorate flux of sufficient magnitude where an interim remedial action would be appropriate?	Surface water investigation (currently in progress), Phase I Investigation with refinement in Phase II Investigation.
10)	Is perchlorate-impacted groundwater bypassing the seep well field on its eastern side in the vicinity of monitoring well COH2B1?	Phase I Investigation
11)	Do high volumes of low-concentration, perchlorate-impacted groundwater provide more flux to the LVW than low volumes of high-concentration perchlorate-impacted groundwater?	Phase II Investigation
12)	Do concentrations of perchlorate in groundwater fluctuate over time, seasonally, or after a rain event?	Comparison of perchlorate concentrations in 19 existing wells sampled in April 2016 and to be sampled during Phase I Investigation. Possible follow-up sampling required dependent upon findings.

Table 2 provides that rationale for each of the ten proposed monitoring wells. The remaining data gaps will be the focus of the more extensive Phase II investigation that will build on the Phase I results, as well as additional surface water and geophysical studies currently underway.

3.0 Data Quality Objectives

In this section, the United States Environmental Protection Agency (EPA) DQO process is followed to assist with systematic planning for the proposed environmental sampling program described in this DGIP (EPA 2006). The DQO process is EPA's recommended planning process when environmental data are used to select between two alternatives or derive an estimate of contamination (EPA 2001). The DQO process is used to develop performance and acceptance criteria that clarify study objectives, and to define the appropriate type of data and specific tolerable levels of potential decision errors that will be used as the basis for establishing the quality and quantity of data needed to support decisions. Performance criteria apply to new data collected for the Project, while acceptance criteria apply to existing data proposed for inclusion in the Project.

The QAPP describes in comprehensive detail the necessary quality assurance (QA), quality control (QC), and other technical activities that must be implemented to ensure that the results of the work performed will satisfy the stated performance criteria. The QAPP for the proposed sampling at the Downgradient Study Area is a separate document adapted from the existing QAPP for the NERT RI and is consistent with EPA guidance.

The DQO process as described in EPA guidance involves the following seven steps:

1. Define the problem.
2. Identify the goal of the study.
3. Identify information needed for the study.
4. Define the boundaries of the study.
5. Develop the analytic approach.
6. Specify the performance or acceptance criteria.
7. Develop the plan for obtaining data.

A summary of steps 1 through 6 is provided in the following sub-sections for the installation and sampling of new groundwater wells. The sampling plan details for step 7 are described in Sections 4.0 through 6.0.

3.1 State the Problem

As discussed in Section 2.4, perchlorate discharge to the LVW is currently not well understood. While capture and treatment of perchlorate-contaminated water by Kerr McGee (currently operated by NERT) and others have substantially reduced the flux of perchlorate to the LVW, other, more diffuse sources of perchlorate to the LVW are present, likely through groundwater discharge within the reaches along the LVW within the Downgradient Study Area. Surface water grab sampling data collected in May 2016 (AECOM 2016c) and illustrated in **Figure 4** have shown that concentrations of perchlorate increase with distance downstream. Specifically, concentrations appear to increase downstream of the seeps near Pabco Road and the Historic Lateral Weir, at a location between LW4.95 (upstream of Calico Weir) and LWC4.6 (downstream of Lower Narrows Weir), and downstream of Three Kids Weir (AECOM 2016c).

The complex hydrology described in the CSM (Section 2.0), together with the construction of weir structures, confound locating perchlorate discharge points. While some perchlorate may be entering the LVW upstream of the Downgradient Study Area, ongoing sampling efforts have shown those contributions are relatively insignificant. To control perchlorate flux to the LVW, the sources of perchlorate discharge must be located and, ultimately, addressed. These sources are likely contaminated groundwater discharging as seeps or springs that may be entering via overland flow or, more likely, discharge in the LVW directly under the water surface. The points of discharge may be on the southern bank, mid-channel, or near the northern bank of the LVW.

Surface water gaging and transect sampling data are needed that represent the current nature and distribution of target constituents, including perchlorate and chlorate, in the LVW within the limits of the Downgradient Study Area. Those data will help evaluate for variations in concentration across each cross section. The surface water transect sampling will also include total dissolved solids, chloride, and bromide analyses to evaluate if differences in the concentrations of these analytes can be used in identifying areas of potential groundwater flux to the LVW, as not all groundwater discharge contributes perchlorate to the LVW and these fluxes of groundwater need to be accounted for in any future perchlorate flux calculations and modeling.

Potential groundwater and perchlorate discharges may be near the northern or southern banks or closer to the middle of the LVW. To help refine understanding of the perchlorate discharge, transect sampling in the LVW will be conducted at target locations near the northern bank, the southern bank, and mid-channel. Collecting data from a transect across the LVW will provide information to the cross-sectional differences in perchlorate concentrations, as well as a better average concentration at that point in the flow path of the LVW. The transect sampling will occur at locations where perchlorate discharge may be occurring, as determined by past sampling events, and will include a sampling transect in the upstream reaches of the Downgradient Study Area to refine the upstream and off-site inputs to the Downgradient Study Area. The transect locations will include a surface water level gage, either a USGS gage that will provide water level as well as volumetric flow, or a water level gage that will indicate water level only. The differences in water level at the staff gages will be used in relationship to the USGS gages, where volumetric flow as a function of water level has been calibrated, to estimate differences in flow at each transect.

Near the Pabco Weir, the leading edge of the NERT Plume is discharging approximately 10 to 35 pounds per day of perchlorate to the LVW as groundwater underflow that passes by the east side of the Seep Area Well Field and Pabco Weir. Perchlorate mass is also believed to be entering the LVW through paleochannels that discharge into the LVW. Although paleochannels have been mapped and groundwater monitoring wells exist within the Downgradient Study Area, data are limited and geophysical data have not been verified with soil borings or groundwater wells. As part of the Downgradient Investigations, additional geophysical data are being generated and more extensive surface water sampling is being conducted. Data gap analyses were conducted for NDEP by several consultants (Environ 2015 and Broadbent 2015) that presented perceived data gaps and various recommendations on how to address those data gaps. The recommendations presented in these data gap analyses were considered in the development of this DGIP. Additional downgradient geophysical investigations are being conducted under a separate work plan to evaluate paleochannels.

Additional groundwater and lithology data are needed in target areas to refine the CSM and to further the understanding of perchlorate flux to the LVW. The installation of the proposed ten Phase I wells will provide lithologic data, soil property data, and groundwater elevation and chemical data that will be used to identify areas of potential groundwater flux to the LVW.

3.2 Identify the Goals of the Study

Principal Study Questions:

- Where are additional data needed to identify areas of potential perchlorate flux to the LVW?

The program will provide data to supplement the existing database of analytical concentrations in groundwater in the Downgradient Study Area. Specifically, the field data will be collected to:

- Provide additional data to refine CSM; and
- To identify areas of potential perchlorate flux to the LVW.

Groundwater collected from the new wells will be analyzed for perchlorate, chlorate, chloride, bromide and total dissolved solids, total chromium, and hexavalent chromium. These analytes have been analyzed previously in groundwater and/or surface water, and new data will be used to establish patterns of concentrations. In addition, a more accurate understanding of the extent and migration pathways for these chemicals, with an emphasis on perchlorate, will be applicable to other site-related chemicals. Analytical methods are provided in **Table 3**. In addition, 17 existing wells near the LVW will be sampled, but these will only be analyzed for the key constituents (perchlorate and chlorate).

3.3 Identify the Information Inputs

Information required to answer the study questions will include existing field data and data to be obtained from the planned sampling event.

Historic groundwater and surface water data were collected by SNWA, Kerr McGee, Tronox, NERT and, most recently in April/May 2016, by AECOM. Groundwater samples have been collected from wells along the LVW, but often not during the same sampling event or not from wells in the Downgradient Study Area. Recently collected data in the Downgradient Study Area include April 2016 groundwater samples from 61 wells, and May 2016 surface water samples consisting of 14 samples from the LVW, and 7 samples from LVW tributaries and 3 seep locations along the LVW. These data were used in conjunction with the historical data to provide a more refined view of the perchlorate concentrations and other constituents in the Downgradient Study Area and the LVW. Based on these data, it was determined that perchlorate and chromium concentrations have generally decreased over time. Groundwater concentrations varied throughout the Downgradient Study Area and concentrations throughout the reach of the LVW sampled also varied, with higher concentrations indicating potential perchlorate discharge between Calico Ridge Weir and Three Kids Weir (**Figure 6**).

3.4 Define the Study Area Boundaries

Step 4 of the DQO process is to define the boundaries of the study area. The boundary of the Downgradient Study Area for the RI includes the LVW north, west and east of the Off-Site NERT Study Area (**Figure 1**). New wells to be installed and sampled as part of this DGIP are located within the Downgradient Study Area, between the Pabco Road Erosion Control Structure and Three Kids Weir (**Figure 7**).

3.5 Develop the Analytic Approach

Step 5 of the process involves designing the approach to answer the questions and achieve the goals. QA/QC is considered during the design process. **Table 2** provides the rationale for each of the ten proposed monitoring wells. The ten wells are located within areas where groundwater, for the most part, exhibits perchlorate concentrations of 1,000 µg/L or higher and the surface water sampling indicates there is perchlorate flux to the LVW. Details are provided in **Table 2** and, as indicated, some wells are positioned to measure the change in perchlorate concentration between two wells (**Figure 7**).

Groundwater samples will be collected from each new well using low-flow sampling techniques similar to those used in the April 2016 sampling event and elsewhere in the NERT RI study areas. The goal of this program is to collect groundwater data from areas where data gaps exist. Samples from new wells will be analyzed for perchlorate, chlorate, chloride, bromide and total dissolved solids, total chromium, and hexavalent chromium. Methods are provided in **Table 3**. In addition groundwater samples will be collected from 17 existing nearby wells along the LVW and analyzed for perchlorate and chlorate only (**Table 4**).

Project reporting limits are provided in the QAPP. QA/QC samples will be analyzed with the groundwater samples for each analytical method, as defined in the QAPP and as described below in Section 6.7. QA/QC samples will include field duplicates (FDs); field blanks (FBs), laboratory duplicates, laboratory control and matrix control spikes, and equipment blanks (EBs). Data verification and validation protocols are detailed in the QAPP and described below in Section 6.8.

3.6 Specify Performance or Acceptance Criteria

Step 6 of the process outlines the performance and acceptance criteria for the study. Major sources of uncertainty are identified and the measures taken to minimize the impacts of these uncertainties are defined. Uncertainty is always present in the measurement and interpretation of environmental data. In this case, the focus is on collecting and interpreting data to better characterize the nature and extent of contamination including identification of potential sources (i.e., contaminated groundwater discharge).

In the absence of defined decision tolerance limits, the sampling design should still strive to identify possible sources of error and minimize them, to the extent practical. The most significant type of error that may be encountered includes that of field sampling. Both random and systematic errors can be introduced during the physical collection of the sample, sample handling, sample analysis, and data handling.

Errors introduced through these steps will be controlled by preparing and following standard operating procedures (SOPs), and establishing appropriate controls for data quality. These controls apply to field procedures (e.g., adherence to SOPs, field equipment calibration, and FDs), laboratory analytical errors (e.g., calibration standard, internal standard, surrogate recoveries, and laboratory control samples [LCS]), and data validation. The QAPP provides further detail on error control procedures, both in the field and in the laboratory, and details the target detection limits for the analytes.

4.0 Monitoring Well Installations, Sampling Objectives and Locations

Sampling objectives for the Phase I groundwater monitoring well installation are discussed in the following subsections. In addition, the new well locations and the rationale for the locations are described in these subsections.

4.1 Phase I Groundwater Monitoring Well Installation Objectives

The objective of the Phase I groundwater monitoring well installation is to address several key data gaps identified along the LVW with regard to perchlorate concentrations that are likely sources of flux of perchlorate to the LVW. This Phase I investigation is the first step in addressing these data gaps and subsequent investigation (Phase II) will be needed. Groundwater data collected in April 2016 from 61 wells in the Downgradient Study Area showed a wide range of perchlorate concentrations. As an example, concentrations of perchlorate differed from 270 milligrams per liter (mg/L) in WMW4.9S to 3,800 mg/L in WM-13, two wells that are located approximately 600 feet apart. To help determine lateral changes between wells, further characterize impacts, and assist in the future evaluations of potential flux, ten groundwater wells will be installed within the Downgradient Study Area along the LVW under this Phase I data gap investigation (**Table 2 and Figure 7**). These new wells will be used in conjunction with a selection of existing nearby monitoring wells to monitor groundwater levels and chemical concentrations near the LVW. The new wells will help fill in some of the spatial gaps in the existing groundwater well network. Information collected from the new well locations will help identify and refine the locations where additional Phase II wells will be needed to further assess impacts and flux to the LVW. Following installation and development the new wells will be sampled along with 17 existing wells along the LVW (**Figure 9 and Table 4**).

4.2 Rationale for Phase I Well Installation Locations

Perchlorate concentrations obtained from the April and May 2016 groundwater and surface water analysis were used to identify key locations along the LVW where data gaps exist that could be addressed by the installation of groundwater monitoring wells completed in the shallow (0 – 90 feet below ground surface) water bearing zone (**Figure 7**). In addition, historical data and recommendations presented in the data gap technical memorandums were also evaluated (Broadbent 2015 and Environ 2015). **Figure 7** shows the locations of the proposed ten groundwater monitoring wells in relation to the perchlorate concentrations present in April and May 2016 in groundwater, surface water and seeps. **Figure 8** shows the geology, proposed Phase I wells, and the perchlorate concentrations in groundwater from April 2016. **Table 2** presents the rationale for the installation of each well.

Although it is anticipated that over 20 new wells will be needed to address existing data gaps, a phased approach is proposed to focus the data collection effort. Phase I will consist of installing ten new groundwater monitoring wells along the LVW in the areas of greatest interest and potential largest perchlorate flux to the LVW (**Table 2**). Based on the data obtained from these wells a plan for the Phase II well installation will be prepared.

4.3 Groundwater Sampling Activities

The ten groundwater monitoring wells to be installed as part of this DGIP will be developed and sampled. All ten wells are located within the Downgradient Study Area along the north and south banks of the LVW. A list of the proposed wells to be sampled and which constituents will be analyzed for by well is presented in **Table 4**. The well locations are shown on **Figures 7 and 8**. A typical well construction diagram is provided in **Figure 10.** Groundwater samples will be analyzed for the following constituents:

- Perchlorate (EPA Method 314.0);
- Chlorate (EPA Method 300.1);

- Chromium, Dissolved (EPA Method 200.8 [ICP-MS]);
- Hexavalent Chromium, Dissolved (Method 218.7);
- Chloride (EPA Method 300.0);
- Bromide (EPA Method 300.0); and
- Total Dissolved Solids (Method SM 2540C).

To obtain a more complete picture of the perchlorate and chlorate concentrations in groundwater along the LVW, 17 wells are proposed to be sampled simultaneously with the ten new wells (**Figure 9**). These wells will only be analyzed for perchlorate and chlorate.

As directed by NDEP on November 18, 2015, field-filtering of water samples for perchlorate analysis is not required (NDEP 2015). Filtering for chromium analysis will be conducted in the field using a 0.45-micron filter. Details of the analytical methods to be used are provided in **Table 3**. Groundwater sampling procedures are described in Section 5.6.

5.0 Well Installation and Sampling Procedures and Equipment

Monitoring well installation, well development, sampling and other data collection equipment and associated procedures are described in the following sections. Sampling equipment will generally include pumps (with dedicated tubing) or bailers for groundwater sampling. Water levels will be measured using hand-held electronic water level sounders during groundwater sampling. Sampling methods and materials are generally based on the EPA publication SW-846, Test Methods for Evaluating Solid Waste, Physical/Chemical Methods (EPA 1997).

To maintain consistency in the methods applied in the field for this assessment, field activities will adhere to the procedures described in relevant Field Guidance Documents (FGDs) in the Field Sampling Plan for the NERT RI/Feasibility Study (ENVIRON 2014). The relevant FGDs for this DGIP are provided in **Appendix B,** including a memorandum titled Modified Groundwater Sampling Techniques for Wells with Slow Recharge Rates approved by NDEP on May 2, 2016.

5.1 Documentation Procedures

Records that may be generated during field work include field logs, photographic logs, boring logs, sample chain-of-custody records, equipment inspection/calibration records, and others, as necessary. Units of measure for any field measurements and/or analyses will be clearly identified on the field forms and in notes and logs as necessary. The QA/QC Officer, or other appropriate person designated by the AECOM Project Manager, will review the field data to evaluate the completeness of the field records.

5.1.1 Field Data Sheets

Field data sheets will be completed by field personnel during sample collection activities. The types of field data sheets used include boring logs, well construction diagrams, well development records, groundwater sampling logs and well inspection forms. Copies of the data sheets, as appropriate, will be provided in an appendix to the technical memorandum that presents the results of this assessment. Example field data sheets are provided in **Appendix C**.

5.1.2 Field Notes

Field logbooks will provide the means of recording data collection activities at the time they take place. The logbooks will be bound field survey notebooks assigned to field personnel, but they will be stored with the project files in a centralized document repository at an AECOM office location when not in use. Activities will be described in as much detail as possible such that the activity being described can be reconstructed without reliance on memory. Entries will be made in language that is objective, factual, and free of personal opinions or terminology that might later prove unclear or ambiguous.

The cover of each logbook will be identified by the project name, project-specific document number, and the time period which the logbook describes (beginning and end dates). The title page of each logbook will have contact information for the AECOM Project Manager. Entries into the logbook will contain a variety of project-specific information. At the beginning of each entry, the date, start time, weather, names of all team members present, level of personal protection being used, and the signature of the person making the entry will be entered. Names and affiliations of visitors to the Downgradient Study Area and the purpose of their visit will be recorded.

Entries will be made in ink, signed and dated and no erasures will be made. If an incorrect entry is made, the information will be crossed out with a single strike mark, initialed, and dated by the user. Whenever a sample is collected or a field water quality measurement is made it shall be recorded. Photographs taken will be identified by number and a description of the photograph will be provided. Equipment used to conduct water quality measurements will be identified including serial number and any calibration conducted will be recorded.

5.1.3 Photographs

Digital photographs will be taken to supplement and verify information entered into field logbooks. Photos of sonic drill cores will be labeled for depth intervals and provided for reference. For each photograph taken, the following will be recorded in the field logbook:

- Date, time, and location;
- Number and brief description of the photograph; and
- Direction in which the photograph was taken, if relevant.

If a number of photographs are taken during a task, general notes will be sufficient on the group of photographs taken, so long as the information outlined above can be inferred from the information provided for each photograph.

5.2 Instrument Calibration Procedures

Instruments requiring calibration include water quality meters (e.g., pH, dissolved oxygen, specific conductivity, and turbidity meters). Equipment that can be field calibrated will be calibrated at least once per day prior to beginning sampling activities, with calibration results documented in the field logbook. Equipment that must be calibrated in a laboratory setting will be used only if a current calibration certificate is available (for example, a calibration certificate is provided with a piece of rental monitoring equipment). Calibration procedures will be consistent with manufacturer instruction manuals for each instrument. Calibration and maintenance procedures for field equipment are detailed in the QAPP.

5.3 Decontamination Procedures

Non-dedicated, drilling, sampling and monitoring equipment that is exposed to environmental contaminants will be thoroughly decontaminated prior to first use and between uses. At a minimum, decontamination procedures will include scrubbing the equipment with a brush or sponge in a solution of Alconox™ detergent (or equivalent) in potable water, followed by two rinses in distilled or deionized water.

Equipment that is new from the factory must be wrapped in plastic as it is being transported to the Downgradient Study Area. If equipment is not wrapped in plastic during transport it must be decontaminated prior to use.

Instructions and guidance for decontamination of sampling equipment is included in each SOP that pertains to sampling or testing of environmental media. SOPs/FGDs[1] are provided in the QAPP; well installation, well development, and groundwater well sampling FGDs are provided in **Appendix B**.

5.4 Investigation-Derived Waste Management

In general, investigation-derived waste (IDW) for the installation of wells will consist of soil cuttings and of purged groundwater for the sampling activities. Other IDW generated during these activities includes equipment cleaning water and used personal protective equipment (PPE) (disposable nitrile gloves) and household trash such as used paper towels, etc.

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[1] SOPs refer to procedural documents developed by AECOM for this program. FGDs are procedural documents already provided for this program by ENVIRON International Corporation.

The liquid IDW will be temporarily placed into a polyethylene tank; at the end of each day, the liquid IDW will be taken to the groundwater extraction and treatment system at the NERT Site and discharged into the GW-11 pond, which receives groundwater pumped from extraction wells at the Seep Area and Athens Road Well Fields.

Soil cuttings from the installation of groundwater wells will be placed in 55-gallon steel drums, or other appropriate containers. The drums or containers will be sealed and labeled “Pending Analysis” until analytical data is obtained to represent the IDW. Labels will include the contents of the container (e.g., soil cuttings), the origin of the material (e.g., Downgradient Study Area soil sampling), the date(s) the IDW was generated, and a contact phone number for the Generator (i.e., NERT) of the material.

Soil-filled drums will be transported to a secured staging area at the NERT facility at the end of each day. The staging area at the NERT facility will be a designated section of the property where drums will be temporary stored until cuttings are ready for loading, off-site transportation, and disposal. NERT will sample and analyze the contents of the drums to develop a waste profile for disposal and will arrange for transport and disposal of the IDW.

The remaining IDW will be double-bagged in plastic trash bags and will be disposed as municipal trash. The FGD for IDW management is provided in the **Appendix B**.

5.5 Well Installation Procedures

All well installation activities must comply with the latest versions of the HASP (AECOM 2016e) and QAPP (AECOM 2016d). Field staff needs to take care to ensure skin does not contact the water or soil. Appropriate PPE, as described in the HASP, will be used.

5.5.1 Pre-field Activities

A site-specific HASP has been developed for the Downgradient Study Area and the planned field work. The existing NERT RI QAPP has been adapted to include the proposed Downgradient Study Area investigations, including the proposed well installations described in this DGIP.

Access to properties where new groundwater wells will be installed will be obtained by AECOM. The new wells are located on U.S. Bureau of Reclamation (BOR) lands; therefore, an Application for Transportation and Utility Systems and Facilities on Federal Lands Standard Form-299 permit application will be submitted. Issuance of this permit allows work to proceed per requirements noted in permit. NDEP, EPA, NERT, BOR and applicable stakeholders, including the U.S. Fish and Wildlife service, property owners and well owners will be notified of the well installation and sampling schedule. AECOM, in conjunction with the drilling subcontractor, will obtain the standard well drilling approvals from the Nevada Division of Water Resources.

At least 5 business days prior to the start of ground-disturbing activities, a notification will be made to Nevada’s “Call Before You Dig” service to have utilities in vicinity of the proposed well marked. A utility geophysical clearance survey, with a magnetometer or similar devise, will be conducted at each boring location. The top 6 feet of the borehole will be hand augured to minimize the possibility of hitting any subsurface utilities. For worker safety and fire prevention, all or part of the drilling area will be cleared of vegetation.

5.5.2 Field Activities

Soil borings will be advanced using the rotary sonic drilling method. This is the preferred method due to relative ease of use, speed, and presence of an outer casing in the drill tooling. Equipment that comes in contact with impacted soil or water will be decontaminated prior to drilling and decontaminated between boreholes.

Each well borehole will be completed to depths up to 70 feet below ground surface or until the UMCf or bedrock such as the Horse Spring formation or the Thumb formation is encountered whichever comes first (**Table 2**). In the Downgradient Study Area the UMCf is typically composed of mudstone and is easily distinguished from the overlying alluvial sands and gravels. It is possible that some coarse grained UMCf facies may be encountered and they are distinguished from the alluvial sands and gravels by the presence of volcanic clasts. The Horse springs formation is present at about RM 4.6 and consists of interbedded limestone, dolomite, calcareous sandstone, siltstone and mudstone. The Horse Springs formation also includes andesite sills. It can be recognized by very thin bedded, fissile, siltstone and claystone beds (GES 2007). The Thumb formation is present along the LVW from approximately RM 3.5 to 4.5 and includes three bedrock sequences as described by GES (2007 and 2008) (**Figure 8**). The upper bedrock sequence is composed of silica cemented breccia with gneiss, schist and granite clasts. The middle sequence is 20 to 30 feet thick and is composed of thinly bedded pink to reddish claystone and siltstone. The lower sequence is composed of red to reddish brown, interbedded sandstone, siltstone, and claystone. It is weakly to moderately cemented. The lithology at each soil boring will be logged by a geologist using the Unified Soil Classification System.

The total depth of each boring will be determined in the field based on if and where the UMCf or other bedrock such as the Horse Spring or Thumb formation is encountered. The boreholes will be 12 inches in diameter. In order to reach bedrock, well depths are anticipated to be between 40 and 60 feet below ground surface (**Table 2**). If needed, these depths can be adjusted in the field based on site-specific field conditions such as depth to groundwater and where the bedrock formation is encountered. The borehole will be backfilled to the desired total depth of the well using cement grout placed using a tremmie pipe. Wells will be constructed of 4-inch diameter schedule 40 PVC with a screened interval of 10 feet. The length of the screen interval may be modified depending on field conditions encountered. The well depth and screened interval have been selected to match the surrounding wells and to intercept the same flow zone of interest. This is because the purpose of the well is to determine the change in concentration between two or more wells. Subsequent investigations conducted under Phase II may explore longer or shorter wells screens, multiple well screens and pump tests. Filter pack material will be Monterey #3 sand and will extend at least 1 foot above the well screen. A minimum 2-foot hydrated bentonite seal will be placed above the filter pack and the annular space will be backfilled with bentonite cement slurry to the surface. Well completions will be above ground with approximately 3 feet of mild steel casing and lockable well cap above grade with four protective posts installed around each well. Steel casing and protective posts will be painted yellow to improve their visibility. A conceptual well construction diagram is provided in **Figure 10.**

No sooner than 72 hours after construction, the wells will be developed by bailing and surging to remove fine particles that may have gotten into the well or filter pack. Well development will continue until the water is clear and field parameters have stabilized or it has been conducted for 4 hours whichever occurs first. Stabilization of field parameters is over three readings and is as follows: pH ± 0.1, Temperature ± 1 degree Celsius, Specific Conductivity, Dissolved Oxygen, Oxygen Reduction Potential and Turbidity within ± 10 percent. The following FGDs are provided in **Appendix B**:

- Managing Investigative derived waste,
- Drilling and destruction of soil borings,
- One time “grab” groundwater sampling,
- Low-Flow groundwater sampling,
- Groundwater well installation,
- Groundwater well development,
- Groundwater and free product level measurements, and
- Aquifer hydraulic testing.

5.5.3 Soil Property Testing

Soil property samples will be collected from each boring location. One soil sample will be collected from the unsaturated zone and up to five samples will be collected from the saturated zone. The samples locations will be selected by the field geologist and the task lead based on field observations. In general, samples will be collected where a lithologic change is observed. The soil property testing will include grain-size distribution (ASTM-D422 or D446M), moisture content (ASTM-D2216) and Atterberg Limits (ASTM D4318) will be used to confirm the field lithologic observations during the drilling of the well borings. In addition, these properties will be useful in the interpretation of future full-scale geophysical testing to be performed in several areas of the Downgradient Study Area.

Approximately 2.5 pounds of soil will be collected for each sample. Soil from the Sonic soil core will be placed in a bulk soil collection bag or Ziplock bag for transport to the soil testing laboratory. Samples do not need to be preserved on ice as no chemical analysis will be conducted on these samples. Samples will be identified using the identification system noted in Section 6.1.1. Samples will be shipped under chain-of-custody protocols to PTS Laboratories in Santa Fe Springs, California.

5.5.4 Induction Logging of Bore Holes

Induction logging will be conducted at each new well after the well has been constructed. Data collected through induction logging will be used to verify lithologic boundaries identified during field logging of the bore hole. This logging method records conductivity data and is practical for this application as data can be recorded through the well casing and the interpretation is not affected by the gravel pack around the well screen. Induction logs will be included in an appendix to the technical report.

5.5.5 Transducer Installation

Transducers will be installed in each well following sampling for chemical analysis. The transducer automatically records and stores the groundwater level data. The data can be accessed by direct download from the transducer at the surface.

Prior to the installation of the transducer and again following installation of the transducer, a manual groundwater level measurement will be collected using a water-level sounder. Static groundwater level readings will be measured and recorded to the nearest 0.01 foot from the surveyed reference mark on the top edge of the inner well casing. If no reference mark is present, the measurement should be taken from the north side of the inner casing and the location noted in the field notes. Manual water levels will be recorded in each well monthly while the transducers are in use. This will provide comparison data in case the transducer instrument starts to drift. Manual water levels will be collected when the data are downloaded as well. The monthly download of data from these wells will be synced to the downloading of transducer data from wells equipped with transducers as part of the Data Gap Investigation.

The installation of each dedicated transducer typically consists of placing the transducer at approximately 20 feet below the top of the water table and securing the transducer with a cable within the well head. As shown on **Table 1,** some wells have less than 20 feet of water column so for these wells the transducer will be placed approximately 2 feet above the bottom of the well. For each well, the depth below the groundwater level and elevation of the transducer will be recorded in the field notes. The transducer cable will be secured in the well with the well cap.

Each transducer will be programmed to record pressure at a frequency of every 15 minutes (96 times per day). Automated readings from the transducers will need to be corrected for barometric pressure fluctuations. Barometric data will be available from the barometer in well WMW4.9S. Transducers will remain in the wells for approximately 6 months.

5.5.6 Surveying and identification of New Groundwater Well Locations

The new groundwater monitoring wells will be identified as NERT (as the owner) followed by the approximate RM to the nearest hundredth of a mile, followed by the N or S for the north or south side of the LVW, followed by 1,2,3, etc. for the number of wells within that hundredth of a RM. For example the easternmost Phase I monitoring well would be identified as follows: NERT-5.91S1. Once installation of a well is complete, groundwater well locations and elevation (surface and top of casing) will be surveyed by a licensed land surveyor. Locations will be referenced to the State Plan Coordinate System and elevations will be referenced to the North American Datum 83 Nevada East Zone (2701) with vertical datum based on NAVD 88 referenced to the City of Henderson Benchmark network. These are the systems that are used for the NERT RI.

5.6 Groundwater Sampling Procedures

5.6.1 Pre-Field Activities

A site-specific HASP (AECOM 2016e) and QAPP (2016d) have been developed to specify procedures to be used during implementation of this DGIP. Field personnel are provided copies and/or electronic access to these documents. Field personnel review and sign the acknowledgement page (Chapter 10) in the HASP stating they understand its contents and will comply with the provisions contained therein.

Access to properties where the groundwater wells are located will be obtained by AECOM. NDEP, EPA, NERT, BOR and applicable stakeholders, including the U.S. Fish and Wildlife service, property owners and well owners will be notified of the groundwater sampling schedule.

5.6.2 Field Activities

Groundwater sampling activities will be conducted under the requirements of the Standard Form-299 permit issued by BOR. Groundwater sampling will be conducted using the “low-flow” method (in which low volumes of water are purged with little or no drawdown, while allowing water quality field parameters to stabilize as specified in the field guidance document, if achievable between three successive measurements. If field parameters do not stabilize by the time six volumes have been purged, then final water quality parameters will be recorded and a sample of groundwater collected. Low-flow groundwater samples may be collected using a bladder pump. The pump intake will be positioned at the approximate midpoint of the well screen.

Some groundwater wells may be drawn down at pumping rates as low as 50 milliliters per minute (mL/min) due to slow recharge rates possibly caused by the low hydraulic conductivity of the formation and/or fouling of the well screen and gravel pack. If drawdown in a well occurs while pumping at 100 mL/min during purging of the well, the following modified sampling techniques should be used:

- Purge the complete pump system (hoses and flow-through cell).
- Record Field Parameters – collection of only one to two readings is acceptable. Field parameters do not need to stabilize before collecting a sample.
- Collect sample after pump system (pump and lines) has been purged completely.

These modified sampling procedures were implemented during the groundwater sampling program conducted by AECOM in April 2016. Implementation of these procedures reduced sampling times and minimized the volume of purge water generated. These sampling techniques are consistent with those used at the NERT site wells with slow recharge rates are encountered. A memorandum documenting the changes to the groundwater sampling techniques for wells with slow recharge rates was submitted to NDEP on April 28, 2016, and approved by NDEP on May 2, 2016. This memorandum is included in **Appendix D**.

During groundwater sampling, a water quality meter (equipped with a flow-through cell) will be used during purging to track water quality field parameters and assess when stabilization of parameters has occurred. Samplers will conduct in-field measurements for depth to water; pH, electrical conductivity, dissolved oxygen, oxidation-reduction potential, turbidity and temperature of groundwater samples. An appropriate water quality meter, calibrated as recommended by the manufacturer, will be used. The FGD for low-flow groundwater sampling is included in **Appendix B**.

Groundwater samples obtained from the ten new wells for analyses of total chromium (i.e., combined trivalent and hexavalent chromium) and hexavalent chromium will be filtered in the field using a 0.45-micron filter. Groundwater samples designated only for hexavalent chromium analysis will be analyzed within 24 hours of sample collection or the sample will be preserved by pH adjustment upon arrival at the laboratory (i.e., within 24 hours after sample collection) to allow for a longer holding time.

5.6.3 Water Level Measurements

During each monitoring event, groundwater monitoring wells will be sounded for depth to water from top of casing. An electronic sounder or interface probe, accurate to the nearest ± 0.01 feet, will be used to measure depth to water in each well. The electronic sounder or interface probe will be lowered down the casing to the top of the water column, and the graduated markings on the probe wire or tape will be used to measure the depth to water from the surveyed point on the rim of the well casing. The FGD for groundwater level measurements is included in **Appendix B**.

6.0 Sample Designation, Handling and Analysis

In general, field sampling personnel and subcontracted analytical laboratories will handle samples in a manner to maximize data quality. Samples will be collected, handled, and stored in such a manner that they are representative of their original condition and chemical composition. Identification of samples and maintenance of custody are important elements that will be utilized to ensure samples represent groundwater conditions in the locations sampled. All samples will be properly identified and maintained under chain-of-custody protocol to protect sample integrity. The following sections discuss the sample handling and custody requirements in detail. It should be noted that this information is also provided in the QAPP where appropriate, and is included in this DGIP for ease of use by field staff during the investigation.

6.1 Sample Identification

To maintain consistency, a sample identification convention has been developed and will be followed throughout the implementation of the DGIP. The sample identification numbers (IDs) will be entered onto the sample labels, field forms, chain-of-custody forms, logbooks, and other records documenting sampling activities.

The identification system for primary field samples from a groundwater well consist of the well ID followed by the sample date in YYYYMMDD format. For example, a groundwater sample collected from monitoring well NERT5.91S1 on June 28, 2017, will be identified as NERT5.91S1-20170628.

The identification system for primary field samples from soil borings will consist of the well ID followed by the depth that the sample was collected and then the sample date in YYYYMMDD format. For example, a soil sample collected from well NERT5.91S1 at a depth of 50 feet below ground surface on June 28, 2017, will be identified as NERT5.91S1-50’-20170628.

6.1.1 Field QA/QC Sample Identification Numbers

Field QA/QC samples and procedures are discussed in Section 6.7. The field QC sample codes that may be applied include:

- EB for Equipment Blanks,
- FB for Field Blanks, and
- FD for Field Duplicates.

Field QA/QC sample codes will be appended to the end of the primary sample ID that is represented by the field QA/QC sample.

An EB should be named for the sample collected immediately prior to the collection of the EB.

The FB represents a group of samples: a batch of 20 for the FB. Thus, the FB should be named after the first sample of the batch.

The FD represents the primary sample that is being duplicated, thus the FD should be named after the corresponding primary sample.

For example, the first groundwater sample to be placed in a cooler is NERT5.91S1-20170628. The sample is to be analyzed for perchlorate, and a duplicate sample is collected. A FB is placed in the cooler with the sample, and an EB is collected immediately following the collection of the soil sample (after decontamination of sampling equipment). The associated field QA/QC samples will be identified as:

- NERT5.91S1-20170628.-EB (Equipment Blank);
- NERT5.91S1-20170628.-FB (Field Blank); and
- NERT5.91S1-20170628.-FD (Field Duplicate).

Field QA/QC samples and the frequencies of collection are summarized in Section 6.7 of this DGIP and detailed in the QAPP.

6.2 Sample Labels

A sample label will be affixed to all sample containers sent to the analytical laboratory. Field personnel will complete an identification label for each sample with the following information written in waterproof, permanent ink:

- Client name (“NDEP”) and project number;
- Sample location;
- Unique sample identifier;
- Date and time sample collected;
- Filtering performed, if any;
- Preservative used, if any;
- Name or initials of sampler; and
- Analyses or analysis code requested.

The use of pre-printed sample labels is preferred in order to reduce sample misidentification problems due to transcription errors. Sample labels must be completed and affixed to the sample container in the field at the time of sample collection.

If errors are made on a sample label, corrections will be made by drawing a single line through the error and recording the correct information. All corrections will be dated and initialed.

6.3 Containers, Preservation, and Hold Time

The analytical methods, type of sample containers to be used for each sample type and analysis, preservation requirements for all samples, and holding times are provided in the QAPP.

Each lot of preservative and sampling containers will be certified as contaminant-free by the provider and/or the laboratory. The laboratories will maintain certification documentation in their files. Preserved samples will be clearly identified on the sample label and chain-of-custody form. If samples requiring preservation are not preserved, field records will clearly specify the reason for the discrepancy.

Groundwater sample containers will be placed in airtight plastic bags, if possible, and refrigerated or placed in a cooler with ice to chill and maintain a sample temperature of 4 degrees (± 2 degrees) Celsius.

The time from the collection of the sample to the analysis is defined as the holding time.

6.4 Sample Handling and Transport

Proper sample handling techniques are used to ensure the integrity and security of the samples. Field parameters will be measured prior to sample collection in the field by the sampling crew and recorded in the field logbook and field data sheets. Samples for laboratory analysis will be transferred immediately to appropriate laboratory supplied containers in accordance with the following sample handling protocols:

- The Sampler will don clean gloves before touching any sample containers, and take care to avoid direct contact with the sample.
- Samples will be quickly observed for color, appearance, and composition and recorded as necessary.
- The sample container will be labeled before or immediately after sampling in accordance with Section 6.2 of this DGIP.
- Sample containers will be placed in Ziploc™-type plastic bags. The samples will be placed in an ice chest and cooled to 4 degrees (± 2 degrees) Celsius or lower for transport to the laboratory.
- All sample lids will stay with the original containers, and will not be mixed.
- Sample bottles will be wrapped in bubble wrap as necessary to minimize the potential for breakage or damage during shipment.
- The chain-of-custody form will be placed in a separate plastic bag and taped to the cooler lid or placed inside of the cooler. A custody seal will be affixed to the cooler.

The Samplers are responsible for proper handling practices until receipt at the laboratory, or by the courier, at which time the Laboratory Project Manager assumes responsibility of the samples through analysis and ultimately to the appropriate disposal of samples. Sample handling procedures specific to the laboratory are described in the individual laboratory QA Manuals provided in the QAPP.

6.5 Sample Custody

Standard sample custody procedures will be used to maintain and document sample integrity during collection, transportation, storage, and analysis. Custody documents must be written in waterproof, permanent ink. Documents will be corrected by drawing one line through the incorrect entry, entering the correct information, and initialing and dating the correction. The AECOM Project Manager is responsible for proper custody practices so that possession and handling of individual samples can be traced from the time of collection until receipt at the laboratory, or by the courier. The Laboratory Project Manager is responsible for establishing and implementing a control system for the samples in their possession that allows tracing from receipt of samples to disposal.

The chain-of-custody form provides an accurate written record that traces the possession of individual samples from the time of collection in the field until they are accepted at the analytical laboratory. The chain-of-custody form also documents the samples collected and the analyses requested. The Sampler will record the following information on the chain-of-custody forms:

- Client and project number;
- Name or initials and signature of Sampler;
- Name of destination analytical laboratory;
- Name and phone number of Project Manager and Deputy Project Manager in case of questions;
- Unique sample identifier for each sample;
- Data and time of collection for each sample;
- Number and type of containers included for each sample;

- Analysis or analyses requested for each sample;
- Preservatives used, if any, for each sample;
- Sample matrix for each sample;
- Signatures of all persons having custody of the samples;
- Dates and times of transfers of custody;
- Shipping company identification number, if applicable; and
- Any other pertinent notes, comments, or remarks.

Unused lines on the form will be crossed out and initialed.

A sample is considered to be under the control of, and in the custody of, the responsible person if the samples are in their physical possession, locked or sealed in a tamper-proof container, or stored in a secure area.

The person who collects the sample is the initial custodian of the sample. Any transfers are documented on the chain-of-custody form by the individuals relinquishing and receiving the sample, along with their signature, and the date and time of transfer. This transfer must continue until the custody is released to a commercial carrier (i.e. FedEx), or the laboratory (either at the laboratory or to a laboratory-employed courier). If relinquished to a commercial carrier, the carrier assumes custody through their shipping receipt. A copy of the shipping receipt should be attached to the chain-of-custody form as a permanent part of the custody control. If the sample is relinquished to a laboratory courier, the courier will then need to relinquish the sample to the stationary laboratory upon arrival. Once the sample has arrived at the stationary laboratory, it must be entered into the sample custody control system of the laboratory. If the sample is further transported to a subcontracted laboratory, the laboratory will produce an internal chain-of-custody form that will be available upon request. Chain-of-custody forms will be maintained in the digital project file by AECOM and at the analytical laboratory.

To discourage tampering during transport, a custody seal will be placed on each cooler after the samples are packed. These consist of a security tape or label with the date and initial of the sampler or person currently in possession of the sample. Receiving personnel at the laboratory will note on the cooler receipt form whether or not the custody seals are intact.

6.6 Field Measurement and Laboratory Analytical Methods

Field measurement methods and laboratory analytical methods will be utilized to analyze samples during implementation of the DGIP.

6.6.1 Field Measurement Methods

Samplers will conduct in-field measurements for depth of water; dissolved oxygen, pH, conductivity, turbidity, and temperature of the ground water for each well listed in Table 4. For field parameter measurements, an appropriate water quality meter, calibrated as recommended by the manufacturer, will be used. Meter calibrations and field measurements will be recorded on the appropriate field forms and/or in the field logbook.

6.6.2 Laboratory Analytical Methods

The Project will involve the analysis of groundwater samples for the target chemicals and physical parameters. The laboratory analytical methods that will be used to analyze samples are summarized in the QAPP and listed on **Table 3**. Additional information about each analytical method and sampling requirements such as containers, preservation, and hold times is provided in the QAPP (AECOM 2016d). Analytical methods and laboratory QA/QC procedures are further detailed in the QAPP.

6.7 Field QA/QC Procedures

Field QA/QC samples that will be collected during the proposed investigation include FD samples, FBs, and EBs. The description and purpose of these samples is discussed in this section. In addition, matrix spike/matrix spike duplicate (MS/MSD) samples and LCS/laboratory control sample duplicate (LCSD) procedures are used as laboratory control measures. While not defined as field QA/QC samples, they may require additional sample volume as described in Section 6.7.4.

6.7.1 Equipment Blanks

EB samples are used to assess the effectiveness of decontamination procedures. EB samples are obtained by filling decontaminated sampling equipment with reagent-grade deionized water, sampling this water, and submitting the sample for analysis. Alternatively, deionized water can be poured over or through the decontaminated sampling equipment and then collected and submitted for analysis. EBs will be collected at a frequency of one in every 20 samples and will be analyzed for the same suite of parameters as the primary sample to assess the effectiveness of decontamination procedures.

6.7.2 Field Blanks

FB samples are used to assess the presence of contaminants arising from field sampling procedures. FB samples are obtained by filling a clean sampling container with reagent-grade DI water, in the field at a sample location. The sample then is analyzed in the same manner as the primary sample. FB samples will be collected at a frequency of one in every 20 samples and will be analyzed for the same suite of parameters as the primary sample to assess potential background contamination or errors in the sampling process.

6.7.3 Field Duplicates

The FD is a replicate sample collected as close as possible to the same time that the primary sample is collected and from the same location, depth, or source, and is used to document analytical precision. FD samples will be labeled and packaged in accordance with the identification scheme provided in Section 6.1.1. FD samples will have “FD” appended to the sample ID. FDs will be collected at a frequency of one in every 10 primary samples and will be analyzed for the same suite of parameters as the primary sample. The relative percent difference (RPD) between the FD sample and the primary sample will be evaluated to assess the homogeneity of the sample matrix and to assess the reproducibility of laboratory and field sample collection techniques. As stated in the QAPP, the objectives for field sample RPDs are ≤30 percent for aqueous samples (AECOM 2016d).

6.7.4 Matrix Spike/Matrix Spike Duplicates and Laboratory Control Samples/Laboratory Control Sample Duplicates

The MS/MSD is an LCS on which additional QA/QC analyses are performed in order to assess the effect of matrix interference on the analytical results. MS/MSD procedures will be performed on field samples at a frequency of one per 20 samples. Field samples to be used for MS/MSD analyses must be collected with a double sample volume. Similarly, LCS/LCSDs provide controls during laboratory analysis and may also require additional sample volume to be collected in the field.

6.8 Data Validation

Data generated from sampling activities will undergo two levels of review. For these samples, laboratory deliverables equivalent to EPA Level IV will be provided. Approximately 90 percent of the data will be validated to NDEP Stage-2b and approximately 10 percent of data will be validated to NDEP Stage-4. Additional details regarding data validation are provided in the QAPP (AECOM 2016d).

7.0 Schedule and Reporting

It is anticipated that the activities described in this DGIP will begin after the DGIP has been approved, as applicable, by NDEP, EPA, and NERT, and U.S. Bureau of Reclamation (BOR) completes its National Environmental Policy Act (NEPA) Environmental Assessment (EA) of the proposed work in the Downgradient Study Area. It is further anticipated that the EA process will result in a Finding of No Significant Impact (FONSI) and that subsequently an access permit will be issued by BOR. Utility clearance and clearing of vegetation at the well locations will take approximately 2 weeks to complete. Well installation and development and groundwater sampling will take approximately 3 months to complete.

The groundwater samples will be analyzed by TestAmerica at their laboratory in Irvine, California, under a standard turnaround time of 7 business days. Due to the restrictions in holding time (i.e., 24 hours), hexavalent chromium samples will be analyzed at Silver State Analytical Laboratories in Las Vegas, Nevada. Standard turnaround time for Silver State Analytical Laboratories is 10 business days. Analytical results are expected to be completed and final laboratory reports received within two weeks of submittal of the last sample. Once the final laboratory results have been transmitted to AECOM, data validation will be performed, which is estimated to take one week. Soil property samples will be tested by PTS Laboratories in Santa Fe Springs, California, under standard turnaround time of 15 business days.

Maps showing groundwater concentrations of perchlorate and chlorate will be constructed to depict the current groundwater conditions and analyte concentrations within the Downgradient Study Area. Summary tables of the laboratory data will be prepared.

A technical memorandum will be prepared that will summarize the results of well installation and the groundwater evaluation in the new wells as well as the data obtained from the 17 existing wells. The technical memorandum will include a brief description of field methods used and will present the summary tables of analytical results and maps. The technical memorandum will also include copies of the field data sheets, the final laboratory report and data validation summary report.

A preliminary draft of the technical memorandum will be issued within approximately 3 weeks of completion of data validation for review by NDEP, NERT and EPA. Upon receipt of review comments, which will be consolidated by NDEP, responses to comments will be prepared for concurrence from NDEP, NERT and EPA. Once the responses to comments are approved by NDEP, NERT and EPA, a final draft will be submitted to stakeholder for review. Comments received from stakeholders will be addressed and a final technical memorandum will be distributed to NDEP, NERT, EPA, and other stakeholders. Data collected under this investigation will be used by NERT during the preparation of the RI Report.

A summary of the DGIP field implementation is provided by task below.

Task	Approximate Schedule from BOR Access Permit
Notifications, Utility Clearance and Vegetation Clearing Activities	3 weeks
Well Installation and Development Activities	8 weeks following utility and vegetation clearing activities
Groundwater Sampling Activities	2 weeks following completion of well installation
Laboratory Analytical Report	3 weeks following completion of groundwater sampling activities
Data Validation	2 weeks from receipt of final laboratory analytical reports
Draft Technical Memorandum	3 weeks from data validation

8.0 References

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Tables

Table 1
Existing and Proposed Weirs In and Near the Downgradient Study Area
NERT Remedial Investigation, Downgradient Study Area, Henderson, Nevada

Weir	Approximate Location (RM)	Year Completed
Duck Creek Confluence Weir	6.85	2013
Upper Narrows Weir	6.65	2013
Sunrise Mountain Weir	6.35	Proposed
Pabco Weir	6.05	2000
Historic Lateral Weir	5.4	2000
Historic Lateral Weir Expansion	5.25	Proposed
Bostick Weir	4.95	2003
Calico Ridge Weir	4.7	2004
Lower Narrows Weir	4.4	2011
Homstead Weir	4.1	2011
Demonstration Weir	near 3.6[1]	1999
Three Kids Weir	3.6	2015
Rainbow Gardens Weir	3.3	2004
Powerline Crossing Weir	3.2	2006
Fire Station Weir	2.9	2000

Notes:
RM = River Mile as measured from the historic high water level mark on Lake Mead
Locations of existing and proposed weirs provided on Figure 1.
[1] Demonstration Weir was moved in 2007 and ultimately replaced with Three Kids Weir.

Sources:

Las Vegas Wash Coordination Committee.
https://www.lvwash.org/html/being_done_stabilization_bed.html

Table 2
Proposed Phase I Groundwater Monitoring Wells
NERT RI - Downgradient Study Area
Henderson, Nevada

Proposed New Well	Borehole depth	Well Depth[1] in feet bgs	Well Diameter	Well Screen in feet bgs	Rationale Based on Perchlorate Concentrations Detected in Groundwater and Surface Water Samples Obtained April and May 2016	Geology and Approximate Distance from Pertinent Features
NERT5.91S1	70	50	4"	40 - 50	Determine perchlorate concentrations between COH2B1 (total well depth of 67 feet bgs and 5,600 µg/L) and WMW5.5S (total well depth of 38.3 feet bgs and 3,200 µg/L) to further characterize this area of perchlorate impact east of the seep well field. Surface water concentrations are 15 to 17 µg/L.	This well is in alluvium overlying the Muddy Creek formation 1,000 feet east northeast from well COH2B1 and 1,900 feet west southwest of well WMW5.5S. It is 450 feet west of a paleochannel identified by Ed Krish (2015).
NERT5.49S1	60	40	4"	30 - 40	Determine concentrations between WMW5.58S1 (total well depth of 40.95 feet bgs and 510 µg/L) and WMW5.5S (total well depth of 38.3 feet bgs and 3,200 µg/L) There is a significant drop off of concentration. This is an area identified as a paleochannel and there is a layer of coarse grained sediment, wash gravels, present. Placing a well in this area will help evaluate the significance of the wash gravels and further characterize perchlorate impacts. Surface water concentrations are 19 to 23 µg/L.	This well is in alluvium overlying the Muddy Creek formation 570 feet southeast from well WMW5.58S1 and 350 feet west northwest of well WMW5.5S. It is on a paleochannel identified by BRC (2007) and 250 feet northwest of a paleochannel identified by Ed Krish (2015).
NERT5.11S1	60	45	4"	35 - 45	Determine concentrations between proposed wells NERT5.49S1 and NERT4.93S1. Surface water concentrations are 19 to 23 µg/L.	This well is in alluvium overlying the Muddy Creek formation 1,700 feet northeast from proposed well NERT5.49S1 and 800 feet west southwest of proposed well NERT4.93S1. It is 380 feet west of a paleochannel identified by Ed Krish (2015).
NERT4.93S1	60	50	4"	40-50	Determine concentrations between MW-13 (total well depth of 49.4 feet bgs at 3,800 µg/L and WMW4.9S (total well depth of 46.75 feet bgs at 270 µg/L) to obtain additional data on the paleochannel and perchlorate impacts in the area. Surface water concentrations are 15 to 23 µg/L.	This well is in alluvium overlying the Muddy Creek formation 470 feet northwest from well MW-13 and 500 feet southwest of well WMW4.9S. It is 400 feet east of a paleochannel identified by Ed Krish (2015).
NERT4.71S1	60	50	4"	40-50	Determine concentrations between WMW4.9S (total well depth of 46.75 feet bgs at 270 µg/L) and proposed well NERT4.9-51S1 to obtain additional data on the paleochannel and perchlorate impacts in the area. Surface water concentrations are 15 to 44 µg/L.	This well is in alluvium overlying the Muddy Creek formation 65 feet northeast from well WMW4.9S and 1100 feet west southwest of proposed well NERT4.51S1. It is on a paleochannel identified by Northgate (2010), 150 feet northeast of a paleochannel identified by Ed Krish (2015), and 500 feet southwest of a paleochannel identified by BRC (2007).
NERT4.51S1	60	50	4"	40-50	Determine concentrations between proposed well NERT4.71S1 and LNDMW1 (total well depth of 61 feet bgs at 1,900 µg/L) to obtain additional data on the paleochannel and perchlorate impacts in the area. Surface water concentrations increase from 15 to 44 µg/L in this area.	This well is in alluvium overlying the Muddy Creek formation 1,150 feet east northeast of proposed well NERT4.71S1 and 1,000 feet west southwest of well LNDMW1. It is 600 feet northeast of a paleochannel identified by BRC (2007).
NERT4.38N1	60	55	4"	45-55	Determine concentrations west of LNDMW2 (total well depth of 55.05 feet bgs at 1,500 µg/L) to further characterize perchorate concentrations on the north side of LVW. Surface water concentrations increase from 15 to 44 µg/L in this area.	This well is in alluvium overlying the Thumb formation. It is 450 feet west from well LNDMW2 and 1,900 feet east northeast of well WMW4.9N.
NERT4.21N1	60	55	4"	45-55	Determine concentrations southeast of LNDMW2 (total well depth of 55.05 feet bgs at 1,500 µg/L) to further characterize perchlorate impacts on the north side of LVW. Surface water concentrations increase from 15 to 44 µg/L in this area.	This well is in alluvium overlying the Thumb formation 450 feet southeast from well LNDMW2 and 100 feet southeast of proposed well NERT4.38N1. This well is 1,400 feet southwest of a mapped fault within the Frenchmean Fault zone.
NERT3.80S1	60	60	4"	50-60	Determine concentrations between LNDMW1 (total well depth of 61 feet bgs at 1,900 µg/L) and WMW3.5S (total well depth of 59.8 feet bgs at 1,400 µg/L) on the south side of LVW to further characterize perchlorate impacts in the area. This well may also provide additional data regarding faulting in the area. Surface water concentrations are 35 to 50 µg/L.	This well is in alluvium overlying the Thumb formation. It is 2,550 feet east northeast from well LNDMW1 and 70 feet southwest of proposed well NERT3.65S1. It is between the projected traces of two mapped faults within the Frenchman Fault zone.
NERT3.65S1	60	60	4"	50-60	Determine concentrations southwest of WMW3.5S (total well depth of 59.8 feet bgs at 1,400 µg/L) near Three Kids Weir to further characterize perchlorate impacts in the area. This well may also provide additional data regarding faulting in the area. Surface water concentrations in LVW are 26 to 35 µg/L and there is a seep in this area (KM67) with a concentration of 1,400 µg/L.	This well is in alluvium over the Thumb formation. It is 500 feet south of the KM67 seep and is 25 feet southwest of well WMW3.5S. It is within Frenchman Fault zone as documented in the Demonstration Weir (Three Kids Weir) geotechnical report (GES, 2003).

Table 3
Analytical Methods for Groundwater Samples
NERT Remedial Investigation - Downgradient Study Area
Henderson, Nevada

Analytes	Matrix	Analytical Method	Analytical Laboratory
Perchlorate	Water	EPA Method 314.0 [(1)]	TestAmerica (Irvine, CA)
Chlorate	Water	EPA Method 300.1	TestAmerica (Irvine, CA)
Chromium (dissolved)	Water	EPA Method 200.8 (ICP-MS) [(2)]	TestAmerica (Irvine, CA)
Hexavalent Chromium (dissolved)	Water	EPA Method 218.7 [(2)]	Silver State Analytical (Las Vegas, NV)
Total Dissolved Solids (TDS)	Water	SM 2540C	TestAmerica (Irvine, CA)
Chloride	Water	EPA Method 300.0	TestAmerica (Irvine, CA)
Bromide	Water	EPA Method 300.0	TestAmerica (Irvine, CA)

Notes:

EPA = United States Environmental Protection Agency

SM = Standard Method

Groundwater samples will be analyzed for one or more of the constituents listed above.

(1) For this NERT RI Downgradient Study Area, field-filtering of sgroundwater samples for perchlorate analysis is not required (NDEP, 2015).

(2) Sampling activities for the NERT RI Study Area include field-filtering groundwater samples analyzed for chromium and hexavalent chromium using a 0.45 micron filter.

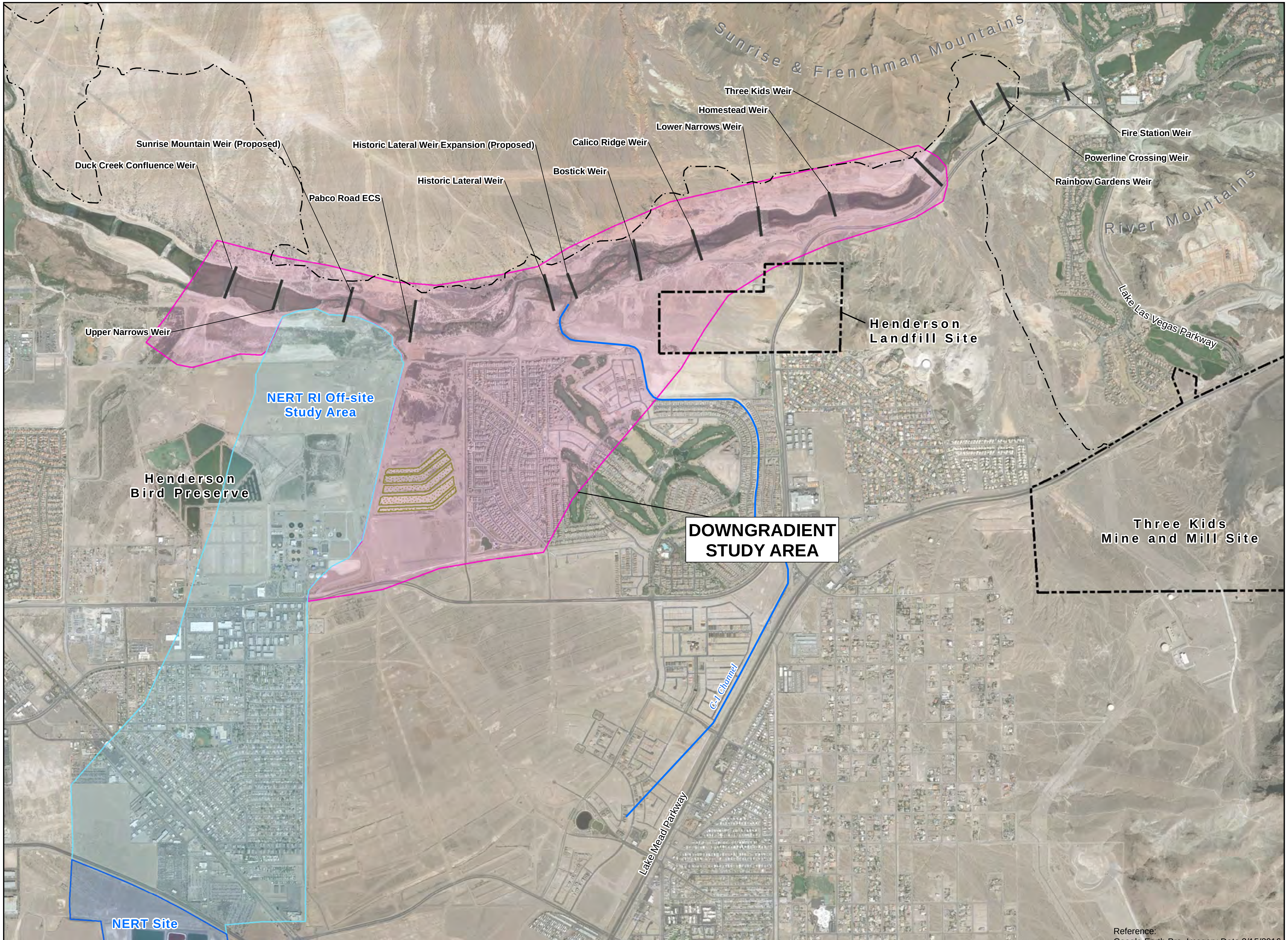
Sources:

NDEP. 2015. Email from James Dotchin, Chief Bureau of Industrial Site Cleanup, Nevada Division of Environmental Protection, re: Sterile Filtration Not Required for NERT Regional Groundwater RI Perchlorate Samples, November 18.

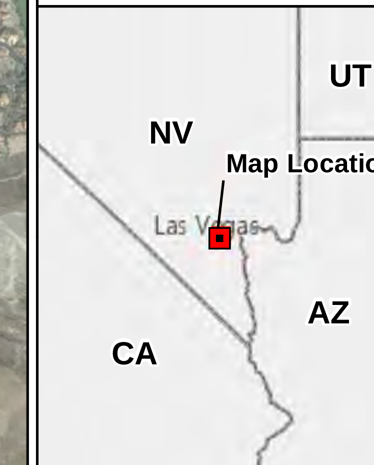
Table 4
Proposed Phase I Groundwater Sampling Plan
NERT RI - Downgradient Study Area
Henderson, Nevada

Well Identification	Well Depth in feet bgs	Well Diameter	Well Screen in feet bgs	Perchlorate	Chlorate	Hexavalent Chromium	Total Dissolved Chromium	Total Dissolved Solids	Chloride	Bromide
NERT5.91S1	50	4"	40 - 50	X	X	X	X	X	X	X
NERT5.49S1	40	4"	30 - 40	X	X	X	X	X	X	X
NERT5.11S1	45	4"	35-45	X	X	X	X	X	X	X
NERT4.93S1	50	4"	40-50	X	X	X	X	X	X	X
NERT4.71S1	50	4"	40-50	X	X	X	X	X	X	X
NERT4.51S1	50	4"	40-50	X	X	X	X	X	X	X
NERT4.38N1	55	4"	45-55	X	X	X	X	X	X	X
NERT4.21N1	55	4"	45-55	X	X	X	X	X	X	X
NERT3.80S1	60	4"	50-60	X	X	X	X	X	X	X
NERT3.56S1	60	4"	50-60	X	X	X	X	X	X	X
AA-30	34	4"	11.7 - 31.7	X	X					
COH2B1	67	4"	Unknown	X	X					
LNDMW1	61.56	4"	Unknown	X	X					
LNDMW2	55.05	4"	Unknown	X	X					
MW-02	44.83	4"	32-42	X	X					
MW-3	13	4"	Unknown	X	X					
MW-4	14.5	4"	Unknown	X	X					
MW-13	49.4	4"	38-48	X	X					
MW-20	67.25	4"	50-65	X	X					
MW-25	54.15	4"	38-53	X	X					
WMW3.5N	56.6	4"	Unknown	X	X					
WMW3.5S	59.80	4"	Unknown	X	X					
WMW4.9N	53.00	4"	Unknown	X	X					
WMW4.9S	46.75	4"	Unknown	X	X					
WMW5.58S1	40.95	4"	Unknown	X	X					
WMW5.5S	38.3	4"	Unknown	X	X					
WMW5.7N	21	4"	Unknown	X	X					

Figures



OVERVIEW MAP



Legend

- Wetlands Trail
- C-1 Channel
- Northern Rapid Infiltration Basins
- NERT RI Downgradient Study Area
- NERT RI Off-site Study Area
- NERT Site

NORTH

0 2,000
Feet

Scale 1:24,000
1 inch = 2,000 feet

NERT RI
Downgradient Study Area

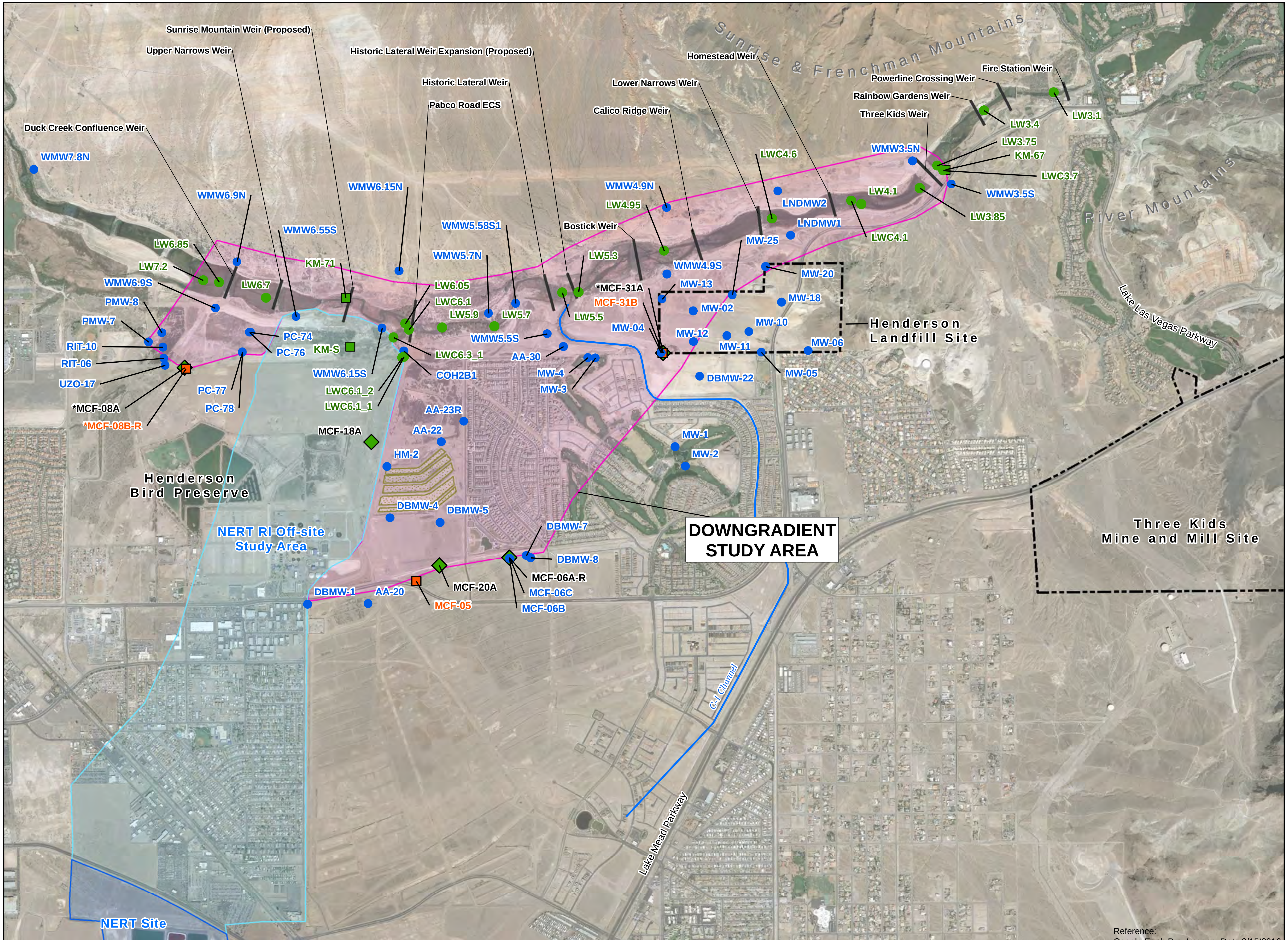
DOWNGRADIENT STUDY AREA LOCATION MAP

Date: 1/12/2017 Project: 60477365

AECOM

Figure 1

Path: J:\Client-Projects\NDEP\NERT_GW_RI\900-CAD\00-GIS\MXDs\DGIP\Fig1 Vicinity Map.mxd | Coordinate System: NAD 1983 StatePlane Nevada East FIPS 2701 Feet | User: scopm1



OVERVIEW MAP

Legend

- Groundwater Monitoring Well in Shallow Water Bearing Zone
- Groundwater Monitoring Well in Middle Water Bearing Zone
- Groundwater Monitoring Well in Deep Water Bearing Zone
- Surface Water Sample Location - Seeps
- Surface Water Sample Location - LVW/Tributaries
- Weir
- C-1 Channel
- Northern Rapid Infiltration Basins
- NERT RI Downgradient Study Area
- NERT RI Off-site Study Area
- NERT Site
- * Artesian Well

NORTH

0 2,000

Feet

Scale 1:24,000

1 inch = 2,000 feet

NERT RI
Downgradient Study Area

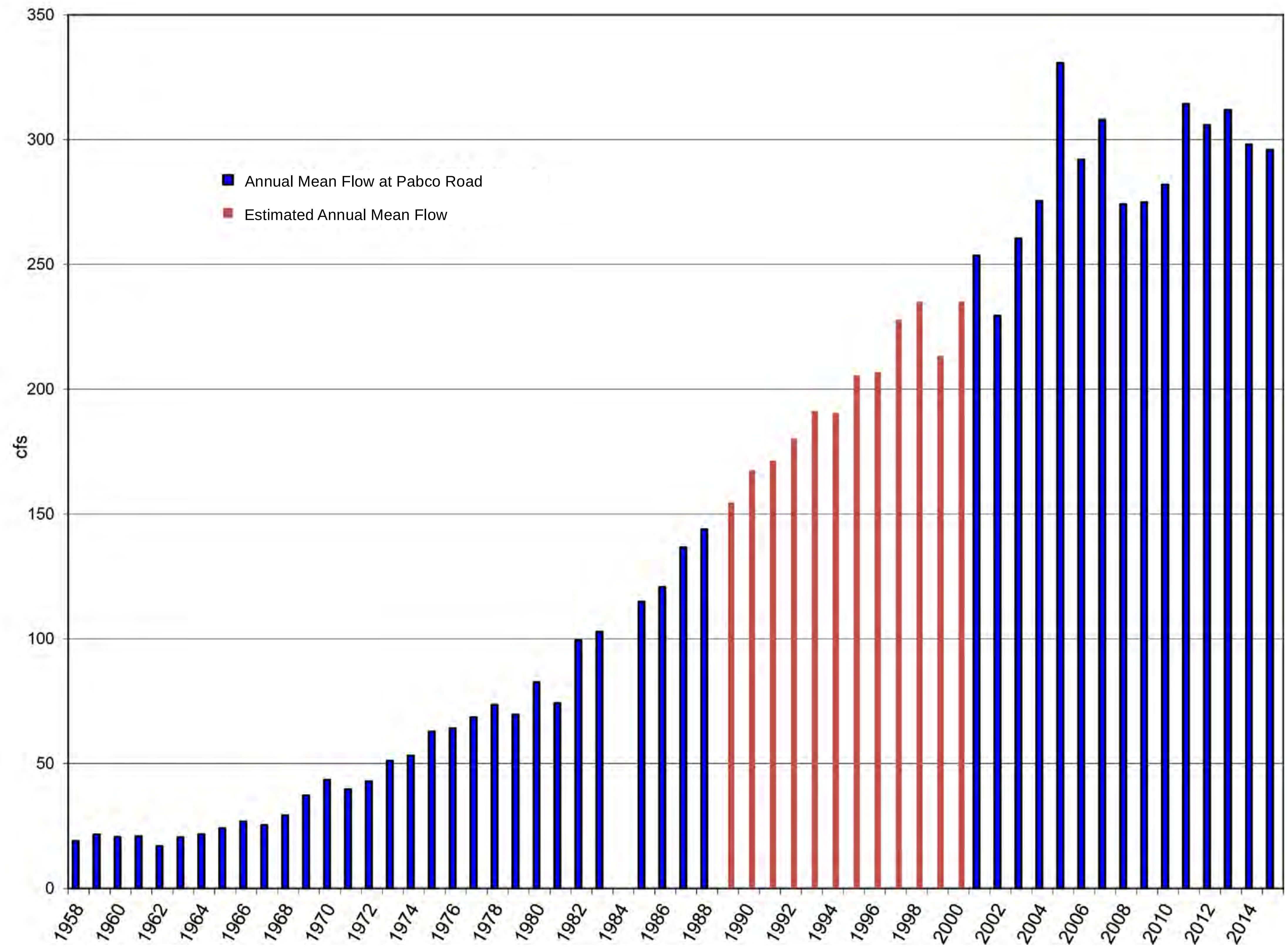
GROUNDWATER, SURFACE WATER & SEEP SAMPLE LOCATIONS APRIL AND MAY 2016

Date: 1/12/2017 Project: 60477365

AECOM

Figure 2

Path: J:\Client-Projects\NDEP\NERT_GW_RI\900-CAD\00-GIS\MXDs\DGIP\Fig2 GW_SW Sample Locations-1.mxd | Coordinate System: NAD 1983 StatePlane Nevada East FIPS 2701 Feet | User: scopm1



OVERVIEW MAP

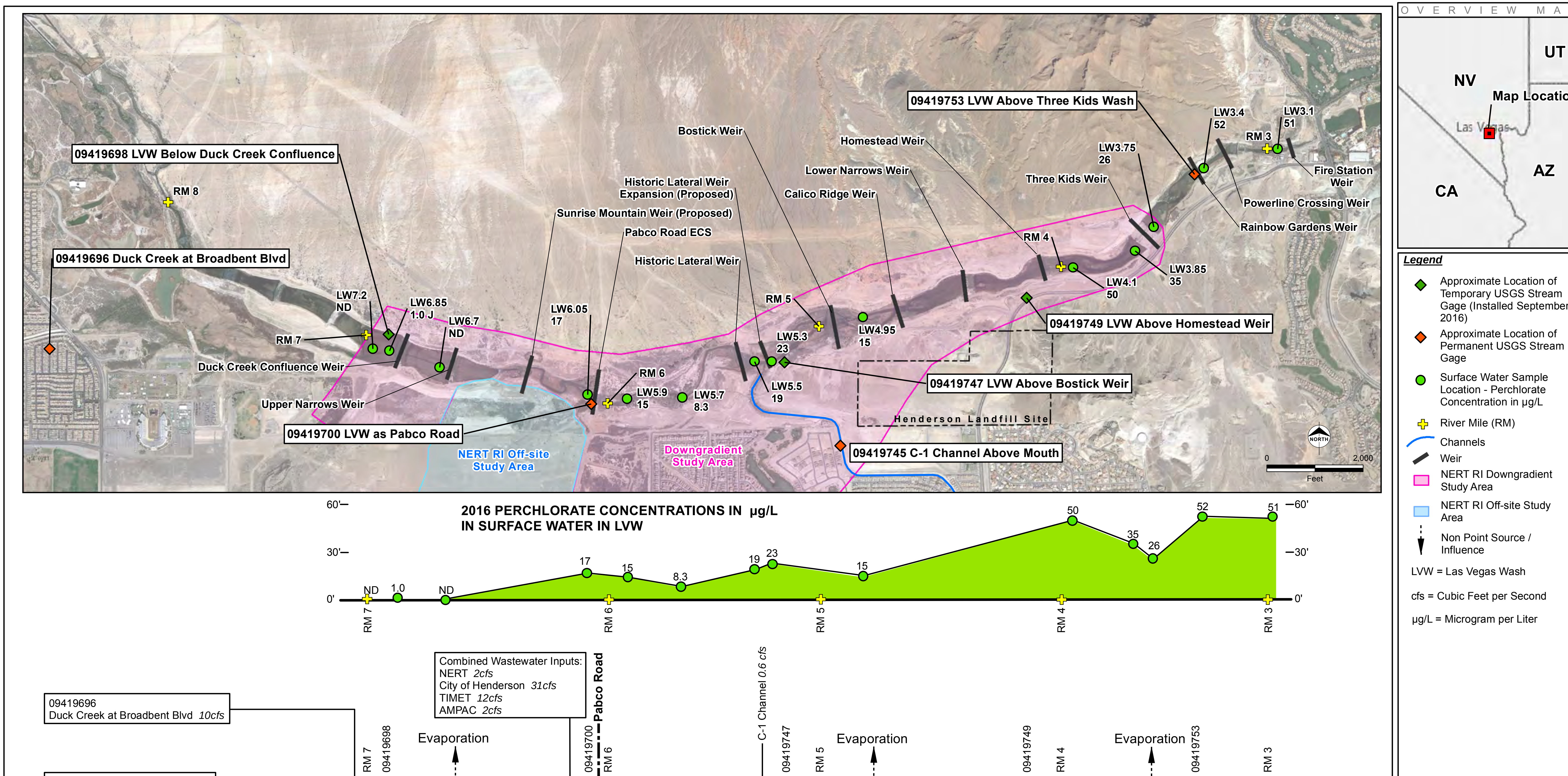
NERT RI
Downgradient Study Area

Annual Average Flow in the Las Vegas Wash at Pabco Road

Date: 1/12/2017 Project: 60477365

AECOM

Figure 3



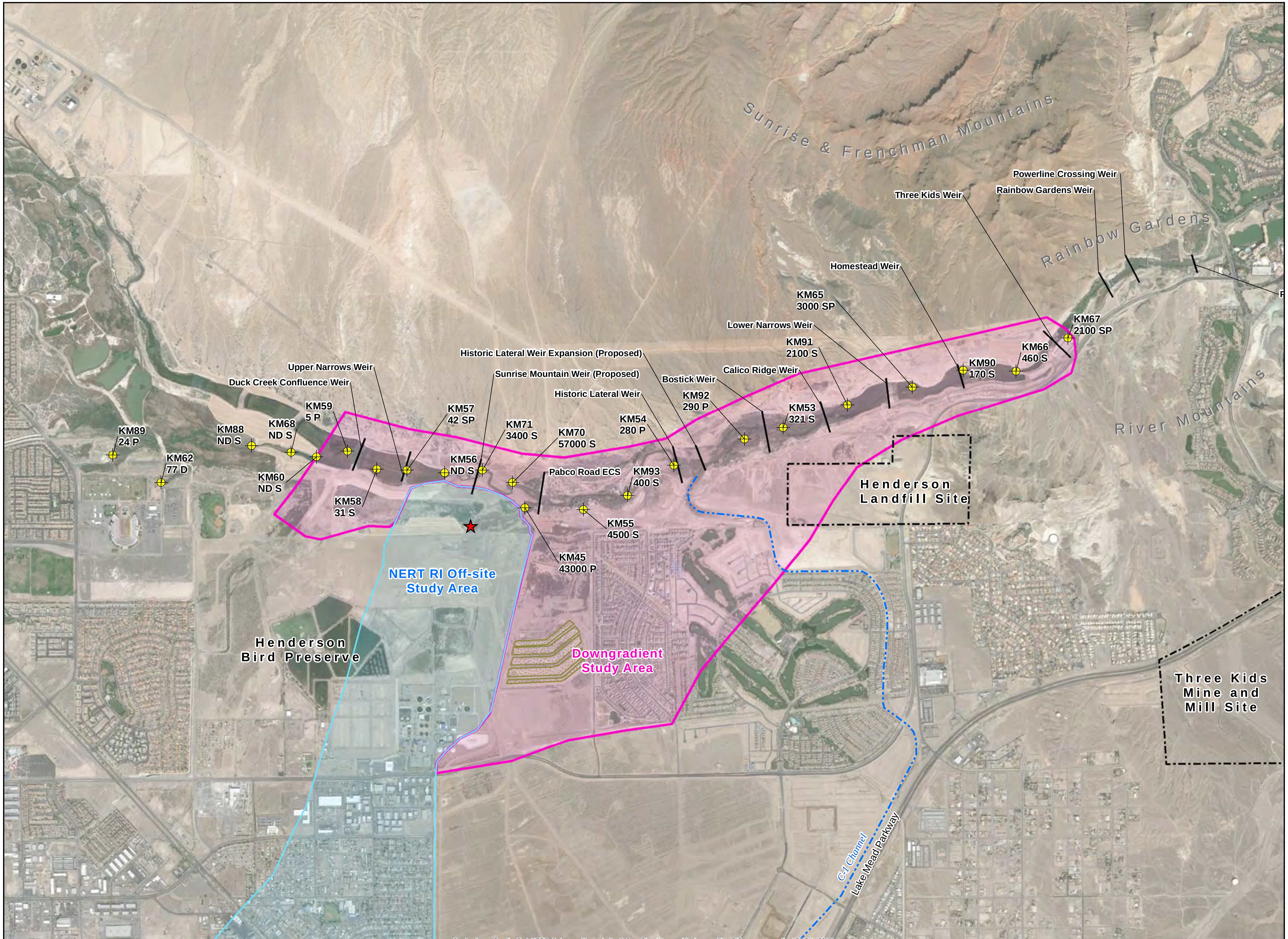
NERT RI
Downgradient Study Area

Conceptual Site Model Las Vegas Wash

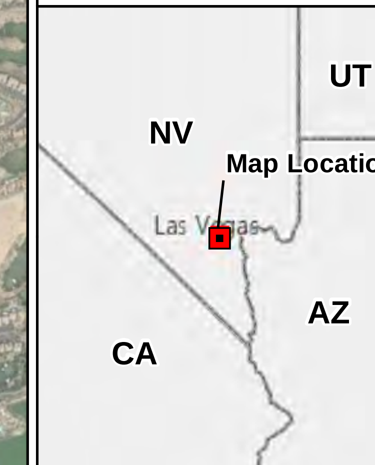
Date: 1/12/2017 Project: 60477365

AECOM

Figure 4



OVERVIEW MAP



Legend

- Original Seep Location
- 2000 Seep Locations
- Channels
- Weir
- Evaporation Basin

KM66 **460 S**	Location ID Perchlorate Result in microgram per liter (µg/l)
ND	Non detected above method detection limit (MDL)

Category Chart

P = Pit
S = Seep
Sp = Spring
D = Drain

NORTH

0 2,000
Feet
Scale 1:24,000
1 inch = 2,000 feet

NERT RI
Downgradient Study Area

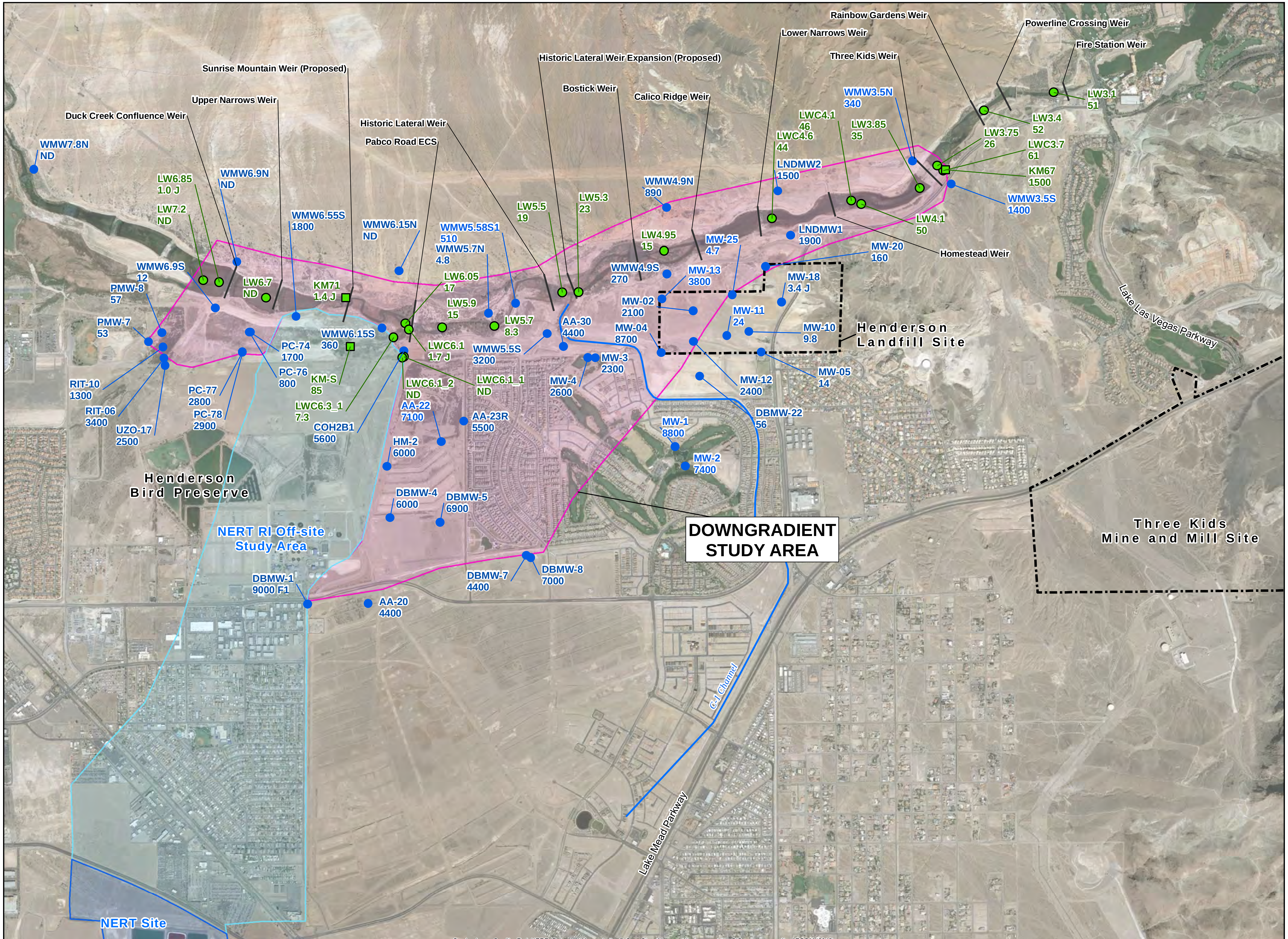
SEEP AND SURFACE WATER SAMPLING CONDUCTED BY KERR MCGEE IN 2000

Date: 1/12/2017 Project: 60477365

AECOM

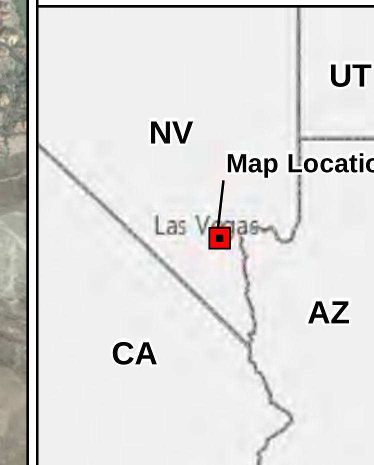
Figure 5

Path: J:\Client-Projects\NDEP\NERT_GW_RI\900-CAD\00-GIS\MXDs\DGIP\Fig5 2000 Perchlorate Surface Water Result.mxd | Coordinate System: NAD 1983 StatePlane Nevada East FIPS 2701 Feet | User: scopm1



Path: J:\Client-Projects\NDEP\NERT_GW_RI\900-CAD\00-GIS\MXDs\DGIP\Fig6 GW_SW_Sampling_perchlorate_20161111.mxd | Coordinate System: NAD 1983 StatePlane Nevada East FIPS 2701 Feet | User: scopm1

OVERVIEW MAP



Legend

- Groundwater Monitoring Well in Shallow Water Bearing Zone
- Surface Water Sample Location - Seeps
- Surface Water Sample Location - LVW/Tributaries
- C-1 Channel
- Northern Rapid Infiltration Basins
- NERT RI Downgradient Study Area
- NERT RI Off-site Study Area
- NERT Site

Perchlorate Concentration in µg/L

F1 = "Matrix Spike and/or Matrix Spike Duplicate Recovery is outside acceptance limits

ND Non detected above method detection limit (MDL)

J Result is less than the RL but greater than or equal to the MDL and the concentration is an approximate value

µg/L Micrograms per liter

NORTH

0 2,000

Feet

Scale 1:24,000

1 inch = 2,000 feet

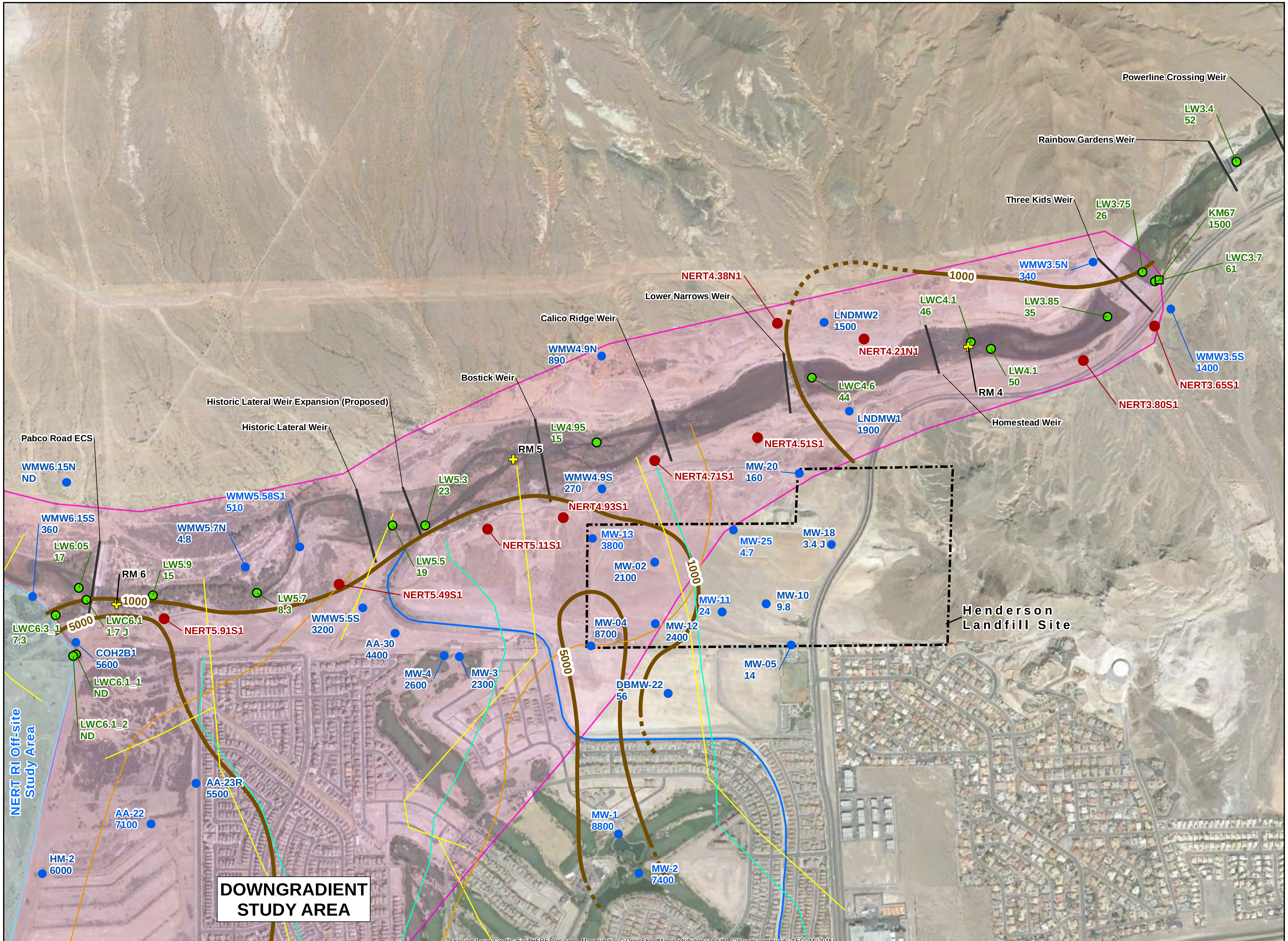
NERT RI
Downgradient Study Area

PERCHLORATE CONCENTRATIONS IN GROUNDWATER, SEEP AND SURFACE WATER SAMPLING RESULTS (APRIL AND MAY 2016)

Date: 1/12/2017 Project: 60477365

AECOM

Figure 6



Legend

- Groundwater Monitoring Well in Shallow Water Bearing Zone
- Surface Water Sample Location - Seeps
- Surface Water Sample Location - LVW/Tributaries
- Proposed Phase I Well
- River Mile
- Perchlorate Isoconcentration Contour (dashed where inferred)
- Paleochannels (BRC 2007)
- Paleochannels (Krish 2015)
- Paleochannels (Northgate 2010)
- C-1 Channel
- NERT RI Downgradient Study Area
- NERT RI Off-site Study Area

Perchlorate Concentration in µg/L

ND - Not detected above method detection limit (MDL)

J - Result is less than the RL but greater than or equal to the MDL and the contentration is an approximate value

µg/L - Micrograms per liter

0 — 1,000 Feet

Scale 1:12,000

1 inch = 1,000 feet

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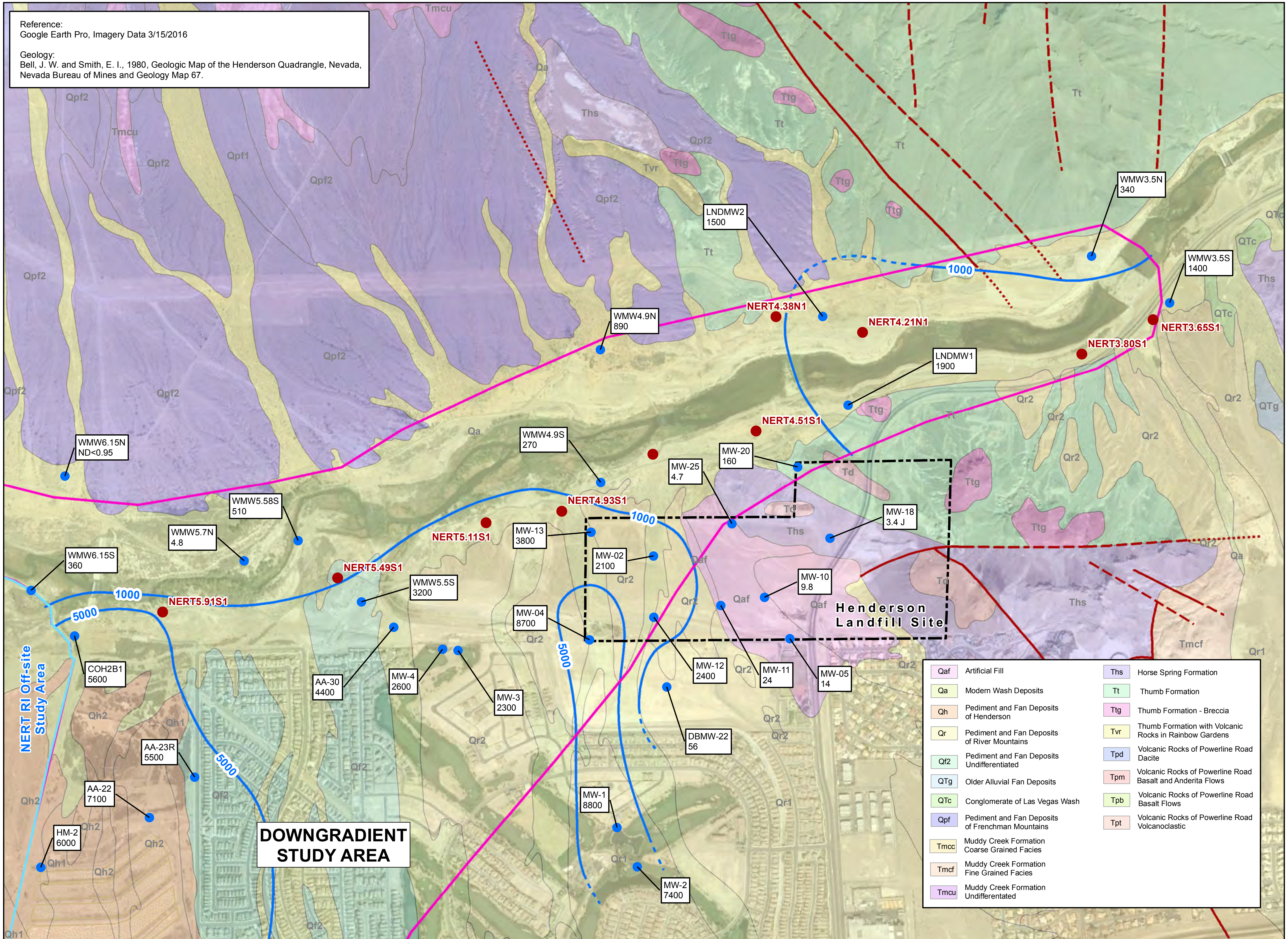
NERT RI
Downgradient Study Area

PROPOSED PHASE I MONITORING WELLS AND GROUNDWATER AND SURFACE WATER PERCHLORATE CONCENTRATIONS FROM APRIL AND MAY 2016

Date: 3/8/2017 Project: 60477365

AECOM Figure 7

Path: J:\Client-Projects\NDEP\NERT_GW_RI\900-CAD\00-GIS\MXDs\DGIP\Fig7 Pro GW_SW_Sampling_perc.mxd | Coordinate System: NAD 1983 StatePlane Nevada East FIPS 2701 Feet | User: scopm1



Qaf	Artificial Fill	Ths	Horse Spring Formation
Qa	Modern Wash Deposits	Tt	Thumb Formation
Qh	Pediment and Fan Deposits of Henderson	Ttg	Thumb Formation - Breccia
Qr	Pediment and Fan Deposits of River Mountains	Tvr	Thumb Formation with Volcanic Rocks in Rainbow Gardens
Qf2	Pediment and Fan Deposits Undifferentiated	Tpd	Volcanic Rocks of Powerline Road Dacite
QTg	Older Alluvial Fan Deposits	Tpm	Volcanic Rocks of Powerline Road Basalt and Anderita Flows
QTc	Conglomerate of Las Vegas Wash	Tpb	Volcanic Rocks of Powerline Road Basalt Flows
Qpf	Pediment and Fan Deposits of Frenchman Mountains	Tpt	Volcanic Rocks of Powerline Road Volcanoclastic
Tmcc	Muddy Creek Formation Coarse Grained Facies		
Tmcf	Muddy Creek Formation Fine Grained Facies		
Tmcu	Muddy Creek Formation Undifferentiated		

OVERVIEW MAP

Legend

- Northern Rapid Infiltration Basins
- NERT Downgradient Study Area
- NERT Off-site Study Area
- Proposed Phase I Well
- Fault, dashed where inferred, dotted where concealed
- Groundwater Monitoring Well
- Perchlorate Isoconcentration Contour From April 2016 (dashed where inferred)

Perchlorate Concentration in μg/L
(Data from April 2016)

ND - Not detected above method detection limit (MDL)
J - Result is less than the RL but greater than or equal to the MDL and the contentration is an approximate value
μg/L - Micrograms per liter

Source:
From: 1980. Bell, J.W. and Smith, E.I., Geologic Map of the Henderson Quadrangle, Nevada, Nevada Bureau of Mines and Geology, Map 67.

NORTH

0 1,000
Feet

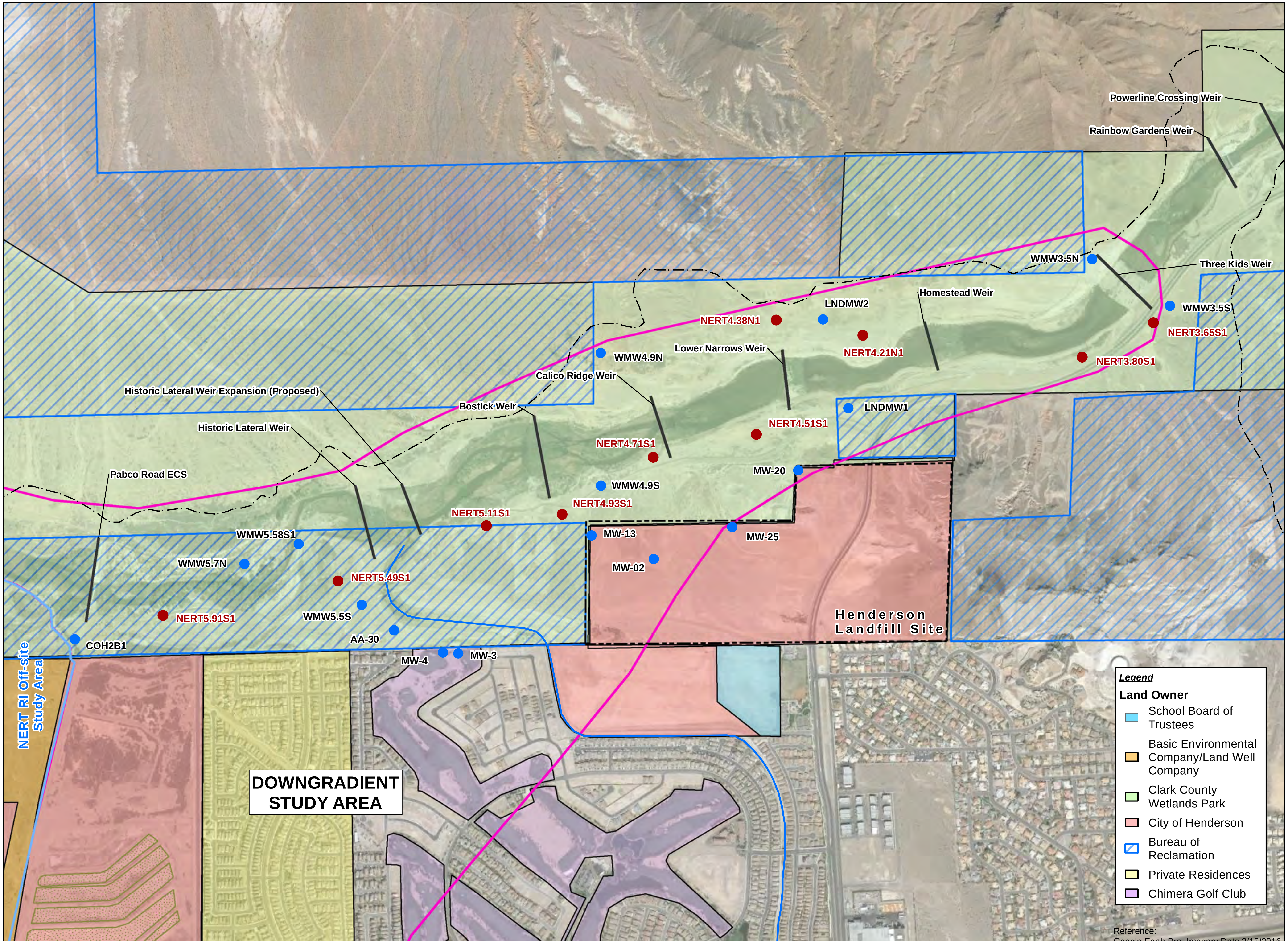
NERT RI
Downgradient Study Area

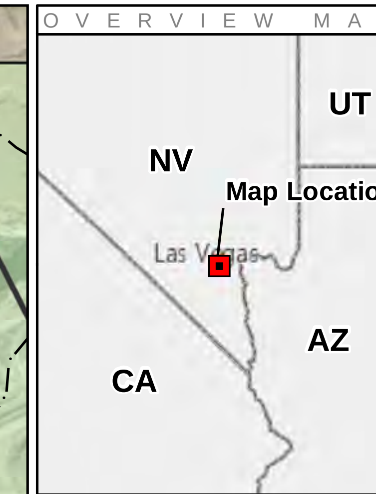
GEOLOGY, PROPOSED PHASE I MONITORING WELLS AND PERCHLORATE CONCENTRATIONS IN GROUNDWATER APRIL 2016

Date: 3/8/2017 Project: 60477365

AECOM **Figure 8**

Path: J:\Client-Projects\NDEP\NERT_GW_RI\900-CAD\00-GIS\MXDs\DGIP\Fig8 Geology-perc-12_2016.mxd | Coordinate System: NAD 1983 StatePlane Nevada East FIPS 2701 Feet | User: scopm1





Legend

- Groundwater Monitoring Well in Shallow Water Bearing Zone
- Proposed Phase I Well
- Weir
- C-1 Channel
- Northern Rapid Infiltration Basins
- NERT RI Downgradient Study Area
- NERT RI Off-site Study Area

NORTH

0 — 1,000
Feet

Scale 1:12,000
1 inch = 1,000 feet

NERT RI
Downgradient Study Area

Proposed Wells to be Sampled in Phase I Investigation

Date: 3/8/2017 Project: 60477365

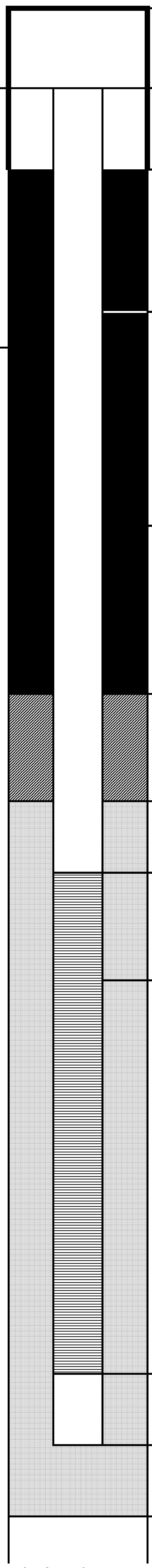
AECOM

Figure 9

Path: J:\Client-Projects\NDEP\NERT_GW_RI\900-CAD\00-GIS\MXDs\DGIP\Fig9 LVW Well Samples.mxd | Coordinate System: NAD 1983 StatePlane Nevada East FIPS 2701 Feet | User: scopm1

AECOM	*Client:* *Nevada Division of Environmental Protection*	***WELL ID:*** _____
	Project Number: *60477365*	
	Site Location: *Henderson, NV*	*Date Installed:* *mm/dd/yyyy*
	Well Location: *Coords:* *(easting, northing)*	*Inspector:*
	Method: *Sonic Drilling*	*Contractor:*

Figure 10 Example Monitoring Well Construction Detail



Measuring Point for Surveying & Water Levels

Cement, Bentonite, Bentonite Slurry Grout, or Native Materials

30 % Cement

50 % Bentonite

20 % Native Materials

	Depth from G.S. (feet)	Elevation(feet) Datum ________
Top of Steel Guard Pipe	3.0 (above g.s.)	
Top of Riser Pipe	2.0 (above g.s.)	
Ground Surface (G.S.)	0.0	
Bottom of Steel Guard Pipe	5.0	
Top of Bentonite	32.0	
Top of Sand	37.0	
Top of Screen	40.0	
▼ Stabilized Water Level	To be measured	
Bottom of Screen	50.0	
Bottom of Tail Pipe:	51.0	
Bottom of Borehole	52.0	

Riser Pipe:

- Length: 50
- Inside Diameter (ID): 4
- Type of Material: Sch. 40 PVC

Bentonite Seal Thickness: 5

Screen:

- Length: 10
- Inside Diameter (ID): 4
- Slot Size: 0.020
- Type of Material: Sch. 40 PVC

Type/Size of Sand: No. 3

Sand Pack Thickness: ________

Borehole Diameter: 12

Approved:

________________ Signature

________________ Date

Describe Measuring Point:

Notch on north side of riser pipe

Appendix A

Response to Stakeholder Comments

AECOM
1220 Avenida Acaso
Camarillo, CA 93012

(805)388-3775 tel
(805)388-3577 fax

Memorandum

To	NDEP: Carlton Parker, J.D. Dotchin	Pages	3
CC	Harry Van Den Berg		
Subject	Response to Comments – Final Draft Data Gap Investigation Plan		
From	AECOM: Sally Bilodeau/Carmen Caceres-Schnell		
Date	May 4, 2017		

This memorandum summarizes AECOM's responses to comments (RTCs) on the Final Draft Data Gap Investigation Plan (DGIP) received from the Metropolitan Water District (MWD) via email on April 19, 2017. For context of the comments and RTCs, AECOM provided the portions of the text that the comments pertain to in *italics*. Proposed text revisions, where applicable, are also presented in *italics*.

MWD Comments:

1. An objective of the Downgradient Study Area data gap investigation is to identify perchlorate sources and pathways through which perchlorate mass enters the Las Vegas Wash.

   RTC 1: As stated on page 1-1 of the DGIP *The overall objective of the investigation of the Downgradient Study Area is to identify subsurface pathways downgradient and cross-gradient of the NERT RI Study Area through which perchlorate-impacted groundwater is entering the LVW. The objective of installing new wells is to address specific data gaps identified based on historic data and recent groundwater monitoring data collected in April 2016 as well as LVW surface water data collected in May 2016.* Identification of sources of perchlorate impacts was specifically omitted from the objectives because identification of perchlorate sources is being addressed in the remedial investigations in the NERT RI Study Area.

2. The Endeavour perchlorate plume, as well as background levels in wastewater discharged to the Wash, were not described in the report and should also be included as sources that contribute to the perchlorate mass entering Las Vegas Wash.

   RTC 2: The outfall from American Pacific Corporation is mentioned in section 2.2 and the text will be modified to say: *American Pacific Corporation (Endeavour*). Chapter 2 will be revised to include the following statement, "*Please refer to the Annual Remedial Performance Report for Chromium and Perchlorate by Ramboll Environ dated October 31, 2016 for additional information on groundwater impacts and perchlorate mass entering LVW.*" This report will also be added to the reference section.

3. Recent groundwater sampling and testing identified perchlorate concentrations throughout the Study Area. These data suggest several pathways where the perchlorate source may be migrating downgradient into the Study Area from the primary paleochannel (NERT

plume) and from the Eastside Areas. These pathways are shown on the attached figure by the orange arrows. The perchlorate concentration data also suggest that there is a mixing zone (see attached figure) where perchlorate mass is mixing with Wash water as it discharges to the Las Vegas Wash. The location of this mixing zone is consistent with the USGS' recent findings of where groundwater discharge to the Wash occurs. We suggest that groundwater monitoring wells be installed to better understand the following:

a) Confirm perchlorate pathways entering the Study Area from upgradient sources

b) Perchlorate mass flux (measured in pounds/day) migrating along pathways into the downgradient area

c) Hydrodynamics of the mixing zone where perchlorate in groundwater interacts with Wash water

RTC 3a: The Downgradient groundwater investigation will be limited to areas adjacent to LVW with an emphasis on identifying perchlorate pathways entering LVW. With regard to perchlorate pathways entering the Downgradient study area from the south, Phase II work will be coordinated with the investigations being conducted by others in the Eastside Area.

RTC 3b: Perchlorate mass flux in surface water and suspected contributions from groundwater will be evaluated and estimated based on recent surface water sampling, which will be reported in a separate Surface Water Investigation Technical Memorandum currently in preparation. These estimates will be refined and revised as needed when additional information becomes available.

RTC 3c: An element of the downgradient groundwater investigation is to characterize and evaluate the groundwater and surface water interactions along the wash particularly with respect to how they affect perchlorate concentrations. As shown on the attached figure, 3 of the 10 wells proposed in the Phase I investigation are within the area of interest identified by MWD with an orange circle. During Phase II it is anticipated that hydraulic tests will be conducted within this area of interest.

4. In order to better understand the list of items above, we suggest the following.

a) Wells should be optimally located in the perchlorate pathways where upgradient sources enter the Study Area to characterize the hydrogeology including: alluvial thickness; depth to and character of the UMCf/g; groundwater level; aquifer hydraulics (transmissivity, permeability, seepage velocity, etc.); perchlorate concentrations and for the other listed parameters; test for stable water isotopes (O-18 and deuterium) to characterize their concentration in groundwater.

b) Existing and planned wells that are located within the mixing zone should be used to test groundwater and Wash water for stable water isotopes, which may assist in understanding groundwater and Wash water mixing in this zone where groundwater discharges to the Las Vegas Wash. The existing and planned wells in the mixing zone should be used to characterize the hydrogeology, including the parameters listed above

RTC 4a: Refer to response 3a with regard to locating wells along the south boundary of the Downgradient Study Area. All wells and borings will identify alluvial thickness, depth to and character of the UMCf, perchlorate concentrations, and groundwater level. Phase II will address aquifer hydraulics. We plan to test each new well for perchlorate, chlorate, chromium, chloride, bromide and TDS. We are not planning on analyzing for other constituents at this time.

RTC 4b: Refer to response 4a.

5. The plan does not identify any additional studies downgradient of the Endeavour plume to better understand the mass flux from this plume as it discharges to the Las Vegas Wash. We suggest a couple wells may be needed in this area to better characterize the mixing zone along the Wash where groundwater interacts with Wash water.

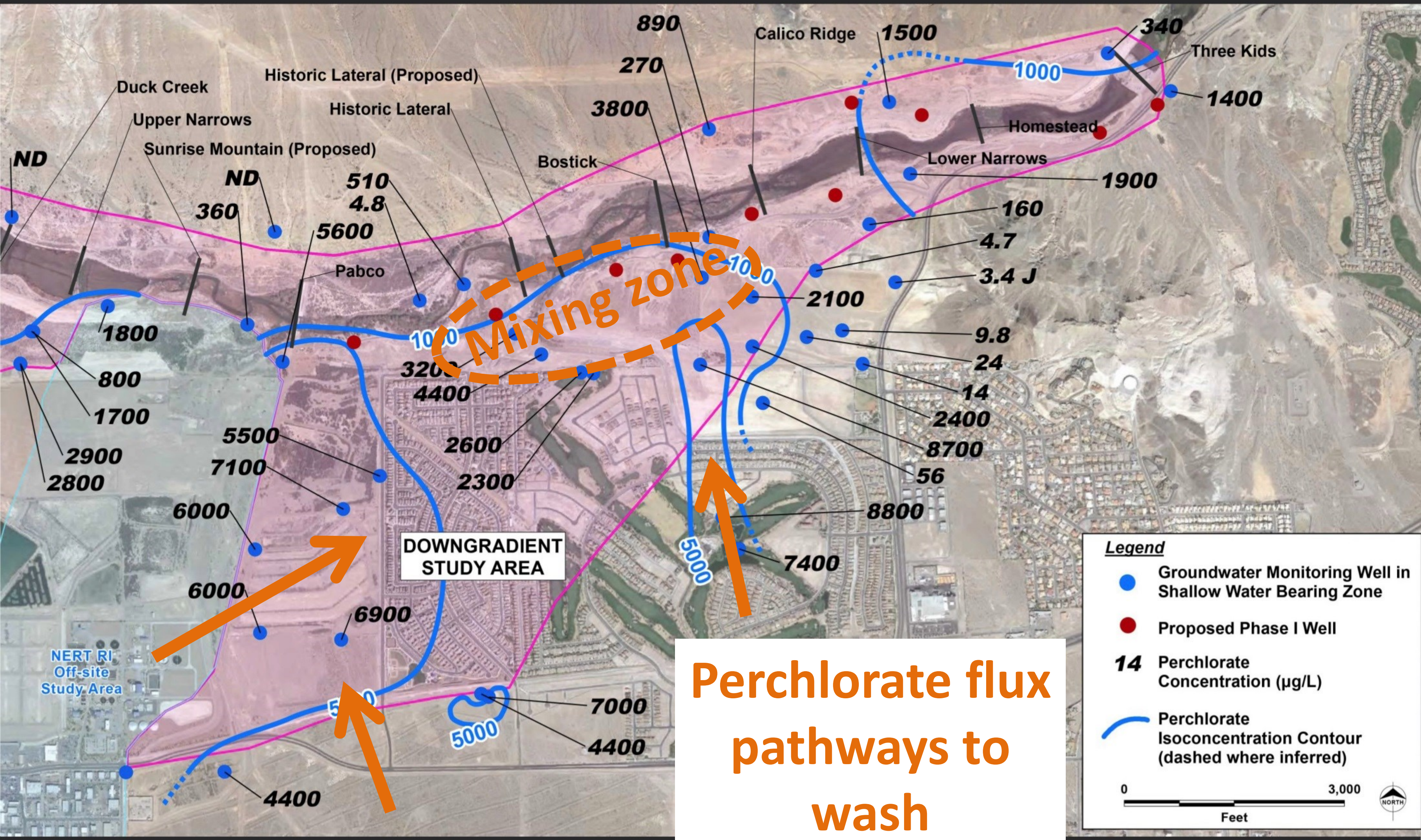
RTC 5: Based on the surface water collected in May 2016 and April 2017 significant perchlorate flux is not entering LVW upgradient of the NERT seep, for that reason, the downgradient perchlorate mass flux investigations are focused on areas downgradient of the seep.

6. If Endeavour is conducting studies in this area to characterize groundwater and surface water interaction within/downstream of its plume extents, that should also be noted within a background section of this report as there will be a need to integrate those efforts as part of the overall Downgradient Study Area investigation and data evaluation.

RTC 6: The Downgradient investigations are being and will continue to be integrated with the other investigations being conducted in the area. The following sentence will be added to Chapter 1. "*Environmental assessment investigations performed within the downgradient area will be coordinated with other ongoing environmental investigations in the area and on adjacent properties."*

Attachment: Figure - Perchlorate Pathways to Wash (as included by MWD with their comments)

GW Investigation - Phase I Groundwater Wells



Perchlorate flux pathways to wash

Note: Mixing Zone and pathways interpretations added by MWD

AECOM

Appendix B

Field Guidance Documents

FIELD GUIDANCE DOCUMENT NO. 001
MANAGING INVESTIGATION-DERIVED WASTE

Prepared by	Elysha Anderson, PE
Peer Reviewed by	Dan Clark
Approved by	John M. Pekala, PG, CEM
Applicable to	Nevada Environmental Response Trust Site Henderson, Nevada
Effective date	January 24, 2014
Revision Notes	0 First Issuance
Documents used as reference during preparation	Code of Federal Regulations (CFR), Title 40, Part 261 CFR, Title 49, Parts 172, 173, 178, and 179 Nevada Revised Statutes (NRS) Chapter 459.400 US Environmental Protection Agency (USEPA), *Guide to Management of Investigation-Derived Waste*, Publication 9345.3-03FS, dated April 1992

Table of Contents

1.0 INTRODUCTION

This Field Guidance Document (FGD) describes procedures for managing investigation-derived waste (IDW) at the Nevada Environmental Response Trust Site that will be conducted by or under the oversight of ENVIRON personnel. Although this FGD describes procedures for managing IDW for this project, it should be understood that there may be details of this type of work not specifically discussed in this FGD that would be followed by personnel trained in these techniques. To ensure that management of IDW is performed safely and completely, ENVIRON personnel involved in field activities should be sure that they understand the scope of work and the level of detail necessary for each field activity prior to mobilizing to perform the work.

This FGD is intended as a guidance document and does not supersede ENVIRON Health and Safety procedures or Site-Specific Health and Safety Plan (HASP) requirements. All ENVIRON employees shall follow the guidelines, rules, and procedures contained in site-specific HASPs prior to adhering to any procedures recommended in this FGD. The ENVIRON Project Manager and Task Leader must ensure that all project personnel review and sign the applicable HASP, and that the completed HASP and relevant project information is maintained in the project file. The signatures of the Project Manager and Task Leader indicate approval of the methods and precautions outlined in the HASP. The ENVIRON Project Manager and Task Leader will also be responsible for seeing that project personnel involved in field activities follow the procedures outlined in this and other applicable FGDs.

All personnel performing on-site operations with the potential for exposure to hazardous substances or health hazards are required to be 40-hour trained in accordance with Code of Federal Regulations (CFR) 1910.120 and will meet the personnel training requirements in accordance with 29 CFR 1910.120(e).

Environmental investigation activities such as drilling and sampling may generate solid, liquid, and other wastes that must be properly managed. This FGD describes the procedures to be followed for handling and managing routine IDW, including:

- Solid waste, both hazardous and non-hazardous (e.g., soil cuttings, contaminated debris or equipment)
- Liquid waste, both hazardous and non-hazardous (e.g., purge water, rinse water from decontamination)
- Personal Protective Equipment (PPE) (e.g., gloves, spent respirator cartridges, chemical-resistant coveralls)

This FGD is not applicable to the handling of flammable liquid wastes such as non-aqueous phase liquids (NAPL), which require additional protective measures. Nor is this FGD designed to address management of industrial wastes unrelated to an environmental investigation. This FGD describes the procedures for assisting clients with on-site handling and managing of IDW; however, disposal of IDW is the responsibility of the client.

The procedures presented herein are intended to be of general use and may be supplemented by a Work Plan, Sampling and Analysis Plan, Quality Assurance Project Plan, and/or a Health and Safety Plan. Some of these procedures may not be required depending on the specific scope of work being conducted. As the work progresses, and if warranted, appropriate revisions may be made by the Task Manager. Procedures in this protocol may be superseded by applicable regulatory requirements.

2.0 EQUIPMENT/MATERIALS

Equipment and materials needed to conform to this FGD include:

- Health and Safety Plan (HASP)
- Site information (maps, contact numbers, previous field logs, etc.)
- Containers for waste (e.g., 55-gallon open and closed top drums, or covered roll-off bins) and material to cover waste to protect from weather
- Fire extinguisher and spill containment equipment
- Equipment for transferring solid wastes (e.g., shovels, buckets, front-end loaders, etc.)
- Equipment for transferring liquid wastes (e.g., pumps, portable tanks, etc.)
- Secondary containment pallet for drums containing liquids
- Equipment for moving containers (e.g., drum dolly, truck with lift gate, etc.)
- Air monitoring equipment (i.e., air monitoring pumps, Photoionization Detector (PID), Flame Ionization Detector (FID), other as required by the HASP)
- Water quality meters for measuring temperature, pH, and specific electrical conductance
- Sampling equipment (trowels, telescoping sampling arm, dipper or coliwasa, sample pump and tubing, etc.)
- Certified-clean sample containers and preservation supplies, sample labels, ZiplocTM bags
- Cooler with ice
- Decontamination supplies (e.g., phosphate-free detergent, alconox, distilled water)
- Tool kit with appropriate tools (socket wrench set, pry bar, drum wrench)
- Hazardous/non-hazardous waste drum labels
- Permanent marking pens
- Plastic garbage bags, ZiplockTM storage bags, roll of plastic sheeting
- PPE (Long-sleeved shirt and pants, steel-toed boots, hardhat, nitrile gloves, safety glasses with side sheets, etc.)

- Field Forms (If the project requires it, a project-specific Field Logbook may substitute for the following)
  - *Field Investigation Daily Log*

3.0 PROCEDURES

Several types of waste are generated during site investigations that may require special handling methods. These include solid, liquid, and used PPE. The storage and handling of these materials is discussed below.

3.1 Solid Waste

Soil cuttings and drilling mud generated during investigation activities shall be kept on-site in containers. Covers should be included on the containers and must be secured at all times and only open during filling activities. The containers shall be labeled in accordance with this FGD. An inventory containing the source, volume, and description of material put in the containers shall be logged on prescribed forms and kept in the project file.

3.2 Liquid Waste

Groundwater generated during monitoring well development, purging, and sampling can be collected in truck-mounted containers and/or other transportable containers (i.e., 55-gallon drums). Only closed-top drums will be used for storing liquid wastes; open-top drums are generally not appropriate containers for liquids. Bungs on drums must be secured at all times and only open during filling or pumping activities. The containers shall be labeled in accordance with this FGD. Waste that is generated during equipment decontamination shall be collected in a separate container. All waste containers shall be properly accounted for through an inventory process.

3.3 Personal Protective Equipment (PPE)

PPE that is generated throughout investigation activities shall be placed in plastic garbage bags and stored in secure containers. The containers shall be properly sealed and labeled according to this FGD. If the solid or liquid waste is characterized as hazardous waste, then the corresponding PPE should also be disposed as hazardous waste. If not, all PPE should be disposed as non-hazardous waste at an appropriate facility. Trash that is generated as part of field activities may be disposed of in regular collection facilities as long as the trash was not exposed to hazardous media.

3.4 Waste Container Labeling

For situations where the waste characteristics are known, the waste containers should be packaged and labeled in accordance with state and federal regulations that govern the labeling of waste. General labeling requirements are discussed below.

The following information shall be placed on all non-hazardous waste labels:

- Description of waste (i.e., purge water, soil cutting);
- Contact information (i.e., contact name and telephone number); and
- Date when the waste was first accumulated.

The following information shall be placed on all hazardous waste labels:

- Description of waste (i.e., purge water, soil cutting);
- Generator information (i.e., name, address, contact telephone number);
- EPA identification number (supplied by on-site client representative); and
- Date when the waste was first accumulated.

When the final characterization of a waste is unknown, a notification label should be placed on the drum with the words "waste characterization pending analysis" (or similar) and the following information included on the label:

- Description of waste (i.e., purge water, soil cutting);
- Generator information (i.e., contact name and telephone number);
- Date when the waste was first accumulated.

Once the waste has been characterized, the label should be changed as appropriate for a non-hazardous or hazardous waste.

Waste labels should be constructed of a weatherproof material and filled out with a permanent marker to prevent being washed off or becoming faded by sunlight. It is recommended that waste labels be placed on the side of the container, since the top is more subject to weathering.

However, when multiple containers are accumulated together, it also may be helpful to include duplicate labels on the top of the containers to facilitate organization and disposal. Each container of waste generated shall be recorded in the field notebook used by the person responsible for labeling the waste. After the waste is disposed of, either by transportation off-site or disposal on-site in an approved disposal area, an appropriate record shall be made in the same field notebook to document proper disposal of the IDW.

3.5 Waste Characterization

Waste characterization will be performed to determine if the IDW generated is a hazardous waste as defined by federal and state regulations. Waste characterization will be performed through the use of existing information and without additional testing if the existing information is sufficient to make a professional judgment (e.g., manifests, Material Safety Data Sheets, preliminary assessments, previous test results, knowledge of the waste generation process, direct observation of the IDW for discoloration, odor or other indicators of contamination). If existing information is not available to properly characterize the IDW, testing will be performed using USEPA-recommended methods described in SW 846: Test Methods for Evaluating Solid Waste Physical/Chemical Methods, or other methods as applicable.

Discrete samples collected during the environmental investigation may be used for waste characterization by comparing sample results to federal hazardous waste characteristic thresholds. The Toxicity Characteristic Leaching Procedure (TCLP) is the threshold based on Federal guidelines. This applies to organic as well as inorganic compounds.

Solid IDW concentrations can be compared to twenty times the established federal TCLP (20xTCLP) values. The 20xTCLP values is generally regarded as a threshold level for requiring additional leach testing to characterize the toxicity characteristics of a waste.

Acid leach testing may be performed following the federal TCLP for comparison with the TCLP value. The TCLP method uses an acetic acid buffer solution as the extraction fluid. The mixing is done for 18 hours during the TCLP test. The dilution factor is 20x for the TCLP test. If a sample has a total metal concentration less than 20x its TCLP value, it cannot fail with respect to the TCLP index even if the compound is totally soluble; hence, the comparisons to 20x TCLP values.

3.6 Waste Accumulation On-site

The accumulation of IDW on-site is the responsibility of the client and/or the site owner. The following procedures should be followed for accumulation of IDW.

Solid, liquid, or PPE waste generated during investigation activities that are classified as nonhazardous or “characterization pending analysis” should be disposed of as soon as possible by the client. Until disposal, such containers should be inventoried, stored as securely as possible, and inspected regularly, as a general good practice.

Solid, liquid, or PPE waste generated during investigation activities that are classified as hazardous shall not be accumulated on-site longer than 90 days. All hazardous waste containers shall be stored in a secured storage area. The following requirements for the hazardous waste storage area must be implemented:

- Proper hazardous waste signs shall be posted as required by any state or federal statutes that may govern the labeling of waste;
- Secondary containment to contain spills;
- Spill containment equipment must be available;
- Fire extinguisher; and
- Adequate aisle space for unobstructed movement of personnel.

Weekly storage area inspections shall be performed and documented to ensure compliance with these requirements. Throughout the project, an inventory shall be maintained to itemize the type and quantity of the waste generated.

3.7 Waste Sampling and Profiling

The waste material will be profiled and approval will be received before transportation and disposal is arranged. Final determination of the disposal site will be based on approval from the disposal facility. The facility may require profiling of the containerized IDW including collection of additional samples from the containers themselves. The following procedures will be followed for sampling IDW containers.

In general, one composite sample will be collected using a trowel or coring device from each large container or from a group of drums containing equivalent solid wastes. Small samples of soil cuttings or drill mud will be taken from several locations and depths of the handling containers and placed in sampling jars. Composite samples should not be collected in a manner to dilute high concentration wastes with low concentration wastes. Grab water samples will be collected using a dipper or composite liquid waste sampler or “coliwasa.” Sampling handling and custody procedures will be followed as described in Section 7 of this SOP. Documentation of the sampling will be performed in accordance with the procedures outlined in Section 8 herein.

If a container is known or suspected to contain a hazardous waste based on the initial characterization, the applicable procedures outlined in USEPA document, Samplers and Sampling Procedures for Hazardous Waste Streams (EPA-600/2-80-018) will be followed.

3.8 Waste Transport

Non-hazardous or unclassified waste that is presumed to be non-hazardous or non-designated waste may be transported on-site to a waste accumulation area using appropriate tools such as a drum dolly or a truck with a lift-gate. Containers must be properly closed during transport and care must be taken to secure the containers so they do not move in an uncontrolled manner.

Hazardous waste may be moved on-site using the same precautions as described above. However, it may not be transported using a vehicle in the public right-of-way. A state-certified hazardous waste hauler shall transport all wastes classified as hazardous. Typically, the facility receiving any waste can coordinate a hauler to transport the waste. Shipped hazardous waste shall be disposed of in accordance with all RCRA/USEPA requirements. All waste manifests or bills of lading will be signed either by the client or the client’s designee. In general, ENVIRON personnel should not sign client manifests.

3.9 Waste Disposal

The disposal of IDW is the responsibility of the client. This section is for assisting the client in IDW disposal. All waste generated during field activities will be stored, transported, and disposed of according to applicable state, federal, and local regulations. All wastes classified as hazardous will be disposed of by the client at a licensed treatment storage and disposal facility or managed in other approved manners.

Solid, liquid, and PPE waste will be characterized for disposal through the use of client knowledge, laboratory analytical data created from soil or groundwater samples gathered during the field activities, and/or composite samples from individual containers.

In general, waste disposal should be carefully coordinated with the facility receiving the waste. Facilities receiving waste have specific requirements that vary even for non-hazardous waste, so characterization should be conducted to support both applicable regulations and facility requirements.

3.10 Equipment Decontamination

The equipment used to transfer wastes, all sampling equipment, and water quality meters will be decontaminated by the following procedures:

- The sampling and waste transferring equipment (shovels, buckets, pumps) will be hand washed with phosphate-free detergent and a scrubber, then thoroughly rinsed with distilled water, or steam-cleaned.
- Water quality meter sensors will be rinsed with distilled water between sampling locations. No other decontamination procedures are necessary or recommended for these meters since they are sensitive instruments. After sampling, the meters must be cleaned and maintained per the manufacturer's requirements.
- Decontamination water will be collected and stored on-site for future disposal by the client unless other arrangements have been made.

3.11 Sample Handling and Custody

Samples (if required for waste characterization) will be collected, handled, and stored in such a manner that they are representative of their original condition and chemical composition. Identification of samples and maintenance of custody are important elements that must also be utilized to ensure samples characterize site conditions. All samples will be properly identified and maintained under chain-of-custody protocol to protect sample integrity. The following sections discuss the sample handling and custody requirements.

3.11.1 Sample Identification

To maintain consistency, a sample identification convention including unique identifiers for all groundwater and QC samples must be developed and followed throughout the project. The sample identifiers will be entered onto the sample labels, field forms, chain-of-custody forms, and other records documenting sampling activities.

3.11.2 Sample Labels

A sample label will be affixed to all sample containers sent to the analytical laboratory. Field personnel will complete an identification label for each sample with the following information written in waterproof, permanent ink:

- Client and project number
- Sample location and depth, if relevant
- Unique sample identifier
- Date and time sample collected
- Filtering performed, if any
- Preservative used, if any
- Name or initials of sampler
- Analyses or analysis code requested

The use of pre-printed sample labels is preferred in order to reduce sample misidentification problems due to transcription errors. Sample labels must be completed and affixed to the sample container in the field at the time of sample collection.

If errors are made on a sample label, corrections will be made by drawing a single line through the error and recording the correct information. Corrections will be dated and initialed.

3.11.3 Containers, Preservation, and Hold Time

Each lot of preservative and sampling containers will be certified as contaminant-free by the supplier. All preserved samples will be clearly identified on the sample label and Chain-of-Custody form. If samples requiring preservation are not preserved, field records will clearly specify the reason for the discrepancy.

Chemical activity continues in the sample until it is either analyzed or preserved. Once the sample has been preserved, the sample may be held for a period of time before analysis. The time from the collection of the sample to the analysis is defined as the holding time. The holding time varies depending on the media being sampled and the analyses being performed. The collection, preservation, and analysis of samples must be conducted to avoid exceeding relevant holding times.

3.11.4 Sample Handling and Transport

Proper sample handling techniques are used to ensure the integrity and security of the samples. Samples for field measured parameters will be analyzed immediately in the field and recorded in the appropriate field forms. Samples for laboratory analysis will be transferred immediately to appropriate laboratory supplied containers in accordance with the following sample handling protocols:

- Don clean gloves before touching any sample containers, and take care to avoid direct contact with the sample;
- Samples will be quickly observed for color, appearance, and composition and recorded as necessary;
- The sample container will be labeled before or immediately after sampling;
- Sample containers and liners will be capped with Teflon®-lined caps before being placed in Ziploc™-type plastic bags. The samples will be placed in an ice chest kept at 4 °C for transport to the laboratory.
- All sample lids will stay with the original containers, and will not be mixed.
- Sample bottles will be wrapped in bubble wrap as necessary to minimize the potential for breakage during shipment.
- The *Chain-of-Custody* form will be placed in a separate plastic bag and taped to the cooler lid or placed inside the cooler. A custody seal will be affixed to the cooler if the samples are to be shipped by commercial carrier. For shipped samples, U.S. Department of Transportation shipping requirements will be followed and the sample shipping receipt will be retained in the project files as part of the permanent Chain-of-Custody document.

3.11.5 Sample Chain of Custody

Sample chain-of-custody procedures will be used to maintain and document sample integrity during collection, transportation, storage, and analysis. A sample is considered to be under the control of, and in the custody of, the responsible person if the samples are in their physical possession, locked or sealed in a tamper-proof container, or stored in a secure area.

The *Chain-of-Custody* form provides an accurate written record that traces the possession of individual samples from the time of collection in the field until they are accepted at the analytical laboratory. The Chain-of-Custody form also documents the samples collected and the analyses requested. The sampler will record the following information on the Chain-of-Custody forms:

- Client and project number
- Name or initials and signature of sampler
- Name of destination analytical laboratory
- Name and phone number of Project Leader in case of questions
- Unique sample identifier for each sample
- Data and time of collection for each sample
- Number and type of containers included for each sample
- Analysis or analyses requested for each sample

- Preservatives used, if any, for each sample
- Sample matrix for each sample
- Any filtering performed, if applicable, for each sample
- Signatures of all persons having custody of the samples
- Dates and times of transfers of custody
- Shipping company identification number, if applicable
- Any other pertinent notes, comments, or remarks

Blank spaces on the Chain-of-Custody will be crossed out and initialed by the field sampler between the last sample listed and the signatures at the bottom of the sheet.

The field sampler will sign the Chain-of-Custody and will record the time and date at the time of transfer to the laboratory or an intermediate person. A set of signatures is required for each relinquished/received transfer, including internal transfer. The original imprint of the Chain-of-Custody will accompany the sample containers and a duplicate copy will be kept in the project file.

If the samples are to be shipped to the laboratory, the original *Chain-of-Custody* relinquishing the samples will be sealed inside a plastic bag within the ice chest, and the chest will be sealed with custody tape that has been signed and dated by the last person listed on the *Chain-of-Custody*. U.S. Department of Transportation shipping requirements will be followed and the sample shipping receipt will be retained in the project files as part of the permanent *Chain-of-Custody* document. The shipping company (e.g., Federal Express, UPS) will not sign the *Chain-of-Custody* forms as a receiver; instead the laboratory will sign as a receiver when the samples are received.

4.0 PRECAUTIONS

Certain precautions should be taken to ensure safety during the implementation of this FGD. It is important to always remain alert and aware of your surroundings.

The activities described in this FGD require the implementation of a site-specific Health and Safety Plan to inform personnel of the hazards associated with this work and to describe the methods that will be employed to mitigate those hazards. The HASP must be prepared and approved by the Project Manager, Task Leader and the Project Health and Safety Coordinator prior to initiating field work.

5.0 RECORDKEEPING

Information collected during the performance of these procedures may be recorded on individual field forms. If the project requires it, a project-specific Field Logbook may replace any of the individual field forms with the exception of the Chain-of-Custody form. Following review by the Task Manager, the original field records will be kept in the project file. The following forms may be used to document the field activities:

- *Field Investigation Daily Log*
- *Equipment Calibration Log*
- *Chain-of-Custody*

The *Field Investigation Daily Log* will be completed for each day of fieldwork containing (at a minimum) the times and descriptions of the work performed, the activities of any contractors and/or visitors on-site, arrival and departure times for all involved, and any other pertinent information. For larger projects, or when otherwise deemed appropriate by the Task Manager, this information may alternatively be recorded in a field logbook. In these cases, a separate Field Logbook must be used for each project or site.

The *Equipment Calibration Log* will be used to document the calibration and status of any measuring instruments used in the field, e.g., PID/FID, water level measuring device, water quality meters, etc. The frequency and method of calibration will depend on the instrument. Any instruments used will be used in accordance with the factory-provided operating and/or service manuals.

Locations and unique identification of samples collected will be recorded on the *Field Investigation Daily Log*, a site map, and/or other appropriate forms.

Sample names, date/times, analyses to be performed and other pertinent information will be recorded on the *Chain-of-Custody* form as a means of identifying and tracking the samples.

FIELD GUIDANCE DOCUMENT NO. 003
DRILLING AND DESTRUCTION OF SOIL BORINGS

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Table of Contents

1.0 INTRODUCTION

This Field Guidance Document (FGD) describes the procedures for drilling and destruction of soil borings at the Nevada Environmental Response Trust Site that will be conducted by or under the oversight of ENVIRON personnel. Although this FGD describes procedures for drilling and destruction of soil borings for this project, it should be understood that there may be details of this type of work not specifically discussed in this FGD that would be followed by personnel trained in these techniques. To ensure that soil boring drilling and destruction is performed in a complete and safe manner, ENVIRON personnel involved in field activities should be sure that they understand the scope of work and the level of detail necessary for each field activity prior to mobilizing to perform the work.

This FGD is intended as a guidance document and does not supersede ENVIRON Health and Safety procedures or Site-Specific Health and Safety Plan (HASP) requirements. All ENVIRON employees shall follow the guidelines, rules, and procedures contained in site-specific HASPs prior to adhering to any procedures recommended in this FGD. The ENVIRON Project Manager and Task Leader must ensure that all project personnel review and sign the applicable HASP, and that the completed HASP and relevant project information is maintained in the project file. The signatures of the Project Manager and Task Leader indicate approval of the methods and precautions outlined in the HASP. The ENVIRON Project Manager and Task Leader will also be responsible for seeing that project personnel involved in field activities follow the procedures outlined in this and other applicable FGDs.

All personnel performing on-site operations with the potential for exposure to hazardous substances or health hazards are required to be 40-hour trained in accordance with Code of Federal Regulations (CFR) 1910.120 and will meet the personnel training requirements in accordance with 29 CFR 1910.120(e).

This FGD describes the procedures to be followed by a Field Geologist/Engineer during drilling and destruction of soil borings. The purpose of soil borings is to provide access to the subsurface at specified locations and depths. Soil borings allow for the inspection and sampling of subsurface materials as well as the installation of groundwater wells, soil vapor probes, and in-situ remediation systems. If the soil boring is to be used for discrete soil sampling, the FGD applicable to soil sampling should be followed as necessary. Likewise, if the soil boring is ultimately utilized for the collection of soil vapor or groundwater samples, the FGDs specific to those activities should be followed.

This FGD covers several of the most common drilling methods used for advancing soil borings for environmental purposes; however, it does not discuss how to select the appropriate drilling method for a given task. The selection of drilling method depends on many factors and each method has advantages as well as limitations. The Task Leader will select the drilling method best suited for the site and the objectives of the project based on professional judgment and past experience.

The drilling contractor, if used, shall be a licensed driller, in accordance with local and state requirements, and qualified for the drilling and destruction of soil borings for environmental purposes.

2.0 EQUIPMENT/MATERIALS

Equipment and materials needed to conform to this FGD include:

- Health and Safety Plan
- Site information (maps, contact numbers, previous field logs, etc.)
- Photoionization Detector (PID) or Flame ionization detector (FID) for field screening for VOCs and monitoring of breathing zones for inhalation hazards
- Other monitoring equipment such as Lower Explosion Limits (LEL) meter or combustible gas/methane meter as specified in the Health and Safety Plan
- Hand lens
- Logging assistance tools (e.g., grain size charts, Munsell color charts)
- Measuring tapes (both long weighted cloth type and small measuring tape, preferably marked in tenths and hundredths of a foot)
- Electronic water level indicator (Solinst or similar)
- Decontamination supplies (e.g. phosphate-free detergent, distilled water)
- Drum labels
- Personal Protective Equipment (PPE), typically PPE will consist of:
- Long-sleeved shirt and long pants
- Steel-toed boots
- Hardhat
- Nitrile gloves
- Safety glasses with side shields
- Other as required by Health and Safety Plan
- Field Forms (If the project requires it, a project-specific Field Logbook may substitute for any or all of the following)
  - *Field Investigation Daily Log*
  - *Field Soil Boring Log*
  - *Equipment Calibration Log*
  - *Chain of Custody*

Based on the field activity and project, the drilling contractor needs to provide:

- Drilling equipment (depends upon the type of drilling, e.g., proper diameter augers or drive rods, generators, compressors, steam cleaners, etc.)

- Drilling supplies (depends upon the type of drilling, e.g., drilling fluids, conductor casing, etc.)
- Sampling equipment (split-spoon sampler, sampling sleeves, etc.)
- Decontamination supplies
- Containers (drums or covered bins) for separate on-site containment of cuttings, drilling fluids, and purge/decontamination water
- Well construction supplies if wells are to be installed (screen, well casing, sand pack, bentonite chips, bentonite, cement mixture, water)
- Health and safety records required for working on-site
- Support vehicles
- PPE, typically:
  - Long-sleeved shirt and long pants
  - Steel-toed boots
  - Hardhat
  - Nitrile gloves when handling potentially contaminated materials
  - Leather work gloves when chemical exposures are not anticipated
  - Safety glasses with side shields
  - Other as required by Health and Safety Plan

3.0 PROCEDURES

The planned depth of each soil boring will be determined by the Task Leader or project-specific document before drilling. The Field Geologist/Engineer will specify to the drill rig operator the desired total depth of the boring, the depth of soil sample collection, method of sample retrieval, and other matters pertaining to the satisfactory completion of the borings. The Field Geologist/Engineer will anticipate the volume and nature of drill cuttings and arrange for appropriate handling and storage on-site including designating a secure and convenient storage area. Drill cuttings, unused soil samples, and drilling fluids—collectively referred to as Investigation-Derived Waste (IDW)—generated during drilling of soil borings will be stored properly for future disposal by the client, unless other arrangements have been made. When water or other materials are to be introduced to the borehole, arrangements will be made so that those materials are sampled and analyzed as control samples.

Prior to the start of drilling, drilling permits must be obtained and a utility survey must be conducted.

3.1 Pre-Drilling Activities

Soil borings may be advanced using any appropriate drilling technique. The type of equipment used depends upon the site geology, hydrology, equipment available, and monitoring design. Control of cuttings and other potentially contaminated materials at the drill site may influence drilling method selection. Depending upon equipment availability and site geology, more than one method may be combined to complete a particular monitoring well installation. Typically, soil borings will be continuously cored or cored at selected intervals. At selected locations, discrete soil samples may be collected.

3.2 Drilling Oversight

During drilling the Field Geologist/Engineer shall oversee field operations, document field activities, prepare boring logs, and oversee containment of the drilling residuals. The following section describes what the Field Geologist/Engineer should observe during drilling.

During the initial five feet of drilling:

- If surface is protected by asphalt or concrete, remove this material. Asphalt can usually be penetrated by augers or other drill tooling. However, if the surface is covered with concrete, it is advisable to arrange for a concrete cutter to provide access to the subsurface.
- The top five feet of soil should be hand-augered or cleared using air knife whenever possible, in case subsurface utilities are encountered.
- Observe surface soil type to determine the presence of fill or evidence of surface contamination (e.g., soil staining, odors).

During ensuing operation of the drilling rig and as drilling progresses, note and observe the following:

- Keep an accurate record of the drilling depth, depth at which samples are collected, sample condition and recovery, and blow counts. Blow counts are used in most drilling techniques other than DPT, and they represent the number of blows (by the 140-pound sampling hammer falling 30 inches, or equivalent auto-hammer) that are required to advance an 18-inch long split-spoon sampler and are recorded as three numbers. The first number is the number of blows required to advance the sampler the first 6 inches, and the second and third numbers are the number of blows required to advance the sampler from 6 to 12 inches and from 12 to 18 inches. Blow counts are used to estimate ground density and are used in many empirical geotechnical formulae.
- Observe depth(s) at which groundwater is encountered, including occurrence of perched water.
- Observe depth(s) at which obvious contamination is encountered (discolored soil, non-aqueous phase liquids [NAPLs]).
- Record relevant rig operations (e.g., leaks, breakdowns, fast or slow drilling, and rig chatter).
- Observe that drilling residuals are properly contained. If using drums, make sure that the drums are sealed, labeled with the date, boring location, and depth interval, and stored in the

designated waste storage area. Drilling residuals from one boring should not be mixed with those from another boring.

- Observe that proper rig decontamination procedures are followed and that the augers are not reused between borings until they have been decontaminated. Decontamination rinse water should be contained in drums. Drums should be sealed, labeled, and handled in the same manner as drums containing drilling residuals.
- Communicate with the Project Manager during field activities. Normally, the Field Geologist/Engineer should call the Project Manager once each day to provide a progress report. If unusual events or difficulties occur during drilling, the field staff should report to the Project Manager and discuss approaches for problem resolution, or the significance of unusual field events. Unusual field events that should be reported include (but are not limited to) unanticipated geologic conditions, unexpected groundwater conditions, and unexpected evidence of chemical contamination.

3.3 Drilling Methods

3.3.1 Direct-Push Technology

Direct-push technology (DPT), e.g., Geoprobe® (or equivalent), although not "drilling" in the traditional sense, is a commonly used technique for quickly advancing small-diameter tooling in shallow unconsolidated soils. DPT uses both static force and the dynamic percussion force of a soil-probing hammer to advance small diameter sampling tools. It rearranges particles in the subsurface by application of weight and percussion thereby advancing the tool string producing no cuttings in the process. Soil samples can be continuously collected from the center of some DPT tooling in sections of clear plastic sleeves for logging and sampling purposes. Because of the manner in which DPT tooling is advanced, the term "soil boring" may be a misnomer when referring to DPT; however, through common usage boreholes made by removing and displacing subsurface materials using DPT are generally included in discussions of soil borings.

3.3.2 Sonic Drilling

Sonic drilling utilizes high-frequency vibration, aided by downward pressure and rotation, to advance tooling in various subsurface formations. A sonic rig uses an oscillator or head with eccentric weights driven by hydraulic motors to generate high sinusoidal force in a rotating pipe drill. The frequency of vibration of the drill bit or core barrel can be varied to allow optimum penetration of subsurface materials. A dual string assembly, typically 10-feet in length, allows advancement of casing with the inner casing used to collect samples. Small amounts of air and water can be used to remove the material between the inner and outer casing. Bits used in sonic drilling can penetrate boulders, construction debris, and bedrock (to a limited depth). Excess formation material generated by the cutting face of the bit is forced into the borehole wall thus resulting in the generation of no cuttings during the drilling process other than the generated core sample. However, the vibratory action used during advancement of the sampling barrel into the subsurface and during removal of the sample from the sample barrel can stratify some formations and consolidate or loosen others, thereby resulting in disturbed samples in some cases.

3.3.3 Hollow-Stem Auger (HSA) Drilling

The hollow-stem, continuous-flight auger, or "hollow-stem auger" (HSA), is a commonly employed tool for drilling and installing wells in unconsolidated and semi-consolidated materials. Augers utilize a spiral tool form consisting of a long inclined plane with fixed mechanical advantage ("flighting") wrapped around a central stem. Continuous flighting refers to a design in which the flights of the auger extend the entire length of the auger stem. Individual auger sections, typically 5-feet in length, are also called flights. HSA employs rotation of the flights to advance through the formation and remove drill cuttings. When drilling, a cutting head is attached to the first auger flight, and as the auger is rotated downward, additional auger flights are attached, one at a time, to the upper end of the previous auger flight. As the augers are advanced downward, the cuttings move upward outside of the hollow-stem along the continuous flighting. The hollow-stem or core of the auger allows drill rods and samplers to be inserted through the center of the augers. The hollow-stem of the augers also acts to temporarily case the borehole, so that well screen and casing may be inserted down through the center of the augers once the desired depth is reached. During drilling with the hollow stem auger, the drill cuttings will be discharged up through the open hole; the sediment will be shoveled and transferred into appropriate soil waste bins for transport and disposal.

3.3.4 Air-Rotary and Air-Rotary Casing Hammer Drilling

In rotary drilling, a drill rod with an attached bit is continuously rotated with downward pressure to disaggregate formation material into drill cuttings. Rotary drilling involves the use of circulating fluids (i.e., mud, water, or air) to remove the drill cuttings as drilling progresses. The use of any drilling fluids must be evaluated to ensure that their introduction into the subsurface will not adversely affect subsurface chemistry nor affect the ability to collect representative subsurface samples.

In the case of air-rotary drilling, compressed and filtered air is force down the drill pipe and back up the borehole to remove the drill cuttings. Air-rotary drilling is a very fast and efficient means of drilling. Rigs that are properly equipped and staffed can drill several hundred feet of hole per day. The air-rotary method can reach to several thousand feet in depth and create borehole diameters up to approximately 17 inches. Sediment sampling is supported both in poorly consolidated materials (by split-barrel samplers) and in consolidated rock (by coring). The use of air can result in an acute hazard when air rotary techniques are employed in contaminated formations because the air flow can transport vapors to the surface where they can become an inhalation hazard. Special attention must be paid to the monitoring of workers' breathing zones during air-rotary drilling.

Air rotary rigs are sometimes fitted with a casing driver to overcome borehole instability problems in unconsolidated sediments. When equipped with such a casing, air-rotary rigs also minimize the potential for inter-aquifer contamination. The Air-Rotary Casing Hammer System (ARCH) is one such system consisting of a non-rotating flush-threaded casing driven in conjunction with a conventional air-rotary drill string. The casing, which is a heavy wall flush-threaded pipe, is driven with a pneumatic or hydraulic drill-through casing hammer. Cuttings are cleared from the hole by the bit rotation and air circulation as in traditional air-rotary. The material is discharged through a hose into a cyclone, which separates the air from the formation cuttings to facilitate sampling and containment of drill cuttings.

3.3.5 Mud Rotary

Mud-rotary operates by the same general principles as air-rotary except that the cuttings are removed by a drilling fluid (water or water mixed with clays or “mud”). Mud-rotary drilling is a very fast and efficient means of drilling. Efficient rigs can produce several hundred feet of hole per day. The mud-rotary method can reach to several thousand feet in depth and create borehole diameters to greater than 48 inches. The method is adaptable to a wide range of geologic conditions. Sediment sampling is broadly supported in mud-rotary drilling: standard split-barrel and thin-wall sampling are available for use in poorly consolidated materials while a broad range of coring apparatus are supported for consolidated rock.

While there are hydrogeological conditions where mud rotary drilling is the best option (e.g., where it is difficult to maintain a stable borehole), mud rotary creates a potential for affecting aquifer characteristics and groundwater quality. If the mud rotary method is used, the drilling mud(s) should not affect the chemistry of groundwater samples or samples from the borehole, or adversely impact the operation of an installed groundwater well.

Because drilling muds can invade permeable zones, mud-rotary drilling is generally not recommended for installing soil vapor probes or vapor wells. In cases where mud-rotary drilling is used to install groundwater wells, increased well development time will likely be required to remove drilling mud pushed into the formation during drilling.

3.4 Samples and Logging

The following sections describe the procedures for obtaining soil samples for lithologic logging of soils.

3.4.1 Obtaining Samples

Borings will be cored or sampled at depth intervals specified by the Project Manager and Task Leader, based on the intended use of the boring. Generally, samples and/or cuttings will be obtained for logging purposes at a minimum 5-foot interval for borings. The samples and/or drill cuttings will be collected, observed, and described by the Field Geologist/Engineer. A lithologic log of these samples will be recorded on the Field Soil Boring Log.

3.4.2 Discrete Sampling

For discrete sampling of auger borings, sampling will be accomplished by driving or pushing a split barrel sampler or Shelby tube. The Field Geologist/Engineer will record information on the Field Soil Boring Log pertaining to the sampling, such as rate of penetration, drive-hammer blow count, and sample recovery. In general, the split-barrel sampler will be opened for observation and logging of the retrieved core. At selected depth intervals, the split-barrel sampler may be fitted with brass or stainless steel liners for collection of soil samples for possible subsequent chemical or physical testing. Similarly, direct-push tooling can be utilized to collect discrete samples within plastic liners appropriately sized to fit within the tooling. Samples may be retained for future review and/or preserved for chemical and physical testing, as specified by the Task Leader and/or project-specific documents.

Any discrete samples collected will be stored and labeled to show project number, boring number, and cored interval denoted either by depth or a sequential numbering system.

3.4.3 Logging of Soil Borings

The observations of the field geologist/engineer will be recorded on a Field Soil Boring Log at the time of drilling. The drill rig operator and the Field Geologist/Engineer will discuss significant changes in material penetrated, drilling conditions, hydraulic pressure, and drilling action. The Field Geologist/Engineer will be present during drilling of soil borings and will observe and record such changes by time and depth.

Drill cuttings and core samples will be observed in the field. A lithologic description will be recorded on the Field Soil Boring Log using the Unified Soil Classification System (USCS) as described in the American Society of Testing and Materials (ASTM) Standard D 2488-90. This description will include the USCS soil type, grain sizes and estimated percentages of each, moisture content, color according to the Munsell color charts, plasticity for fine-grained materials, consistency, and other pertinent information, such as degree of induration, calcareous content, presence of fossil and other distinctive materials.

3.4.4 Soil Screening

Soil samples collected from the borings may be screened using a portable meter such as a photoionization detector (PID), a flame ionization detector (FID), a lower explosion limit (LEL) meter or other organic vapor meter (OVM). The meter may be used to assess the presence of volatile organic compounds (VOCs) or other gases in soil samples.

3.4.5 Rock Coring

Rock coring is performed to obtain relatively undisturbed samples of solid, fractured, or weathered rock formations using a conventional or wire-line coring system combined with diamond or carbide-bit drilling methodology, for environmental, geotechnical, or mineral exploration purposes. Rock coring requires the use of drilling fluids to cool the bit and circulate cuttings. The drilling fluid may affect the chemistry of groundwater in fractures and interstices, and it is difficult to avoid such effects if direct sampling of core materials is required. Depending on the type of fluid used, it is usually possible to collect representative groundwater samples following well development, if the borehole is to be converted into a well. A critical component of rock coring, however, is the description and characterization of rock types and fracture zones. Geologic descriptions will be recorded on the Field Soil Boring Log using a visual-manual identification and classification system based on ASTM Standard D5434 and describing the following factors: field hardness, weathering, color, grain size/texture, lithology, fracture types, characteristics/attitudes, bedding/foliation, and additional characteristics (e.g., rock continuity, rock quality designation [RQD], crystallinity, fossil content, etc. as required by project guidelines). For additional information of rock coring, see Classification of Rocks by Russell B. Travis, Quarterly of the Colorado School of Mines, Vol. 50, January 1955.

3.5 Destruction of Soil Borings

Soil borings that are not completed as monitoring wells or soil vapor probes will be destroyed by grouting the borings with a neat cement grout, cement/sand grout, or cement/bentonite grout or bentonite grout in accordance with the permit conditions, local ordinances, and/or State requirements. The following procedure is general in nature and may be superseded by any or all of these requirements.

The Field Geologist/Engineer will calculate the borehole volume and compare it to the volume of grout used to evaluate whether bridging has occurred. These calculations and the actual volume emplaced will be noted on the Field Soil Boring Log. In boreholes containing groundwater or any borehole greater than 80 feet in depth, the grout will be placed in continuous lifts from the bottom of boring to the ground surface using gravity pouring with a tremie pipe. In dry boreholes less than 80 feet in depth, grout may be placed by gravity pouring without a tremie pipe. In some situations, grout may be pumped into a borehole using a tremie pipe. After the borehole is grouted, additional grout will be added to the soil boring if significant settlement has occurred after the grout has set.

3.6 Post-Drilling Activities

Upon completion of grouting (if the borehole is completed as a monitoring well, or if it is abandoned), the grout should be allowed to cure for approximately 24 hours. At that time, the borehole site should be revisited, and additional grout should be added if necessary to bring the grout level to near surface. The ground surface should be restored to its original condition (e.g., asphalt, concrete, etc.) using material of a comparable quality and thickness to the original materials. The Field Geologist/Engineer should check that no cracks or openings are present, and that the completed surface is flush with the surrounding surface.

Once grouting and surface restoration have been completed, the boring location may be marked in the field. The Field Geologist/Engineer may drive nails for flagging or use paint to mark the boring location. The locations must be marked to allow surveyors to locate the borings when performing subsequent surveying activities.

In general, the Field Geologist/Engineer should arrange for a licensed surveyor to survey boring and well locations. Horizontal location coordinates are generally surveyed to the nearest 0.1 foot and referenced to the Nevada Coordinate System of 1983 (NAD83). Ground surface elevations are generally surveyed to the nearest 0.01 foot, and referenced to mean sea level datum (NAVD88).

3.7 Equipment Decontamination

The drill rods, drill pipe, hoses, bits, and other components that fluids and cuttings contact will be steam-cleaned before drilling at each boring location or alternatively washed in laboratory-grade alconox detergent and water solution using a brush, followed by rinsing in clean water. Only potable water from a municipal supply will be used for decontamination of drilling equipment.

Decontamination rinsate and water will be collected and stored on-site for future disposal by the client unless other arrangements have been made.

3.8 Site Clean-Up

ENVIRON staff should review the site with the drilling contractor after the work has been completed. The site should be left as clean as before the work was performed, and no residual safety hazards should remain as a result of the drilling. Specifically, the Field Geologist/Engineer should make sure that:

- If it is necessary to leave the rig on site overnight, the rig and all associated equipment are secured. The driller may want to hire a security guard. Safe-keeping of the rig and all associated equipment is the driller's responsibility.
- All waste containers containing IDW are properly labeled, securely sealed, and stored safely in the pre-designated location. Waste containers should be counted by the Field Geologist/Engineer, and the number and type of containers and the nature of waste generated should be documented. If necessary, waste samples should be collected for waste profiling.
- All trash, debris, and equipment should be removed from the site or stored properly on-site.
- Drilling residuals should be removed from the ground surface. If the ground surface is covered by concrete or asphalt, the surface should be patched with like material and cleaned to remove residual soil.
- All surface conditions and stored containers or equipment should pose no danger to site employees, and should not interfere with business operations at the site.

After these conditions have been met, the Field Geologist/Engineer can sign the drilling contractor's daily log. The Field Geologist/Engineer should leave the site only after the drilling contractor has departed.

3.9 Quality Control Samples

All field Quality Control (QC) samples must be prepared the same as primary samples with regard to sample volume, containers, and preservation. The sample handling and chain-of-custody procedures for the QC samples will be identical to the primary samples. The following are QC samples that may be collected during soil sampling:

- A field duplicate is an independent sample collected as close as possible to the same time that the primary sample is collected and from the same source. Field duplicates are used to document sample precision. Field duplicates will be labeled and packaged in the same manner as primary samples so that the laboratory cannot distinguish between the primary sample and the duplicate sample. Field duplicates are analyzed for the same suite of parameters as the primary samples. The frequency of analysis of field duplicates is generally one for every 20 primary samples, but may vary depending on project requirements.
- Equipment blanks are obtained by running distilled or deionized water over or through the sample collection equipment after it has been decontaminated, and capturing the water in the appropriate sample containers for analysis. Equipment blanks are analyzed for the same suite of parameters as the primary samples. The frequency of analysis of equipment blanks is generally one for every day that non-dedicated sampling equipment is used, but may vary depending on project requirements.
- Field blanks are used to assess the presence of contaminants arising from field sampling procedures. Field blank samples are obtained by filling a clean sampling container with reagent-grade deionized water. Field blanks are analyzed for the same suite of parameters as the primary samples. Field blanks may or may not be incorporated into a groundwater sampling plan depending on project requirements.
- Trip blanks are sample containers that are used to evaluate sample cross-contamination of VOCs during shipment. For groundwater sampling, trip blanks consist of hydrochloric acid-preserved, analyte-free, deionized water prepared by the laboratory in VOA vials that will be carried to the field, stored with the samples, and returned to the laboratory for VOC analysis. Generally, one trip blank is required to accompany each sample shipping container or cooler that contains samples for VOC analysis; however, this may vary depending on project requirements.

The following is an additional type of QC sample that may be collected during soil sampling from boreholes:

- Control samples are samples of any materials (water, drilling mud, etc.) that are to be introduced to the borehole to aid in drilling or for any other valid reason. Generally, introducing any foreign materials into boreholes should be avoided; however, when environmentally acceptable and approved materials are used during drilling, samples should be collected and analyzed (at a minimum) for the same analyses to be performed on primary samples. The frequency of analysis is generally one for every material used.

3.10 Sample Handling and Custody

Samples will be collected, handled, and stored in such a manner that they are representative of their original condition and chemical composition. Identification of samples and maintenance of custody are important elements that must also be utilized to ensure samples characterize site conditions. All samples will be properly identified and maintained under chain-of-custody protocol to protect sample integrity. The following sections discuss the sample handling and custody requirements.

3.10.1 Sample Identification

To maintain consistency, a sample identification convention including unique identifiers for all groundwater and QC samples must be developed and followed throughout the project. The sample identifiers will be entered onto the sample labels, field forms, chain-of-custody forms, and other records documenting sampling activities.

3.10.2 Sample Labels

A sample label will be affixed to all sample containers sent to the analytical laboratory. Field personnel will complete an identification label for each sample with the following information written in waterproof, permanent ink:

- Client and project number
- Sample location and depth, if relevant
- Unique sample identifier
- Date and time sample collected
- Filtering performed, if any
- Preservative used, if any
- Name or initials of sampler
- Analyses or analysis code requested

The use of pre-printed sample labels is preferred in order to reduce sample misidentification problems due to transcription errors. Sample labels must be completed and affixed to the sample container in the field at the time of sample collection.

If errors are made on a sample label, corrections will be made by drawing a single line through the error and recording the correct information. Corrections will be dated and initialed.

3.10.3 Containers, Preservation, and Hold Time

Each lot of preservative and sampling containers will be certified as contaminant-free by the supplier. All preserved samples will be clearly identified on the sample label and Chain-of-Custody form. If samples requiring preservation are not preserved, field records will clearly specify the reason for the discrepancy.

Chemical activity continues in the sample until it is either analyzed or preserved. Once the sample has been preserved, the sample may be held for a period of time before analysis. The time from the collection of the sample to the analysis is defined as the holding time. The holding time varies depending on the media being sampled and the analyses being performed. The collection, preservation, and analysis of samples must be conducted to avoid exceeding relevant holding times.

3.10.4 Sample Handling and Transport

Proper sample handling techniques are used to ensure the integrity and security of the samples. Samples for field measured parameters will be analyzed immediately in the field and recorded in the appropriate field forms. Samples for laboratory analysis will be transferred immediately to appropriate laboratory supplied containers in accordance with the following sample handling protocols:

- Don clean gloves before touching any sample containers, and take care to avoid direct contact with the sample;
- Samples will be quickly observed for color, appearance, and composition and recorded as necessary;
- The sample container will be labeled before or immediately after sampling;
- Sample containers and liners will be capped with Teflon®-lined caps before being placed in Ziploc™-type plastic bags. The samples will be placed in an ice chest kept at 4 °C for transport to the laboratory.
- All sample lids will stay with the original containers, and will not be mixed.
- Sample bottles will be wrapped in bubble wrap as necessary to minimize the potential for breakage during shipment.
- The *Chain-of-Custody* form will be placed in a separate plastic bag and taped to the cooler lid or placed inside the cooler. A custody seal will be affixed to the cooler if the samples are to be shipped by commercial carrier. For shipped samples, U.S. Department of Transportation shipping requirements will be followed and the sample shipping receipt will be retained in the project files as part of the permanent Chain-of-Custody document.

3.10.5 Sample Chain of Custody

Sample chain-of-custody procedures will be used to maintain and document sample integrity during collection, transportation, storage, and analysis. A sample is considered to be under the control of, and in the custody of, the responsible person if the samples are in their physical possession, locked or sealed in a tamper-proof container, or stored in a secure area.

The *Chain-of-Custody* form provides an accurate written record that traces the possession of individual samples from the time of collection in the field until they are accepted at the analytical laboratory. The Chain-of-Custody form also documents the samples collected and the analyses requested. The sampler will record the following information on the Chain-of-Custody forms:

- Client and project number
- Name or initials and signature of sampler
- Name of destination analytical laboratory
- Name and phone number of Project Leader in case of questions
- Unique sample identifier for each sample
- Data and time of collection for each sample
- Number and type of containers included for each sample
- Analysis or analyses requested for each sample
- Preservatives used, if any, for each sample
- Sample matrix for each sample
- Any filtering performed, if applicable, for each sample
- Signatures of all persons having custody of the samples
- Dates and times of transfers of custody
- Shipping company identification number, if applicable
- Any other pertinent notes, comments, or remarks

Blank spaces on the Chain-of-Custody will be crossed out and initialed by the field sampler between the last sample listed and the signatures at the bottom of the sheet.

The field sampler will sign the Chain-of-Custody and will record the time and date at the time of transfer to the laboratory or an intermediate person. A set of signatures is required for each relinquished/received transfer, including internal transfer. The original imprint of the Chain-of-Custody will accompany the sample containers and a duplicate copy will be kept in the project file.

If the samples are to be shipped to the laboratory, the original *Chain-of-Custody* relinquishing the samples will be sealed inside a plastic bag within the ice chest, and the chest will be sealed with custody tape that has been signed and dated by the last person listed on the *Chain-of-Custody*. U.S. Department of Transportation shipping requirements will be followed and the sample shipping receipt will be retained in the project files as part of the permanent *Chain-of-Custody* document. The shipping company (e.g., Federal Express, UPS) will not sign the *Chain-of-Custody* forms as a receiver; instead the laboratory will sign as a receiver when the samples are received.

4.0 PRECAUTIONS

Certain precautions should be taken to ensure safety during the implementation of this FGD. It is important to always remain alert and aware of your surroundings. All personnel performing on-site operations with the potential for exposure to hazardous substances or health hazards are required to be 40-hour trained in accordance with Code of Federal Regulations (CFR) 1910.120 and will meet the personnel training requirements in accordance with 29 CFR 1910.120(e). The drilling contractor shall be a licensed driller in accordance with local and state requirements, and a qualified drilling contractor for the installation of soil borings for environmental investigations.

Where required, permits will be obtained from the appropriate agency, and an underground utility check will be performed before drilling or excavating begins. An underground utility check will, at a minimum, consist of contacting the local utility alert service, e.g., Underground Service Alert (USA), if available. Typically, subsurface clearance should also be conducted by a private utility locating company contacted specifically to clear individual boring locations. Under certain circumstances, including at sites with deeply buried, unknown, or multiple underground utilities, as well as at high risk sites such as oil refineries and heavy industrial facilities, manual utility clearance using hand auger or air knife methods should also be performed. Additional subsurface clearing requirements may be described in the site-specific Health and Safety Plan.

The activities described in this FGD require the implementation of a site-specific Health and Safety Plan to inform personnel of the hazards associated with this work and to describe the methods that will be employed to mitigate those hazards. The HASP must be prepared and approved by the Project Manager, Task Leader and the Project Health and Safety Coordinator prior to initiating field work.

5.0 RECORDKEEPING

Information collected during drilling may be recorded on individual field forms. If the project requires it, a project-specific Field Logbook may replace any of the individual field forms with the exception of the Chain-of-Custody form. Following review by the Task Leader, the original field records will be kept in the project file. The following forms may be used to document the field activities:

- *Field Investigation Daily Log*
- *Field Soil Boring Log*
- *Equipment Calibration Log*
- *Chain-of-Custody*

A *Field Investigation Daily Log* will be completed for each day of fieldwork containing (at a minimum) the times and descriptions of the work performed, the activities of the drillers and any other subcontractors or visitors on-site, arrival and departure times for all involved, and any other pertinent information. For larger projects, or when otherwise deemed appropriate by the Task Leader, this information may alternatively be recorded in a field logbook. In these cases, a separate Field Logbook must be used for each project or site.

The *Field Soil Boring Log* will be used to record the locations and unique identification of soil samples collected from the soil borings. The Field Soil Boring Log will also be used to record lithological descriptions of the soils and rock types encountered.

The *Equipment Calibration Log* will be used to document the calibration and status of any measuring instruments used in the field, e.g., PID/FID, LEL, OVM, measuring tapes, water level measuring device, etc. The frequency and method of calibration will depend on the instrument. Any instruments used will be used in accordance with the factory-provided operating and/or service manuals.

Locations and unique identification of any samples collected from the borings will be recorded on the *Field Investigation Daily Log, Field Soil Boring Log*, a site map, and/or other appropriate forms.

If samples are collected, samples names, date/times, analyses to be performed, and other pertinent information will be recorded on the *Chain-of-Custody* form as a means of identifying and tracking the samples.

FIELD GUIDANCE DOCUMENT NO. 004
ONE-TIME "GRAB" GROUNDWATER SAMPLING

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Documents used as reference during preparation ……………..	

Table of Contents

1.0 INTRODUCTION

This Field Guidance Document (FGD) describes procedures for one-time (or "grab") groundwater sampling at the Nevada Environmental Response Trust Site that will be conducted by or under the oversight of ENVIRON personnel. Although this FGD describes procedures for grab groundwater sampling for this project, it should be understood that there may be details of this type of work not specifically discussed in this FGD that would be followed by personnel trained in these techniques. To ensure that sampling is performed in a safe and complete manner, ENVIRON personnel involved in field activities should be sure that they understand the scope of work and the level of detail necessary for each field activity prior to mobilizing to perform the work.

This FGD is intended as a guidance document and does not supersede ENVIRON Health and Safety procedures or Site-Specific Health and Safety Plan (HASP) requirements. All ENVIRON employees shall follow the guidelines, rules, and procedures contained in site-specific HASPs prior to adhering to any procedures recommended in this FGD. The ENVIRON Project Manager and Task Leader must ensure that all project personnel review and sign the applicable HASP, and that the completed HASP and relevant project information is maintained in the project file. The signatures of the Project Manager and Task Leader indicate approval of the methods and precautions outlined in the HASP. The ENVIRON Project Manager and Task Leader will also be responsible for seeing that project personnel involved in field activities follow the procedures outlined in this and other applicable FGDs.

All personnel performing on-site operations with the potential for exposure to hazardous substances or health hazards are required to be 40-hour trained in accordance with Code of Federal Regulations (CFR) 1910.120 and will meet the personnel training requirements in accordance with 29 CFR 1910.120(e).

2.0 EQUIPMENT/MATERIALS

Equipment and materials needed to conform to this FGD include:

- Health and Safety Plan
- Site information (maps, contact numbers, previous field logs, etc.)
- Electronic water level indicator (Solinst or similar)
- Photoionization Detector (PID) of Flame ionization detector (FID) if VOCs are suspected
- Sampling pump – peristaltic, submersible, or bladder pump with adjustable rate controls (the latter for low-flow sampling)
- Bladders for sample pump if applicable
- Sample tubing (Teflon® or Teflon®-lined tubing preferred for sampling organic compounds)
- Bailers and string if applicable

- Multi-parameter water quality meter capable of measuring (at a minimum) temperature, pH, and specific electrical conductance (SEC)
- Turbidity meter
- In-line filters (if required, e.g. for dissolved metals)
- Certified-clean sample containers and preservation supplies, sample labels, Ziploc™ bags
- Cooler with ice
- Decontamination supplies (e.g. phosphate-free detergent, distilled water)
- Tool kit with appropriate tools (socket wrench set, pry bar, Dolphin locks/keys)
- Drum(s) to collect purged water and decontamination water
- Drum labels
- Personal Protective Equipment (PPE), typically PPE will consist of:
  - Long-sleeved shirt and long pants
  - Steel-toed boots
  - Hardhat
  - Nitrile gloves
  - Safety glasses with side shields
  - Earplugs
  - Other as required by Health and Safety Plan
- Field Forms (If the project requires it, a project-specific Field Logbook may substitute for any of the following with the exception of the Chain of Custody)
  - *Field Investigation Daily Log*
  - *Field Soil Boring Log*
  - *Water Level Measurement Log*
  - *Water Purging Log and Sampling Log*
  - *Equipment Calibration Log*
  - *Chain-of-Custody*

3.0 METHODOLOGY

The HydroPunch, EnviroProbe, temporary well point, and other grab groundwater sampling methods can be used with various subsurface exploration methods, including direct-push drilling, hollow stem auger drilling, rotary drilling, and cone penetration testing (CPT). Selection of the appropriate sampling tool should be based on anticipated field conditions such as the site hydrogeology (e.g., depth of sampling location below the water table, soil grain size, and estimated permeability), and type of subsurface exploration method employed. The following sections discuss the methods that may be used for the collection of grab groundwater samples.

3.1 Hydropunch

The HydroPunch consists of a drive point, a stainless steel screen section, a sample reservoir integral with the tool body, and assorted o-rings and check valves to create watertight seals between the various components. Two models of the HydroPunch have been developed, each having slightly different designs and/or component parts. All components are made of stainless steel, Teflon, or other relatively inert materials. The tool can be disassembled easily for cleaning between sampling events.

3.2 EnviroProbe

The EnviroProbe consists of a stainless steel drive point with a retractable outer sleeve, a stainless steel wire-cloth filter, various viton rubber o-rings, and a flexible viton rubber seal (septum) at the upper end of the probe. The rubber septum provides a watertight seal that prevents water from readily entering or exiting the top of the probe. The filter is attached to the inside body of the probe and is protected by the retractable outer sleeve. The sample reservoir is part of a separate assembly. The tool can be disassembled readily for cleaning between sampling events.

3.3 Temporary Well Point

Temporary well points are similar to installing traditional monitoring wells in that there is a polyvinyl chloride (PVC) riser and slotted screen installed within a drilled borehole; however, for temporary well points, a well seal is not installed. The well points typically consist of 1-inch or 2-inch diameter well screen and riser, the well screen typically being 5-feet in length within the targeted water-bearing zone. A sand pack can be emplaced surrounding the well screen like a traditional monitoring well, or a pre-pack well (a well screen with an integral filter pack) can be installed. Alternatively, in certain cases, the temporary well point can be installed without a filter pack; however, turbidity may be significant.

3.4 Sampling from Drilling Augers or Drive Rods

If it is not feasible to obtain a grab groundwater sampling using either HydroPunch or temporary well points, grab groundwater samples also can be collected directly from inside the drilling augers or drive rods; however, turbidity may be significant.

4.0 PROCEDURES

Installation of the EnviroProbe or HydroPunch generally follows the same procedure. A target sample interval (target zone) is usually identified prior to collecting a sample. When sampling using conventional drilling methods, the soil boring is advanced to a depth immediately above the target zone prior to installing the sampling tool. The sampling tool is attached to one of several different types of standard drilling rods (minimum 1-inch inside diameter for the EnviroProbe), lowered to the bottom of the existing borehole, and advanced (driven or pushed) approximately 2 to 4 feet into undisturbed formation. Internal seals and/or check valves create a water tight sampling tool while in the closed position, so that the EnviroProbe or HydroPunch can be used in fluid filled boreholes.

After the sampling tool is emplaced at the target sample depth, the outer sleeve is retracted approximately 1 to 1.5 feet (generally 1 foot of retraction for the EnviroProbe and 1.5 feet of retraction for the HydroPunch). As the outer sleeve is retracted, subsurface friction keeps the drive point in place, exposing the screen section, and allowing water to enter the sampling tool.

4.1 Hydropunch

HydroPunch I groundwater samples are usually collected under hydrostatic conditions, whereby groundwater flows from the formation through the screened section and into the sample reservoir. Accordingly, HydroPunch I cannot be used at depths less than approximately 5 feet below the groundwater table. The sample reservoir is allowed to fill until groundwater enters the drive rod; the water level inside the drive rod can be measured using a water level indicator.

The actual sample collection time at each depth depends upon the physical properties of the target zone and the fluid pressure outside the probe. Once the sample reservoir is filled, the HydroPunch is returned to the surface. Although the sample reservoir is sealed at both ends by internal one way check valves, care must be taken to avoid cross-communication with transmissive units or borehole fluids at a higher potentiometric head than the target zone. Before retrieving the tool, deionized water should be added to the drive rod to a level that exceeds the highest potentiometric surface in the borehole.

HydroPunch II can be used below the water table, in a manner similar to HydroPunch I, or it can used at the water table in the "hydrocarbon mode." If HydroPunch II is used in the "hydrocarbon mode," the sample is collected by lowering a narrow diameter bailer through the drive rod (minimum 1- inch diameter) and bailing out the volume of water required for analysis. The screen and drive point are left in the hole as the HydroPunch II tool is removed. When the sample is retrieved to the surface, it is decanted into laboratory prepared sample containers suitable for the analysis desired. The HydroPunch is then disassembled for decontamination and preparation for subsequent sampling depths. The HydroPunch I can be continued in the same borehole to the next desired depth.

4.2 EnviroProbe

Groundwater samples are collected by lowering the appropriate groundwater monitoring system (GMS) tool down the drive rod (i.e., drill rod). The GMS tools consist of a pore pressure transducer unit (i.e., an in-situ pressure transducer with a cable of appropriate length and an electronic data logger or other type of read out unit) and a GMS groundwater sample collection kit. The GMS groundwater sample collection kit consists of sample vials, ranging in size from 35 to 1,000 milliliters (ml), and a sample vial housing assembly. The sample vial(s) are sealed with a flexible viton rubber septum and cap similar to the upper end of the probe.

Prior to collecting a groundwater sample, the pore pressure unit is connected in series with the sample vial housing via an arrangement of double-ended hypodermic needles. After the housing and pore pressure unit have been connected, the sample vial is evacuated with a hand vacuum pump. Sampling and pore pressure measurements are obtained by lowering the pressure transducer unit and housing assembly down the drive rod. The tools connect the EnviroProbe via a quick coupling system through the hypodermic needles, which provide a temporary, closed system, hydraulic connection. Groundwater samples are obtained directly from the EnviroProbe and into the pre-evacuated sample vials. The pressure transducer is used to monitor filling of the sample vial and to measure hydrostatic pressure of the formation after the sample vial has filled.

If needed, the pore pressure unit or the GMS groundwater sampling unit can be used independently. The time allowed to fill the vial depends on the physical properties of the target formation and the groundwater pressure at the depth of the probe.

After the sample vial has filled, the sample housing is withdrawn from the drive rods and the sample vial removed. The EnviroProbe is generally purged by removing one probe volume (approximately 15 ml) of groundwater prior to collecting a sample for preservation and transport to the laboratory. At locations where multiple sample containers must be filled, the probe can be sampled repeatedly at the same depth by repeating the sample collection procedures.

4.3 Hydropunch and EnviroProbe Constraints

The EnviroProbe require drive rods of a minimum 1-inch inside diameter. HydroPunch I and Hydropunch II ("in the groundwater mode") require drive rods of sufficient diameter to allow passage of the water level indicator, generally about ½ inch. HydroPunch II in the "hydrocarbon mode" (water table sampling) requires drive rods of a minimum of 1-1/8-inch diameter to allow passage of the 1-inch-outside-diameter bailer. As stated earlier, HydroPunch I (and HydroPunch II in the "groundwater mode") cannot be used at sampling depths less than 5 feet below the water table. HydroPunch I, when full, has a capacity of 500 ml; HydroPunch II, when full, has a capacity of 1250ml. The EnviroProbe system and HydroPunch II in the "hydrocarbon mode" allow for collection of unlimited sample volumes. The HydroPunch I can be assembled to allow samples to be bailed in a manner similar to hydrocarbon mode so that unlimited sample volume is available.

4.4 Temporary Well Point Sampling

After allowing sufficient water from the formation to enter the temporary well (typical times range from 15 minutes to 1 hour), a groundwater sample is collected by carefully and slowly lowering a new polyethylene bailer into the temporary well. After removal from the boring, fluid in the bailer will be carefully transferred to the appropriate sampling container. Samples obtained for volatile organic compound (VOC) analysis will be collected to minimize the potential for volatilization (e.g., slowly and carefully lowering the bailer into the temporary well and carefully transferring the water into VOC vials). Unless otherwise specified, for obtaining samples for analysis other than VOCs, or dissolved gases, a peristaltic pump may also be used for shallow groundwater sample collection. Once the groundwater sample has been collected, the temporary well is removed from the borehole.

Depending on field conditions, temporary well point purging may be conducted. If temporary well purging takes place, then 1 to 3 casing volume may be purged depending on the depth of the well, the depth to water, and the production of the temporary well point. Low-flow sampling techniques may be employed in temporary well points if deemed appropriate by the Task Leader. If so, see the FGD entitled, Low-Flow Groundwater Sampling.

4.5 Field Filtration

Field filtering of groundwater may be necessary for some analyses, such as dissolved metals. However, field filtering can negatively affect other analyses, therefore, it is critical to confirm with the Task Leader or project-specific document which samples and analyses require field filtration prior to sampling.

Typically, a high-capacity polyethersulfone filter with a pore size of 0.45 microns is used to field filter groundwater samples (e.g. Quickfilter® Model No. QF045). Filters of this type have a capacity of 100-500 milliliters per minute (ml/min) and can be used with a pump via clean flexible tubing or a bailer using an included bailer interface tube. The filter cartridge must be certified to exhibit non-detectable levels of the compounds for which the sampling and analysis is intended to investigate.

- Regulate flow of groundwater to between 100 and 500 ml/min.
- Remove unused filter cartridge from the factory packaging and connect to tubing orienting the filter such that the flow of water follows the arrow on the filter cartridge.
- Filter approximately 100 ml groundwater through filter and discard to purge water container.
- Filter into clean sample containers and preserve immediately according to analytical method requirements.

Groundwater filter cartridges are dedicated sampling equipment. A new cartridge should be used at each sampling location. Do not attempt to clean filter cartridges. If the filter becomes clogged or groundwater flow is too slowed, remove and replace with a new filter cartridge.

4.6 Equipment Decontamination

The EnviroProbe and HydroPunch are cleaned by complete disassembly, including o-rings and/or check valves, followed by a laboratory-grade detergent and potable water wash, followed by a deionized water rinse. All decontamination rinsate will be collected and stored properly for future off-site disposal. The condition of o-rings should be checked during each cleaning and replaced as necessary. The tool will be reassembled after cleaning, following the instructions provided in the appropriate sampling kits.

In case of a temporary well point, once the PVC is removed from the hole, it will be discarded and new dedicated PVC will be used on the next borehole. When collected a sample directly from drilling augers or drive rods, decontamination follows the same procedures as described in the FGD entitled Drilling and Destruction of Soil Borings.

4.7 Quality Control Samples

All field Quality Control (QC) samples must be prepared the same as primary samples with regard to sample volume, containers, and preservation. The sample handling and chain-of-custody procedures for the QC samples will be identical to the primary samples. The following are QC samples that may be collected during groundwater sampling:

- A field duplicate is an independent sample collected as close as possible to the same time that the primary sample is collected and from the same source. Field duplicates are used to document sample precision. Field duplicates will be labeled and packaged in the same manner as primary samples so that the laboratory cannot distinguish between the primary sample and the duplicate sample. Field duplicates are analyzed for the same suite of parameters as the primary samples. The frequency of analysis of field duplicates is generally one for every 20 primary samples, but may vary depending on project requirements.
- Equipment blanks are obtained by running distilled or deionized water over or through the sample collection equipment after it has been decontaminated, and capturing the water in the appropriate sample containers for analysis. Equipment blanks are analyzed for the same suite of parameters as the primary samples. The frequency of analysis of equipment blanks is generally one for every day that non-dedicated sampling equipment is used, but may vary depending on project requirements.
- Field blanks are used to assess the presence of contaminants arising from field sampling procedures. Field blank samples are obtained by filling a clean sampling container with reagent-grade deionized water. Field blanks are analyzed for the same suite of parameters as the primary samples. Field blanks may or may not be incorporated into a groundwater sampling plan depending on project requirements.
- Trip blanks are sample containers that are used to evaluate sample cross-contamination of VOCs during shipment. For groundwater sampling, trip blanks consist of hydrochloric acid-preserved, analyte-free, deionized water prepared by the laboratory in VOA vials that will be carried to the field, stored with the samples, and returned to the laboratory for VOC analysis. Generally, one trip blank is required to accompany each sample shipping container or cooler that contains samples for VOC analysis; however, this may vary depending on project requirements.

4.8 Sample Handling and Custody

Samples will be collected, handled, and stored in such a manner that they are representative of their original condition and chemical composition. Identification of samples and maintenance of custody are important elements that must also be utilized to ensure samples characterize site conditions. All samples will be properly identified and maintained under chain-of-custody protocol to protect sample integrity. The following sections discuss the sample handling and custody requirements.

4.8.1 Sample Identification

To maintain consistency, a sample identification convention including unique identifiers for all groundwater and QC samples must be developed and followed throughout the project. The sample identifiers will be entered onto the sample labels, field forms, chain-of-custody forms, and other records documenting sampling activities.

4.8.2 Sample Labels

A sample label will be affixed to all sample containers sent to the analytical laboratory. Field personnel will complete an identification label for each sample with the following information written in waterproof, permanent ink:

- Client and project number
- Sample location and depth, if relevant
- Unique sample identifier
- Date and time sample collected
- Filtering performed, if any
- Preservative used, if any
- Name or initials of sampler
- Analyses or analysis code requested

The use of pre-printed sample labels is preferred in order to reduce sample misidentification problems due to transcription errors. Sample labels must be completed and affixed to the sample container in the field at the time of sample collection.

If errors are made on a sample label, corrections will be made by drawing a single line through the error and recording the correct information. Corrections will be dated and initialed.

4.8.3 Containers, Preservation, and Hold Time

Each lot of preservative and sampling containers will be certified as contaminant-free by the supplier. All preserved samples will be clearly identified on the sample label and Chain-of-Custody form. If samples requiring preservation are not preserved, field records will clearly specify the reason for the discrepancy.

Chemical activity continues in the sample until it is either analyzed or preserved. Once the sample has been preserved, the sample may be held for a period of time before analysis. The time from the collection of the sample to the analysis is defined as the holding time. The holding time varies depending on the media being sampled and the analyses being performed. The collection, preservation, and analysis of samples must be conducted to avoid exceeding relevant holding times.

4.8.4 Sample Handling and Transport

Proper sample handling techniques are used to ensure the integrity and security of the samples. Samples for field measured parameters will be analyzed immediately in the field and recorded in the appropriate field forms. Samples for laboratory analysis will be transferred immediately to appropriate laboratory supplied containers in accordance with the following sample handling protocols:

- Don clean gloves before touching any sample containers, and take care to avoid direct contact with the sample;
- Samples will be quickly observed for color, appearance, and composition and recorded as necessary;
- The sample container will be labeled before or immediately after sampling;
- Sample containers and liners will be capped with Teflon®-lined caps before being placed in Ziploc™-type plastic bags. The samples will be placed in an ice chest kept at 4 °C for transport to the laboratory.
- All sample lids will stay with the original containers, and will not be mixed.
- Sample bottles will be wrapped in bubble wrap as necessary to minimize the potential for breakage during shipment.
- The *Chain-of-Custody* form will be placed in a separate plastic bag and taped to the cooler lid or placed inside the cooler. A custody seal will be affixed to the cooler if the samples are to be shipped by commercial carrier. For shipped samples, U.S. Department of Transportation shipping requirements will be followed and the sample shipping receipt will be retained in the project files as part of the permanent Chain-of-Custody document.

4.8.5 Sample Chain of Custody

Sample chain-of-custody procedures will be used to maintain and document sample integrity during collection, transportation, storage, and analysis. A sample is considered to be under the control of, and in the custody of, the responsible person if the samples are in their physical possession, locked or sealed in a tamper-proof container, or stored in a secure area.

The *Chain-of-Custody* form provides an accurate written record that traces the possession of individual samples from the time of collection in the field until they are accepted at the analytical laboratory. The Chain-of-Custody form also documents the samples collected and the analyses requested. The sampler will record the following information on the Chain-of-Custody forms:

- Client and project number
- Name or initials and signature of sampler

- Name of destination analytical laboratory
- Name and phone number of Project Leader in case of questions
- Unique sample identifier for each sample
- Data and time of collection for each sample
- Number and type of containers included for each sample
- Analysis or analyses requested for each sample
- Preservatives used, if any, for each sample
- Sample matrix for each sample
- Any filtering performed, if applicable, for each sample
- Signatures of all persons having custody of the samples
- Dates and times of transfers of custody
- Shipping company identification number, if applicable
- Any other pertinent notes, comments, or remarks

Blank spaces on the Chain-of-Custody will be crossed out and initialed by the field sampler between the last sample listed and the signatures at the bottom of the sheet.

The field sampler will sign the Chain-of-Custody and will record the time and date at the time of transfer to the laboratory or an intermediate person. A set of signatures is required for each relinquished/received transfer, including internal transfer. The original imprint of the Chain-of-Custody will accompany the sample containers and a duplicate copy will be kept in the project file.

If the samples are to be shipped to the laboratory, the original *Chain-of-Custody* relinquishing the samples will be sealed inside a plastic bag within the ice chest, and the chest will be sealed with custody tape that has been signed and dated by the last person listed on the *Chain-of-Custody*. U.S. Department of Transportation shipping requirements will be followed and the sample shipping receipt will be retained in the project files as part of the permanent *Chain-of-Custody* document. The shipping company (e.g., Federal Express, UPS) will not sign the *Chain-of-Custody* forms as a receiver; instead the laboratory will sign as a receiver when the samples are received.

5.0 PRECAUTIONS

Certain precautions should be taken to ensure safety during the implementation of this FGD. It is important to always remain alert and aware of your surroundings. All personnel performing on-site operations with the potential for exposure to hazardous substances or health hazards are required to be 40-hour trained in accordance with Code of Federal Regulations (CFR) 1910.120 and will meet the personnel training requirements in accordance with 29 CFR 1910.120(e).

The laboratory must be certified by the appropriate regulating agency for the analyses to be performed. If required, permits will be acquired from the appropriate agency, and an underground utility check will be performed before drilling or excavating begins. An underground utility check will, at a minimum, consist of contacting the local utility alert service, e.g., Underground Service Alert (USA), if available. Typically, subsurface clearance should also be conducted by a private utility locating company contacted specifically to clear individual boring locations. Under certain circumstances, including at sites with deeply buried, unknown, or multiple underground utilities, as well as at high risk sites such as oil refineries and heavy industrial facilities, manual utility clearance using hand auger or air knife methods should also be performed.

The activities described in this FGD require the implementation of a site-specific Health and Safety Plan to inform personnel of the hazards associated with this work and to describe the methods that will be employed to mitigate those hazards. The Health and Safety Plan must be prepared and approved by the Project Manager, Task Leader and Project Health and Safety Coordinator prior to initiating field work.

6.0 RECORDKEEPING

Information collected during groundwater sampling may be recorded on individual field forms. If the project requires it, a project-specific Field Logbook may replace any of the individual field forms with the exception of the *Chain-of-Custody* form. Following review by the Task Leader, the original field records will be kept in the project file. The following forms may be used to document the field activities:

- *Field Investigation Daily Log*
- *Field Soil Boring Log*
- *Water Level Measurement Log*
- *Water Purging and Sampling Log*
- *Equipment Calibration Log*
- *Chain-of-Custody*

The *Field Investigation Daily Log* will be completed for each day of fieldwork containing (at a minimum) the times and descriptions of the work performed, the activities of the drillers and any other subcontractors or visitors on-site, arrival and departure times for all involved, and any other pertinent information. For larger projects, or when otherwise deemed appropriate by the Task Leader, this information may alternatively be recorded in a Field Logbook. In these cases, a separate Field Logbook must be used for each project or site.

The *Field Soil Boring Log* will be used to record information relating to the installation of soil borings for grab groundwater sampling including rig type, location, depths, and sampling methods.

The *Water Level Measurement Log* will be used to record water level measurements taken prior to and after groundwater sampling. The type, serial number, and calibration date for the water level measuring device will be included on this form.

The *Water Purging and Sampling Log* will be used to record the details of grab groundwater sampling information for each location including the sampling methods used at each location. This form will also be used to record all of the measurements of drawdown (if applicable) and water quality parameters.

The *Equipment Calibration Log* will be used to document the calibration and status of any measuring instruments used in the field, e.g., PID/FID, water level measuring device, water quality meters, etc. The frequency and method of calibration will depend on the instrument. Any instruments used will be used in accordance with the factory-provided operating and/or service manuals.

Locations and unique identification of water samples collected from the monitoring wells will be recorded on the *Field Investigation Daily Log, Field Soil Boring Log, Low-Flow Purging and Sampling Log,* a site map, and/or other appropriate forms.

Samples names, date/times, analyses to be performed, and other pertinent information will be recorded on the *Chain-of-Custody* form as a means of identifying and tracking the samples.

FIELD GUIDANCE DOCUMENT NO. 006
LOW-FLOW GROUNDWATER SAMPLING

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Table of Contents

1.0 INTRODUCTION

This Field Guidance Document (FGD) describes procedures for low-flow groundwater sampling at the Nevada Environmental Response Trust Site that will be conducted by or under the oversight of ENVIRON personnel. Although this FGD describes procedures for low-flow groundwater sampling for this project, it should be understood that there may be details of this type of work not specifically discussed in this FGD that would be followed by personnel trained in these techniques. To perform this work in a safe and competent manner, ENVIRON personnel involved in field activities should be sure that they are trained in those field activities they are tasked with, and they understand the scope of work and the level of detail necessary for each field activity prior to mobilizing to perform the work.

This FGD is intended as a guidance document and does not supersede ENVIRON Health and Safety procedures or Site-Specific Health and Safety Plan (HASP) requirements. All ENVIRON employees shall follow the guidelines, rules, and procedures contained in site-specific HASPs prior to adhering to any procedures recommended in this FGD. The ENVIRON Project Manager and Task Leader must have project personnel review and sign the applicable HASP, and maintain the completed HASP and relevant project information in the project file. The signatures of the Project Manager and Task Leader indicate approval of the methods and precautions outlined in the HASP. The ENVIRON Project Manager and Task Leader will also be responsible for seeing that project personnel involved in field activities follow the procedures outlined in this and other applicable FGDs.

All personnel performing on-site operations with the potential for exposure to hazardous substances or health hazards are required to be 40-hour trained in accordance with Code of Federal Regulations (CFR) 1910.120 and will meet the personnel training requirements in accordance with 29 CFR 1910.120(e).

2.0 EQUIPMENT/MATERIALS

Equipment and materials needed to conform to this FGD include:

- Health and Safety Plan
- Site information (maps, contact numbers, etc.)
- Well information (previous water levels, well depths and screen intervals, previous purge logs, etc.)
- Electronic water level meter (Solinst or similar)
- Photoionization Detector (PID) and/or Flame ionization detector (FID)
- Adjustable-rate sampling bladder pump capable of rates <0.5 liters per minute (e.g., QED Sample Pro); other pumps may be acceptable, but must be approved by the Project Manager and/or Task Leader prior to use
- Bladders for sample pump

- Pump controller with or without on-board air compressor (If no on-board compressor, have a stand-alone air compressor and/or nitrogen tanks for operating bladder pumps
- Sample tubing (Teflon® or Teflon®-lined tubing for sampling organic compounds)
- Multi-parameter meter (e.g. YSI 556 Multi-Parameter Meter or equivalent) with flow through cell capable of measuring (at a minimum) temperature, pH, specific electrical conductance (SEC), dissolved oxygen (DO), and oxidation-reduction potential (ORP)
- Turbidity meter
- In-line filters (if required, e.g., for dissolved metals)
- Certified-clean sample containers and preservation supplies, sample labels, Ziploc™ bags
- Cooler with ice
- Decontamination supplies (e.g. phosphate-free detergent, distilled water)
- Tool kit with appropriate tools (socket wrench set, pry bar, Dolphin locks/keys)
- Drum(s) to collect purged water and decontamination water
- Drum labels
- PPE typically will consist of:
  - Long-sleeved shirt and long pants
  - Steel-toed boots
  - Hardhat
  - Nitrile gloves
  - Safety glasses with side shields
  - Other as required by the site-specific Health and Safety Plan
- Field Forms
  - *Field Investigation Daily Log*
  - *Water Level Measurement Log*
  - *Low-Flow Purging and Sampling Log*
  - *Equipment Calibration Log*
  - *Chain-of-Custody*

3.0 METHODOLOGY

This FGD has been prepared in accordance with the United States Environmental Protection Agency (USEPA) Standard Operating Procedure for Low-Stress (Low Flow)/Minimal Drawdown Ground-Water Sample Collection, dated 2002. This guidance document is included as Attachment 3 of the Ground-Water Sampling Guidelines for Superfund and RCRA Project Managers.

Unlike traditional purging methods, low-flow purging and sampling does not require the removal of an arbitrary volume of water from a well prior to sampling. Instead, low-flow purging and sampling relies on careful monitoring of water quality indicator parameters to determine when a representative groundwater sample can be collected. The low-flow methodology minimizes the effects on groundwater chemistry caused by the purging process by minimizing drawdown, reducing the amount of water removed from the well, and reducing the amount of turbidity in groundwater samples.

4.0 PROCEDURES

The following sections discuss the procedures to follow during low-flow purging and sampling of shallow monitoring wells with dedicated or non-dedicated equipment since both are employed. Where applicable and when possible, the purging and sampling techniques should remain consistent from one sampling event to the next.

Non-dedicated pumps made of inert materials may be used (see Section 2). To prevent cross-contamination, at least two separate pumps must be maintained for use at the Site: one for on-site wells with higher contaminant concentrations, and one for off-site wells having lower contaminant concentrations. All non-dedicated pumps must be easily decontaminated in the field. Tubing must be changed between each well. The reuse of tubing dedicated to a single well is encouraged to reduce waste between sampling events.

4.1 Pre-Sampling Activities

To the extent practical, sampling should begin at the well with the least contamination and proceed systematically to the wells with the higher expected concentrations. All measuring devices and monitoring equipment should be calibrated according to the manufacturer's instructions. Water quality meters must be calibrated daily before use. Equipment calibration details should be recorded in the *Equipment Calibration Log*.

If opening a well cap for sampling, the headspace at the top of the wells will be monitored for VOCs with a PID or FID. If VOCs are present, monitor worker breathing zones during purging/sampling and record measurements on field logs.

The proper procedure is as follows:

1. Unlock well and/or remove well cap. Note that wells may be flush-mount or above-grade completions.
2. Monitor the headspace at the top of the well for VOCs.
3. Measure the water level to obtain the static water level (see Section 4.2). Water levels should be measured to the nearest 0.01 foot relative to the TOC.

4. Use existing site information for total depth (TD) and the water level measurement to calculate the volume of water in the well.

4.2 Water Level Measurement

Water levels will be recorded on a *Water Level Measurement Log* and/or a *Water Purging and Sampling Log*.

Water levels can be measured by several techniques, but the most common method is using an electronic water level meter (e.g., Solinst). Other methods used at the site may include remote data logging via pressure transducers or from a pressure gauge at the top of artesian wells. Refer to manufacture's manuals for specific protocols for collecting data from remote water level measuring devices. For artesian wells, readings of pressure in pounds per square inch (psi) are recorded from a pressure gauge at the wellhead.

Water level meters must be decontaminated before initial use and after measurements are made in each well.

The proper sequence for water level measurement is as follows:

1. Turn water level meter on and check that its indicator is working.
2. Record the following information on the *Water Level Measurement Log* or the *Water Purging and Sampling Log*:
   - Well number
   - Top of casing elevation
   - Surface elevation, if available.
3. Use caution when opening the well. If pressure has developed inside the well casing, allow the well to stand without a cap for a few minutes until the water level stabilizes before taking a water level measurement. Record observance of positive or negative pressures in the well.
4. Inspect well for abnormalities (e.g., broken locks, damaged casing, blockages, etc.) and note on field logs. If there is dedicated tubing inside the well, it may have to be removed prior to gauging the well to avoid blocking the water level meter.
5. Lower the water level meter cable slowly into the well until the buzzer indicates a closed circuit. Raise and lower the electric cable slightly until the maximum response on the indicator is found. Record the static water level to the nearest hundredth (0.01) foot from the surveyed reference mark on the top edge of the well casing (TOC). If no reference mark is present, record in the log book where the measurement was taken (e.g., from the north side of the inner casing).

6. Repeat the measurement as necessary to confirm the level by raising and lowering the probe until the maximum response is observed.

7. Record the time and day of the measurement.

8. Compare measurement against historical measurements to perform a "reality check" of the measurement and recheck water level as needed.

9. The probe (or portion of the instrument that was immersed in ground water) will be cleaned with a solution of laboratory-grade phosphate-free detergent (e.g., Alconox™) and deionized water. The equipment will then be rinsed with deionized water and dried with a clean paper towel. Steam-cleaning is also an acceptable method of decontaminating the probe.

Water level measurements at the site will be taken as quickly as practically possible, to best represent the potentiometric surface across the site at a single time. Care will be taken not to drop foreign objects into the wells and not to allow the monitoring and sampling equipment to touch the ground or any other contaminating surfaces.

4.3 Purging and Sampling

1. If using a dedicated pump, attach sample tubing to the wellhead according to manufacturer's procedures.

2. If there is dedicated tubing in the well, but no dedicated pump, using appropriate PPE, pull the tubing and keep it from kinking or knotting by using a reel or by hand coiling it. Inspect the tubing for damage while removing it from the well and protect the tubing from touching the ground or other contaminated surfaces. If necessary to store the tubing, place in a clean plastic bag. If there is no tubing, or the dedicated tubing needs replacement, use only new tubing.

3. If using a non-dedicated pump, attach the tubing to the pump according to manufacturer's procedures, place the pump and support equipment at the well head and slowly lower the pump and tubing down into the monitoring well until the location of the pump intake is set at a predetermined location within the screen interval. Where possible, pre-measured tubing should be used to place the pump intake at the same depth as previous sampling events, or at a depth where there is known contamination within the screen interval. If there is no previous information for the well, the pump intake should be placed at the middle (or slightly above the middle) of the screen interval. Record the pump depth in the *Low-Flow Purging and Sampling Log*.

4. Measure depth to water to the nearest 0.01 feet relative to the reference measuring point on the TOC with an electronic water level indicator. Record depth to groundwater information in the *Low-Flow Purging and Sampling Log*. Leave water level indicator in the well.

5. Connect the discharge line from the pump to a flow-through cell that at a minimum measures temperature, pH, SEC, DO, and ORP. Turbidity measurements can be made using a separate turbidity meter. The discharge line from the flow-through cell must be directed to a container to hold purge water collected during purging and sampling of the well. Purge water will be collected in a portable tank (e.g., trailer-mounted polyethylene tank) and discharged to the on-site groundwater treatment system at the end of the sampling or when tank is full.

6. Connect the air lines to the flow controller and start pumping the well at a flow rate of between 0.1 and 0.5 liters per minute (L/min) and slowly increase the flow rate. (For new wells or wells with no purging history, start at the lower end of that range.) Check the water level. Maintain a steady flow rate while maintaining a drawdown of less than 0.3 feet. (Zero drawdown is optimal, but may not be achievable). If drawdown is greater than 0.3 feet, lower the flow rate; 0.3 feet is a goal to help guide with the flow rate adjustment. This goal will be difficult to achieve in some wells due to low hydraulic conductivities and limitations to the lowest flow rate a pump can produce while maintaining steady flow. See the Special Advisory at the end of these procedures.

7. Measure the discharge rate of the pump with a graduated cylinder and a stopwatch. Also, measure the water level and record both flow rate and water level on the *Low-Flow Purging and Sampling Log*. Continue purging, monitor and record water level and pump rate every 3 to 5 minutes. Purging rates should be kept at minimal flow to ensure minimal drawdown in the monitoring well.

8. A minimum of one tubing volume (including the volume of the water in the pump and flow cell) must be purged prior to recording the water quality indicator parameters. After this has been accomplished, monitor and record the water quality indicator parameters every three to five minutes in the *Low-Flow Purging and Sampling Log*. Stable readings of temperature, pH, SEC, DO, turbidity and ORP indicate when a representative sample can be collected. The stabilization criterion is based on three successive readings of the water quality indicator parameters as shown in Table 1. ORP may not always be an appropriate stabilization parameter and will depend on site-specific conditions. However, readings should be recorded because of its value for double-checking oxidizing conditions.

TABLE 1: Recommended Stabilization Criteria for Water Quality Indicator Parameters During Low-Flow Purging and Sampling

Parameter	Stabilization Criteria
Temperature	± 3% of reading (minimum of ±0.2° C)
pH	± 0.1 pH units
Specific Electrical Conductance (SEC)	± 3% S/cm
Dissolved Oxygen (DO)	± 0.3 milligrams per liter
Turbidity	± 10% NTUs (when turbidity is greater than 10 NTUs)
Oxidation-Reduction Potential (ORP)	± 10 millivolts

9. Once stabilization is achieved samples can be collected. Maintain the same pumping rate or reduce slightly for sampling as necessary in order to minimize disturbance of the water column. Disconnect the pump's tubing from the flow-through cell so that the samples are collected from the pump's discharge tubing. For samples collected for dissolved gases or VOC analyses, the pump tubing needs to be completely full of ground water to prevent the ground water from being aerated as it flows through the tubing. Generally, the sequence of the samples is immaterial unless filtered (dissolved) samples are collected. Filtered samples must be collected last (see below). All sample containers should be filled with minimal turbulence by allowing the ground water to flow from the tubing gently down the inside of the container. When filling VOC samples using volatile organic analysis (VOA) vials, a meniscus must be formed over the mouth of the VOA vial to eliminate the formation of air bubbles and head space prior to capping. Effervescence and colorimetric reactions should be recorded in the *Low-Flow Purging and Sampling Log.*

10. If a filtered (dissolved) metal sample is to be collected (or filtered samples for any other analyte are required), then an inline filter is fitted at the end of the discharge tubing and the sample is collected after the filter. The inline filter must first be flushed in accordance with manufacturer's recommendations and if there are no recommendations for flushing, a minimum of 0.5 to 1.0 liter of groundwater from the monitoring well must pass through the filter prior to sampling. (Note: Groundwater filter cartridges are dedicated sampling equipment. A new cartridge should be used at each sampling location. Do not attempt to clean filter cartridges. If the filter becomes clogged or groundwater flow is too slowed, remove and replace with a new filter cartridge.)

11. For non-dedicated systems, remove the pump from the monitoring well. Decontaminate the pump and hang the tubing within the well for the next sampling event. If tubing is damaged or otherwise needs replacing, remove and dispose of the tubing. For dedicated systems, disconnect the tubing that extends from the plate at the wellhead (or cap) and discard after use.

12. Close and lock the well.

Special Advisory: If a stabilized drawdown in the well can't be maintained at 0.3 feet and the water level is approaching the top of the screened interval, reduce the flow rate or turn the pump off (for 15 minutes) and allow for recovery. It should be noted whether or not the pump has a check valve. A check valve is required if the pump is to be shut off during purging. Under no circumstances should the well be pumped dry. Begin pumping at a lower flow rate, if the water draws down to the top of the screened interval again, turn pump off and allow for recovery. If two tubing volumes (including the volume of water in the pump and flow cell) have been removed during purging, then sampling can proceed next time the pump is turned on. This information should be noted in the *Low-Flow Purging and Sampling Log.* This behavior may necessitate an alternative purging and sampling procedure for subsequent sampling events.

4.4 Equipment Decontamination

The electronic water level meter and the water quality meters will be decontaminated by the following procedures:

1. The water level meter will be hand washed with phosphate-free detergent (e.g., Alconox™) and a scrubber, then triple rinsed with distilled water, or steam-cleaned.

2. The water quality meters and flow-through cell (if used) will be rinsed with distilled water between sampling locations. No other decontamination procedures are necessary or recommended for these meters since they are sensitive instruments. After the sampling event, the flow-through cell and sensors must be cleaned and maintained per the manufacturer's requirements.

Sample tubing will either be replaced or be dedicated to an individual well. Non-dedicated pumps will be decontaminated between monitoring wells and prior to moving off-site. The pump and discharge line (including support cable and electrical wires which were in contact with the groundwater in the well casing) must be decontaminated by the following procedure:

1. The outside of the pump, support cable, and electrical wires must be pressure-sprayed with soapy water, tap water and distilled water. Use bristle brush to help remove visible dirt and contaminants.

2. Place the sampling pump and discharge line in a bucket or in a short cylinder (e.g., a 4-inch diameter casing) with one end capped. The pump must be completely submerged in the water.

A small amount of phosphate-free detergent (e.g., Alconox™) must be added with the potable (tap) water.

3. Remove the pump from the bucket or 4-inch casing and scrub the outside of the pump housing and cable.

4. Place pump and discharge line back in the container, start pump and re-circulate soapy water for approximately 2 minutes. Add 5 gallons of potable (tap) water as needed.

5. Turn pump off and place pump into a second bucket of potable (tap) water. Turn on pump and allow to run until rinsed free of soapy water, adding tap water as necessary.

6. Turn off and place pump into a third bucket which contains 3 to 5 gallons of distilled/deionized water. Turn on pump and cycle water through until gone.

7. If hydrophobic contaminants are present (such as separate phase (i.e. LNAPL or DNAPL, high levels of PCBs, etc.) an additional decontamination step, or steps, may be required.

8. Decontamination water will be collected in a portable tank (e.g., trailer-mounted polyethylene tank) and discharged to the on-site groundwater treatment system.

Other decontamination procedures may be proposed, but must be reviewed and approved by the Trust prior to implementation.

4.5 Quality Control Procedures

All field Quality Control (QC) samples must be prepared the same as primary samples with regard to sample volume, containers, and preservation. The sample handling and chain-of-custody procedures for the QC samples will be identical to the primary samples. The following are QC samples that may be collected during groundwater sampling:

- A field duplicate is an independent sample collected as close as possible to the same time that the primary sample is collected and from the same source. Field duplicates are used to document sample precision. Field duplicates will be labeled and packaged in the same manner as primary samples so that the laboratory cannot distinguish between the primary sample and the duplicate sample. Field duplicates are analyzed for the same suite of parameters as the primary samples. The frequency of analysis of field duplicates is generally one for every 20 primary samples, but may vary depending on project requirements.
- Equipment blanks are obtained by running distilled or deionized water over or through the sample collection equipment after it has been decontaminated, and capturing the water in the appropriate sample containers for analysis. Equipment blanks are analyzed for the same suite of parameters as the primary samples. The frequency of analysis of equipment blanks is

generally one for every day that non-dedicated sampling equipment is used, but may vary depending on project requirements.

- Field blanks are used to assess the presence of contaminants arising from field sampling procedures. Field blank samples are obtained by filling a clean sampling container with reagent-grade deionized water. Field blanks are analyzed for the same suite of parameters as the primary samples. Field blanks may or may not be incorporated into a groundwater sampling plan depending on project requirements.
- Trip blanks are sample containers that are used to evaluate sample cross-contamination of VOCs during shipment. For groundwater sampling, trip blanks consist of hydrochloric acid-preserved, analyte-free, deionized water prepared by the laboratory in VOA vials that will be carried to the field, stored with the samples, and returned to the laboratory for VOC analysis. Generally, one trip blank is required to accompany each sample shipping container or cooler that contains samples for VOC analysis; however, this may vary depending on project requirements.

4.6 Sample Handling and Custody

Samples will be collected, handled, and stored in such a manner that they are representative of their original condition and chemical composition. Identification of samples and maintenance of custody are important elements that must also be utilized to ensure samples characterize site conditions. All samples will be properly identified and maintained under chain-of-custody protocol to protect sample integrity. The following sections discuss the sample handling and custody requirements.

4.6.1 Sample Identification

To maintain consistency, a sample identification convention including unique identifiers for all groundwater and QC samples must be developed and followed throughout the project. The sample identifiers will be entered onto the sample labels, field forms, chain-of-custody forms, and other records documenting sampling activities.

4.6.2 Sample Labels

A sample label will be affixed to all sample containers sent to the analytical laboratory. Field personnel will complete an identification label for each sample with the following information written in waterproof, permanent ink:

- Client and project number
- Sample location and depth, if relevant
- Unique sample identifier
- Date and time sample collected
- Filtering performed, if any
- Preservative used, if any

- Name or initials of sampler
- Analyses or analysis code requested

The use of pre-printed sample labels is preferred in order to reduce sample misidentification problems due to transcription errors. Sample labels must be completed and affixed to the sample container in the field at the time of sample collection.

If errors are made on a sample label, corrections will be made by drawing a single line through the error and recording the correct information. Corrections will be dated and initialed.

4.6.3 Containers, Preservation, and Hold Time

Each lot of preservative and sampling containers will be certified as contaminant-free by the supplier. All preserved samples will be clearly identified on the sample label and Chain-of-Custody form. If samples requiring preservation are not preserved, field records will clearly specify the reason for the discrepancy.

Chemical activity continues in the sample until it is either analyzed or preserved. Once the sample has been preserved, the sample may be held for a period of time before analysis. The time from the collection of the sample to the analysis is defined as the holding time. The holding time varies depending on the media being sampled and the analyses being performed. The collection, preservation, and analysis of samples must be conducted to avoid exceeding relevant holding times.

4.6.4 Sample Handling and Transport

Proper sample handling techniques are used to ensure the integrity and security of the samples. Samples for field measured parameters will be analyzed immediately in the field and recorded in the appropriate field forms. Samples for laboratory analysis will be transferred immediately to appropriate laboratory supplied containers in accordance with the following sample handling protocols:

- Don clean gloves before touching any sample containers, and take care to avoid direct contact with the sample;
- Samples will be quickly observed for color, appearance, and composition and recorded as necessary;
- The sample container will be labeled before or immediately after sampling;
- Sample containers and liners will be capped with Teflon®-lined caps before being placed in Ziploc™-type plastic bags. The samples will be placed in an ice chest kept at 4 °C for transport to the laboratory.
- All sample lids will stay with the original containers, and will not be mixed.
- Sample bottles will be wrapped in bubble wrap as necessary to minimize the potential for breakage during shipment.

- The *Chain-of-Custody* form will be placed in a separate plastic bag and taped to the cooler lid or placed inside the cooler. A custody seal will be affixed to the cooler if the samples are to be shipped by commercial carrier. For shipped samples, U.S. Department of Transportation shipping requirements will be followed and the sample shipping receipt will be retained in the project files as part of the permanent Chain-of-Custody document.

4.6.5 Sample Chain of Custody

Sample chain-of-custody procedures will be used to maintain and document sample integrity during collection, transportation, storage, and analysis. A sample is considered to be under the control of, and in the custody of, the responsible person if the samples are in their physical possession, locked or sealed in a tamper-proof container, or stored in a secure area.

The *Chain-of-Custody* form provides an accurate written record that traces the possession of individual samples from the time of collection in the field until they are accepted at the analytical laboratory. The Chain-of-Custody form also documents the samples collected and the analyses requested. The sampler will record the following information on the Chain-of-Custody forms:

- Client and project number
- Name or initials and signature of sampler
- Name of destination analytical laboratory
- Name and phone number of Project Leader in case of questions
- Unique sample identifier for each sample
- Data and time of collection for each sample
- Number and type of containers included for each sample
- Analysis or analyses requested for each sample
- Preservatives used, if any, for each sample
- Sample matrix for each sample
- Any filtering performed, if applicable, for each sample
- Signatures of all persons having custody of the samples
- Dates and times of transfers of custody
- Shipping company identification number, if applicable
- Any other pertinent notes, comments, or remarks

Blank spaces on the Chain-of-Custody will be crossed out and initialed by the field sampler between the last sample listed and the signatures at the bottom of the sheet.

The field sampler will sign the Chain-of-Custody and will record the time and date at the time of transfer to the laboratory or an intermediate person. A set of signatures is required for each relinquished/received transfer, including internal transfer. The original imprint of the Chain-of-Custody will accompany the sample containers and a duplicate copy will be kept in the project file.

If the samples are to be shipped to the laboratory, the original *Chain-of-Custody* relinquishing the samples will be sealed inside a plastic bag within the ice chest, and the chest will be sealed with custody tape that has been signed and dated by the last person listed on the *Chain-of-Custody*. U.S. Department of Transportation shipping requirements will be followed and the sample shipping receipt will be retained in the project files as part of the permanent *Chain-of-Custody* document. The shipping company (e.g., Federal Express, UPS) will not sign the *Chain-of-Custody* forms as a receiver; instead the laboratory will sign as a receiver when the samples are received.

5.0 PRECAUTIONS

Certain precautions should be taken to ensure safety during the implementation of this FGD. It is important to always remain alert and aware of your surroundings. All personnel performing on-site operations with the potential for exposure to hazardous substances or health hazards are required to be 40-hour trained in accordance with Code of Federal Regulations (CFR) 1910.120 and will meet the personnel training requirements in accordance with 29 CFR 1910.120(e).

The laboratory must be certified by the appropriate regulating agency for the analyses to be performed.

The activities described in this FGD require the implementation of a site-specific Health and Safety Plan to inform personnel of the hazards associated with this work and to describe the methods that will be employed to mitigate those hazards. The Health and Safety Plan must be prepared and approved by the Project Manager, Task Leader and Project Health and Safety Coordinator prior to initiating field work.

6.0 RECORDKEEPING

Information collected during groundwater sampling may be recorded on individual field forms. A project-specific Field Logbook may replace any of the individual field forms with the exception of the Chain-of-Custody form. Following review by the Task Leader, the original field records will be kept in the project file. The following forms may be used to document the field activities:

- *Field Investigation Daily Log*
- *Water Level Measurement Log*
- *Low-Flow Purging and Sampling Log*
- *Equipment Calibration Log*
- *Chain-of-Custody*

The *Field Investigation Daily Log* will be completed for each day of fieldwork containing (at a minimum) the times and descriptions of the work performed, the activities of the drillers and any other subcontractors or visitors on-site, arrival and departure times for all involved, and any other pertinent information. For larger projects, or when otherwise deemed appropriate by the Task Leader, this information may alternatively be recorded in a Field Logbook. In these cases, a separate Field Logbook must be used for each project or site.

The *Water Level Measurement Log* will be used to record water level measurements for all wells. The type, serial number, and calibration date for the water level measuring device will be included on this form. Additionally, this form will be used to record general observations of the conditions of the wells, wellheads, well boxes, and/or monuments.

The *Low-Flow Purging and Sampling Log* will be used to record the details of purging and sampling information for each well including the depth of the pump, purge rates, and volume purged from each well. This form will also be used to record all of the measurements of drawdown and water quality indicator parameters used for evaluating stabilization.

The *Equipment Calibration Log* will be used to document the calibration and status of any measuring instruments used in the field (e.g., PID/FID, water level measuring device, water quality meters, etc.). The frequency and method of calibration will depend on the instrument. Any instruments used will be used in accordance with the factory-provided operating and/or service manuals.

Samples names, date/times, analyses to be performed, and other pertinent information will be recorded on the *Chain-of-Custody* form as a means of identifying and tracking the samples.

FIELD GUIDANCE DOCUMENT NO. 007
GROUNDWATER WELL INSTALLATION

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Applicable to ……………………	Nevada Environmental Response Trust Site Henderson, Nevada
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Table of Contents

1.0 INTRODUCTION

This Field Guidance Document (FGD) describes procedures for groundwater well installation at the Nevada Environmental Response Trust Site that will be conducted by or under the oversight of ENVIRON personnel. Although this FGD describes procedures for groundwater well installation for this project, it should be understood that there may be details of this type of work not specifically discussed in this FGD that would be followed by personnel trained in these techniques. To ensure that well installation is performed in a safe and competent manner, ENVIRON personnel involved in field activities should be sure that they understand the scope of work and the level of detail necessary for each field activity prior to mobilizing to perform the work.

All personnel performing on-site operations with the potential for exposure to hazardous substances or health hazards are required to be 40-hour trained in accordance with Code of Federal Regulations (CFR) 1910.120 and will meet the personnel training requirements in accordance with 29 CFR 1910.120(e).

The drilling contractor shall be a licensed water well driller, in accordance with local and state requirements, and a qualified drilling contractor for the installation of groundwater monitoring wells for environmental purposes.

Before drilling begins, groundwater monitoring well permits must be obtained from the appropriate agency as necessary. Prior to the start of drilling, an underground utility check will be performed before drilling begins. An underground utility check will, at a minimum, consist of contacting the local utility alert service, e.g., Underground Service Alert (USA), if available. Typically, subsurface clearance should also be conducted by a private utility locating company contacted specifically to clear individual boring locations. Under certain circumstances, including at sites with deeply buried, unknown, or multiple underground utilities, as well as at high risk sites such as oil refineries and other heavy industrial facilities, manual utility clearance using hand auger or air knife methods should also be performed.

This FGD is intended as a guidance document and does not supersede ENVIRON Health and Safety procedures or Site-Specific Health and Safety Plan (HASP) requirements. All ENVIRON employees shall follow the guidelines, rules, and procedures contained in site-specific HASPs prior to adhering to any procedures recommended in this FGD. The ENVIRON Project Manager and Task Leader must ensure that all project personnel review and sign the applicable HASP, and that the completed HASP and relevant project information is maintained in the project file. The signatures of the Project Manager and Task Leader indicate approval of the methods and precautions outlined in the HASP. The ENVIRON Project Manager and Task Leader will also be responsible for seeing that project personnel involved in field activities follow the procedures outlined in this and other applicable FGDs.

2.0 EQUIPMENT/MATERIALS

Many materials are required for successfully completing the installation of groundwater wells. The drilling contractor often supplies much of the equipment and materials. However, the Field Geologist/Engineer should be aware of what is required to conduct the work so they have their own supplies and can provide technical expertise and competent oversight. Equipment and materials needed to conform to this FGD include:

- Health and Safety Plan
- Site information (maps, contact numbers, previous field logs, etc.)
- Well construction specifications and diagrams
- Drilling rig and associated equipment (supplied by drilling contractor)
- Monitoring well construction equipment (supplied by drilling contractor)
- Weighted, calibrated measuring tape (often provided by drilling contractor)
- Calibrated measuring tape to measure well construction materials
- Electronic water level indicator (Solinst or similar)
- Water-quality monitoring meter to measure pH, temperature, specific electrical conductance (SEC), and turbidity.
- Sample containers, preservation supplies, sample labels, Ziploc™ bags (if samples are specified)
- Cooler with ice (if samples are specified)
- Decontamination supplies (e.g. phosphate-free detergent [Alconox or similar])
- Drum(s) or roll-off bin(s)to collect soil cuttings and decontamination water (usually supplied by drilling contractor)
- Drum/bin labels
- Personal Protective Equipment (PPE), typically PPE will consist of:
  - Long-sleeved shirt and long pants
  - Steel-toed boots
  - Hardhat
  - Nitrile gloves
  - Safety glasses with side shields
  - Hearing protection
  - Other protective equipment as required by Health and Safety Plan
- Field Forms (if required, a project-specific Field Logbook may substitute for any of the following)
  - *Field Investigation Daily Log*
  - *Field Soil Boring Log*
  - *Field Well Completion Log*
  - *Equipment Calibration Log*

3.0 PROCEDURES

Construction of all monitoring wells will be in conformance with the provisions outlined in the following sections. After well installation, well completion report(s) will be completed and filed with the State Department of Water Resources and/or other appropriate agency.

Specific monitoring well design and installation procedures depend on project-specific objectives and subsurface conditions. When planning a well installation, the following particulars will need to be determined prior to mobilization:

- Borehole drilling method;
- Construction materials;
- Well depth;
- Screen length;
- Well construction materials;
- Location, thickness, and composition of annular seals; and
- Well completion and protection requirements.

All drill cuttings and fluids generated during well installation will be containerized pending analytical results and determination of disposal options as outlined in the FGD entitled, *Managing Investigation-Derived Waste* unless project-specific requirements specify otherwise. Waste containment and disposal will occur in a manner that will not result in contamination of the immediate area or result in a hazard to individuals who may come in contact with these materials.

3.1 Drilling

Several drilling methods are available for use in creating a borehole for groundwater well installation. These methods include hollow stem auger, rotosonic, air-rotary and air-rotary casing hammer (ARCH), mud-rotary, and cable tool, among others. The drilling method selected will be based on the physical properties of the subsurface materials and understandings of the advantages and limitations of each of the drilling methods considered. For procedures during drilling see the FGD entitled, *Drilling and Destruction of Soil Borings.*

In general, the borehole diameter must be a minimum of four (4) inches greater than the outside diameter of the well screen or riser pipe used to construct the well. This is necessary so that sufficient annular space is available to install filter packs and grout seals. For wells to be screened in deeper water-bearing zones, it is important to isolate shallower water-bearing zones. Using rotary sonic drilling, this isolation of shallower zones is accomplished by the outer drill casing. If other methods are to be used for groundwater monitoring well installation in deeper water bearing zones, a conductor casing will first be installed through the shallower water-bearing zone(s) and cemented into place in order to seal off the shallow water-bearing zone and prevent cross-contamination between shallower and deeper water-bearing zones. The installation of conductor casing requires a wider diameter drill tooling to be used for the portion of the borehole that is to be lined with conductor casing. After the installation of the conductor casing, a narrower diameter drill tooling is used to advance the well borehole through the conductor casing to the intended total depth of the well.

3.2 Borehole Logging and Sampling

Boreholes will be logged using cuttings and samples collected during drilling activities. Soil or rock samples will be logged and collected as described in the FGD entitled *Soil Sampling for Chemical Analysis and Physical Testing.*

Cuttings and soil and rock samples will be described at the frequency presented in the FSP. After drilling has been completed, the Field Geologist/Engineer will measure the total open depth of the borehole with a weighted, calibrated tape measure and document the depth. The Field Geologist/Engineer will then collaborate with the Task Leader or other designated professional by reviewing observed lithologic units, water levels, and other logged information to finalize the well construction details.

Boreholes/well locations should be clearly designated in the *Field Soil Boring Log* or Field Logbook using notes and a hand sketched layout to include the following information:

- Measurements of each boring/sample point relative to fixed objects (building, structures, etc);
- Boring/sample location with their identification number noted;
- North arrow or other compass directional indicator; and
- Other essential site features and/or investigation features (underground storage tanks, piping, above ground tanks, etc.).

3.3 Backfilling

If backfilling the borehole to the appropriate well installation depth is necessary, neat cement, bentonite grout, bentonite pellets or filter pack sand may be used. The backfill material selected for use will depend on site conditions, and lithology. Most often the borehole requires the complete sealing of lower layers, so neat cement, bentonite grout, or bentonite pellets are used. Adequate time should be given for the bottom seal to set prior to beginning well construction. The Field Geologist/Engineer should re-measure and verify that the bottom of the bore hole is exactly where it should be set before proceeding with well construction.

If neat cement or bentonite grout is used, a tremie pipe will be required to place the grout in the bottom of the hole. Grouting the borehole may be difficult to accomplish, if the portion of the borehole to be grouted is significantly lower than the groundwater level. Provisions will be necessary to support the screen and riser pipe to prevent them from sinking into the grout. Care will be taken to frequently measure the total borehole depth when adding grout to the bottom of the hole. Grout should have thickened to a hardened state before proceeding. The thickness of the grout will be calculated based on depth readings and recorded. If a well has been backfilled too much it may require reaming to clear out the overfilled material.

Depending upon the lithology some distance should be planned between the bottom seal (backfill) in a borehole and the bottom of the screened interval. Unless this distance would result in a breach confining layer, or the well screen requires setting directly on the impermeable zone due to observed site conditions, the bottom of the well screen should be set at a maximum of six (6) inches above the top of any backfill. The distance between the top of backfill and the bottom of the well screen should be filled with a fine sand buffer or sand pack.

Bentonite pellets should be carefully placed into the borehole to minimize the risk of pellets sticking to the side of the borehole when dropped through a water column.

3.4 Well Screen and Casing

Wells will consist of factory-sealed commercially available well screen and casing. Well screens and casing will typically be constructed of polyvinyl chloride (PVC), a type of plastic, but may also be constructed of stainless steel depending on subsurface conditions, expected contaminants and concentrations, or other site-specific factors. Regardless of material of construction, casing and screen shall meet applicable standards for use in groundwater monitoring wells.

Well screens shall be constructed of non-corrosive and non-reactive material for the chemicals to be encountered. Well screens shall be permanently joined to the well casing and shall be centered in the borehole. Casing will be connected by flush-threaded or coupled joints and will be completed with a bottom cap. A collection sump may be installed below the screen and will vary in length depending on lithology and project needs. The collection sump and bottom cap will be connected to the well screen by flush threaded or coupled joints. Plastic casing must have threaded joints and o-ring seals. Solvent, glue, or anti-seize compounds will not be used on the joints. With deep wells (greater than approximately 100 feet below grade), centralizers should be used to keep the well casing plumb and straight in the borehole. Centralizers should be placed at the approximate top and bottom of the screened interval and 40 foot intervals throughout the blank casing interval.

For water table wells, well screens should be placed such that some of the screened interval is above the water table, and some section is below the water table. This allows for seasonal fluctuations. The amount of split should be determined by the Task Leader and be based upon local conditions.

Casing and screen must be clean, free of rust, grease, oil or contaminants and be composed of materials that will not affect the quality of the water sample. All casing shall be watertight. The casing shall be centered in the borehole, be free of any obstructions and allow sampling devices to be lowered into the well. The well string shall be hung in the borehole during installation so that the well is sufficiently plumbed and straight after completion.

Well construction details (anticipated screen interval, casing diameter, screen slot size, etc.) will be provided by the Task Leader or in project-specific documents. Modification can be made in the field, but will be done in consultation with the Task Leader, or their designee.

3.5 Setting Screens and Riser Casing

Upon completion of drilling, the boring will be sounded to verify the total depth, and the well casing will be assembled and lowered into the boring.

Well casing materials will be measured to the nearest 0.1 foot and steam-cleaned before being lowered into the borehole. Steam cleaning is not necessary if well materials are in factory-sealed packaging prior to well assembly. The well assembly will be designed so that the well screen is placed within the formation target zone, such that the top of the screen is as high or higher than the highest estimated groundwater elevation, depending on project requirements. No PVC cement or other solvents will be used to fasten the well casing joints, well screen joints, or end caps.

The well casing will be allowed to hang by a wireline in the borehole prior to sand pack placement so that the well can be situated at the desired depth interval. As described above, for monitoring wells greater than approximately 100 feet in depth, centralizers should be used to stabilize the casing in the center of the borehole. Once the well has been situated at the desired depth, sand pack will be emplaced in a calculated quantity sufficient to fill the annular space from the bottom of the boring to the level above the top of the well screen as specified Table 4 of the FSP. Significant differences from the calculated sand pack volume should be noted and investigated. For example, a volume less than the calculated volume may indicate bridging and a volume greater than calculated may indicate large void spaces within the borehole. The depth to the top of the sand pack will be verified by measuring, using a tremie pipe or a weighted tape. Prior to final placement of the sand pack, a surge block will be repeatedly lowered and raised through the water column to promote sand pack material settlement firmly around the screen interval of the well. Following surging, additional sand will be added as required to bring the top of the sand surface to the level above the top of the well screen as specified in the FSP.

Once the depth to the top of the sand pack material has been verified, bentonite chips will be placed in the annular space above the sand pack as a transition seal between the filter material and the grout. A sufficient quantity of bentonite chips will be placed to fill the annular space to the level above the top of the filter pack as specified in the FSP. Bentonite chips will be placed in approximately 6-inch lifts. The completed bentonite transition seal will be allowed to hydrate for at least 30 minutes prior to placing the grout. The depth to the top of the transition seal will be verified by measuring, using the tremie pipe or a weighted tape. No work will be done on the monitoring well until after the grout has set at least 48 hours.

3.6 Sand Pack Material

Monitoring wells installed in unconsolidated material will be constructed with sand packs. When used, the sand pack will be the only material in contact with the well screen. The filter pack will consist of either a No. 2/12 or No. 3 sand. The sand used for sand pack material shall be sized to match the screen slot size and the surrounding lithology to prevent subsurface materials from penetrating through the sand or filter pack, and preventing the sand or filter pack from entering the well. The sand pack will extend approximately six (6) inches below the bottom of the screen to two (2) feet above the top of screen. The sand pack material may be placed in the well by pouring the sand into the open borehole, or tremied into place depending upon field conditions. However, in all cases, filter pack material should be added carefully with continuous measurements by the Field Geologist/Engineer to prevent bridging of the sand pack material.

The well will be gently bailed and surged with a bailer and surge block after the filter pack has been added to the borehole and before the seal is placed in the annular space. A surge block consists of a rubber or leather and metal plunger attached to a rod or pipe of sufficient length to reach the bottom of the screen. Surging should be maintained for at least five minutes and the entire length of saturated screen will be surged to help settle the sand pack. The top of the sand pack will need to be measured after surging and additional sand pack material may need to be added if settling has occurred.

Sometimes observed field conditions may require transition sand be emplaced above the main sand pack. This transition sand is usually much smaller grain size than the sand pack, and is emplaced to provide added protection that grout invasion into the sand pack will not occur when deep wells are installed. An alternative to transition sands is to use additional well seal material such as bentonite pellets.

3.7 Well Seal

Wells will have an annular space seal that extends from the top of the sand pack to the surface. The annular sealing material above the sand pack will prevent the migration of fluids into the water bearing zone from the surface and from other water-bearing zones. Sealing material will be chemically compatible with anticipated contaminants. Hydrated bentonite chips will be used as an annular seal directly above the filter pack. The annular seal should be a minimum of 2 feet thick unless observed field conditions dictate otherwise. For example, as mentioned above, deep wells may require additional sealant material between the sand pack and cement grout annular fill above to prevent grout invasion into the sand pack interval. Neat cement grout will be used as annular fill above the seal to within 2 feet of the surface. Grouting emplacement will occur using a tremie pipe so that the grout fills the annular space from the bottom to the surface without allowing air pockets to form. Only potable water will be used to prepare the grout. No work will be done on the monitoring well until after the grout has set at least 48 hours.

3.8 Surface Completion

In non-vehicle areas, an aboveground completion consisting of a tamper-resistant steel surface casing (extending to an approximately depth of five feet depth) and concrete apron will be installed with the top elevation of the casing at approximately three to four feet above surrounding grade, and the concrete apron slightly above the surrounding grade.

In addition, a "weep" hole should be drilled in the bottom of the steel surface casing. In areas where freezing may occur, placement of the weep hole is critical; little volume should exist in the steel surface casing above the weep hole where water could accumulate and freeze thereby damaging the well. A "V" notch or other permanent mark will be placed at the north edge of the top of the well casing that will be used as the reference point for well elevation surveying and water level monitoring.

In vehicle areas such as roadways or parking lots, a flush-mounted completion consisting of a tamper-resistant, traffic-rated vault box will be installed with an elevation about ½ inch above surrounding grade, and vault boxes will be clearly marked as "Monitoring Well". The well casing should extend approximately 3 inches above the sealant in the bottom of the well box. The surface completion should provide positive drainage away from the well box to prevent ponding around the well. In traffic areas and sidewalks, this positive drainage slope away from the box should be minimized to prevent physical hazards. As discussed above a reference mark should be placed on the top of the well casing for well elevation surveying and water level monitoring. All wells will be capped with a water-tight locking cap.

3.9 Surveying

Well locations and elevations will be surveyed by a licensed surveyor in Nevada and tied to an established state or county benchmark, site conditions permitting. Horizontal coordinates be surveyed to a horizontal accuracy of at least 0.1 foot and referenced to the Nevada Coordinate System of 1983 (NAD83). The vertical elevations survey will be accurate to 0.01 foot relative to mean sea level datum (NAVD88). The top of casing, top of rim, and ground surface elevation near the well will be surveyed for vertical control. The "V" notch cut on the north side of each well casing will be used as the surveyor's reference mark.

3.10 Equipment Decontamination

Cleaning of the drill rig and associated drilling equipment will follow the procedures discussed in the FGD entitled, *Drilling and Destruction of Soil Borings*.

All well casing materials will be cleaned before they are installed. Well development equipment will also be cleaned before use. The following cleaning procedure has been found to be effective and will be used or adapted as appropriate for general conditions of materials or equipment to be cleaned. This procedure may be modified based on project requirements.

- Steam-rinse with potable water or rinse in deionized or organic-free water.

- Cover with clean plastic to protect materials and equipment from contact with chemical products, dust, or other contaminants.

Alternatively, well casing materials that have been steam-cleaned and sealed in individual airtight plastic bags by the factory can be used.

Decontamination rinsate will be collected and stored properly in labeled containers for future disposal by the client, unless other arrangements have been made. Drums or other containers must be constructed of materials that are compatible with any contaminants that may be potentially present in the rinsate.

4.0 PRECAUTIONS

Certain precautions should be taken to ensure safety during the implementation of this FGD. It is important to always remain alert and aware of your surroundings. All personnel performing on-site operations with the potential for exposure to hazardous substances or health hazards are required to be 40-hour trained in accordance with Code of Federal Regulations (CFR) 1910.120 and will meet the personnel training requirements in accordance with 29 CFR 1910.120(e). The drilling contractor shall be a licensed driller in accordance with local and state requirements, and a qualified drilling contractor for the installation of soil borings for environmental investigations.

Where required, permits will be obtained from the appropriate agency, and an underground utility check will be performed before drilling or excavating begins. An underground utility check will, at a minimum, consist of contacting the local utility alert service, e.g., Underground Service Alert (USA), if available. Typically, subsurface clearance should also be conducted by a private utility locating company contacted specifically to clear individual boring locations. Under certain circumstances, including at sites with deeply buried, unknown, or multiple underground utilities, as well as at high risk sites such as oil refineries and heavy industrial facilities, manual utility clearance using hand auger or air knife methods should also be performed. Additional subsurface clearing requirements may be described in the site-specific Health and Safety Plan.

The activities described in this FGD require the implementation of a site-specific Health and Safety Plan to inform personnel of the hazards associated with this work and to describe the methods that will be employed to mitigate those hazards. The Health and Safety Plan must be prepared and approved by the Project Manager and the local Health and Safety Coordinator prior to initiating field work.

5.0 RECORDKEEPING

Information collected during soil sampling may be recorded on individual field forms. If the project requires it, a project-specific Field Logbook may replace any of the individual field forms. Following review by the Project Manager, the original field records will be kept in the project file. The following forms may be used to document the field activities:

- *Field Investigation Daily Log*
- *Field Soil Boring Log*
- *Field Well Completion Log*
- *Equipment Calibration Log*

A *Field Investigation Daily Log* will be completed for each day of fieldwork containing (at a minimum) the times and descriptions of the work performed, the activities of the drillers and any other subcontractors or visitors on-site, arrival and departure times for all involved, and any other pertinent information. For larger projects, or when otherwise deemed appropriate by the Project Manager, this information may alternatively be recorded in a field logbook. In these cases, a separate Field Logbook must be used for each project or site.

The *Field Soil Boring Log* will be used to record the locations and unique identification of soil samples collected from the soil borings. The Field Soil Boring Log will also be used to record lithological descriptions of the soils and rock types encountered.

The *Field Well Construction Log* will be completed for each well and will include a diagram of the well showing the depths of the tops and bottoms of all well construction intervals including the well casing riser, well screen, sand filter pack, seal, etc. All materials used will be clearly and completely described as appropriate including type, manufacturer, sizes, specifications, etc.

The *Equipment Calibration Log* will be used to document the calibration and status of any measuring instruments used in the field, e.g., PID/FID, LEL, OVM, measuring tapes, water level measuring device, etc. The frequency and method of calibration will depend on the instrument. Any instruments used will be used in accordance with the factory-provided operating and/or service manuals.

Locations and unique identification of wells will be recorded on the *Field Investigation Daily Log*, *Field Soil Boring Log*, a site map, and/or other appropriate forms.

After well installation, well completion report(s) will be completed and filed with the State Department of Water Resources or other appropriate agency.

FIELD GUIDANCE DOCUMENT NO. 008
GROUNDWATER WELL DEVELOPMENT

Prepared by …………………………	Elysha Anderson, PE
Peer Reviewed by ………………	Dan Clark
Approved by ……………………..	John M. Pekala, PG, CEM
Applicable to ……………………	Nevada Environmental Response Trust Site Henderson, Nevada
Effective date ……………………	January 24, 2014
Revision Notes …………………	0 First Issuance
Documents used as reference during preparation ……………..	United States Environmental Protection Agency (USEPA) *Handbook of Suggested Practices for the Design and Installation of Ground-Water Monitoring Wells*, dated 1991 USEPA Office of Solid Waste *RCRA Ground Water Monitoring: Draft Technical Guidance*, dated November 1992. *Water Well Standards: State of California, December 1981, Department of Water Resources (DWR) Bulletin 74-81, the supplement California Well Standards, June 1991, DWR, DWR Bulletin 74-90.*

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1.0 INTRODUCTION

This Field Guidance Document (FGD) describes the procedures for groundwater well development at the Nevada Environmental Response Trust Site that will be conducted by or under the oversight of ENVIRON personnel. Although this FGD describes procedures for groundwater well development for this project, it should be understood that there may be details of this type of work not specifically discussed in this FGD that would be followed by personnel trained in these techniques. To ensure that groundwater well installation is performed in a complete and safe manner, ENVIRON personnel involved in field activities should be sure that they understand the scope of work and the level of detail necessary for each field activity prior to mobilizing to perform the work.

This FGD is intended as a guidance document and does not supersede ENVIRON Health and Safety procedures or Site-Specific Health and Safety Plan (HASP) requirements. All ENVIRON employees shall follow the guidelines, rules, and procedures contained in site-specific HASPs prior to adhering to any procedures recommended in this FGD. The ENVIRON Project Manager and Task Leader must ensure that all project personnel review and sign the applicable HASP, and that the completed HASP and relevant project information is maintained in the project file. The signatures of the Project Manager and Task Leader indicate approval of the methods and precautions outlined in the HASP. The ENVIRON Project Manager and Task Leader will also be responsible for seeing that project personnel involved in field activities follow the procedures outlined in this and other applicable FGDs.

All personnel performing on-site operations with the potential for exposure to hazardous substances or health hazards are required to be 40-hour trained in accordance with Code of Federal Regulations (CFR) 1910.120 and will meet the personnel training requirements in accordance with 29 CFR 1910.120(e).

The well development contractor shall be a licensed water well driller, in accordance with local and state requirements, and a qualified drilling contractor for the installation and development of groundwater monitoring wells for environmental purposes.

2.0 EQUIPMENT/MATERIALS

Many materials are required for successfully completing the installation and development of groundwater wells. The drilling and/or well development contractor often supplies much of the equipment and materials. However, the Field Geologist/Engineer should be aware of what is required to conduct the work so they have their own supplies and can provide technical expertise and competent oversight. Equipment and materials needed to conform to this FGD include:

- Health and Safety Plan
- Site information (maps, contact numbers, previous field logs, etc.)
- Well construction specifications and diagrams

- Development rig and associated equipment (supplied by drilling contractor)
- Monitoring well development equipment (supplied by drilling contractor)
- Weighted, calibrated measuring tape
- Electronic water level indicator (Solinst or similar)
- Water-quality monitoring meter to measure pH, temperature, specific electrical conductance (SEC), and turbidity.
- Sample containers, preservation supplies, sample labels, Ziploc™ bags (if samples are specified)
- Cooler with ice (if samples are specified)
- Decontamination supplies (e.g. phosphate-free detergent [Alconox or similar])
- Drum(s) to collect soil cuttings and decontamination water
- Drum labels
- Personal Protective Equipment (PPE), typically PPE will consist of:
  - Long-sleeved shirt and long pants
  - Steel-toed boots
  - Hardhat
  - Nitrile gloves
  - Safety glasses with side shields
  - Other protective equipment as required by Health and Safety Plan
- Field Forms (if required, a project-specific Field Logbook may substitute for any of the following)
  - *Field Investigation Daily Log*
  - *Field Well Development Log*
  - *Equipment Calibration Log*

3.0 PROCEDURES

Development of monitoring wells will be in conformance with the provisions outlined in the following sections. After well installation, well completion report(s) will be completed and filed with the State Department of Water Resources and/or other appropriate agency.

All fluids generated during well development will be containerized pending analytical results and determination of disposal options as outlined in the FGD entitled *Managing Investigation-Derived Waste* unless project-specific requirements specify otherwise. Waste containment and disposal will occur in a manner that will not result in contamination of the immediate area or result in a hazard to individuals who may come in contact with these materials.

3.1 Well Development

The objectives of well development are to remove drilling induced formation smear from the borehole walls, and to remove sediment that may have accumulated during well installation, and to remove mud cake from the walls of the borehole if the wells were installed by a mud-rotary drill rig. Additional objectives include consolidation of the filter pack around the well screen, and to enhance the hydraulic connection between the formation target zone and the well. The appropriate development method will be selected for each project based on the lithology, objectives, and requirements of that project. Project-specific planning documents will identify the specific development method to be used.

When planning for well development, the following particulars will need to be identified for each well prior to mobilization:

- Borehole drilling method;
- Well depth;
- Screen length;
- Well construction materials;
- Location, thickness, and composition of annular seals; and

In general, most wells will be developed by using surge block and bailing methods to draw the coarse and/or fine material out of the sand pack. Other development methods that may be used include jetting, airlift, and submersible pump methods. These methods are discussed further below. Jetting is typically not used as a development method for environmental investigations, but is commonly used for water resource monitoring wells or production wells.

Well development should begin no sooner than 48 hours after well installation. However, if drilling muds are used during well installation, well development should occur approximately 24 hours following well installation so that the drilling mud does not set up in the well screen section.

Generally a phased process is used to develop wells, starting with a gentle bailing phase to remove sand, followed by a surging phase, and then a pumping phase after the well begins to clear up. The following paragraphs provide more detailed information.

After the well casing, screen, and filter pack are initially placed in the borehole, gentle bailing is used to remove water and sand from the well. The purpose of this technique is used to settle the sand pack. After further well sealant materials have been added and allowed to set for approximately 48 hours, bailing is resumed as part of well development. The purpose of bailing is to remove any fine material that may have accumulated in the well, and start pulling in natural material into the sand pack. Bailing is often conducted until the sand content in the removed water begins to decrease.

After the sand content begins to decrease, surging is conducted. A surge block is used to move sediments from the filter pack into the well casing. A surge block consists of a rubber (or leather) and metal plunger attached to a rod or pipe of sufficient length to reach the bottom of the well. All surge blocks will be constructed of materials that will not introduce contamination into the well. Surge blocks should have some manner of allowing pressure release to prevent casing collapse. The surge block is moved up and down the well screen interval and then removed, followed by a return to bailing to remove any sand brought into the well by the surging action. Care should be taken during surging to prevent casing deformation or collapse as the well screen interval is often the weakest part of a well. Surging should be followed by additional bailing to remove fine materials that may have entered the well during the surging effort.

After surging has been completed and the sand content of the bailed water has decreased, a submersible pump may be used to continue well development. The pump should be moved up and down the well screen interval until the obtained water from the entire screen interval is relatively clear. Well development will continue until the water in the well clarifies and monitoring parameters such as pH, specific electrical conductance (SEC), and temperature stabilize as defined in the project-specific planning documents. It should be noted that where very fine-grained formations are opposite the screened interval, continued well development until clear water is obtained might be impossible. Decisions regarding when to cease development where silty conditions exist should be made between the Field Geologist/Engineer and Project Manager.

During well development pH, specific conductivity, temperature, and turbidity should be monitored frequently to establish natural conditions and evaluate whether the well has been completely developed. Drawdown and recovery will be measured during and at the end of the development process, respectively, using an electric sounder. Water quality parameters and water levels will be recorded on the Well Development Log. The main criteria for well development is clear water (Nephelometric turbidity units or NTU of less than 5). As mentioned above, clear water can often be impossible to obtain with environmental monitoring wells. Further criteria for completed well development is that the other water quality parameters mentioned above stabilize to within 10 percent between readings over one well volume.

The minimum volume of water purged from the well during development will be approximately a minimum of three (3) borehole volumes (wells will typically not reach stabilization of water quality parameters before this condition is achieved and may not have reached stability even after this threshold has been achieved). The above is a general guideline for difficult well development. Project-specific planning documents should address project constraints on well development.

Development purge water will be stored in 55-gallon Department of Transportation (DOT) –approved drums and/or baker tanks depending upon the total volume of purge water removed from the newly installed wells. Drums or other containers must be constructed of materials that are compatible with any contaminants that may be potentially present in the development purge water.

3.2 Equipment Decontamination

Cleaning of the drill rig and associated drilling equipment will follow the procedures discussed in the SOP entitled, Drilling and Destruction of Soil Borings.

All well casing materials will be cleaned before they are installed. Well development equipment will also be cleaned before use. The following cleaning procedure has been found to be effective and will be used or adapted as appropriate for general conditions of materials or equipment to be cleaned. This procedure may be modified based on project requirements.

- Steam-rinse with potable water or rinse in deionized or organic-free water.
- Cover with clean plastic to protect materials and equipment from contact with chemical products, dust, or other contaminants.

Alternatively, well casing materials that have been steam-cleaned and sealed in individual airtight plastic bags by the factory can be used.

Decontamination rinsate will be collected and stored properly in labeled containers for future disposal by the client, unless other arrangements have been made. Drums or other containers must be constructed of materials that are compatible with any contaminants that may be potentially present in the rinsate.

4.0 PRECAUTIONS

Certain precautions should be taken to ensure safety during the implementation of this FGD. It is important to always remain alert and aware of your surroundings. All personnel performing on-site operations with the potential for exposure to hazardous substances or health hazards are required to be 40-hour trained in accordance with Code of Federal Regulations (CFR) 1910.120 and will meet the personnel training requirements in accordance with 29 CFR 1910.120(e). The drilling contractor shall be a licensed driller in accordance with local and state requirements, and a qualified drilling contractor for the installation of soil borings for environmental investigations.

The activities described in this FGD require the implementation of a site-specific Health and Safety Plan to inform personnel of the hazards associated with this work and to describe the methods that will be employed to mitigate those hazards. The Health and Safety Plan must be prepared and approved by the Project Manager and the local Health and Safety Coordinator prior to initiating field work.

5.0 RECORDKEEPING

Information collected during soil sampling may be recorded on individual field forms. If the project requires it, a project-specific Field Logbook may replace any of the individual field forms. Following review by the Project Manager, the original field records will be kept in the project file. The following forms may be used to document the field activities:

- *Field Investigation Daily Log*
- *Field Well Development Log*
- *Equipment Calibration Log*

A *Field Investigation Daily Log* will be completed for each day of fieldwork containing (at a minimum) the times and descriptions of the work performed, the activities of the drillers and any other subcontractors or visitors on-site, arrival and departure times for all involved, and any other pertinent information. For larger projects, or when otherwise deemed appropriate by the Project Manager, this information may alternatively be recorded in a field logbook. In these cases, a separate Field Logbook must be used for each project or site.

The *Field Well Development Log* will be completed for each well and will include the methods of well development used, time intervals for each development procedure (bailing, surging, pumpiong, etc.), volumes of water purged, and results of water quality monitoring.

The *Equipment Calibration Log* will be used to document the calibration and status of any measuring instruments used in the field, e.g., PID/FID, LEL, OVM, measuring tapes, water level measuring device, etc. The frequency and method of calibration will depend on the instrument. Any instruments used will be used in accordance with the factory-provided operating and/or service manuals.

Locations and unique identification of wells will be recorded on the *Field Investigation Daily Log,* a site map, and/or other appropriate forms.

FIELD GUIDANCE DOCUMENT NO. 009
GROUNDWATER AND FREE PRODUCT LEVEL MEASUREMENTS

Prepared by	Elysha Anderson, PE
Peer Reviewed by	Dan Clark
Approved by	John M. Pekala, PG, CEM
Applicable to	Remedial Investigation and Feasibility Study (RI/FS) Nevada Environmental Response Trust Site Henderson, Nevada
Effective date	January 24, 2014
Revision Notes	0 First Issuance
Documents used as reference during preparation	

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1.0 INTRODUCTION

This Field Guidance Document (FGD) presents general guidelines established by ENVIRON for groundwater level measurements (depth to water) and free product level measurements (depth of free product) in groundwater monitoring wells or piezometers at the Nevada Environmental Response Trust Site that will be conducted by or under the oversight of ENVIRON personnel. Although this FGD describes procedures for groundwater and free product level measurements for this project, it should be understood that there may be details of this type of work not specifically discussed in this FGD that would be followed by personnel trained in these techniques. To ensure that sampling is performed in a complete and safe manner, ENVIRON personnel involved in field activities should be sure that they understand the scope of work and the level of detail necessary for each field activity prior to mobilizing to perform the work.

This FGD is intended as a guidance document and does not supersede ENVIRON Health and Safety procedures or Site-Specific Health and Safety Plan (HASP) requirements. All ENVIRON employees shall follow the guidelines, rules, and procedures contained in site-specific HASPs prior to adhering to any procedures recommended in this FGD. The ENVIRON Project Manager and Task Leader must ensure that all project personnel review and sign the applicable HASP, and that the completed HASP and relevant project information is maintained in the project file. The signatures of the Project Manager and Task Leader indicate approval of the methods and precautions outlined in the HASP. The ENVIRON Project Manager and Task Leader will also be responsible for seeing that project personnel involved in field activities follow the procedures outlined in this and other applicable FGDs.

All personnel performing on-site operations with the potential for exposure to hazardous substances or health hazards are required to be 40-hour trained in accordance with Code of Federal Regulations (CFR) 1910.120 and will meet the personnel training requirements in accordance with 29 CFR 1910.120(e).

Groundwater level measurements are collected to determine the depth to groundwater within a well relative to ground surface, top of the well casing, and/or an established elevation datum. Similarly, free product measurements are collected to determine the depth to non-aqueous phase liquid (NAPL) accumulated within a well relative to an established elevation datum. The accumulated thickness of NAPL within a well can be determined if the bottom of the free product can be additionally measured. Properly collected and recorded measurements can be utilized for generation of potentiometric surface maps to establish groundwater flow direction, define horizontal and vertical hydraulic gradients, evaluate variations in groundwater elevations over time, evaluate NAPL mobility or recovery, and other project specific tasks.

2.0 EQUIPMENT/MATERIALS

Below is a general checklist of equipment that may be needed for typical groundwater level measurement efforts. This checklist only suggests general equipment that may be necessary for a project or task and should not be considered exhaustive.

1. General Water and Free Product Level Measurement Equipment Checklist
   - Electronic water level indicator
   - Electronic oil/water interface probe for wells containing known or suspected NAPL
   - GPS or other locating device
   - Site map showing locations of wells
   - Well construction records and previous water level measurements
2. Project or Task Specific Water and Free Product Level Measurement Equipment Checklist
   - Well lock keys
   - Steel tape measure or submersible water level meter for use in measuring total well depth
   - Decontamination supplies /equipment (non-ionic detergent, tub, brushes, etc.);
   - Wash bottles/bucket
   - Trash Bags - used to dispose of gloves and any other non-hazardous waste generated during sampling
   - Appropriate waste container – used to dispose of any Investigation Derived Wastes (IDW) and/or decontamination wastes
   - Socket wrench (manhole bolt sizes vary; most commonly require a 9/16” socket).
   - Water valve gate box key (for older style flush-mounted wells).
   - Pry bar (or other equivalent tool to assist in the removal of the flush mounted well cover or handhole).
   - Syringe (or other equivalent tool such as a turkey baster to assist in removing standing water in flush mounted wells).
   - Extra batteries for the water level meter (usually 9-volt).
3. Miscellaneous Additional Suggested Equipment
   - Extra vehicle keys
   - Metal locator (to find buried/obstructed flush mounted wells)
   - First aid kit
   - Mobile phone
   - Credit card for gas and emergencies
   - Road and site maps

- Chemical protective gloves and other personal protective equipment (PPE) as required by the HASP; and
- Field notebook and field data sheets
- Waterproof pens
- Bolt cutters (to remove rusted padlocks)
- Replacement padlocks
- Camera and extra batteries

3.0 PROCEDURES

3.1 Pre-Field Work Preparation Guidelines

At a minimum, the following tasks should be completed to prepare field staff for what may be expected during implementation of the work:

- Review and sign the a site-specific HASP;
- Coordinate and obtain permission for site access;
- Review project-specific Work Plan/sampling plan, where applicable;
- Review project-specific Quality Assurance Project Plan (QAPP), where applicable;
- Review and discuss with the PIC and/or PM the proposed activities or Work Plan/sampling plan;
- Review the standard instruction manual provided by the manufacturer of the specific equipment being used for water level monitoring and field screening;
- Inspect the water level meter(s) for any signs of damage and test for proper operation;
- Identify well locations and any specific order in which they are to be collected;
- Obtain copies of recent or historic (i.e., same season) water or free product level data to be able to anticipate the approximate depth of water or free product minimizing unnecessary wetting of the tape and as a check of the measured levels;
- Obtain copies of well construction records, as these can be used to confirm the well identification if not clearly identifiable; and
- Identify wells that are known or suspected to contain NAPL or other free product. An electronic oil/water interface meter must be used in these wells in lieu of an electronic water level indicator.

All significant field activity decisions will be approved by the PIC and/or PM before the initiation of associated field activities. The work plan/sampling plan will be designed for the collection of quality data that will best answer the questions and meet the goals of the study/monitoring program. The work plan/sampling plan will generally provide for some discretion in the field depending on encountered conditions; however, any significant departure from prescribed field activities should be approved by the PIC and/or PM).

Prior to the commencement of the field effort, inspect, test, and/or calibrate equipment that will be used to take field measurements.

3.2 General Water Level Measurement Guidelines

Water level measurements are generally taken in monitoring wells, piezometers, or boreholes using electronic water level indicators. There are different manufacturers of electronic water level indicators including Solinst, Keck, and Heron. Electronic water level indicators consist of a reel of dual conductor wire embedded within a pre-marked tape, a probe with an insulating gap between the wire attached to the end of the tape, and an indicator on the reel. Generally, tapes are marked every $1/100^{th}$ of a foot and/or millimeter. When the probe comes into contact with water, the circuit is closed and the indicator signals this contact with an audible buzzer and/or an optical light. The meters usually use 9-volt batteries within the reel as a power source. Many water level meters include a sensitivity adjustment on the indicator. The sensitivity adjustment diminishes potential short circuiting of the probe in moist environments such as those encountered in a well.

The following provides a recommended list of practices for water and/or free product level measurement activities:

- Where applicable, contact the identified key site personnel upon arrival to the Site and assess proposed work areas.
- Because groundwater or free product depth can vary due to natural fluctuations, all measurements for a specific sampling event should be collected within as short of a time frame as possible.
- Although equipment will be decontaminated between uses, to further limit potential cross-contamination between wells, perform measurements from least to most contaminated locations.
- Complete depth to water or free product measurements prior to any planned withdrawals, sampling or disturbance of groundwater unless otherwise specified in the work plan/sampling plan.
- All water or free product level measurements should be made relative to an established reference datum and should be recorded in the field notes. The reference datum is usually marked, notched or etched on the well or casing at the time of installation on the north side of the inner casing. In the absence of a marked, notched or etched reference datum take water level and depth measurements from the north side of the inner casing and mark or etch it for future reference. In the case of a casing notched or etched at a distinct angle, the measurements should be made from the highest point in the casing. Note this procedure in the field book.

- Record in the field book the model name, number, and serial number of the electronic water level meter or interface probe being used.
- Identify the well to be measured and confirm by checking for proper identification markings on the well, comparing to a site map, and if needed historical water and/or product level measurements and well construction records. If the well cannot be positively identified, contact the Project Manager or Task Leader before proceeding.
- Decontaminate the water level meter probe, interface probe, and/or tape (if total well depth measurements are being conducted with a tape) prior to each use.
- Remove well cover or equivalent protective casing cover. Inspect the interior of the well box for insects, etc., that could present a biological hazard. If there is water in the well box, remove all water (at least to a level below the top of the inner well casing) prior to removing the well cap or plug. Indicate that water was removed from the well box and identify possible causes (e.g., missing bolts, damaged well cover, etc.).
- Remove the well cap or plug, noting well identification, time of day, and date in field book. Also note any abnormal conditions in the well (e.g., damaged inner casing, limited clearance between the bottom of the well box and the top of the inner well casing, absence of reference datum, etc.) If the top of the well casing has been damaged, the reference datum may no longer be accurate.
- If the wells are outfitted with expansion caps, these should be removed and the wells allowed to equilibrate for an appropriate period of time prior to the collection of water level measurements. This is especially critical for wells screened below the water table or in confined units. There are no set guidelines and appropriate equilibration times can range from minutes to hours depending on well recharge, local geology and topography, and project objectives.
- Record observance of positive or negative pressure in the well upon removal of the well cap. The presence of pressure/vacuum in the well could be qualitatively assessed during loosening and removal of an expansion cap (resulting in air either being audibly pushed out or drawn in to the well casing) or using a piece of paper or other light object (i.e., easily moved or displaced by light air flow) placed immediately above the inner well casing and observing its movement (i.e., if it adheres to well casing, there is a negative pressure in the well; if it moves from the well casing, there is a positive pressure in the well). If pressure was observed, the water level should be measured multiple times over a 5 to 10 minute period to allow time for equilibration and confirm that the water level has reached static conditions.
- Monitor the headspace of well with a field screening device in accordance with the applicable manufacturer instructions and FGD. Record field screening readings in field book. The necessity and methodology to conduct field screening should be detailed in the site-specific HASP, sampling plan or Work Plan.
- Check that the indicator is working properly by pushing the test button on the reel. Replace batteries in the electronic water level meter or product interface probe if testing or operation of

indicates the battery is not providing sufficient power. If the battery is replaced during a field measurement event this must be recorded in a field log book.

- Lower the probe slowly into the well taking care to minimize contact with the well casing. If significant kinks are observed in the tape, attempt to straighten manually and record observations in project field book or log.
- When a strong and steady signal from the indicator signals water or free product has been encountered slowly pull the tape up until the signal ceases.
- Manually lower and raise the probe to exactly locate the water or free product interface.
- At the point where the signal indicates free water or free product has been encountered, measure and record the depth of the probe using the marked tape.
- If free product is encountered, continue to manually lower the probe into the well until a strong and steady signal from the indicator signals that water has been encountered. Lower and raise the probe to exactly locate the water or free product interface. Measure and record the depth of the probe using the marked tape.
- Measurements should be referenced to the established reference datum.
- Repeat the measurement to verify accuracy. Measurement should be recorded to the nearest 0.01 feet and/or millimeter.
- Withdraw the probe from the well, replace the well cap, and re-secure the well.
- Total well depth measurements should be made in reference to the top of casing as well as the ground surface. These measurements should be performed after sampling, if positive well identification has be completed.
- Record in the field book any abnormal conditions within the well (e.g., evidence of blockage, root growth into the well casing, separated casing sections, etc.). Inform the PIC or PM so necessary maintenance, redevelopment or repairs are conducted before the next planned water level measurement event.
- To minimize potential cross-contamination of samples among stations, decontaminate the probe and portions of the tape that made contact with water, product, or well materials.

3.3 QA/QC

Quality Assurance/Quality Control (QA/QC) procedures described in the project-specific Work Plan/sampling plan and/or QAPP must be followed throughout the water level measurement process.

4.0 PRECAUTIONS

Certain precautions should be taken to ensure safety during the implementation of this FGD. It is important to always remain alert and aware of your surroundings. All personnel performing on-site operations with the potential for exposure to hazardous substances or health hazards are required to be

40-hour trained in accordance with Code of Federal Regulations (CFR) 1910.120 and will meet the personnel training requirements in accordance with 29 CFR 1910.120(e).

The activities described in this FGD require the implementation of a site-specific Health and Safety Plan to inform personnel of the hazards associated with this work and to describe the methods that will be employed to mitigate those hazards. The Health and Safety Plan must be prepared and approved by the Project Manager, Task Leader and Project Health and Safety Coordinator prior to initiating field work.

Additional precautions regarding methods for groundwater and free product level measurement are described below:

- Operate electronic water level meters and product interface probes in accordance with the manufacturer's instructions and recommendations.
- The protective casing of flush-mount wells often fills with run-off surface water. If upon removing the well cover, the top of inner well casing is submerged, utilize a syringe, turkey baster, or equivalent tool to remove the excess water before removing the well cap in order to avoid surface water flow into the well.
- Provided well keys may not work with rusted/outdated well locks; bolt cutters may be used to remove the lock, which should be replaced upon completion of water level measurement. Do not use petroleum based solvent sprays to free seized locks as this may impact water quality in the well.
- Wells with a water-tight cap may experience a buildup of pressure, especially if they are screened below the static water level. Keep your face and body from the top of the well when loosening or removing the cap.
- Ensure that the water level has reached the static level prior to recording the depth to water. Should the water level be in a state of flux due to pressure buildup, allow ample time for the water level to stabilize to static conditions before recording measurement.
- Indicator response may be indicative of potential faults that could be corrected in the field:
  - If the signal from the indicator is intermittent or weak it may be necessary to decrease the sensitivity since it may be short circuiting prior to encountering free water.
  - If there is no signal it may be necessary to increase the sensitivity since some water is less conductive and may not complete the circuit.
  - If the signal is still intermittent, weak, or absent then replace the battery and reattempt the measurement.

- Cascading water may interfere with the measurement of free water; particularly in boreholes or rock wells.
- Some well casings have sharp edges; care should be taken when lowering or withdrawing the tape to avoid damaging the tape of the water level meter.
- Oil or other product floating on the water column may insulate the contacts of the probe resulting in a misleading indication of the depth to free water. An oil/water level indicator should be used if there is known or suspected product in a well.
- It should be noted that some water level indicators will have a 2 to 3 inch weight on the tip of the probe which can displace water in a well before the water indicator detects it. These models also make it difficult to detect small amounts of water in wells, i.e. less than 3 inches. If this is expected to be a potential issue, then request a model with the water indicator located on the tip of the probe.
- Meters should be inspected periodically to ensure accurate readings. Electronic water level meters and interface probes may not function properly if the electric wire is broken, cut, or if insulation is removed exposing the wire (resulting in short circuiting). Repaired meters may have had sections of the tape removed and/or spliced and may not meet data quality objectives. Damaged tapes or tapes suspected of being damaged should be repaired by the manufacturer or replaced.
- If using the water level meter for total depth measurements, confirm that the probe is designed for total immersion and the maximum acceptable depth of immersion.
- Tape lengths can be confirmed using a calibrated steel tape periodically or as necessary to adhere to data quality objectives. Discrepancies in tape length must be noted in the field log book and/or field sheet.
- For high conductivity water (brine) decreasing the sensitivity control prevents bridging so a moist probe is not detected as being in water.

5.0 RECORDKEEPING

Information collected during drilling may be recorded on individual field forms. If the project requires it, a project-specific Field Logbook may replace any of the individual field forms with the exception of the Chain-of-Custody form. Following review by the Task Leader, the original field records will be kept in the project file. The following forms may be used to document the field activities:

- *Field Investigation Daily Log*
- *Water Level Measurement Log*

A *Field Investigation Daily Log* will be completed for each day of fieldwork containing (at a minimum) the times and descriptions of the work performed, the activities of the drillers and any other subcontractors or visitors on-site, arrival and departure times for all involved, and any other pertinent information. For larger projects, or when otherwise deemed appropriate by the Task Leader, this information may alternatively be recorded in a field logbook. In these cases, a separate Field Logbook must be used for each project or site.

The *Water Level Measurement Log* will be used to record the monitoring well ID, time of measurement, total depth of well, depth to water, measuring point, presence of product, product thickness, and notes about the condition of the well.

FIELD GUIDANCE DOCUMENT NO. 011
AQUIFER HYDRAULIC TESTING

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Table of Contents

1.0 INTRODUCTION

This Field Guidance Document (FGD) defines the recommended procedures established by ENVIRON for performing the following types of aquifer hydraulic tests: (1) slug tests, (2) aquifer pumping tests, and (3) recovery tests. Although this document describes procedures for typical projects, it should be understood that for certain projects more or less prescriptive procedures may be warranted based on the project-specific data quality objectives. To ensure that high-quality data is obtained, ENVIRON personnel involved in field activities should be sure that they understand the scope of work and the level of detail necessary for each field activity prior to mobilizing to perform the work.

This FGD is intended as a guidance document and does not supersede ENVIRON Health and Safety procedures or Site-Specific Health and Safety Plan (HASP) requirements. All ENVIRON employees shall follow the guidelines, rules, and procedures contained in site-specific HASPs prior to adhering to any procedures recommended in this FGD. The ENVIRON Project Manager and Task Leader must ensure that all project personnel review and sign the applicable HASP, and that the completed HASP and relevant project information is maintained in the project file. The signatures of the Project Manager and Task Leader indicate approval of the methods and precautions outlined in the HASP. The ENVIRON Project Manager and Task Leader will also be responsible for seeing that project personnel involved in field activities follow the procedures outlined in this and other applicable FGDs.

All personnel performing on-site operations with the potential for exposure to hazardous substances or health hazards are required to be 40-hour trained in accordance with Code of Federal Regulations (CFR) 1910.120 and will meet the personnel training requirements in accordance with 29 CFR 1910.120(e).

2.0 EQUIPMENT/MATERIALS

A list of common equipment and materials needed to conform to this FGD and pertinent to all aquifer tests include:

- Site-specific HASP, and any personal protective or other equipment required by the HASP
- Site information (maps, contact numbers, etc.)
- Well information (previous water levels, well depths and screen intervals, previous purge logs, etc.)
- Electronic water level meter to take manual measurements (Solinst or similar)
- Data-logging pressure transducers (e.g., Solinst Levellogger™)
- Direct-read transducer cables and/or low-stretch nylon or Kevlar cord for hanging transducers
- Steel measuring tape
- Laptop computer
- Decontamination supplies (e.g. phosphate-free detergent, deionized water)

- Well keys (if necessary)
- Stopwatch (this functionality is available on many newer cell phones)
- Duct tape or other adhesive tape
- Extra batteries
- Field Forms and/or Field Logbook
    - *Field Investigation Daily Log*
    - *Water Level Measurement Log*
    - *Equipment Calibration Log*

Additional equipment pertinent to slug tests, pumping tests, and recovery tests are discussed in those particular sections.

3.0 SLUG TESTING PROCEDURES

This section provides guidance for performing slug tests. This section does not cover the analysis of slug test results.

A slug test is a single-well testing method that is commonly used as a quick and cost-effective means to estimate the hydraulic conductivity of an aquifer or water-bearing zone in close proximity to the well. A slug test is performed by instantaneously raising or lowering the water level in the well by inserting or removing a “slug” of known volume and then monitoring and recording the recovery of hydraulic head to the initial level.

There are a variety of methods by which the water level in the well can be lowered or raised by a “slug” composed of air, water, or a solid material. The use of slugs made up of air is complicated due to the need for special equipment to apply pressure or a vacuum to the well. In addition, the well screen must be entirely below the static water level to avoid short-circuiting of air to the surrounding formation. The use of slugs made up of water is often infeasible because of (1) the need to dispose of contaminated groundwater pumped from the well, (2) the difficulty of instantaneously removing a slug of water from a well, and (3) the potential bias in groundwater sampling results due to the dilution of groundwater with the addition of clean slug water. For practical purposes, this section focuses on slug tests conducted using a solid slug.

In addition to being more quick and cost-effective, slug tests are often chosen instead of pumping tests because they can be performed in lower permeability zones not appropriate for pumping tests and do not require the disposal of large, potentially hazardous quantities of water. Some disadvantages of slug tests are that hydraulic conductivity estimates (1) are sensitive to near-well conditions (e.g., poor well development, gravel pack, and skin effects), (2) only apply to the immediate vicinity of the well, and (3) are not able to identify boundary conditions, hydraulic anisotropy, storage coefficients, or pumping characteristics of the well.

3.1 Planning and Design Considerations

Aquifer characteristics and well construction details should be evaluated prior to the start of testing to ensure wells selected for testing will adequately characterize the aquifer. At a minimum, the conceptual site model should include whether the aquifer is confined or unconfined, wells fully or partially penetrate the aquifer, the water table intersects or lies above the well screen, and the permeability of the aquifer.

The slug size should be determined using procedures specified in Butler (2013) to ensure that the formation response will be sufficient to enable analysis of the response data. In general, an initial displacement of the water column of one to three feet is sufficient to enable analysis of the response data. Smaller displacements may not yield a sufficient response in the aquifer and larger displacements may result in large frictional losses and unnecessarily long test durations. In very high conductivity formations, larger displacements may be needed to reduce the effects of nonlinear response mechanisms. Larger slugs may also be required for wells screened across the water table to account for the effects of filter pack drainage.

If practical, it is desirable to confirm the reproducibility of the results by repeating the slug test either with the same slug or with a slug that produces an initial displacement that differs by at least a factor of two; however, this is not always achievable in the field.

3.2 Performing the Slug Test

This section describes the protocol for performing a slug test. Prior to conducting a slug test, field personnel will be provided a field sheet specifying the well to be tested, the well construction, the anticipated water column height within the well, the slug dimensions to be used, the anticipated initial displacement, the suggested transducer placement depth, the suggested transducer data acquisition rates, and whether background measurements and/or barometric pressure measurements are required.

3.2.1 Equipment

In addition to the equipment specified in Section 2.0, the following equipment shall be used while conducting slug tests:

- Pulley system with static nylon or coated-steel cord to raise and lower slugs
- Solid slugs or other equipment for initiating slug tests
- Pressure transducer(s)
- Field computer
- Polyethylene sheeting

- Field Forms:
  - *Daily Field Investigation Log*
  - *Slug Test Field Log*

3.2.2 Water Level Measurement

- Prior to initiating the slug test, a pressure transducer with integral data loggers should be installed in the test well. The transducer should be securely deployed by a direct-read cable if real-time viewing of data is needed. Otherwise, transducers should be deployed using inert, low-stretch nylon or Kevlar cord. The transducer should be installed above the bottom of the well with enough room to accommodate the slug to avoid damage to the transducer. The transducer should be installed at an appropriate depth for which it is calibrated accounting not only for the static hydraulic head, but also for the rise and fall of the hydraulic head during testing. Record the depth of the transducer.
  Verify the total well depth with the electronic water level meter or steel tape and record the result. It is not uncommon to measure well depths that differ from as-built well depths in well construction tables.

- Allow water levels to stabilize. The static water level in the well should be measured and monitored long enough to evaluate whether or not any trends exist that could interfere with testing. In general, pre-test water levels should be monitored and recorded for at least a period longer than the duration of the test (ASTM, 2008). One or more background transducers may be specified to record background data for an extended period prior to and during the course of aquifer testing. Background transducers may be situated such that external influences that may influence the testing results will be recorded. Ultimately, the pre-test monitoring program will be based on field conditions and the project-specific data quality objectives.

- Confirm data and settings from previous tests have been cleared. Program data loggers to record water level measurements during the test period. Generally, the measurement schedule is selected to have an initially high rate, followed by a period of reduced measurement frequency as the test progresses. The initial frequency at the time the test is initiated must be sufficient to record the initial displacement produced by insertion of the slug. A high frequency is also required for the period when the slug is removed. For the remainder of the test, the measurement frequency selected will depend on the conductivity of the formation tested, with higher frequencies required for tests in more conductive formations. Tests in less conductive formations will require longer test durations, and the limits of the data logger will need to be taken into account.

- Collect manual water level measurements using an electronic water level indicator with gradations to the nearest 0.01 foot before testing to determine static water levels as well as during the tests to confirm the transducer data. Wristwatches used to record the time of manual water level measurements should be synchronized with the computer used to program the data loggers.

- After the completion of the test(s), download the water level data from the transducer data logger for analysis and ensure the file is saved. This is routinely stored in .txt, .csv, or .xls file formats for importation into Microsoft Excel®, or similar spreadsheet programs. It is also useful to download any time-series figures created by the data logger software during the test; these typically include graphs of pressure head versus time and temperature versus time.

- Pressure readings from the transducer will be adjusted for changes in barometric pressure as necessary. A transducer dedicated to record atmospheric pressure should be placed within one of the test wells or in close proximity and at similar elevation to the tested well. Atmospheric pressure should also be recorded when static levels are recorded.

3.2.3 Slug Insertion and Withdrawal

- Securely attach the cord in the pulley system to the eyelet drilled into one end of the slug. More than one slug may need to be connected end-to-end in order to achieve the desired volume.

- Measure and mark the cord with a permanent pen or secure tape to indicate when the bottom of the slug has been lowered to just above the water table.

- Lower the slug into position in the well just above the water table. Be careful not to hit the pressure transducer cable as you lower the slug and record any disturbances.

- Ensure that a transducer is installed in the well below the water table and has started logging. Start logging if necessary and allow for pre-test data collection.

- Upon collection of suitable pre-test data, initiate the falling-head test by rapidly introducing the solid slug into the well, simulating an instantaneous change in water level. Care should be taken not to drop the slug, but to quickly lower the slug, to avoid excessive splash. Secure the slug during testing to prevent movement. The falling-head test start time shall be recorded.

- Compare the estimate of initial displacement based on well dimensions with the observed initial displacement in the field, which can be calculated from the pressure head versus time graph displayed with the real-time viewing data logger software. Record the observed initial displacement. If values are significantly different, the casing diameter will be measured and used to recalculate the initial displacement. Field staff should also inspect the real-time data collected by the data logger at the start of the test to see if the slug insertion was clean and rapid enough to allow the initial displacement to be identified. If the discrepancy cannot be explained, or the early data is too noisy, the well may require re-testing (check with project manager).

- Continue to monitor progress with the real-time viewing data logger software if available or by frequently checking the water level using an electronic water level indicator until water levels have returned to equilibrium.

- Before initiating the rising-head test, download the data from the falling-head test and re-program the measurement frequency schedule on the data logger. Allow at least one minute to pass after reprogramming before initiating the rising-head test. More time may be allowed as necessary to gather pre-test data.

- Initiate the rising-head test by rapidly removing the slug from the well and secure the slug above the pre-determined static water level by tying off the cord. Removal of the slug should be done in a gentle manner similar to the method of slug insertion described above. The rising-head test start time and observed initial displacement shall be recorded.

- The slug test will continue until water levels have recovered to the static water level measured prior to the test, or until the water level is changing less than 0.01 feet over 10 minutes. Rising head data is unusable for analysis if there hasn't been at least 95% recovery from the falling head test. For tests in low conductivity materials where recovery occurs over an extended period of time, it is preferable to continue the falling head test to the point of 80% recovery than to initiate the rising head test.

- If time permits, both the falling-head and rising-head tests should be repeated.

3.2.4 Equipment Decontamination

All equipment should be decontaminated prior to and after contacting groundwater by washing with a non-phosphate detergent solution (Alconox or equivalent) followed by rinsing with deionized water or by using a steam cleaner if available. Decontamination water will be collected and stored in labeled sealed buckets or drums on-site for future disposal by the client unless other arrangements have been made.

4.0 AQUIFER PUMPING TEST PROCEDURES

This section provides guidance regarding the design and performance of step-drawdown and constant-rate aquifer pumping tests. This section does not cover analysis of aquifer pumping test results.

<u>Step-Drawdown Pumping Tests</u>

A step-drawdown test is performed by pumping a well at a set of sequentially increasing pumping rates and measuring the change in water level in the pumping well, and optionally, in one or more observation wells. At least three pumping steps should be used, with each pumping step maintained ideally until the drawdown in the pumping well has stabilized (this may be impractical for tests in low conductivity formations). Data from step-drawdown pumping tests are used to predict the potential yield of an extraction well, identify performance criteria such as well loss and well efficiency, and provide estimates of the hydraulic conductivity of the surrounding formation.

Constant-Rate Pumping Tests

A constant-rate pumping test is performed by pumping an aquifer for an extended period of time and recording water level changes at the pumping well and in nearby observation wells. The goal of a constant-rate pumping test is to estimate the hydraulic properties of an aquifer including transmissivity, hydraulic conductivity and storativity. In addition, the extended period of pumping allows for the potential identification of aquifer boundaries such as flow barriers (e.g. faults, impermeable materials) and hydraulic connections to sources of recharge (e.g. surface water features). Generally, a step-drawdown test is performed prior to a constant-rate test to establish the flow rate to be used.

4.1 Planning and Design Considerations

Aquifer characteristics and well construction details should be evaluated prior to the start of testing to ensure selected pumping and observation wells will adequately characterize the aquifer in accordance with the test objectives. The conceptual site model should incorporate: whether the aquifer is confined or unconfined; whether wells fully or partially penetrate the aquifer; whether the water table intersects or lies above the well screen; previously determined aquifer characteristics (e.g., permeability, transmissivity, thickness, hydraulic gradients); the location and type of aquifer boundaries; surface water features; and the presence of nearby pumping or injection wells. Knowledge of site conditions will help determine which analytical method to use (ASTM, 2010). This FGD does not cover analysis of aquifer pumping test results, but the chosen analytical method may prescribe specific requirements with regard to well selection; these requirements should be observed.

The well development and construction history of wells should also be evaluated prior to selection of the well network to ensure there are no issues that might interfere with interpretation of test results. For example, an improperly developed well can yield hydraulic conductivity estimates that are biased low due to interference by drilling mud or formation fines.

Once potential wells are identified for the testing program, preliminary estimates of drawdown should be made based on known or estimated site conditions. In general, pumping wells should have an adequate number of potential observation wells nearby that are expected to exhibit significant drawdown. Observation well locations may also be chosen in order to identify aquifer boundaries or anisotropy.

It is also necessary to identify nearby extraction and injection wells that could interfere with the pumping test. These wells should either be turned off well in advance or operated at a constant rate for the duration of the test. It may be prudent to disable automatic pump controls.

The pumping rate(s) selected for the pumping well should be sufficient to stress the aquifer but prevent the well from becoming dry for the duration of the test. Drawing the water level below the perforations in the screen has adverse effects (e.g., cascading water and air entrainment in the well). It is essential to maintain a constant pumping rate for the duration of each pumping step or pumping period. If pumping stops or deviates significantly from the target pumping rate, it is necessary to restart the test after the aquifer has fully recovered. In general, the pumping rate should not be allowed to vary by more than 5 to 10% (ASTM, 2008).

The pumping rate should be monitored very closely at the beginning of each pumping step and then adjusted less often as the test progresses. An instantaneous flow meter is typically used to monitor the pumping rate and should be verified with manual measurements using a graduated cylinder or bucket and a stopwatch. The magnitude of the target pumping rate will determine what types of controls are used to regulate the pumping rate. Higher flow rates generally necessitate both a primary valve installed on the discharge line and a second valve that can be used to make finer adjustments to the flow rate. Lower flow rates can be manipulated with a rheostatic control on the pump, a valve installed in the discharge line, or both of these mechanisms.

Consider installing a “stilling tube” (a small-diameter PVC pipe) to encase the pressure transducer and electronic water level meter tape in order to reduce interference caused by turbulence in the well due to pumping and cascading water. This is particularly important for pumping at higher flow rates.

ENVIRON typically coordinates with a subcontractor to operate the pumps for the well testing, but it is important to confirm that the power supply and pumping equipment are capable of maintaining a constant pumping rate for the duration of the test. In some cases it may be warranted to obtain a backup generator (when using a diesel or gasoline generator) and in exceptional cases it may be warranted to have the local power company provide a power drop (long-term tests in residential areas).

The pump should be sized to operate for sustained periods at the range of flows necessary to perform the tests. The pump should have a maximum capacity higher than the maximum anticipated pumping rate, but should also be able to cool itself properly at the lowest anticipated pumping rate to avoid heat-induced pump failure during the test. A check valve should be installed that prevents backflow of water into the well once pumping is stopped in order to ensure high quality data is obtained at the beginning of the recovery period.

Plans must be made to contain, store, transport, and/or discharge/dispose of the water generated during pump tests in accordance with local, state, and federal laws as well as in accordance with project-specific requirements. Handling investigation-derived waste is a critical task that must be planned in advance particularly for pump testing projects where large volumes of water are to be generated.

4.2 Performing the Pumping Test

This section describes the protocol for performing a pumping test. Prior to conducting a pumping test, field personnel will be provided a field sheet specifying the pumping and observation wells, well construction for these wells, the anticipated water column height within the pumping and observation wells, the pumping rates and step durations to be used, the suggested transducer data acquisition rates, the suggested pump and transducer placement depths, and whether background measurements and/or barometric pressure measurements are required.

4.3 *Equipment*

Equipment needs vary based on the field activity and project. ENVIRON typically collaborates with subcontractors to perform aquifer pumping tests, thus eliminating the need to obtain certain types of equipment such as submersible pumps and holding tanks. In addition to the equipment specified in Section 2.0, the following equipment shall be used to conduct pumping tests:

- Graduated cylinders or buckets
- Field Forms:
  - *Field Investigation Daily Log*
  - *Pump Test Field Log*
- Submersible pump with flow regulator, and tubing
- Pressure transducer(s)
- Field computer
- Generator (if electricity is not available)
- Flow meters
- Heavy duty extension cords
- Polyethylene sheeting
- Large capacity barrels or trailer-mounted holding tanks and/or other means to store and transport pumped groundwater

4.3.1 Water Level Measurement

- Prior to initiating the pumping test, pressure transducers with integral data loggers should be installed in the test well and surrounding observation wells to be monitored and the water level allowed to stabilize. The transducers may be securely deployed by a direct-read cable allowing real-time viewing of data. Confirm data and settings from previous tests have been cleared and that new settings have been programmed. Record the depths of the transducers.

- The static water level in each well should be measured and recorded long enough to evaluate whether or not any trends exist. In general, pre-test water levels should be monitored and recorded for at least one week or a period longer than the duration of the test (ASTM, 2008; USEPA, 1993). Ultimately, the duration of pre-test monitoring will be based on field conditions and the project-specific data quality objectives.

- Program data loggers to record water level measurements during the test period. Generally, the measurement schedule is selected to have an initially high rate, followed by a period of reduced measurement frequency as the test progresses. The frequency selected must be sufficient to record the initial displacement produced at the start of each pumping step and at the start of the recovery period, but not so frequent that the storage limits of the data logger will be exceeded. Similar measurement frequencies should be chosen for the pumping and recovery periods. The following table of measurement frequencies can be used as a general guideline; however, more frequent measurements are typically made (ASTM, 2008):

Elapsed Time	Measurement Frequency
0 to 3 minutes	Every 30 seconds
3 to 15 minutes	Every minute
15 to 60 minutes	Every 5 minutes
60 to 120 minutes	Every 10 minutes
2 to 3 hours	Every 20 minutes
3 to 15 hours	Every hour
• 15 to 60 hours	• Every 5 hours

- Manual water level measurements shall be collected from the test well and monitoring wells immediately prior to the start of each pumping test and recorded on the appropriate field forms or logbook. Manual water level measurements should be recorded periodically for the duration of the test. These measurements should be collected using an electronic water level indicator with gradations to the nearest 0.01 foot. Wristwatches used to record the time of manual water level measurements should be synchronized with the computer used to program the data loggers.

- After the completion of the test(s), download the water level data from the transducer data logger for analysis. This is routinely stored in .txt, .csv, or .xls file formats for importation into Microsoft Excel®, or similar spreadsheet programs. Verify the file is saved. It is also useful to download any time-series figures created by the data logger software during the test; these typically include graphs of pressure head and temperature versus time.

- Pressure readings from the transducer should be compensated for changes in barometric pressure as necessary. A transducer dedicated to record atmospheric pressure should be placed within one of the test wells or in close proximity and at similar elevation to the tested well. Atmospheric pressure should also be recorded when static levels are recorded.

4.3.2 Pumping Period

- At the start of each test, the initial volume of the water in the pump discharge tank will be measured and recorded.

- A properly-sized submersible pump will be set in the pumping well with the intake set two feet above the base of the well screen.

- After the pump is initially placed in the well, field personnel will monitor the water level in the well to ensure that the head change caused by displacement of casing water by the pump and tubing has dissipated. The pump should not be turned on until the static water level has returned to the initial level prior to insertion of the pump.

- During step drawdown or constant rate testing, the flow rate will be continually measured and adjusted to maintain the pumping rate for each step within 10% of the design pumping rate. If the flow rates to be used are low (less than 1.0 gallon per minute [gpm]), the most reliable method of measuring them will be by filling graduated cylinders over 5, 10, 20, or 30-second time intervals. For flows over 1.0 gpm, a calibrated inline flow meter may be used to monitor flow rate. Multiple means of measuring flow are recommended in order to confirm results. Along with flow rate measurements, record the exact time of each pumping rate change.

- For step drawdown tests, each pumping step shall be maintained until the drawdown in the pumping well has stabilized, however this may be impractical for tests in low conductivity formations. For constant rate pumping tests, pumping shall continue for the duration specified for the test to meet established project-specific data quality objectives.

4.3.3 Recovery Period

- After the final pumping step, the pump will be switched off and water levels will be allowed to recover.

- Water level monitoring will continue during the recovery period. Ideally, the recovery period should continue until full recovery (> 90% of long-term drawdown) has been achieved; however, this is not always feasible in low permeability geologic materials.

<u>Equipment Decontamination</u>

At the end of each test, all field equipment that has contacted groundwater will be decontaminated by washing with a detergent solution (Alconox or equivalent) followed by rinsing with deionized water or a steam cleaner if available. Decontamination water will be collected and stored in labeled sealed buckets or drums on-site for future disposal by the client unless other arrangements have been made.

5.0 RECOVERY TESTING PROCEDURES

This section discusses recovery testing conducted as a standalone test at an operating extraction well. Recovery testing conducted as part of the recovery phase of an aquifer pumping test is discussed in Section 5.0. Recovery test results assist in the determination of hydraulic conductivity and storativity of the formation, while also providing information on the extent to which cones of depression may overlap for neighboring wells.

5.1 Planning and Design Considerations

Wells are selected for recovery testing based on a review of long-term pumping rates for each extraction well. Recovery tests should only be conducted at extraction wells where recent pumping rates are relatively stable.

Prior to initiating each recovery test, the long-term drawdown at the extraction well should be estimated by comparing historical water levels trends at the test well and neighboring cross-gradient monitoring wells, and/or by modeling the long-term drawdown based on the average pumping rate and previous estimates of hydraulic conductivity in the vicinity of the extraction well. This information is required to compute the residual drawdown during the course of the test.

5.2 Performing the Recovery Test

This section describes the protocol for performing a recovery test.

5.2.1 Equipment

In addition to the equipment specified in Section 2.0, the following equipment shall be used to conduct recovery tests:

- Field Forms:
    - *Field Investigation Daily Log*
    - *Pump Test Field Log*

5.2.2 Water Level Measurement

- Prior to conducting the recovery test, pressure transducers with integral data loggers should be installed in the test well (if possible) and in one or more monitoring wells in proximity to the test well. The transducers should be securely deployed by direct-read cables allowing real-time viewing of data if possible. Otherwise, transducers should be deployed using inert, low-stretch nylon or Kevlar cord. Record the depths of the transducers. Water levels shall be allowed to stabilize.

- Data loggers shall be programmed to record water level measurements during the test period at the specified frequency. The frequency selected must be sufficient to record the initial displacement produced at the start of the recovery test, but not so frequent that the storage limits of the data logger will be exceeded. The following table of measurement frequencies can be used as a general guideline; however, more frequent measurements are typically made (ASTM, 2008):

Elapsed Time	Measurement Frequency
0 to 3 minutes	Every 30 seconds
3 to 15 minutes	Every minute

15 to 60 minutes	Every 5 minutes
60 to 120 minutes	Every 10 minutes
2 to 3 hours	Every 20 minutes
3 to 15 hours	Every hour
15 to 60 hours	Every 5 hours

- Manual water level measurements shall be collected from the test well and monitoring wells immediately prior to the start of each recovery test and recorded on the appropriate field forms and/or logbook. Manual water level measurements should be recorded periodically for the duration of the test. These measurements should be collected using an electronic water level indicator with gradations to the nearest 0.01 foot.
- Initiate the recovery test by shutting off the extraction well pump. Record the exact pump shutdown time and depth to water.
- Ideally, the recovery test should continue until full recovery (> 90% of long-term drawdown) has been achieved; however, this is not always feasible in low permeability geologic materials.
- Upon completion of the recovery test, restart the pump and record the exact time and depth to water on the Pump Test Field Log.
- After the completion of the test(s), download the water level data from the transducer data loggers for analysis and verify the file is saved. This is routinely stored in .txt, .csv, or .xls file formats for importation into Microsoft Excel®, or similar spreadsheet programs. It is also useful to download any time-series figures created by the data logger software during the test; these typically include graphs of pressure head and temperature versus time.
- Pressure readings from the transducer should be compensated for changes in barometric pressure as necessary. A transducer dedicated to record atmospheric pressure should be placed within one of the test wells or in close proximity and at similar elevation to the tested well. Atmospheric pressure should also be recorded when static levels are recorded.

5.2.3 Equipment Decontamination

At the end of each test, all field equipment that has contacted groundwater should be decontaminated by washing with a detergent solution (Alconox or equivalent) followed by rinsing with deionized water or steam cleaning if available. Decontamination water will be collected and stored in labeled sealed buckets or drums on-site for future disposal by the client unless other arrangements have been made.

6.0 PRECAUTIONS

Certain precautions should be taken to ensure safety during the implementation of this FGD. It is important to always remain alert and aware of your surroundings.

The activities described in this FGD require the implementation of a site-specific Health and Safety Plan to inform personnel of the hazards associated with this work and to describe the methods that will be employed to mitigate those hazards. The Health and Safety Plan must be prepared and approved by the Project Manager and the local Health and Safety Coordinator prior to initiating field work.

7.0 RECORD-KEEPING

Information collected during the performance of these procedures may be recorded on individual field forms. If the project requires it, a project-specific Field Logbook may replace any of the individual field forms with the exception of the Chain-of-Custody form. Following review by the Task Manager, the original field records will be kept in the project file. The following forms may be used to document the field activities:

- *Field Investigation Daily Log*
- *Equipment Calibration Log*
- *Slug Test Field Log*
- *Pump Test Field Log*

The *Field Investigation Daily Log* will be completed for each day of fieldwork containing (at a minimum) the times and descriptions of the work performed, the activities of any contractors and/or visitors on-site, arrival and departure times for all involved, and any other pertinent information. For larger projects, or when otherwise deemed appropriate by the Task Manager, this information may alternatively be recorded in a field logbook. In these cases, a separate Field Logbook must be used for each project or site.

The *Equipment Calibration Log* will be used to document the calibration and status of any measuring instruments used in the field, e.g., PID/FID, water level measuring device, water quality meters, etc. The frequency and method of calibration will depend on the instrument. Any instruments used will be used in accordance with the factory-provided operating and/or service manuals.

The *Slug Test Field Log* will be used to document the procedures, parameters, and results of the slug test.

The *Pump Test Field Log* will be used to document the procedures, parameters and results of the pump test.

Locations and unique identification of samples collected will be recorded on the *Field Investigation Daily Log*, a site map, and/or other appropriate forms.

Appendix C

Field Data Sheets

AECOM

Boring/Well ID Number:

SUBSURFACE SOIL BORING FIELD LOG

CLIENT:
GEOLOGIST:
TOTAL DEPTH:
JOB NUMBER:
DATE DRILLED:
DRILLING METHOD:
LOCATION:
DRILLING COMPANY:
SAMPLE METHOD:
SURFACE ELEVATION:
NORTHING:
EASTING:

Depth (feet)	Samples	Sample Number	Time	FID/PID (ppm)	Blow Count	Recovery (ft)	GEOLOGIC DESCRIPTION															USCS soil class.	litho. contact (ft bgs)
							% Gravel	% Sand	% Silt	% Clay	NAME	COLOR	moisture	density	plasticity	angularity	grain size range/gravel	grain size range/sand	max gravel size	grading	Additional Modifiers		
5																							
10																							
15																							
20																							
25																							
30																							
Notes:							**>1/4 inch**	visible - 1/4 in.	visible with hand lens	not visible	see USCS flow charts. <5-5%=trace, 10%=few,15-25%=little, 30-45%=some, 50%+=mostly (cobbles only)	use Munsell color chart	**D**ry **M**oist **W**et	Dense, D. Sand	**N**on **H**igh **M**ed **L**ow	Angular, **SA**, **SR**, Rounded	**F**ine, **C**oarse	**F**ine, **M**ed, **C**oarse	in inches	**P**oorly, **W**ell	Odor, Staining, Mineralogy, etc.		

Rev.10/27/2016

AECOM

Boring/Well ID Number:

SUBSURFACE SOIL BORING FIELD LOG

CLIENT:
JOB NUMBER:
LOCATION:
SURFACE ELEVATION:

GEOLOGIST:
DATE DRILLED:
DRILLING COMPANY:
NORTHING:

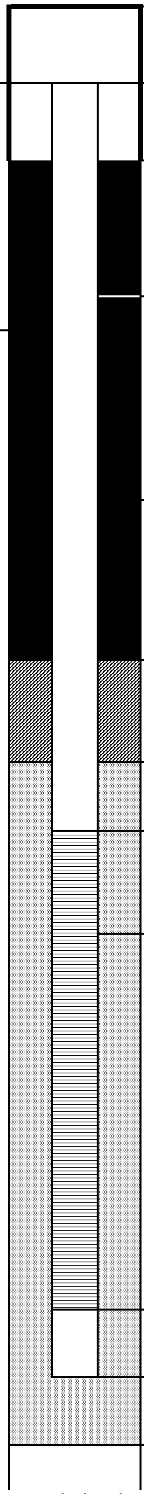
TOTAL DEPTH:
DRILLING METHOD:
SAMPLE METHOD:
EASTING:

Depth (feet)	Samples	Sample Number	Time	FID/PID (ppm)	Blow Count	Recovery (ft)	GEOLOGIC DESCRIPTION															USCS soil class.	litho. contact (ft bgs)
							% Gravel	% Sand	% Silt	% Clay	NAME	COLOR	moisture	density	plasticity	angularity	grain size range/gravel	grain size range/sand	max gravel size	grading	Additional Modifiers		
35																							
40																							
45																							
50																							
55																							
60																							
Notes:							>1/4 inch	visible - 1/4 in.	visible with hand lens	not visible	see USCS flow charts. <5-5%=trace, 10%=few,15-25%=little, 30-45%=some, 50%+=mostly (cobbles only)	use Munsell color chart	Dry Moist Wet	Dense, D. Sand	Non High Med Low	Angular, SA, SR, Rounded	Fine, Coarse	Fine, Med, Coarse	in inches	Poorly, Well	Odor, Staining, Mineralogy, etc.		

Rev.10/27/2016

AECOM	*Client:*	***WELL ID:***
	Project Number:	
	Site Location:	*Date Installed:*
	Well Location: *Coords:*	*Inspector:*
	Method:	*Contractor:*

MONITORING WELL CONSTRUCTION DETAIL



	Depth from G.S. (feet)	Elevation(feet) Datum ________
Top of Steel Guard Pipe	________	________
Top of Riser Pipe	________	________
Ground Surface (G.S.)	0.0	________
Bottom of Steel Guard Pipe	________	________
Top of Bentonite	________	________
Top of Sand	________	________
Top of Screen	________	________
▼ Stabilized Water Level	________	________
Bottom of Screen	________	________
Bottom of Tail Pipe:	________	________
Bottom of Borehole	________	________

Measuring Point for Surveying & Water Levels

Cement, Bentonite, Bentonite Slurry Grout, or Native Materials

________ % Cement

________ % Bentonite

________ % Native Materials

Riser Pipe:
- Length ________
- Inside Diameter (ID) ________
- Type of Material ________

Bentonite Seal Thickness ________

Screen:
- Length ________
- Inside Diameter (ID) ________
- Slot Size ________
- Type of Material ________

Type/Size of Sand ________

Sand Pack Thickness ________

Borehole Diameter: ________

Approved:

________________ Signature

________ Date

Describe Measuring Point:

____

AECOM

Well/Piez. ID:

Well/Piezometer Development Record

Client: ____________________ Site Location: ____

Project No: ____________________ Date: __________ Developer: ____________________________________

WELL/PIEZOMETER DATA

Well ☐ Piezometer ☐ Diameter __________ Material ___________

Measuring Point Description ________________ Geology at Screen Interval (if known) ____________________

Depth to Top of Screen (ft.) ________________

Depth to Bottom of Screen (ft.) ________________ Time of Water Level Measurement ________

Total Well Depth (ft.) ________________ Calculate Purge Volume (gal.) ________

Depth to Static Water Level (ft.) ________________ Disposal Method ____________________________

Wellhead PID/FID ____________________________

Original Well Development ☐ Redevelopment ☐ Date of Original Development __________

DEVELOPMENT METHOD ________________ **PURGE METHOD** ____________________________

Field Testing Equipment Used: Make Model Serial Number

Field Testing Calibration Documentation Found in Field Notebook # ______________ Page # ______________

Time	Volume Removed (gal)	T° (C/F)	pH	Spec. Cond (umhos)	Turbidity (NTUs)	DO	Color	Odor	Other

ACCEPTANCE CRITERIA (from workplan)

Min. Purge Volume (____ well volumes) _____gallons

Maximum Turbidity Allowed _____ NTUs

Stabilization of parameters _____%

	Yes	No	N/A
Has required volume been removed	☐	☐	☐
Has required turbidity been reached	☐	☐	☐
Have parameters stabilized	☐	☐	☐

If no or N/A explain below:

Signature ____ Date: ____________________

AECOM

Well ID:

Low-Flow Ground Water Sample Collection Record

Client: ______ Date: ______ Time: Start ______ am/pm
Project No: ______ Finish ______ am/pm
Site Location: ______
Weather Conds: ______ Collector(s): ______

1. WATER LEVEL DATA: (measured from Top of Casing)

a. Total Well Length ______ c. Length of Water Column ______ (a-b) Casing Diameter/Material ______

b. Water Table Depth ______ d. Calculated System Volume (see back) ______

2. WELL PURGE DATA

a. Purge Method: ______

b. Acceptance Criteria defined (see workplan)

- Temperature	± 2°C	-D.O.	0.3 mg/l
- pH	± 0.1 unit	Turbidity	10% if NTU reading is > 10 NTUs
- Sp. Cond.	± 3%	ORP	± 10 milivolts

c. Field Testing Equipment used: Make Model Serial Number

______
______
______

Time (24hr)	Volume Removed (Liters)	Temp. (°C)	pH	Spec. Cond. (µS/cm)	DO (mg/L)	ORP (mV)	Turbidity (NTU)	Flow Rate (ml/min)	Drawdown (feet)	Color/Odor

d. Acceptance criteria pass/fail Yes No N/A (continued on back)

Have parameters stabilized ☐ ☐ ☐

If no or N/A - Explain below.

______

3. SAMPLE COLLECTION: Method: ______

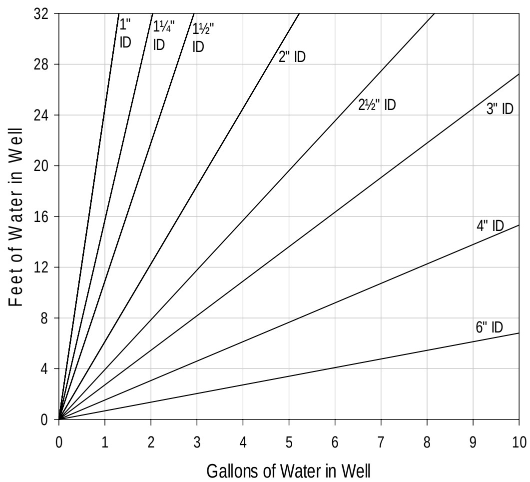
Sample ID	Container Type	No. of Containers	Preservation	Analysis Req.	Time

Comments ______

______

Signature ______ Date ______

Purge Volume Calculation



Volume / Linear Ft. of Pipe		
ID (in)	Gallon	Liter
0.25	0.0025	0.0097
0.375	0.0057	0.0217
0.5	0.0102	0.0386
0.75	0.0229	0.0869
1	0.0408	0.1544
1.25	0.0637	0.2413
1.5	0.0918	0.3475
2	0.1632	0.6178
2.5	0.2550	0.9653
3	0.3672	1.3900
4	0.6528	2.4711
6	1.4688	5.5600

(continued from front)

Time (24 hr)	Volume Removed (Liters)	Temp (°C)	pH	Spec. Cond. (μS/cm)	DO (mg/L)	ORP (mV)	Turbidity (NTU)	Flow Rate (ml/min)	Drawdown (ft)	Color/Odor

Appendix D

Modified Groundwater Sampling Procedures

AECOM
1220 Avenida Acaso
Camarillo, CA 93012

(805)388-3775 tel
(805)388-3577 fax

Memorandum

To	Carlton Parker and Weiquan Dong	Pages	2
CC	James Dotchin		
Subject	Modified Groundwater Sampling Techniques for Wells with Slow Recharge Rates		
From	AECOM		
Date	April 28, 2016		

The Initial Sampling of Groundwater for the Nevada Environmental Response Trust Site (NERT) – Downgradient Study Area commenced on April 18, 2016. The scope of work calls for wells to be sampled using low-flow sampling techniques in which low volumes of water are purged (using a bladder pump) with little or no drawdown, while allowing water quality field parameters to stabilize. Field personnel reported that groundwater levels in several wells were being drawn down even at low pumping rates of 50 milliliters per minute (mL/min). The drawdown is the result of slow recharge rates, which may be caused by the low hydraulic conductivity of the formation or fouling of the well screen and gravel pack. Recovery rates as low as 50 percent of the initial water column were observed over a 14.5-hour period, even after the screen interval was swabbed to try to improve recharge. Drawdown at low pumping rates experienced at several wells does not fall within the sampling protocols in the approved Groundwater Sampling Plan.[1]

These field conditions in wells were discussed with Nevada Department of Environmental Protection (NDEP) and NERT on April 26, 2016. During the NERT coordination call, NERT suggested that AECOM use the same sampling techniques that Ramboll (NERT consultant) uses to sample wells with slow recharge rates in their program so that the AECOM sample results are comparable to those of Ramboll. Mr. Chris Ritchie of Ramboll was contacted to see how they deal with slow recharging wells. Mr. Ritchie is not aware of any swabbing of the well conducted by Ramboll to improve recharge rates. Ramboll is currently revising the Low-Flow Field Guidance Document (FGD) because they too have experienced drawdown in certain wells at very low pumping rates. The FGD will be revised with the sampling procedures listed below, which, after consultation with NDEP, have been adopted for the remaining groundwater sampling in the Downgradient Study Area.

The following groundwater sampling procedures will be used when drawdown in a well occurs while pumping at 100 mL/min:

- Purge the complete pump system (hoses and flow-through cell).

[1] AECOM 2016. Groundwater Sampling Plan, NERT Remedial Investigation – Downgradient Study Area, Nevada Environmental Response Trust Site, Henderson, Nevada, February 29.

- Record Field Parameters – collection of only one to two readings is acceptable. Field parameters do not need to stabilize before collecting a sample.
- Collect sample after pump system (pump and lines) has been purged completely.

Implementation of these sampling procedures will reduce sampling times, minimize the volume of purge water generated, and will be consistent with those used by Ramboll for the NERT site. Using the same sampling techniques as Ramboll will allow for better comparison between the two datasets.

On April 27, 2016, Mr. Carlton Parker and Mr. Weiquan Dong agreed (via email) that mirroring the Ramboll procedures is acceptable for the Downgradient Study Area. Sampling procedures were implemented in the field on the morning of April 27, 2016.

NEVADA DIVISION OF
ENVIRONMENTAL PROTECTION

STATE OF NEVADA
Department of Conservation & Natural Resources
Brian Sandoval, Governor
Leo M. Drozdoff, P.E., Director
David Emme, Administrator

May 2, 2016

Harry Van Den Berg
AECOM, Inc
1220 Avenida Avenue
Camarillo, CA 93012

Re: **Tronox LLC (TRX) Facility**
Nevada Environmental Response Trust (Trust) Property
NDEP Facility ID #H-000539
Nevada Division of Environmental Protection (NDEP) Response to:
Modified Groundwater Sampling Techniques for Wells with Slow Recharge Rates
Dated: April 28, 2016

Dear Mr. Van Den Berg,

The NDEP has received and reviewed the Trust's above-identified Deliverable and finds that the document is acceptable.

Please contact the undersigned with any questions at jcarltonparker@ndep.nv.gov or 702-486-2850 x228.

Sincerely,

Carlton Parker, P.G.
Supervisor, Bureau of Industrial Site Cleanup
NDEP-Las Vegas City Office

CP:jp

EC:
James Dotchin, NDEP BISC Las Vegas
Carlton Parker, NDEP BISC Las Vegas
Weiquan Dong, NDEP BISC Las Vegas
Adam Baas, Edgcomb Law Group
Allan Delorme, Ramboll Environ
Alison Fong, U.S. Environmental Protection Agency, Region 9
Andrew Barnes, Geosyntec
Andrew Steinberg, Nevada Environmental Response Trust
Anna Springsteen, Neptune & Company Inc.
Betty Kuo Brinton, MWDH2O
Brenda Pohlmann, City of Henderson
Brian Waggle, Hargis + Associates

Carol Nagai, MWDH2O
Charles K. Hauser, Esq., Southern Nevada Water Authority
Chris Ritchie, Ramboll Environ
Chuck Elmendorf, Stauffer Management Company, LLC
Dave Share, Olin
David Johnson, Central Arizona Water Conservation District
Dave Johnson, LVVWD
Derek Amidon, Tetratech
Ebrahim Juma, Clean Water Team
Ed Modiano, de maximis, inc.
Eric Fordham, Geopentech
Frank Johns, Tetratech
Gary Carter, Endeavour
George Crouse, Syngenta Crop Protection, Inc.
Jasmine Mehta, AG Office
Jay Steinberg, Nevada Environmental Response Trust
Jeff Gibson, Endeavour
Jill Teraoka, MWDH2O
Joanne Otani
Joe Kelly, Montrose Chemical Corporation of CA
Joe Leedy, Clean Water Team
John Pekala, Ramboll Environ
Katherine Baylor, U.S. Environmental Protection Agency, Region 9
Kelly McIntosh,GEI Consultants
Kevin Fisher, LV Valley Water District
Kirk Stowers, Broadbent & Associates
Kirsten Lockhart, Neptune & Company Inc.
Kim Kuwabara, Ramboll Environ
Kurt Fehling, The Fehling Group
Kyle Gadley, Geosyntec
Kyle.Hansen, Tetratech
Lee Farris, BRC
Marcia Scully, Metropolitan Water District of Southern California
Maria Lopez, Water District of Southern California
Mark Paris, Landwell
Michael J. Bogle, Womble Carlyle Sandridge & Rice, LLP
Michael Long, Hargis + Associates
Mickey Chaudhuri, Metropolitan Water District of Southern California
Nicholas Pogoncheff, PES Environmental, Inc.
Paul Black, Neptune and Company, Inc.
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Patti Meeks, Neptune & Company Inc.
Peggy Roefer, CRC
Ranajit Sahu, BRC
Richard Pfarrer, TIMET
Rick Kellogg, BRC
Scott Bryan, Central Arizona Project
Steve Clough, Nevada Environmental Response Trust
Tanya O'Neill, Foley & Lardner L
Todd Tietjen, SNWA