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Supplemental Surface Water Investigation Plan

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

Final

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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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January 30, 2018
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List of Acronyms

cfs	cubic feet per second
COA	certificate of waiver or authorization
CSM	conceptual site model
Downgradient Study Area	NERT RI Downgradient Study Area
DQO	data quality objective
DTS	distributed temperature survey
EB	equipment blank
EPA	United States Environmental Protection Agency
FAA	Federal Aviation Administration
FB	field blank
FD	field duplicate
FGD	Field Guidance Document
FO-DTS	fiber-optic distributed temperature sensing survey
gpm	gallons per minute
HASP	Health and Safety Plan
ID	identification number
IDW	investigation-derived waste
JHA	job hazard analysis
km	kilometer
LCS	laboratory control sample
LCSD	laboratory control sample duplicate
LVW	Las Vegas Wash
LVWCC	Las Vegas Wash Coordination Committee
µg/L	micrograms per liter
µm	micron
MS/MSD	matrix spike/matrix spike duplicate
NDEP	Nevada Division of Environmental Protection
NERT	Nevada Environmental Response Trust
NERT On-Site Study Area	on-site portion of the NERT RI
±	plus or minus
PPE	personal protective equipment
lb/day	pounds per day
QA	quality assurance
QAPP	Quality Assurance Project Plan

QC	quality control
RI	Remedial Investigation
RM	river mile
SM	Standard Method
SNWA	Southern Nevada Water Authority
SOPs	Standard Operating Procedures
SSWIP	Supplemental Surface Water Investigation Plan
SWI	Surface Water Investigation
TIMET	Titanium Metals Corporation
TIR	thermal infrared
UAS	unmanned aircraft system
USGS	United States Geological Survey

1.0 Introduction

This Supplemental Surface Water Investigation Plan (SSWIP) describes the locations, procedures, and methods for further investigation of the Las Vegas Wash (LVW), supporting 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 SSWIP was developed at the direction of the Nevada Division of Environmental Protection (NDEP) and describes the procedures and methods for conducting an aerial thermal infrared (TIR) imaging program, a focused temperature study (fiber-optic distributed temperature survey [FO-DTS]) and collecting and analyzing surface water samples from locations along transects in the LVW.

The objective of the investigation of the Downgradient Study Area is to identify downgradient and cross-gradient subsurface pathways through which perchlorate-impacted groundwater is entering the LVW (**Figure 1**). Quarterly sampling has been conducted at a limited number of surface water locations in the past few years. To support the Project, AECOM has conducted several rounds of more focused sampling including discrete sampling in May 2016 (AECOM 2016a) and transect and discrete sampling to quantify perchlorate concentrations relative to flow and location in the LVW in February 2017 (AECOM 2017a). The work described in this SSWIP is intended to expand on these initial sampling programs by performing infrared imaging of the LVW in the Downgradient Study Area to demonstrate loci of groundwater input, a focused temperature study in the LVW in areas of increased perchlorate flux as determined during the 2017 surface water investigation (AECOM 2017a), and a refined transect sampling event to further examine patterns of perchlorate in the LVW.

Determination of the seasonal patterns of perchlorate concentrations is not the intent of the one-time sampling event described in this SSWIP. Although the concentrations in the LVW may vary significantly with time, both diurnally (from wastewater reclamation discharge) and seasonally (due to sporadic rain events, evapotranspiration, etc.), the sampling design described in this SSWIP is intended to provide indication as to which reaches in the LVW are currently receiving significant perchlorate from groundwater or seep discharges. This, in turn, will assist in focusing additional investigations of perchlorate pathways in groundwater within the Downgradient Study Area.

Construction of the proposed Sunrise Mountain Weir and Historic Lateral Weir Expansion is currently underway. Diversion of the LVW may cause a disruption in flow and potentially change the perchlorate flux. Dewatering in the area of the weir construction involves construction of an open pit in an area known to contain perchlorate (reported concentrations of influent range from 370 to 1,900 micrograms per liter [µg/L]). NERT has a permit to treat the influent water for perchlorate to less than 18 µg/L (NDEP Permit NV0024228, effective August 14, 2017). Capture and treatment of the groundwater from dewatering will minimize perchlorate impacts to the LVW. Treatment started January 2, 2018. Although potential temporary changes to the hydrology of the LVW will be caused by weir construction and associated dewatering, the studies being conducted under this SSWIP cannot be postponed for the duration of the construction of Sunrise Mountain Weir and the Historic Lateral Weir.

Sample locations proposed in this SSWIP have been selected to achieve these objectives while also taking into account safe access to the LVW. Extensive onshore riparian zone restoration has occurred, making it difficult to access all of the locations on foot. As needed, boats will be used to access the majority of sampling locations in the LVW; any sample locations in the seep areas, the wastewater discharge streams, and tributaries, will be accessed on foot. While no accessibility problems are anticipated, should any occur due to safety concerns or physical limitations, AECOM will evaluate options to collect the required data in consultation with NDEP.

The activities in this SSWIP will be conducted in conformance with the Quality Assurance Project Plan (QAPP) (AECOM 2017b) and the site-specific Health and Safety Plan (HASP) (AECOM 2017c) developed by AECOM. Modifications to the HASP that specifically address on-water safety are also provided as **Appendix A** to this

SSWIP. As needed, Job Hazard Analyses (JHAs) will be prepared during the pre-field activities and, if conditions dictate, during the field efforts to cover any additional concerns with working on or near the water.

Data collected under this SSWIP will be reported in a technical memorandum to be used by NERT during the preparation of the RI Report.

1.1 Supplemental Surface Water Investigation Plan Organization

This document includes the following sections:

- Section 1.0 provides an introduction, including the overall objectives and organization of the SSWIP.
- Section 2.0 presents a generalized CSM of the LVW excerpted from the final Surface Water Investigation (SWI) Technical Memorandum (AECOM 2017a).
- Section 3.0 discusses the data quality objectives (DQOs) for the infrared imaging, the FO-DTS and the sampling and analyses program.
- Section 4.0 describes the sampling and scope for the SSWIP and describes the sampling types, locations, and frequency along with pre-field and field activities to be conducted.
- Section 5.0 details the sampling/testing 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 SSWIP.

1.2 Definitions and Key Terms

The following terms are used throughout the SSWIP and are defined here for consistency.

Emissivity: The efficiency of a surface to emit energy as thermal radiation. This value is an input parameter used to determine the temperature of a surface based on the material being evaluated.

Fiber-optic cable: A flexible linear cable that is composed of glass fiber coated in an insulated plastic casing that transmits light.

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

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

Orthomosaic: A single composite geospatial image created from merging individual images.

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

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

Potential discharge: A location where discharge may be occurring, but there is still uncertainty

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 runoff water.

2.0 Conceptual Site Model of Las Vegas Wash

This section provides an abbreviated description of the CSM of the LVW and known and suspected inputs. This information has been presented previously in the SWI Plan (AECOM 2016b) and the SWI Technical Memorandum (AECOM 2017a). These documents contain additional information not presented herein.

Before development of the Las Vegas area, the LVW was a natural stream that drained a series of large springs and occasional stormwater runoff from the Las Vegas Valley. 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 constructed, and are continuing to be constructed, to slow down the water velocities through major portions of the LVW. A list of current and proposed weirs is provided in **Table 1**. 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. The paths by which the contaminated groundwater enter the LVW and introduce contamination to the surface waters are not well understood.

Discharges from the four major wastewater treatment plants in the valley represent the vast majority of anthropogenic 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, and Titanium Metals Corporation [TIMET]) and the TIMET non-contact cooling water discharge join the channel conveying treated wastewater from the City of Henderson, entering LVW above Pabco Road Weir. The remaining flow in the LVW comes from other sources such as 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 some reaches of the LVW are below the groundwater table and, therefore, receive groundwater discharge. Other reaches of the LVW are above the groundwater table, 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, seasonal fluctuations of the groundwater table and occasional episodes of precipitation in the LVW drainage area.

Figure 2 presents a plan-view map of the LVW within the Downgradient Study Area with the perchlorate data collected from the transect sampling conducted in February 2017. The figure indicates increases in perchlorate concentrations near the proposed Sunrise Mountain Weir (under construction), the Calico Ridge Weir, and the Three Kids Weir. A series of discrete grab sampling data were also generated in 2017 and these data, combined with surface water flow data collected from the United States Geological Survey (USGS) gages along the LVW, were used to generate estimates of flux. While these individual flux estimates may be subject to significant margins of error, the data indicate and support increases in perchlorate load along the LVW that are generally analogous to the concentrations encountered in the transect samples obtained in the same vicinity. **Figure 3** presents the flux data in a generalized CSM of perchlorate in the LVW.

Based on the 2017 sampling program described in the SWI Technical Memorandum (AECOM 2017a), several locations of potential perchlorate input have been identified:

- Near the Sunrise Mountain Weir currently under construction, Wastewater Discharge Channel and Pabco Road Weir, perchlorate concentrations increase, indicating there may be uncaptured perchlorate.
- An increase in perchlorate is noted near Calico Ridge Weir. This increase is approximately 45 percent or 5 to 10 pounds per day (lb/day).

- An increase of approximately 6 lb/day is noted at Lower Narrows Weir.
- Up to 10 lb/day of perchlorate is added to the LVW near Three Kids Weir.
- Downstream of Rainbow Gardens Weir, the flux of perchlorate almost doubles to an estimate 68 lb/day (from 37 to 47 lb/day at Three Kids Weir).

While these flux measurements are estimates based on a one-time sampling event, they do indicate reaches where perchlorate may be entering the LVW. To help focus the investigation, additional sampling is being conducted to confirm the observations described in the SWI Technical Memorandum (AECOM 2017a).

3.0 Data Quality Objectives

In this section, the United States Environmental Protection Agency (EPA) DQO process (EPA 2006) is followed to assist with systematic planning for the proposed environmental sampling program described in this SSWIP with the overall objective of addressing the surface water data gaps identified SWI Technical Memorandum (AECOM 2017a). 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.

After performance criteria have been developed, 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 (AECOM 2017b). 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.

The field work described in this SSWIP includes three distinct consecutive data collection efforts, each intended to provide information to fill the data gaps identified in SWI Technical Memorandum (AECOM 2017a). The DQO process for each of these is provided below. The three data collection efforts include an aerial TIR survey, a FO-DTS, and a transect-based surface water sampling event.

A summary of steps 1 through 6 is provided in the following sub-sections for each of the three primary activities covered in the SSWIP. Those three activities will both help refine knowledge of where perchlorate is entering the LVW. The aerial TIR survey (Section 3.1) will be used first to provide an overview of the LVW, with generalized areas of groundwater discharge, identified through the infrared photography. The FO-DTS (Section 3.2) will be used to refine the loci of groundwater inputs based on the CSM discussed in Section 2.0 and the information generated with the TIR survey data. Transect sampling (Section 3.3) will be used to confirm the results of the February 2017 sampling results, evaluate the variability in perchlorate concentrations across each cross section and identify potential locations of seepage. The sampling plan details for step 7 are described in Sections 4.0 through 6.0 of this SSWIP.

3.1 Aerial Infrared Mapping

3.1.1 Define the Problem

As discussed in Section 2, perchlorate discharge to the LVW needs to be further defined. 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, more groundwater sources of perchlorate to the LVW are likely present via groundwater discharge pathways along the LVW within the Downgradient Study Area.

The complex geology and hydrology described in the CSM (Section 2.0), together with the construction of weir structures, confound locating perchlorate-impacted groundwater discharge locations. While some perchlorate mass may be entering the LVW upstream of the Downgradient Study Area, ongoing sampling efforts have shown those contributions to be minor or relatively insignificant. To evaluate more significant perchlorate flux to the LVW, the sources of perchlorate discharge must be located. These sources are likely contaminated groundwater discharging as seeps or springs that may be entering via overland flow or, more likely, discharging in the LVW directly under the water surface.

An aerial TIR survey is a method sensitive to discerning temperature differences in surface water and discharging groundwater. Differences in surface water and groundwater temperature often occur in summer and winter where groundwater is cooler or warmer than surface water, respectively. This “out-of-phase” relationship of groundwater temperature is the basis for successful implementation of the TIR method and identification of potential groundwater discharge locations. The TIR survey is a non-invasive means of evaluating the current nature and distribution of groundwater discharge locations in the LVW within the limits of the entire Downgradient Study Area. The TIR data aims to help evaluate generalized locations of groundwater discharge to instruct future sampling, as not all groundwater discharges contribute perchlorate to the LVW.

To help refine understanding of the perchlorate discharge for the entire stream reach of interest, the aerial TIR data collection from an Unmanned Aircraft System (UAS) will occur from Duck Creek Confluence Weir to the Lake Las Vegas Inlet. This will refine the upstream and off-site groundwater discharge distributions to the LVW within and downstream of the Downgradient Study Area.

3.1.2 Identify the Goals of the Aerial Infrared Mapping

<u>Principal TIR Study Questions:</u>

- Which reaches along the LVW have groundwater discharge zones?
- Where are the significant groundwater discharges?

The TIR Study will provide data to evaluate potential locations of groundwater discharge, which may provide the following:

- Additional data to refine/confirm the reaches in the LVW of potential discharge of perchlorate to the LVW; and,
- Data to help direct the subsurface investigation to track potential loci of groundwater discharge, regardless of perchlorate concentration, to the LVW.

The data collected during the TIR survey will cover the entire reach of the LVW in the Downgradient Study Area, which will provide a comprehensive spatial evaluation of the surface water thermal patterns that can be used to evaluate groundwater discharge locations.

3.1.3 Identify the Information Inputs

TIR surveys are commonly used to evaluate where groundwater may be discharging into surface water bodies. The method is intended to identify surface water temperature contrasts, which may indicate the presence of groundwater discharge. As groundwater can exhibit a thermal signature distinguishable from that of surface water, using temperature as a groundwater discharge indicator is a reconnaissance technique to identify potential locations of discharge.

TIR imaging best practices from Hare et al. (2015) and Dugdale (2016) will be utilized for aerial data collection to the extent feasible. The results from the TIR survey will be qualitative, but the data collected may allow for absolute temperature measurements at each pixel in the image (depending on the design and execution of the TIR survey). Measured temperature differences between groundwater and surface water have been used successfully to quantify surface water-groundwater interactions (Loheide and Gorelick [2006] and Cory and Leib [2003]). Even if absolute temperature measurements throughout the LVW are not possible, relative temperature differences are adequate for the objectives of this work. Absolute temperature will be collected from discrete locations along the LVW during the aerial survey. These measurements will aid in confirming the temperature differences observed in the FIR images. In addition, the transducers in the monitoring wells will collect groundwater temperature data during the survey. Temperature anomalies will be identified by comparing temperature values between adjacent pixels or zones on the TIR images.

While the method has proven to be effective in a wide variety of applications, it does have limitations, particularly if thermal contrasts are minimal. The limitations of the TIR method are largely due to the fact that the results only provide a measure of surface temperature (i.e. "skin" temperature from the surface of the water body). It is possible that in specific circumstances, groundwater discharge may not display a surface temperature expression, particularly in deep or fast flowing waters. Ideal conditions for applications of TIR for groundwater discharge evaluation include shallow, low flow water bodies, such as the LVW which has monthly mean flows from the past 10 years that range from approximately 250 to 480 cfs at Pabco Road Weir (USGS 2018).

Interference from background temperature contrasts may obscure evaluation of TIR imagery for the purpose of identifying groundwater discharges. For example, the input of wastewater to a system may change the surface water temperature, and thus must be considered when determining optimal flight times and daily locations. With the exception of discharge from the wastewater channels near Pabco Road Weir, the majority of wastewater inputs are upstream of the Study Area. From the 2016 SWI Plan field data, the differences in surface water temperature between low flow (low wastewater input) and high flows (high wastewater inputs) near Duck Creek and Pabco Road Weir is approximately 2.5 degrees Celsius. To minimize the potential impacts of wastewater on the temperature signature, the TIR survey will be conducted during low flow conditions when wastewater inputs are lowest. There is no substantial difference in temperature from the surface water in the wastewater channel at Pabco Road Weir itself, indicating that the wastewater from this channel is not significantly impacting the temperatures in the LVW.

3.1.4 Define the Study Area Boundaries

Step 4 of the DQO process is to define the boundaries of the study area, which for the TIR aerial survey is from river mile (RM) LW6.85 to LW2.9, approximately Duck Creek Confluence Weir to the Lake Las Vegas Inlet as shown on **Figure 4**.

3.1.5 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.

The TIR survey will be completed by AECOM UAS Services Support using a UAS platform. The study area is located in airspace that will require the UAS support staff to file for Federal Aviation Administration (FAA) certificate of waiver or authorization (COA) for operation. The appropriate TIR camera will be attached to a UAS, provided and operated by the AECOM UAS Services Support Group. The full project area scan (~250 acres) will be completed above all transmission lines and associated infrastructure, and flights will only focus on approved locations safe to survey using an UAS. Data will be collected using both TIR and optical visible light sensors (i.e., images visible to the human eye; "pictures") over the entire extent of the LVW stream channel located within the Downgradient Study Area. The visible light images will be used to ground-truth the TIR images and provide pictures of anomalies (e.g., outcroppings, vegetation, weirs, human activity, etc.) that may be difficult to discern from the TIR images.

To allow the data to be georeferenced, access will be provided to known ground control points, or a surveyor will coordinate collection of survey control on the same day of initial UAS data collection. All delivered orthoimages will be georeferenced. At the end of each survey day, the collected data will be uploaded to a server where further review and processing will be conducted.

Post-processing of the TIR data will include creating a mosaic of the orthoimages, and georeferencing these data. The TIR geospatial data will then be analyzed and further data processing will be implemented to improve identification of potential groundwater discharge locations. For example processing may be done to accentuate the differences between adjacent pixels/zones of interest, and generate raster images that best meet the outlined objectives.

Through the data evaluation, thermal anomalies will be cross compared with the visible light images to evaluate whether the anomalies may be a result of groundwater discharge zones, rather than thermal distortion or other thermal signatures.

3.1.6 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 of the TIR survey is on collecting and interpreting data to better characterize along which reaches of the LVW groundwater discharges may be occurring.

In the absence of defined decision tolerance limits, the TIR survey will identify possible sources of error and minimize them, to the extent practical. Both random and systematic errors can be introduced during the physical collection of the imagery, data processing, data analysis, data interpretation, and data handling.

When collecting and evaluating TIR survey data, a critical level of uncertainty arises from the fact that TIR imagery only captures the surface temperature of an object; therefore, these data are important to compare to *in situ* data that are available, particularly in areas that are not optimal for thermal data collection. Hare et al. (2015) identified aquatic environments that have a total depth of 0.5 meter (approximately 1.6 feet) or greater and have 20 cfs waters typically obscure the groundwater thermal signal before the signature can be seen on the surface of the water, unless there is a strong inflowing flux. In these environments, however, TIR data is still optimal for surveying shallow locations, particularly along the stream bank and slower, shallow areas. As the LVW is a wide, shallow stream and flows in the center are typically faster, TIR may not be able to determine the presence of groundwater discharge in the center of the wash. However, TIR is still a useful approach along the banks, even though flows are greater than 20 cfs. The aerial TIR method is the only feasible approach that can assess groundwater discharge over the entire ~250 acre study reach.

Interpretation of TIR image data can be complex. To minimize interpretation error, it is imperative that these data be viewed critically and with knowledge of the potential artefacts or interferences that may cause distortion in the TIR imagery. TIR imagery may induce erroneous data, or obscure the fundamental thermal signature of an area. To ensure these potential impacts inherent in TIR data collection are understood to those viewing the data, the most significant concerns have been outlined in basic terms below.

- TIR, as with any heat-tracing methods, relies on the distinct temperature between groundwater and surface water to elucidate exchange patterns. Therefore, for successful application of thermal methods, the temperature difference between the two reservoirs (i.e., surface water and groundwater) must be greater than the resolution, even when evaluating qualitative data. Like most sites, temperature differences can vary seasonally, and the most optimal times to perform the survey at the LVW are between January and March, or July and September. Also channel temperature can vary spatially, particularly downgradient around the wastewater input at Pabco Road Weir, and after large wastewater inputs from upgradient of the Downgradient Study Area. During survey preparation these inputs should be considered before deployment.

- TIR data only accounts for the surface 'skin' temperature; therefore, only processes that are apparent in the water's surface can be visualized. Also, additional processes affect the surface temperature more so than the water column, such as exposure to the sun, wind, and waves (the latter unlikely to be a concern in the LVW). To minimize these effects, images during the LWV TIR survey will be captured during early day hours when the sunlight impacts and wind should be low.
- The thermal stratification effects on data collection occurs due to the buoyancy effects of warmer versus cooler waters when not compensated by vertical mixing. For example, a cool seep may not express its thermal signature on the surface of a, relatively, warmer stagnant pool or stream.
- Emissivity (i.e., efficiency of thermal radiation based on temperature) variability can occur within a single image or over multiple images, due to water roughness, suspended sediment, or other physical affects;
- Reflection interferences:
  - Near-bank TIR radiation reflection – radiated TIR wavelengths from an object may reflect off an adjacent surface (i.e. water); thus, the radiant signal from the reflecting surface may be masked. This includes reflections from clouds, which should generally not be a major concern in the Downgradient Study Area.
  - Ambient reflection – solar radiation is minimized within the TIR wavelength range (8-14 micron [μm]); however, this can cause spectral distortions within imagery.
- The wider the observation angle of the TIR sensor, the higher the likelihood for spectral distortions; therefore the data in the center of the image is the most accurate and decreases away from the center. Remote sensing practice dictates that 35% of the image, either side of nadir (i.e., lowest point), is the most reliable.
- Atmospheric interference – TIR wavelengths are absorbed and emitted from water vapor; therefore, changes in humidity may have a significant effect on the data recorded by the sensor. This is unlikely to be a concern in the Downgradient Study Area.

To minimize these sources of interference, and thus minimize uncertainty, AECOM will evaluate both complete orthomosaic determined locations that contain potential thermal anomalies based on observed patterns consistent with groundwater discharge, and analyze the raw data in locations of interest to confirm the presence/absence of thermal signatures. The characteristics that will be used to identify thermal anomalies of interest are relative temperature difference, as well as the anomalies' shape, pattern, presence in multiple raw images, and shoreline features. To the extent possible, data will be collected during low light (i.e., early morning) hours.

3.1.7 Develop the Plan for Collecting Data

Step 7 is detailed in Sections 4.0 through 6.0.

3.2 Distributed Temperature Sensing

3.2.1 Define the Problem

The concentrations of perchlorate generally match the existing CSM, confirming increases in perchlorate concentrations observed in previous sampling near the proposed Sunrise Mountain Weir and Pabco Road Weir (RM 6.05-6.35), Calico Ridge Weir (RM 4.6) and Three Kids Weir (RM 3.55). As stated in Section 3.1.1, the complexity of the hydrology in the LVW can confound interpretation of perchlorate sample data as a means to identify specific loci of perchlorate inputs (as contaminated groundwater).

The TIR data (Section 3.1) will be used to help identify generalized locations where temperature differences indicate potential groundwater influx to the LVW. These data will be used with existing perchlorate concentration data from previous sampling events to select locations where a more precise, continuous, meter-scale temperature differential study can be conducted. Ambient temperature will be used as a tracer to evaluate the location of the groundwater discharge to refine and confirm the locations of perchlorate contribution. Currently, the study has been designed to target reaches of the LVW near Calico Ridge Weir and Three Kids Weir. As stated, these reaches may be refined or moved based on the TIR study data.

This survey will assist in determining the exact locations of the groundwater discharge for further investigation, and because FO-DTS collects time series data, changes over the study period can be evaluated (e.g. changes in stage impact on groundwater discharge location). These additional high resolution data will be collected following the TIR survey data analysis and evaluation, since the results of the TIR may affect the scope of the FO-DTS. Two FO-DTS surveys will be utilized to evaluate groundwater seeps to confirm groundwater discharge locations and the daily temporal variability of these groundwater discharge locations in strategic locations.

3.2.2 Identify the Goals of the Distributed Temperature Sensing

Principal FO-DTS Study Questions:

- Within identified reaches of interest, where are the groundwater discharge locations within the LVW?
- Are the groundwater discharge results comparable between changes in flow over the study period?

The FO-DTS Study will provide data to supplement the existing database of concentrations of perchlorate in surface water of the LVW. Specifically, the field data will be collected to:

- Provide high-resolution spatial and temporal temperature data along the LWV streambed,
- Provide data that can augment existing data and provide a unique set of data by collecting synoptic samples from the LVW at temporal resolution (notably daily low and high flows); and
- Provide data to help track potential loci of groundwater discharges to the LVW.

FO-DTS provides temperature data along the streambed, providing a more representative temperature signature to detect groundwater discharge patterns in a specific reach of the LVW as identified by previous sampling events and the TIR. Also this method allows for data collection over the time of the deployment, which can provide additional information when assessing groundwater discharge locations.

3.2.3 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.

Based on historical data and recent data obtained during 2017 sampling event (AECOM 2017a), it was determined that locations of a high resolution groundwater discharge survey would be useful around the Three Kids Weir and the Calico Weir; however, these survey extents are subject to change based on the TIR survey. Further, if the TIR survey provides data with sufficient detail for the purposes of locating groundwater discharges in all locations, FO-DTS may be limited to those areas where the TIR data is considered inconclusive.

3.2.4 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 is shown on **Figure 1** and includes an approximately 3.5-mile stretch of the LVW.

Based on previous sampling data, it is anticipated that two FO-DTS deployments will be conducted in the general regions shown on **Figure 5**. The exact placement of the fiber-optic cables will be dependent on installation feasibility, coverage in the area of interest and safety considerations. The location of the deployments will be based on the TIR survey results and historical site knowledge. Currently, three locations of interest have been chosen and will be examined in two FO deployments: south bank Calico Weir, north bank Calico Weir (first deployment), and the south bank Three Kids Weir (second deployment). A cable 2 kilometers (km)[1] (i.e., approximately 1.25 miles) in length will be utilized and is anticipated to be able to cover both sides of the bank during one deployment. The proposed locations of deployment were selected based on historical perchlorate sampling results; however, these target areas are subject to change pending the results of the TIR survey and feasibility of deployment. Up to three additional reaches may be included in the FO-DTS program. These reaches will be determined upon further interpretation of the FIR data and in consultation with NDEP.

3.2.5 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.

The FO-DTS method is intended to identify discrete temperature contrasts directly on the streambed, which may indicate the presence of groundwater discharge using temperature similar to that of the TIR method, but TIR methodology can only visualize the surface of the water and cannot resolve the temperature of the streambed, thus is more susceptible to interferences and depth changes. TIR surveys also can only provide a 'snap-shot-in-time' dataset and cannot resolve groundwater discharge changes through time as FO-DTS can. FO-DTS methodology allows for a much more rigorous groundwater discharge evaluation of a km-scale reach than TIR, which is more useful as a reconnaissance tool and assessing large areas. As groundwater typically exhibits a thermal signature distinct to that of surface water, using temperature as a groundwater indicator is a promising technique to identify potential locations of discharge. Groundwater has a stable diurnal signature in comparison with surface water, thus statistical analysis can be used as an additional indicator that groundwater discharge is present. Both of these criteria can be utilized to determine locations of groundwater discharge to surface water when deploying a FO-DTS survey.

Up to three locations of interest along the LVW will be studied using FO-DTS deployments assuming the TIR data indicate that these data will be useful to furthering the CSM development. The deployment lengths will be between 1 and 1.5 km (approximately 0.62 to 0.93 miles) long and will be configured in a manner to best meet the objectives of the survey, protection of the equipment, and safety of the personnel on site. Each deployment will collect data for a minimum of 72 hours; the actual deployment period may be longer dependent upon weather or other factors, such as signal strength or background temperature shifts, and retrieval safety. At least one calibration bath with at least 20 meters (approximately 65 feet) of active cable will be maintained throughout the duration of each survey. The temperature within the calibration bath will be recorded with an independent temperature logger, at a similar temporal resolution as the FO-DTS unit. The spatial resolution will be between 1-2 meters (approximately 3.3 to 6.6 feet) and sampled at a minimum of 3-minute time steps, or the specific unit's minimal time interval within the best practices for the method. The time steps will be determined based on field conditions and will be documented throughout the program. These data will be uploaded directly to AECOM for daily analysis and evaluation; data will also be reviewed in the field to monitor data quality.

The location of the cable will be recorded via GPS in the field to allow the data to be placed on an aerial figure during processing. Locations of interest identified during real-time data evaluation will be investigated with a hand-held temperature probe. Temperature data will be evaluated in the office for absolute temperature and basic statistical analysis will be conducted to determine potential locations of groundwater discharge.

3.2.6 Specify Performance or Acceptance Criteria

Step 6 of the process outlines the performance and acceptance criteria for the investigation. Major sources of uncertainty are identified and the measures taken to minimize the impacts of these uncertainties are defined.

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[1] The FO-DTS is standardized to metric units. To place this in context, approximate Imperial distance units (miles or feet) are provided as well.

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 temperature measurement/sampling design will identify possible sources of error and minimize them, to the extent practical. The most significant type of error that may be encountered is from FO-DTS field data collection. Both random and systematic errors can be introduced during the data collection process.

Errors introduced through these steps will be controlled by providing guidance from experienced personnel with this equipment and method, who will detail QCs required for data collection during the field preparation. These controls apply to field procedures, and include field equipment calibration, equipment monitoring, equipment analytical errors, and data interpretation.

As this method does not allow complete coverage of the LVW reach within the Downgradient Study Area, there is possibility that some features of the natural variability will be missed laterally. Sampling design error can increase the chance for misrepresenting the natural variability by random error (imprecision) or systematic error (bias) in measurement.

This investigation is meant to characterize the physical qualities of the LVW using a comprehensive temperature evaluation of the LVW surface water. By reducing the errors associated with data collection, analysis and reporting with the strict adherence and use of documented FO-DTS best practices and procedures, as well as the noting of deviations from these procedures, the induced variability of the data set is minimized and the data set is a better representation of the surface water.

3.2.7 Develop the Plan for Collecting Data

Step 7 is detailed in Sections 4.0 through 6.0.

3.3 Transect Sampling

3.3.1 Define the Problem

The characterization of perchlorate concentrations in the LVW has been ongoing for several decades. Surface water in the LVW has been sampled from various locations on a routine basis by the Southern Nevada Water Authority (SNWA) in accordance with the Las Vegas Wash Coordination Committee's (LVWCC's) Las Vegas Wash Comprehensive Adaptive Management Plan (LVWCC 2000). Overall, perchlorate concentrations in the LVW have generally decreased over time. However, the surface water grab sampling and transect sampling data collected by AECOM (May 2016, December 2016, and February 2017) have shown that concentrations of perchlorate increase with distance downstream. Specifically, concentrations appear to increase near the proposed Sunrise Mountain Weir, which may have been related to a previously sampled seep (KM-71) or may be related to uncaptured portions of the NERT and AMPAC plumes. The seep at KM-71 has been destroyed during recent weir construction. Perchlorate concentrations also increase upstream of the Calico Ridge Weir, downstream of the Calico Ridge Weir, and downstream of the Three Kids Weir. The gains near the Calico Ridge and Three Kids weirs are attributed largely to groundwater discharge along the southern bank, where near shore concentrations have been observed to be on the order of 800 to 1,500 µg/L. Elevated concentrations were also observed along the northern bank (90 to 400 µg/L) (**Figure 2**). Upstream of Calico Ridge Weir, the C-1 Channel enters the LVW. The C-1 Channel may receive perchlorate-contaminated groundwater via subdrains beneath the residential developments south of the LVW.

Transect data, in which a series of samples are collected near the streambed along a cross-sectional area, help refine knowledge of where additional perchlorate is entering the LVW. Surface water sampling data are needed that represent the current nature and distribution of target constituents, including perchlorate, chlorate, and total dissolved solids in the LVW within the limits of the Downgradient Study Area by minimizing fluctuations of the unknown variable of flow between datasets. To accomplish this goal, transect samples will be collected during the daily low flow periods. The timing of those low flow periods will be forecasted from flow data at the USGS stations and from stage data at the gaging stations installed by AECOM in 2017. These stage data have been well-documented in the Surface Water Investigation Plan (AECOM 2016b) and the SWI Technical Memorandum (AECOM 2017a) and low flows occur in the morning hours, ranging from approximately 0830 to 0930 daily at Pabco Road Weir, with a 2-hour lag at Three Kids Weir.

3.3.2 Identify the Goals of the Surface Water Transect Sampling

Principal Study Questions:

- Which reaches along the LVW are primary contributors of perchlorate flux within the LVW?
- Are the concentrations of the target constituents different along cross-sections from the northern to southern bank along the length of the LVW in the Downgradient Study Area?
- Can data generated by sampling along the transects refine the locations of potential seep areas (where perchlorate discharge is occurring) near the northern bank, southern bank, or mid-channel?
- Is perchlorate entering the LVW via the C-1 Channel?
- How do perchlorate concentrations and estimated flux in the Downgradient Study Area compare to concentrations and flux observed at the Northshore Road Station?

The program will provide data to supplement the existing database of perchlorate, chlorate and total dissolved solids concentrations in the LVW. Total dissolved solids data are used primarily to help identify changes in the surface water quality, indicating potential areas of groundwater discharge. Specifically, the field data will be collected to:

- Confirm the perchlorate concentrations measured in 2017;
- Provide additional data to refine the reaches in the LVW of potential discharge of perchlorate to the LVW;
- Provide data to help direct the subsurface investigation to track potential loci of groundwater discharge, regardless of perchlorate concentration, to the LVW;
- Collect total dissolved solids data that may further the understanding of the relationship, if significant, between groundwater and surface water chemistry; and
- Collect perchlorate samples at the Northshore Road station (below Lake Las Vegas) for comparison to results within the Downgradient Study Area.

All samples will be analyzed for perchlorate, chlorate, and total dissolved solids. These analytes have been analyzed previously in groundwater and/or surface water, and new data are required to establish current patterns of concentrations and confirm the findings of the transect sampling reported in the 2017 SWI Technical Memorandum (AECOM 2017a). Analytical methods are provided in **Table 2**.

3.3.3 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.

Based on historical data and recent data obtained during the Downgradient Study Area investigation, it has been determined that perchlorate concentrations have generally decreased over time. Concentrations had some variation throughout the reach of the LVW sampled, with higher concentrations indicating potential discharge near proposed Sunrise Mountain Weir and Pabco Road Weir, Calico Ridge Weir, and Three Kids Weir (**Figure 2** and **Figure 3**).

As indicated above, USGS has two permanent stream gages in the LVW in the Downgradient Study Area. Stream gages are installed near Pabco Road Weir (USGS 09419700; approximately RM 6) and at Three Kids Wash (USGS 09419753; approximately RM 3.5) and three additional temporary stream gages in the Downgradient Study Area that will be monitored for 5 years. These gages are located upstream of Duck Creek Confluence Weir (approximately RM 6.85), upstream of Bostick Weir (approximately RM 5.1), and upstream of Homestead Weir (approximately RM 4.3). USGS installed these gages in September 2016.

3.3.4 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 is shown on **Figure 1** and includes an approximately 3.5-mile stretch of the LVW.

Surface water samples will be collected from 17 transects along the LVW, extending from approximately RM 6.8 downstream to RM 3.3. The transect locations are shown on **Figure 6** and listed in **Table 3**. Note that two transects are located downstream of the area designated as the Downgradient Study Area. During the SSWIP field program, samples may be added based on the TIR and/or FO-DTS surveys and following discussions with NDEP. This SSWIP is focused on the area adjoining the LVW along the reach roughly between Duck Creek Confluence Weir and to just downstream of the Rainbow Gardens Weir as shown on **Figure 6**. In addition, grab samples will be collected several times (daily, is possible, during the transect study) from Northshore Road, at approximately RM 0.9 concurrent with the transect sampling. If the C-1 Channel contains flowing water during the transect sampling program, a grab sample will be collected south of the confluence with the LVW in the approximate location shown on **Figure 6**.

3.3.5 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.

Samples will be collected during the “daily lower flow” along the transects. For purposes of this sampling event, “daily lower flow” is defined from the daily minimum flow (occurring at Pabco Road Gage at approximately 0830 to 0930 during weekdays) to the daily average flows (occurring at approximately 1300 to 1400 daily). The flows are off-set by approximately 2 hours from Pabco Road Weir to Three Kids Wash (Figure 6) (USGS 2016). The timing of these flows was preliminarily established by evaluating data from October through December of 2015 and from September 2016. See Section 3.2.5 of the Surface Water Investigation Plan (AECOM 2016b) for complete details. The goal of this program is not to target the potential impact in concentrations from daily flow fluctuations, but to provide data during relatively consistent flows. The time of each sample will be compared to flows from the nearest USGS gage and temporary staff gages installed by AECOM in 2017 to allow qualification of any apparently anomalous high or low concentrations and to confirm that current weir construction is not impacting or altering flow patterns. All samples will be analyzed for perchlorate, chlorate, and total dissolved solids. Methods are provided in **Table 2**.

The transect sampling data to be collected as part of this SSWIP will be evaluated both along the LVW and across the LVW. Looking at the concentrations of perchlorate from upstream to downstream, the transect samples will provide more information about the average perchlorate concentration at locations along the LVW by providing more than one data point from the channel. Looking from bank to bank, there may be differences in perchlorate concentration, which could inform the program as to the discharge point of perchlorate, or a preferential path in the LVW. In other words, are discharges of perchlorate closer to the northern or southern bank? Is perchlorate well-mixed in the LVW, or are there channels, specifically in areas where the LVW shows multiple channels, where perchlorate concentrations are different? The timing of the transect sampling will be closely coordinated within each transect and between the transects. This will provide samples across each transect that are collected during similar flows.

Grab samples will be collected at the Northshore Road station (RM 0.9) to represent a range of flow conditions (low, mid and high) for comparison to results from this and previous AECOM sampling events. AECOM will collect between five and ten daily samples from this location under different flow regimes (i.e., not targeting a specific flow) to provide context of estimated perchlorate flux. One grab sample will be collected from the C-1 Channel if it contains flowing water during the transect sampling program.

Project reporting limits are provided in the QAPP (AECOM 2017b). QA/QC samples will be analyzed with the surface water samples for each analytical method, as defined in the QAPP and as described below in Section 6.8. QA/QC samples will include field duplicates (FDs), field blanks (FBs), laboratory duplicates, laboratory control samples (LCS) and matrix control spikes, and equipment blanks (EBs). Data verification and validation protocols are detailed in the QAPP and described below in Section 6.9.

3.3.6 Specify Performance or Acceptance Criteria

Step 6 of the process outlines the performance and acceptance criteria for the investigation. 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 is from 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) (**Appendix B**), and establishing appropriate controls for data quality. These controls apply to field procedures (e.g., adherence to SOPs [**Appendix B**], field equipment calibration, and FDs), laboratory analytical errors (e.g., calibration standard, internal standard, surrogate recoveries, and LCS), and data validation. The QAPP (AECOM 2017b) provides further detail on error control procedures, both in the field and in the laboratory, and details the target detection limits for the analytes.

Sampling design error is the result of the inherent variability of the sampled population over space and time, the sample collection design, and the number of samples available upon which to base the decision. Because it is impossible to sample every inch of the LVW, there is always a possibility that some feature of the natural variability is missed. The results of the TIR and FO-DTS studies will help reduce these sampling errors (i.e., by increasing precision of groundwater discharge loci). Sampling design error can increase the chance for misrepresenting the natural variability by random error (imprecision) or systematic error (bias) in sampling.

Because the number of samples controls how well the sampled population (i.e., LVW surface water) is characterized, use of the DQO process requires that the variability of data be understood to evaluate the trade-off between uncertainty (confidence limit) and sampling intensity. This investigation is meant to characterize the physical and chemical qualities of the LVW using a small but robust data set of the LVW surface water. This data set has a characteristic natural variability that will be represented if all other sources of variability are minimized. By reducing the errors associated with sample collection handling, analyses, and reporting with the strict adherence and use of standardized and documented procedures, as well as the noting of deviations from these procedures, the induced variability of the data set will be minimized and the data set will be a better representation of the surface water.

3.3.7 Develop the Plan for Collecting Data

Step 7 is detailed in Sections 4.0 through 6.0.

4.0 Sampling and Testing Objectives and Locations

Sampling objectives for surface water are discussed in the following subsections. In addition, the number and types of investigation locations (i.e., surface water sampling locations) are described in these subsections.

4.1 Supplemental Surface Water Investigation Objectives

4.1.1 Aerial Infrared Imaging

The objectives of the aerial infrared imaging work are to identify potential locations of groundwater discharge into the LVW based on thermal anomalies that may be identified during a TIR survey. Due to the size of the desired survey area, an aerial survey is proposed with use of a UAS. Performing this TIR survey during times when groundwater temperature is distinct from surface water temperature has the potential to show locations of groundwater discharge, but the method is dependent on the temperature differences and the presence of groundwater thermal signature on the surface of the water body in locations where groundwater discharge is occurring. After evaluation of the site, and based on previous work, the method has the potential to work at LVW when performed during optimal times of the year as defined by the site-specific temperature contrasts between surface water and groundwater (January March, or July-September).

4.1.2 Distributed Temperature Sensing

After performing the aerial infrared imaging work, the objective of the FO-DTS survey would be to evaluate two LWV reaches with high spatial and temporal resolution to confirm groundwater contribution within reaches of particular interest for perchlorate fate and transport. This method records temperature along the streambed and, thus, is considered more robust for evaluation of groundwater discharge compared to TIR methods, which relies on surface ‘skin’ temperature. FO-DTS also allows for collection of temperature time series data, from which additional data can be used to evaluate groundwater discharge locations and temporal changes, and confirm observations made with the TIR data collection. As the LWV does demonstrate daily stage changes, evaluating the consistency of groundwater discharge locations could be evaluated with the FO-DTS temperature time series data, when paired with surface water stages.

4.1.3 Transect Sampling

Several seeps and springs were previously identified along the LVW, but the locations of these seeps may have been altered or they may have been eliminated during the construction of the flood control weirs. Not all seeps contain water with detectable concentrations of perchlorate. At locations where perchlorate discharges are suspected, transect sampling will be conducted to provide an average perchlorate concentration within the transect and to help determine if discharges are occurring on the northern bank, the southern bank, or within the channel of the LVW. These data, combined with grab sampling data to be collected from North Shore Road and the C-1 Channel (if flowing water is present), will be used to help refine perchlorate flux estimates in the LVW.

4.2 Field Activities

4.2.1 Aerial Infrared Imaging

The aerial TIR survey will cover up to 250 acres, which includes the entire reach of the LVW within the Downgradient Study Area. Optical visual light imagery and thermal infrared images will simultaneously be captured from an UAS for the study area (**Figure 4**). This work will be conducted from 10 to 12 launch points, where the pilot and visual observer will be located. The work will be conducted over six days to capture TIR during the optimal portions of the day to reduce solar interference and capture the low flow conditions to decrease the method uncertainty. The visual light UAS data will be collected during periods of non-optimal TIR flight time.

A team of AECOM staff will collect water quality measurements using a hand-held water quality meter for the duration of the fly-over time. These data will be collected near the UAS activity. Temperature is the primary measurement of concern, but the additional data including conductivity will be useful during interpretation of the data. The team will walk along the south bank only.

4.2.2 Distributed Temperature Sensing

Two deployments will be conducted during the FO-DTS surveys, each 1-1.5 km (approximately 0.62 to 0.93 miles) in total length; reach length will depend of final configuration to cover optimal data area (**Figure 5**). At one end of the deployment the cable will be attached to the operating unit and calibration bath(s). Each deployment will take approximately six days to completed, which includes one day on either end of the deployment to install/remove the cable. During the days of deployment, staff will continually monitor the data collection, and correct any situations that may arise (e.g. migration of cable, sediment covering cable), georeference cable, and maintain calibration baths.

4.2.3 Transect Sampling of Surface Water

At each transect, a cross-sectional diagram of water depth and bottom contour will be developed using a metered pole by wading across the LVW and recording water depth at intervals to be determined in the field, based on the field conditions at each transect.

Approximately 65 surface water locations will be sampled from the 17 transects. A list of the surface water transect locations are presented in **Table 3**. The locations along the transects will include the northern bank, southern bank, and a minimum of one location near mid-channel. At many transects, multiple mid-channel locations will be sampled. For instance, during the February 2017 sampling event, a total of six locations were sampled at transect T3.6. The transect locations are shown on **Figure 6**. Surface water samples will be analyzed for the following constituents:

- Perchlorate (EPA Method 314.0);
- Chlorate (EPA Method 300.1), and
- Total dissolved solids (Standard Method [SM] 2540C).

Water sampling activities for the NERT RI include field-filtering water samples analyzed for perchlorate using the sterile filtration method described in NDEP guidance document (2010); however, the NERT RI QAPP can be modified to indicate that sterile filtration is no longer required for the NERT site groundwater monitoring program. As directed by NDEP, field-filtering of water samples for perchlorate analysis is not required (NDEP 2015). Details of the analytical program are listed in **Table 2**.

A site-specific HASP has been developed for the Downgradient Study Area (AECOM 2017c). As needed, this HASP has been augmented by task-specific safety documentation, such as the On Water Safety (**Appendix A**). Because sampling may occur after sunset, locations deemed unsafe for any reason may not be sampled. Working on water or near water in low-light conditions can be dangerous. In addition to the unstable footing in the channel or on weirs, water depth cannot be discerned in low-light conditions. The low light can exacerbate the potential hazards already in place. The LVW is also known to host a large homeless encampment and may draw illicit activities from other parties. A JHA will be prepared prior to the field investigation and will outline the specific hazards associated with sampling in low-light conditions on the LVW. The JHA will be circulated to NDEP and will be included in the health and safety appendix of the technical memorandum. The JHA is designed to augment the site-wide HASP (AECOM 2017c) with information on hazards specific to a task. Teams have the authority to stop work should they deem conditions suspicious or unsafe. All members of the sampling teams will be in contact with each other and with the task lead during the sampling event. As each team finishes work, they will indicate so to the Task Manager and other teams, and assist, as needed, teams still working.

The existing NERT RI QAPP has been adapted to include the proposed Downgradient Study Area investigations, including the proposed surface water sampling described in this SSWIP as well as groundwater and subsurface investigations (AECOM 2017b).

Investigation procedures and equipment are described in greater detail in Section 5.0.

5.0 Investigation Procedures and Equipment

Sampling or other data collection equipment and associated procedures are described in the following sections. Sampling equipment will generally include direct immersion of sample bottles, but may also include pumps with dedicated tubing as need to obtain samples from the depths required. Sampling methods and materials are generally based on the EPA publication Test Methods for Evaluating Solid Waste, Physical/Chemical Methods (SW-846) (EPA 1997). SOPs for surface water sampling and staff gage installation are provided in **Appendix B**.

5.1 Documentation Procedures

Records that may be generated during field work include field logs, photographic 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 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. At the beginning of each entry, the date, start time, weather, names of all team members present, level of personal protective equipment (PPE) 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; 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.

5.1.2 Photographs

Digital photographs of sampling locations will be taken if necessary to supplement and verify information entered into field logbooks. 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 group of photographs is taken during a task, general notes will be sufficient, as long as the information outlined above can be inferred from the notes provided.

The images collected as part of the TIR survey will be treated as raw data, as described in Section 3.1.5.

5.2 Instrument Calibration Procedures

Instruments requiring calibration include water quality meters (e.g., pH, dissolved oxygen, specific conductivity, and turbidity meters), and FO-DTS. TIR is not field-calibrated, but QC records can be maintained. 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 (AECOM 2017b).

5.2.1 TIR

TIR equipment cannot be calibrated in the field. Rather, images of a maintained calibration bath will be taken and recorded to facilitate QC. In addition, the factory calibration will be recorded and provided in the Technical Memorandum for this study.

5.2.2 FO-DTS

The FO-DTS unit will be calibrated by placing a calibration coil of FO cable in a constantly maintained temperature calibration bath with independent logger. Calibration will occur during deployment and in processing steps. The results of the field calibration will be recorded in the field log book.

5.2.3 Water Quality Meters

Water quality meters will be calibrated daily, a minimum of once per day prior to beginning sampling activities. Calibration data will be recorded in the field log book and on calibration forms.

5.3 Equipment Cleaning Procedures

Non-dedicated 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/Field Guidance Documents[2] (FGDs) are provided in the QAPP (AECOM 2017b); surface water sampling and staff gage installation SOPs are provided in **Appendix B**.

5.4 Investigation-Derived Waste Management

In general, investigation-derived waste (IDW) associated with the collection of surface water samples will consist mainly of purged surface water, used PPE (disposable nitrile gloves) and household trash such as used paper towels, etc. The liquid IDW (i.e., surface water from purging) will be temporarily placed into a polyethylene tank or bucket and returned to the LVW upon completion of sampling at each location. The remaining IDW will be double-bagged in plastic trash bags and will be disposed as municipal trash. The SOP/FGD for IDW management is provided in the QAPP (AECOM 2017b).

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

5.5 Field Procedures

All activities must comply with the HASP (AECOM 2017c), AECOM's On-Water Safety procedures (**Appendix A**), and task-specific JHAs to be developed for the field activities described in this SSWIP. Samplers need to take care to ensure skin does not contact the water. Appropriate PPE, as described in the HASP, will be used.

5.5.1 Aerial Thermal Imaging

Prior to starting field activities, on-site personnel will review site conditions and site objectives to identify potential hazards, particularly those that may increase the risk of an incident affecting people, property, or the environment. The identified risks and associated risk abatement measures will be reviewed in the context of a site-specific HASP, and will be discussed during the daily pre-job and post-job briefs. As additional health and safety requirements are necessary for operating UAS equipment, particular attention will be dedicated to addressing all federal, state, local, and client requirements, communications and standard operating procedures. All UAS requirements will be the responsibility of the UAS pilot and visual observer; however, all on-site personnel will be responsible for reviewing all flight plan details and requirements for the purpose of evaluating whether the documents meet the objectives of the work. The AECOM UAS service support group will be responsible for developing and submitting the FAA COA, and will be the official COA holder. The UAS service support team will maintain all records of training of operators and a plan of flight path to minimize overflight of riskier areas, and will document checking of equipment fail-safes, along with all other requirements as determined by risk management and safety standards.

Flights will occur from up to 12 pre-determined locations, and the flight paths will be pre-programed to data quality and safety consideration. Flights will return to the same take-off location, and will be collecting data for approximately 10 minutes. At least one UAS pilot will have control of the aircraft at any time if changes in conditions arise. Data will be recorded and downloaded during the day and uploaded to the AECOM server daily.

5.5.2 Distributed Temperature Sensing

For the FO-DTS survey event all on-site personnel will review site conditions and site objectives to identify potential hazards, particularly those that may increase the risk of an incident affecting people, property, or the environment for the daily tasks and is documented within the task-specific hazard analysis. The identified risks and associated risk abatement measures will be reviewed in the context of a site-specific HASP, and will be discussed during the daily pre-job and post-job briefs. Location of operating unit for each deployment will be determined in the initial site scouting mission and based on TIR survey results, and it will be determined whether the locked box can be left on site due to safety considerations. The cable will be installed along the reach of interest in a configuration to cover the optimal study areas, and that is feasible logistically and safely. All debris within the deployment area will be removed ahead of cable installation. The cable installation will be completed with three persons: one operating the cable reel, and two along the cable. The cable will be secured with rocks and natural debris items at important locations, to allow movement with changes in flow to avoid the fiber-optic cable breaking. Once installed and calibration bath set up, the operating unit will be started and will collect integrated data on 15-minute intervals. The cable will remain in place for up to 72 hours before moving the cable to the next location (dependent on weather, safety, and property conditions). Data collection would be optimal to collect straight through this time; however, due to equipment safety considerations, data may only be able to be collected during day light hours. This will be determined through the initial visit, daily visits and communications with the project team. During data collection times cable locations will be georeferenced and monitored for changing conditions, calibration baths will be maintained, and real-time data will be evaluated for cable integrity and data anomalies.

5.5.3 Water Sampling

For this sampling event, surface water samples will primarily be collected using direct immersion of sampling bottles in the LVW. Direct immersion, as described in the SOPs (**Appendix B**) can be a desirable method when filtration and preservation are not required and conditions (i.e., depth) are amenable. Where conditions are not amenable to direct immersion due to water depth or access concerns, samples will be collected using a peristaltic pump (or comparable pump) and disposable tubing. These methods are included in the SOPs (**Appendix B**). Transect samples will be collected from the designated location along the transect across the LVW and will be collected near-bottom (i.e., as close to the bottom as possible without disturbing substrate). At transect sampling locations where the water is over 3 feet deep, a sample will be collected from near bottom and from approximately one-third of total depth.

To collect a sample by dipping the sample bottle into the LVW, the Sampler will carefully wade into the LVW, so that the Sampler is facing upstream. Samples must be collected so that the Sampler is not standing upstream of the bottle. The Sampler must then slowly lower the capped bottle into the water with the mouth of the bottle pointed toward upstream, until the lower lip of the opening is submerged to approximately mid-depth. The cap is then removed and the water fills the bottle very gradually, avoiding creating turbulence (which could add sediment to the sample and possibly bias the analytical results). When the water level in the bottle has stabilized, the Sampler must slowly rotate the bottle upright and fill it completely before capping the bottle while still submerged and then must affix the label. The Sampler must then fill out the label and record the sample on the chain-of-custody form.

Samples may be collected using a pump and tubing. When this method is used, the tubing will be purged with three volumes of water prior to sample collection. Tubing will be held at the desire sampling depth (mid-depth in the water column for grab sampling and near-bottom for transect sampling) by affixing the end of the tubing to a weighted line or pole. Prior to and during sample collection, care shall be taken to prevent the tubing from coming into contact with sediments.

Non-dedicated sampling and monitoring equipment that is exposed to environmental contaminants will be 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. Instruments requiring calibration will be calibrated prior to first use and once per day following initial calibration, or the manufacturer’s specifications. If necessary, instruments may be re-calibrated to confirm readings.

6.0 Sample Designation, Handling and Analysis

This Section applies only to the proposed sampling and analysis program. 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 surface water 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 (AECOM 2017b) where appropriate, and is included in this SSWIP 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 SSWIP. 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. To maintain consistency with previous sampling programs, the location IDs for re-visited locations are the approximate RM prefaced by "LW" for samples within the LVW. The transect locations are identified as the RM of the transect prefaced by "T". RMs were determined relative to existing LW locations and are only approximate.

The identification system for Downgradient Study Area Investigation primary field samples from a surface location consists of the surface water location number (usually as RM) followed by the sample date in YYYYMMDD format. The depth of each sample will be identified at the end of the sample identification by "-X", where X equals the measured sample depth in feet (within approximately $1/10^{th}$ of a foot) from the water surface at the time of sampling. For example, a surface water sample collected from location LW0.9 on April 29, 2018 at 0.8 feet depth from the water surface, will be identified as LW0.9-20180429-0.8.

At the transect locations, the transect name (e.g., T5.3) will be followed by a letter designation (A, B, C, etc.) which will identify its location along the transect. Station "A" will be the southern bank, "B" will be the next station north, etc. For example, a surface water sample collected from the southern bank of T5.3 on April 29, 2018, at a depth of 1.5 feet, will be identified as T5.3A-20180429-1.5.

6.1.1 Field QA/QC Sample Identification Numbers

Field QA/QC samples and procedures are discussed in Section 6.8. 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 surface water sample collected is LW0.9-20180468-0.8. The sample is to be analyzed for total dissolved solids, and a duplicate sample is collected. An EB is collected immediately following the collection of the surface water sample (after decontamination of sampling equipment). The associated field QA/QC samples will be identified as:

- LW0.9-20180468-0.8-EB (Equipment Blank),
- LW0.9-20180468-0.8-FB (Field Blank), and
- LW0.9-20180468-0.8-FD (Field Duplicate).

Field QA/QC samples and the frequencies of collection are summarized in Section 6.8 of this SSWIP and detailed in the QAPP (AECOM 2017b).

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 for 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 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 (AECOM 2017b).

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.

Surface water sample containers will be refrigerated or placed in a cooler with ice to chill and maintain a sample temperature of 4 degrees (plus or minus [±] 2 degrees) Celsius.

6.4 Sample Handling and Transport

Proper sample handling techniques will be 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.
- The sample container will be labelled before or immediately after sampling in accordance with Section 6.2 of this SSWIP.
- 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 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 will be responsible for proper handling practices until receipt at the laboratory, or by the courier, at which time the Laboratory Project Manager will assume 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 (AECOM 2017b).

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 Shipping Procedures

If shipping samples using a commercial courier is necessary, each container sent will have a separate chain-of-custody form. Samples collected during the investigation will be identified as environmental samples. Samples will be packed in the same manner as when being transported from the sampler to the laboratory, with the following changes:

- Dry ice is not allowed to be used to chill samples requiring commercial shipment. Frozen water (ice) will be used to chill samples.
- Extra packing material will be used to fill the coolers in order to limit movement within the container.
- Ice should be contained in zip-closure bags, and the cooler should be lined with plastic as described below.
- Coolers containing ice and/or liquid samples should be lined with a plastic bag (such as a contractor garbage bag) to limit the potential for leaks in the event of ice bags leaking or sample container breakage. All necessary precautions must be taken to prevent any liquids leaking from sample coolers while in transit.
- Coolers will be closed and taped shut. If the cooler has a drain, it too will be closed and taped shut to prevent leaks.

- A minimum of two custody seals will be affixed to the front and side openings of the cooler so that the cooler cannot be opened without breaking a seal. The seals will be covered with wide clear tape so that the seals do not accidentally break in transit.
- Non-perishable samples collected on the weekend may be held for more than 3 days if there is no threat of exceeding hold times. If the samples require being chilled and maintained at a cool temperature (4 degrees [± 2 degrees] Celsius), they will be stored under refrigeration and shipped the following workday.
- For FO-DTS shipping requirements please ship equipment back in the same manner as is required by the vendor. Regular communication with the vendor will be expected.

6.7 Field Measurement and Laboratory Analytical Methods

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

6.7.1 Field Measurement Methods

Samplers will conduct in-field measurements for depth of water; dissolved oxygen, pH, conductivity, turbidity, and temperature of the surface water at each location. 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. FO-DTS and TIR measurements will be recording absolute and relative temperature of the surface water respectively.

6.7.2 Laboratory Analytical Methods

The Project will involve the analysis of surface water samples for the target chemicals and physical parameters (e.g., total dissolved solids) listed in **Table 2**. The laboratory analytical methods that will be used to analyze samples are summarized in the QAPP (AECOM 2017b) and listed in **Table 2**. Additional information about each analytical method and sampling requirements such as containers, preservation, and hold times is provided in the QAPP. Analytical methods and laboratory QA/QC procedures are further detailed in the QAPP.

6.8 Field QA/QC Procedures

Field QA/QC samples that will be collected during the proposed investigation include FDs and EBs. The description and purpose of these samples are 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 6.8.3.

6.8.1 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.

6.8.2 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 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.

6.8.3 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 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.

6.9 Data Validation

Data generated from sampling activities will undergo two levels of review. The laboratories and AECOM will provide data verification. Data validation will be performed by AECOM. For purposes of this project, laboratory deliverables equivalent to EPA Level 2 will be required to support the DQOs. The data will be validated to NDEP Stage-2A. Additional details regarding data validation are provided in the QAPP (AECOM 2017b).

7.0 Schedule and Reporting

It is anticipated that the activities described in this SSWIP will begin in January 2018 after the SSWIP has been approved, as applicable, by NDEP, EPA, and NERT. The aerial TIR survey will take approximately 6 days to complete. The FO-DTS survey will take approximately 12 days to complete. Transect sampling will take approximately 2 weeks to complete.

The schedule of TIR and FO-DTS deployment is highly dependent on the temperature differential of groundwater and surface water, thus schedule considerations for these methods are critical when determining deployment periods. While we can predict the optimal times of deployment based on previous years data, annual shifts in seasonal temperatures can impact the ability to perform these methods during certain time periods.

The water samples will be analyzed by TestAmerica at their laboratory in Irvine, California, under standard turnaround time of 10 business days. Once the final laboratory results have been transmitted to AECOM, data validation will be performed, which is estimated to take 4 weeks.

Dependent upon the results, maps showing the perchlorate, chlorate, and total dissolved solids concentrations will be prepared to depict the current surface water conditions and analyte concentrations in the LVW. Figures depicting concentrations of all analytes with distance along the LVW (i.e., by RM) will be prepared. Summary tables of the laboratory data will also be prepared.

A technical memorandum will be prepared that will summarize the results of this surface water investigation. The technical memorandum will include a brief description of field methods used and will present the summary tables of analytical results and the maps. The technical memorandum will also include copies of the field data sheets, the final laboratory report and data validation summary report.

A 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 into one comment table, the technical memorandum will be finalized and distributed to NDEP, NERT, EPA, and other stakeholders. This technical memorandum will be further evaluated by NERT, and the associated data will be incorporated into the RI report.

A summary of the SSWIP task schedule is provided below.

Task	Approximate Schedule
Aerial TIR Activities	January – February 2018
FO-DTS Activities	March 2018
Transect Sampling Activities	April – May 2018
Laboratory Analytical Report	2 weeks following completion of surface water sampling activities
Data Validation	4 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 Weirs and WeirsUnder Construction 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	Under construction
Pabco Weir	6.05	2000
Historic Lateral Weir	5.4	2000
Historic Lateral Weir Expansion	5.25	Under construction
Bostick Weir	4.95	2003
Calico Ridge Weir	4.7	2004
Lower Narrows Weir	4.4	2011
Homestead 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
Locations of existing and weirs that are under construction are provided on Figure 2.
[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 Analytical Plan for Surface Water Samples

NERT Remedial Investigation, Downgradient Study Area, Henderson, Nevada

Analytes	Matrix	Analytical Method	Analytical Laboratory
Perchlorate	Water	EPA Method 314.0 (1)	TestAmerica (Irvine, California)
Chlorate	Water	EPA Method 300.1	TestAmerica (Irvine, California)
Total Dissolved Solids	Water	SM 2540C	TestAmerica (Irvine, California)

Notes:

EPA = United States Environmental Protection Agency

SM = Standard Method

All surface water samples will be analyzed for the constituents listed above.

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

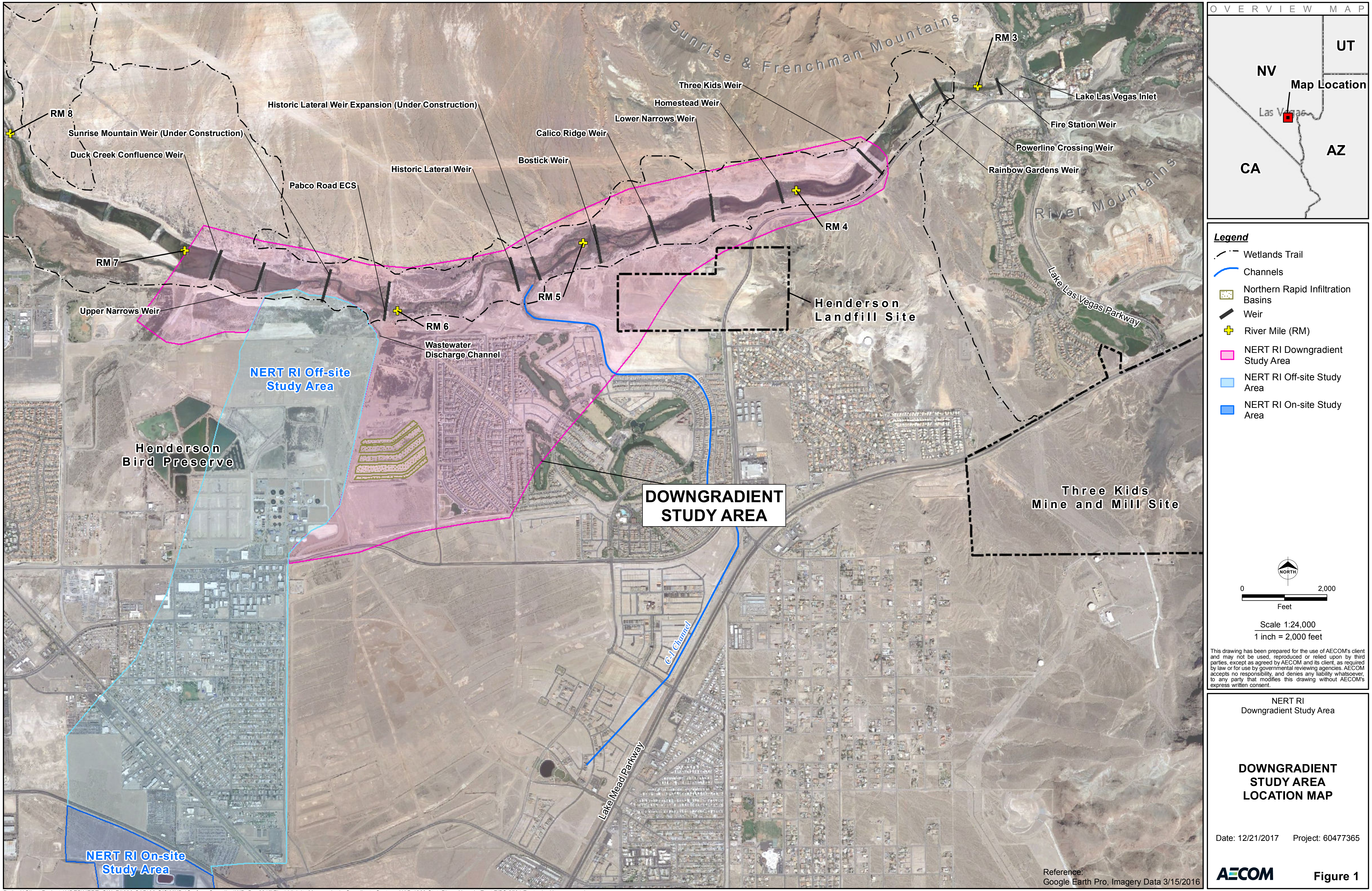
Sources:

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 3 List of Surface Water Grab Location and Transect Locations Proposed for Sampling
NERT Remedial Investigation, Downgradient Study Area
Henderson, Nevada

Transect Identification or Grab Location	Location	Rationale for Location
LW0.9	Downstream of Lake Lake Vegas at North Shore Road	Long term monitoring location with perchlorate flux estimates. Data from this location will be compared to flux estimates in the Study Area
C1	In the C-1 Channel prior to confluence with LVW, downstream of housing developments.	Will be sampled if water is present. The C-1 Channel may receive perchlorate-contaminated groundwater via subdrains in the housing development located south of the LVW.
T3.3	Midway between T3.6 and the Rainbow Gardens Weir	Evaluate for water quality changes downstream of study area
T3.5	Mid-way between Three Kids Weir and Rainbow Gardens Weir	Evaluate water quality downstream of groundwater inputs near Three Kids Weir
T3.75	Immediately downstream of Three Kids Weir	Check for potential groundwater inputs along Three Kids Weir upstream of KM67 (2100 parts per billion of perchlorate)
T3.8	Immediately upstream of Three Kids Weir	Evaluate water quality entering Three Kids Weir
T4.0	Immedialely downstream of the Homestead Weir	Identify the location of the perchlorate inputs in this area
T4.2	Upstream of Homestead Weir	Downgradient of western edge of Henderson Landfill Site near new USGS staff gage/seepage study
T4.6	Downstream of Lower Narrows Weir	Downgradient of middle portions of Henderson Landfill Site in region of observed perchlorate gain
T4.65	Upstream of Lower Narrows Weirs	Downgradient of middle portions of Henderson Landfill Site in region of observed perchlorate gain
T4.75	Downstream of Calico Ridge Weir	Downgradient of western edge of Henderson Landfill Site in region of potential perchlorate gain
T4.8	Immediately upstream of the Calico Ridge Weir	Evaluate water quality above the inputs observed below the Calico Ridge Weir
T4.85	Immediately downstream of Bostick Weir	Evaluate suspected increase in perchlorate concentrations immediately below Bostick Weir
T5.3	Downstream of Historic Lateral Weir Expansion	Mid-point between Pabco Road and Calico Ridge Weir
T6	Upstream of Pabco Road Weir	Downstream of Groundwater inputs from NERT Off-Site Study Area and Henderson wastewater treatment plants
T6.35	Downstream of Proposed Sunrise Mountain Weir	Downgradient of NERT Off-Site Study area near mapped location of KM71 seep (3,400 parts per billion)
T6.45	Upstream of the proposed Sunrise Mountain Weir	Identify the location of the perchlorate inputs observed between Upper Narrows Weir and T6.35
T6.55	Downstream of Upper Narrows Weir	Identify the location of the perchlorate inputs observed between Upper Narrows Weir and T6.35
T6.8	Upstream of Duck Creek Confluence Weir	Upper end of the Downgradient Study at new USGS Gage (09419698)

Figures



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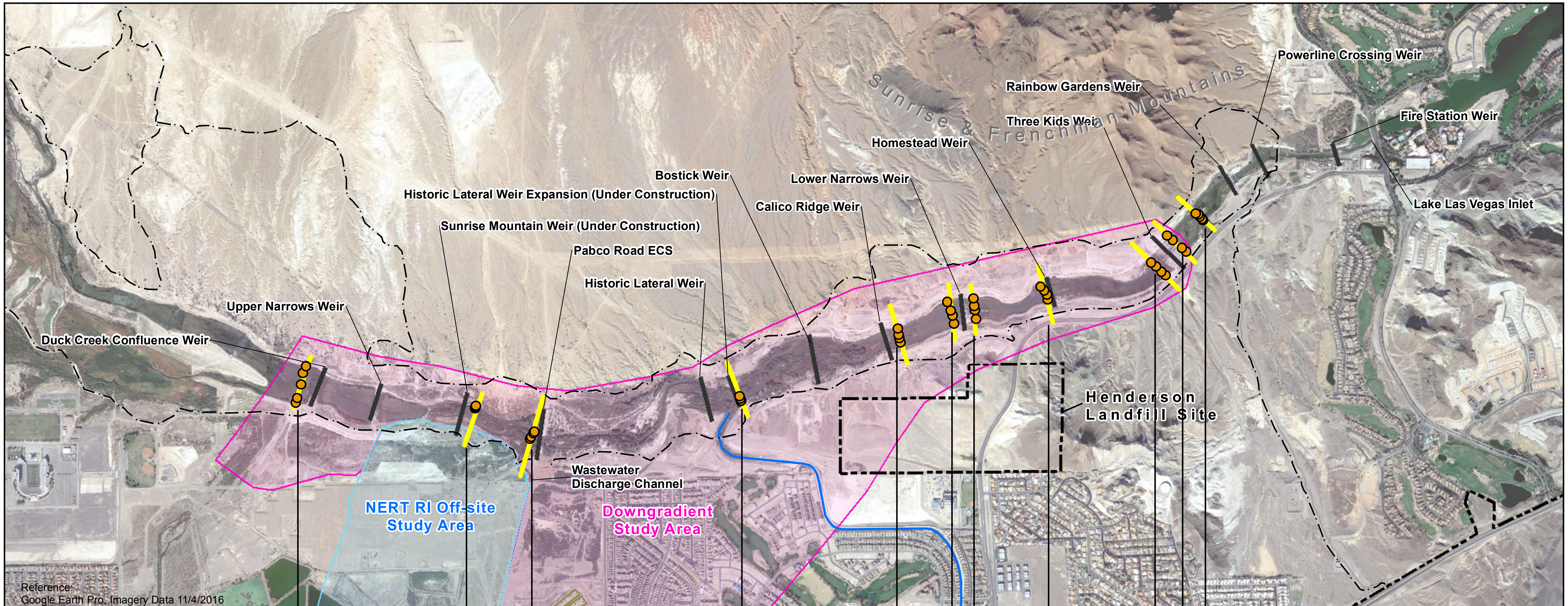


Legend

- Transect Sample Location
- Transects
- Weir
- Northern Rapid Infiltration Basins
- Wetlands Trail
- Channels
- NERT RI Downgradient Study Area
- NERT RI Off-site Study Area

Perchlorate Concentration in µg/L

J - Associated concentration is estimate
µg/L - Micrograms per liter

Transect ID	North Bank → South Bank
T6.8 / S6.8	<0.95; <0.95; 1.6 J; <0.95; <0.95
T6.35 / S6.35	18; 17, 17; 18
T6.0 / S6.0	15; 16; 16; 16
T5.3 / S5.3	17; 18; 32, 33
T4.75 / S4.75	**420 J**; 22 J; 23 J; **820 J**
T4.65 / S4.65	30; 31; **51**; **57 J**
T4.6 / S4.6	32 J; 30 J; **57 J**; **64 J**
T4.2 / S4.2	25; 27; 40; **66**
T3.8 / S3.8	46 J; 32 J; 45 J; 57 J
T3.75 / S3.75	**85**; 31; **51 J**; **63 J**
T3.5 / S3.5	38, 37; 47; **66**; **98**; **140**; **73**

Color Scale Perchlorate Concentration (µg/L)

>90
80
70
60
50
40
30
20
10
0

NORTH

0 2,000
Feet

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

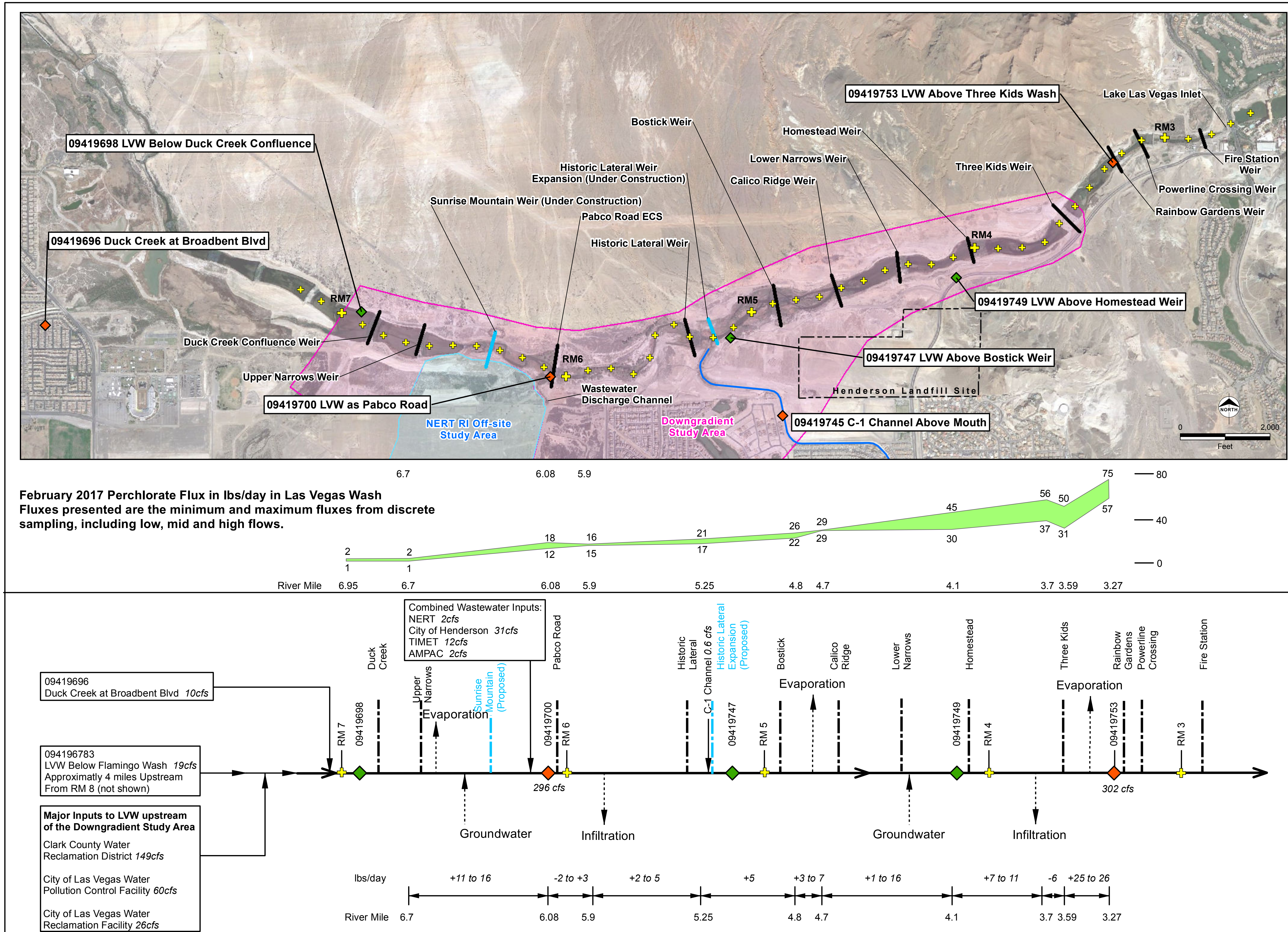
NERT RI
Downgradient Study Area

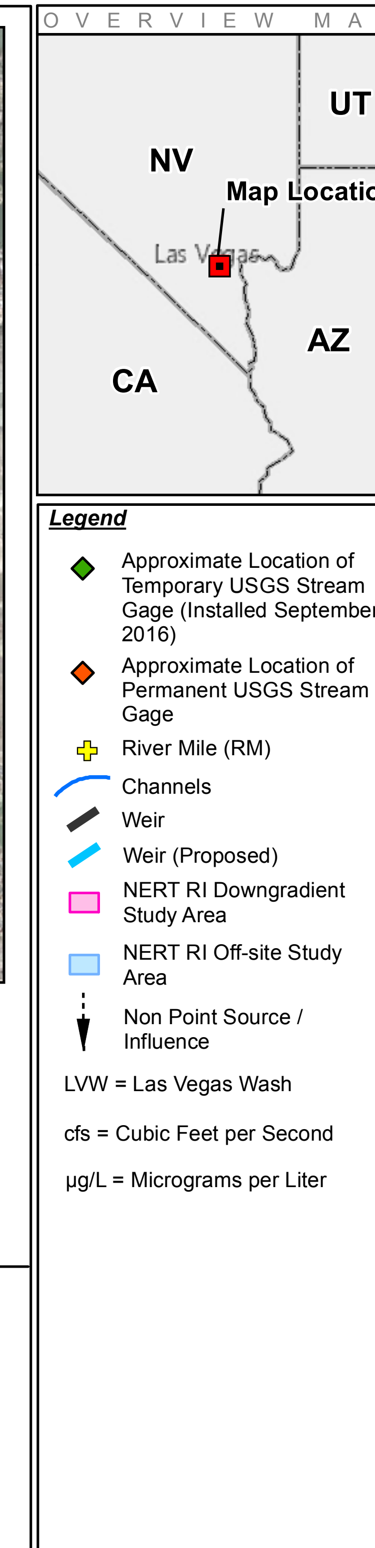
TRANSECTS SAMPLING PERCHLORATE CONCENTRATIONS (February 2017)

Date: 12/21/2017 Project: 60477365

AECOM

Figure 2





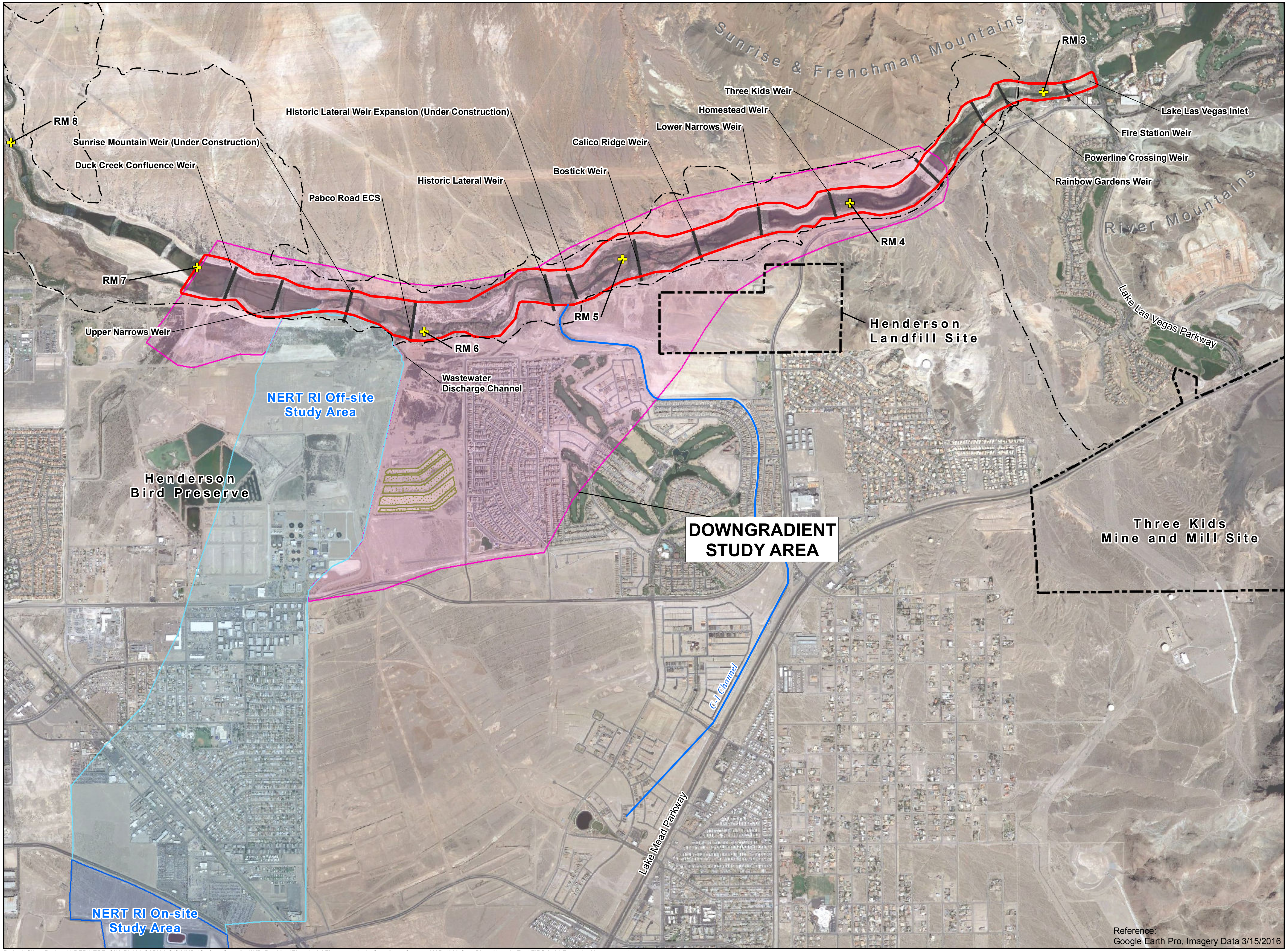
NERT RI
Downgradient Study Area

Conceptual Site Model Las Vegas Wash

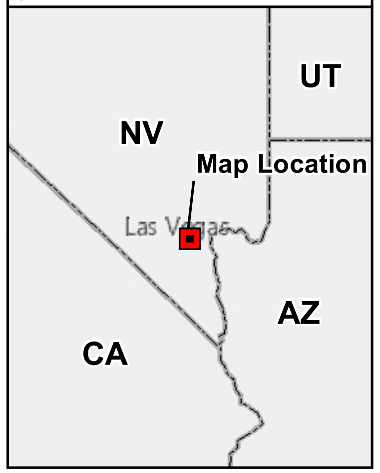
Date: 12/21/2017 Project: 60477365

AECOM **Figure 3**

Path: J:\Client-Projects\NDEP\NERT_GW_RI\900-CAD\00-GIS\MXDs\Surface Sampling\WP_Dec2017\Fig 3 CSM.mxd | Coordinate System: NAD 1983 StatePlane Nevada East FIPS 2701 Feet | User: scopm1



OVERVIEW MAP



Legend

- Approximate Extent of Aerial Flyover
- Wetlands Trail
- Channels
- Weir
- Northern Rapid Infiltration Basins
- River Mile (RM)
- NERT RI Downgradient Study Area
- NERT RI Off-site Study Area
- NERT RI On-site Study Area

NORTH

0 2,000
Feet

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

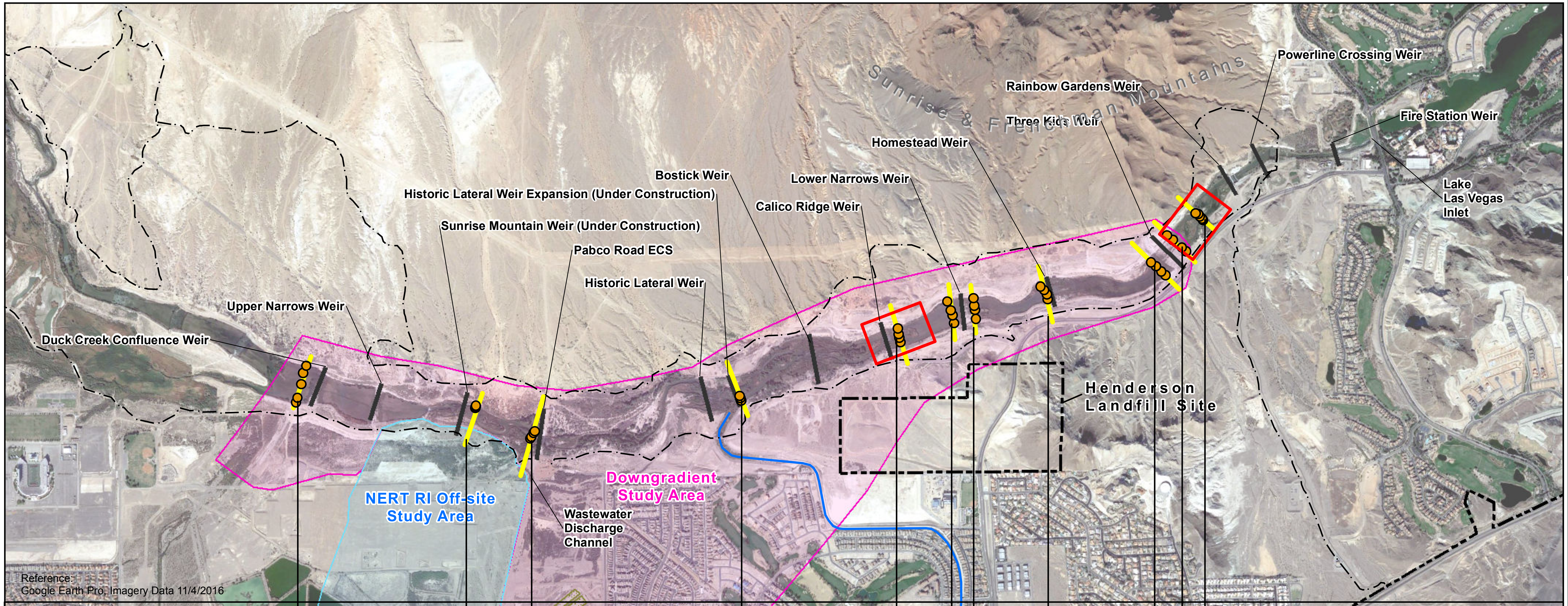
NERT RI
Downgradient Study Area

THERMAL INFRARED SURVEY AREA

Date: 12/21/2017 Project: 60477365

AECOM **Figure 4**

Path: J:\Client-Projects\NDEP\NERT_GW_RI\900-CAD\00-GIS\MXDs\Surface Sampling\WP_Dec2017\Fig 4 Aerial Flyover.mxd | Coordinate System: NAD 1983 StatePlane Nevada East FIPS 2701 Feet | User: scopm1



Perchlorate concentration by transect (North Bank to South Bank)

Transect ID	North Bank → South Bank
T6.8 S6.8	<0.95, <0.95, 1.6 J, <0.95, <0.95
T6.35 S6.35	18, 17 (17), 18
T6.0 S6.0	15, 16, 16, 16
T5.3 S5.3	17, 18, 32 (33)
T4.75 S4.75	**420 J**, 22 J, 23 J, **820 J**
T4.65 S4.65	30, 31, **51**, **57 J**
T4.6 S4.6	32 J, 30 J, **57 J**, **64 J**
T4.2 S4.2	25, 27, 40, **66**
T3.8 S3.8	46 J, 32 J, 45 J, **57 J**
T3.75 S3.75	**85**, 31, **51 J**, **63 J**
T3.5 S3.5	38 (37), 47, **66**, **98**, **140**, **73**

Color Scale Perchlorate Concentration (µg/L)

>90, 80, 70, 60, 50, 40, 30, 20, 10, 0

Legend

- Transect Sample Location
- Transects
- Approximate Extent of Fiber Optic-DTS Installation Area
- Weir
- Northern Rapid Infiltration Basins
- Wetlands Trail
- Channels
- NERT RI Downgradient Study Area
- NERT RI Off-site Study Area

Perchlorate Concentration in µg/L

Data from February 2017 Transect Sampling Program

J - Associated concentration is estimate

µg/L - Micrograms per liter

NORTH

0 2,000

Feet

Scale 1:24,000

1 inch = 2,000 feet

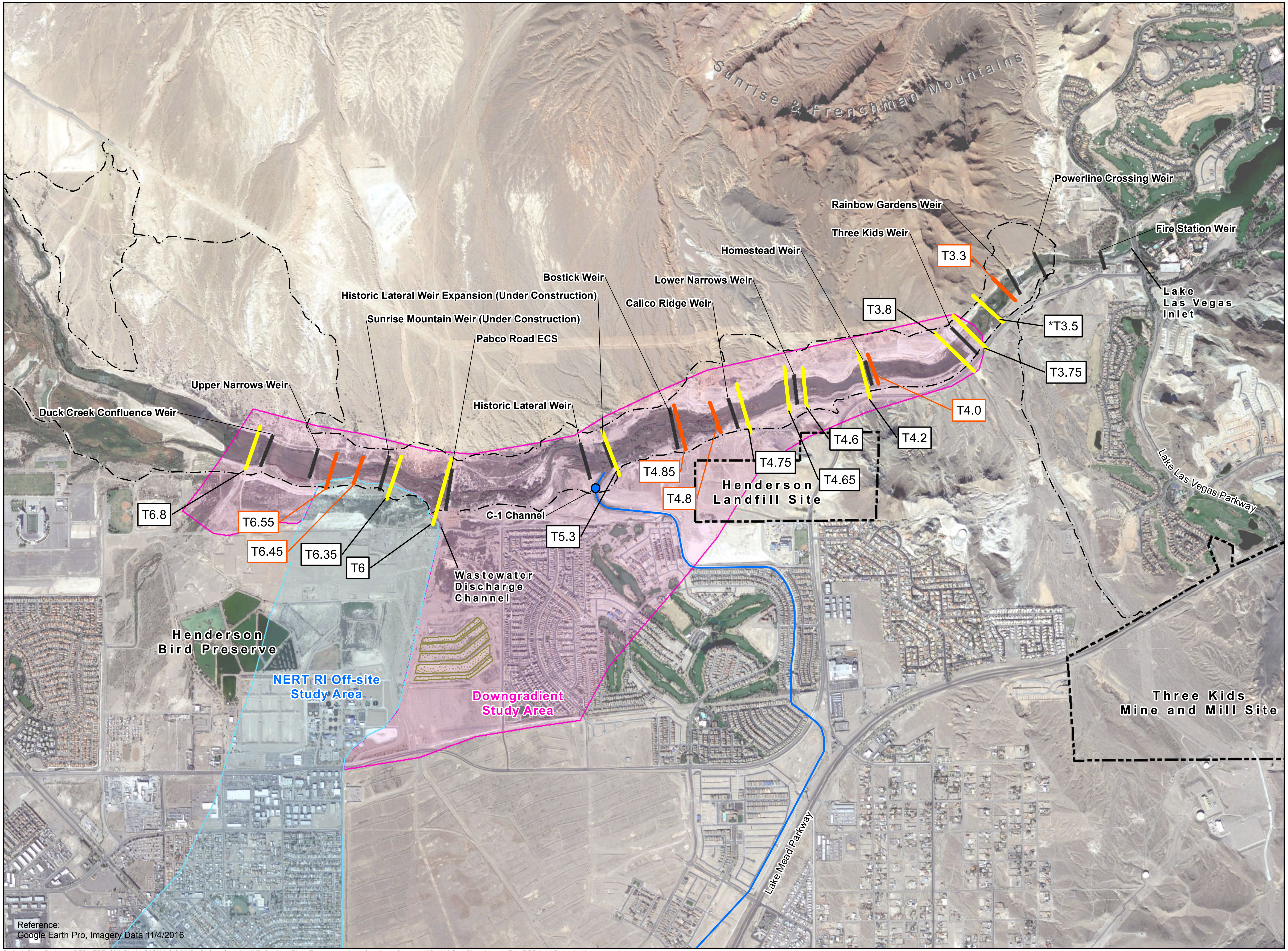
NERT RI
Downgradient Study Area

PROPOSED DISTRIBUTED TEMPERATURE SURVEY LOCATIONS

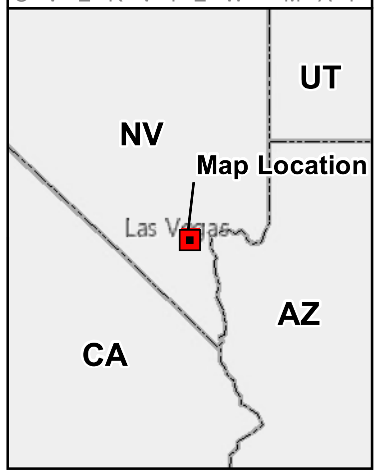
Date: 12/21/2017 Project: 60477365

AECOM

Figure 5



OVERVIEW MAP



Legend

- Proposed Transects (Previously Sampled in February 2017)
- Proposed Additional Transects
- Approximate C-1 Channel Sample Point; may change based on presence of water
- Weir
- Northern Rapid Infiltration Basins
- Wetlands Trail
- Channels
- NERT RI Downgradient Study Area
- NERT RI Off-site Study Area

Note

* This transect was originally labeled T3.6 but the identification was changed to T3.5 during the field program.

NORTH

0 2,000

Feet

Scale 1:24,000

1 inch = 2,000 feet

NERT RI
Downgradient Study Area

LOCATIONS OF PROPOSED TRANSECTS

Date: 12/21/2017 Project: 60477365

AECOM

Figure 6

Path: J:\Client-Projects\NDEP\NERT_GW_RI\900-CAD\00-GIS\MXDs\Surface Sampling\WP_Dec2017\Fig 6_Transects.mxd | Coordinate System: NAD 1983 StatePlane Nevada East FIPS 2701 Feet | User: scopm1

Appendix A

On Water Safety

Working on Water

1.1 Working on Water

Surface water samples are being collected from the Las Vegas Wash by boat (jon boat or canoe) and by wading.

1.1.1 Wading from Shore

If it is necessary to wade into the river, site workers will be required to wear hip waders, or knee high boots, depending on the specific conditions at hand. Because of the increased chance of a slip or fall while wading, it is necessary that all site workers exercise additional care and caution while performing such sampling activities. Site workers are cautioned not to wade into water that are more than knee high in depth, or where the employee cannot visibly see the stream bottom. All water work must be conducted via the buddy system. NO site worker will be permitted to work on or near the water alone. An appropriate personal flotation device (PFD) must be worn at all times when working in or near the water's edge.

1.1.2 Use of Jon Boat or Canoe

A jon boat or canoe may be used in areas of the project site where the water depth limits the practicality of wading. When working from a jon boat or other similar boat, the following precautions will be adhered to:

- Make sure that the right boat is chosen for the work. Evaluate the conditions at the work location and the waterways you must cross to reach that location. Select a boat that is appropriate for the most hazardous waterway. Small, flat bottom boats tend to be unstable and are easily capsized. In addition they often have little freeboard (i.e., distance between the actual water line and the top of the boat's side shell) making them prone to swamping, particularly in rough water.
- The on board sampling team should be comfortable about working on the water (i.e., minimally, each occupant should know how to swim) and should have experience in handling the type of boat that is chosen for the work.
- Do not load the boat beyond its safe loading capacity (SLC), typically found on a label or plate mounted near the stern of the boat. Don't forget to include the weight of equipment brought on board.
- If there is no capacity label, use the following formula to determine the SLC: # People = (length of boat x width) ÷15
- Be aware that the SLC is determined for calm conditions and should be reduced if rough water is anticipated.
- Once on board, distribute the load (people and equipment) evenly and secure all equipment to prevent it from shifting.
- While on the boat, Coast Guard approved Type III or Type V PFDs must be worn at all times by all occupants. PFDs will also be worn while transferring from boat to boat, boat to shore, or during portage.
- Boats longer than 16 feet must also be equipped with at least one Coast Guard approved Type IV throwable PFD.
- No less than two people shall be in the boat during sampling activities. In addition, an on-shore observer should maintain visual contact with the sampling team at all times. The on shore observer must be equipped with communications equipment to contact either the client or emergency responders directly in the event that an emergency situation occurs (e.g., man overboard).
- If work is to be done away from shore or the use of an observer is simply not feasible, the boat or the occupants must be equipped with emergency communications equipment.

- All sampling should be conducted from a seated or otherwise stable position. Do not stand in the boat.
- Samples shall be collected from the bow or stern of the boat (not over the side) to ensure stability.

1.1.3 General Boat Safety

This project presents unique hazards to the sampling team when compared to land-based investigation programs. No effort has been made to incorporate all applicable USCG regulations; however, some selected excerpts from USCG regulations have been included to provide general guidance. The boat operator is ultimately responsible for having knowledge of, and complying with, all USCG and any other applicable marine regulations. The Site Saftey Officer (SSO) for the project will verify that the boat captain (i.e., the AECOM team lead) adheres to USCG requirements.

1.1.3.1 Boat Inspection

Before being placed in service, boats will be inspected by the boat captain and in consultation with the SSO and determined to be in safe operating condition. The boat captain also must verify that all required safety gear is aboard before use. A pre-use inspection of the watercraft also must be performed by the boat captain before each daily use. A daily inspection sheet is provided below.

The boat captain must provide written documentation of the initial boat inspection and the daily inspections to the SSO. These inspections will be documented on standard inspection forms used by the boating contractor.

Watercraft determined to be in unsafe condition shall be taken out of service and its use prohibited until unsafe conditions have been corrected.

1.1.3.2 Boat Registration

All watercraft must meet USCG or state watercraft registration and numbering requirements. The USCG requires that all motorized watercraft be numbered in the state of principal use. A valid certificate showing the numbers issued to the watercraft is required to be on board the watercraft whenever the watercraft is in use. Watercraft registration numbers are required to be painted or permanently attached to each side of the forward half of the watercraft. Watercraft registration must be updated as the governing laws require.

1.1.3.3 Boat Capacity

Support watercraft shall not be loaded (passengers and gear) beyond the weight capacity printed on the USCG information plate attached to the stern. If there is no capacity label, use the following formula to determine the safe loading capacity:

- # People = (length of boat x width) ÷15

Support watercraft shall have sufficient room, freeboard, and stability to safely carry the cargo and number of passengers allowed, with consideration given to the weather and water conditions in which the water craft will be operated. Once on board, distribute the load (people and equipment) evenly and secure all equipment to prevent shifting.

1.1.3.4 Personal Flotation Devices

Site workers working over or near water, where the danger of drowning exists, shall wear a USCG-approved PFD. When selecting the appropriate type and style of PFD, the type of activity being conducted and the required mobility of the user must be considered because some activities may require a PFD which is less restrictive.

Site workers will be required to wear a USCG-approved Type III or Type V PFD work vest when working on the boat. Prior to and after each use, each PFD shall be inspected for defects that would alter their strength or buoyancy. Defective units shall be discarded and suitably replaced.

In situations where the water temperature has fallen below 50˚F, a USCG-approved Mustang flotation suit shall be worn in place of the Type III or Type V PFD work vest.

1.1.3.5 Float Plan

Prior to leaving shore, a plan of the day's activities, including time and place of departure, anticipated return time, and list of employees working on the project, will be filed with the PM. In the event the boat crew does not check in at the designated time stated on the float plan, the PM will be responsible for implementing the emergency procedures outlined in the float plan. A Float Plan Form is provided below.

1.1.3.6 Emergency Equipment

All site personnel conducting activities on all boat(s) are to be informed of the locations of all safety equipment on the boat, including communication with the shore (i.e., VHF radio or cellular phone) and emergency contact list, first-aid kit, fire extinguishers, and throw-ring, as applicable to the specific boat being used. Additionally, each site worker shall be provided written instructions in "Abandon ship/boat" and "person overboard" procedures during their marine safety briefing and verbally prior to the first departure of the work day by the boat captain.

1.1.4 Portage

When using a boat in the Las Vegas Wash, the vessel will need to be carried (portaged) over or around a series of erosion control weirs. These weirs are generally rocky with varying amounts and types of vegetation, depending on the age of the weir. The Pabco Road Weir is a concrete structure that will require circumventing.

When portaging the boat or canoe, field team members should remove heavy items from the boat and carry them separately. The boat should be emptied enough to allow for ease of transport of the vessel across or around the weirs. Dragging the boat may be required at times.

Daily Float Plan

Name of vessel's operator:	
Telephone Number:	
Name of Vessel:	
Registration No.:	
Description of Vessel: Type: Make: Color of Hull/Trim Most distinguishing identifiable feature:	

Rafts/Dinghies: Number: __ Size: __ Color: __

Radio/Communication Type:

Number of persons onboard:

Name:	Age:	Address & Telephone:

Engine Type:____________ H.P.:________ Normal Fuel Supply (days):________

Survival equipment on board: (check as appropriate)

- ☐ Life Jackets
- ☐ Flares
- ☐ Smoke Signals
- ☐ Medical Kit
- ☐ EPIRB
- ☐ Paddles
- ☐ Anchor
- ☐ Loran/GPS
- ☐ Life Ring

Trip:

Date & Time of Departure:	
Departure From:	Departure To:

Expected to arrive by:_____________ In no case later than:______________

Date & Time of Arrival:	Boat Lead Signature at Arrival:

Boat Safety Checklist

Keep this page with your boat, ready for inspection. By using this checklist, or one fine-tuned by yourself, you'll be sure that everything is on board and in good working order. Your passengers will appreciate knowing you're concerned about boating safety.

- [ ] Float plan--let a friend or relative know when you're leaving, where you're going, when you expect to return, what to do if you don't, and a description of your boat

- [ ] Registration certificate or documentation

- [ ] Personal Flotation Devices (wearable and throw able)--USCG approved, good condition, readily accessible, assigned and fitted

- [ ] Fire Extinguishers--right number, size, and class for boat; charged, not corroded, nozzle clear, bracketed, readily accessible

- [ ] Visual Distress Signals--current dates on flares, proper number, batteries good if lights or EPIRB

- [ ] Anchors and Line--adequate anchor for bottom, adequate line for water depth

- [ ] Bilge device --bilge pump operable, alternative bailing device available

- [ ] Watch or clock--operable

- [ ] Bright flashlight or searchlight

- [ ] Navigation lights --tested and operable, spare bulbs

- [ ] Batteries--fully charged, encased in plastic boxes or terminals covered, securely fastened down

- [ ] Sound-producing device--horn, whistle appropriate for boat

- [ ] Alternate propulsion--paddle or oar

- [ ] First Aid Kit

- [ ] Tools, spare outboard prop and lock nut

- [ ] Compass

- [ ] Sunscreen

- [ ] Weather Radio

Appendix B

Standard Operating Procedures

Project Standard Operating Procedure
NERT RI - Downgradient Study Area

Water-Level Monitoring with Pressure Transducers in a Surface-Water Feature

Procedure Number: NERT-FI-02

Revision No.: 1

Revision Date: October 2016

Prepared by

C. Steve Howe

Reviewed by:

Date: November 3, 2016

Chad Roper, PhD. CEM #2428, Analytical Task Lead

Date: October 25, 2016

Kristen Durocher, Surface Water Task Manager

Contents

1.0 Scope and applicability

1.1 This project Standard Operating Procedure (SOP) defines the operating procedures for the collection of water samples and in-situ water property data associated with the Nevada Environmental Response Trust (NERT) Remedial Investigation (RI) for the Downgradient Study Area. This SOP addresses the installation of the transducer, proper field data-collection methods, and programming/downloading concerns.

1.2 Water-level data will be collected at a series of locations along the Las Vegas Wash to help evaluate the timing of water-quality samples relative to the predictable pattern of diurnal streamflow fluctuation.

1.3 It is expected that Solinst Levelogger Edge units will be installed in stilling wells along with staff gages for manual observation of water levels. The Levelogger Edge is a recording pressure transducer that records absolute pressure readings. In order to compensate for changes in atmospheric pressure, one or more Solinst Barologgers will also be deployed.

1.4 The information contained in this SOP in not intended to be a substitute for equipment user manuals. Consult the manufacturer's manual for a complete guide to the proper use of the Levelogger and associated software (Solinst, 2015).

1.5 It is fully expected that the procedures outlined in this SOP will be followed. Procedural modifications may be warranted depending upon field conditions or limitations imposed by the procedure. Substantive modification to this SOP will be approved in advance by the Analytical Task Lead and the Surface Water Task Manager and communicated to NDEP. Deviations from this SOP will be documented in the field records.

2.0 Health and safety considerations

2.1 The health and safety considerations for the work associated with this SOP, including physical, chemical, and biological hazards are addressed in the site-specific Health and Safety Plan (HASP) (AECOM, 2016). The major health and safety considerations for the work associated with water quality data collections are the near and on-water safety aspects of the program.

2.2 Daily safety briefs are to be conducted at the start of each working day before any work commences. These daily briefs are to be facilitated by the Site Safety Officer (SSO) or his/her designee to discuss the day's events and any potential health risk areas covering every aspect of the work to be completed. Weather conditions are often part of these discussions. As detailed in the HASP, everyone on the field team has the authority to stop work if an unsafe condition is perceived until the conditions are fully remedied to the satisfaction of the SSO.

3.0 Interferences

3.1 Water-level data may be compromised unless care is taken to ensure all equipment (stilling well, staff gage, and transducer) are installed to maintain a constant position relative to the streambed.

3.2 The pressure transducer will be installed with direct read cables to allow the downloading of data without removal from the stilling well.

3.3 Care must be taken to avoid disturbing water flow/stage during manual readings of the staff gage as those measurements will be used to correlate water pressure data from the transducer to stream stage on the staff gage.

3.4 Changes to the stream channel may take place over time due to sedimentation/erosion. Changes to flow dynamics may also occur due to the blockage of flow by debris. When such changes are noted, the condition needs to be recorded in field notes along with observations of stream stage both before and after corrective actions are taken to return the channel and flow dynamics back to their original configuration

4.0 Equipment and materials

The following equipment list contains materials which may be needed in carrying out the procedures contained in this SOP. Not all equipment listed below may be necessary for a specific activity. Additional equipment may be required, pending field conditions.

- Solinst Levelogger Edge F15 with direct-read cables;
- Solinst Barologger;
- Solinst communications cable;
- Computer (laptop, tablet, etc.) loaded with Levelogger Software Version 4.0 and having correct port for levelogger communications cable;
- 5- to 6-foot-long steel fenceposts;
- 5-foot sections of rebar;
- Section of 2-inch-diameter Schedule 40 polyvinyl chloride (PVC) to be cut into appropriate lengths in the field;
- PVC joints and glue for constructing the stilling well;
- Staff gage (0.00 to 3.33 feet in 0.01-foot increments);
- Drill and drill bits to ventilate PVC stilling well to allow equilibration with stream, and to drill holes for security padlock;
- 2-inch-diameter PVC cap for bottom to prevent loss of transducer, drilled to allow equilibration;
- long shackle padlock (keyed or combination);
- Screws to secure staff gage to fenceposts;
- Stainless steel eyebolts and associated washers and nuts;
- Post driver, 3-pound sledgehammer, shovel, and pickaxe; and
- PVC saw.

5.0 Procedures

5.1 Site Selection

The general location of stream stations (stilling wells and flow measurement transects) along the Las Vegas Wash will be determined ahead of time based upon site characteristics (inflow from tributary streams, observed or inferred locations of groundwater discharge to the stream, locations of United States Geological Survey stations, and locations of other site features such as weirs). The specific location will be determined in the field based upon physical setting. The depth of water at the stilling well should be 2 or more feet to allow proper submergence of the transducer under all anticipated flow regimes.

5.2 Stilling Well Installation

Probe the streambed near the selected transect with a section of rebar to determine a location that will allow the fencepost to be vertically advanced several feet into the alluvium, After advancing the fencepost into the streambed, drive the rebar into the alluvium within the fencepost slot. The rebar should penetrate deeper than the fencepost, helping to further secure the installation. Attach the fencepost to the rebar using several stainless steel ring clamps. Attach the staff gage to the fencepost so that it is facing the nearby bank to allow reading from the shoreline.

The stilling well will be constructed in a manner similar to that shown in Figure1 (Freeman et al, 2005).

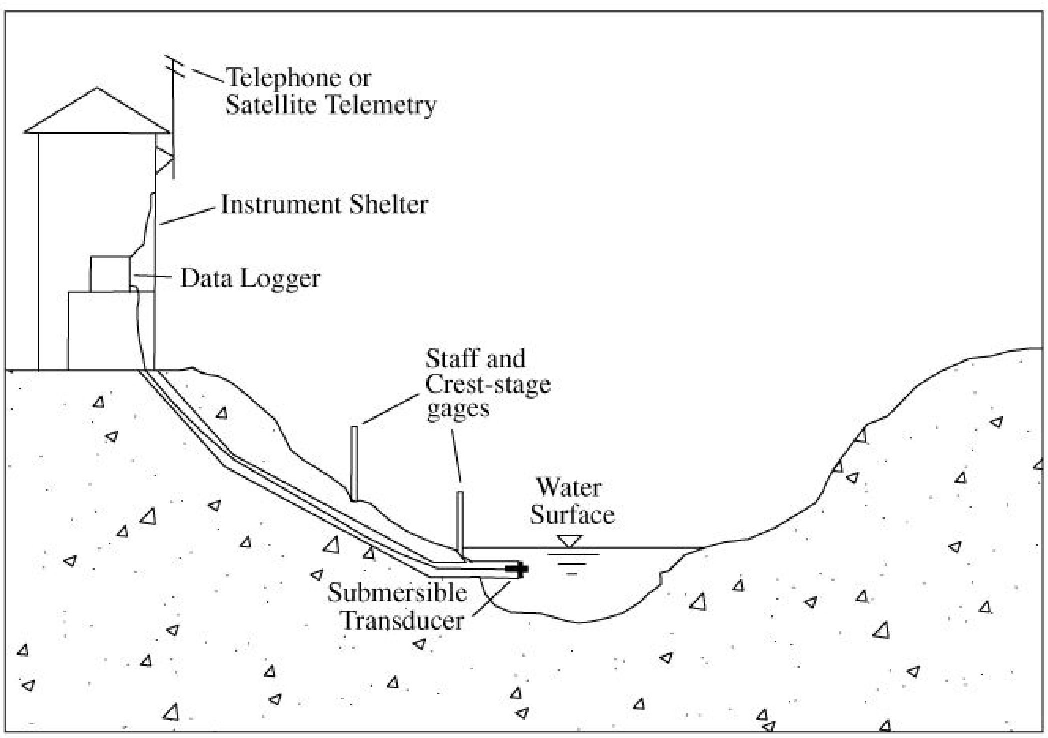


Figure 1. Staff Gage and Stilling Well Schematic.

It will be secured to the fencepost, running parallel to the streambed towards the bank, and then angling up towards the surface.

Near the surface the stilling well will be installed within a shallow, covered trench, daylighting with a short riser. Cut and layout the component pieces of the stilling well prior to installation before gluing. Drill a series of quarter-inch holes in the portions of the stilling well that will be submerged. Using a shovel and pickaxe, dig a shallow trench that will conceal the stilling well on the bank. Install the transducer (Section 5.3) before securing the stilling well. Secure first to the fencepost, then lay the assembly in the trench and backfill.

The top of the stilling well will be comprised of a cap drilled through the top for ventilation and an eye-bolt, and through the side for the shackle of the padlock. After attaching the eyebolt on the inside of the cap (for securing the connection on the direct read cable), pressure fit the cap to the top of the stilling well and drill two parallel holes through the cap and pipe for installation of the lock.

5.3 Transducer Installation and Programming

If there is sufficient depth, the Levelogger should be hung within the stilling well approximately 3.5 feet below the average water level of the wash. If the water depth is shallower than 3.5 feet, place the transducer/stilling well near the streambed. Install the transducer such that the sensor location is secured and open to the water. Attach the direct read cable to the eyebolt on the cap.

The Barologger should be installed in the general vicinity of the project in a location that is protected from direct sunlight. If there is ready access, a nearby building or shed would be ideal provided it is well ventilated. The Barologger should hang vertically in a location that would protect it from any tampering. A backup Barologger should also be installed at a second location. Program and install the Barologgers prior to programming and installing the Leveloggers.

Due to the magnitude of daily streamflow fluctuation within the Las Vegas Wash in the study area, Leveloggers and Barologgers should be programmed to record pressure at a 5-minute frequency. Follow the programming directions provided by the manufacturer (Solinst, 2015). Program the units for a delayed start so they all record on the same 5-minute schedule.

When installing a programmed Levelogger, allow the unit to record at least one pressure reading before recording a manual staff gage reading. Manual readings, which are used to calibrate the automated readings, need to be taken at the same time as a 5-minute frequency Levelogger reading.

5.4 Water Depth Profiling

Following the installation of water-level monitoring equipment, take readings to generate cross-sectional profiles of the streambed at each transect location. Water depth readings will be recorded from a metered pole while wading across the LVW. Measurement intervals will be determined in the field, based on the field conditions at each transect. While recording profile data, the staff gage will be periodically checked to allow for correction of flow/stage variation.

5.5 Monitoring and Downloading

The transducers (Leveloggers and Barologgers) should be downloaded at a regular frequency (to be determined). Before removing a Levelogger for downloading, record a manual stage reading to the nearest hundredth of a foot from the staff gage. Remove the cap and Levelogger, and download the data from the transducer following directions provided by the manufacturer. Save the data to a designated location on the computer hard drive, and save a backup file to a thumb drive. The file name should reference both the specific location and date of download, such as "LVW_3_030116" for Las Vegas Wash Station 3 on March 1, 2016.

Reprogram the transducer, replace the direct read assembly, and lock the riser cap. When a minimum of one pressure reading has occurred, record a manual reading of the staff gage. It is important to record stream stage before and after the download in case there has been a shift in the stilling well or transducer cable. After the last Levelogger has been downloaded and reprogrammed, download and reprogram the Barologgers.

6.0 Quality assurance / quality control

6.1 Entries in the field logbook will be checked by the observers to verify that the information is correct.

6.2 It is the responsibility of the Field Task Manager (FTM) or designee to spot check adherence to the procedural requirements of this SOP and to review the associated documentation for accuracy and completeness.

6.3 The FTM will be responsible for ensuring that instruments are properly functioning. The FTM (with assistance from field personnel) will be responsible for inspecting and accepting field supplies and consumables and providing replacements as necessary.

7.0 Data and records management

Field records will be generated and maintained as outlined in the SWIP. The SWIP addresses all aspects of collection including data and sample types, station locations, and chronology of events.

Deviations to the procedures detailed in the SOP must be recorded in the field logbook and communicated to the Surface Water Task Manager and the Analytical Task Lead as soon as practicable, but no later than the end of the work day.

8.0 Personnel qualifications and training

The individuals executing these procedures must have read, and be familiar with, the requirements of this SOP and the corresponding SWIP. Water level data collection is a relatively simple procedure requiring minimal training. However, inexperienced personnel performing these activities will be initially be supervised by the FTM or designee.

9.0 References

AECOM. 2016. Health and Safety Plan NERT Remedial Investigation – Downgradient Study Area. February 11.

Freeman, L.A., Carpenter, M.C., Rosenberry, D.O., Rousseau, J.P., Unger, R. and McLean, J.S. 2005. Use of Submersible Pressure Transducers in Water-Resources Investigations, U.S. Geological Survey Techniques of Water Resources Investigations, Book 8. Chap A3, 57p.

Solinst. 2015. User Guide: Levelogger Series – Software Version 4.1.2.

10.0 Revision history

Revision	Date	Changes
0	August 2016	Not applicable
1	October 2016	Stilling well design

Project Standard Operating Procedure
NERT RI - Downgradient Study Area

Water Quality Data Collection and Surface Water Sampling

Procedure Number: NERT-FI-01

Revision No.: 0

Revision Date: January 2016

Prepared by

Dion Lewis

Reviewed by:

Chad Roper, PhD CEM#2428, Analytical Task Lead

Date: November 3, 2016

Kristen Durocher, Surface Water Task Manager

Date: October 31,2016

Contents

1.0 Scope and applicability

1.1 This project Standard Operating Procedure (SOP) defines the operating procedures for the collection of surface water samples and *in-situ* water property data associated with the Nevada Environmental Response Trust (NERT) Remedial Investigation (RI) for the Downgradient Study Area. In-situ water property data (temperature, conductivity, dissolved oxygen, turbidity), hereafter referred to as water quality (WQ) data, are collected using multiparameter sensors from a boat or other sampling platform during field activities. Water samples are collected either directly, by immersing and filling sampling containers, or with the aid of a peristaltic (or other equivalent) water pump.

1.2 Samples will be collected for chemical, microbiological, and physical analyses. Analytes for a particular program are specified in the Quality Assurance Project Plan (QAPP).

1.3 It is fully expected that the procedures outlined in this SOP will be followed. Procedural modifications may be warranted depending upon field conditions or limitations imposed by the procedure. Substantive modification to this SOP will be approved in advance by the Analytical Task Lead and the Surface Water Task Manager and communicated to Nevada Division of Environmental Protection (NDEP). Deviations from this SOP will be documented in the field records.

2.0 Health and safety considerations

2.1 The health and safety considerations for the work associated with this SOP, including physical, chemical, and biological hazards are addressed in most recent update of the site specific Health and Safety Plan (HASP) (AECOM, 2016), AECOM's On-Water Safety protocol (see **Appendix A of Surface Water Investigation Plan [SWIP]**) and applicable Job Hazard Analyses. The major health and safety considerations for the work associated with WQ data collections are the near and on-water safety aspects of the program.

2.2 Daily safety briefs are to be conducted at the start of each working day before any work commences. These daily briefs are to be facilitated by the Site Safety Officer (SSO) or his/her designee to discuss the day's events and any potential health risk areas covering every aspect of the work to be completed. Weather conditions are often part of these discussions. As detailed in the HASP, everyone on the field team has the authority to stop work if an unsafe condition is perceived until the conditions are fully remedied to the satisfaction of the SSO.

3.0 Interferences

3.1 Cross-contaminations of samples may result if sample handling equipment is inadequately or improperly decontaminated.

3.2 Contamination of samples may result if samples are exposed to certain environmental conditions. Exposure to potential sources of contamination (e.g., exhaust fumes) will be minimized.

3.3 Care must be taken to avoid disturbing the river bed sediment during sampling. Re-suspended bed sediments may contaminate the surface water samples and artificially bias the analytical results.

3.4 Inappropriate sampling equipment, such as that manufactured from non-inert plastics, may contaminate samples. Using Teflon, polymer, or stainless steel sampling equipment will minimize contamination during sample collection activities.

3.5 For samples collected with a pump, purging of the tubing and pump system with a minimum of three volumes of site water prior to sample collection will ensure a representative sample.

3.6 For samples collected by direct immersion, care should be taken to sample upstream of the boat or the sampling personnel so that any contamination from the boat or personal protective equipment (PPE) on the personnel does not affect the sample.

3.7 Ensuring that the in-situ sensors are maintained and calibrated properly and that samples are preserved in accordance with the specified laboratory method will help reduce interference risks related to these sample and data collection efforts.

4.0 Equipment and materials

The following equipment list contains materials which may be needed in carrying out the procedures contained in this SOP. Not all equipment listed below may be necessary for a specific activity. Additional equipment may be required, depending on the field conditions encountered:

- Peristaltic water pump, variable speed, capable of approximately (~) 5 liters per minute (L/minute) discharge;
- 12-volt battery (as needed);
- CFLEX or equivalent polymer tubing (typical configuration requires 1.2-inch outside diameter; a 25-foot length will meet all project sampling (depth) requirements;
- Voss Technologies 0.45-micron inline metals filter (or equivalent);
- Sample containers as specified in the SWIP and QAPP;
- Multiparameter instrument package that includes temperature, pH, dissolved oxygen (DO), and turbidity (YSI sonde or equivalent);
- Connective (serial) cabling;
- Weight-bearing line/cable;
- Field computer (if applicable);
- Project-specific field log book;
- Chemical-free wipes;
- Disinfectant wipes;
- Approved plans, including target sampling locations;
- Insulated coolers with ice;
- Field notebook, pen, standardized forms (as needed);
- Chain-of-custody forms and seals;
- Multiparameter WQ sensor operating manual;

- Replacement batteries (12 volt and others as specified by equipment manufacturers);
- GPS;
- Safety gear (work vests, HASP-specified PPE);
- Nitrile gloves;
- Gauntlet gloves;
- Storage bags (plastic, sealable bags preferred) ;
- Boat (jon boat, canoe, or similar) with all applicable safety equipment (anchor, etc.); and
- Insulated Storage cooler.
- Tap Water
- Deionized Water

5.0 Procedures

5.1 In-situ Sensor Testing/Calibration

Make sure sensor/probes are clean and free of visible defects (housing cracks, etc.). Check the DO sensor for excessive wear and ensure that no air bubbles exist beneath the sensor membrane.

Instrument calibration is to be accomplished following the instrument manual. Ensure that all sensors are immersed in the calibration solutions for this activity. An instrument-specific calibration cup is standard equipment available for this purpose. Readings should be stable for ~30 seconds before accepting each calibration point. Sensors should be returned to the manufacturer if they are not operating within specified accuracy and precision limits.

5.2 Water Pump/Tubing Set-up

Connect the pump to a 12-volt battery. The water pumps and associated tubing used on this investigation should be dedicated to the project and rinsed with tap water before and after each (daily) use. Project tubing should be new at the project start, and rinsed thoroughly with deionized water. The tubing should be sealed in a storage bag when not in use; open tube ends should also be covered and protected when not in use, including between stations. Between-station rinsing is not generally required but flushing the system with site water at each sampling location is to be performed. The number of minutes required to purge the pump and tubing will be calculated as follows:

$(((\pi r^2 \times l)/10)/f) \times 3$ = minutes to purge the pump

Where:
π = 3.14 (rounded)
r = half the inner diameter of the tubing (centimeters)
l = length of tubing used on station (meters)
f = flow rate of the pump (L/minute)

5.3 Field Data and Sample Collections

5.3.1 Navigate to sampling stations outlined in the project sampling plan using the GPS unit.

5.3.2 Estimate and record the depth of the water. Water depth may be recorded using a weighted line with 0.1-foot increments marked.

5.3.3 At each station, the instruments should be lowered to the depth of interest and allowed to stabilize. If a profile is desired, then the instruments should be lowered to the near bottom and slowly raised between data collection points. Avoid contacting the river bed sediments, if possible. Data may be recorded electronically or entered into field logbooks. Water collections are typically made after the WQ data are collected.

Profile collection from a boat: At the station of interest, the datasonde should be lowered through the water column until it is near bottom as determined by the weighted line. If the operator “feels” the bottom with the weight, the instrument should be raised and data collection delayed to allow any resuspended sediment to dissipate as determined by monitoring real-time turbidity readings. Based on the water depth provided by the datasonde, field technicians will determine the water column structure and define the desired depths for data and sample collection. The datasonde should be allowed to equilibrate at bottom depth for at least 1 minute (or until readings for all parameters stabilized) before beginning profiling.

Profile collection from wading or shore point: At the station of interest, the field team should lower the datasonde through the water column until the probes and tubing inlet are completely submerged and at least 3 inches below the water surface. If the instrument package makes contact with the bottom profiling should be delayed for 5 minutes to allow for any suspended sediments to dissipate as confirmed by monitoring real-time turbidity readings. The datasonde should be allowed to equilibrate at sample depth for at least 1 minute (or until readings for all parameters stabilized) before beginning profiling.

5.3.4 In areas that require pumped collections (i.e., deep water or sampled from the boat) or for parameters that require filtration (i.e., total and hexavalent chromium), flush the tubing with water collected at the depth of interest. Given the small (typically quarter-inch) tube diameter, flushing will be complete for a 25-foot tube well within 10 seconds with a flow rate of ~5 L/min or better (Section 5.2).

When the purge is complete, wearing nitrile gloves, fill each sample container while avoiding contact between the sampling tube and the bottle. Bottles that contain preservatives should not be overfilled.

5.3.5 In areas and for parameters that allow direct/grab sampling, storage containers may be used to collect the sample unless they contain preservatives (e.g., nitric acid). Put on clean nitrile gloves and gauntlets, select an empty storage container, immerse below the water surface, uncap and allow the bottle to fill. Note: submerging the bottle before uncapping avoids collection of the surface film. Cap the container tightly, and remove from the water. Place the capped container in a bag and on ice in an insulated cooler.

5.3.6 If a parameter has a pre-preserved storage container, use a clean (laboratory-provided) unpreserved bottle and collect the sample in the same way. Gently pour the water sample into the storage bottle containing the preservative, avoid overfilling, cap tightly, seal in a storage bag, and place on ice in a cooler.

5.3.7 Samples will be placed in insulated coolers and stored on ice (refer to the QAPP for containerization and storage specifications) until shipment or transfer to the laboratory.

5.3.8 All discrete water samples should be collected and stored/transferred to laboratories according to the procedures described in Field Guidance Documents for Packaging and Shipping.

6.0 Quality assurance / quality control

It is the responsibility of the Field Team Leader (FTL) to check the calibration information, to spot check instrument operations, and to check the documentation accuracy of all field staff.

Quality control (QC) samples may include equipment blanks and field and laboratory duplicates.

6.1 Equipment blanks

Equipment blanks will be collected at the frequency specified in the QAPP, and from each set of sampling gear (e.g., tubing, tubing outfitted with a filter, and bottle sampler with tubing, etc.), after the sampling gear is decontaminated.

Equipment blanks may be collected if required by the SWIP for pumped samples by flushing the collection tube with deionized water and filling a set of containers with deionized water that has been pumped through the system.

If required, bottle blanks may be used to evaluate potential contamination associated with the direct grab sampling technique. In this case, bottles may be filled directly with deionized water, capped, bagged, and stored on ice for transfer to the laboratory.

6.2 Field and laboratory duplicates

Field and laboratory duplicates will be collected at the frequency specified in the SWIP. In the case of field duplicates, each container will be filled in parallel: First, one bottle will be filled one-quarter full, then the corresponding replicate will be filled one-quarter full, and the sequence should be repeated until both bottles are ready to cap.

If multiple bottles are required for evaluating laboratory accuracy and precision, then the same parallel filling approach will apply.

7.0 Data and records management

Calibration records will be recorded in the field log. Field records will be generated and maintained as outlined in the SWIP. The SWIP addresses all aspects of collection including data and sample types, station locations, and chronology of events.

Deviations to the procedures detailed in the SOP must be recorded in the field logbook and communicated to the Surface Water Task Manager and the Analytical Task Lead as soon as practicable, but no later than the end of the work day.

8.0 Personnel qualifications and training

The individuals executing these procedures must have read, and be familiar with, the requirements of this SOP and the corresponding SWIP. WQ data and water sample collections are relatively simple procedures requiring minimal training. However, initial instrument calibrations and sample/data collections should be supervised by the FTL.

9.0 References

AECOM. 2016. Health and Safety Plan, NERT Remedial Investigation – Downgradient Study Area. February 11.

10.0 Revision history

Revision	Date	Changes
0	January 2016	Not applicable
1	November 2016	Review and update to reflect SWIP