Prepared for
Nevada Environmental Response Trust
Henderson, Nevada

Prepared by
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SEMI-ANNUAL REMEDIAL PERFORMANCE MEMORANDUM FOR CHROMIUM AND PERCHLORATE

NEVADA ENVIRONMENTAL RESPONSE TRUST SITE HENDERSON, NEVADA

RAMBOLL ENVIRON

Semi-Annual Remedial Performance Memorandum for Chromium and Perchlorate

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

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

Office of the Nevada Environmental Response Trust

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

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

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

Title: Solely as President and not individually

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

Date: 4/24/17

Semi-Annual Remedial Performance Memorandum for Chromium and Perchlorate

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

Responsible Certified Environmental Manager (CEM) for this project

I hereby certify that I am responsible for the services described in this document and for the preparation of this document. The services described in this document have been provided in a manner consistent with the current standards of the profession and, to the best of my knowledge, comply with all applicable federal, state and local statutes, regulations and ordinances.

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ACRONYMS AND ABBREVIATIONS

AWF	Athens Road Well Field
BMP	Best Management Practice
BMI	Black Mountain Industrial
CD	compact disc
CEM	Certified Environmental Manager
COP	Continuous Optimization Program
DVSR	Data Validation Summary Report
EDD	Electronic Data Deliverable
Endeavour	Endeavour LLC
Envirogen	Envirogen Technologies, Inc.
ENVIRON	ENVIRON International Corporation
FBR	fluidized bed reactor
gpm	gallons per minute
GWETS	groundwater extraction and treatment system
GWTP	Groundwater Treatment Plant
ITRC	Interstate Technology and Regulatory Council
IWF	Interceptor Well Field
IX	ion exchange
lbs	pounds
lbs/day	pounds per day
mg/L	milligrams per liter
NDEP	Nevada Division of Environmental Protection
NERT	Nevada Environmental Response Trust
NPDES	National Pollutant Discharge Elimination System
Qal	Quaternary alluvium
Ramboll Environ	Ramboll Environ US Corporation
RI	Remedial Investigation
RI/FS	Remedial Investigation and Feasibility Study
Site	Nevada Environmental Response Trust Site
SNWA	Southern Nevada Water Authority
SQL	sample quantitation limit

SWF	Seep Well Field
Tetra Tech	Tetra Tech, Inc.
Tronox	Tronox LLC
Trust	Nevada Environmental Response Trust
ug/L	micrograms per liter
UMCf	Upper Muddy Creek Formation
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
VOC	volatile organic compound
WBZ	water-bearing zone

1. INTRODUCTION

Ramboll Environ US Corporation (Ramboll Environ) submits this remedial performance memorandum to the Nevada Division of Environmental Protection (NDEP) on behalf of the Nevada Environmental Response Trust (the Trust or NERT) for the Nevada Environmental Response Trust Site (the Site). The Site, which was formerly owned and operated by Tronox LLC (Tronox), comprises approximately 346 acres located within the Black Mountain Industrial (BMI) Complex in unincorporated Clark County and is surrounded by the city of Henderson, Nevada.

A revised groundwater monitoring program for the Site was presented in the 2016 Groundwater Monitoring Optimization Plan (Ramboll Environ 2016b), which was approved by NDEP on June 24, 2016. The plan proposed that the semi-annual remedial performance reports be replaced with semi-annual performance memoranda, containing streamlined data transmittals and summaries of remedial performance with respect to the performance metrics[1] and objectives of the Continuous Optimization Program (COP). This document is the first such streamlined semi-annual performance memorandum.

For the purposes of the ongoing Remedial Investigation and Feasibility Study (RI/FS), two investigation areas were defined in 2014: the On-Site NERT Remedial Investigation (RI) Study Area and the Off-Site NERT RI Study Area.[2] Two additional study areas have also been defined: the Downgradient Study Area (investigations beginning in 2016) and the NERT Eastside Study Area (investigations to begin pending work plan approval in late 2017). At the direction of NDEP, the Trust will revise and expand the current performance metrics to incorporate all of these study areas. A technical memorandum describing the strategy and schedule for developing these revised performance metrics is planned for submittal to NDEP in third quarter 2017. After these revised metrics are developed, with input from NDEP and the United States Environmental Protection Agency (USEPA), they will be used to evaluate remedial performance once sufficient data are available from the Downgradient Study Area investigation, the Phase 2 RI, and the Phase 3 RI (NERT Eastside Study Area investigation). It is anticipated that these metrics will again be revised as the Trust develops and implements a final remedy in the early 2020s.

1.1 Purpose

This memorandum is an abbreviated version of the annual remedial performance reports, which describe the performance of the groundwater extraction and treatment system (GWETS)[3] in removing and treating groundwater contaminated with perchlorate and hexavalent chromium. The primary infrastructure of the GWETS was completed by Kerr-McGee Chemical Corporation in the early 2000s. The GWETS currently serves as an

[1] Performance metrics were developed as part of the 2013 GWETS Optimization Work Plan (ENVIRON 2013c), approved by NDEP on December 3, 2013 (NDEP 2013). These performance metrics differ from the metrics being utilized as part of NERT's monthly GWETS operations reporting, which were developed by Tetra Tech and included in their Enhanced Operational Metrics Proposal dated August 20, 2014 (Tetra Tech 2014).

[2] The Off-Site NERT RI Study Area was formerly defined in the RI/FS Work Plan (ENVIRON 2014) as the Downgradient Plume Area.

[3] Herein "GWETS" will be used to refer to the entirety of all systems and components of the groundwater extraction and treatment systems owned by the Trust, both on-site and off-site, including extraction well fields, treatment facilities, and groundwater conveyance systems.

interim measure designed to capture the highest concentrations of perchlorate and hexavalent chromium. This memorandum, covering the period July through December 2016, presents data collected during this period while providing a focused discussion of GWETS performance relative to the established performance metrics.

1.2 Organization

This memorandum is provided in both hard copy and electronic forms. Where electronic files are referenced or information is stated as provided on compact disc (CD), this information is contained on the CD attached to the hard copy memorandum.

This memorandum is organized as follows:

- **Section 1** presents the purpose and organization of the memorandum.
- **Section 2** provides a summary of GWETS operations during the reporting period.
- **Section 3** provides an evaluation of GWETS performance relative to the established performance metrics.
- **Section 4** provides an update on ongoing and proposed future activities.
- **Section 5** lists citations for key documents referenced in this memorandum.
- **The Electronic Map** (on the CD) is a Google Earth compatible file showing the locations of all former and current wells in the vicinity.
- **Appendix A** contains Table A-1, which has five quarters of analytical and groundwater elevation data, including data from the Phase 1 RI supplementary sampling events conducted in first, second, and third quarter 2016 (Phase 1 RI supplementary sampling). Appendix A also contains Table A-2 which has volatile organic compound (VOC) analytical data from the third quarter 2016 Phase 1 RI supplementary sampling.
- **Appendix B** (on the CD) contains well data sheets for monitoring and extraction wells, which show groundwater elevations, perchlorate concentrations, and chromium concentrations over time for each well, in addition to well construction details and the location of the Upper Muddy Creek Formation (UMCf) contact. In addition, extraction wells' pumping rates, specific capacities, and estimated mass removals of perchlorate and chromium over time are shown.
- **Appendix C** (on the CD) contains the field records from the July through December 2016 groundwater monitoring events and the third quarter Phase 1 RI supplementary sampling.
- **Appendix D** (on the CD) contains the Data Validation Summary Report (DVSR).
- **Appendix E** (on the CD) contains the Electronic Data Deliverable (EDD), which includes an Access© compatible data file containing analytical results, an Access© compatible data file containing water level monitoring data, and analytical lab reports for July through December 2016.
- **Appendix F** contains an inventory of energy and materials used, wastes generated, and activities and services conducted at the Site for the purpose of an environmental footprint analysis for July through December 2016.

2. MONITORING AND OPERATIONS SUMMARY

This section provides a summary of groundwater monitoring and GWETS operations during the period of performance from July through December 2016.

2.1 Groundwater Monitoring Program Summary

A revised groundwater monitoring program was presented in the 2016 Groundwater Monitoring Optimization Plan (Ramboll Environ 2016b) and was implemented in November 2016. The revised program was designed to optimize the existing groundwater monitoring program, eliminating spatial and temporal redundancies, in order to enhance understanding of the conceptual site model and reduce inefficiencies in data collection and interpretation. Details of the program (including the scope of sampling events, key roles and responsibilities, and data collection procedures) are described in the Remedial Performance Groundwater Sampling and Analysis Plan (Ramboll Environ 2017), which was approved by NDEP on April 7, 2017. Figure 1 shows the locations of all monitoring wells included in the previous and revised monitoring programs.

2.2 Groundwater Extraction

The GWETS utilizes three groundwater capture well fields: the Interceptor Well Field (IWF); the Athens Road Well Field (AWF); and the Seep Well Field (SWF). The IWF coupled with the on-site bentonite-slurry groundwater barrier wall (the "barrier wall") provides capture of the highest concentrations of perchlorate and chromium and significantly reduces the amount of perchlorate and chromium in downgradient groundwater. The off-site AWF, located approximately 8,200 feet downgradient of the IWF, captures significantly lower concentrations of both perchlorate and chromium, but operates at higher extraction rates than the IWF, resulting in significant contributions to overall perchlorate mass removal from the environment and mitigation of perchlorate migration in groundwater. The SWF, located in close proximity to Las Vegas Wash, operates at the highest extraction rate of the three well fields, but captures groundwater containing significantly lower perchlorate concentrations.

Average discharge rates for the IWF, AWF, and SWF during the reporting period and from the previous four years are shown in Table 1, Table 2, and Table 3, respectively. Monthly extraction rates during the reporting period for individual IWF, AWF, and SWF wells are presented in Table 4.

From July to December 2016, the combined discharge rate of the IWF averaged 59.9 gallons per minute (gpm), which is generally consistent with the prior reporting period. As seen in Table 4, average monthly IWF extraction rates generally ranged from 59 to 65 gpm during the reporting period, with the exception of July 2016 when total average extraction was 53.8 gpm. This decrease was due primarily to IWF aquifer tests conducted in July in support of the COP, resulting in temporary well shutdowns that decreased the total average extraction.

Total combined discharge at the AWF averaged 316.4 gpm during the reporting period, which is an increase of approximately 46 gpm compared to the prior reporting period. AWF flow rates increased from 292.8 gpm in July 2016 to 416.9 gpm in December 2016 as a result of recent infrastructure upgrades at the AWF and Lift Station 3 in support of well field optimization efforts, which allowed total extraction rates to increase. The

upgrades at Lift Station 3 were performed in October 2016, resulting in decreased average flows at the AWF in October while the well field was temporarily shut down for equipment installation activities.

Total combined discharge at the SWF averaged 516.8 gpm during the reporting period, which is a slight decrease compared to the prior reporting period. The decrease is due to lower total extraction rates in October and December 2016 as a result of temporary shutdowns associated with Lift Station 1 infrastructure improvements. The improvements were associated with construction of an ion exchange (IX) treatment system designed to treat a portion of groundwater captured by the SWF. The IX system started operating in February 2017, as discussed in Section 4.

2.3 Groundwater Treatment

Treatment of chromium-contaminated groundwater extracted at the IWF occurs via the on-site Groundwater Treatment Plant (GWTP),[4] which chemically reduces hexavalent chromium and removes total chromium via chemical precipitation. Treatment of perchlorate-contaminated groundwater from all well fields occurs via the on-site fluidized bed reactors (FBRs), which biologically remove perchlorate as well as chlorate, nitrate, and trace concentrations of residual chromium. The FBRs discharge treated water to the Las Vegas Wash just upgradient of the Pabco Road erosion control structure under authority of National Pollutant Discharge Elimination System (NPDES) Permit NV0023060. A simplified process flow diagram is presented on Figure 2.[5] In the past, the GW-11 Pond has been used for equalization purposes to temper large variations in perchlorate concentrations prior to treatment by the FBRs. During the reporting period, the equalization tanks were largely used for this purpose given operational challenges posed by algae growth in the GW-11 Pond.

2.4 Chromium Removal

For the 6-month period lasting from July to December 2016, a total of approximately 1,270 pounds of total chromium were captured and removed from groundwater, as shown in Table 5.[6] This is consistent with the 1,300 pounds of chromium removed between July and December 2015. Total and hexavalent chromium concentrations in the FBR effluent during the reporting period are presented in Table 6. Effluent hexavalent chromium concentrations were between <0.000066 milligrams per liter (mg/L) and 0.0007 J mg/L during the current reporting period – well below the NPDES effluent discharge limitation of 0.01 mg/L (daily maximum). Total chromium was reported in effluent samples at concentrations ranging from <0.0025 to 0.041 mg/L – also below the NPDES effluent discharge limitation of 0.1 mg/L (daily maximum).

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

[5] The average total extraction rates reported in Table 4 differ from the average total effluent of the GWETS as shown in Figure 2. The discrepancy is the result of flow into and out of GW-11, evaporation from GW-11, and additions of stabilized Lake Mead water, which are used for various maintenance procedures. Perchlorate removal calculations are based on the extraction rates at each individual extraction well for the IWF, AWF, and SWF.

[6] Chromium mass removal, reported herein, was calculated using a methodology which has been approved by NDEP (Tetra Tech 2015).

2.5 Perchlorate Removal

During the period July to December 2016, a total of approximately 184,200 pounds of perchlorate were captured and removed from groundwater by the GWETS, as shown in Table 7.[7] This is a 17.7% decrease compared to the 223,800 pounds removed between July and December 2015.[8] This decrease is due primarily to lower average perchlorate concentrations at the IWF and AWF, as further discussed in Section 3.2.1. Perchlorate concentrations in the FBR effluent during the reporting period are presented in Table 8. Perchlorate was not detected at concentrations exceeding the laboratory sample quantitation limit (SQL) (0.0025 mg/L) in effluent discharged to the Las Vegas Wash during the current reporting period.[9]

[7] Perchlorate mass removal, reported herein, was calculated using a methodology which has been approved by NDEP (Tetra Tech 2015).

[8] Historic mass removals may differ from previously presented values, as mass removals have been revised in Table 7 based on recent updates to the flow data.

[9] Perchlorate was detected in the seven-day composite sample for the week ending on August 6, 2016 at a concentration of 0.039 mg/L. This detected concentration is believed to be the result of cross-contamination during the compositing of daily effluent samples collected between July 31 and August 6, 2016. When the individual daily samples and a new composite sample were analyzed, perchlorate was not detected.

3. PERFORMANCE EVALUATION

This section provides an evaluation of the performance of the GWETS against a set of performance metrics developed in coordination with NDEP. The performance metrics are intended to establish a consistent framework for evaluating performance of the GWETS.

3.1 Performance Metrics

The performance metrics are discrete measures of performance that are used to understand and adjust GWETS operations over time. The performance metrics were initially developed as part of the 2013 GWETS Optimization Work Plan (ENVIRON 2013c), approved by NDEP on December 3, 2013 (NDEP 2013). Additional metrics have since been developed, as discussed in the 2015-2016 Annual Remedial Performance Report (Ramboll Environ 2016c).

The performance metrics evaluated herein include the following:

- Mass Removal and Remaining Plume Mass;
- Capture Zone Evaluation;
- Estimated Mass Flux; and
- Perchlorate Mass Loading to Las Vegas Wash.

Additional performance metrics, including surface water and groundwater interaction near the SWF, the environmental footprint of groundwater monitoring and GWETS activities, GW-11's operation as an equalization basin, and barrier wall performance, will be evaluated and discussed in the 2016-2017 Annual Remedial Performance Report. Though not discussed in this memorandum, an inventory of energy and materials used, wastes generated, and activities and services conducted at the Site is presented in Appendix F for the purpose of an environmental footprint analysis.[10]

At the direction of NDEP, the Trust anticipates revising and expanding the current performance metrics to incorporate additional RI study areas. A technical memorandum describing the strategy for developing these revised metrics, including a strategy for developing plume mass estimates incorporating the Downgradient Study Area and the Eastside Study Area, will be submitted to NDEP in third quarter 2017.

3.2 Evaluation of Performance

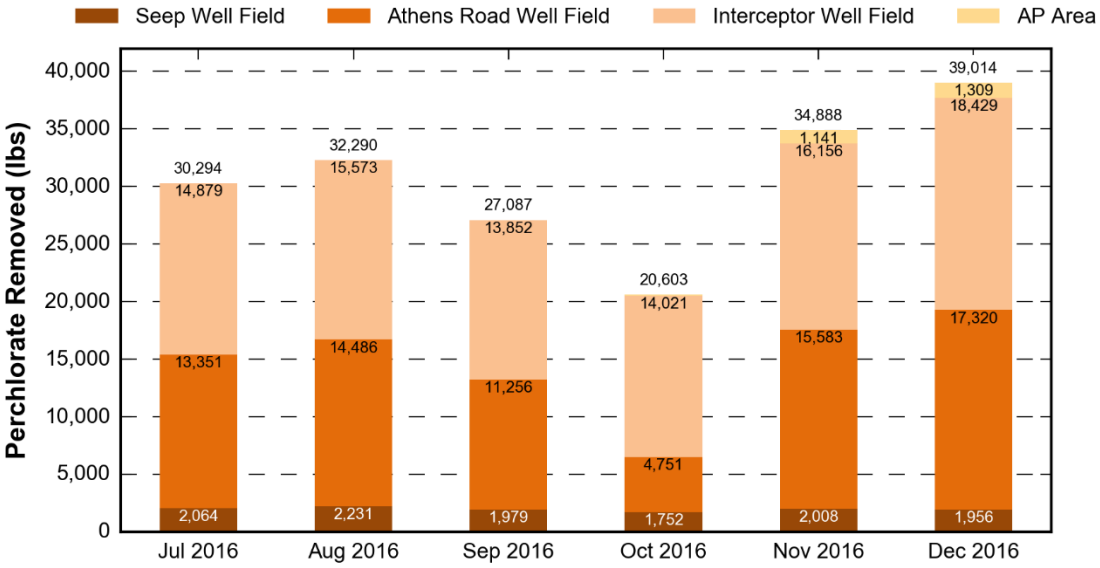
In this section, the performance of the GWETS is discussed in relation to the metrics presented in Section 3.1.

3.2.1 Mass Removal and Remaining Plume Mass

During the period July through December 2016, approximately 184,200 pounds of perchlorate were captured and removed from groundwater by the GWETS, as shown in Table 7 and in the figure below. Of this total, approximately 92,900 pounds were

[10] The Trust anticipates conducting a review of Best Management Practices (BMPs) for the GWETS and groundwater monitoring program by mid-2017 following the ASTM Standard Guide for Greener Cleanups (E2893-16). BMPs will be implemented between July 2017 and June 2018, with input from NDEP and USEPA. The implementation of BMPs, along with an expanded evaluation of the environmental footprint of the GWETS and monitoring program, will be discussed in the 2016-2017 Annual Remedial Performance Report to be submitted to NDEP in October 2017.

captured by the IWF, approximately 76,700 pounds were captured by the AWF, approximately 12,000 pounds were captured by the SWF, and approximately 2,500 pounds were captured by the AP Area extraction wells[11].



Perchlorate Mass Removal. This chart shows monthly perchlorate removed by the IWF, AWF, SWF, and AP Area extraction wells during the reporting period. The total amount of perchlorate removed by the GWETS and the AP extraction wells is shown above each bar. (The AP Area extraction wells removed 79 pounds [lbs] of perchlorate in October 2016; this number is not printed on the chart, but is reflected in the total mass removal number.)

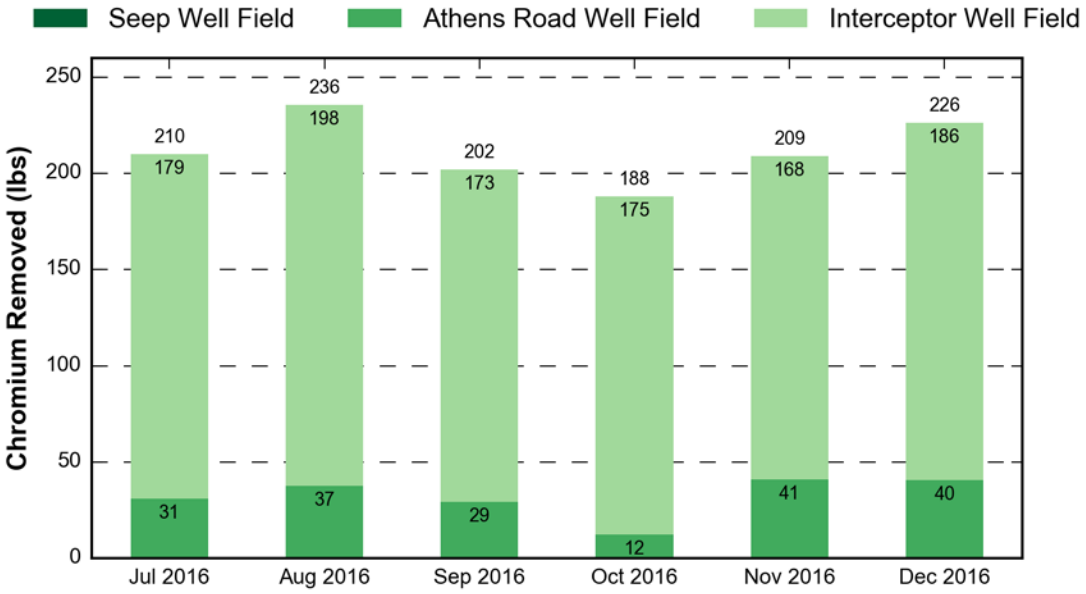
The total combined perchlorate mass removal from all extraction wells during the reporting period decreased by 17.7% compared to the 223,800 pounds removed between July and December 2015. The decrease in removal is primarily the result of lower average perchlorate concentrations at the IWF and AWF. The average perchlorate concentrations at the IWF and AWF during the reporting period were approximately 700 mg/L and 110 mg/L, respectively; for July through December 2015, the average IWF and AWF concentrations were approximately 840 mg/L and 160 mg/L, respectively. In addition, regional drought conditions from 2013 through 2016 reduced natural recharge at the Site, which in turn limited the pumping rate of the wells within the IWF. Barring additional historic rain events or changes in system operation, it is expected that perchlorate concentrations and mass removals will continue to decrease consistent with the trend established prior to December 2012.[12] However, the Trust has taken actions in

[11] The AP Area Soil Flushing Treatability Study was implemented in 2016. Down flushing and extraction well testing was conducted in October 2016, and the extraction wells in Plot 1 began operating continuously in November 2016. Average extraction rates, concentrations, and total mass removals from the AP Area are reported in the GWETS operation monthly reports submitted to NDEP (Envirogen 2016, 2017).

[12] Starting in September 2012 there was a significant increase in the mass of perchlorate captured and removed from groundwater due to a series of storm events between August and October 2012 and subsequent infiltration, causing mobilization of perchlorate from the vadose zone. The effects of the storm events on groundwater conditions were discussed in previous remedial performance reports beginning with the 2012 Semi-Annual Remedial Performance Report (ENVIRON 2013a).

2016 to improve the extraction rate of the AWF through the installation of new pumps and variable frequency drives, and AWF extraction rates increased from 292.8 gpm in July 2016 to 416.9 gpm in December 2016. The soil flushing treatability study implemented in the AP Area has also begun to contribute to mass removal near the IWF.

Approximately 1,270 pounds of total chromium were captured and removed from groundwater by the GWETS during the reporting period, as shown in Table 5 and in the figure below. This is consistent with the 1,300 pounds of total chromium removed between July and December 2015. Of the total chromium mass removed during the current reporting period, approximately 1,080 pounds were captured by the IWF and 190 pounds were captured by the AWF.



Chromium Mass Removal. This chart shows monthly total chromium removed by the IWF, AWF, and SWF during the reporting period. The total amount of chromium removed by the GWETS is shown above each bar.

The plume masses as of second quarter 2016 are estimated to be 2,504 ± 638 tons for perchlorate and 21.41 ± 6.88 tons for chromium, and were originally presented in the 2015-2016 Annual Remedial Performance Report (Ramboll Environ 2016c). The mass estimates presented herein are based only on the mass contained within the On-Site NERT RI Study Area and the Off-Site NERT RI Study Area. A technical memorandum describing the strategy and schedule for developing mass estimates for the entire NERT RI Study Area (including the Downgradient Study Area and the Eastside Study Area) is planned for submittal to NDEP in third quarter 2017. Accordingly, future mass estimates are expected to increase substantially in subsequent evaluations.

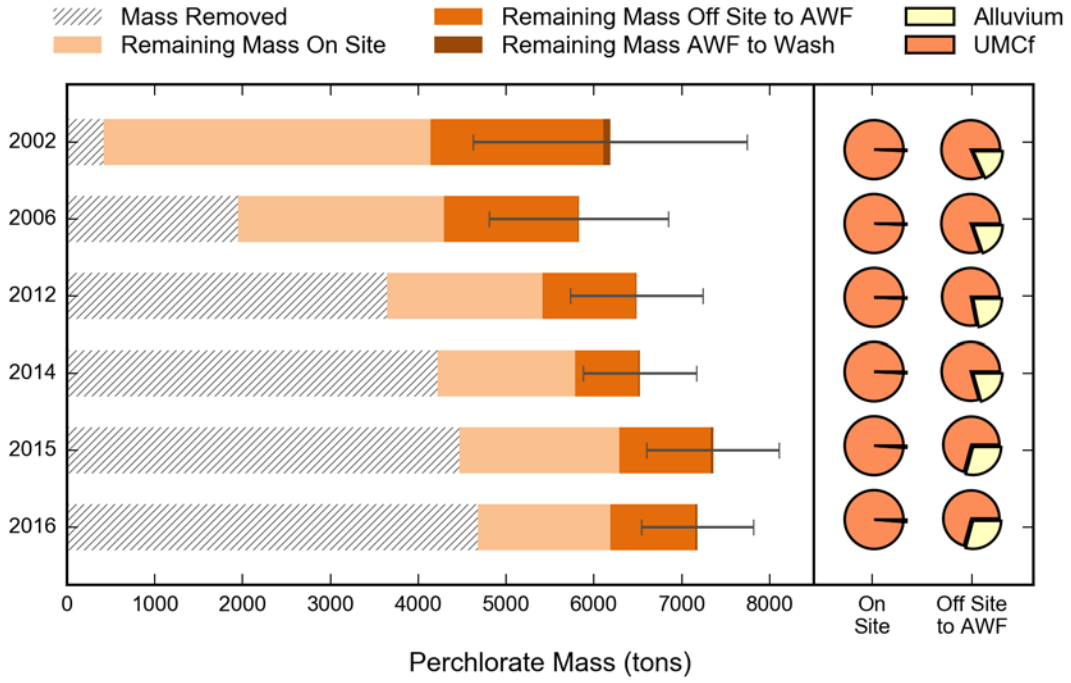
The figures below present perchlorate and chromium plume mass estimates[13] for 2002, 2006, 2012, 2014, 2015, and 2016, with subdivisions showing estimated mass within the

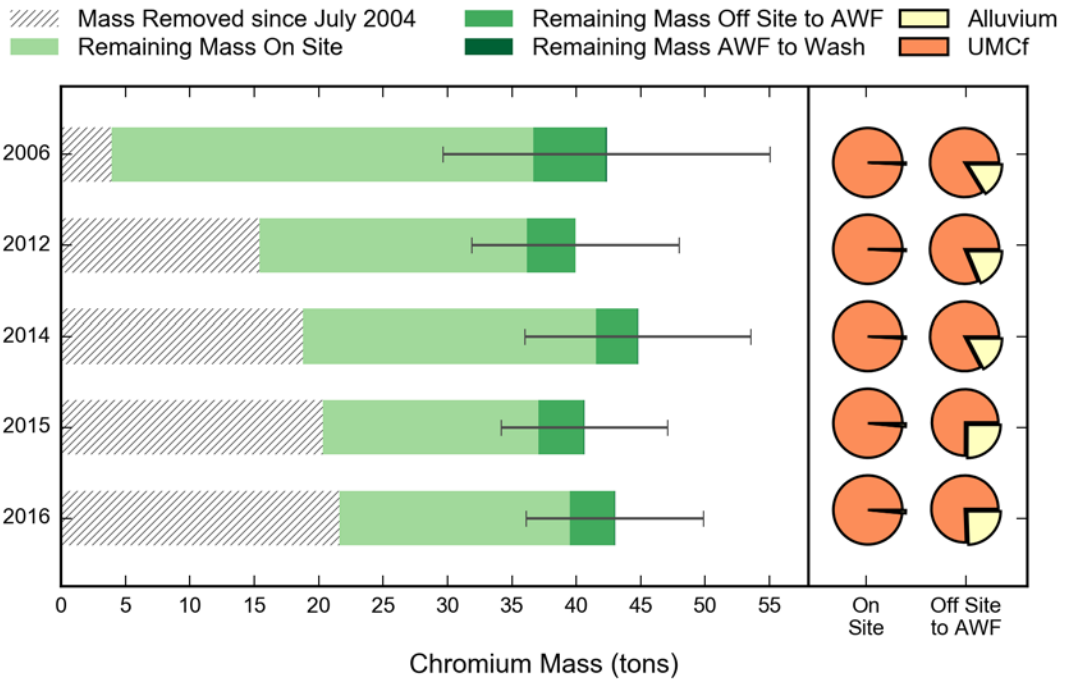
[13] Estimates of remaining plume mass were first presented in the 2012-2013 Annual Remedial Performance Report (ENVIRON 2013b) for years 2002, 2006, and 2012. No estimate of chromium mass for 2002 could

Site boundary, within the Off-Site NERT RI Study Area between the Site and the AWF, and within the Off-Site NERT RI Study Area between the AWF and the Las Vegas Wash (the Wash). Pie charts on the right side of the figure depict the estimated fraction of mass in the Quaternary alluvium (Qal) and the UMCf in each of these areas.[14] The figures also depict estimated cumulative mass removal over time, showing that the sum of cumulative mass removal and estimated remaining plume mass is generally consistent from year to year when the expected uncertainty is taken into account. As discussed above, future estimates will include mass estimates for the Eastside Study Area and the Downgradient Study Area, and as such, future estimates are expected to increase.

be developed due to lack of available data. Since 2014, plume mass estimates have been calculated annually as part of the annual remedial performance reports.

[14] As described in the 2015-2016 Annual Remedial Performance Report (Ramboll Environ 2016c), current mass estimates were developed under the assumption that UMCf thickness is zero north of the AWF.





Remaining Plume Mass. These charts show the plume mass estimates and cumulative mass removal of perchlorate (above) and chromium (below) in the On-Site and Off-Site NERT RI Study Areas. Future estimates will include the Downgradient Study Area and the Eastside Study Area. The error bars represent the uncertainty in the plume mass estimates. Pie charts show the proportions of mass in the alluvium and UMCf in the On Site and Off Site to AWF areas.

3.2.2 Capture Zone Evaluation

Capture zones for each of the well fields were estimated in the Shallow, Middle, and Deep water-bearing zones (WBZs) using forward particle tracking, calculated using MODPATH (Pollock 1994), and using a steady state version of the Phase 5 Groundwater Model[15] and fourth quarter 2016 pumping rates. Particles were released in the center of each model cell in model layers 1, 2 and 3 (representing the Shallow WBZ), layers 4 and 5 (representing the Middle WBZ), and layers 6 and 7 (representing the Deep WBZ). Simulated capture zones in the Shallow, Middle, and Deep WBZs are shown in Figure 3a, Figure 3b, and Figure 3c, respectively.

As shown in Figure 3a, the majority of shallow groundwater within the Site and Off-Site NERT RI Study Area is captured by the combination of the IWF, AWF, and SWF. There are three areas of shallow groundwater that are not captured by the existing system: 1) a small area between the SWF and Las Vegas Wash where perchlorate concentrations were generally less than 3 mg/L during the reporting period, 2) an area east of the SWF where perchlorate concentrations collected from well PC-94 were approximately 20 to 22 mg/L during the reporting period, and 3) an area west of the SWF where perchlorate concentrations in second quarter 2016[16] were less than 3 mg/L.

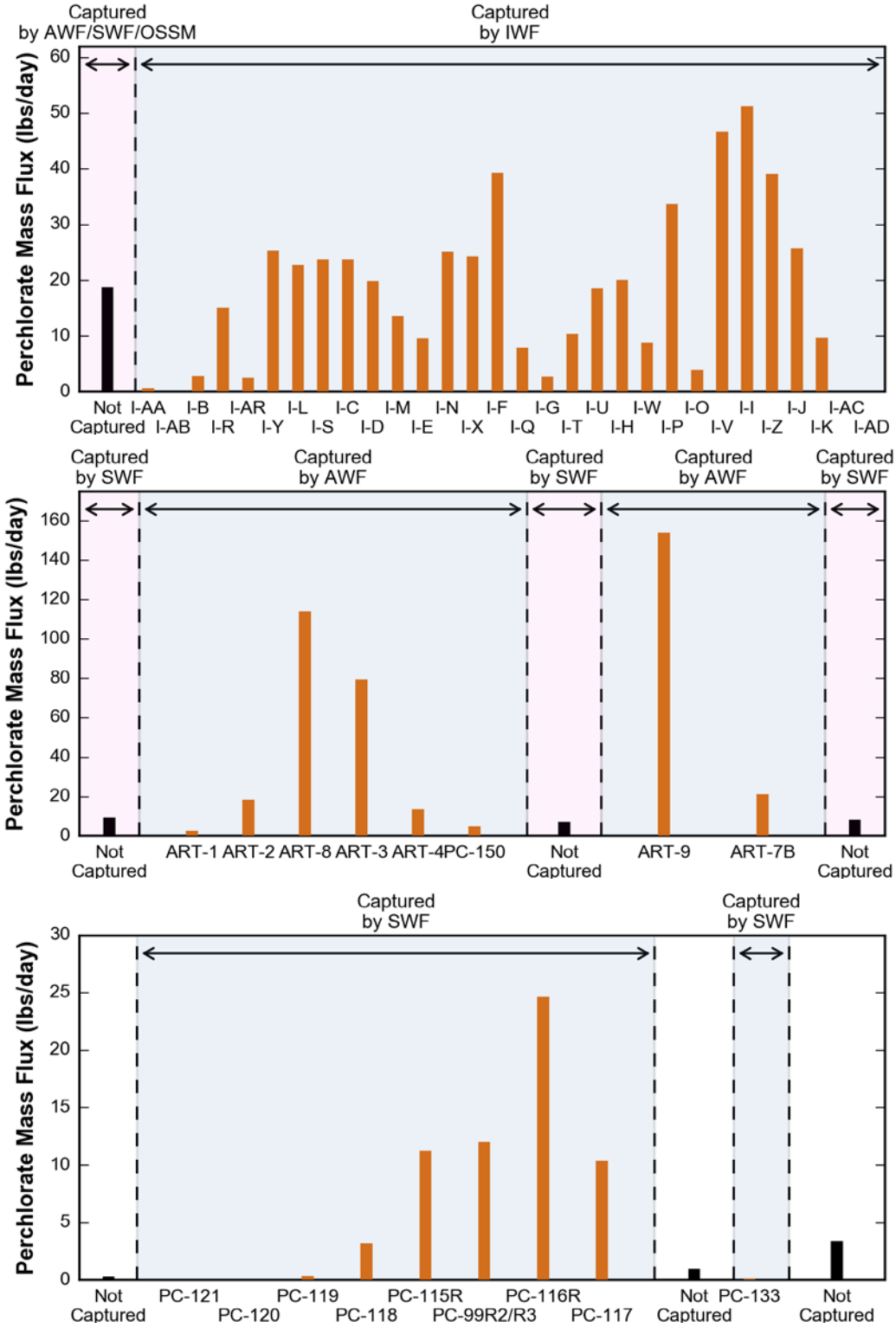
3.2.3 Estimated Mass Flux

To further evaluate the performance of each well field, perchlorate mass flux at the IWF, AWF, and SWF were estimated at transects within the On-Site NERT RI Study Area and Off-Site NERT RI Study Area, located just upgradient of each of the three NERT well fields and drawn perpendicular to groundwater flow as shown on Figure 4. Mass flux was calculated using the methods described in the 2015-2016 Annual Remedial Performance Report (Ramboll Environ 2016c), consistent with applicable guidance by the Interstate Technology and Regulatory Council (ITRC 2010). Mass flux in the Downgradient Study Area and Eastside Study Area will be evaluated as part of the revised performance metrics. A technical memorandum describing the strategy for developing these revised metrics will be submitted to NDEP in third quarter 2017.

Perchlorate mass fluxes within each capture zone are estimated as 528, 409, and 62 pounds per day (lbs/day) for the IWF, AWF, and SWF, respectively, while the perchlorate mass fluxes outside each capture zone are estimated as 18.7, 24.8, and 4.7 lbs/day for the IWF, AWF, and SWF, respectively. The capture efficiencies of the IWF, AWF, and SWF were calculated as 96.6%, 94.3%, and 92.9%, respectively. The distributions of perchlorate mass flux at the IWF, AWF, and SWF along these transects are shown in the figures below.

[15] A transient groundwater model (the Phase 5 model) representing groundwater conditions from 2000 to 2015 was developed by Ramboll Environ and submitted to NDEP in November 2016 (Ramboll Environ 2016d). A steady-state version of the Phase 5 model calibrated to 2015 groundwater conditions was updated with average pumping rates for fourth quarter 2016 to be used in the evaluations presented in this memorandum. The model grid size near the well fields was refined in the steady state version of the Phase 5 model; however, the model layers and the layer properties remained unchanged.

[16] Monitoring wells west of the SWF are sampled annually in second quarter.



Estimated Mass Flux. These charts show perchlorate mass flux inside and outside the capture zones at the IWF, AWF, and SWF, respectively. Fluxes inside the capture zones were calculated directly from measured flow rates and concentrations. Fluxes outside the capture zone were estimated from the groundwater model.

The mass flux calculations indicate that during fourth quarter 2016, an estimated average of 4.7 lbs/day of perchlorate discharged into Las Vegas Wash from within the boundary of the Off-Site NERT RI Study Area. It is important to note this estimate only accounts for perchlorate passing through the transects within the boundary of the Off-Site NERT RI Study Area and not captured by the well fields. Mass loading to the Las Vegas Wash is greater than this estimate due to additional perchlorate sources outside the Off-Site NERT RI Study Area, including Endeavour LLC's (Endeavour's) perchlorate plume and residual perchlorate from the Lower Ponds Area east of Pabco Road. Data collected as part of the ongoing Downgradient Study Area investigation, the ongoing Phase 2 RI, and the upcoming Phase 3 RI (NERT Eastside Area investigation) will be used in future performance evaluations to expand the mass flux transects.

As requested in NDEP's April 9, 2014 letter on the 2013 Semi-Annual Remedial Performance Report (NDEP 2014), the mass flux across each transect was also estimated using an alternative calculation method, one based only on model-estimated groundwater flow rates and interpolated concentrations as described in the 2015-2016 Annual Remedial Performance Report (Ramboll Environ 2016c). As shown in the table below, the estimated mass captured at the three well fields using the alternative method is generally consistent with the estimated mass captured using the extraction well mass removal rates (baseline method). While it is Ramboll Environ's opinion that the baseline method is likely to be most accurate, the alternative method provides a comparison to check the accuracy of the baseline method.

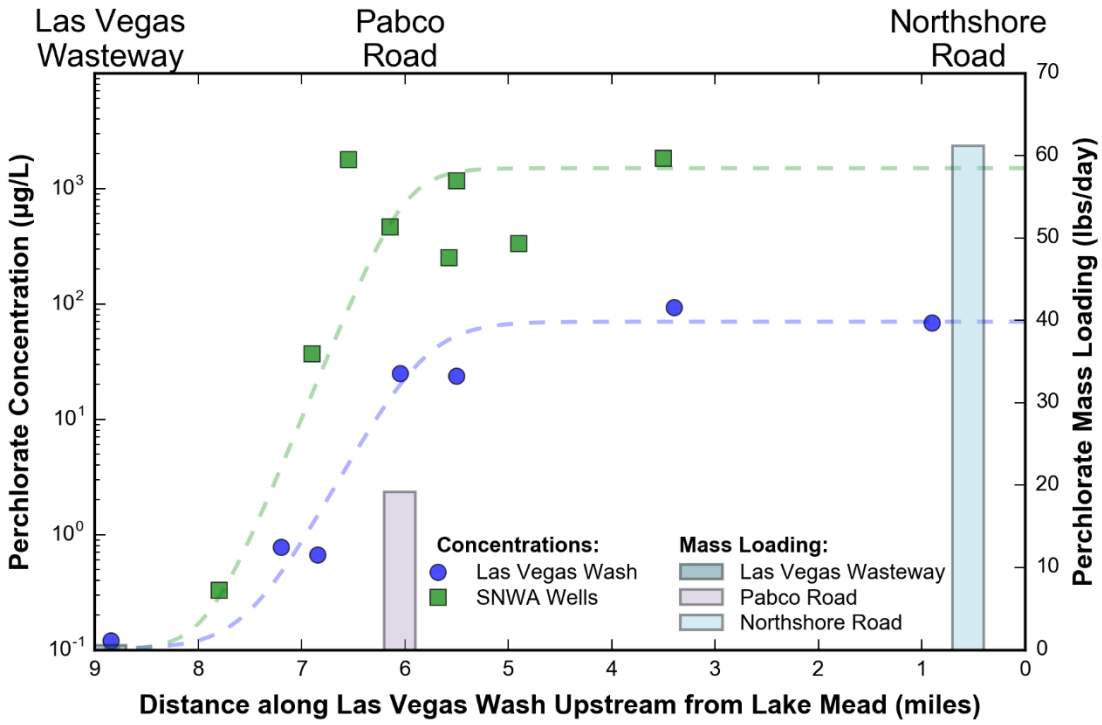
	Baseline Method[1]		Alternative Method	
Well Field	**Perchlorate Mass Captured (lbs/day)**	**Capture Efficiency**	**Perchlorate Mass Captured (lbs/day)**	**Capture Efficiency**
IWF	528	96.6%	626	97.1%
AWF	409	94.3%	438	94.6%
SWF	62	92.9%	65	93.2%

[1] From measured flow rates and perchlorate concentrations at each well during fourth quarter 2016.

3.2.4 Perchlorate Mass Loading to Las Vegas Wash

The Las Vegas Wash is sampled for perchlorate monthly at various locations by Envirogen Technologies, Inc. (Envirogen) for compliance with the site's NPDES permit, and by the Southern Nevada Water Authority (SNWA) as part of their quarterly monitoring program. Based on the measured perchlorate concentrations in stream water and corresponding stream flow (at the time of chemical sampling), perchlorate mass loading was estimated at the following three locations, which are co-located with the United States Geological Survey (USGS) gaging stations shown on Figure 4: Las Vegas Wasteway (LW8.85), Pabco Road (LW6.05), and Northshore Road (LW0.55). Annual average perchlorate mass loading at these stations for each year (July through June) are

presented in Table 9. During the reporting period, approximately 30% of the mass loading measured at Northshore Road can generally be attributed to mass entering the Las Vegas Wash between the Las Vegas Wasteway and Pabco Road stations, while approximately 69% can be attributed to mass entering the Las Vegas Wash between the Pabco Road and Northshore Road stations. The figure below shows the perchlorate concentrations in the Las Vegas Wash and in the SNWA groundwater monitoring wells along the length of the Las Vegas Wash from the Las Vegas Wasteway to Lake Mead during fourth quarter 2016, as well as average mass loading at the three stations for the current reporting period.



Mass Loading to Las Vegas Wash. This chart shows perchlorate concentrations measured in the Las Vegas Wash and SNWA groundwater monitoring wells along the Las Vegas Wash. Average mass loading to the Las Vegas Wash during the current reporting period is also shown for three locations. The dashed lines are estimates of how perchlorate concentrations in the Las Vegas Wash and SNWA wells vary with distance.

The estimated average perchlorate mass loading to Las Vegas Wash between Las Vegas Wasteway and Pabco Road is 18.6 lbs/day during the reporting period. This number is larger than the estimated 4.7 lbs/day discharged to the Las Vegas Wash through the transects discussed in Section 3.2.3 because it accounts for additional sources of perchlorate loading outside of the Off-Site NERT RI Study Area boundary, such as bank storage, wash gravels, residual perchlorate from the Eastside Area, and Endeavour's perchlorate plume. According to Endeavour's recent monitoring and performance report, Endeavour's average perchlorate loading to the Athens Drainage Channel[17] was 12.3

[17] The Athens Drainage Channel is located west of the City of Henderson Bird Viewing Ponds and discharges to the Las Vegas Wash, as discussed in the Phase 4 Model Refinement report (Ramboll Environ 2016a).

lbs/day from July to December 2016 (Endeavour 2017, pg. 12). Endeavour additionally reported that the perchlorate loading not captured in shallow groundwater was 4 to 5 lbs/day in the second half of 2016 (Endeavour 2017, pg. 18). The sources of mass loading between Las Vegas Wasteway and Pabco Road during the current reporting period are summarized in the table below:

Perchlorate Loading Source	Mass Loading between Las Vegas Wasteway and Pabco Road (lbs/day)
Endeavour Athens Drainage Channel	12.3
Endeavour Shallow Groundwater	4-5
NERT Shallow Groundwater	4.7
Total	**21-22**

Therefore, based on the data reported by Endeavour, approximately 78-79% of the perchlorate loading to the Las Vegas Wash between Las Vegas Wasteway and Pabco Road occurs upstream of the NERT shallow groundwater plume.

4. ONGOING AND FUTURE ACTIVITIES

The table below lists the current status of upcoming tasks related to the groundwater monitoring program and the COP. Ongoing activities in support of the RI/FS, including the ongoing Downgradient Study Area investigation, the ongoing Phase 2 RI, and the upcoming Phase 3 RI, will be discussed in the 2016-2017 Annual Remedial Performance Report.

Task	Purpose	Current Status	Planned Activities
Monitoring Program			
Implementation of 2016 Groundwater Monitoring Optimization Plan	Enhance understanding and reduce inefficiencies in data collection and interpretation.	Comprehensive well inspections and surveys were completed in late 2016. The revised program was implemented in November 2016. The Sampling and Analysis Plan was submitted to NDEP in March 2017 and approved on April 7, 2017.	Tetra Tech, Inc. (Tetra Tech) and Envirogen will continue to conduct sampling for the revised program, including the first expanded annual sampling event in second quarter 2017. Data collected from the revised program will be presented in future performance evaluations.
Continuous Optimization Program			
IX System	Treat a portion of groundwater captured by the SWF to better manage GW-11 capacity and FBR hydraulic capacity.	NDEP approved the proposed system design on August 30, 2016. Construction was completed in December 2016, and the system began operating in February 2017.	The IX system will continue to operate, as dictated by project needs. It currently treats flow from five SWF extraction wells.

Task	Purpose	Current Status	Planned Activities
GWETS Infrastructure Improvements	Accommodate larger flow rates in support of the COP.	A larger backup pump was installed at Lift Station 2 and both submersible pumps were replaced at Lift Station 3 in October 2016. Lift Station 1 upgrades were completed in December 2016. The ART-7B pump was lowered and new pumps were installed in ART-9 and ART-8A in July 2016. A memorandum summarizing the GWETS effluent pipeline evaluation was finalized in fourth quarter 2016.	Larger capacity pumps will be installed in ART-2 and ART-8 in 2017 to increase AWF extraction rates. In 2017, Tetra Tech will evaluate options to address pipeline fouling and will prepare for sections of pipeline to be replaced.
GWETS/NET	Improve accessibility of near real-time GWETS data.	GWETS/NET was launched in December 2016 to provide remote monitoring of the GWETS.	Baseline and historic mass removal and flow tables will be developed for GWETS/NET in 2017.
Well Field Optimization	Increase perchlorate mass removal in support of the COP.	AWF extraction increased to over 400 gpm by December 2016. PC-120 and PC-121 were turned on in February 2017.	Well field rebalancing is ongoing, with a goal to increase AWF extraction to 500 gpm in 2017.
Extraction Well Inspections and Aquifer Testing	Support the well field rebalancing for the COP and provide aquifer data for the groundwater model.	Pump inspections and aquifer testing were conducted at the IWF in June-July 2016 and the AWF in October-November 2015. SWF pumps were inspected in August 2016.	Aquifer testing at the SWF is anticipated to take place in 2017. Following completion of aquifer testing, results will be summarized in a technical memorandum.

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