BISC Semi-Annual Monitoring and Performance Report

July 1 to December 31, 2019

Perchlorate Bioremediation System
Endeavour LLC
Henderson, Nevada

NDEP Facility ID: H-000534

Submitted: February 14, 2020

ENDEAVOUR, LLC
900 Wiesner Way
Henderson, NV 89011

BISC Semi-Annual Monitoring and Performance Report
July 1 to December 31, 2019

Prepared by:
Endeavour LLC
900 Wiesner Way
Henderson, NV 89011

February 14, 2019

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 Endeavour LLC. Based on my own involvement and/or my inquiry of the person or persons who manage the system(s) or those directly responsible for gathering the information or prepared the document, or the immediate supervisor of such person(s), the information submitted and provided herein is, to the best of my knowledge and belief, true, accurate, and complete in all material respects. I am aware that there are significant penalties for submitting false information such as those set forth in NRS 459.595, including the possibility of fines and imprisonment for knowing violations.

2/14/20

Jeff Gibson
Authorized Representative

Date

I hereby certify that I am responsible for the services described in this document and for the preparation of this document. The services described in this document have been provided in a manner consistent with the current standards of the profession and to the best of my knowledge comply with all applicable federal, state and local statutes, regulations and ordinances. I hereby certify that all laboratory analytical data was generated by a laboratory certified by the NDEP for each constituent and media presented herein. I am aware that there are significant penalties for submitting false information such as those set forth in NRS 459.595, including the possibility of fines and imprisonment for knowing violations.

2/14/20

Gary Carter, P.E., C.E.M.
Facility Manager
Nevada Certified Environmental Manager CEM #1909, expires 01/26/21

Date

Table of Contents

List of Tables iv
List of Figures iv
List of Appendices vi
Executive Summary 1
1.0 Introduction 1
2.0 Objectives 2
3.0 Scope of Work 2
4.0 Description of the Groundwater Treatment System 3
4.1 AGTS Plant and Discharge 3
4.2 Plant Systems and Control 4
4.3 Groundwater Extraction Systems 5
5.0 Remediation and Monitoring Activities 5
5.1 Remediation Operation & Maintenance 5
5.1.1 Maintenance and Repairs 5
5.1.2 Plant Optimization 7
5.2 Groundwater and Surface Water Monitoring Procedures 7
5.2.1 Well and Surface Water Collection Procedure 7
5.2.2 Procedure for Taking Field Measurements 7
5.2.3 AGTS Plant Influent and Effluent Sampling Activities 8
5.2.4 Extraction Well Area Sampling Activities 8
5.2.5 Surface Water Sampling Activities 8
5.3 Data Assimilation 9
5.4 Eastgate Storm Water Mitigation System Design 9
6.0 Performance Data, Field Measurements, and Analytical Results 9
6.1 System Performance Data 9
6.2 Groundwater and Surface Water Monitoring Results 10
6.2.1 Monthly Monitoring Results 10
6.2.2 Quarterly Monitoring Results 10
6.2.3 Semi-Annual Monitoring Results 11
6.2.4 Surface Water Monitoring Results 11
6.3 Groundwater Hydraulics and System Performance Assessment 11
6.3.1 Approach and Methodology 13

6.3.2 Perchlorate Mass Capture and Removal 20
6.3.3 Remediation Tracking 23
6.4 Monitoring Well Trend Analysis 25
7.0 Summary and Conclusions 28
8.0 Plan and Recommendations 29
9.0 Limitations 29

List of Tables

Table 1a Athens Road Extraction Wells (AREW) Average Monthly Perchlorate (mg/L)

Table 1b Athens Road Extraction Wells (AREW) Average Monthly Flow (GPM)

Table 2a Athens Pen Extraction Wells (APEW) Average Monthly Perchlorate (mg/L)

Table 2b Athens Pen Extraction Wells (APEW) Average Monthly Flow (GPM)

Table 3a Auto Mall Extraction Wells (AMEW) Average Monthly Perchlorate (mg/L)

Table 3b Auto Mall Extraction Wells (AMEW) Average Monthly Flow (GPM)

Table 4 Flow Rate and Monthly Sampling Results

Table 5 Quarterly Analytes and Field Measurements

Table 6 Selected History of Perchlorate Concentrations in Athens Road Extraction Wells (mg/L)

Table 7 Selected History of Perchlorate Concentrations in Athens Pen Extraction Wells (mg/L)

Table 8 Selected History of Perchlorate Concentrations in Auto Mall Extraction Wells (mg/L)

Table 9 Semi-Annual Analytes and Field Measurements

List of Figures

Figure 1 Sample Locations and Frequency (North)

Figure 2 Sample Locations and Frequency (South)

Figure 3 Site Plan

Figure 4a Average Monthly Mass Removal by Athens/Galleria Extraction Well, October 2012 to December 2019

Figure 4b Average Monthly Mass Removal by Auto Mall Extraction Well, October 2012 to December 2019

Figure 5a Cumulative Mass Removed by Athens/Galleria Extraction Well, October 2012 to December 2019

Figure 5b Cumulative Mass Removed by Auto Mall Extraction Well, October 2012 to December 2019

Figure 6 Selected Historical Perchlorate Concentrations in AREW Wells

Figure 7 Selected Historical Perchlorate Concentrations in APEW Wells

Figure 8 Selected Historical Perchlorate Concentrations in AMEW Wells

Figure 9 Monthly Perchlorate Loading in AC Main, July 1 to December 31, 2019

Figure 10 Monthly Perchlorate Loading in Eastgate Storm Drain, July 1 to December 31, 2019

Figure 11 Groundwater Equipotentials in Shallow Water Bearing Zone, Athens/Galleria Extraction Area, November 3, 2019 to November 14, 2019

Figure 12 Perchlorate in Shallow Water Bearing Zone, Athens/Galleria Extraction Area, November 3, 2018 to November 14, 2019

Figure 13 Perchlorate Loading per Width in Shallow Water Bearing Zone, November 3, 2019 to November 14, 2019

Figure 14 Groundwater Equipotentials in Deep Water Bearing Zone, Auto Mall Extraction Area, November 3, 2019 to November 14, 2019

Figure 15 Perchlorate Concentrations and Water Levels, Shallow Water Bearing Zone, Auto Mall West

Figure 16 Perchlorate Concentrations and Water Levels, Shallow Water Bearing Zone, Auto Mall East

Figure 17 Perchlorate Concentrations and Water Levels, Shallow Water Bearing Zone, Warm Springs/Eastgate

Figure 18 Perchlorate Concentrations and Water Levels, Shallow Water Bearing Zone, Sunset/Boulder West

Figure 19 Perchlorate Concentrations and Water Levels, Shallow Water Bearing Zone, Sunset/Boulder East

Figure 20 Perchlorate Concentrations and Water Levels, Shallow Water Bearing Zone, Boulder/Galleria

Figure 21 Perchlorate Concentrations and Water Levels, Shallow Water Bearing Zone, AGTS Plant Area

Figure 22 Perchlorate Concentrations and Water Levels, Shallow Water Bearing Zone, Wiesner/Sam Boyd

Figure 23 Perchlorate Concentrations and Water Levels, Shallow Water Bearing Zone, Former DRIT Area

Figure 24 Perchlorate Concentrations and Water Levels, Shallow Water Bearing Zone, DRIT East

Figure 25 Perchlorate Concentrations and Water Levels, Middle Water Bearing Zone, Auto Mall South

Figure 26 Perchlorate Concentrations and Water Levels, Middle Water Bearing Zone, Auto Mall East

Figure 27 Perchlorate Concentrations and Water Levels, Middle Water Bearing Zone, Sunset/Boulder

Figure 28 Perchlorate Concentrations and Water Levels, Deep Water Bearing Zone, Auto Mall South

Figure 29 Perchlorate Concentrations and Water Levels, Deep Water Bearing Zone, Auto Mall West

Figure 30 Perchlorate Concentrations and Water Levels, Deep Water Bearing Zone, Auto Mall East

List of Appendices

Appendix A Geosyntec Mass Capture Assessment Memorandum

Appendix B Acronyms

Appendix C Definitions

Appendix D Calculations

Appendix E NDEP Correspondence

Appendix F Data Validation Summary Report

Appendix G NPDES Permit NV0024112

Appendix H Laboratory Certifications

Executive Summary

Forward flow through the Athens Road/Galleria Drive and Auto Mall area Groundwater Treatment System (AGTS) plant to the effluent line continued in the second half of 2019 (2H2019) averaging approximately 695 gpm. The plant flow rate was lowered to approximately 700 gpm between September 17 and October 18, 2019 due to flow and pressure issues in the effluent pipeline. A comprehensive maintenance and inspection project was performed on FBR-140 in October with no flaws or damage found on the fluidization nozzles or laterals. The plant flow rate was approximately 415 gpm during the week-long project, and was gradually brought back up to full flow of approximately 740 gpm in November 2019.

Compliance with permit and regulatory action limits was achieved in samples collected during the reporting period. The long-awaited renewed NPDES discharge permit was officially issued on August 15, 2019. The optimized FBR-based system continued to perform well on a perchlorate mass reduction basis. The total mass of perchlorate destroyed during 2H2019 was approximately 148,260 pounds and the total amount of water treated was approximately 184,732,000 gallons.

Design work for the Eastgate Drain Storm Water Mitigation (ESWM) system and the associated infrastructure improvements at the AGTS facility was commenced in November 2019. Sixty-percent design packages are being prepared by the engineering firm, Atkins, and anticipated to be submitted to Endeavour in the spring 2020.

Several monitoring and extraction wells in the deep WBZ showed a continued decreasing perchlorate concentration trend during the 2H2019. In the shallow WBZ several wells show a decreasing perchlorate concentration trend or changed from an increasing trend to a stable trend, likely in response to start-up of the AMEWs in 2013 and the intended reduction in perchlorate mass flux from the deep to the shallow WBZ. A couple of wells, however, show an increasing trend most likely due to heterogeneous conditions in the WBZ. Most of the monitoring wells that are used to optimize the groundwater models and monitor system performance are sampled during the annual event in April-May and therefore the key trends will be further observed in the next reporting period.

The results of Geosyntec's performance analysis and mass capture calculations for the 2H2019 reporting period showed that the total perchlorate loading captured in the shallow water bearing zone (Athens/Galleria area) as a function of the total loading in that groundwater was in the range of 80% to 84% and the total loading captured (groundwater and surface water) was in the range of 57% to 59%. This is slightly lower than in 1H2019 and 2018 due to the extraction wells undergoing maintenance and/or being down due to plant maintenance, including during the site-wide monitoring period. The average loading of perchlorate in the Athens Drainage Channel from July to December 2019 was 12.7 lbs/day. The daily average perchlorate captured from the deep water bearing zone was calculated to be approximately 822 lbs/day.

1.0 Introduction

Endeavour LLC has prepared this semi-annual monitoring and performance report for the Nevada Division of Environmental Protection (NDEP) Bureau of Industrial Site Cleanup (BISC) for its

perchlorate treatment system at Henderson, Nevada. This report comprises groundwater monitoring and FBR remediation system data collected during the 2H2019 (July 1 through December 31, 2019) and includes results of the annual monitoring well sampling event.

The purpose of this narrative is to provide periodic remediation data to the BISC. The NDEP Facility ID for the project is H-000534.

Supporting information for this report includes a technical memo prepared by Geosyntec on the perchlorate mass capture assessment found in Appendix A, a list of acronyms in Appendix B, definitions of key terms in Appendix C, calculations in support of the groundwater hydraulics and mass capture assessment in Appendix D, and pertinent NDEP correspondence in Appendix E. The Data Validation Summary Report for this reporting period is provided in Appendix F, a copy of the renewed NPDES discharge permit NV0024112 in Appendix G, and electronic copies of laboratory certifications in PDF format are provided as Appendix H.

2.0 Objectives

The objectives of the remediation project during this reporting period were to:

- Continue reliable operation of the expanded long-term FBR remediation system that treats groundwater closer to the former perchlorate chemicals manufacturing facility in addition to the Leading Edge (Athens/Galleria extraction area).
- Continue to pursue optimization opportunities for the entire FBR-based remediation system to maximize the contaminant mass removal and groundwater capture.
- Continue groundwater sampling activities per the Rev. 2 Sampling and Analysis Plan (SAP).
- Demonstrate the ability to reduce the perchlorate load in the surface water resulting from groundwater seepage into the Athens drainage channel.

3.0 Scope of Work

This report, as with the previous reports, contains information pertinent to the Mitigation System Area (MSA) Work Plan and the approved Rev. 2 SAP. Since the FBR remediation system treated effluent discharges directly into the Las Vegas Wash, Endeavour LLC submits quarterly Discharge Monitoring Reports (DMRs) separately to the Bureau of Water Pollution Control (BWPC) per our National Pollution Discharge Elimination System (NPDES) permit, NV0024112 which was renewed on August 15, 2019.

Monitoring for the Bureau of Industrial Site Cleanup (BISC) was originally described in the MSA Work Plan and associated documents submitted to NDEP Bureau of Corrective Actions (BCA) in February, 2005. A SAP covering the requirements of the combined BCA and BWPC Underground Injection Control (UIC) programs was submitted to NDEP and approved on September 8, 2010. This was updated after the UIC permit cancellation and submitted to the BCA on March 26, 2013

for conditional approval. BCA approved that Rev. 1 SAP for use in the 2013 annual sampling event in a letter dated April 19, 2013.

A Rev. 2 SAP was prepared per an agreement with NDEP during a meeting held July 18, 2013 and as required under our Administrative Order on Consent (AOC) which became effective on July 1, 2013 and was assigned to, and assumed by, Endeavour LLC in December, 2015. The Rev. 2 SAP was approved by NDEP in a letter dated September 30, 2013.

A Rev. 2 Work Plan for Demonstration of Groundwater Capture was prepared by Geosyntec which concluded that taking water levels from 12 additional wells on a semi-annual basis was necessary to better assess groundwater capture in the shallow WBZ. This was added to an updated Rev. 2 SAP dated September 19, 2014. The updated Rev. 2 SAP also included a change which required that nitrate analyses only be conducted during the annual sampling, which was approved by email correspondence from NDEP on September 4, 2014. Both of these updated plans were officially approved by NDEP in compliance with the AOC in a letter dated October 16, 2014.

The scope of work performed during the reporting period included:

- Operation, maintenance and monitoring of the FBR treatment system.
- Collection of groundwater levels, field parameters and samples from extraction wells, new plant processes, surface water channels, and monitoring wells covered under the BISC's monthly, quarterly, and semi-annual monitoring programs.
- Management of field measurements, plant operational data and laboratory analytical results.
- Preparation of this technical report.

4.0 Description of the Groundwater Treatment System

4.1 AGTS Plant and Discharge

The AGTS operation is based at a 9,000 square foot building located within a 1.77 acre site at 900 Wiesner Way, Henderson, NV 89011, which is northeast of Boulder Highway and Sunset Road (see Figure 1). The operational controls, offices, chemical storage, and analytical laboratory are located here. There were no material changes to any of these items during the reporting period.

The FBR system began operation in late September 2012 and is designed to remove perchlorate from groundwater extracted from the Valley Auto Mall area (near the source area close to the former PEPCON facility) as well as the shallow groundwater bearing zone along Galleria Drive and the Athens Pen area (the Leading Edge) before it enters the Las Vegas Wash to the north.

The treatment system comprises 14 extraction wells, a water handling and FBR treatment plant, and a discharge system. Five Auto Mall extraction wells (AMEWs) are located within the Valley

Auto Mall area of Henderson (see Figure 2), six Athens Road extraction wells (AREWs) are located along the north side of Galleria Drive (formerly Athens Road) west of Wiesner Way, and three Athens Pen extraction wells (APEWs) are located east of Wiesner Way along the private driveway to the treatment plant (see Figure 1).

The target contaminant for treatment in the AGTS is perchlorate (ClO_4^-). During the process, chlorate (ClO_3^-), nitrate (NO_3^-), and dissolved oxygen (DO) are also reduced in biologically mediated redox reactions. For purposes of this report, perchlorate, chlorate and nitrate will be often referred to as "electron acceptors."

The AGTS FBR plant consists of two first stage FBRs that contain sand media while a second stage FBR contains granular activated carbon. Internal FBR components include a fluidization flow distribution system, a biomass separator with an in-bed biomass control system, and an effluent collection system. A media separator is included within the first stage. Microorganisms growing as a film on the media and utilizing metabolic pathways reduce the perchlorate, chlorate, nitrate and oxygen in redox reactions resulting in nitrogen, carbon dioxide, water, and minerals. This is accomplished through the precise addition of an electron donor (ethanol), nutrients (di-ammonium phosphate/urea mixture), and other trace elements (micro-nutrients). Additionally, pH is adjusted through the addition of a 50 percent (by weight) solution of sodium hydroxide.

The treated effluent from the FBRs is aerated in an aeration tank with hydrogen peroxide added to control the formation of sulfides. The treated water then flows from the aeration tank directly to the effluent tank. The dissolved air filtration units (DAFs), sludge digestion, truck loading, and sand filtration components still exist at the site but were taken offline in September, 2013 with approval by NDEP. The layout of the AGTS facility showing these process components is provided on Figure 3.

Effluent is pumped from the effluent tank to the Las Vegas Wash via one or two 8-inch HDPE pipelines. The first 7,700 feet of effluent line from the plant consists of an 8-inch HDPE pipe that was installed in 2006 and used during the ISB operation. It feeds into a maintenance vault at the former re-injection area. Dual 8-inch HDPE pipelines extend out from the mixing vault approximately 6,200 feet to the discharge point within the Las Vegas Wash where those lines recombine to one line immediately prior to discharge. In the maintenance vault, effluent can be switched from one pipe to the other, or to both simultaneously, based on a set schedule or as necessary if line maintenance is required. Discharge into the Las Vegas Wash is subject to a NPDES permit (NV0024112, renewed and dated August 15, 2019) and quarterly DMRs are submitted to NDEP under this permit (see Appendix G).

4.2 Plant Systems and Control

The components of the AGTS are managed through the Human Machine Interface (HMI). The HMI is located within a desktop PC and provides process graphics, alarms for process parameters, and trending data. Several key data points of the HMI are captured in a Microsoft Access data log system. Those data include influent and effluent flow rates, extraction well flow rates and water levels, and FBR system operational data.

4.3 Groundwater Extraction Systems

Groundwater containing perchlorate is extracted through a series of extraction wells as described above in Section 4.1. The primary function of the AMEWs is to extract a higher volume of perchlorate-contaminated groundwater near the former PEPCON manufacturing site area, principally groundwater from the deep water-bearing zone (Deep WBZ), thus reducing the overall duration of the remediation project. The purpose of the AREWs is to intercept groundwater containing perchlorate from the shallow water-bearing zone (Shallow WBZ), lowering the groundwater elevation broadly, before it can enter (seep into) the Athens Drainage Channel (ADC) and thereby become surface water. The other function of the AREW's is to reduce the flux of perchlorate moving in the aquifer below the ADC that moves down-gradient towards the Las Vegas Wash.

The APEW-1 and APEW-2 wells are located down-gradient of the AREWs and have therefore been used solely to remove perchlorate mass from the Shallow WBZ. APEW-3 is located furthest to the east of all the extraction wells, close to the AGTS building and screened in the shallow alluvium east of a ridge of clayey siltstone of the Muddy Creek formation. The function of APEW-3 is to provide capture of the relatively small flux of perchlorate in the Shallow WBZ east of the "Muddy Creek High."

5.0 Remediation and Monitoring Activities

5.1 Remediation Operation & Maintenance

Forward flow through the plant to the effluent line continued in the third and fourth quarters of 2019, averaging approximately 695 gpm (1.0 MGD). The effluent pipeline was pigged on a regular basis during the reporting period to maintain appropriate maximum line pressure at the desired flow rates, however, line pressure was observed to be increasing more rapidly between pigging events in September 2019 resulting in operations staff reducing flow to approximately 715 gpm (not running AREW-2 and either AREW-1 or -3) while investigating and testing. The line pressure issue improved in late November 2019 but is still being closely monitored.

The most significant issues affecting operations were two separate unplanned effluent discharge events that occurred on September 2 and September 7, 2019, and a planned maintenance and inspection project on FBR-140 that occurred October 21 – 28, 2019. Further details are provided in the bullets in Section 5.1.1 below.

5.1.1 Maintenance and Repairs

The following list presents the notable maintenance and repair activities that occurred during the reporting period.

- In late July 2019, visible corrosion was discovered throughout the inside of the effluent tank (T-130) including the upper regions where mist and humidity have contributed, and excessive corrosion along the seams. A new replacement tank was ordered in September 2019 that will have a stronger corrosion-resistant coating, will be an open-top, and will have the inlet near

the bottom coming in at an angle so as to allow for good mixing without creating any splashing/misting. These new features will significantly reduce the chances for corrosion to occur going forward. Demolition of the existing tank and assembly of the new tank is scheduled to take place in late February 2020 which will include a week-long plant shut-down.

- On September 2, 2019 at approximately 6:10 am, a cracked 8-inch schedule 80 PVC pipe section of the effluent line located a few feet above the floor inside the AGTS 9000 ft^2 process/warehouse building resulted in a release of roughly 15,000 gallons of treated effluent water into the building and adjacent parking area. Soon thereafter the operator was able to stop the discharge and isolate the section of piping that was cracked. Flow to the plant was stopped and the plant was put into recycle mode at 7:00 am in order for temporary repairs to be completed by operations staff. The repairs were completed within two hours and forward flow through the plant was re-commenced at 9:30 am. A permanent replacement for the affected section of piping was completed on September 6, 2019. A 5-Day report in regards to this release per NPDES permit condition C.8.2 was submitted to the Compliance Coordinator via letter dated September 3, 2019. In a letter dated October 8, 2019, NDEP closed the release investigation determining that no further assessment is necessary.

- On September 7, 2019 at approximately 7:34 am, another release of treated effluent water occurred at the maintenance vault approximately ¾ mile from the AGTS building. While isolating the north (dual) effluent discharge line to investigate a suspected blockage in that line, the threaded cap on the "wye" section where a foam pig is inserted into the north line popped off from the increased pressure in the line. This resulted in the maintenance vault filling up and releasing approximately 1,500 gallons onto the surrounding soil. Another roughly 3,500 gallons was pumped out of the vault onto the south side of the vault. Upon discovery of the release the effluent flow was shut off. After pumping out the vault, the cap was replaced with an aluminum and Schedule 80 PVC 8-bolt blind flange assembly.

  During the repair, flow to the plant was stopped and the plant was put into recycle mode. The repairs were completed within a couple hours and forward flow through the plant was re-commenced at approximately 10:30 am. Another 5-Day report per NPDES permit condition C.8.2 was submitted to the Compliance Coordinator via letter dated September 10, 2019 in regards to this release. In a letter dated October 8, 2019, NDEP closed the release investigation determining that no further assessment is necessary.

- Upon restarting the effluent pumps on September 7, 2019, the pump motor on extraction well AREW-2 failed and flow was maintained at approximately 710 gpm. The pump and motor were replaced in AREW-2 on September 18, 2019 but remained off due to ongoing pumping and pipeline issues still being investigated. Meanwhile, the flow was maintained at 700 – 710 gpm while operations staff continued investigation and testing the effluent line.

- A faulty check valve was discovered within the extraction piping inside the vault for AREW-1 on September 24, 2019. A new replacement check valve was installed on September 29, 2019.

- A planned cleanout, inspection, and maintenance project on FBR-140 was successfully performed October 21 – 28, 2019, the same as was performed on the FBRs in previous years. FBR-140 was emptied, the media set aside in super sacks, and the PVC laterals and nozzles inside the reactor were cleaned and inspected. There was no damage discovered on the nozzles or laterals. The plant continued to operate using FBR-130 and FBR-210 with a flow

rate of approximately 410 gpm during the week-long project. The flow was increased gradually through November 2019.

- Power outages at the AGTS facility occurred on consecutive evenings December 3, 2019 and December 4, 2019. The first outage lasted approximately one hour causing operations staff to shut down the flow and treatment overnight, restarting the morning of December 4, 2019. It was caused by an automobile collision with a power pole near the plant. The second outage on the evening of December 4, 2019 was caused by NV Energy performing additional repairs to the damaged pole and power line. The plant was again shut down overnight and restarted the next morning on December 5, 2019.

5.1.2 Plant Optimization

There were no optimization activities performed on the AGTS plant during the reporting period. Design work has been initiated for infrastructure improvements in support of the ESWM project (see Section 5.4 below). These include a direct overhead pipeline from the aeration tank to the effluent tank and a booster pump system for the effluent line.

5.2 Groundwater and Surface Water Monitoring Procedures

Groundwater samples are collected in accordance with the SAP and Endeavour internal procedures included in SOP-02 Water and Soil Sample Collection. Samples are collected by qualified personnel on a monthly, quarterly, semi-annual and annual basis as referenced in the aforementioned documents.

Short summaries of methods used to collect samples and take field measurement readings can be found in sections 5.2.1 and 5.2.2, respectively. A brief synopsis of the major sampling events of 2H2019 in reference to location and analyte can be found below in sections 5.2.3 through 5.2.5.

5.2.1 Well and Surface Water Collection Procedure

Monitoring wells are purged and samples collected using a peristaltic pump, a submersible pump or bailers according to the physical constraints of the well. Surface waters are not purged and do not require pumps or specialized equipment. New, unused, pre-labeled bottles are rinsed with groundwater or surface water from the location sampled prior to collection unless a sample preservative is used. The sample is collected and the bottles are placed in individual sealed bags (to minimize possible cross contamination) and stored in a cooler with ice, blue ice or some other cooling block until they are delivered to AGTS. At the AGTS, samples are placed in a designated refrigerator to maintain sample preservation requirements, if needed. Chain of Custody (COC) forms are completed, signed and accompany samples that are shipped to a laboratory for analyses.

5.2.2 Procedure for Taking Field Measurements

Field measurements (parameters) consist of temperature, pH, conductivity, Oxidation-Reduction Potential (ORP) and Dissolved Oxygen (DO). These are taken at the time of sample collection subsequent to the monitoring well having been purged (not applicable for active extraction wells). Sample measurements are taken using field meters that are calibrated to NIST traceable

standards, if available. Samples are collected in a cup or bottle, briefly stirred and once stabilized a reading is taken and recorded on a paper and/or tablet form. Water level readings are also taken in the field using a sounder prior to the purging of the well. The field measurement data is uploaded to an electronic spreadsheet then transferred to a data warehouse which is backed up daily.

5.2.3 AGTS Plant Influent and Effluent Sampling Activities

During the reporting period, samples are collected on a daily basis per the NPDES permit as well as for operational purposes. Influent samples (INF) are obtained daily at a sample port immediately before the FBR vessels with weekly composites analyzed for perchlorate. Effluent water (EFF) is also sampled daily with weekly composites analyzed for perchlorate. These samples are also analyzed monthly and quarterly under the NPDES permit for total dissolved solids (TDS), sulfide, total inorganic nitrogen (TIN), ammonia, phosphorus, major anions, and total suspended solids (TSS).

5.2.4 Extraction Well Area Sampling Activities

AREW and APEW samples are collected in order to analyze perchlorate mass loading from each extraction well. Groundwater drawdown levels relative to static levels are measured in order to confirm reduced infiltration into the ADC via the lowering of the groundwater below the bottom of the ADC structure. The samples are collected on a quarterly basis for electron acceptors and field measurements.

5.2.5 Surface Water Sampling Activities

The subsurface and surface flood channels which transect the mitigation system area are monitored monthly during the reporting period to provide additional input for the system performance assessment and mass capture calculations. They are analyzed on a monthly basis for electron acceptors per the Rev. 2 SAP. The sample locations and parameters monitored include:

- Flow rate and concentration of perchlorate in waters flowing from the EGSD entering the ADC from the southwest at Boulder Highway and Galleria Drive.
- Athens Channel North-South (ACNS) for perchlorate to provide information on loss or gain of perchlorate along the AREWs.
- Concentrations of perchlorate in the French Drain (F6) which de-waters the residential area west of Wiesner Way (South Valley Ranch Subdivision).
- Total loading of the ADC (measured at ACMain), located east of Wiesner Way downstream of where the ACNS and F6 flows merge for perchlorate concentrations and flow rate.

These surface water sample locations are shown on Figure 1.

5.3 Data Assimilation

Geosyntec was retained by Endeavour LLC to provide an assessment of perchlorate mass captured by the AGTS system during the reporting period. All data from the reporting period used in the assessment were provided to Geosyntec by Endeavour LLC.

The mass captured by the combined shallow and deep WBZ extraction wells was assessed as follows:

- Shallow WBZ extraction system at Athens Road/Galleria Drive area: the system is designed to cut off the flow of perchlorate-impacted groundwater that is being transported in this WBZ toward the Las Vegas Wash area and other down-gradient discharge points, and therefore perchlorate percent capture (perchlorate mass capture compared to perchlorate mass not captured) is evaluated as the metric of effectiveness, and

- Deep WBZ extraction system in the Auto Mall area: the system is designed to reduce perchlorate mass in the deep WBZ that would otherwise contribute to an upward flux of perchlorate into the adjacent shallow WBZ and therefore the area of hydraulic containment and the perchlorate mass captured by deep WBZ wells (AMEWs) are evaluated as metrics of effectiveness.

5.4 Eastgate Storm Water Mitigation System Design

As first presented in the previous semi-annual/annual report dated August 15, 2019, Endeavour developed a Work Plan for the ESWM system that was approved by NDEP on August 5, 2019. It presents a project plan to capture a significant portion of the unabated EGSD water and pump it to the AGTS plant for perchlorate removal. The work plan also addresses design and construction of infrastructure improvements at the AGTS facility that include an overhead pipeline to eliminate potential bottlenecks and installation of a booster pump system on the effluent discharge line.

Endeavour has retained the engineering firm, Atkins, to provide detailed design of the sump, pumping, and collection system along with the associated infrastructure improvements at the AGTS facility. The design work was initiated in November 2019 and sixty-percent design packages are scheduled to be issued to Endeavour in the spring 2020.

6.0 Performance Data, Field Measurements, and Analytical Results

6.1 System Performance Data

As described in Section 5.1 above, the system flow rate averaged approximately 695 gpm during the 2H2019 reporting period. The following monthly performance breakdown is based on the first and second quarter data presented in the NPDES DMRs.

Month	Average System Flow Rate (gpm)	Average Influent ClO_4 Concentration (mg/L)	Average ClO_4 Destruction (pounds/day)	Total ClO_4 Destruction (pounds/month)
July	742	99.8	888	27,520
August	737	96.5	853	26,450
September	691	96.4	800	23,900
October	583	97.7	683	21,000
November	693	97.5	811	24,400
December	738	91.0	806	25,000

Approximate total perchlorate destroyed July – December, 2018: **148,260 pounds**
Approximate total gallons treated July – December, 2017: **184,732,000 gallons**

Average monthly perchlorate concentrations and average monthly flow for each of the AREWs, APEWs, and AMEWs for the reporting period is shown on Tables 1 (a,b), 2 (a,b), and 3 (a,b) respectively. The monthly average mass removal and the cumulative mass removal by the AREW and APEW extraction wells are also depicted in graphical form in Figures 4a and 5a respectively. Figures 4b and 5b pertain to the AMEWs. These figures were prepared by Geosyntec as part of the mass capture analysis of the Athens drainage area which is presented in Section 6.3 below.

6.2 Groundwater and Surface Water Monitoring Results

Groundwater monitoring data including level measurements, field parameters and laboratory analytical results for the reporting period are summarized in Sections 6.2.1 through 6.2.4 below. Samples collected in the field were either analyzed in the certified Endeavour laboratory or transported to Test America laboratories where the samples were analyzed by a Nevada-certified lab. The full laboratory analytical data reports are provided in electronic format in Appendix H. The data presented in these sections was used by Geosyntec to create the figures used in their assessment of groundwater hydraulics and mass capture presented in Section 6.3 and in Appendix A.

6.2.1 Monthly Monitoring Results

Monthly electron acceptor results for AC Main, Athens Channel North-South, Eastgate Storm Drain, and F6 French Drain surface water sample points are presented in Table 4.

6.2.2 Quarterly Monitoring Results

Quarterly sampling results for perchlorate, chlorate and other data are presented in Table 5. These include the fourteen extraction wells (AMEWs, AREWs and APEWs), and thirteen monitoring wells. The sample locations are shown on Figures 1 and 2.

6.2.2.1 Historical Quarterly Perchlorate Results

Selected historical quarterly sampling results for perchlorate are provided for the AREWs, APEWs, and AMEWs. Selected quarterly historical perchlorate results for the AREWs and APEWs are presented in Table 6 and Figure 6, and Table 7 and Figure 7, respectively. Similar historical perchlorate results for the AMEWs are presented in Table 8 and Figure 8.

6.2.3 Semi-Annual Monitoring Results

Semi-annual sampling for perchlorate, chlorate and field parameters for twelve monitoring wells that are in addition to the quarterly sampling points was performed during the reporting period as required per the Rev. 2 SAP. These are commonly referred to as the semi-annual samples and are presented in Table 9.

6.2.4 Surface Water Monitoring Results

Surface water along the Athens Drainage Channel was sampled monthly during this period and analyzed for two electron acceptors (perchlorate and chlorate) at four locations noted on Table 4 and Figure 1 (Monthly Samples). The locations are further described above in Section 5.2.5.

Flow measurements were recorded at the AC Main and EGSD sampling locations and provided to Geosyntec for use in their assessment of groundwater hydraulics and mass capture. The results of Geosyntec's analysis are presented in Section 6.3 below and in Appendix A.

6.3 Groundwater Hydraulics and System Performance Assessment

Prior to 2012, the groundwater extraction system included pumping only from the Shallow Water Bearing Zone (WBZ) in the Athens Road/Galleria Drive area and treatment by in situ biodegradation. During the second half of 2012 (2H2012), there was an expansion of the extraction system to include five Deep WBZ extraction wells in the Valley Auto Mall Area and a change in the groundwater treatment system to a fluidized bed reactor system. The newer treatment system has enabled treatment of the higher loading from the Deep WBZ wells in the Auto Mall area as well as higher pumping rates from the Shallow WBZ wells in the Athens Road/Galleria Drive area.

After a period of system startup, the pumping rates began to stabilize toward the later stages of the first half of 2013 (1H2013). The remainder of 2013 was still considered a "transitional period" with varying flow rates and operational durations. Since 2014, the extraction well pumping rates have been relatively stable, with the following notes on significant and modest changes:

- The previously unused APEW-1 was started on May 28, 2015. The extraction rate remained stable for a period at around 14 gpm. In 2H2017, the extraction rate increased to around 18 gpm. In 2H2018, the extraction rate increased to around 21 gpm. The well was shut down for a pump and motor replacement for three days in March 2019, and the extraction rate increased to 22 gpm by the end of 1H2019. In 2H2019, the extraction rate decreased to 20 gpm;
- APEW-2 had variable flow during 2014 and 2015, including a 9.5-week shutdown in 1H2014. In December 2015, the extraction rate increased from 12 gpm to 27 gpm. In 1H2017 through 1H2019, the extraction rate remained stable around 26-29 gpm. The well was operating at a reduced flow rate and shut down for several days in September 2019 due to maintenance work, and the extraction rate increased to 30 gpm by the end of 2H19;
- In 2H2019, AREW-1 was shut down for two months starting on September 25, 2019 for maintenance and replacement of pipe components within the vault. The extraction rate

increased to 16 gpm by the end of 2H2019, higher than the extraction rate of 10-12 gpm between 1H2017 and 1H2019;

- In 2H2019, AREW-2 was shut down for approximately six weeks starting on September 8, 2019 for maintenance and pump replacement. The extraction rate increased to 52 gpm by the end of 2H2019, higher than the extraction rate of 28-35 gpm between 1H2017 and 1H2019;
- In 2H2016, the extraction rate at AREW-4 increased from 9 to 16 gpm, and the extraction rate remained stable at around 16 gpm through 1H2017. The extraction rate increased slightly in 2H2017 and remained between 17 gpm and 24 gpm through 1H2019. In 2H2019, the extraction rate ranged from 21 gpm to 37 gpm;
- In 2H2019, AREW-5 was shut down for approximately three and a half weeks due to the FBR maintenance starting on October 19, 2019 and was down during most of the site-wide semi-annual monitoring event. When AREW-5 was operating in 2H2019, the extraction rate ranged from 104 gpm to 107 gpm, consistent with historical operations;
- In 1H2017, the extraction rate at AMEW-1 increased from 250 to 275 gpm, and remained stable through 2H2018. In 1H2019, the extraction rate ranged from 277 gpm to 280 gpm. In October/November 2019, all Auto Mall Extraction Wells were shut down or operated at lower extraction rates for approximately three weeks due to FBR system maintenance, as well as other facility maintenance. When AMEW-1 was operational in 2H2019, the extraction rate ranged from 275 gpm to 280 gpm;
- The extraction rate at AMEW-2 increased from 61 to 64 gpm in 2H2017. AMEW-2 was shut down for 25 days in 1H2019. When AMEW-2 was operational in 2H2018, 1H2019 and 2H2019, the extraction rate remained stable at around 61-64 gpm;
- AMEW-3 was shut down for 13 days in 1H2019 and remained stable around 51 gpm otherwise. When AMEW-3 was operational in 2H2019 the extraction rate ranged from 50 gpm to 53 gpm; and
- The extraction rate at AMEW-4 decreased from 39 to 31 gpm between 2H2017 and 1H2018 and remained around 31 gpm in 2H2018 when operational. In 1H2019, the extraction rate decreased to around 28 gpm. When AMEW-1 was operational in 2H2019, the extraction rate ranged from 17 gpm to 29 gpm.

This section assesses the mass captured by the combined Shallow and Deep WBZ extraction wells, assessed as follows.

- **Shallow WBZ extraction system at Athens Road/Galleria Drive area**: the system is designed to cut off the flow of perchlorate-impacted groundwater that is being transported in this WBZ toward the Las Vegas Wash area and other down-gradient discharge points, and therefore perchlorate percent capture (perchlorate mass capture compared to perchlorate mass not captured) is evaluated as the metric of effectiveness, and

- **Deep WBZ extraction system in the Auto Mall area**: the system is designed to remove perchlorate mass in the Deep WBZ that would otherwise contribute to longer-term persistence of perchlorate in the Shallow WBZ and therefore the area of hydraulic containment and the perchlorate mass capture by Deep WBZ wells are evaluated as metrics of effectiveness.

For purposes of this analysis, the following definitions are used:

Perchlorate loading (in units of pounds per day [lbs/day]) refers to the mass of perchlorate per unit time in groundwater moving across a given cross-sectional area.

Perchlorate mass capture (also lbs/day) refers the mass of perchlorate per unit time that is withdrawn from the sub-surface and treated by the AGTS.

Perchlorate percent capture refers to perchlorate mass loading capture as a percentage of the total perchlorate loading estimated at the extraction well locations.

6.3.1 Approach and Methodology

6.3.1.1 Calculation of Perchlorate Percent Capture in Shallow WBZ

The approach to evaluating perchlorate capture in the Shallow WBZ used the following steps:

- Delineate the capture zone(s) of the extraction wells using numerical and analytical methods;
- Quantify the perchlorate loading in:
  - surface water in the Athens Drainage Channel (ADC) (i.e., non-captured surface water perchlorate loading);
  - groundwater in the influent to the extraction system (i.e. perchlorate loading in extraction wells)
  - groundwater outside of the extraction wells capture zone (i.e., non-captured groundwater perchlorate loading).
- Sum the perchlorate loading in groundwater and surface water (i.e., the total perchlorate loading);
- Divide the perchlorate loading in the extraction wells by the total perchlorate loading to quantify the perchlorate percent capture.

The details of these calculations are provided below and are based on data collected during the semi-annual sampling event performed November 3 - 14, 2019. The following sections present the quantification of the three components of perchlorate loading that are used in the perchlorate percent mass capture calculation.

<u>Perchlorate Loading in Surface Water (Not Captured)</u>

The perchlorate loading in surface water is measured monthly in the Athens Drain Channel (ADC) at a location downstream of where groundwater seeps into the ADC but upstream of where the surface water re-infiltrates to the groundwater system (see Section II of the 2007 One Year Performance and Operations Optimization Program Report). The average loading of perchlorate in the ADC from July to December 2019 was 12.7 pounds per day (lbs/day) (Figure 9). The ADC perchlorate loading data derived from field and analytical measurements on November 4, 2018

was 10.9 lbs/day, which is the value used in the mass capture calculation presented in Section 6.3.2 below.[1]

Perchlorate loading was also monitored in the Eastgate Storm Drain (EGSD) that is upgradient and connects to the ADC. The monthly perchlorate loading in the EGSD is presented in Figure 10 and the average perchlorate loading from July to December 2019 was 13.5 lbs/day.

As noted in past reports, perchlorate loading in the ESGD has been increasing over the past several years due to increasing groundwater infiltration. Endeavour has committed to addressing this by means of a mitigation system that includes sump collection, pumping, and abatement via the FBR system. Perchlorate loading in the surface waters will continue to be tracked as the mitigation system is developed and after its implementation.

Perchlorate Loading in Shallow Groundwater Captured by the AGTS

The groundwater volumetric flow rate and perchlorate loading captured by the extraction system are based on directly measurable quantities of flow and concentration. The approximate perchlorate mass capture rates for the shallow extraction wells operating when the site-wide perchlorate groundwater samples were collected (November 3, 2019 through November 14, 2019) are presented in the following table (see Figure 1 for shallow extraction well locations).

Well	Average Operating Rate for 2H2019 Measurement Period (gpm)	Average Perchlorate Concentration for 2H2019 Measurement Period (mg/L)	Average Perchlorate Mass Removal Rate for 2H2019 Measurement Period (lbs/day)
APEW-3	6	56	4.0
APEW-1	20	0.44	0.1
APEW-2	29	10	3.5
AREW-1	0[2]	0.45	0.0
AREW-2	51	0.89	0.5
AREW-3	21	0.62	0.2
AREW-4	35	4	1.7
AREW-5	15[3]	14	2.5
AREW-6	24	32	9.2
Total	**201**	**--**	**21.7**

During this period, the total mass capture rate by the Athens Road/Galleria Drive Extraction Wells was approximately 22 lbs/day of perchlorate. This capture rate is significantly lower than historical

[1] The perchlorate loading at ADC Main measured in November, 2018 coincides with the monitoring and sampling event (November 3 – 14, 2019) that is used for estimating perchlorate loading in groundwater and perchlorate mass capture by the extraction system.

[2] AREW-1 was shut down for two months in 2H19, including during the monitoring period, for maintenance (Section 1.1).

[3] AREW-5 was shut down between October 18 and November 13, 2019; the extraction rate increased to 105 gpm on November 14, 2019 through the end of 2H19.

rates (around 35-40 lbs/day) because AREW-1 and AREW-5 were shut down during the monitoring period, and therefore is not representative of average conditions in 2H2019. The average mass capture rates and cumulative mass captured for all the individual extraction wells from October 2012 to December 31, 2019 are presented in Figures 4a and 5a, respectively.

Perchlorate Loading in Shallow Groundwater Not Captured by the AGTS

The perchlorate loading in groundwater that is not captured by the extraction system cannot be estimated based on directly measured quantities, but rather requires analysis of interpreted subsurface data. The loading in non-captured groundwater was estimated by establishing the capture zone of the Athens Road/Galleria Drive Extraction Wells and estimating the perchlorate loading in groundwater outside of this zone. The evaluation included the following steps:

- Estimation of the capture zone(s) of the extraction system following the multiple lines of evidence approach described in USEPA, 2008[4]
    - Use of the program KT3D-H2O[5] to create a potentiometric surface using linear-log kriging methodology, and calculate capture zones around extraction wells using particle tracking methodology (numerical method); and calculation of capture zones around extraction wells using particle tracking methodology.
    - Export of a raster surface representing the interpolated potentiometric surface and vector datasets representing the equipotential contours on a 5-foot elevation interval, and calculated capture zones.
    - Use of the equations detailed in Javandel and Tsang[6] to estimate the width of hydraulic capture achieved by each extraction well or extraction well series based on groundwater hydraulics analysis and using input parameters consistent with the current Endeavour numerical groundwater flow model.

- Estimate of perchlorate loading outside of the capture zone:
    - Use of the potentiometric surface map to develop a map of hydraulic gradients and convert gradients to groundwater volumetric flow rates by multiplying by aquifer transmissivity.
    - Generation of a map of perchlorate loading in groundwater by multiplying groundwater volumetric flow by the perchlorate concentration at each node of a grid that encompasses the region.
    - Overlay of the delineated capture zones from the numerical model to determine the perchlorate loading outside of the capture zone (the numerical method).

The above steps were accomplished by using a fixed grid for each of the mapped features (e.g. potentiometric head, transmissivity, gradient, etc.) such that the appropriate arithmetic operations

[4] U.S. EPA, 2008. A Systematic Approach for Evaluation of Capture Zones at Pump and Treat Systems – Final Project Report, Office of Research and Development. EPA 600/R-08/003. January. http:/www.epa.gov/ord."

[5] http://www.sspa.com/software/kt3d_h2o.html; Karanovic, M., Tonkin, M., and Wilson, D., 2009. KT3D_H2O: A Program for Kriging Water Level Data using Hydrologic Drift Terms. *Ground Water*, Vol. 47, No. 4, pp. 580-586.

[6] Javandel, I. and C.F. Tsang, 1986. Capture-Zone Type Curves: A Tool for Aquifer Cleanup, Ground Water, Vol. 24, No. 5, pp. 616-625.

could be applied to each cell of the grid. The specific procedures for accomplishing the above steps are described below.

Figure 11 shows the Shallow WBZ potentiometric surfaces generated by the KT3D-H2O software using data from Shallow WBZ monitoring wells and extraction well pumping rates during the measurement period. Contours were modified using professional judgment to better represent hydraulic interaction with the ADC and the presence of the “Muddy Creek High” zone.

Capture zones associated with the operating Athens Road Extraction Wells calculated using the numerical method are presented on Figure 11 as well as on Figure 13 (see discussion below). Figure 11 shows the particle tracks generated by the KT3D-H2O software from the Shallow WBZ potentiometric surfaces. KT3D-H2O is a simplified analytical approach; therefore, the lack of flow in the “Muddy Creek High” zone cannot be included in the evaluation using KT3D-H2O, which explains the apparent “gap” observed in the particle tracks showed in Figure 11. Additional refinements of the current groundwater flow model were performed by Geosyntec to better represent the groundwater flow in the shallow zone and the interaction with the Las Vegas Wash. Based on this refined model, the groundwater in the apparent “gap” flows very slowly towards the north.[7]

Capture zone widths (in feet) associated with each operating extraction well were calculated using the two methods shown below.

Extraction Well	**Operating Rate (gpm)**	**KT3D-H2O Method Capture Zone Width (ft.) Measured at 1,625 ft. msl**	**KT3D-H2O Method Capture Zone Width (ft.) Measured at 1,645 ft msl**	**Analytical Method Maximum Upgradient Capture Zone Width (ft)**
APEW-3	6	50	40	50
APEW-1	20	2,070	3,200	80
APEW-2	29			120
AREW-1	0			0
AREW-2	51			2,190
AREW-3	21			90
AREW-4	35			150
AREW-5	15			60
AREW-6	24			100
Total	**201**	**2,120**	**3,240**	**2,840**

[7] Geosyntec, 2017. Shallow Zone Capture Assessment – Revision 1, Endeavour, Henderson, NV, dated 23 March 2017 and sent to NDEP in an email dated 30 March 2017.

Figure 12 presents a map of perchlorate concentrations in the extraction area in the Shallow WBZ during the 2H2019 period.

Figure 13 presents a map of perchlorate loading per unit width in the shallow groundwater north of Warm Springs Road. Perchlorate loading in groundwater is a function of the chemical concentration and the volumetric flow rate of the water in which it is dissolved. Perchlorate loading in shallow groundwater that is not captured by the extraction wells is calculated by adding up the perchlorate loading linearly along equipotentials that are outside of the capture zones. In order to accomplish this, Figure 13 was generated by performing the following calculations, with each [parameter] shown in brackets representing a map of parameter values on a grid spacing of 10 feet by 10 feet.

1) [Saturated thickness (ft)] = [Potentiometric surface (ft)] – [Top of Middle WBZ formation (ft)]

2) [Transmissivity (ft^2/day)] = [Saturated thickness (ft)] * [Hydraulic conductivity (ft/day)]

3) [Volumetric flow/width (ft^3/day/ft)] = [Transmissivity (ft^2/day)]*[Gradient (ft/ft)]

4) [Loading/width (lbs/day/ft)] = [Volumetric flow/width (ft^3/day/ft)]*[Concentration (mg/L)]*CF

Where,

CF = (2.2×10^{-6} lbs/mg)*(28.3 L/ft^3) = 6.2×10^{-5} lbs*L/mg/ft^3

Top of Middle WBZ and Hydraulic conductivity distribution are obtained from the calibrated current Endeavour numerical groundwater flow model.[8]

And the gridded parameter values are presented in the following figures,

[Potentiometric surface (ft)] - Figure 11

[Concentration (µg/L)] – Figure 12

[Loading/width (lbs/day/ft)] - Figure 13

The gradient term was calculated at each cell in the grid using a slope analysis.

The perchlorate loading per unit width map for the Shallow WBZ (Figure 13) is presented in units of lbs/day/ft since the values represent loading per width perpendicular to flow. Therefore, a value of perchlorate loading in units of lbs/day can be generated by establishing a cross-sectional width along any potentiometric contour and multiplying the cross-sectional width by the average value in lbs/day/ft (equivalent to integrating the loading term along the line of section). The cross-section locations used for this calculation where chosen to be the 1,625 and 1,645 ft mean sea level [msl] potentiometric contours, as shown on Figure 13.

[8] Geosyntec, 2016. Groundwater Flow Model Update Henderson, Nevada. 13 September 2016.

The range in perchlorate loading not captured in shallow groundwater using these methods are shown in Section 6.3.2. Very few changes have been observed in the estimated perchlorate loading per unit width map north of the Shallow extraction system. The perchlorate mass located in this area in the Shallow WBZ is estimated in Section 6.3.2. Additional refinements of the current groundwater flow model were performed by Geosyntec to better represent the groundwater flow in the shallow zone and the interaction with the Las Vegas Wash.

6.3.1.2 Calculation of Perchlorate Mass Capture and Hydraulic Containment in Deep WBZ

The approach to evaluating perchlorate mass capture in the Deep WBZ depends on whether the evaluation coincides with an annual or semi-annual monitoring period. The complete set of Deep WBZ wells used to estimate the extent of the perchlorate groundwater concentration contours is sampled on an annual basis. The approaches to evaluating perchlorate mass capture in the Deep WBZ for both the annual and semi-annual sampling reporting periods are described herein using the following steps:

- Quantify the perchlorate mass capture in groundwater in the influent to the extraction system (i.e. perchlorate loading in extraction wells);
- Delineate the capture zone(s) of the extraction wells using the numerical method (as above); and
- Quantify the total mass of perchlorate in the Deep WBZ within the 700 parts per billion (ppb) contour (completed for annual reporting period only).

As this section presents the data from a semi-annual reporting period (2H2019), the total mass of perchlorate in the Deep WBZ within the 700 ppb contour is not calculated. The details of the calculations that were completed are provided below and are based on data collected during the site-wide water level survey performed November 3 - 14, 2019.

The following sections present the quantification of the perchlorate loading used in the perchlorate mass capture calculation.

<u>Perchlorate Loading in Deep Groundwater Captured by the AGTS</u>

The groundwater volumetric flow rate and perchlorate loading captured by the extraction system are based on directly measurable quantities of flow and concentration. The approximate perchlorate mass capture rates calculated for the deep zone extraction wells operating when the site-wide perchlorate groundwater samples were collected (November 3, 2019 to November 14, 2019) are presented in the following table (see Figure 14 for deep extraction well (AMEW) locations).

Well	Average Operating Rate for 2H2019 Measurement Period	Average Perchlorate Concentration for 2H2019 Measurement Period (mg/L)	Average Perchlorate Mass Removal Rate for 2H2019 Measurement Period (lbs/day)
AMEW-1	272	170	560
AMEW-2	61	180	130
AMEW-3	46	130	72
AMEW-4	21	84	21
AMEW-5	42	77	39
Total	**442**	**--**	**822**

During this period, the total mass capture rate of the Auto Mall Extraction Wells (Deep WBZ) was approximately 822 lbs/day of perchlorate. The approximate daily mass capture rates and cumulative mass captured for all the individual extraction wells operating from initial pumping in October 2012 to December 31, 2019 are presented in Figures 4b and 5b, respectively. The total extraction rate by the Auto Mall Extraction Wells increased from 358 gpm (1H2014) to 452 gpm (2H2016) to 471 gpm (1H2017) and remained stable at around 470 gpm in 2H2017 and 1H2018. The total extraction rate by the Auto Mall Extraction Wells increased to around 475 gpm in 2H2018 and then decreased to around 467 gpm in 1H2019 and 442 gpm in 2H2019. The total perchlorate mass capture was slightly lower in 2H2019 due to slightly lower extraction rates and slightly lower influent perchlorate concentrations. Given the higher flow rates and perchlorate concentrations when compared with the Shallow WBZ extraction wells, these Deep WBZ extraction wells provide the bulk of the perchlorate mass treated in the FBR-based AGTS.

Hydraulic Containment of Perchlorate in Deep Groundwater by the AGTS

Figure 14 shows a map of the potentiometric surface generated by the current Endeavour numerical groundwater flow model using data from Deep WBZ monitoring wells and extraction well pumping rates during the measurement period. Capture zones associated with the operating AMEWs were calculated using the numerical groundwater flow model.

Capture zone widths (in feet) associated with each operating extraction well were calculated numerically and are shown below.

Extraction Well	Operating Rate (gpm)	Capture Width (ft) Measured at 1,815 ft msl Equipotential	Capture Width (ft) Measured at 1,830 ft msl Equipotential
AMEW-1	272	4,970	4,880
AMEW-2	61		
AMEW-3	46		
AMEW-4	21		
AMEW-5	42		
Total	**442**	**4,970**	**4,880**

The calculated capture zones are slightly smaller to those previously estimated in 2017, 2018 and 1H2019, reflecting the small decrease of the extraction rates in 2H2019.

6.3.2 Perchlorate Mass Capture and Removal

6.3.2.1 Shallow WBZ Perchlorate Capture and Removal

The components of Shallow WBZ perchlorate loading described above can be combined to estimate the percentage of perchlorate mass captured by the shallow extraction system in 2H2018. The table below summarizes the perchlorate loading components, with cumulative ranges between the two equipotential measuring points (1,625 and 1,645 ft msl) used in the numerical calculations:

Perchlorate Loading	Groundwater	Surface Water (ADC)	Total
Captured (lbs/day) Not Captured (lbs/day) Total (lbs/day)	21.7 4.2 – 5.5 25.9 – 27.2	0 10.9 10.9	21.7 15.1 – 16.4 36.8 – 38.1
Fraction of Loading Captured (%)	80 – 84	0	57 – 59

Thus, the total perchlorate loading captured as a function of the total loading in groundwater is in the range of 82%. The total loading captured (i.e., groundwater and surface water) is in the range of 60%. This is slightly lower than in 1H2019 and 2018 due to the extraction wells undergoing maintenance and/or being temporarily down due to plant maintenance, including during the site-wide monitoring period.

An estimate of the total perchlorate mass in the Shallow WBZ within the 700 ppb contour was calculated based on the perchlorate contours (Figure 12) and an estimate of the Shallow WBZ thickness (20 ft) and of the porosity range (0.10 – 0.30[9]). The mass within the 700 ppb contour was calculated as the product of:

- the volume of the Shallow WBZ between each contour and the next greater contour; and
- The geometric mean of the measured concentrations above 100,000 ppb for the mass within the 100,000 contour;[10] or

[9] Prior to 2H19, an effective porosity range of 0.10 – 0.25 was used for the calculation. However, the range was updated following an evaluation of the mass estimate methodology. The higher value of 0.30 likely reflects value closer to the total porosity instead of the effective porosity, thereby accounting for mass that is present in groundwater that may not contribute to fluid flow but would still contribute to the total perchlorate mass in the subsurface.

[10] Only DX-30 is measured on an annual basis and the perchlorate concentration was below 100,000 ppb in 2H2018, therefore the geometric mean of the measured concentrations above 100,000 ppb from 1H2018 was used in the mass estimate.

- the concentration at half of the logarithmic scale between the two delineating contours for the lesser contours.

The calculated perchlorate masses are presented below:

Shallow WBZ Contour (ppb)	**Perchlorate Concentration (ppb)**	**Area (square feet)**	**Mass within contour (lbs)**	
			Effective Porosity	
			0.1	0.30
700	837	10,390,000	1,100	3,300
1,000	3,160	16,797,000	6,600	19,900
10,000	31,600	37,553,000	148,200	444,500
100,000	130,000	1,822,000	29,600	88,700
TOTAL		**66,562,000**	**185,500**	**556,400**

The mass estimate in the Shallow WBZ is similar in 2H2019 compared to 1H2019 for the effective porosity of 0.10 and proportionately higher for the total porosity of 0.30.

In addition, an estimate of the perchlorate mass in the Shallow WBZ in the area located north of the Shallow extraction system was calculated using the method outlined above. The mass in this area was estimated to be between 11,700 and 35,100 lbs assuming porosities of 0.1 and 0.30, respectively. This mass corresponds to approximately 6 percent of the total mass estimate in the Shallow WBZ. The shallow zone perchlorate contours north of the AREW extraction well system have been stable over time, as documented in the semi-annual monitoring reports, but increasing perchlorate concentrations have previously been observed at monitoring well MW-S. The perchlorate concentration stabilized at monitoring well MW-S in 1H2017 and remained stable in 1H2018; the perchlorate concentration at MW-S increased slightly in 1H2019 (Figure 21). This well is sampled on an annual basis and therefore was not sampled during the 2H2019 semi-annual reporting period. Additional evaluation of the concentration trend at this well will be performed in future monitoring events.

6.3.2.2 Deep WBZ Perchlorate Capture and Removal

As in the past, an estimate of the total perchlorate mass in the Deep WBZ within the 700 ppb contour will be calculated in the next annual report when the complete suite of perchlorate analyses (i.e., all annually sampled wells) is available.

The perchlorate capture rate in the Deep WBZ during 2H2019 was approximately 822 lbs/day.

A summary of Shallow and Deep WBZ mass capture for 2H2019 is presented below:

Zone	Total Extraction Well Flow Rate (gpm)	Total Perchlorate Mass Removal Rate (lbs/day)
Shallow WBZ	201	22
Deep WBZ	442	822
Total	**643**	**844**

As a result of adding the Deep WBZ extraction wells and installing the FBR system, the total flux of groundwater extracted and treated has increased from approximately 150 gpm (in the second half of 2011 [2H2011], when only the Shallow WBZ wells were operating) to almost 700 gpm (an increase by more than a factor of four since 2H2011). The total mass captured and treated has increased from about 36 lbs/day to as high as 1,600 lbs/day and then currently at approximately 840 lbs/day (an increase by a factor of around 25 since 2H2011). The total flux of extracted and treated groundwater and the total mass captured were slightly lower in 2H2019 at approximately 640 gpm and 840 lbs/day, respectively, due to lower extraction rates while the extraction wells and plant were undergoing maintenance work.

The average mass removed by the Deep WBZ extraction wells decreased from approximately 1,600 lbs/day in 1H2013 to approximately 822 lbs/day in 2H2019, while the average extraction rates increased from 360 to 442 gpm in the same period. The decrease in mass removal is due to expected decreasing influent concentrations at the extraction wells (AMEW-1, AMEW-2, and AMEW-4, in Figure 28), reflecting the decreasing perchlorate mass in the Deep WBZ. The total extraction rates remained relatively stable in 2017 and 2018 and decreased slightly in 1H2019. The total extraction rates decreased further in 2H2019. The influent concentrations decreased between 2018 and 2017 and remained mostly stable in 2018 and 2019. It is anticipated that this decreasing mass removal trend will continue as perchlorate mass decreases in the Deep WBZ. This metric will continue to be tracked in the following monitoring periods to assess the trend.

The uncertainties associated with the method for mass capture and perchlorate loading estimate include the following:

a. These methods rely on interpolation of concentration and water levels, and the interpolated values can be expected to have decreased confidence with distance from measurement points;

b. The hydraulic gradient is calculated at each cell in the grid, so sharp changes in equipotential direction might yield erroneous gradients in certain cells; and

c. These methods assume the hydraulic conductivities assigned to each conductivity zone are constant across those zones, when in fact they may vary.

The uncertainties associated with the methods for mass estimate include the following:

a. These methods rely on interpolation of concentration and the interpolated values can be expected to have decreased confidence with distance from measurement points; and
b. The mass estimate is based on an estimated value for porosity in the Shallow and Deep WBZs.

6.3.3 Remediation Tracking

Remediation tracking was conducted for the Shallow WBZ as outlined in the Work Plan for Demonstration of Groundwater Capture.[11] Remediation tracking metrics for the Deep WBZ are calculated annually (corresponding with the greater number of wells sampled on an annual basis) and are included in the table below. Several metrics are used to track the progress of the AGTS. After several years of consistent operation, some of these metrics start displaying trends which will need to be confirmed over the following monitoring periods.

The estimation of the concentration at which 90% and 99% capture is achieved is limited to the precision at which concentration contours can be reasonably drawn on the available data.

[11] Geosyntec, 2013. Work Plan for Demonstration of Groundwater Capture. Groundwater Extraction Systems Henderson, Nevada. September 18, 2013.

Metric	Metric Value														
	2H19^	1H19	2H18	1H18	2H17	1H17	2H16	1H16	2H15	1H15	2H14	1H14	2H13	1H13	2H12
Shallow Water Bearing Zone															
Total mass of perchlorate within 700 ppb contour (lbs)^	185,500 – 556,400	181,000 - 452,400	181,700 - 454,200	182,000 - 454,700	179,100 - 447,600	183,000 - 460,000	175,000 - 440,000	175,000 - 440,000	200,000 - 505,000	200,000 - 510,000	210,000 - 510,000	210,000 - 510,000	210,000 - 510,000	210,000 - 500,000	210,000 - 530,000
Estimated Concentration at which 90% capture is achieved (Shallow WBZ) (ppb)	>1,000	>1,000	>1,000	>1,000	>1,000	>1,000	>1,000	>1,000	>1,000	>1,000	>1,000	>1,000	>1,000	>1,000	n/a
Estimated Concentration at which 99% capture is achieved (Shallow WBZ) (ppb)	>700	>700	>700	>700	>700	>700	>700	>700	>700	>700	>700	>700	>700	>700	n/a
Estimated Coordinates of the Centroid* of the Perchlorate Contours (Shallow WBZ) 700 ppb contour	E 823,254 N 26,723,624	E 823,254 N 26,723,624	E 823,253 N 26,723,626	E 823,253 N 26,723,626	E 823,225 N 26,723,676	E 823,230 N 26,723,710	E 823,200 N 26,723,700	E 823,200 N 26,723,700	E 823,100 N 26,723,700	E 823,100 N 26,723,700	E 822,900 N 26,723,600	E 822,900 N 26,723,600	E 822,900 N 26,723,700	E 822,900 N 26,723,700	E 820,700 N 26,718,400
Estimated Coordinates of the Centroid* of the Perchlorate Contours (Shallow WBZ) 1,000 ppb contour	E 823,362 N 26,723,599	E 823,362 N 26,723,599	E 823,359 N 26,723,595	E 823,359 N 26,723,595	E 823,348 N 26,723,409	E 823,380 N 26,723,650	E 823,300 N 26,723,700	E 823,300 N 26,723,700	E 823,300 N 26,723,600	E 823,300 N 26,723,600	E 823,000 N 26,723,600	E 823,000 N 26,723,600	E 823,000 N 26,723,700	E 823,000 N 26,723,600	E 823,000 N 26,723,000
Estimated Coordinates of the centroid* of the Perchlorate Contours (Shallow WBZ) 10,000 ppb contour	E 823,309 N 26,723,191	E 823,309 N 26,723,191	E 823,309 N 26,723,191	E 823,310 N 26,723,194	E 823,186 N 26,723,035	E 823,310 N 26,723,200	E 823,300 N 26,723,700	E 823,300 N 26,723,300	E 823,300 N 26,723,200	E 823,300 N 26,723,300	E 823,200 N 26,723,100	E 823,200 N 26,723,100	E 823,200 N 26,723,000	E 823,100 N 26,722,900	E 823,100 N 26,722,600
Estimated Coordinates of the Centroid* of the Perchlorate Contours (Shallow WBZ) 100,000 ppb contour	E 819,960 N 26,717,906	E 819,960 N 26,717,906	E 819,960 N 26,717,906	E 819,960 N 26,717,906	E 819,960 N 26,717,906	E 819,950 N 26,717,910	E 820,000 N 26,717,900	E 820,000 N 26,717,900	E 820,100 N 26,718,200	E 820,100 N 26,718,200	E 820,300 N 26,718,200	E 820,300 N 26,718,300	E 820,300 N 26,718,300	E 820,300 N 26,718,300	E 823,100 N 26,722,300
Average Daily Perchlorate Capture Rate (lbs/day) (Shallow WBZ)	22	37	34	39	34	36	38	38	38	41	42	50	60	62	36
Estimated Perchlorate Loading Not Captured by AGTS at Athens/Galleria Extraction Area (lbs/day)	15 - 16	17 - 18	16 - 17	24 - 25	22 - 24	23 - 24	16 - 17	13 - 15	13 - 14	20 - 21	9 - 10	18 - 19	10 - 12	17 - 18	n/a
Deep Water Bearing Zone															
Total mass of perchlorate within 700 ppb contour (lbs)^	n/a	421,800 – 1,054,500	n/a	420,000 - 1,050,100	n/a	430,000 - 1,070,000	n/a	460,000 - 1,160,000	n/a	430,000 - 1,080,000	n/a	500,000 - 1,240,000	n/a	670,000 - 1,670,000	830,000 - 2,090,000
Rounded Average Daily Perchlorate Capture Rate (lbs/day) (Deep WBZ)	822	930	970	950	1,000	1,100	1,100	1,100	1,200	1,200	1,200	1,200	1,400	1,600	n/a

* Centroid coordinates based on Nevada State Plane NAD83 South System, Feet

6.4 Monitoring Well Trend Analysis

Figures 15 through 30 show historical perchlorate and groundwater elevation trends in select wells within each of the shallow, middle, and deep WBZs. Figures 15 through 24 show shallow WBZ wells, Figures 25 through 27 are middle WBZ, and Figures 28 through 30 are deep WBZ. Some noteworthy observations of the trends in each of the WBZs as depicted in these figures are discussed in the paragraphs below.

Deep WBZ

As discussed in previous reports, the following wells indicate a continued decreasing perchlorate concentration trend:

- Monitoring well AEX-135 located in the Auto Mall South Area (Figure 28), and
- Monitoring well DZ-152 and MW-C located in the Auto Mall West Area (Figure 29).

These decreasing trends are consistent with the significant mass removal (822 pounds per day) achieved with the AMEWs and the associated mass decrease in the Deep WBZ. These wells are sampled on an annual basis and will continue to be monitored to confirm the decreasing perchlorate concentration trends.

Data for extraction wells AMEW-1, AMEW-2 and AMEW-4 (Figure 28) also present a decreasing perchlorate concentration trend, following the initial increase observed after start-up, while extraction wells AMEW-3 and AMEW-5 (Figure 28) present a stable perchlorate concentration trend, following the initial increase observed after start-up.

In 2019, perchlorate concentrations increased slightly at DX-270 (Figure 28), which typically shows a stable perchlorate concentration trend. This well is sampled on an annual basis and will continue to be monitored to evaluate the perchlorate concentration trend. Perchlorate concentrations have fluctuated but shown an overall decreasing or stable perchlorate trend at monitoring wells DX-161, DY-169, and AMOW-3-165, located in the Auto Mall South Area (Figure 28). These three monitoring wells are located close to extraction wells AMEW-1, AMEW-2 and AMEW-3, and the fluctuations in perchlorate concentrations are likely related to the changes in flow field and perchlorate distribution in the vicinity of the extraction well. Perchlorate concentrations at monitoring well ADX-156, located in the vicinity of extraction well AMEW-4 (Figure 28), have also fluctuated but shown an overall decreasing trend.

Monitoring wells AFX-148, ADYX-165 and AFX-195, located in the Auto Mall East Area (Figure 30), presented an initial decrease in perchlorate concentrations following start-up of the AMEWs between 2012 and 2014, followed by an increasing trend between 2015 and 2018. These wells all had a decrease in perchlorate concentration in 2019. Monitoring wells AK-204 and AMX-166, located in the Auto Mall East Area (Figure 30), have presented stable to decreasing perchlorate concentration trends since the start-up of the AMEWs. These wells are sampled on an annual basis and therefore additional data will be necessary to continue assessing the perchlorate concentration trend at these locations.

Monitoring well MW-AX-72 (located in the Auto Mall West Area, Figure 29) presents an increasing trend between 2005 and 2012, a more significant increasing trend following start-up of the AMEWs between 2012 and 2015, and a decreasing trend between 2015 and 2019. This well is sampled on an annual basis and therefore additional data will be necessary to confirm the decreasing perchlorate concentration trend at that location.

Monitoring well AEX-166 (located in the Auto Mall South Area, Figure 28) presents an increasing trend between 2005 and 2012, a decreasing trend following start-up of the AMEWs between 2012 and 2015, and an increasing trend/concentration fluctuations between 2015 and 2019. Well AEX-166 is located in the vicinity of extraction well AMEW-5 with perchlorate concentrations around 80,000 µg/L, and the perchlorate concentration fluctuations at AEX-166 were likely related to the change in flow field and perchlorate distribution in the vicinity of the extraction well.

The perchlorate concentrations at monitoring wells LX-150 and MW-D2D located in the Auto Mall West Area (Figure 29) have been fairly stable since 2000. These wells are sampled on an annual basis and will continue to be monitored for any changing perchlorate concentration trends. Monitoring wells FX-415, AGX-230, FX-180, AGX-190, and ADY-166 in the Auto Mall East Area (Figure 30) have presented fluctuating perchlorate concentration trends but overall remained stable or decreased slightly. These wells are sampled on an annual basis and will continue to be monitored to confirm the decreasing perchlorate concentration trends.

Monitoring well DX-350 (located in the Auto Mall West Area, Figure 29) presents a fluctuating perchlorate concentration trend. This trend is most probably related to the change in flow field and perchlorate distribution, following start-up of the AMEWs. Well DX-350 is located in the vicinity of extraction well AMEW-1 with perchlorate concentrations around 170,000 µg/L. AMEW-1 is screened to 235 feet below ground surface (bgs), while DX-350 is screened between 350 and 370 feet bgs. Prior to remedy startup, DX-350 perchlorate concentrations increased from approximately 400 µg/L in 2005 to 3,000 µg/L in 2012. Since start-up of the AMEWs in 2012, the perchlorate concentrations have fluctuated between 1,300 and 3,000 µg/L, but there has not been an increase in concentration relative to that observed prior to startup. This well is sampled on an annual basis, and the perchlorate concentration will continue to be monitored at this well to confirm that it has stabilized.

All monitoring wells located in Auto Mall East Area (Figure 30) present perchlorate concentrations below 100 µg/L. Well AFX-195 had increasing perchlorate concentrations from 4 µg/L in 1H2014 to 680 µg/L in 1H2018 and decreased to 90 µg/L in 1H2019. Well AFX-195 is located at the eastern edge of the perchlorate Deep WBZ where there are likely significant spatial variations in perchlorate concentrations. These wells are sampled on an annual basis and the perchlorate concentration trend at these wells will continue to be monitored.

<u>Middle WBZ</u>

The effect of the AMEWs on the groundwater elevations is significant in monitoring wells DX-75, ADX-112, and DX-121, located in Auto Mall South Area (Figure 25) and AMX-98, AGX-160, DY-106, AGX-190, and AK-86 located in Auto Mall East Area (Figure 26).

In addition, monitoring wells ADX-112, DX-121, and MW-AX-72, located in the Auto Mall South Area (Figure 25), ZX-45, F3-90, and AK-86, located in Auto Mall East Area (Figure 26), and JX-86, PX-40, TWA-180, TWC-126, TWE-107, and TWB-140, located in Sunset/Boulder Area (Figure 27), present a change in perchlorate concentration trend (from increasing to stable and/or decreasing) following start-up of the AMEWs in October 2012. The perchlorate concentrations at TWB-51 and TWC-48, located in the Sunset/Boulder Area (Figure 27), fluctuated between 2012 and 1H2019 and increased in 1H2019. In 2H2019, the perchlorate concentration at TWB-51 decreased slightly. Except for TWB-51, these wells are sampled on an annual basis and therefore additional data will be necessary to confirm the decreasing perchlorate concentration trend.

Shallow WBZ

South of Warm Springs Road, several shallow monitoring wells listed below show a decreasing perchlorate concentration trend or changed from an increasing trend to a stable trend, likely in response to start-up of the AMEWs and the intended reduction in perchlorate mass flux from the deep to the shallow WBZ.

- Monitoring well MW-AD, MW-D2S (this well is sampled on an annual basis and has been dry since 1H2017; therefore, no sample has been collected), MW-X, MW-I, F3-27, DX-24 and DZ-15, located in Auto Mall East Area (Figure 15),
- MW-AHX, AK-25, and AEX-35 located in Auto Mall West Area (Figure 16), and
- WS1-14 (the perchlorate concentration at this well has been stable or decreasing since 2013), ACY-15, WS5-80, and ZX-11, located in Warm Springs/Eastgate Area (Figure 17).

In contrast, AGX-50 and AMOW-3-52 located in the Auto Mall West Area (Figure 16) show an increasing perchlorate concentration trend. AGX-50 shows a decreasing trend starting in 2015, while AMOW-3-52 shows a stabilization of perchlorate concentration since 2014. The perchlorate concentration at WS4-11 has fluctuated since 2012.

In the vicinity of the AREWs/APEWs (shallow groundwater extraction system), the monitoring wells showed a decreasing trend in groundwater elevations which coincides with the gradual increase in drawdown effects and reduction in flow from the extraction wells. The following wells show a decreasing perchlorate trend since the start-up of the AREWs/APEWs in 2006-2007.

- Monitoring wells NX-17, NY-15, OX-16, and OY-8, located in Boulder/Galleria Area (Figure 20),
- TWE-33 and APX-5-16 located in AGTS Area (Figure 21) (decreasing or stable since 2012), and
- AAX-15, APX-2-P101 (decreased since 2010), APX-7-14, MW-AA, SBMW-4-4, and SB-3-13, located in the Wiesner/Sam Boyd Area (Figure 22).

In contrast, monitoring wells MW-S, APX-4-20, and MW-K1 located in the AGTS Plant Area (Figure 21), present an increasing perchlorate concentration trend. Potential causes for the increasing trend in perchlorate concentration at the monitoring wells include:

- MW-K1 is located close to the eastern edge of the targeted area. The Nevada Environmental Response Trust (NERT) Athens Road Well Field is located northeast of MW-K1 and the Shallow WBZ potentiometric surface in this area suggests that the NERT well field might cause an easterly shift in the direction of groundwater flow in this area. Because of the presence of higher concentrations on the west side of MW-K1, a slight change of the groundwater flow field to a more easterly direction will result in increasing perchlorate concentrations at MW-K1.
- APX-4-20 is located in the vicinity of the Muddy Creek High, between extraction wells APEW-2 and APEW-3. The perchlorate concentrations at APX-4-20 increased between 2007 (start-up of the AREWs/APEWs) and 2015 and have been stable since 2016. The increasing concentrations were likely the result of perchlorate leaching from the low permeability Muddy Creek High. The concentrations at the other monitoring wells located in the vicinity of APX-4-20 (APX-5-7 [which had been increasing between 2007 and 2012, and stable since 2012], PC-107, and APX-5-16 in Figure 21 and APX-2-45 in Figure 22) have been stable. APX-4-20 is sampled on an annual basis and therefore additional data will be necessary to characterize a current perchlorate concentration trend.
- MW-S is located north of the AREWs/APEWs (Figure 21). The perchlorate concentrations at MW-S increased between 1997 and 2006 and increased between 2013 and 2016. Those increasing concentrations were likely indicating that higher than expected perchlorate mass was present north of the AREWs/APEWs. The perchlorate concentrations stabilized between 1H2016 and 1H2019, and additional data will be necessary to characterize a current perchlorate concentration trend at that location. The ongoing NERT investigations north of MW-S will support additional evaluation of the groundwater flow field and perchlorate concentrations in this area. This evaluation is pending the publication of the NERT Remedial Investigation Report.

7.0 Summary and Conclusions

Forward flow through the AGTS plant to the effluent line continued in 2H2019 averaging approximately 695 gpm. The plant flow rate was lowered to approximately 700 gpm between September 17 and October 18, 2019 due to flow and pressure issues in the effluent pipeline. A comprehensive maintenance and inspection project was performed on FBR-140 in October with no flaws or damage found on the fluidization nozzles or laterals. The plant flow rate was approximately 415 gpm during the week-long project, and was gradually increased up to full flow at approximately 740 gpm in November 2019.

Compliance with permit and regulatory action limits was achieved in samples collected during the reporting period. The long-awaited renewed NPDES discharge permit was officially issued on August 15, 2019. The optimized FBR-based system continued to perform well on a perchlorate mass reduction basis. The total mass of perchlorate destroyed during 2H2019 was approximately 148,260 pounds and the total amount of water treated was approximately 184,732,000 gallons.

Design work for the ESWM system and the associated infrastructure improvements at the AGTS facility was commenced in November 2019. Sixty-percent design packages are being prepared by the engineering firm, Atkins, and anticipated to be submitted to Endeavour in the spring 2020.

Several monitoring and extraction wells in the deep WBZ showed a continued decreasing perchlorate concentration trend during the 2H2019. In the shallow WBZ several wells show a decreasing perchlorate concentration trend or changed from an increasing trend to a stable trend, likely in response to start-up of the AMEWs in 2013 and the intended reduction in perchlorate mass flux from the deep to the shallow WBZ. A couple of wells, however, show an increasing trend most likely due to heterogeneous conditions in the WBZ. Most of the monitoring wells that are used to optimize the groundwater models and monitor system performance are sampled in the annual event in April-May, 2020 and therefore the key trends will be further observed in the next reporting period.

The results of Geosyntec's performance analysis and mass capture calculations for the 2H2019 reporting period showed that the total perchlorate loading captured in the shallow water bearing zone (Athens/Galleria area) as a function of the total loading in that groundwater was in the range of 80% to 84% and the total loading captured (groundwater and surface water) was in the range of 57% to 59%. This is slightly lower than in 1H2019 and 2018 due to the extraction wells undergoing maintenance and/or being down due to plant maintenance, including during the site-wide monitoring period. The average loading of perchlorate in the Athens Drainage Channel from July to December 2019 was 12.7 lbs/day. The daily average perchlorate captured from the deep water bearing zone was calculated to be approximately 822 lbs/day.

8.0 Plan and Recommendations

Endeavour LLC will continue operation of the FBR perchlorate treatment system 24 hours per day, 7 days per week. The first stage FBRs have shown steady performance during the 2H2019 reporting period. Bioassays will continue to be conducted on the FBR biomass/media on a regular basis in the foreseeable future to monitor performance. Also, communication and information exchanges with consultant Dr. John Coates of UC Berkeley will continue.

Increases in total mass and corresponding drawdown effects of the AMEWs will be pursued and observed, and hydraulic balancing in the FBRs will be appropriately managed with any increase in flow. Progress on design for the ESWM project and infrastructure will continue into the next reporting period while monitoring and evaluation of the perchlorate loading in the ADC will continue on a monthly basis.

9.0 Limitations

The conclusions and recommendations presented herein are based on analytical data, field measurements, survey data and results of previous environmental assessment and/or treatment activities. The results reported herein are applicable to the time the sampling occurred. Changes in site conditions may occur as a result of rainfall, snowmelt, water usage, or other factors. Endeavour LLC exercised due diligence in selecting consultants and laboratories.

This report is not a legal opinion. The tasks performed by and for Endeavour LLC have been conducted in a manner consistent with the level of care ordinarily exercised by members of the environmental profession currently practicing under similar conditions.

The use of the word "certify" in this document constitutes an expression of professional opinion regarding those facts or findings which are the subject of the certification and does not constitute a warranty or guarantee, either expressed or implied.

TABLES

Table 1a - Athens Road Extraction Wells (AREW) Average Monthly Perchlorate (mg/L)						
Date	**AREW-1**	**AREW-2**	**AREW-3**	**AREW-4**	**AREW-5**	**AREW-6**
January 2014	1.0	1.9	1.5	4.7	16	52
February 2014	0.9	1.7	1.2	4.5	17	48
March 2014	0.9	1.3	1.3	4.4	17	47
April 2014	1.0	1.4	1.7	5.1	17	44
May 2014	1.0	1.2	2.2	5.3	18	49
June 2014	0.9	1.1	1.6	5.0	18	45
July 2014	0.9	1.1	1.5	4.7	17	44
August 2014	0.9	1.0	1.6	4.4	17	42
September 2014	0.9	1.1	1.6	4.7	18	46
October 2014	0.8	1.1	1.6	4.5	16	42
November 2014	0.9	1.2	1.3	3.9	15	44
December 2014	0.8	1.4	1.6	2.4	16	43
January 2015	0.9	2.0	1.7	5.0	15	46
February 2015	0.9	1.9	1.7	5.1	15	45
March 2015	0.8	1.4	1.6	4.9	14	45
April 2015	0.8	1.1	1.5	4.6	15	44
May 2015	0.9	1.2	1.5	4.5	15	50
June 2015	0.9	1.0	NS	3.6	15	47
July 2015	0.9	1.0	1.9	3.7	13	43
August 2015	0.8	1.0	1.3	3.7	16	49
September 2015	0.8	1.0	1.3	3.5	14	46
October 2015	0.8	0.9	1.1	NS	11	43
November 2015	1.0	1.4	1.3	3.4	14	44
December 2015	NS	NS	NS	NS	NS	NS
January 2016	0.7	1.3	1.1	3.0	12	41
February 2016	0.8	1.1	1.1	3.0	13	46
March 2016	0.8	1.0	1.2	3.2	13	44
April 2016	0.8	0.9	1.1	3.0	13	43
May 2016	NS	NS	NS	NS	NS	NS
June 2016	0.8	1.0	1.1	3.4	14	45
July 2016	0.8	0.9	1.0	2.8	13	42
August 2016	0.7	0.8	0.9	2.5	13	43
September 2016	0.7	0.8	0.9	2.5	13	47
October 2016	NS	NS	NS	NS	NS	NS
November 2016	0.7	0.8	0.8	2.8	13	46
December 2016	NS	NS	NS	NS	NS	NS
January 2017	0.66	1.6	0.94	2.5	12	47.0
February 2017	0.66	1.2	0.80	2.1	11	46
March 2017	NS	NS	NS	NS	NS	NS
April 2017	0.59	0.97	0.80	2.1	12	46
May 2017	NS	NS	NS	NS	NS	NS
June 2017	0.63	0.89	0.82	2.2	12	47
July 2017	NS	NS	NS	NS	NS	NS
August 2017	0.61	0.73	0.79	2.2	12	45
September 2017	0.58	0.80	0.81	1.6	10	41
October 2017	0.60	0.84	0.81	1.8	9.7	43
November 2017	0.58	1.0	0.74	2.3	11	51
December 2017	0.63	1.5	0.80	2.6	11	42
January 2018	0.64	1.7	0.89	2.8	12	42
February 2018	0.62	1.4	0.89	2.1	11	41
March 2018	0.46	1.2	0.60	2.4	12	41
April 2018	NS	NS	NS	NS	NS	NS
May 2018	0.55	0.78	0.74	3.0	14	43
June 2018	0.44	0.91	0.72	2.3	12	42
July 2018	0.50	0.64	0.72	2.3	13	40
August 2018	0.63	0.81	0.88	2.8	15	47
September 2018	0.57	0.82	0.85	2.2	12	41
October 2018	0.65	0.70	0.75	2.9	13	42
November 2018	0.52	1.2	0.70	2.4	12	35
December 2018	0.57	1.4	0.82	2.2	12	41
January 2019	0.75	1.7	0.80	1.9	11	40
Feburary 2019	0.58	1.4	0.93	1.8	12	39
March 2019	0.45	1.0	0.68	2.0	12	41
April 2019	NS	NS	NS	NS	NS	NS
May 2019	0.55	0.78	0.74	2.5	13	43
June 2019	0.52	0.7	0.57	2.3	12	40
July 2019	0.54	1.1	0.68	2.5	12	41
August 2019	0.45	0.65	0.63	2.4	12	38
September 2019	0.61	0.5	0.69	2.1	11	39
October 2019	0.57	0.8	0.65	2.1	11	39
November 2019	0.45	0.89	0.62	4.0	14	32
December 2019	0.81	1.3	0.53	2.5	11	37
Screen Interval (feet bgs)	25-35	25-40	25-35	24-34	30-45	25-40
Lithological Classification	Qal/xMCf	Qal/xMCf	Qal/xMCf	Qal/xMCf	Qal/xMCf	Qal/xMCf
Water Bearing Zone	Shallow	Shallow	Shallow	Shallow	Shallow	Shallow
Approx. Operating Depth to Water (feet)	30.4	32.6	29	32	28.5	31

Table 1b - Athens Road Extraction Wells (AREW) Average Monthly Flow (GPM)						
Date	**AREW-1**	**AREW-2**	**AREW-3**	**AREW-4**	**AREW-5**	**AREW-6**
January 2014	21.1	55.0	24.3	24.6	105	20.9
February 2014	30.6	53.9	24.2	24.3	104	24.5
March 2014	30.5	53.7	24.1	24.2	104	24.4
April 2014	30.3	53.3	24.0	23.2	104	24.2
May 2014	30.3	53.1	23.9	19.9	104	24.1
June 2014	30.2	53.2	23.9	18.9	105	23.9
July 2014	29.6	52.8	24.0	17.2	105	23.9
August 2014	29.6	52.4	24.0	16.3	105	23.9
September 2014	17.0	53.2	24.3	16.5	107	22.4
October 2014	29.4	51.3	23.8	15.6	106	23.7
November 2014	19.7	34.2	24.3	16.6	110	24.0
December 2014	29.7	51.6	24.1	15.1	108	24.0
January 2015	29.8	51.4	24.1	14.1	109	24.0
February 2015	29.6	51.5	24.2	13.7	103	23.9
March 2015	29.4	51.1	23.9	13.7	100	23.6
April 2015	26.7	49.5	23.7	11.8	102	23.8
May 2015	24.1	46.6	23.5	10.1	102	23.7
June 2015	21.3	46.9	6.3	10.2	102	23.5
July 2015	20.1	42.7	24.1	8.3	101	23.3
August 2015	18.9	40.4	24.2	7.6	101	23.5
September 2015	17.9	39.1	24.2	7.5	101	23.5
October 2015	18.2	28.0	24.4	3.9	102	23.4
November 2015	17.6	44.3	24.3	10.0	101	19.4
December 2015	17.0	42.2	24.3	9.4	101	23.4
January 2016	16.1	38.4	24.2	8.3	101	23.3
February 2016	15.4	36.4	23.7	8.2	99	22.8
March 2016	14.0	33.3	24.1	7.3	100	23.3
April 2016	13.0	30.7	24.0	6.6	100	23.2
May 2016	13.1	30.6	24.0	7.2	100	23.1
June 2016	13.6	31.3	23.8	8.1	99	23.1
July 2016	12.3	32.9	23.9	9.1	100	23.5
August 2016	12.2	33.1	24.1	10.4	101	23.4
September 2016	12.2	34.4	23.9	11.9	101	23.2
October 2016	13.5	34.9	24.3	12.9	102	23.4
November 2016	15.8	37.3	23.7	16.7	76	22.8
December 2016	12.6	38.1	24.3	16.1	102	23.3
January 2017	12.0	38.0	24.4	16.5	103	23.3
February 2017	12.0	37.9	24.4	16.8	102	23.2
March 2017	12.1	35.9	24.5	17.3	104	23.4
April 2017	12.0	41.8	24.3	16.9	103	19.2
May 2017	12.0	38.7	24.3	16.2	103	24.2
June 2017	12.0	37.2	24.3	15.6	103	24.1
July 2017	11.9	36.5	24.2	14.7	103	24.2
August 2017	11.9	36.7	24.2	17.2	103	24.3
September 2017	11.9	36.7	24.3	18.3	102	24.2
October 2017	11.9	37.4	24.3	19.7	103	24.0
November 2017	11.9	35.8	24.3	20.1	103	23.9
December 2017	11.9	34.8	24.3	20.3	103	23.8
January 2018	11.9	33.6	24.4	20.3	103	23.8
Feburary 2018	11.9	33.1	24.4	21.1	103	23.7
March 2018	11.9	32.5	24.4	21.3	103	23.8
April 2018	11.8	31.2	24.3	20.7	103	23.9
May 2018	11.7	29.7	24.3	19.7	103	23.8
June 2018	11.0	28.4	24.2	18.4	103	23.8
July 2018	10.6	28.9	22.9	19.6	85	22.3
August 2018	10.9	29.4	24.1	14.8	103	23.8
September 2018	8.1	27.5	23.1	19.0	84	22.7
October 2018	11.5	31.0	24.3	19.0	55	23.8
November 2018	10.6	29.8	24.1	20.4	104	23.7
December 2018	9.7	28.9	24.1	18.8	103	23.6
January 2019	9.7	29.4	24.1	18.2	104	23.6
Feburary 2019	9.6	29.0	24.1	18.9	104	23.6
March 2019	9.8	29.8	24.1	21.0	104	23.6
April 2019	10.4	31.3	24.0	22.3	103	23.4
May 2019	10.5	31.7	24.1	22.9	104	23.3
June 2019	10.3	32.3	24.1	23.8	104	23.7
July 2019	9.9	32.6	24.0	23.6	104	24.1
August 2019	9.4	31.8	24.0	22.9	104	24.0
September 2019	8.0	7.0	18.6	24.2	106	22.1
October 2019	0.0	21.6	24.5	27.5	60	24.0
November 2019	3.7	51.6	10.0	30.8	62	23.4
December 2019	15.8	52.6	0.0	27.3	105	18.6
Screen Interval (feet bgs)	25-35	25-40	25-35	24-34	30-45	25-40
Lithological Classification	Qal/xMCf	Qal/xMCf	Qal/xMCf	Qal/xMCf	Qal/xMCf	Qal/xMCf
Water Bearing Zone	Shallow	Shallow	Shallow	Shallow	Shallow	Shallow
Approx. Operating Depth to Water (feet)	30.4	32.6	29	32	28.5	31

Table 2a - Athens Pen Extraction Wells (APEW) Average Monthly Perchlorate (mg/L)			
Date	**APEW-1**	**APEW-2**	**APEW-3**
January 2014	NS	NS	54
February 2014	NS	15	50
March 2014	NS	16	50
April 2014	NS	14	48
May 2014	NS	16	55
June 2014	NS	15	57
July 2014	NS	14	50
August 2014	NS	13	49
September 2014	NS	13	54
October 2014	NS	13	47
November 2014	NS	12	53
December 2014	NS	11	50
January 2015	NS	11	53
February 2015	NS	11	52
March 2015	NS	14	50
April 2015	NS	11	54
May 2015	NS	13	57
June 2015	0.6	10	58
July 2015	0.61	12	50
August 2015	0.58	12	58
September 2015	0.59	12	54
October 2015	0.58	9.9	51
November 2015	0.7	11	49
December 2015	NS	NS	NS
January 2016	0.60	11	52
February 2016	0.64	11	53
March 2016	0.67	12	54
April 2016	0.61	12	54
May 2016	NS	NS	NS
June 2016	0.66	13	57
July 2016	0.62	12	53
August 2016	0.57	11	53
September 2016	0.58	12	54
October 2016	NS	NS	NS
November 2016	0.54	11	54
December 2016	NS	NS	NS
January 2017	0.79	11	55
February 2017	0.59	10	55
March 2017	NS	NS	NS
April 2017	0.66	10	54
May 2017	NS	NS	NS
June 2017	0.44	11	56
July 2017	NS	NS	NS
August 2017	0.55	11	56
September 2017	0.51	9	60
October 2017	0.51	9	59
November 2017	0.50	9.5	10
December 2017	0.55	9.4	54
January 2018	0.59	9.9	57
February 2018	0.58	9.2	55
March 2018	0.62	9.6	54
April 2018	NS	NS	NS
May 2018	0.53	10	53
June 2018	0.41	10	57
July 2018	0.43	10	54
August 2018	0.56	12	63
September 2018	0.43	10	56
October 2018	0.62	11	57
November 2018	0.47	10	51
December 2018	0.46	10	58
January 2019	0.55	11	59
Feburary 2019	0.51	10	56
March 2019	0.40	9.5	59
April 2019	NS	NS	NS
May 2019	0.47	9.7	54
June 2019	0.56	10	59
July 2019	0.54	11	60
August 2019	0.42	11	55
September 2019	0.54	10	60
October 2019	0.56	10	61
November 2019	0.44	10	56
December 2019	0.41	9.8	60

Screen Interval (feet bgs)	20-40	20-30	10-30
Lithological Classification	Qal/xMCf	Qal/xMCf	Qal/xMCf
Water Bearing Zone	Shallow	Shallow	Shallow
Approx. Operating Depth to Water (feet)	17.9	18.2	14.8

NS- Not Sampled

Table 2b - Athens Pen Extraction Wells (APEW) Average Monthly Flow (GPM)			
Date	**APEW-1**	**APEW-2**	**APEW-3**
January 2014	0.0	0.21	7.1
February 2014	0.0	33.1	7.1
March 2014	0.0	56.4	7.0
April 2014	0.0	53.1	7.0
May 2014	0.0	48.2	6.8
June 2014	0.0	47.6	6.9
July 2014	0.0	45.5	7.2
August 2014	0.0	44.1	7.1
September 2014	0.0	44.3	7.2
October 2014	0.0	38.3	7.1
November 2014	0.0	22.0	7.2
December 2014	0.0	22.0	7.2
January 2015	0.0	22.1	7.2
February 2015	0.0	22.1	7.1
March 2015	0.0	22.4	7.0
April 2015	0.0	22.1	7.1
May 2015	1.6	21.8	7.1
June 2015	14.3	20.5	7.1
July 2015	14.2	20.5	7.1
August 2015	14.3	20.6	7.2
September 2015	14.4	20.7	7.2
October 2015	11.4	20.6	5.7
November 2015	14.5	20.9	7.4
December 2015	14.8	22.6	7.3
January 2016	15.8	27.5	7.3
February 2016	15.5	27.0	7.2
March 2016	15.8	28.4	7.4
April 2016	15.9	27.5	7.4
May 2016	15.9	28.1	7.4
June 2016	15.8	27.8	7.3
July 2016	12.9	28.7	7.5
August 2016	15.5	28.9	7.5
September 2016	15.4	28.8	7.4
October 2016	15.7	29.3	7.6
November 2016	15.3	28.4	7.4
December 2016	15.6	29.1	7.6
January 2017	15.7	29.2	7.6
February 2017	15.7	29.2	7.6
March 2017	15.7	29.3	7.6
April 2017	15.7	29.2	7.6
May 2017	15.7	29.3	7.6
June 2017	15.7	28.5	7.5
July 2017	15.5	25.8	7.5
August 2017	18.3	25.9	7.5
September 2017	18.3	26.0	7.6
October 2017	18.3	26.0	7.5
November 2017	18.4	26.1	7.5
December 2017	18.4	26.1	7.5
January 2018	18.4	26.1	7.6
Feburary 2018	18.4	26.1	7.7
March 2018	18.4	26.1	7.7
April 2018	18.4	26.2	7.7
May 2018	11.1	26.3	7.4
June 2018	19.4	26.2	7.0
July 2018	19.3	26.4	6.7
August 2018	21.9	29.6	6.8
September 2018	20.9	28.3	6.5
October 2018	21.9	29.6	6.7
November 2018	21.7	29.5	6.6
December 2018	21.6	29.5	6.6
January 2019	21.5	29.5	6.9
Feburary 2019	21.5	29.6	6.4
March 2019	19.3	29.6	6.0
April 2019	22.5	29.3	5.8
May 2019	22.2	29.4	5.9
June 2019	21.9	29.5	5.8
July 2019	21.1	29.4	5.7
August 2019	20.3	29.1	5.6
September 2019	20.7	27.0	5.6
October 2019	20.0	29.1	5.6
November 2019	19.7	29.0	5.6
December 2019	20.4	29.8	5.5
Screen Interval (feet bgs)	20-40	20-30	10-30
Lithological Classification	Qal/xMCf	Qal/xMCf	Qal/xMCf
Water Bearing Zone	Shallow	Shallow	Shallow
Approx. Operating Depth to Water (feet)	19.3	19.9	15.9

Table 3a - Auto Mall Extraction Wells (AMEW) Average Monthly Perchlorate (mg/L)					
Historical Monthly Averages	**AMEW-1**	**AMEW-2**	**AMEW-3**	**AMEW-4**	**AMEW-5**
January 2014	420	630	140	220	110
February 2014	350	590	130	200	110
March 2014	350	540	140	190	120
April 2014	310	490	130	180	99
May 2014	350	530	140	190	120
June 2014	320	480	130	210	110
July 2014	340	480	120	180	120
September 2014	330	460	140	180	130
October 2014	270	450	130	170	110
November 2014	300	410	120	140	120
December 2014	270	380	130	140	180
January 2015	NS	400	130	120	120
February 2015	270	380	120	140	83
March 2015	270	380	140	120	130
April 2015	250	370	120	130	110
May 2015	280	390	140	150	130
June 2015	260	440	130	150	110
July 2015	270	360	150	130	120
August 2015	290	37	160	140	120
September 2015	280	250	140	140	120
October 2015	250	340	130	120	NS
November 2015	240	360	110	180	110
December 2015	NS	NS	NS	NS	NS
January 2016	240	340	130	120	110
February 2016	260	330	130	120	110
March 2016	250	330	140	120	120
April 2016	NS	NS	NS	NS	NS
May 2016	240	300	130	98	99
June 2016	270	250	130	120	110
July 2016	240	310	130	100	110
August 2016	240	280	130	110	110
September 2016	240	310	140	120	100
October 2016	NS	NS	NS	NS	NS
November 2016	220	280	130	91	91
December 2016	NS	NS	NS	NS	NS
January 2017	230	300	141	97	98
February 2017	200	270	68	93	100
March 2017	230	287	137	98	104
April 2017	220	280	140	95	99
May 2017	NS	NS	NS	NS	NS
June 2017	230	283	144	96	100
July 2017	NS	NS	NS	NS	NS
August 2017	220	250	140	270	210
September 2017	209	260	136	86	94
October 2017	221	272	147	89	100
November 2017	200	240	130	85	90
December 2017	206	242	132	86	94
January 2018	200	250	130	84	90
February 2018	200	240	140	84	97
March 2018	210	240	140	81	90
April 2018	NS	NS	NS	NS	NS
May 2018	190	220	140	76	82
June 2018	200	230	140	83	90
July 2018	200	230	140	82	90
August 2018	210	230	140	90	93
September 2018	190	220	140	82	90
October 2018	200	220	140	88	90
November 2018	190	220	140	82	88
December 2018	200	220	140	89	87
January 2019	190	220	140	81	90
Feburary 2019	200	200	150	80	81
March 2019	190	210	140	83	85
April 2019	NS	NS	NS	NS	NS
May 2019	190	190	140	81	82
June 2019	180	190	130	85	84
July 2019	176	193	129	87	81
August 2019	170	190	130	83	78
September 2019	171	187	129	87	79
October 2019	169	185	133	85	78
November 2019	170	180	130	84	77
December 2019	166	179	123	83	78

Screen Interval (feet bgs)	145-235	175-215	169-199	151-186	165-200
Lithological Classification	UMCf	UMCf	UMCf	UMCf	UMCf
Water Bearing Zone	Deep	Deep	Deep	Deep	Deep
***Approx. Operating Depth to Water (feet)**	145	174	161	153	156

*Does not include days with no flow

Table 3b - Auto Mall Extraction Wells (AMEW) Average Monthly Flow (GPM)					
Date	**AMEW-1**	**AMEW-2**	**AMEW-3**	**AMEW-4**	**AMEW-5**
January 2014	33.1	0.0	53.1	39.8	38.8
February 2014	171.4	32.3	53.9	47.4	0.0
March 2014	170.6	56.4	53.7	47.3	0.0
April 2014	171.1	55.9	53.4	46.1	12.2
May 2014	179.7	55.4	50.8	39.6	46.9
June 2014	179.1	55.6	50.6	38.9	47.2
July 2014	186.9	54.5	50.9	38.9	47.6
August 2014	187.1	54.3	50.9	39.0	46.0
September 2014	176.2	42.4	52.2	41.2	10.4
October 2014	180.7	46.0	51.6	41.6	14.2
November 2014	144.9	57.2	51.7	28.6	36.3
December 2014	204.4	60.5	50.1	39.2	47.7
January 2015	140.0	53.9	51.5	39.1	46.6
February 2015	194.7	46.6	54.0	41.0	47.6
March 2015	216.1	60.2	51.3	40.6	47.2
April 2015	223.0	60.5	52.1	40.8	47.4
May 2015	230.4	60.4	51.4	40.8	46.8
June 2015	234.1	60.3	51.1	42.2	48.6
July 2015	232.4	57.2	46.0	36.4	43.9
August 2015	236.5	38.5	50.8	42.5	46.5
September 2015	237.4	0.0	51.7	42.7	47.6
October 2015	165.9	38.6	51.5	32.4	34.6
November 2015	168.2	62.2	50.3	38.1	39.1
December 2015	249.9	49.9	40.3	36.2	34.3
January 2016	253.3	62.0	48.5	47.0	40.9
February 2016	247.5	59.5	48.5	44.1	44.7
March 2016	252.0	60.8	49.9	42.7	46.4
April 2016	252.0	60.7	50.9	42.5	49.0
May 2016	260.4	60.6	51.0	42.4	49.3
June 2016	264.1	60.4	51.2	42.0	49.4
July 2016	261.8	60.3	52.7	41.8	51.6
August 2016	263.3	62.0	53.7	41.6	45.4
September 2016	260.0	62.4	53.4	41.1	39.4
October 2016	129.2	12.7	48.6	28.7	38.0
November 2016	254.2	58.5	52.9	41.8	43.8
December 2016	236.1	61.3	52.8	41.7	39.3
January 2017	254.2	51.9	44.8	41.5	44.8
February 2017	219.3	32.5	0.0	42.7	48.7
March 2017	247.3	60.0	36.7	41.4	46.7
April 2017	275.1	60.7	49.8	39.8	47.7
May 2017	275.0	60.8	50.5	40.4	25.8
June 2017	276.1	64.4	49.8	37.9	50.6
July 2017	276.0	66.0	50.2	36.7	51.2
August 2017	276.2	65.9	50.1	35.3	46.9
September 2017	276.5	65.8	50.1	33.6	45.1
October 2017	276.7	64.5	50.1	32.0	45.3
November 2017	277.1	64.0	50.2	32.9	48.3
December 2017	277.0	63.9	50.1	32.9	51.8
January 2018	276.9	64.0	50.1	32.6	51.8
Feburary 2018	276.7	64.0	50.1	32.1	51.8
March 2018	276.5	64.0	50.0	31.8	51.8
April 2018	276.1	63.9	49.9	29.0	51.8
May 2018	276.4	64.7	49.9	29.0	51.7
June 2018	276.4	65.0	49.8	29.8	51.7
July 2018	179.0	51.7	46.3	30.5	47.5
August 2018	278.1	63.8	49.9	31.7	47.1
September 2018	266.3	51.5	47.9	30.3	44.8
October 2018	264.5	34.3	36.7	21.4	32.6
November 2018	276.9	64.0	50.8	31.8	51.9
December 2018	277.4	63.9	50.5	31.2	52.9
January 2019	278.0	63.7	50.4	30.1	52.8
Feburary 2019	277.8	63.7	50.4	29.9	52.8
March 2019	277.7	63.6	50.4	29.5	52.8
April 2019	276.5	63.3	50.2	23.6	52.6
May 2019	277.9	58.0	46.1	25.5	52.9
June 2019	279.2	14.2	31.7	28.3	53.9
July 2019	277.4	63.5	50.6	27.8	52.9
August 2019	277.0	63.4	50.5	27.1	52.2
September 2019	276.3	57.0	46.9	26.2	43.8
October 2019	258.8	35.2	28.1	13.1	25.9
November 2019	272.5	60.8	45.4	21.9	43.1
December 2019	275.8	61.2	51.8	20.8	51.6

Screen Interval (feet bgs)	145-235	175-215	169-199	151-186	165-200
Lithological Classification	UMCf	UMCf	UMCf	UMCf	UMCf
Water Bearing Zone	Deep	Deep	Deep	Deep	Deep
***Approx. Operating Depth to Water (feet)**	145	174	161	153	156

*Does not include days with no flow.

Table 4 - Flow Rate and Monthly Sampling Results					
Location	**Date Sampled**	**Flow Rate (ft^3/sec)**	**Flow Rate, gpm**	**Chlorate (mg/L)**	**Perchlorate (mg/L)**
Athens Main	7/2/2019	0.54	241	1.8	5.2
	8/7/2019	0.50	224	2.8	6.2
	9/3/2019	0.50	224	2.6	7.2
	10/2/2019	0.48	215	2.1	4.8
	11/4/2019	0.48	215	2.2	5.1
	12/2/2019	0.48	215	2.1	3.9
Athens North South	7/2/2019	NA	NA	2.3	7.2
	8/7/2019	NA	NA	2.9	7.5
	9/3/2019	NA	NA	3.1	8.2
	10/2/2019	NA	NA	2.2	5.1
	11/4/2019	NA	NA	2.2	5.1
	12/2/2019	NA	NA	3.1	6.9
Eastgate Drain	7/2/2019	0.38	168	3.9	12
	8/7/2019	0.38	170	5.4	14
	9/3/2019	0.36	164	6.1	15
	10/2/2019	0.35	159	3.9	9.8
	11/4/2019	0.36	161	3.8	10
	12/2/2019	0.38	170	5.2	12
F6 French Drain	7/2/2019	NA	NA	0.59	0.14
	8/7/2019	NA	NA	0.80	0.14
	9/3/2019	NA	NA	0.83	0.12
	10/2/2019	NA	NA	0.87	0.11
	11/4/2019	NA	NA	0.91	0.12
	12/2/2019	NA	NA	0.82	0.11

Weir Calculation: 2.5 x (Feet measured using Weir)$^{2.5}$ = flow rate in ft^3/sec

Nitrate as N is sampled annually (April/May)

Table 5 - Quarterly Analytes and Field Measurements											
Location	Date Sampled	Chlorate (mg/L)	Perchlorate (mg/L)	Ref Elev (ft)	DTW (ft)	GW Elev (ft)	Temp (°F)	pH (S.U.)	Conductivity (µS/cm)	DO (mg/L)	ORP (mV)
ADX-112	8/4/2019	0.037	2.7	1807.70	58.88	1,748.82	81.4	7.57	1441	2.57	279.2
	11/3/2019	0.50	2.6	1807.70	28.72	1,778.98	77.0	7.60	1428	1.89	247.6
ADX-156	8/4/2019	1.2	5.0	1808.10	73.28	1,734.82	82.2	7.71	1093	6.84	283.1
	11/3/2019	2.1	7.8	1808.10	38.06	1,770.04	76.3	7.38	1428	2.49	247.5
AEX-166	8/4/2019	2.0	9.7	1783.30	98.60	1,684.70	81.2	7.72	1440	6.55	284.4
	11/10/2019	15	58	1783.30	80.24	1,703.06	76.8	7.63	1706	6.98	254.3
AEX-35	8/4/2019	26	63	1782.70	37.73	1,744.97	80.8	7.45	3560	6.49	313.4
	11/10/2019	24	57	1782.70	37.76	1,744.94	77.5	7.39	3477	6.82	237.7
AMEW-1	8/25/2019	59	170	1826.58	152.70	1,673.88	78.7	7.62	3081	5.64	252.0
	11/10/2019	63	170	1826.58	150.50	1,676.08	76.2	7.58	3051	6.48	229.9
AMEW-2	8/11/2019	35	190	1797.64	178.00	1,619.64	78.4	7.72	3144	7.10	223.1
	11/12/2019	36	180	1797.64	166.68	1,630.96	78.4	7.56	3046	6.91	235.5
AMEW-3	8/6/2019	28	130	1778.04	157.49	1,620.55	79.0	7.77	2303	7.09	241.0
	11/12/2019	27	130	1778.04	150.24	1,627.80	78.2	7.78	2215	7.69	210.8
AMEW-4	8/4/2019	24	83	1804.32	163.00	1,641.32	80.2	7.79	1931	6.94	298.6
	11/3/2019	24	84	1804.32	127.70	1,676.62	79.7	7.72	1884	6.98	252.7
AMEW-5	8/4/2019	21	78	1780.47	159.92	1,620.55	79.7	7.63	1969	6.29	322.4
	11/10/2019	21	77	1780.47	148.80	1,631.67	78.5	7.74	1908	7.24	243.3
AMOW-3-165	8/6/2019	0.11	0.79	1780.03	69.08	1,710.95	81.6	7.85	1399	7.67	235.4
	11/12/2019	0.099	0.61	1780.03	62.25	1,717.78	75.6	7.38	1334	6.88	233.3
AMOW-3-52	8/6/2019	11	57	1779.70	34.12	1,745.58	82.1	7.40	4115	4.84	245.2
	11/12/2019	11	56	1779.70	34.89	1,744.81	77.2	7.34	3989	4.11	239.1
APEW-1	8/6/2019	0.14	0.42	1620.25	0.00	1,620.25	75.7	7.34	4636	6.63	289.9
	11/7/2019	0.18	0.44	1620.25	31.50	1,588.75	76.2	7.29	5389	7.42	144.3
APEW-2	8/6/2019	2.3	11	1617.75	14.87	1,602.88	76	7.33	5359	5.43	282.3
	11/7/2019	2.3	10	1617.75	14.58	1,603.17	76.3	7.17	5199	4.80	176.8
APEW-3	8/6/2019	10	55	1611.25	13.25	1,598.00	78.1	7.20	5893	3.26	263.9
	11/7/2019	11	56	1611.25	13.06	1,598.19	80.1	7.12	6665	3.68	179.4
AREW-1	8/5/2019	0.14	0.45	1646.24	29.80	1,616.44	76.2	7.28	4589	8.43	283.4
	11/13/2019	0.19	0.45	1646.24	22.44	1,623.80	78.1	7.22	5409	6.49	244.8
AREW-2	8/5/2019	0.21	0.65	1640.95	30.90	1,610.05	76.7	7.30	4429	10.67	265.2
	11/13/2019	0.35	0.89	1640.95	30.25	1,610.70	77.0	7.24	5195	8.60	236.6
AREW-3	8/5/2019	0.21	0.63	1639.72	29.29	1,610.43	76.9	7.26	4453	6.11	269.0
	11/13/2019	0.24	0.62	1639.72	23.91	1,615.81	77.0	7.23	5210	6.52	251.7
AREW-4	8/5/2019	0.63	2.4	1638.53	29.80	1,608.73	76.9	7.32	4299	8.13	271.9
	11/13/2019	1.2	4.0	1638.53	29.70	1,608.83	76.4	7.31	4926	8.21	259.7
AREW-5	8/5/2019	3.1	12	1637.49	25.25	1,612.24	78.1	7.34	3805	5.73	268.5
	11/13/2019	3.6	14	1637.49	23.60	1,613.89	77.0	7.28	4545	6.29	259.6
AREW-6	8/5/2019	6.7	38	1635.61	27.90	1,607.71	77.1	7.33	4978	6.13	272.2
	11/13/2019	7.1	32	1635.61	23.76	1,611.85	76.5	7.30	5591	6.71	245.6
DX-161	NS	NS	NS	1830.10	NS	NS	NS	NS	NS	NS	NS
	11/10/199	20	92	1828.33	64.85	1,763.48	76.60	7.36	1854	5.46	250.7
DX-30	8/25/2019	18	110	1830.20	26.20	1,804.00	81.5	7.34	6325	6.01	247.4
	11/10/2019	22	130	1830.70	27.08	1,803.62	75.5	7.31	7013	6.41	253.2
DX-75	8/25/2019	64	290	1830.10	24.70	1,805.40	80.3	7.39	2764	5.26	232.8
	11/10/2019	69	300	1829.94	23.94	1,806.00	75.5	7.20	2852	3.00	259.5
DY-106	8/11/2019	<0.0085	0.0092	1800.40	13.00	1,787.40	80.2	7.84	1323	6.01	243.5
	11/12/2019	<0.0085	0.0085	1800.40	10.81	1,789.59	78.3	7.75	1332	6.26	238.4
DY-169	8/11/2019	0.39	2.7	1800.40	34.33	1,766.07	80.9	7.66	1289	4.59	245.0
	11/12/2019	45	260	1800.40	30.85	1,769.55	77.3	7.43	2767	4.93	244.3
DY-26	8/11/2019	13	75	1800.60	20.29	1,780.31	79.6	7.25	5924	4.65	263.8
	11/12/2019	14	67	1800.60	22.09	1,778.51	77.3	7.17	6644	4.86	254.4
MW-AD	8/4/2019	6.3	16	1807.30	28.76	1,778.54	82.9	7.51	2988	6.53	263.3
	11/3/2019	5.1	14	1807.30	29.46	1,777.84	77.2	7.38	2806	6.84	6.8

NR- Not Recorded
Nitrate as N is sampled annually (April/May)

Table 6 - Selected History of Perchlorate Concentrations in Athens Road Extraction Wells (mg/L)						
Date Sampled	**AREW-1**	**AREW-2**	**AREW-3**	**AREW-4**	**AREW-5**	**AREW-6**
November 2009	0.9	1.4	1.4	5.6	16	37
February 2010	0.8	1.2	1.2	2.0	15	43
May 2010	0.9	1.2	1.3	3.0	18	47
August 2010	1.0	1.4	1.4	2.4	18	49
November 2010	1.0	1.6	1.2	3.1	19	51
February 2011	0.9	1.9	1.5	8.0	19	46
May 2011	0.9	3.7	1.2	2.6	17	49
August 2011	1.0	1.3	1.3	2.5	18	51
November 2011	0.9	1.9	1.2	2.5	18	49
February 2012	1.0	1.7	2.5	10	24	53
May 2012	1.0	1.3	4.0	10	23	49
August 2012	0.8	1.1	1.8	9.6	48	47
November 2012	0.9	2.1	3.0	13	26	83
February 2013	0.9	2.0	1.5	7.3	19	52
May 2013	1.1	1.4	1.8	7.3	20	50
August 2013	1.1	1.4	2.0	10	22	50
November 2013	1.1	1.6	1.8	5.2	18	53
February 2014	0.9	1.7	1.2	4.5	17	48
May 2014	1.0	1.2	2.2	5.3	18	49
August 2014	0.9	1.0	1.6	4.4	17	42
November 2014	0.9	1.2	1.3	3.9	15	44
February 2015	0.9	1.9	1.7	5.1	15	45
May 2015	0.9	1.2	1.5	4.5	15	50
August 2015	0.8	1.0	1.3	3.7	16	49
November 2015	1.0	1.4	1.3	3.4	14	44
February 2016	0.8	1.1	1.1	3.0	13	46
May 2016	0.8	0.9	1.1	3.0	13	43
August 2016	0.7	0.8	0.9	2.5	13	43
November 2016	0.7	0.8	0.8	2.8	13	46
February 2017	0.66	1.20	0.80	2.1	11	46
May 2017	0.59	0.97	0.79	2.1	12	45
August 2017	0.61	0.73	0.79	2.2	12	45
November 2017	0.58	1.0	0.74	2.3	11	51
February 2018	0.57	1.1	0.69	2.3	11	37
May 2018	0.55	0.78	0.74	3.0	14	43
August 2018	0.63	0.81	0.88	2.8	15	47
November 2018	0.52	1.2	0.70	2.4	12	35
Feburary 2019	0.58	1.40	0.93	1.8	12	39
May 2019	0.55	0.78	0.74	2.5	13	43
August 2019	0.45	0.65	0.63	2.4	12	38
November 2019	0.45	0.89	0.62	4.0	14	32

Note: the data for AREW-5 for August 2012 and AREW-6 for November 2012 are shown here but not plotted on Figure 6. The results are incorrect due to sample handling and/or laboratory error.

Table 7 - Selected History of Perchlorate Concentrations in Athens Pen Extraction Wells (mg/L)			
Date Sampled	**APEW-1**	**APEW-2**	**APEW-3**
November 2009		21	52
February 2010		17	50
May 2010		17	53
August 2010		21	57
November 2010		21	58
February 2011		20	54
May 2011		21	57
August 2011		21	56
November 2011		20	52
February 2012		31	56
May 2012		23	55
August 2012		0.9	32
November 2012		34	41
February 2013		30	34
May 2013		18	52
August 2013		21	59
November 2013		18	53
February 2014		15	50
May 2014		16	55
August 2014		13	49
November 2014		12	53
February 2015		11	52
May 2015		13	57
August 2015	0.6	12	58
November 2015	0.7	11	49
February 2016	0.6	11	53
May 2016	0.6	12	54
August 2016	0.6	11	53
November 2016	0.5	11	54
February 2017	0.59	10	55
May 2017	0.66	10	54
August 2017	0.55	11	56
November 2017	0.50	9.5	10
February 2018	0.56	9.5	55
May 2018	0.53	10	53
August 2018	0.56	12	63
November 2018	0.47	10	51
Feburary 2019	0.51	10	56
May 2019	0.47	9.7	54
August 2019	0.42	11	55
November 2019	0.44	10	56

Notes: APEW-1 was started on May 28, 2015. Also, the data for APEW-2 for Aug. 2012 and APEW-3 for Aug. and Nov. 2012, Feb. 2013, and Nov. 2017 are shown here but not plotted on Figure 7. The results are incorrect due to sample handling and/or laboratory error.

Table 8 - Selected History of Perchlorate Concentrations in Auto Mall Extraction Wells (mg/L)					
Date Sampled	**AMEW-1**	**AMEW-2**	**AMEW-3**	**AMEW-4**	**AMEW-5**
December 2012	540	700	65	400	66
January 2013	490	630	140	350	37
March 2013	470	660	140	280	53
May 2013	490	610	130	300	68
August 2013	380	610	140	210	110
November 2013	390	590	140	230	110
Februrary 2014	350	590	130	200	110
May 2014	350	530	140	190	120
August 2014	310	440	130	170	120
November 2014	300	410	120	140	120
Februrary 2015	270	380	120	140	83
May 2015	280	390	140	150	130
August 2015*	290	37	160	140	120
November 2015	240	360	110	180	110
February 2016	260	330	130	120	110
May 2016	240	300	130	98	99
August 2016	240	280	130	110	110
November 2016	220	280	130	91	91
February 2017	200	270	68	93	100
May 2017	220	280	140	95	99
August 2017*	220	250	140	270	210
November 2017	200	240	130	85	90
February 2018	180	210	190	76	81
May 2018	190	220	140	76	82
August 2018	210	230	140	90	93
November 2018	190	220	140	82	88
Feburary 2019	200	200	150	80	81
May 2019	190	190	140	81	82
August 2019	170	190	130	83	78
November 2019	170	180	130	84	77

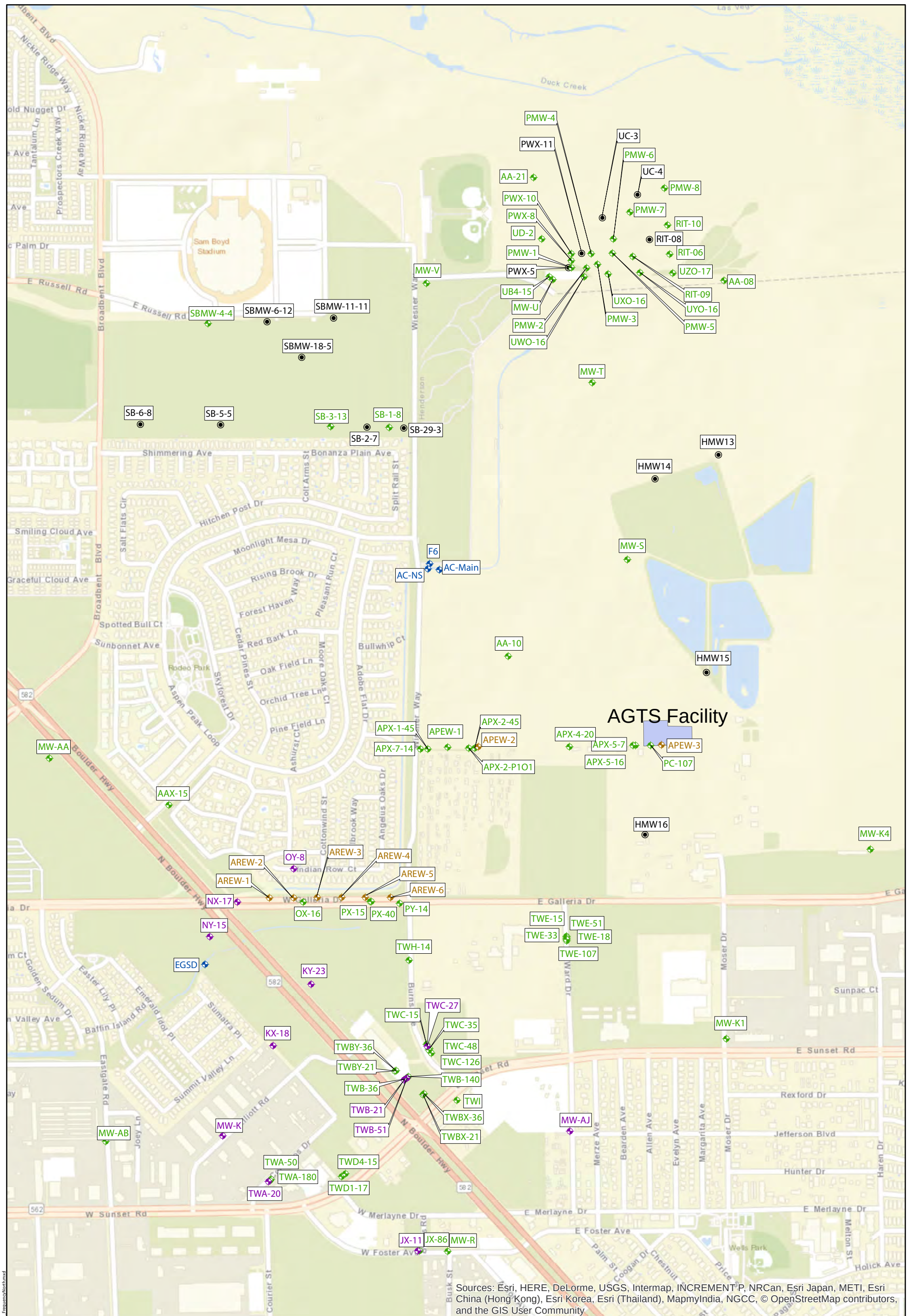
* AMEW-2 was not running during sampling in August 2015 and the well was not purged enough to get a representative sample result. AMEWs 4 and 5 results erroneously high in August 2017 but not re-ran. Outliers not plotted in Figure 8.

Table 9 - Semi-Annual Analytes and Field Measurements											
Location	Date Sampled	Chlorate (mg/L)	Perchlorate (mg/L)	Ref Elevation (ft)	DTW (ft)	GW Elev	Temp (° F)	pH (S.U.)	EC (µS/cm)	DO (mg/L)	ORP (mV)
JX-11	11/3/2019	4.4	49	1669.13	13.31	1655.82	79.1	6.98	5455	1.69	262.6
KX-18	11/3/2019	5.4	16	1657.40	22.72	1634.68	76.6	7.29	4522	5.70	265.6
KY-23	11/7/2019	4.5	13	1653.60	27.35	1626.25	77.1	7.26	4432	6.41	82.4
MW-AJ	11/6/2019	12	42	1649.80	8.50	1641.30	79.3	7.14	4998	1.25	-65.5
MW-K	11/3/2019	0.52	1.6	1668.60	17.66	1651.20	75.5	7.19	4621	5.27	255.2
NX-17	11/6/2019	0.22	0.44	1648.47	20.61	1627.86	76.4	7.14	5457	6.43	233.3
NY-15	11/6/2019	0.22	0.44	1651.90	20.60	1631.30	76.1	7.15	5545	6.52	257.1
OY-8	11/3/2019	0.24	0.46	1629.10	9.66	1619.44	79.2	7.14	5403	5.41	188.4
TWA-20	11/6/2019	2.9	11	1670.90	20.69	1650.21	77.1	7.31	4436	5.18	250.1
TWB-21	11/7/2019	12	59	1654.60	13.67	1640.93	76.6	7.06	6718	2.06	235.3
TWB-51	11/7/2019	0.017	0.067	1654.90	14.69	1640.21	76.7	7.48	3453	1.88	-142.2
TWC-27	11/6/2019	0.0085	0.22	1650.06	12.75	1637.31	78.9	7.63	2463	1.43	-152.4
AA-10[1]	11/14/2019	NM	NM	1615.35	19.72	1595.63	NM	NM	NM	NM	NM
AAX-15[1]	11/13/2019	NM	NM	1644.30	15.73	1628.57	NM	NM	NM	NM	NM
APX-2-45[1]	11/14/2019	NM	NM	1621.10	16.23	1604.87	NM	NM	NM	NM	NM
APX-4-20[1]	11/14/2019	NM	NM	1618.20	11.63	1606.57	NM	NM	NM	NM	NM
APX-5-16[1]	11/14/2019	NM	NM	1613.90	8.11	1605.79	NM	NM	NM	NM	NM
APX-7-14[1]	11/14/2019	NM	NM	1624.70	16.45	1608.25	NM	NM	NM	NM	NM
MW-S[1]	11/14/2019	NM	NM	1606.20	23.28	1582.92	NM	NM	NM	NM	NM
OX-16[1]	11/6/2019	NM	NM	1643.25	21.82	1621.43	NM	NM	NM	NM	NM
PC-107[1]	11/14/2019	NM	NM	1614.27	9.63	1604.64	NM	NM	NM	NM	NM
PX-15[1]	11/6/2019	NM	NM	1640.19	21.6	1618.59	NM	NM	NM	NM	NM
PY-14[1]	11/6/2019	NM	NM	1639.08	21.28	1617.80	NM	NM	NM	NM	NM

NM- Not Measured
OR- Out of Range
Nitrate as N is sampled annually (April/May)

[1] These wells received DTW measurements only to better assess groundwater capture at the shallow zone extraction system on a semi-annual basis.

FIGURES



Sources: Esri, HERE, DeLorme, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), MapmyIndia, NGCC, © OpenStreetMap contributors, and the GIS User Community

500 0 500 1,000 Feet

N

Sampling Frequency

- Monthly
- Quarterly
- Semi-Annually
- Annually Only
- (Removed from SAP April 2013)

Not shown: HMW-8 (Removed from SAP) and MW-K5 (sampled annually)

Sample Locations and Frequency (North)

Endeavour, LLC

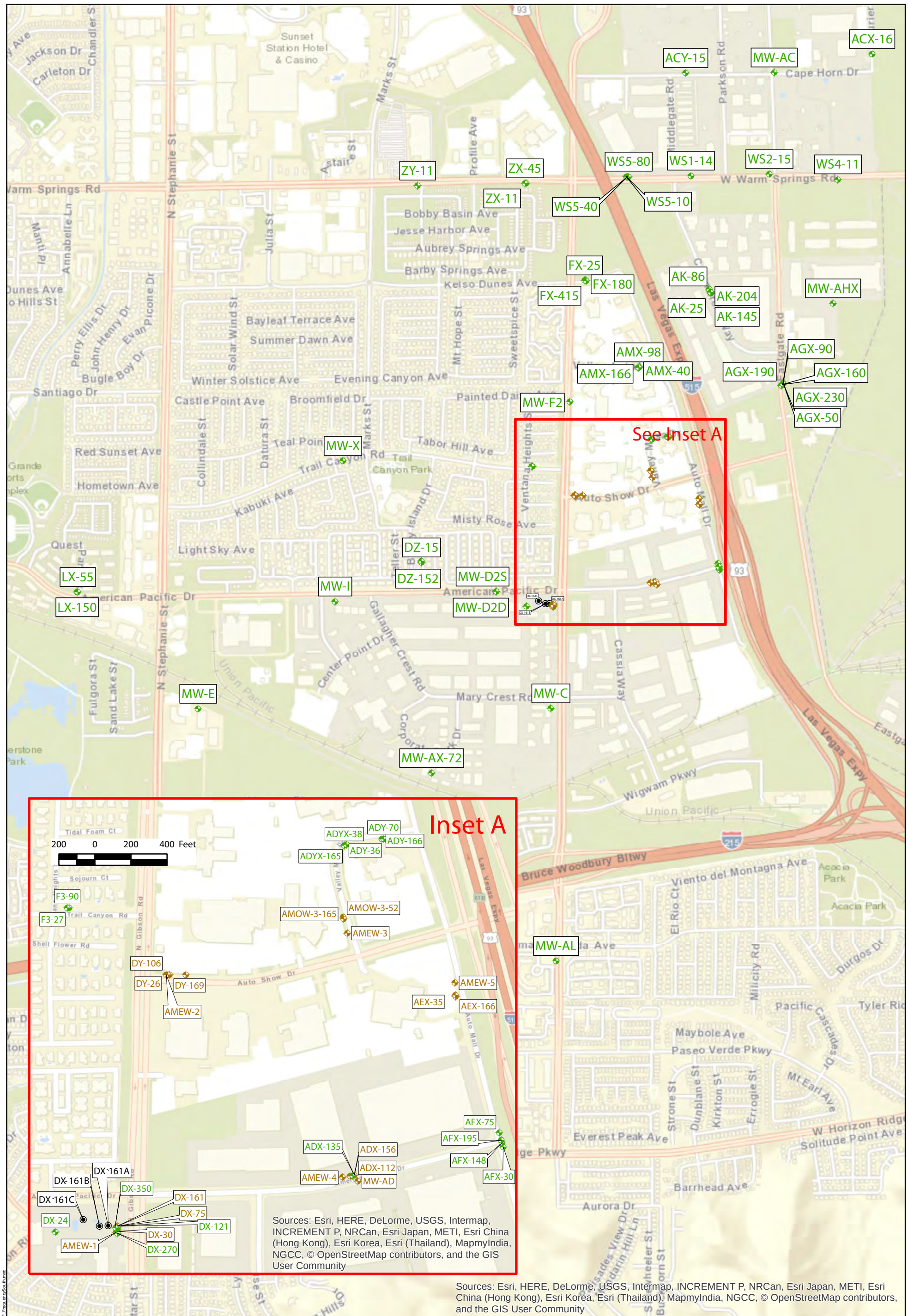
Geosyntec consultants

Guelph

1-Feb-2020

Figure 1

Path: P:\GIS\Endeavour\2018\MXD\Endeavour_SAP_FrequencyNorth.mxd



800 0 800 1,600 Feet

N

Sampling Frequency

- Monthly
- Quarterly
- Semi-Annually
- Annually Only
- (Removed from SAP April 2013)

Not shown: BHE1-10, sampled annually

Sample Locations and Frequency (South)

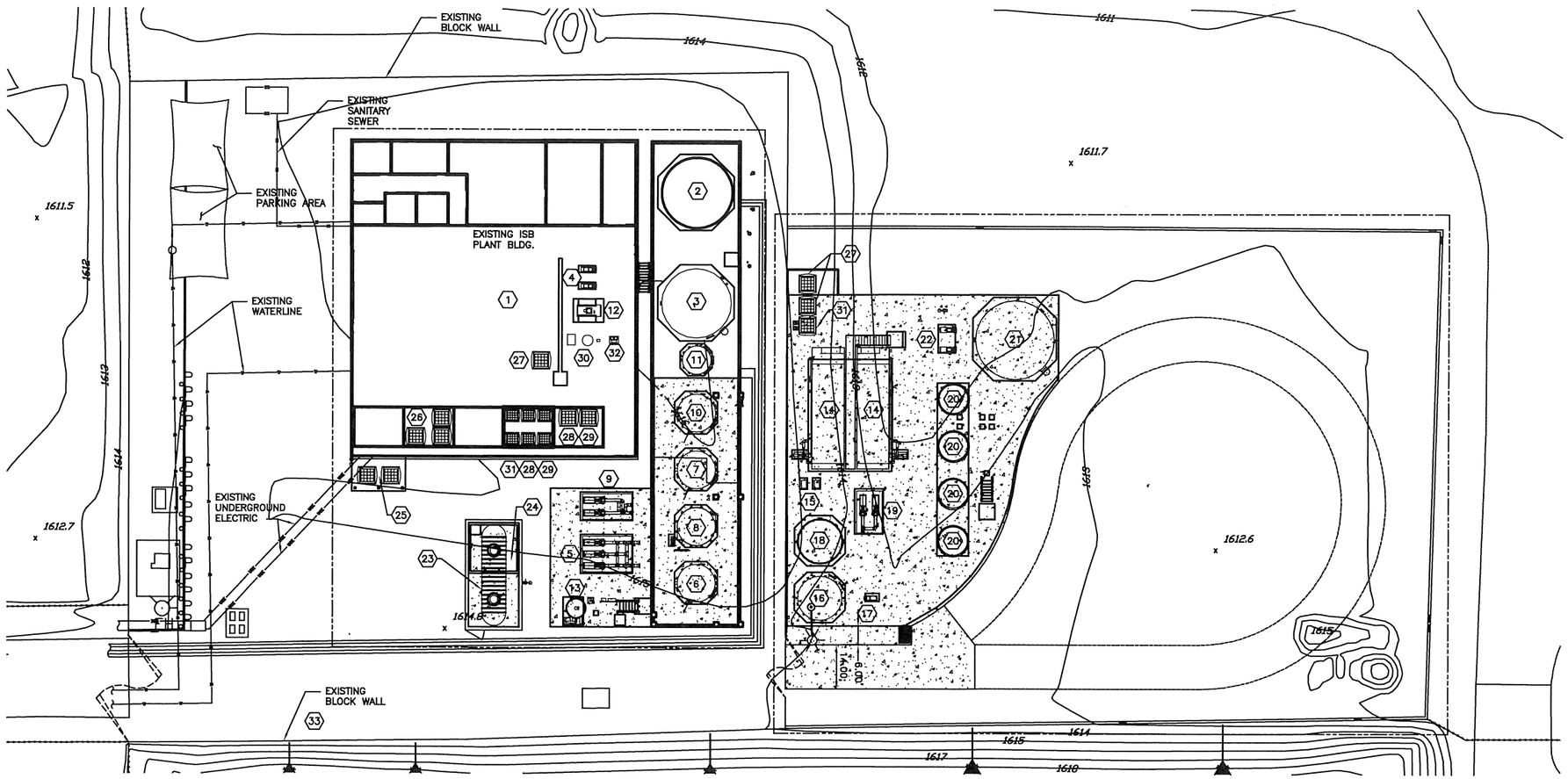
Endeavour, LLC

Geosyntec consultants

Guelph | 1-Feb-2020

Figure 2

Path: P:\GIS\Endeavour\2018\MXD\Endeavour_SAP_FrequencySouth.mxd



OVERALL SITE PLAN

1"=20'-0"

LEGEND

- 1615 — EXISTING CONTOUR
- CMU WALL, BY OTHERS
- PROPOSED CONCRETE

N

GENERAL NOTES:

1. THIS SITE CONTAINS SEVERAL CHEMICALS THAT COULD DEVELOP A HAZARDOUS SITUATION IF INADVERTENTLY MIXED. THE LIST BELOW ARE CHEMICALS THAT HAVE BEEN IDENTIFIED IN A RISK ASSESSMENT AS NEEDING TO BE KEPT SEGREGATED.

(25) HYDROGEN PEROXIDE---------ETHANOL (23) (24)
(27) FERRIC CHLORIDE----------HYDROGEN PEROXIDE (25)
(28) DI-AMMONIUM PHOSPHATE------- SODIUM HYDROXIDE (26)
(34) CATIONIC POLYMER---------- HYDROGEN PEROXIDE (25)
(28) UREA----------SODIUM HYDROXIDE (26)
(28) UREA----------HYDROGEN PEROXIDE (25)

REFERENCE TABLE

REF. #	PROCESS EQUIPMENT	EQUIPMENT TAG
1	NOT IN USE	
2	INFLUENT EQUALIZATION TANK #1	T-110
3	INFLUENT EQUALIZATION TANK #2	T-120
4	INFLUENT PUMPS	P-110A, P-110B
5	FIRST STAGE FBR PUMP SKID	P-130, P-135, P-140
6	1ST STAGE FLUIDIZED BED REACTOR #1	FBR-130
7	1ST STAGE FLUIDIZED BED REACTOR #2	FBR -140
8	MEDIA SEPARATOR	SEP-130
9	SECOND STAGE FBR PUMP SKID	P-210A, P-210B
10	2ND STAGE FLUIDIZED BED REACTOR	FBR-210

REF. #	PROCESS EQUIPMENT	EQUIPMENT TAG
11	AERATION TANK	T-220
12	PACKAGE BLOWERS	B-220A, B-220A
13	BIOFILTER ODOR SCRUBBER	T-600, T-601, B-600
14	DISSOLVED AIR FLOTATION TANKS	D-300, D-310
15	DISSOLVED AIR FLOTATION PUMPS	P-300, P-310
16	SLUDGE STORAGE TANK	T-410
17	MIXING/AERATION PUMP	P-410
18	CLARIFIED WATER TANK	T-400
19	CLARIFIED WATER PUMPS	P-400A, P-400B
20	SAND FILTERS	SF-610, SF-620, SF-630, SF-640

REF. #	PROCESS EQUIPMENT	EQUIPMENT TAG
21	EFFLUENT EQUALIZATION TANK	T-130
22	EFFLUENT PUMPS	P-300A, P-300B
23	UNDERGROUND ETHANOL TANK	T-720, 10,000 GAL
24	ELECTRON DONOR SYSTEM/ ETHANOL	P-720, P-721, P-722, P-723
25	HYDROGEN PEROXIDE FEED SYSTEM	2 - 270 GAL TOTES
26	pH FEED SYSTEM/ SODIUM HYDROXIDE	3 - 270 GAL TOTES
27	COAGULANT FEED SYSTEM/ FERRIC CHLORIDE	2 - 270 GAL TOTES OUTSIDE 1 - TOTE INSIDE
28	NUTRIENT FEED SYSTEM (DI-AMMONIUM PHASPHATE/UREA)	3 - 270 GAL TOTES
29	MICRO NUTRIENT FEED SYSTEM (MET SOURCE AN)	3 - 270 GAL TOTES
30	AIR SUPPLY SYSTEM	COMPRESSOR, TANK, DESSICANT AIR DRYER

REF. #	PROCESS EQUIPMENT	EQUIPMENT TAG
31	DAF POLYMER (ICS 2835B) FEED SYSTEM	1 - 270 GAL TOTE OUTSIDE 2 - TOTES INSIDE
32	OXYGEN GENERATOR	O-400
33	HCl STORAGE	2 - 15 GAL CONTAINERS

ENDEAVOUR, LLC

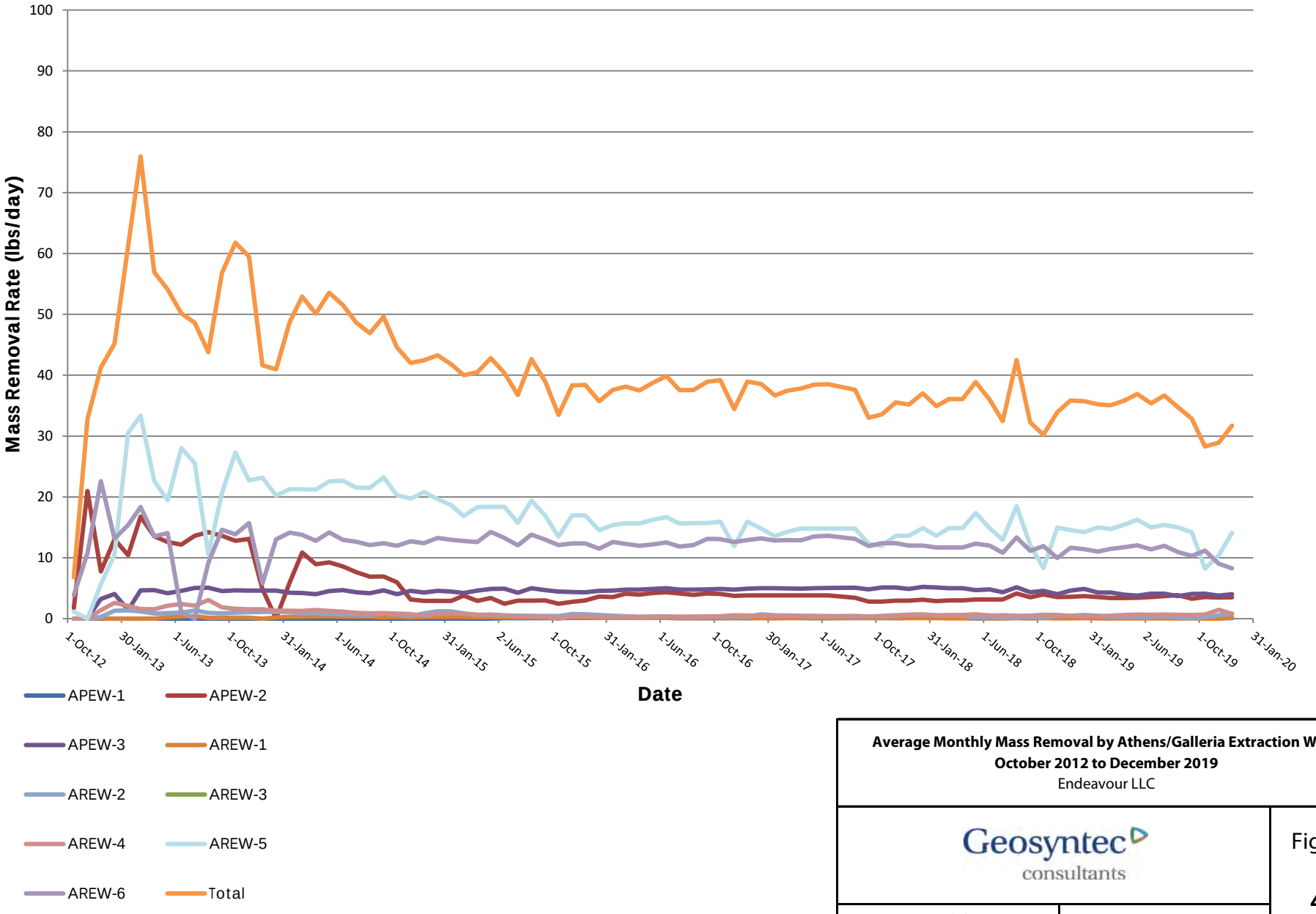
REV	DATE	DESCRIPTION	DWN	CHK	APPR
2	07-31-12	REMOVED FIND NUMBERS	RGS	FWF	GAC
1	07-19-12	NEW DRAWING FOR AGTS	RGS	FWF	GAC

GROUNDWATER TREATMENT SYSTEM
(AGTS)
HENDERSON, NV

FIGURE 3
SITE PLAN

0 1" 2"

FILENAME	400-G-002-1.dwg
SCALE	1"=20'
SHEET	400-G-002-1



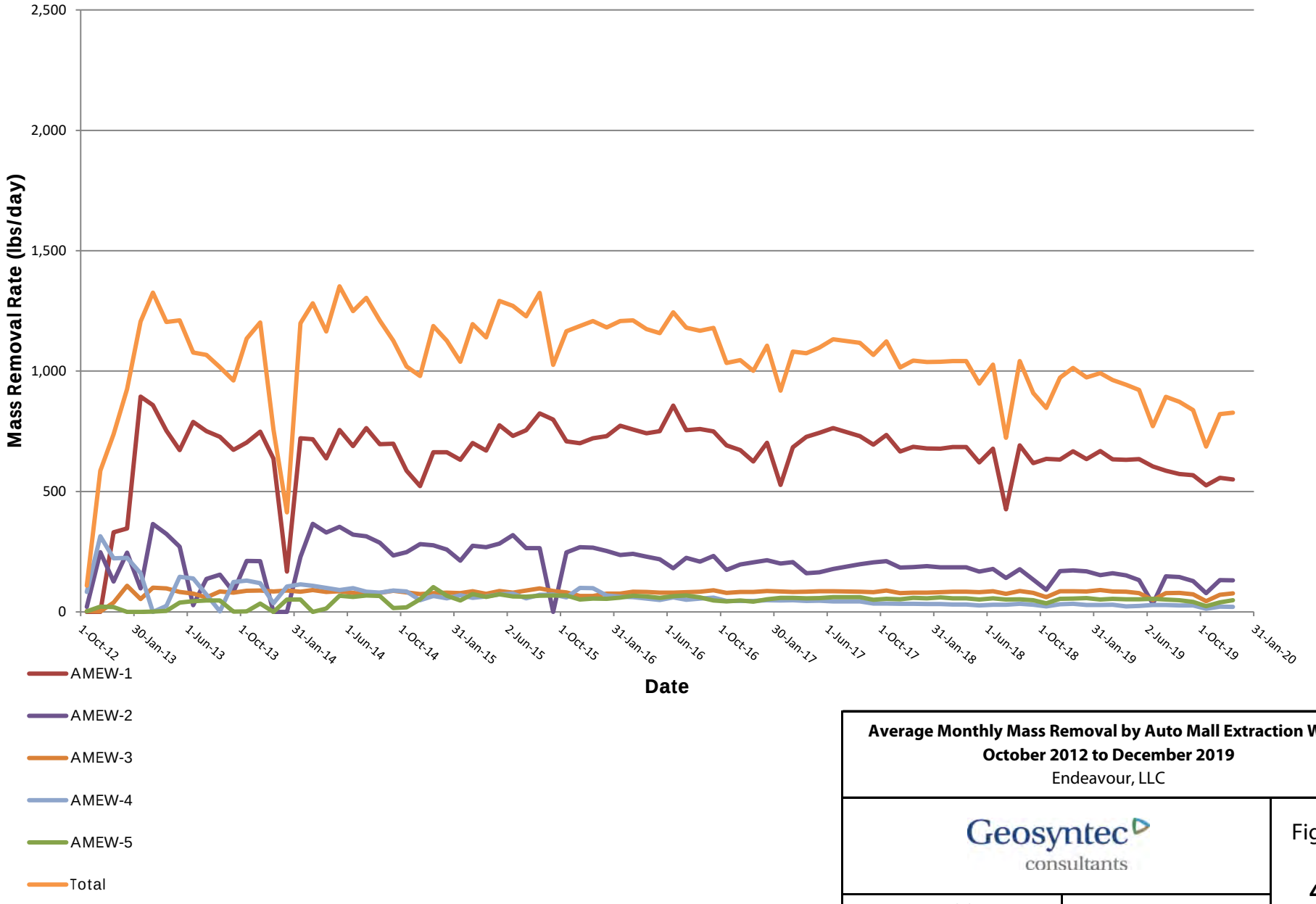
Average Monthly Mass Removal by Athens/Galleria Extraction Wells
October 2012 to December 2019
Endeavour LLC

Geosyntec consultants

Guelph | 26-Jan-2020

Figure **4a**

P:\PRJ2003REM\Endeavour\53. Reports\Monitoring Reports\2H2019\Draft Figures\[Draft_Fig04ab_05ab_MassRemovalByEW_MonthlyData_2019.xlsx]Fig5b-cum.mass.rem.by_EW_Dee



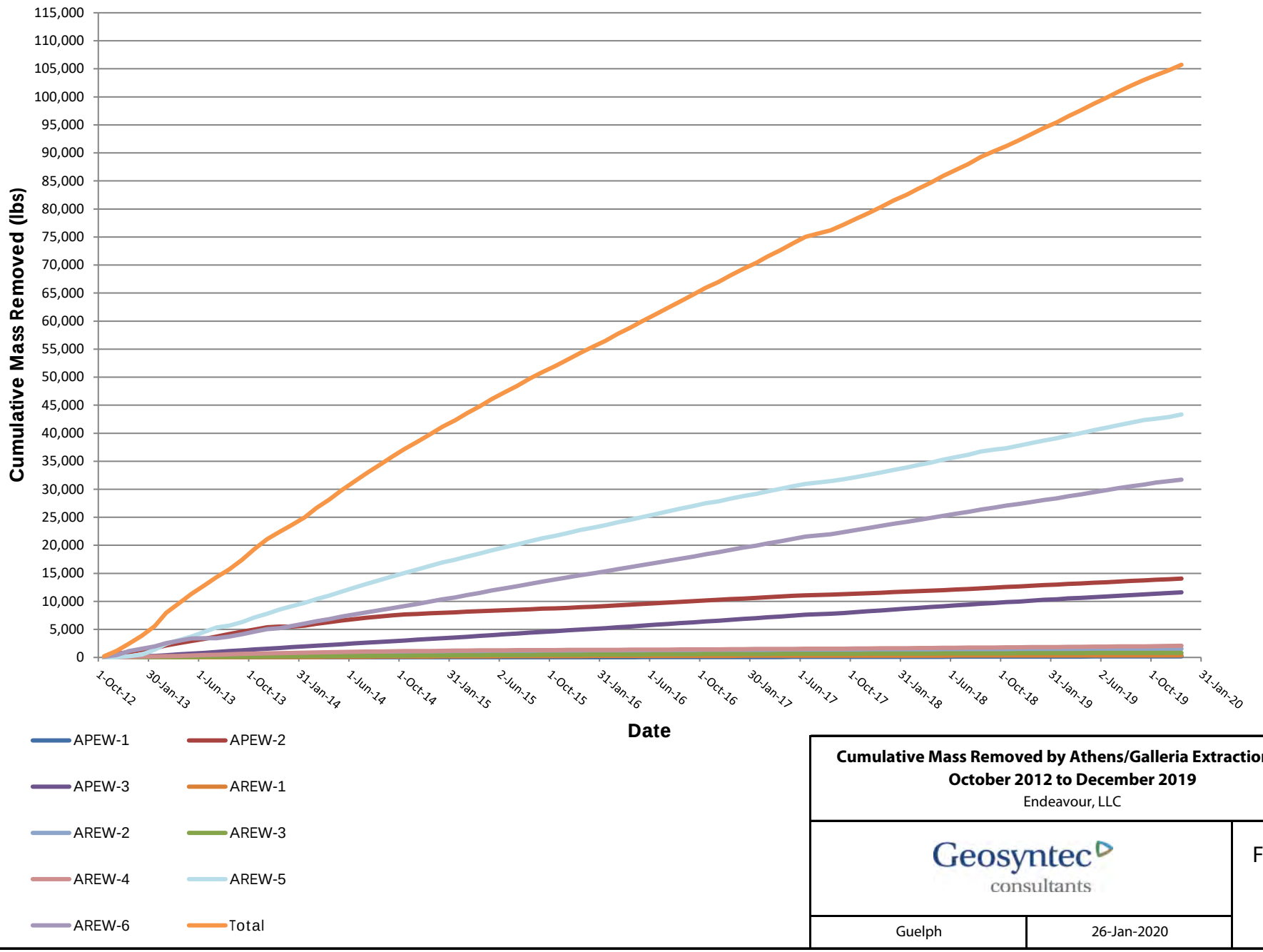
Average Monthly Mass Removal by Auto Mall Extraction Wells
October 2012 to December 2019
Endeavour, LLC

Geosyntec consultants

Figure **4b**

Guelph | 26-Jan-2020

P:\PRJ2003REM\Endeavour\53. Reports\Monitoring Reports\2H2019\Draft Figures\]Draft_Fig04ab_05ab_MassRemovalByEW_MonthlyData_2019.xlsx]Fig5b-cum.mass.rem.by_EW_Dee



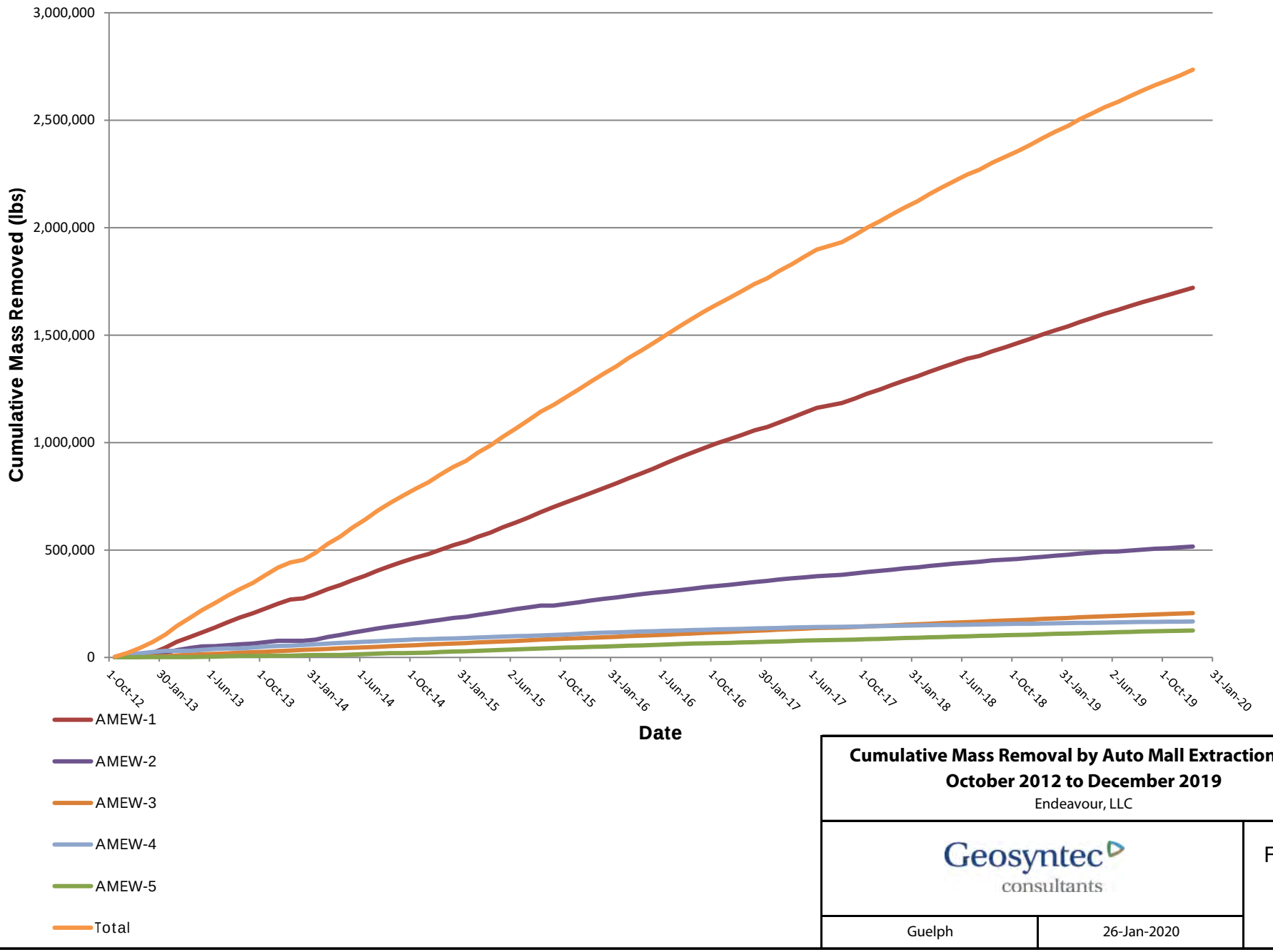
Cumulative Mass Removed by Athens/Galleria Extraction Well
October 2012 to December 2019
Endeavour, LLC

Geosyntec consultants

Guelph | 26-Jan-2020

Figure **5a**

P:\PRJ2003REM\Endeavour\53. Reports\Monitoring Reports\2H2019\Draft Figures\[Draft_Fig04ab_05ab_MassRemovalByEW_MonthlyData_2019.xlsx]Fig5b-cum.mass.rem.by_EW_Dee



Cumulative Mass Removal by Auto Mall Extraction Well
October 2012 to December 2019
Endeavour, LLC

Geosyntec consultants

Guelph | 26-Jan-2020

Figure **5b**

P:\PRJ2003REM\Endeavour\53. Reports\Monitoring Reports\2H2019\Draft Figures\[Draft_Fig04ab_05ab_MassRemovalByEW_MonthlyData_2019.xlsx]Fig5b-cum.mass.rem.by_EW_Dee

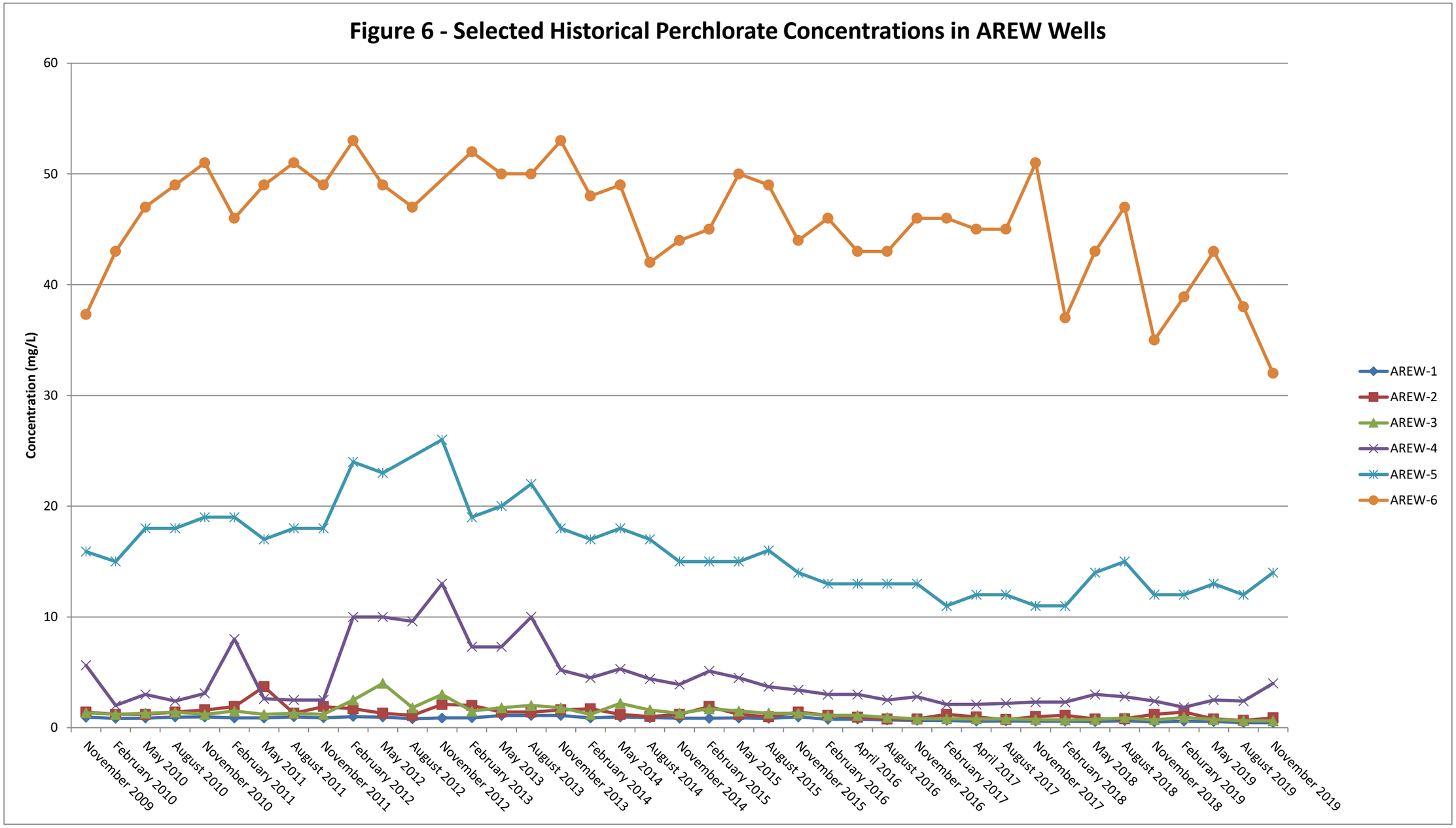


Figure 6 - Selected Historical Perchlorate Concentrations in AREW Wells
Concentration (mg/L)
60
50
40
30
20
10
0
November 2009
February 2010
May 2010
August 2010
November 2010
February 2011
May 2011
August 2011
November 2011
February 2012
May 2012
August 2012
November 2012
February 2013
May 2013
August 2013
November 2013
February 2014
May 2014
August 2014
November 2014
February 2015
May 2015
August 2015
November 2015
February 2016
April 2016
August 2016
November 2016
February 2017
April 2017
August 2017
November 2017
February 2018
May 2018
August 2018
November 2018
Feburary 2019
May 2019
August 2019
November 2019
AREW-1
AREW-2
AREW-3
AREW-4
AREW-5
AREW-6

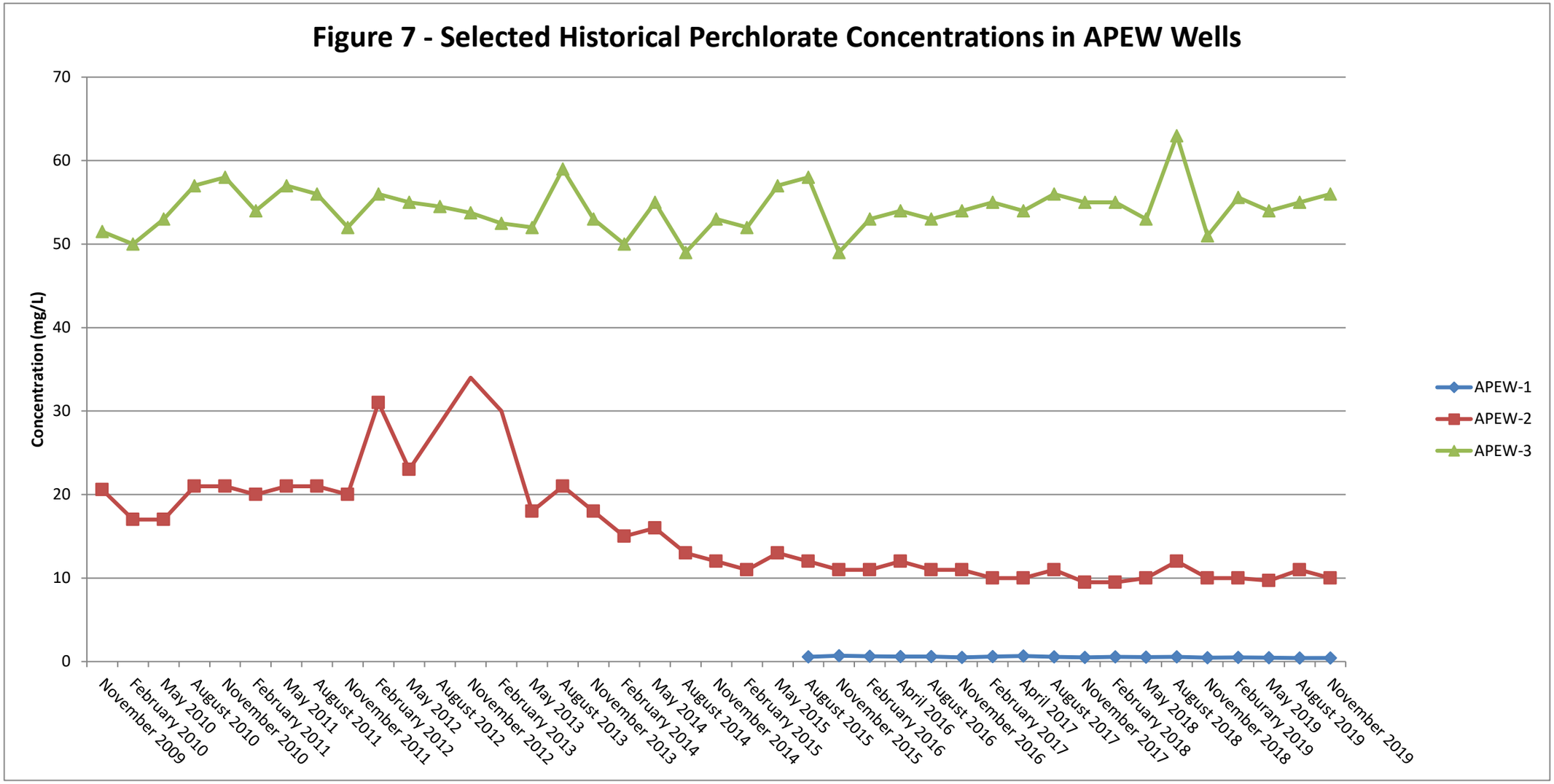


Figure 7 - Selected Historical Perchlorate Concentrations in APEW Wells
Concentration (mg/L)
70
60
50
40
30
20
10
0
November 2009
February 2010
May 2010
August 2010
November 2010
February 2011
May 2011
August 2011
November 2011
February 2012
May 2012
August 2012
November 2012
February 2013
May 2013
August 2013
November 2013
February 2014
May 2014
August 2014
November 2014
February 2015
May 2015
August 2015
November 2015
February 2016
April 2016
August 2016
November 2016
February 2017
April 2017
August 2017
November 2017
February 2018
May 2018
August 2018
November 2018
Feburary 2019
May 2019
August 2019
November 2019
APEW-1
APEW-2
APEW-3

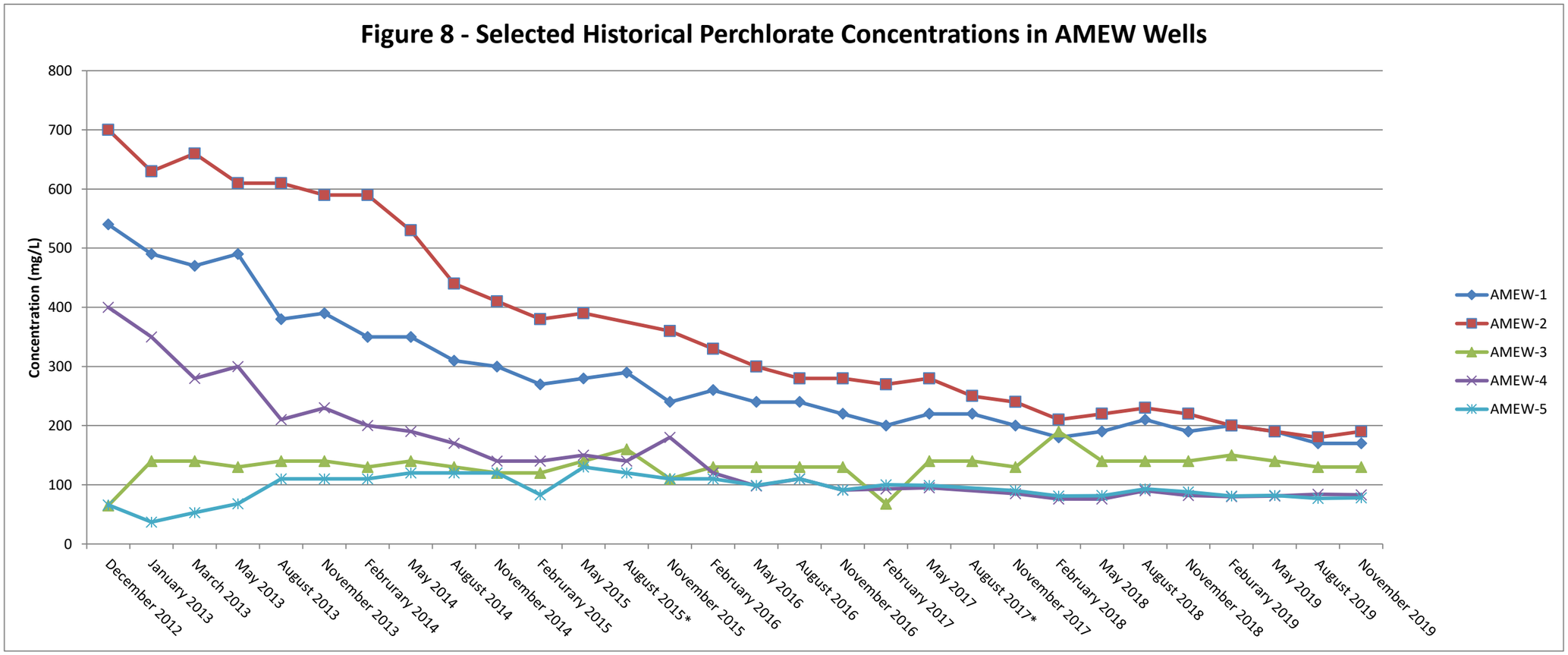
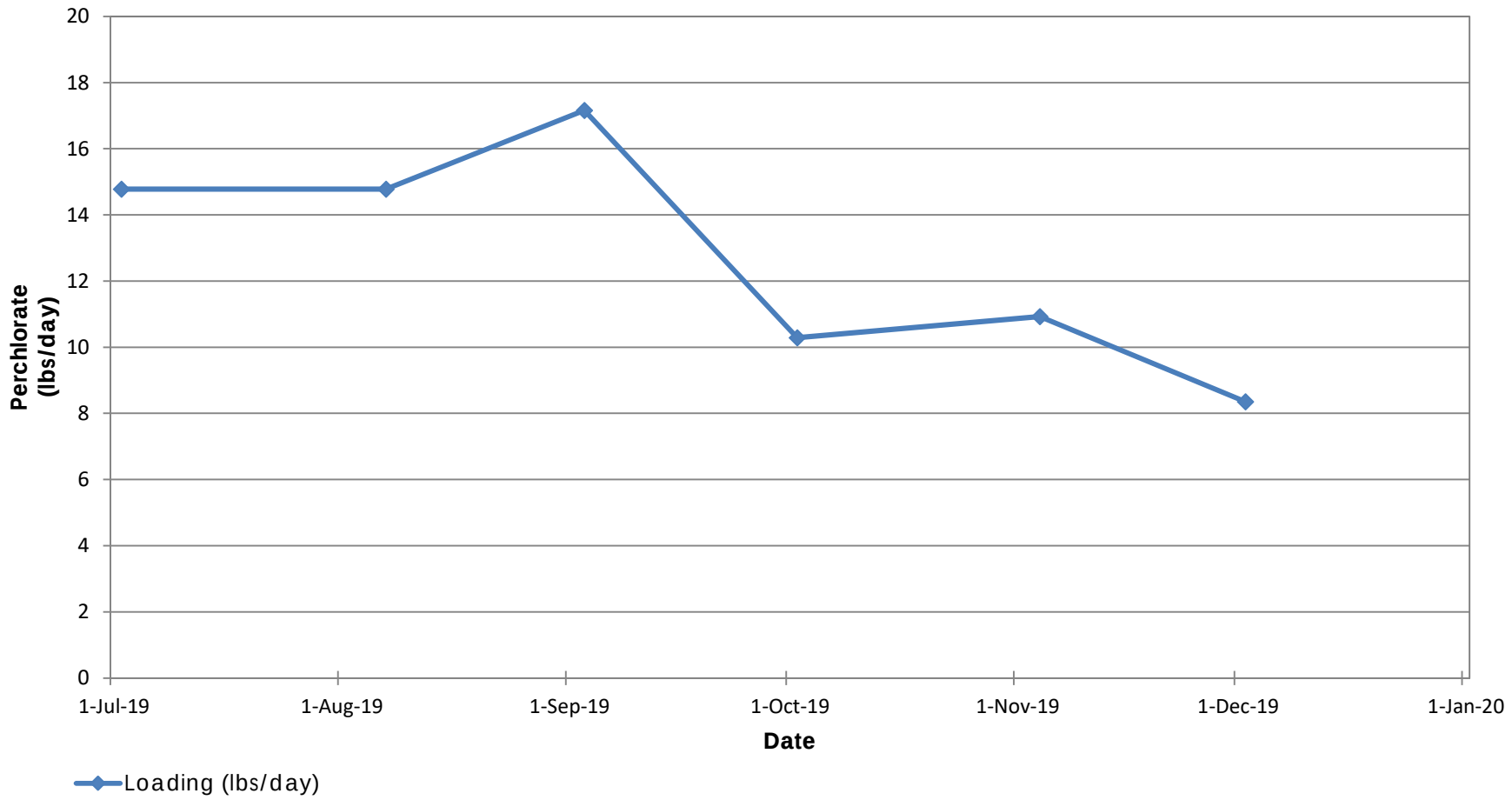


Figure 8 - Selected Historical Perchlorate Concentrations in AMEW Wells
Concentration (mg/L)
800
700
600
500
400
300
200
100
0
December 2012
January 2013
March 2013
May 2013
August 2013
November 2013
Februrary 2014
May 2014
August 2014
November 2014
Februrary 2015
May 2015
August 2015*
November 2015
February 2016
May 2016
August 2016
November 2016
February 2017
May 2017
August 2017*
November 2017
February 2018
May 2018
August 2018
November 2018
Feburary 2019
May 2019
August 2019
November 2019
AMEW-1
AMEW-2
AMEW-3
AMEW-4
AMEW-5



Notes:
lbs/day - pounds per day

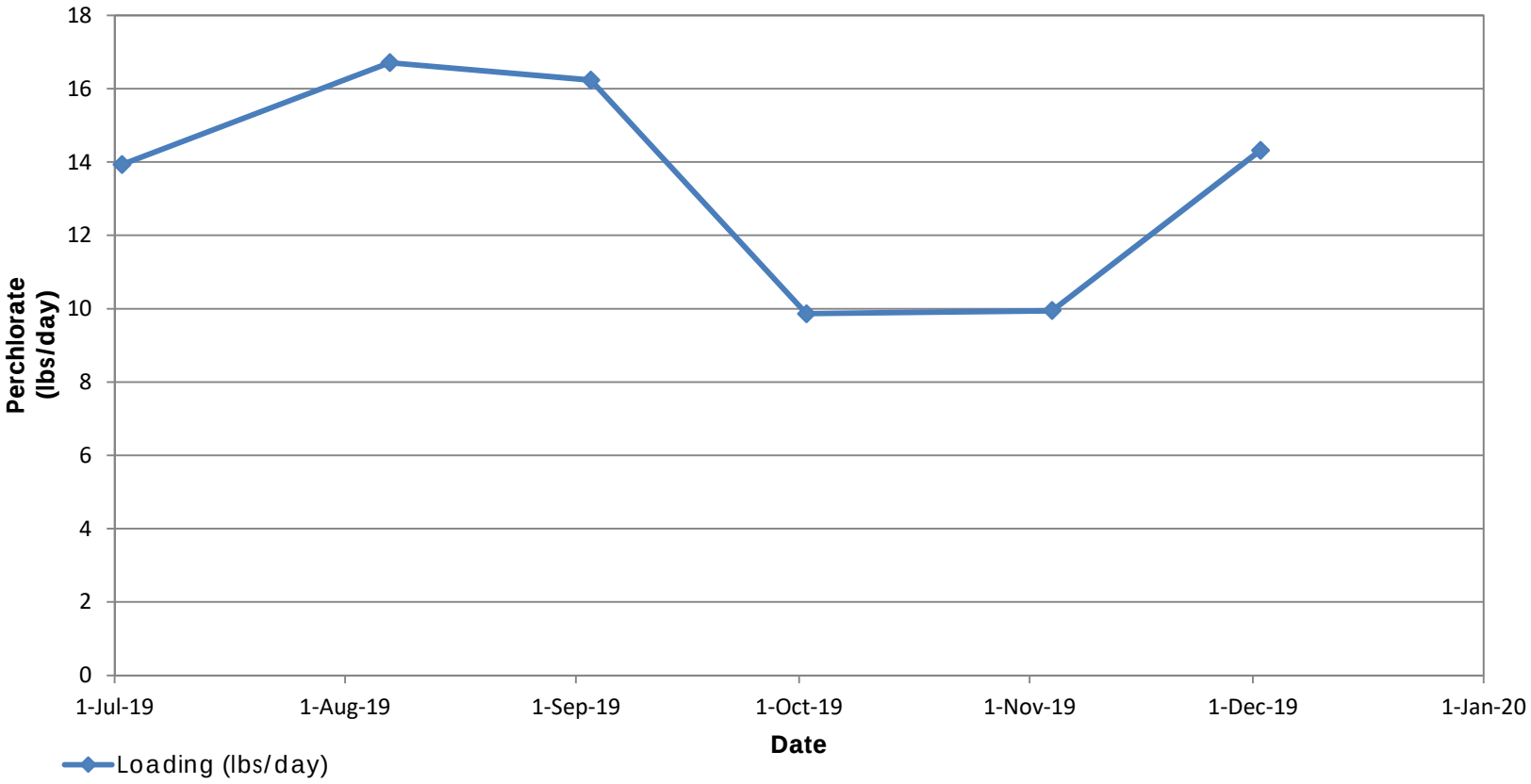
Monthly Perchlorate Loading in AC Main
July 1 to December 31, 2019
Endeavour LLC

Geosyntec consultants

Figure **9**

Oakland | January 2020

P:\PR\2003REM\Endeavour\53. Reports\Monitoring Reports\2H2019_JM_working\[Figure 9 - ADC_PerchlorateLoading_2H2019_DRAFT.xlsx]Fig 9



Note:
lbs/day - pounds per day

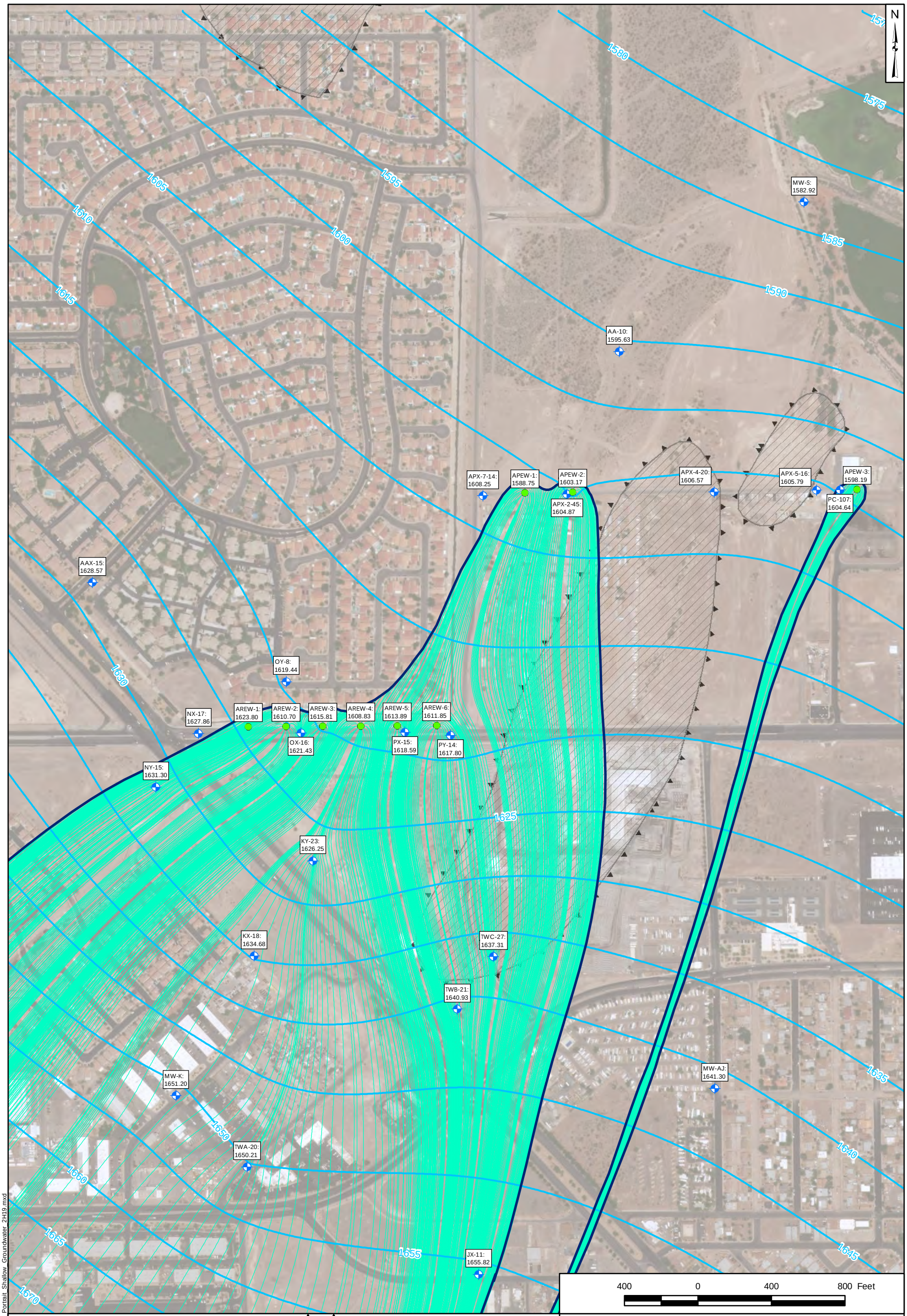
Monthly Perchlorate Loading in Eastgate Storm Drain
July 1 to December 31, 2019
Endeavour LLC

Geosyntec consultants

Figure **10**

Oakland | January 2020

P:\PR\2003REM\Endeavour\53. Reports\Monitoring Reports\2H2019_JM_working\[Figure 10 - Eastgate Storm Drain Perchlorate loading_2H2019_DRAFT.xlsx]Data



400 0 400 800 Feet

Operating Extraction Well

Groundwater Elevation at Monitoring Well (ft msl)

Capture Zone (numerical method)

Groundwater Equipotential (ft msl) - 5 Feet

Particle Tracking

"Muddy Creek High"

Notes:
ft msl - feet mean sea level
Water levels measured in extraction wells not used for contouring
Aerial Photograph courtesy of Microsoft Corporation

Groundwater Equipotentials in Shallow Water Bearing Zone, Athens/Galleria Extraction Area
November 3, 2019 to November 14, 2019

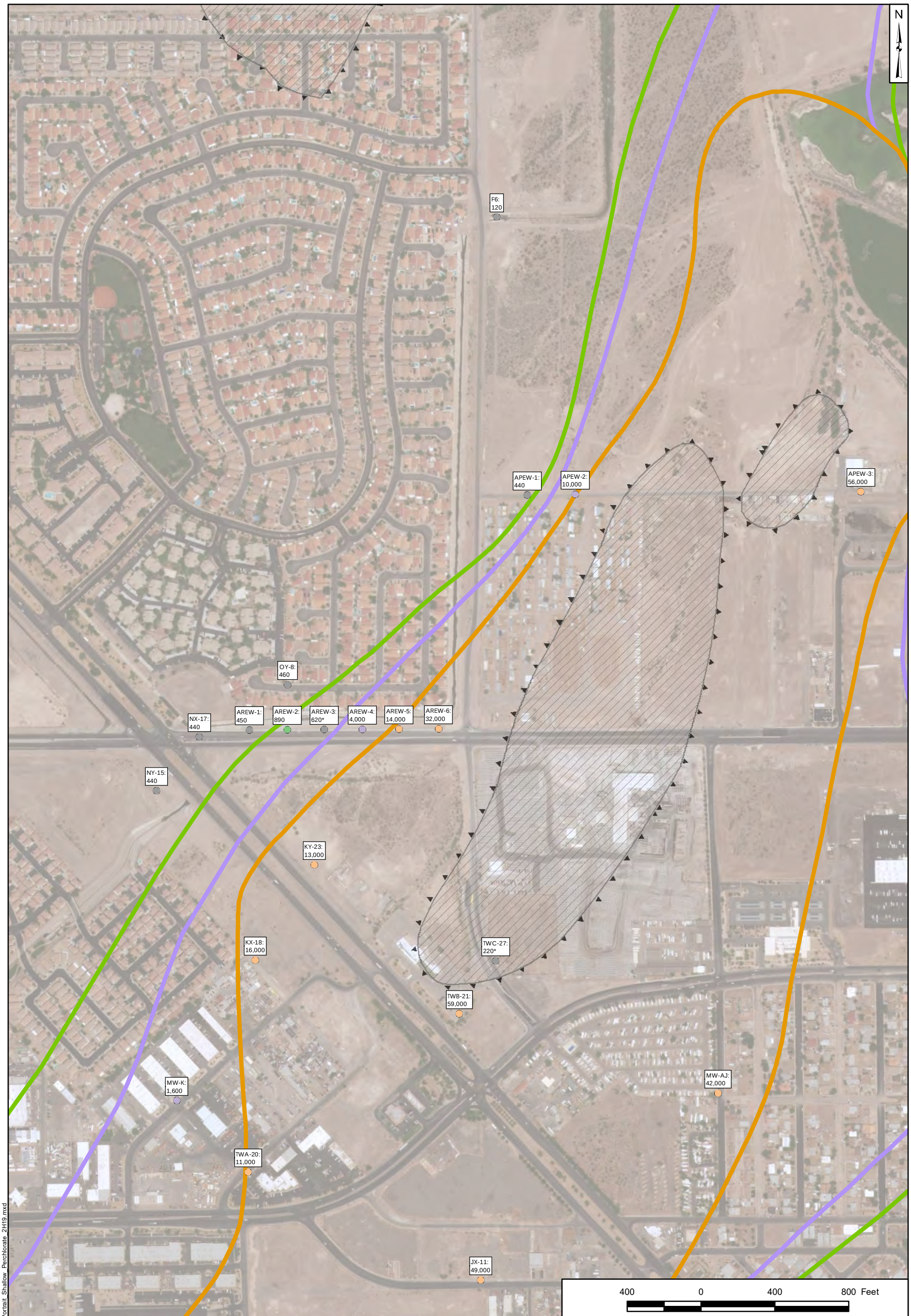
Endeavour LLC

Geosyntec consultants

Guelph | 29-Jan-2020

Figure 11

Path: P:\GIS\Endeavour\2H19\MXD\Endeavour_Tabloid_Portrait_Shallow_Groundwater_2H19.mxd



Measured Concentration (µg/L)

- >10,000
- >1,000 - 10,000
- >700 - 1,000
- ≤700

Isoconcentration Contour (µg/L)

- 10,000
- 1,000
- 700

"Muddy Creek High"

Notes:
µg/L - Micrograms per Liter
All concentrations in µg/L
* - Value not contoured
Aerial Photograph courtesy of Microsoft Corporation

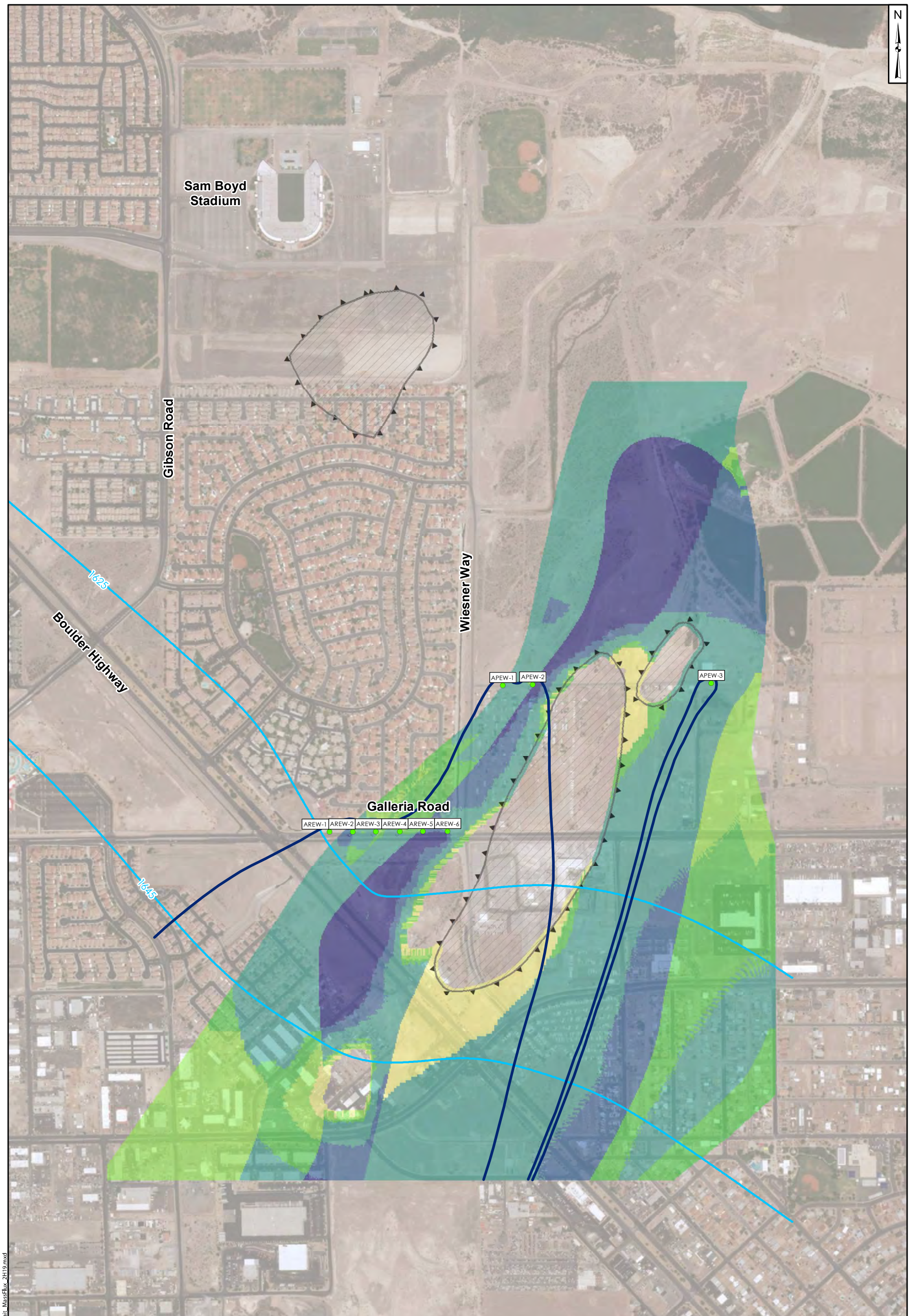
Perchlorate in Shallow Water Bearing Zone,
Athens/Galleria Extraction Area
November 3, 2019 to November 13, 2019
Endeavour LLC

Geosyntec consultants

Guelph | 21-Jan-2020

Figure 12

Path: P:\GIS\Endeavour\2H19\MXD\Endeavour_Tabloid_Portrait_Shallow_Perchlorate_2H19.mxd



Operating Extraction Well

Capture Zone (numerical method)

Groundwater Equipotential (ft msl)

"Muddy Creek High"

Mass Flux per Unit Width (lbs/day/ft)

- ≤0.0001
- >0.0001 - 0.0005
- >0.0005 - 0.001
- >0.001 - 0.005
- >0.005 - 0.01
- >0.01

400 0 400 800 Feet

Notes:
ft msl - feet above mean sea level
lbs/day/ft - pounds per day per foot
Aerial Photograph courtesy of Microsoft Corporation

Perchlorate Loading per Width in Shallow Water Bearing Zone November 3, 2019 to November 14, 2019

Endeavour LLC

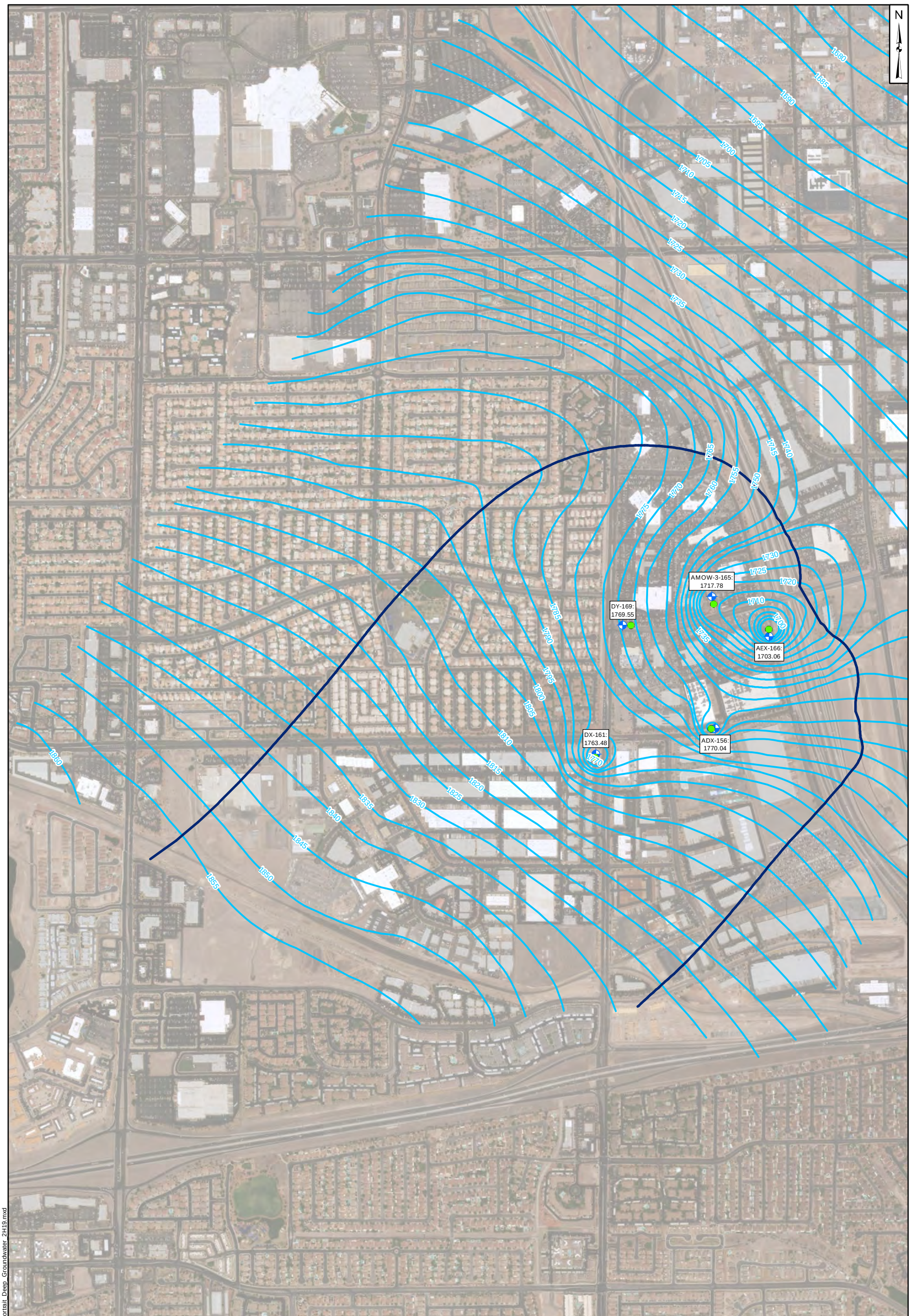
Geosyntec consultants

Guelph

13-Feb-2020

Figure 13

Path: P:\GIS\Endeavour\2H19\MXD\Endeavour_Tabloid_Portrait_MassFlux_2H19.mxd



Operating Extraction Well

Groundwater Elevation at Monitoring Well (ft msl)

Groundwater Equipotential (ft msl) - 5 Feet

Capture Zone (numerical method)

500 0 500 1,000 Feet

Notes:
* - value not contoured
ft msl - feet mean sea level
Aerial photograph courtesy of Microsoft Corporation

Groundwater Equipotentials in Deep Water Bearing Zone, Auto Mall Extraction Area
November 3 2019 to November 12, 2019

Endeavour, LLC

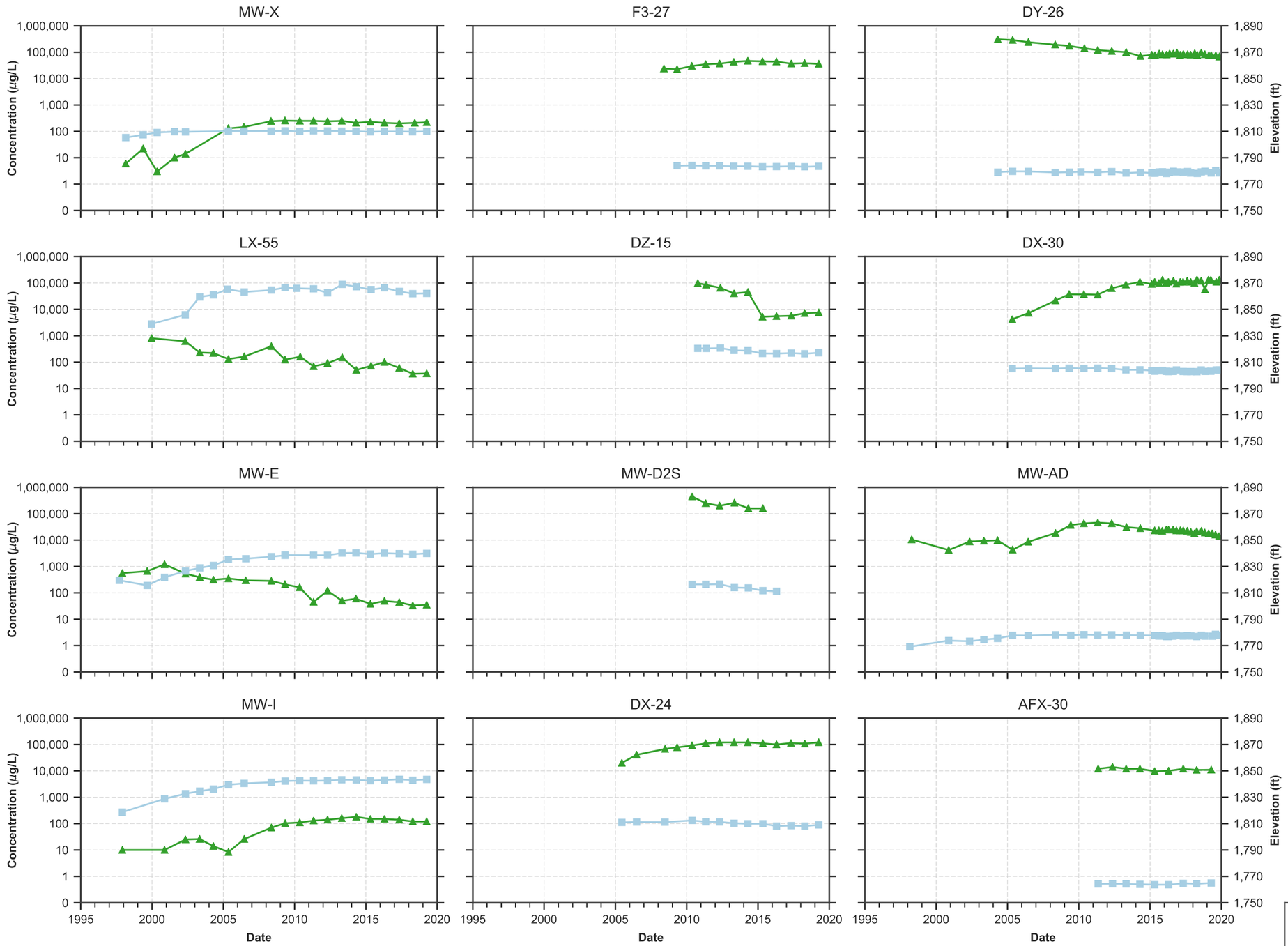
Geosyntec consultants

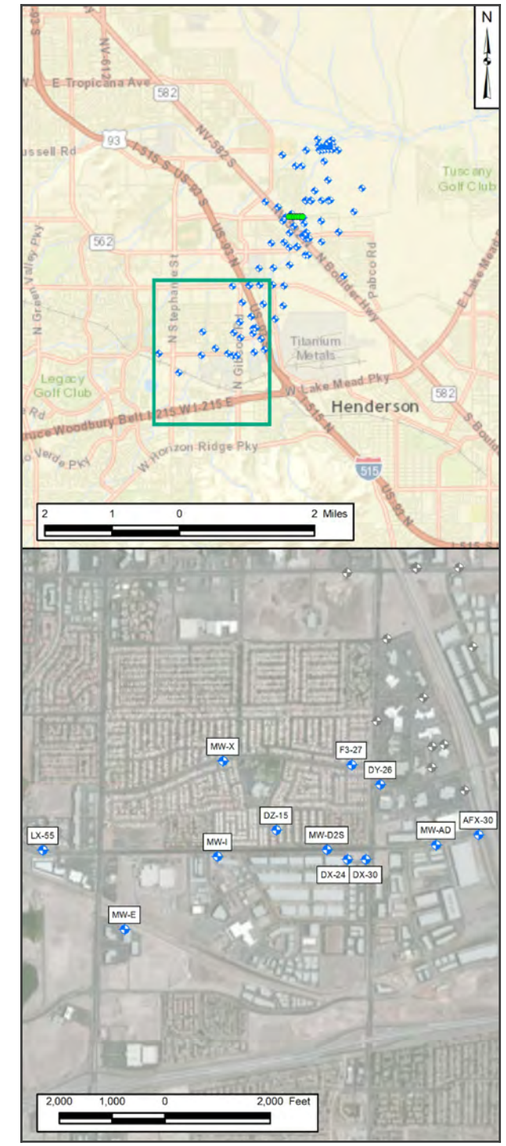
Guelph

21-Jan-2020

Figure 14

Path: P:\GIS\Endeavour\2H19\MXD\Endeavour_Tabloid_Portrait_Deep_Groundwater_2H19.mxd





Notes:
Non-detections are reported at the detection limit.

Perchlorate Concentrations and Water Levels through December 2019
Shallow Water Bearing Zone, Auto Mall West

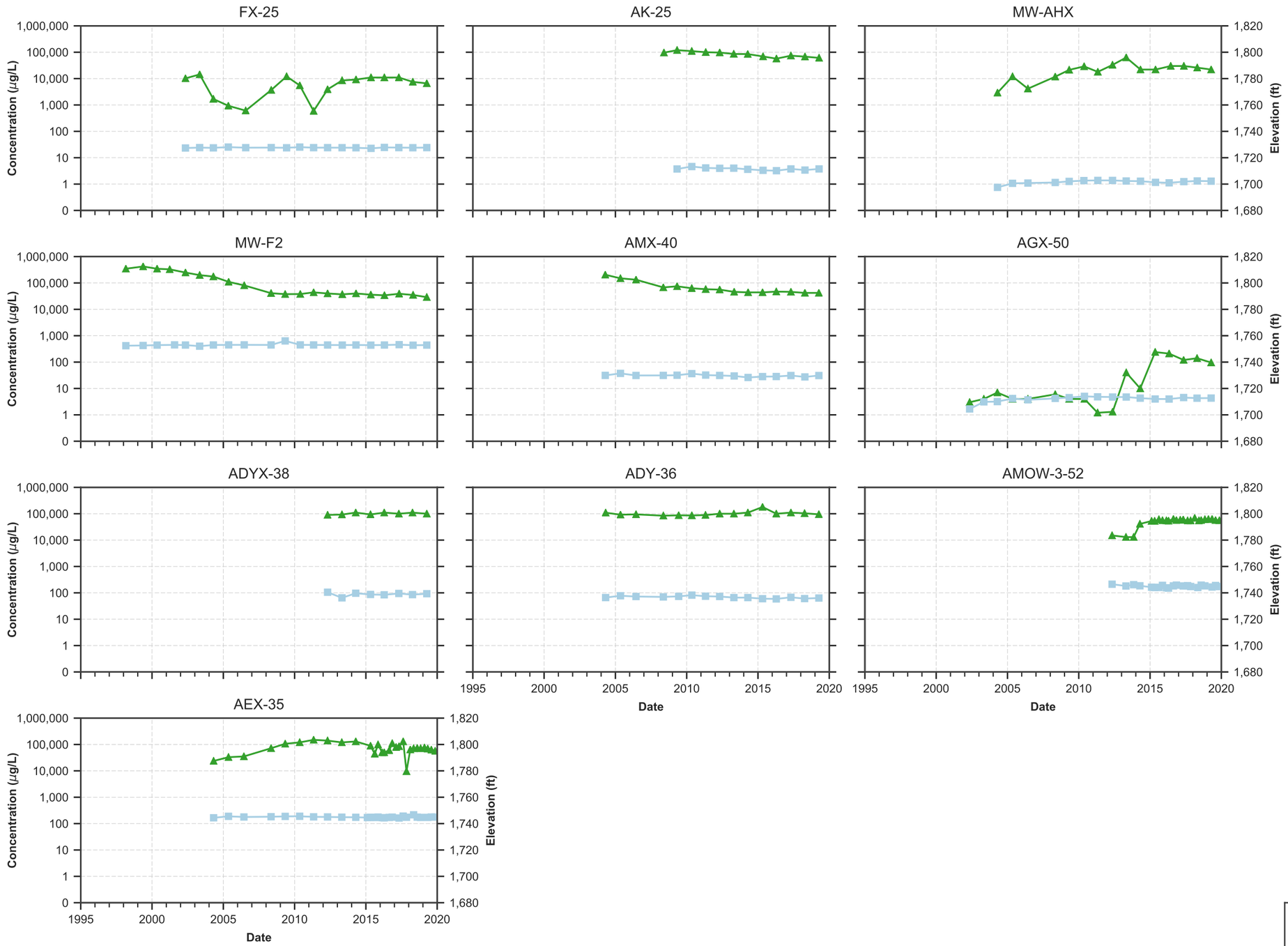
Endeavour LLC
Henderson, Nevada

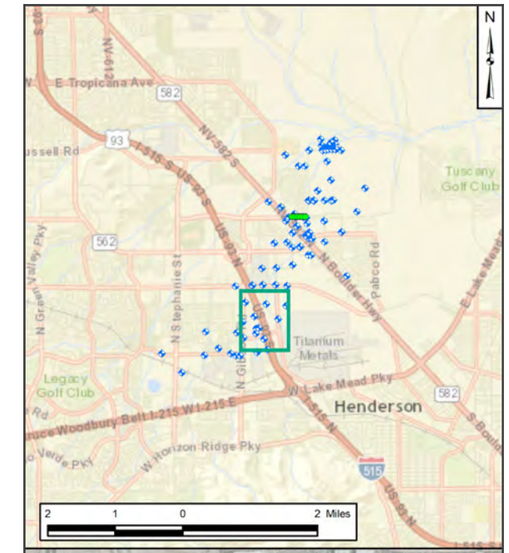
Geosyntec consultants

Oakland | January 2020

Figure 15

Source: O:\GIS\Endeavour_script\jan_2020\02_poc_figures.ipynb





FX-25 Monitoring Well

Extraction Well

Perchlorate Concentration

Groundwater Elevation

Notes:
Non-detections are reported at the detection limit.

Perchlorate Concentrations and Water Levels through December 2019
Shallow Water Bearing Zone, Auto Mall East

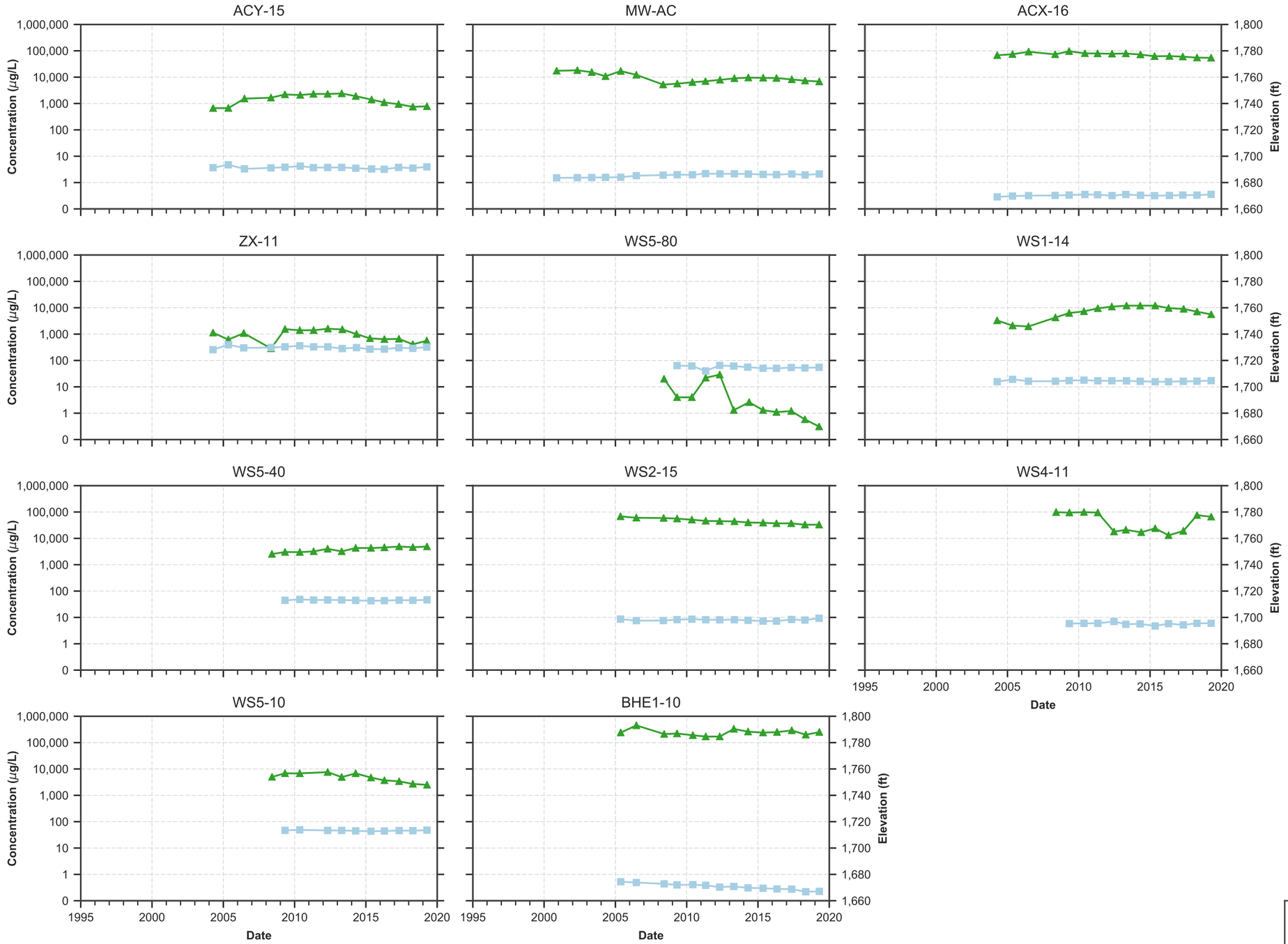
Endeavour LLC
Henderson, Nevada

Geosyntec consultants

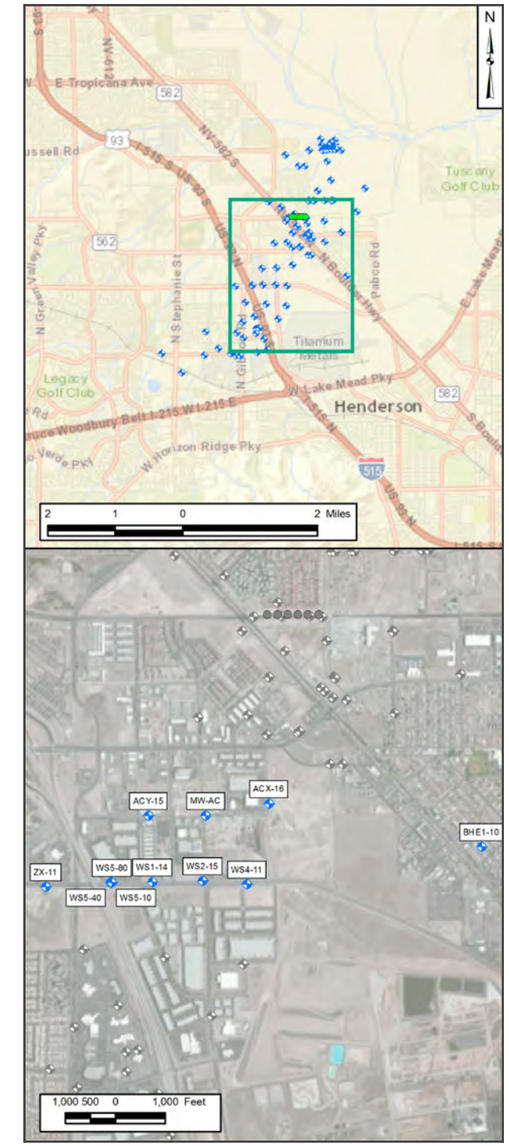
Oakland | January 2020

Figure 16

Source: O:\GIS\Endeavour_script\jan_2020\02_poc_figures.ipynb



Notes:
Non-detections are reported at the detection limit.



ZX-11 Monitoring Well

Extraction Well

Perchlorate Concentrations and Water Levels through December 2019
Shallow Water Bearing Zone, Warm Springs/Eastgate

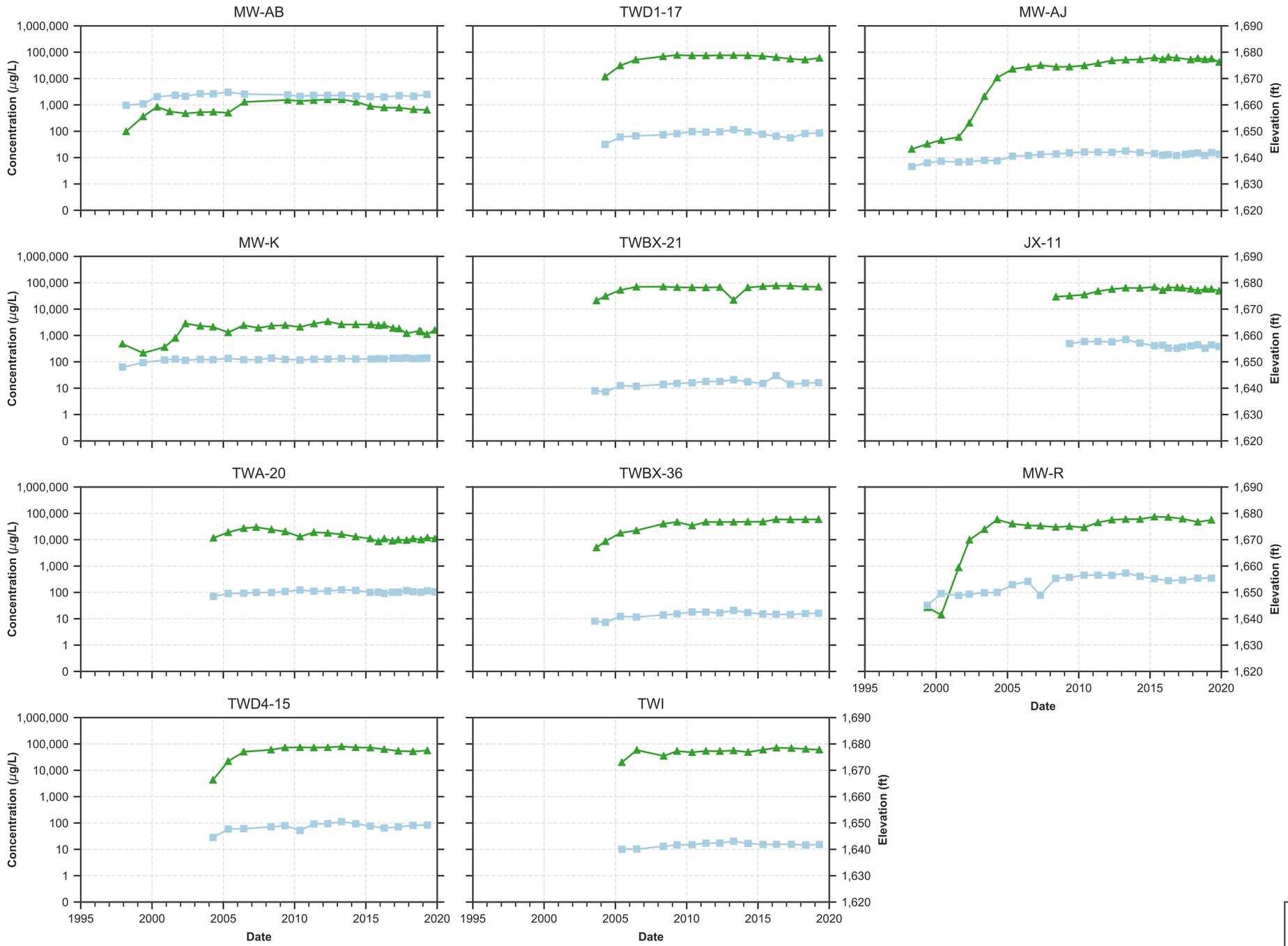
Endeavour LLC
Henderson, Nevada

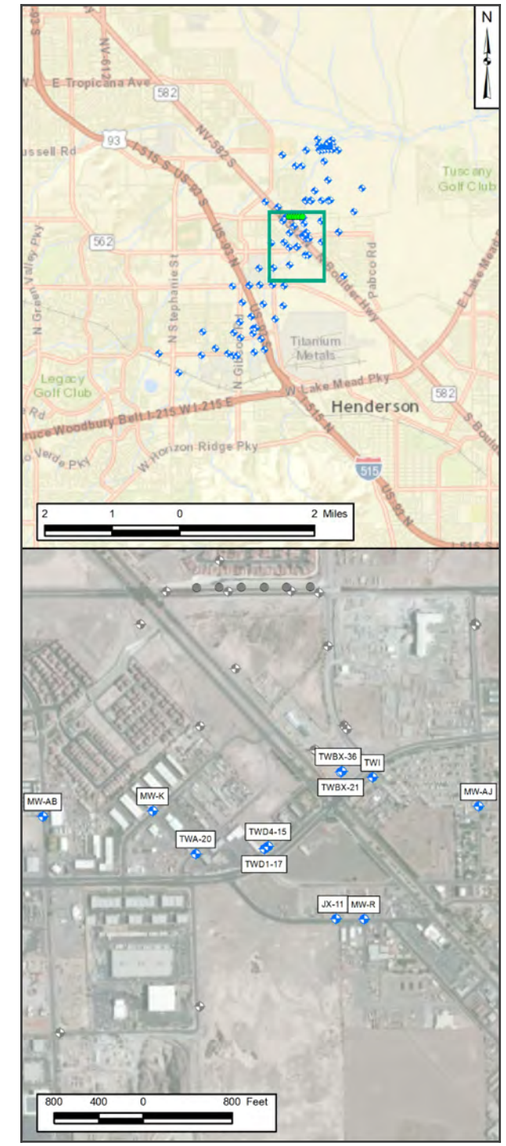
Geosyntec consultants

Oakland | January 2020

Figure 17

Source: O:\GIS\Endeavour_script\jan_2020\02_poc_figures.ipynb





MW-AB Monitoring Well

Extraction Well

Perchlorate Concentration

Groundwater Elevation

Notes:
Non-detections are reported at the detection limit.

Perchlorate Concentrations and Water Levels through December 2019
Shallow Water Bearing Zone, Sunset/Boulder West

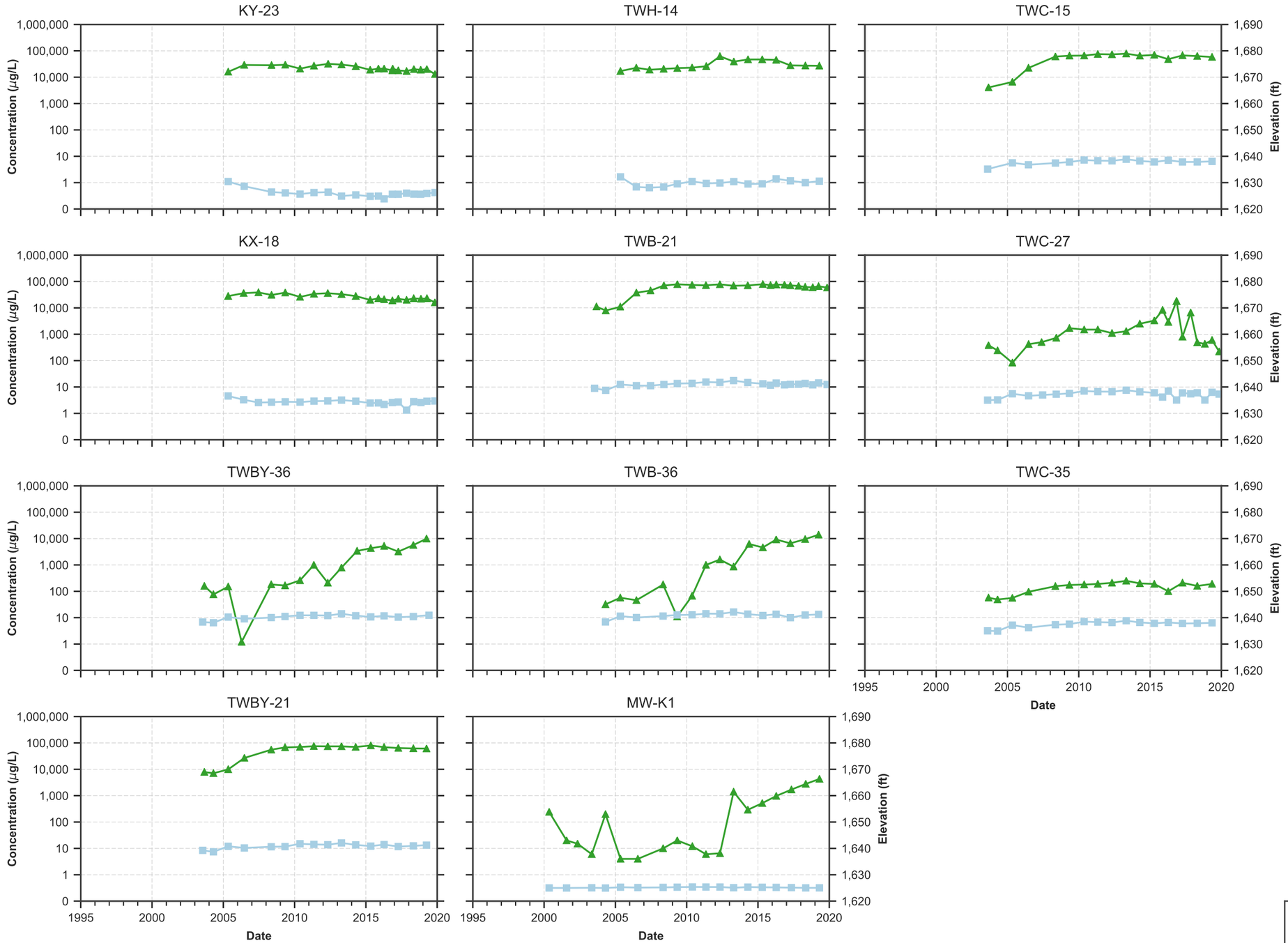
Endeavour LLC
Henderson, Nevada

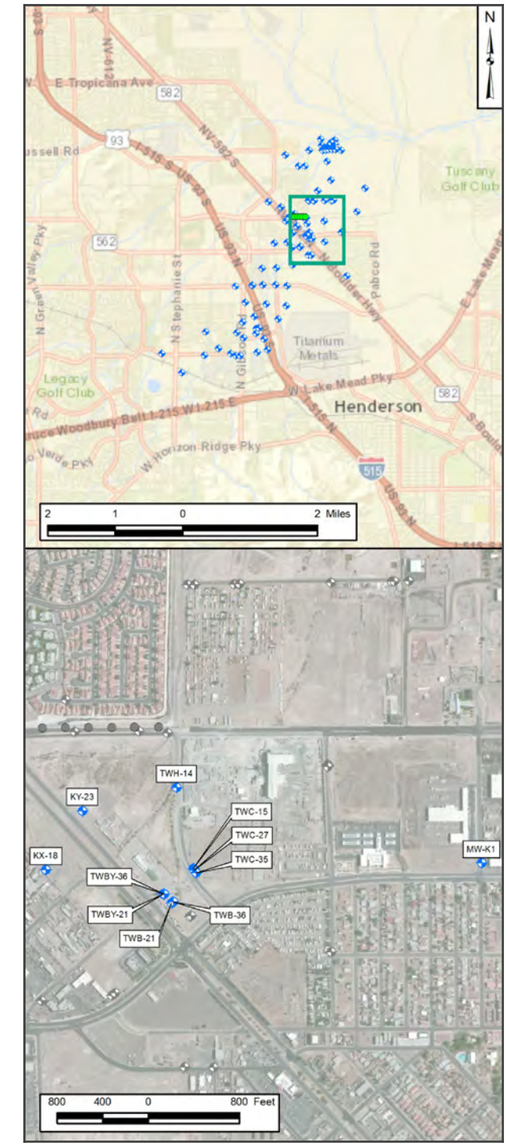
Geosyntec consultants

Oakland | January 2020

Figure 18

Source: O:\GIS\Endeavour_script\jan_2020\02_poc_figures.ipynb





KX-18 Monitoring Well

Extraction Well

Perchlorate Concentration

Groundwater Elevation

Notes:
Non-detections are reported at the detection limit.

Perchlorate Concentrations and Water Levels through December 2019
Shallow Water Bearing Zone, Sunset/Boulder East

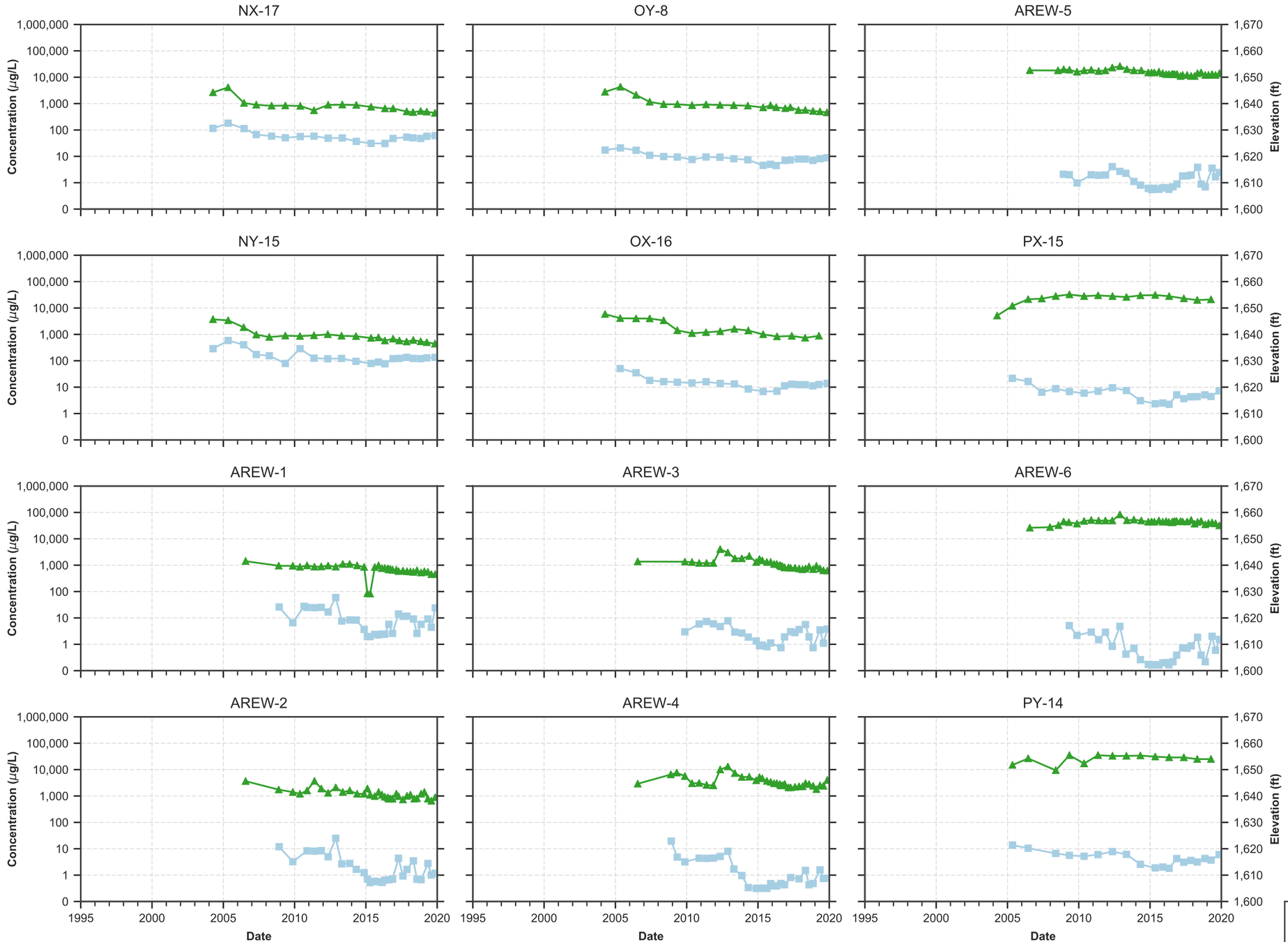
Endeavour LLC
Henderson, Nevada

Geosyntec consultants

Oakland | January 2020

Figure 19

Source: O:\GIS\Endeavour_script\jan_2020\02_poc_figures.ipynb



Notes:
Non-detections are reported at the detection limit.

NY-15 Monitoring Well

AREW-1 Extraction Well

Perchlorate Concentrations and Water Levels through December 2019
Shallow Water Bearing Zone, Boulder/Galleria

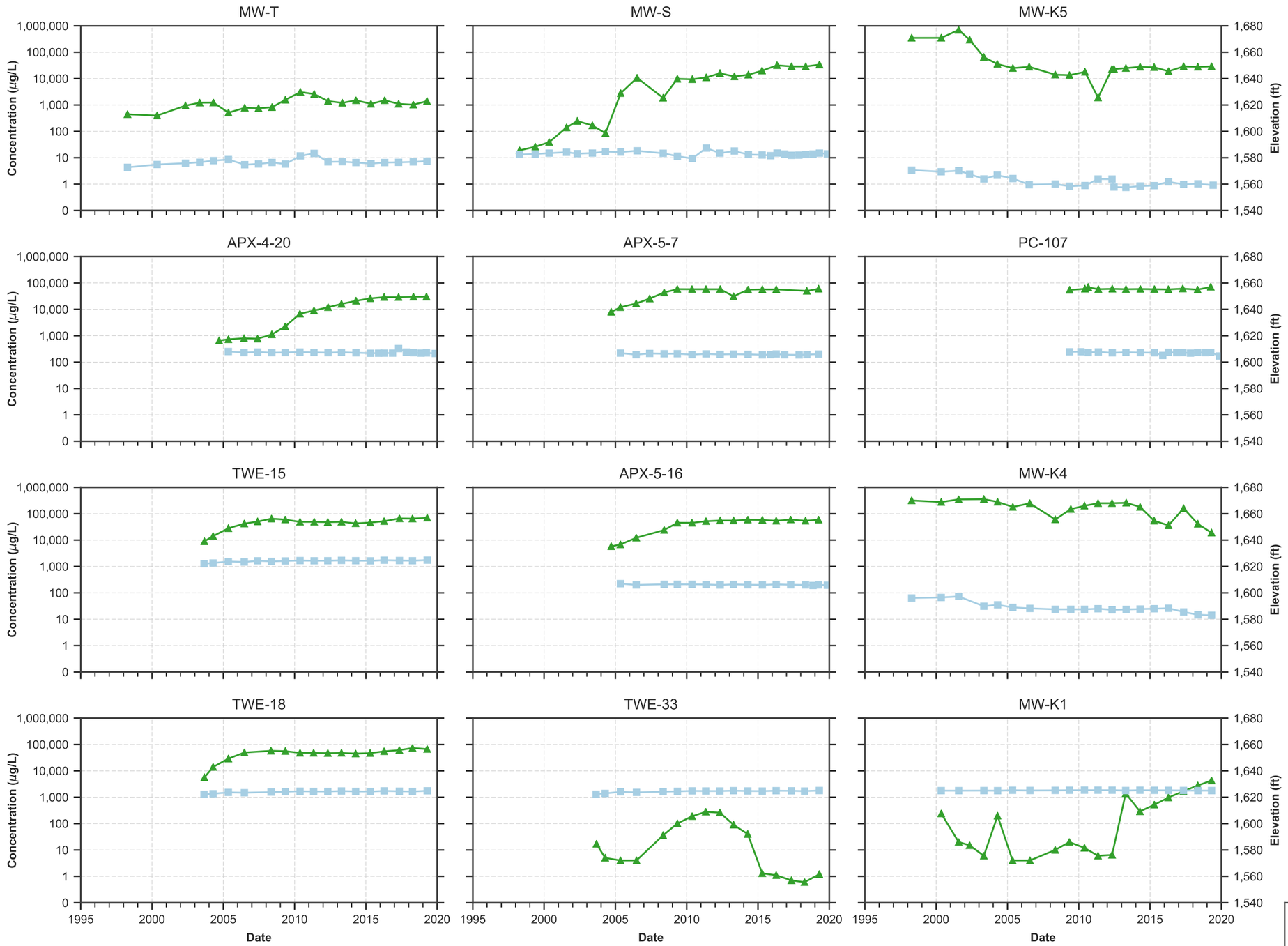
Endeavour LLC
Henderson, Nevada

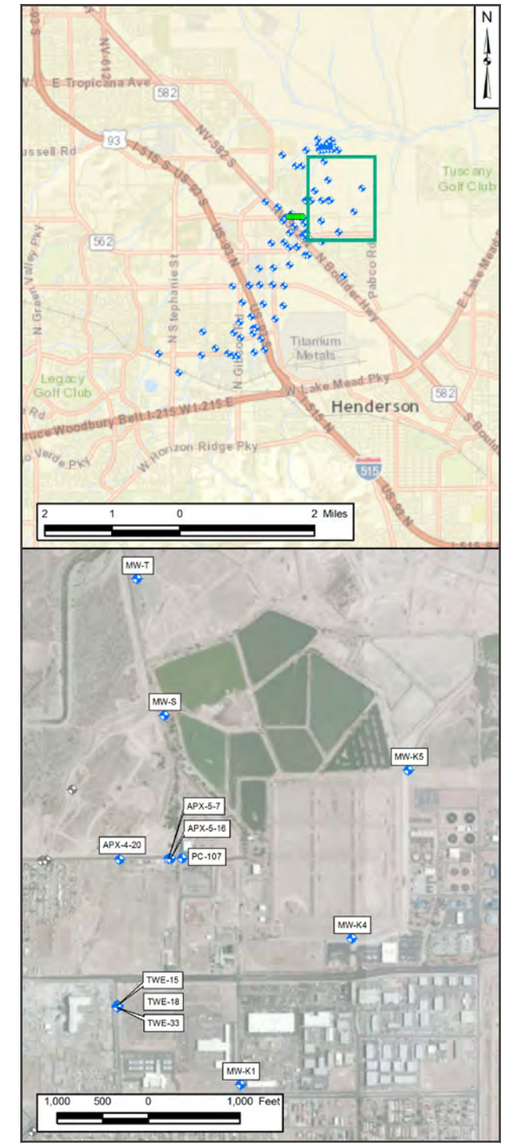
Geosyntec consultants

Oakland | January 2020

Figure 20

Source: O:\GIS\Endeavour_script\jan_2020\02_poc_figures.ipynb





MW-T Monitoring Well

Extraction Well

Perchlorate Concentration

Groundwater Elevation

Notes:
Non-detections are reported at the detection limit.

Perchlorate Concentrations and Water Levels through December 2019
Shallow Water Bearing Zone, AGTS Plant Area

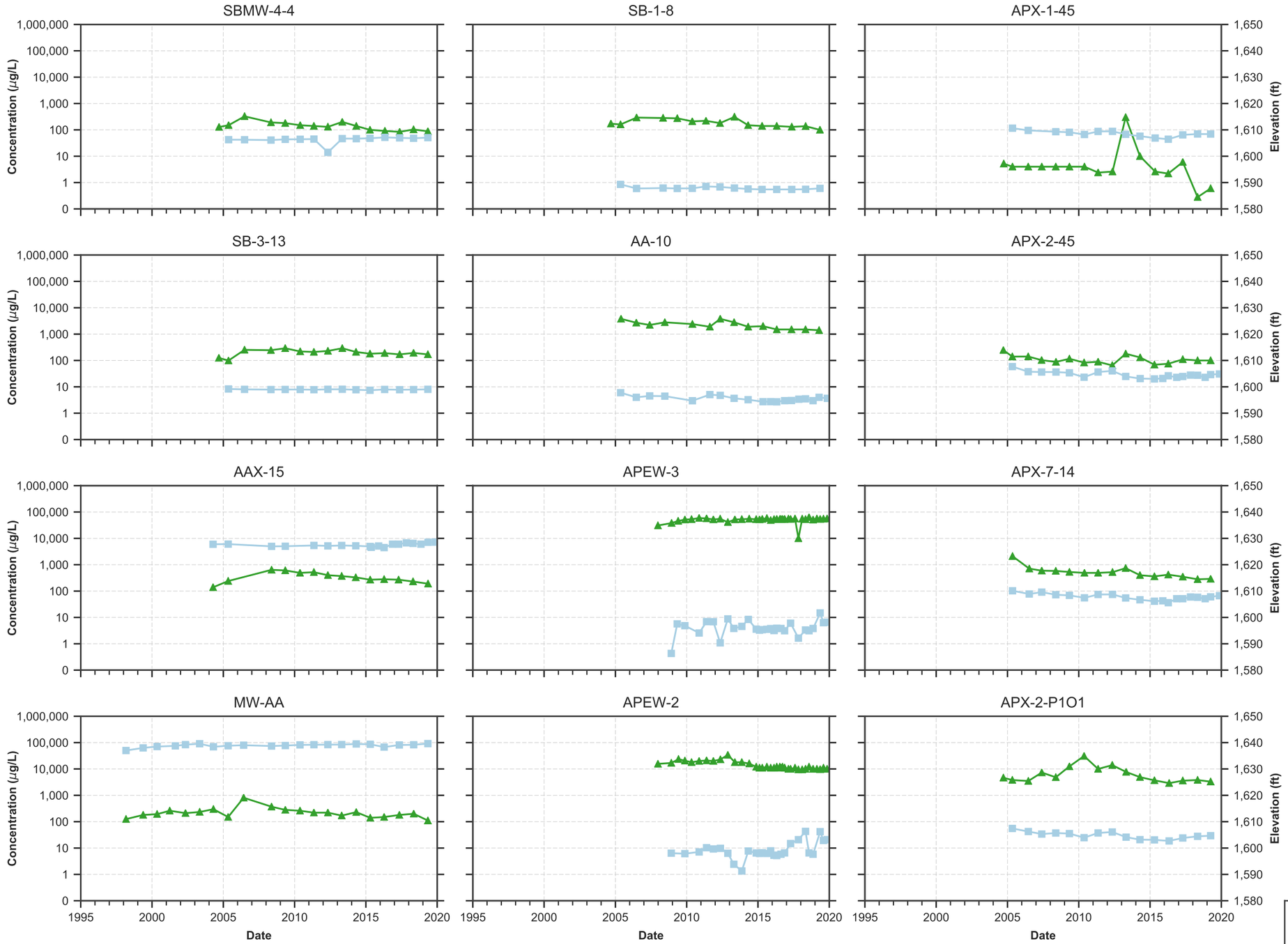
Endeavour LLC
Henderson, Nevada

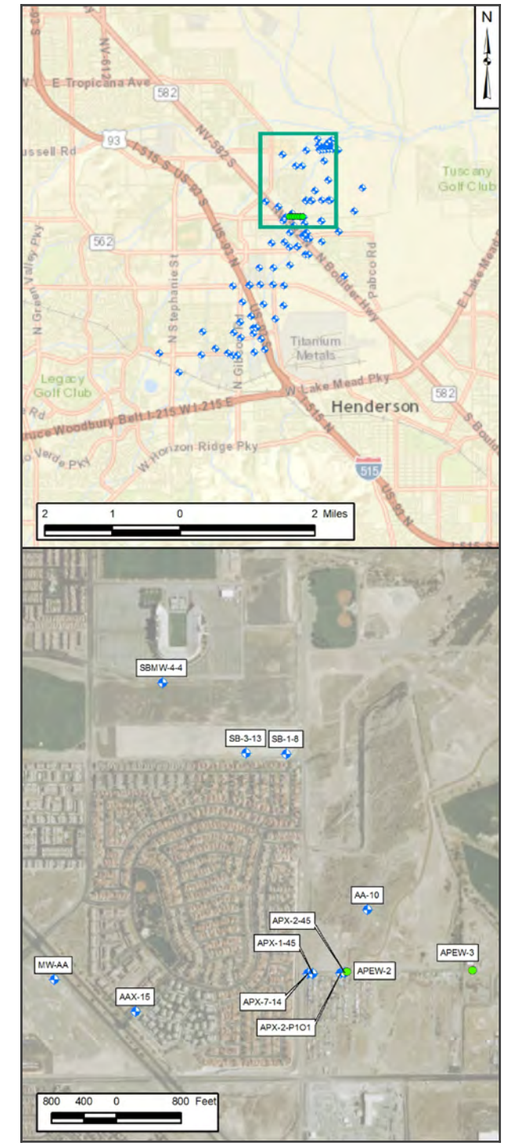
Geosyntec consultants

Oakland | January 2020

Figure 21

Source: O:\GIS\Endeavour_script\jan_2020\02_poc_figures.ipynb





Notes:
Non-detections are reported at the detection limit.

Perchlorate Concentrations and Water Levels through December 2019
Shallow Water Bearing Zone, Wiesner/Sam Boyd

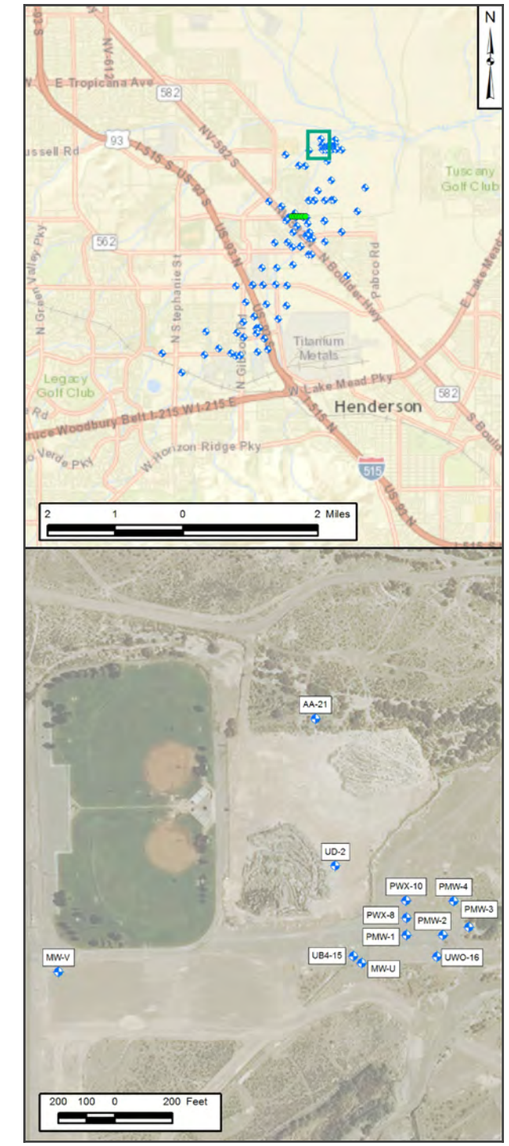
Endeavour LLC
Henderson, Nevada

Geosyntec consultants

Oakland | January 2020

Figure 22

Source: O:\GIS\Endeavour_script\jan_2020\02_poc_figures.ipynb



UD-2 Monitoring Well

Extraction Well

Notes:
Non-detections are reported at the detection limit.
1. The 1H2018 groundwater elevation for PWX-10 appears to be erroneous and is not shown on the plot.

Perchlorate Concentrations and Water Levels through December 2019
Shallow Water Bearing Zone, Former DRIT Area

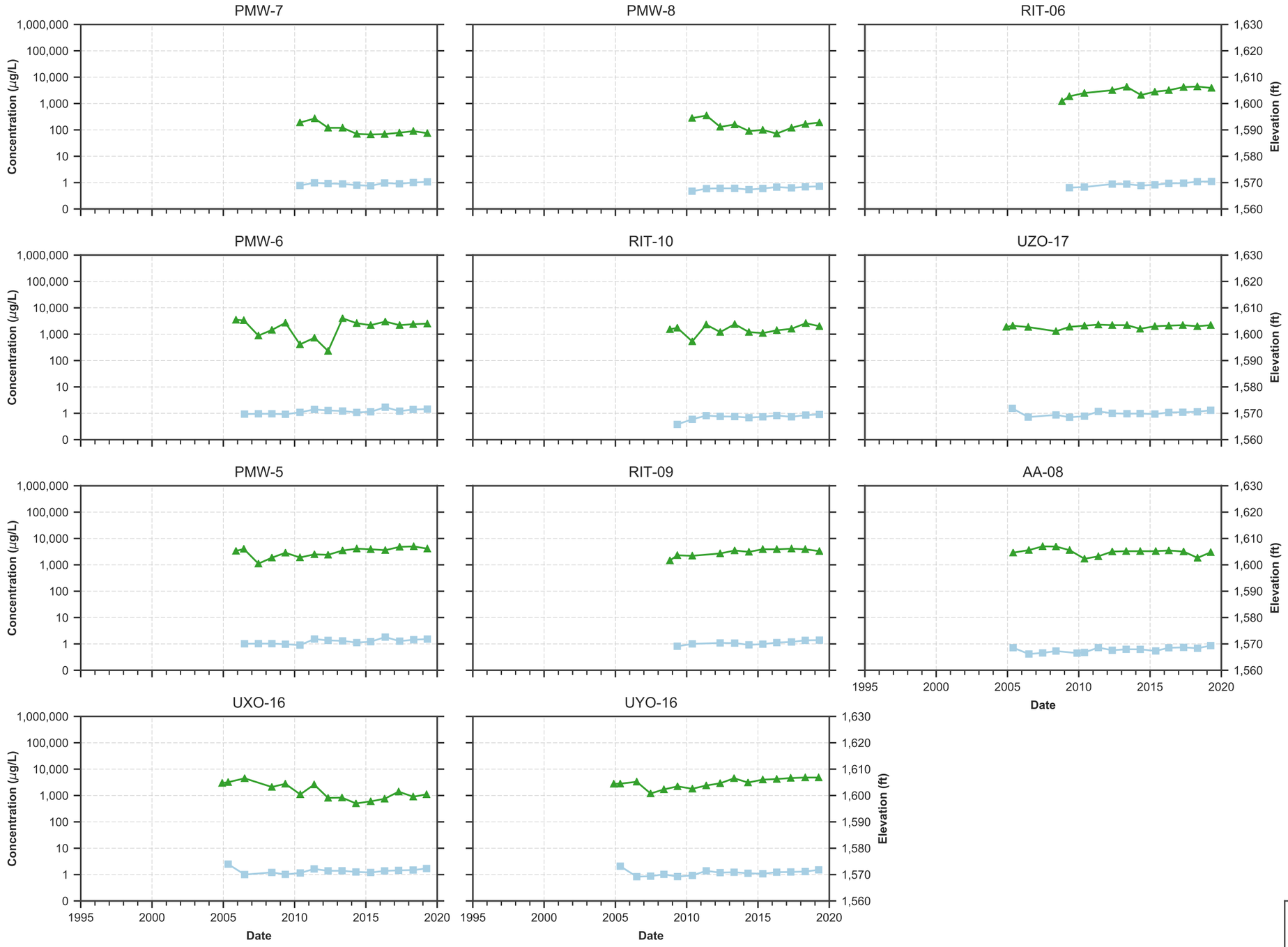
Endeavour LLC
Henderson, Nevada

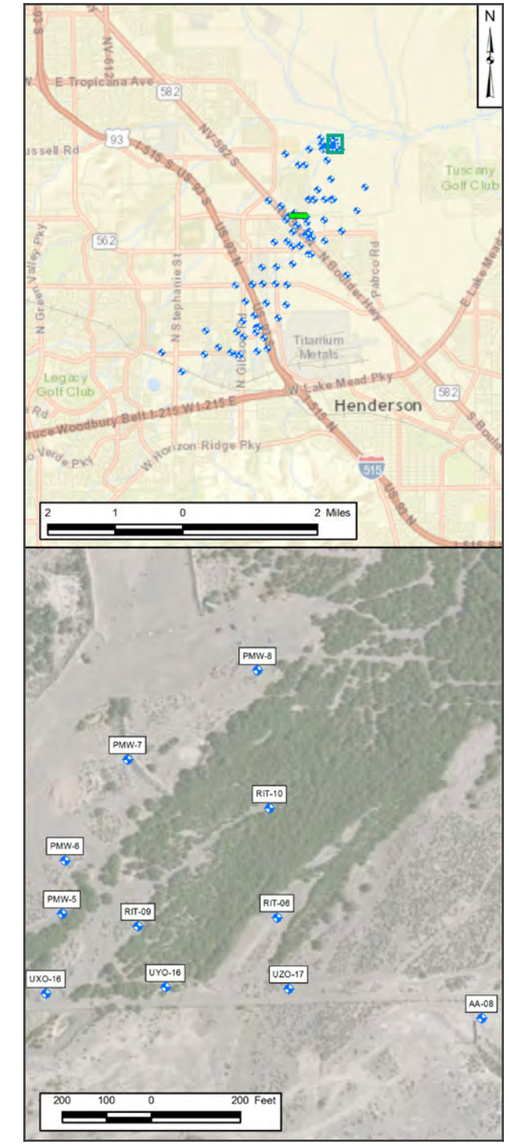
Geosyntec consultants

Oakland | January 2020

Figure 23

Source: O:\GIS\Endeavour_script\jan_2020\02_poc_figures.ipynb





PMW-8 Monitoring Well

Extraction Well

Perchlorate Concentration

Groundwater Elevation

Notes:
Non-detections are reported at the detection limit.

Perchlorate Concentrations and Water Levels through December 2019
Shallow Water Bearing Zone, DRIT East

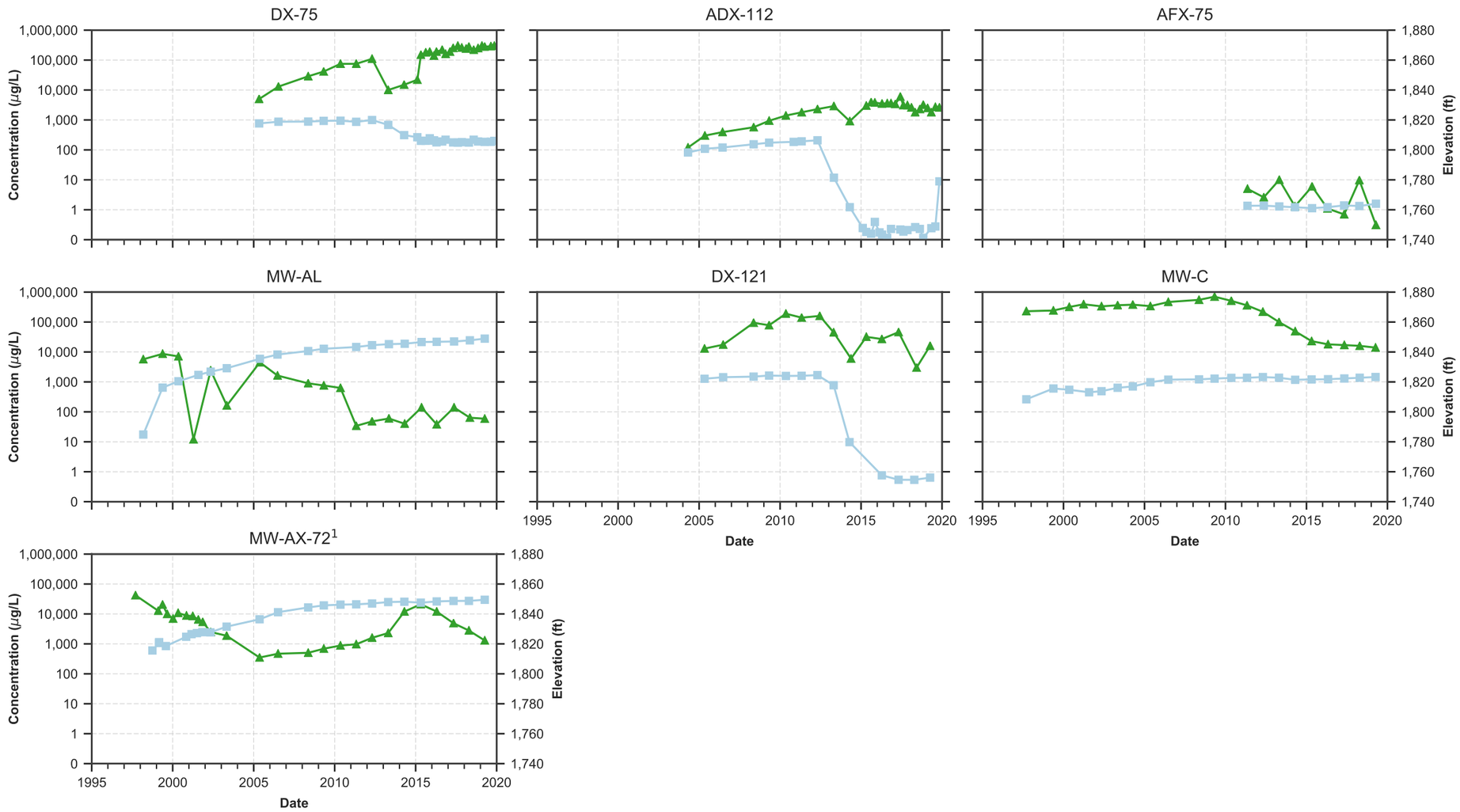
Endeavour LLC
Henderson, Nevada

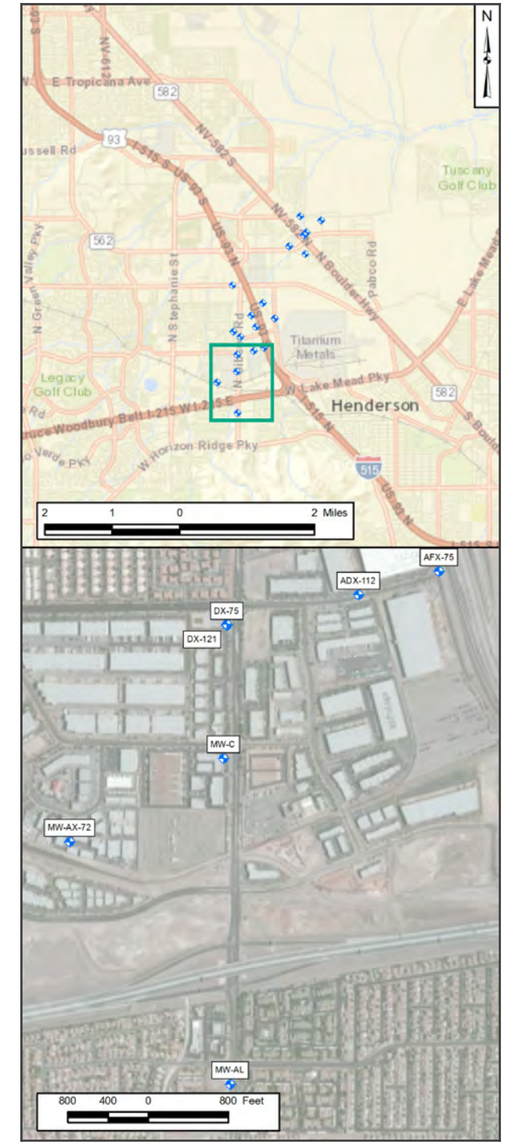
Geosyntec consultants

Oakland | January 2020

Figure 24

Source: O:\GIS\Endeavour_script\jan_2020\02_poc_figures.ipynb





MW-C Monitoring Well

Perchlorate Concentration
Groundwater Elevation

Notes:
Non-detections are reported at the detection limit.
1. Data prior to 2005 are from well MW-A, which was destroyed in 2003 and was replaced by MW-AX-72.

Perchlorate Concentrations and Water Levels through December 2019
Middle Water Bearing Zone, Auto Mall South

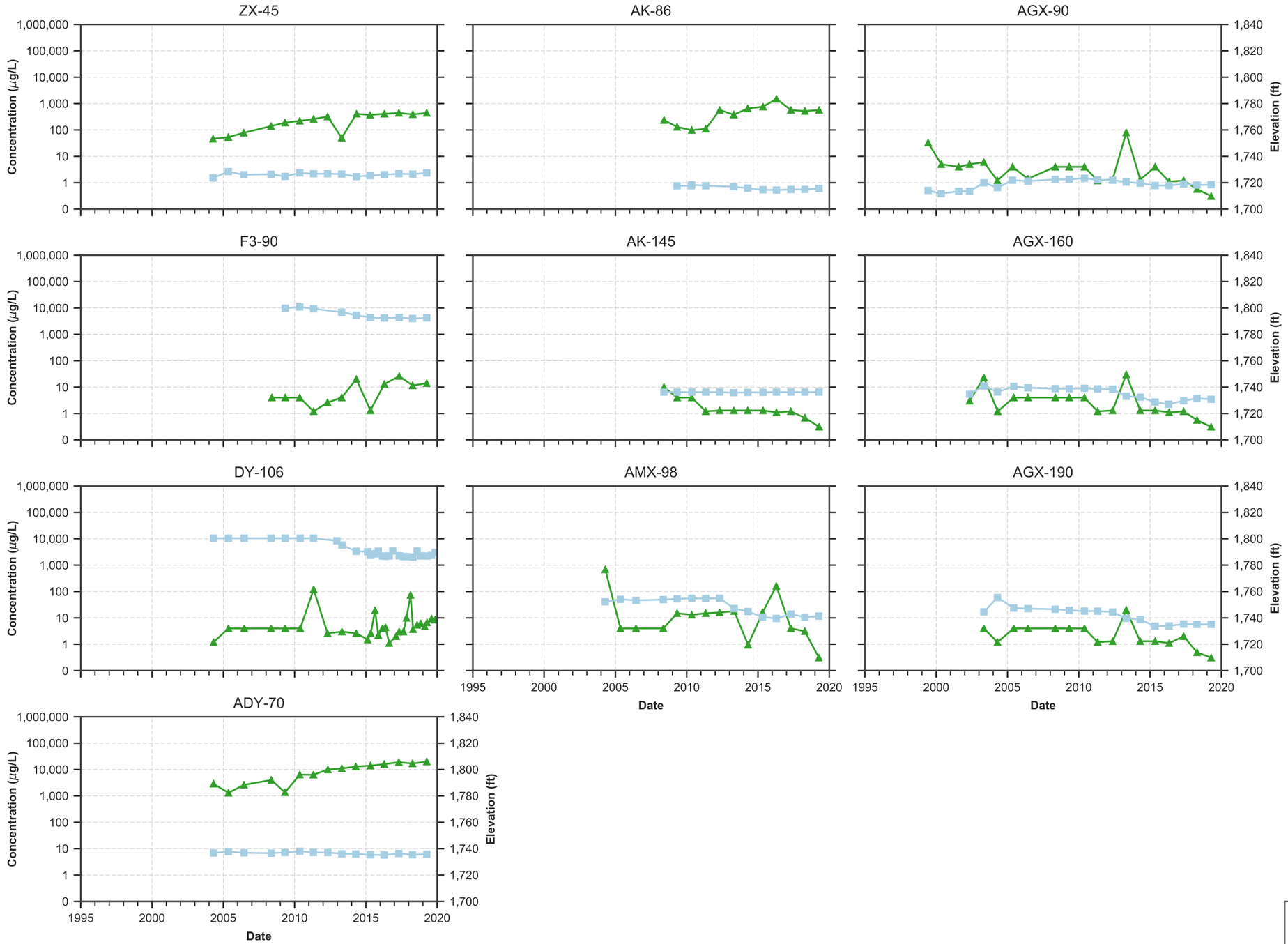
Endeavour LLC
Henderson, Nevada

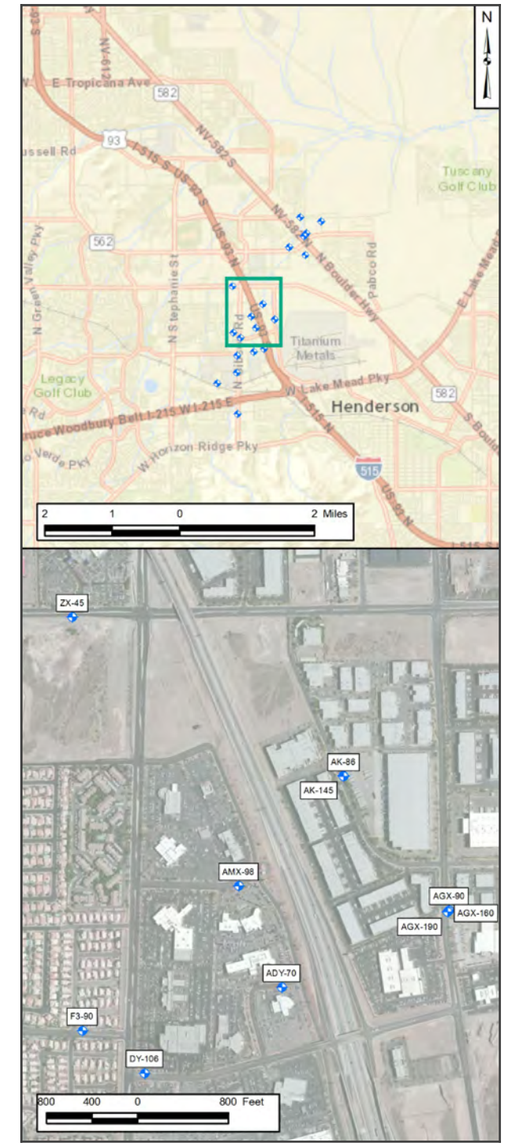
Geosyntec consultants

Oakland | January 2020

Figure 25

Source: O:\GIS\Endeavour_script\jan_2020\02_poc_figures.ipynb





ZX-45 Monitoring Well

Perchlorate Concentration

Groundwater Elevation

Notes:
Non-detections are reported at the detection limit.

Perchlorate Concentrations and Water Levels through December 2019
Middle Water Bearing Zone, Auto Mall East

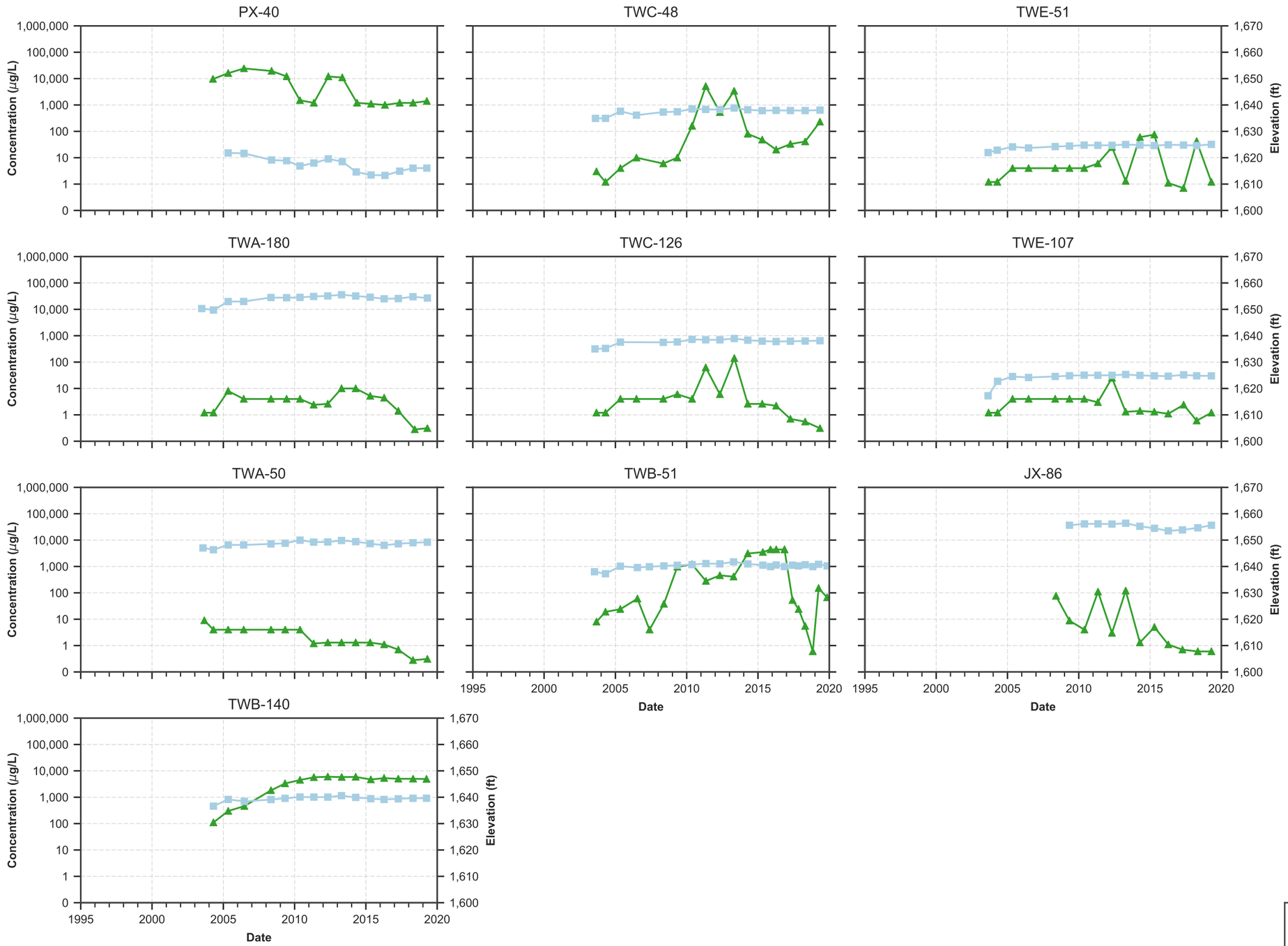
Endeavour LLC
Henderson, Nevada

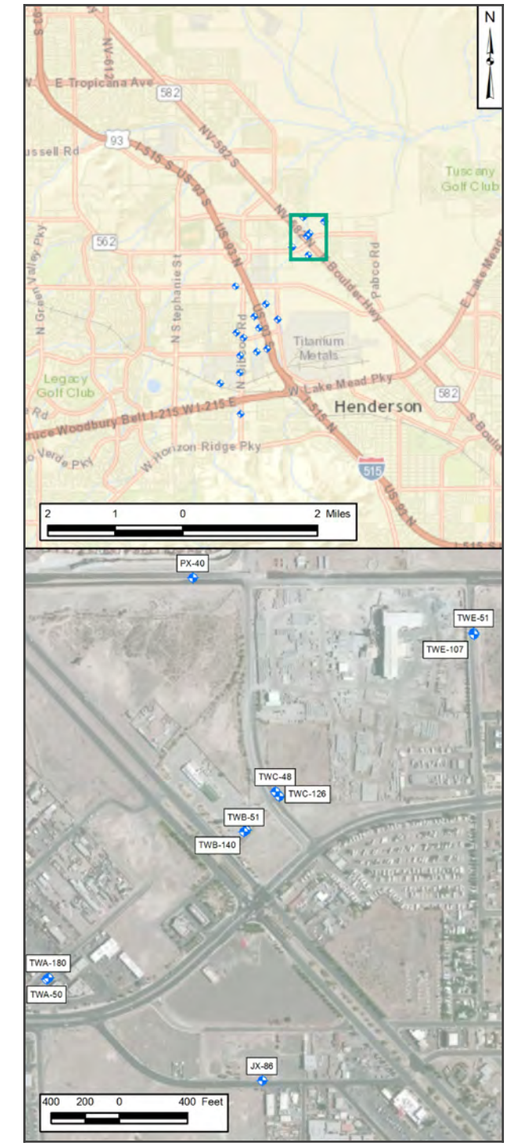
Geosyntec consultants

Oakland | January 2020

Figure 26

Source: O:\GIS\Endeavour_script\jan_2020\02_poc_figures.ipynb





PX-40 Monitoring Well

Perchlorate Concentration
Groundwater Elevation

Notes:
Non-detections are reported at the detection limit.

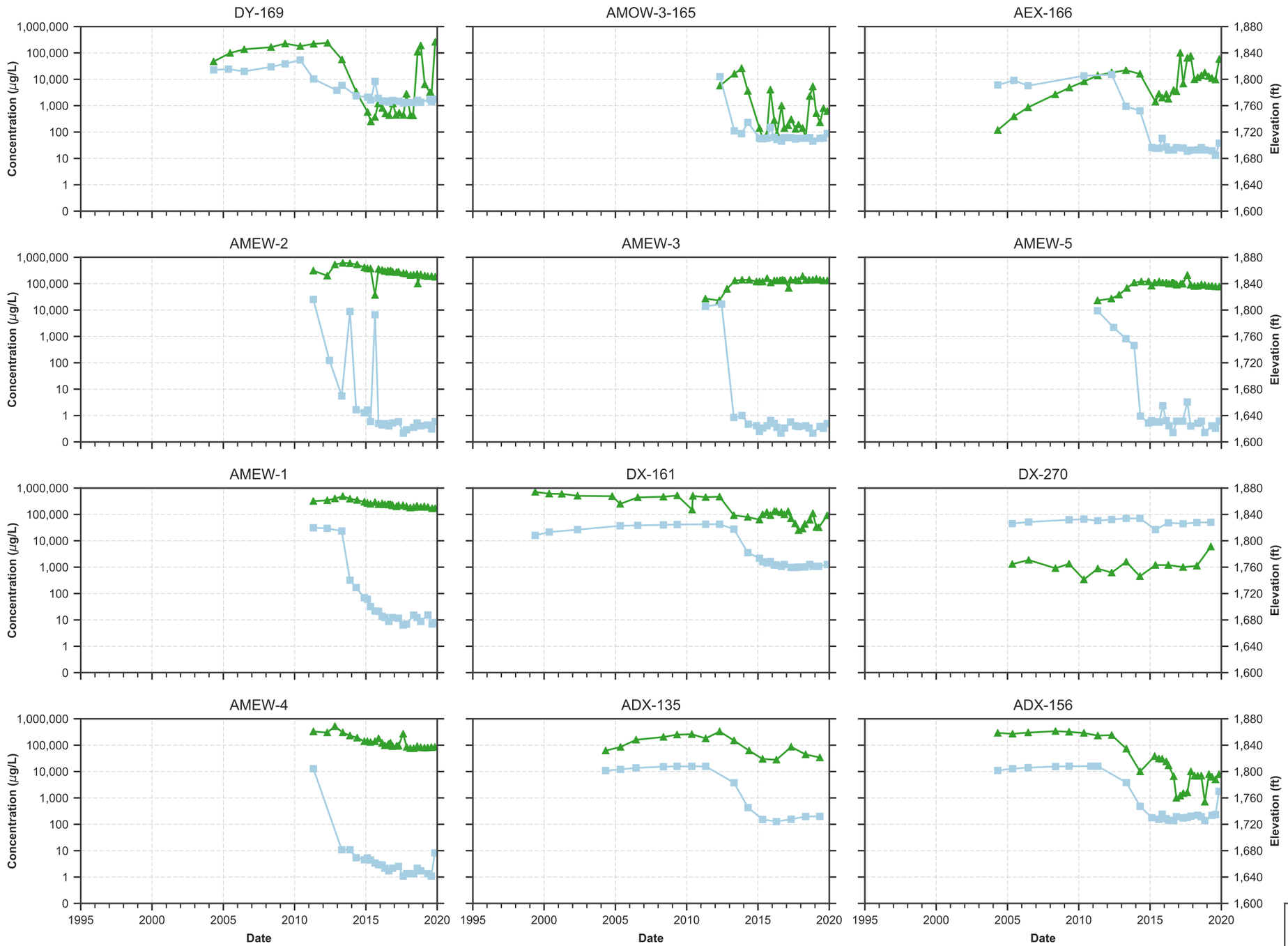
Perchlorate Concentrations and Water Levels through December 2019
Middle Water Bearing Zone, Sunset/Boulder

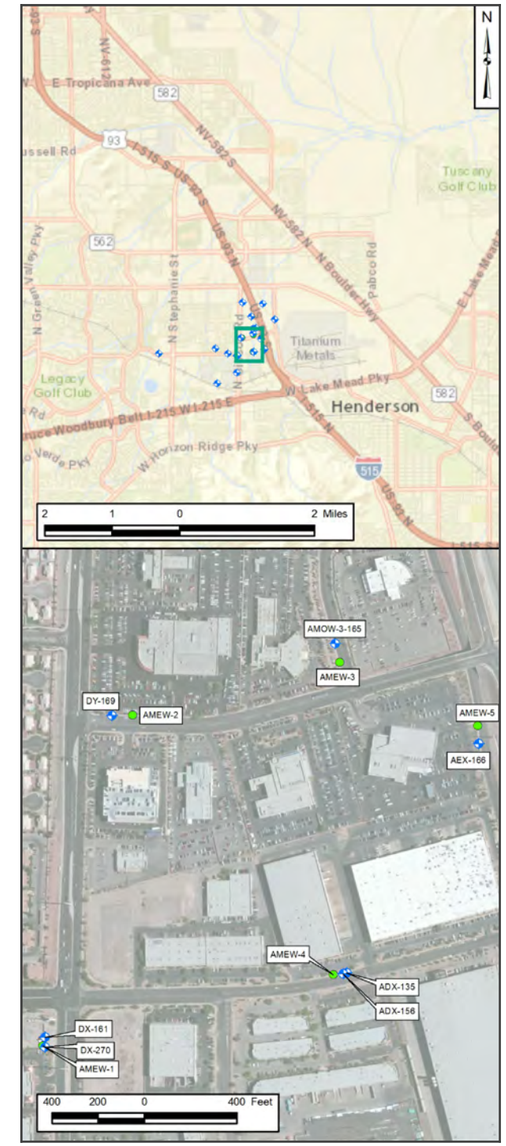
Endeavour LLC
Henderson, Nevada

Geosyntec consultants

Oakland	January 2020	Figure 27

Source: O:\GIS\Endeavour_script\jan_2020\02_poc_figures.ipynb





DX-161 Monitoring Well

AMEW-1 Extraction Well

Notes:
Non-detections are reported at the detection limit.

Perchlorate Concentrations and Water Levels through December 2019
Deep Water Bearing Zone, Auto Mall South

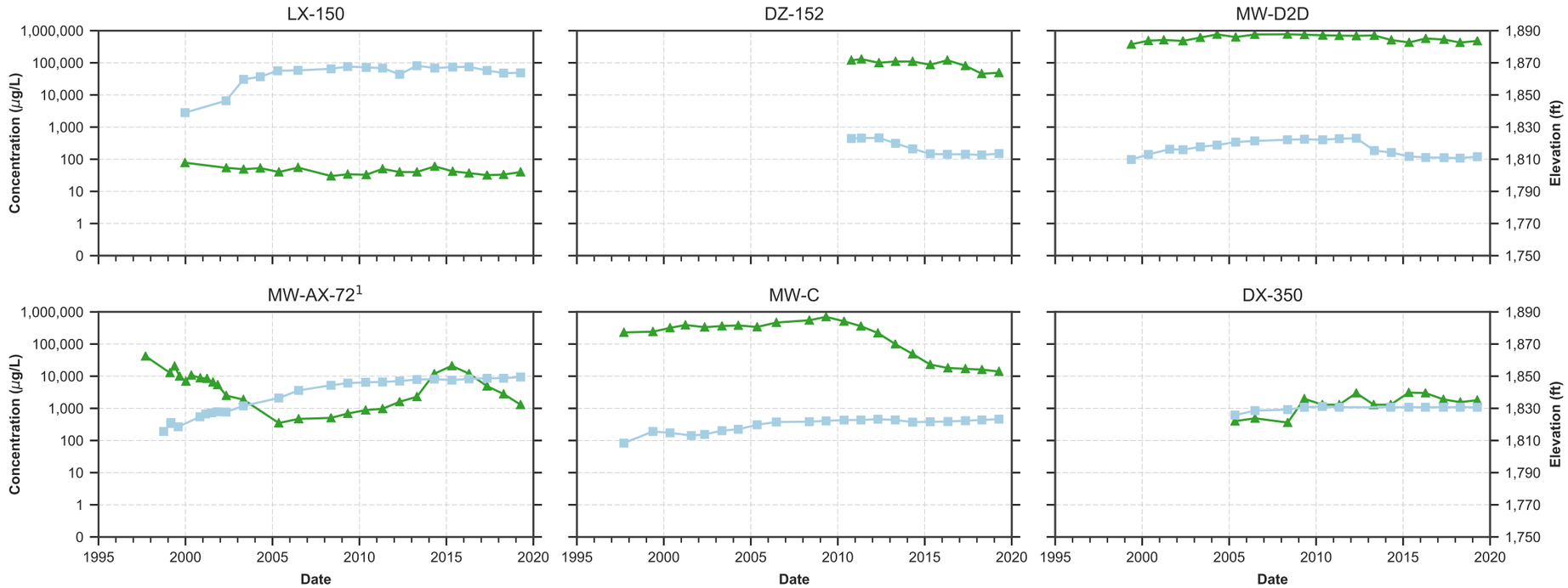
Endeavour LLC
Henderson, Nevada

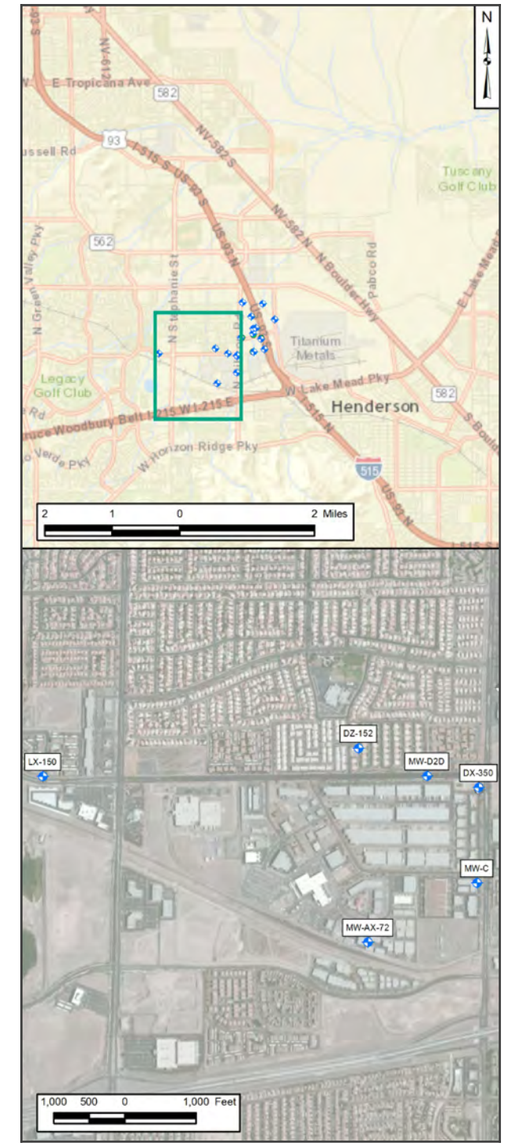
Geosyntec consultants

Oakland | January 2020

Figure 28

Source: O:\GIS\Endeavour_script\jan_2020\02_poc_figures.ipynb





LX-150 Monitoring Well

Extraction Well

Perchlorate Concentration

Groundwater Elevation

Notes:
Non-detections are reported at the detection limit.
1. Data prior to 2005 are from well MW-A, which was destroyed in 2003 and was replaced by MW-AX-72.

Perchlorate Concentrations and Water Levels through December 2019
Deep Water Bearing Zone, Auto Mall West

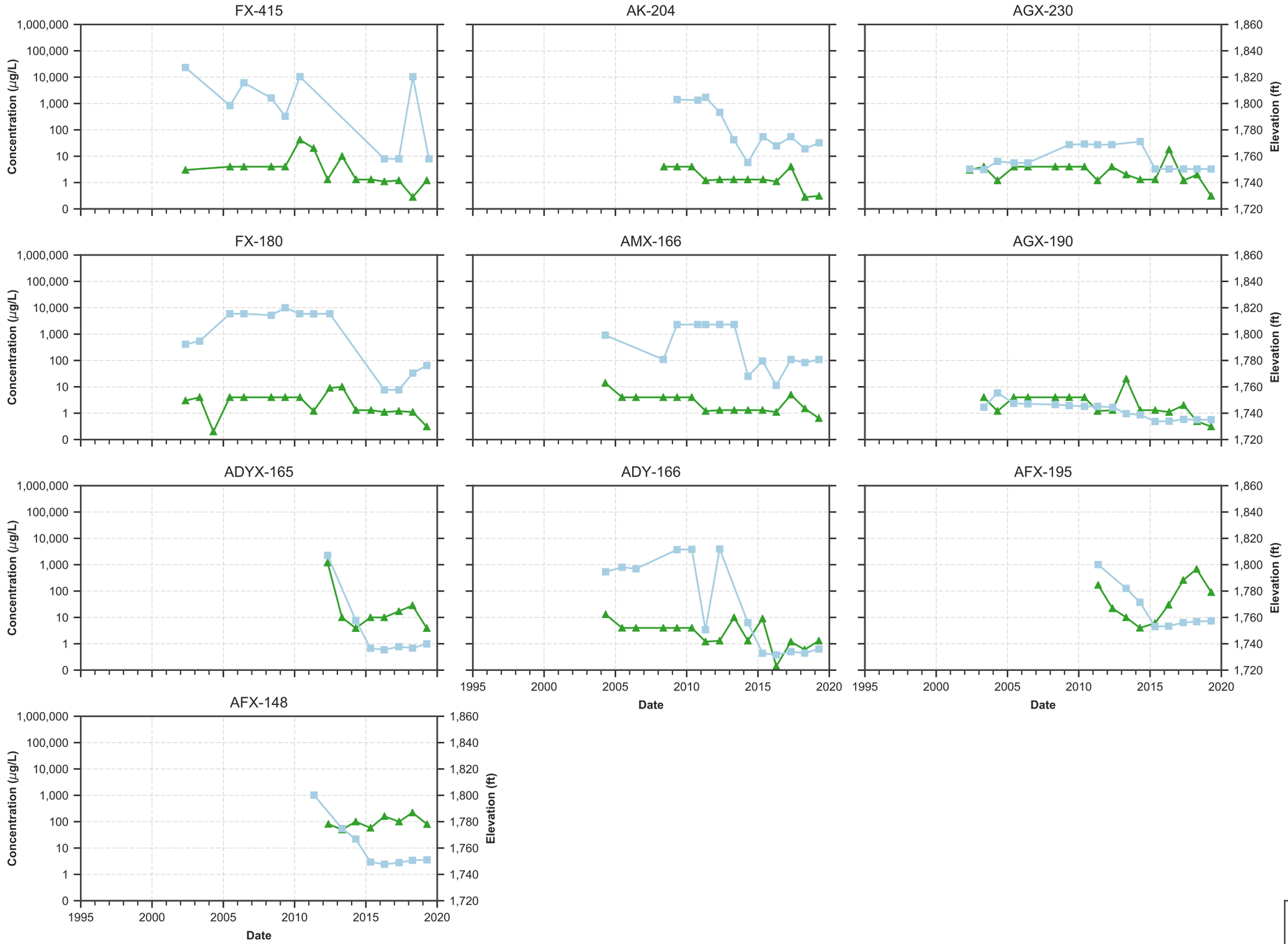
Endeavour LLC
Henderson, Nevada

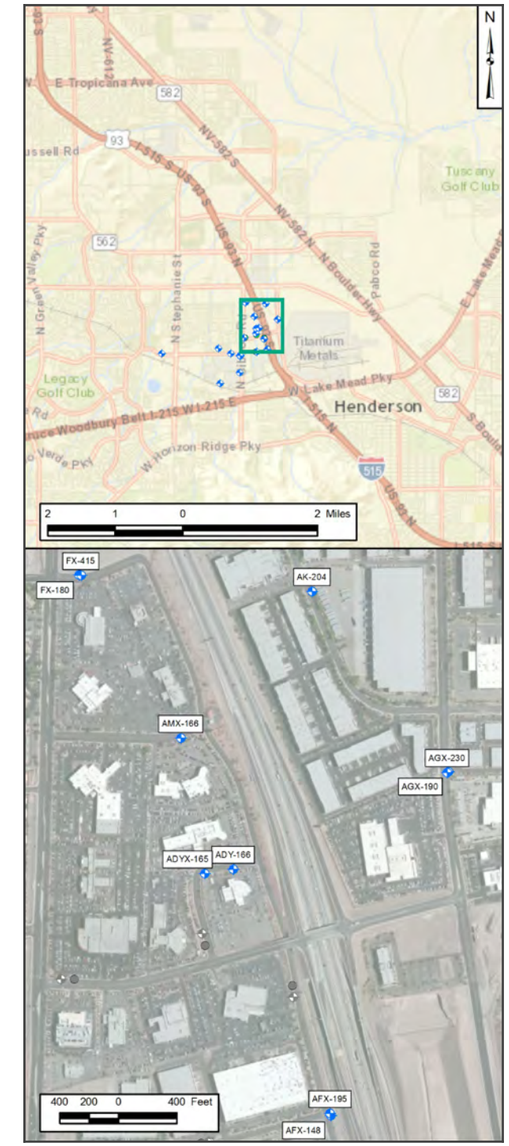
Geosyntec consultants

Oakland | January 2020

Figure 29

Source: O:\GIS\Endeavour_script\jan_2020\02_poc_figures.ipynb





FX-180 Monitoring Well

Extraction Well

Perchlorate Concentration

Groundwater Elevation

Notes:
Non-detections are reported at the detection limit.

Perchlorate Concentrations and Water Levels through December 2019
Deep Water Bearing Zone, Auto Mall East

Endeavour LLC
Henderson, Nevada

Geosyntec consultants

Oakland | January 2020

Figure 30

Source: O:\GIS\Endeavour_script\jan_2020\02_poc_figures.ipynb