PARADOX VALLEY UNIT SALINITY CONTROL INVESTIGATIONS
STUDY 1 – HYDROGEN SULFIDE MANAGEMENT
BEDROCK, COLORADO

TREATMENT OPTIONS BENCH TESTING REPORT
FINAL

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EXECUTIVE SUMMARY

The Bureau of Reclamation (Reclamation) is currently evaluating alternatives for brine disposal for the Paradox Valley Unit (PVU). One of the long-term disposal alternatives under consideration is evaporation of brine in ponds and either the sale or disposal of salt products. The brine includes high levels of naturally-occurring dissolved hydrogen sulfide, which must be managed before the brine can be placed into evaporation ponds. Hydrogen sulfide can be dangerous to human health, has an objectionable odor at low concentrations, and volatilizes into the air rapidly when the brine is exposed to the atmosphere. Several treatment options for hydrogen sulfide removal were identified and evaluated, and where possible, were bench-scale laboratory tested on-site at the PVU facility. This report summarizes the results of the bench-scale testing conducted on-site.

Three general concepts for hydrogen sulfide removal were evaluated, including oxidation, precipitation and equilibrium. Oxidation is the addition of a chemical oxidant to oxidize the sulfide to elemental sulfur or sulfate. Precipitation includes the addition of a chemical coagulant to precipitate the sulfide out as an insoluble solid. Equilibrium involves the adjustment of pH to drive the sulfide equilibrium away from dissolved hydrogen sulfide gas.

Oxidation of the PVU brine was tested on-site using three different chemical oxidants: sodium hypochlorite; sodium permanganate; and hydrogen peroxide. Sodium hypochlorite and sodium permanganate rapidly oxidized the hydrogen sulfide while also producing fine, white, elemental sulfur solids. The sodium permanganate oxidation also produced black manganese dioxide solids. Hydrogen peroxide oxidation proceeded much slower, taking more than 45 minutes to oxidize the hydrogen sulfide in the brine. Hydrogen peroxide oxidation also produced fine, white, elemental sulfur solids.

Though originally proposed in the Draft Bench Testing Plan (Amec Foster Wheeler, 2016), ferrous sulfate precipitation testing was not completed due to possible issues with disposal of the precipitated iron sulfide (FeS) solids generated from both the lab tests and full-scale operation. Iron sulfide is pyrophoric and will rapidly and violently oxidize with air when dry. Dry FeS would present fire and asset risks to the liner, or would be difficult and expensive to dispose of.

Equilibrium requires the pH in the brine to be raised and maintained at a pH greater than 10 to allow for natural oxidation of the sulfide ions in the evaporation ponds. Natural oxidation would be oxidation of the sulfide by oxygen dissolved into the brine naturally from the atmosphere. Equilibrium was tested on-site by increasing the pH of the brine and placing the brine outdoors to simulate pond operation. The test proved that it was difficult to maintain the elevated pH in the brine above 10, even if the initial pH was above 12. A full-scale system would require significant amounts of alkaline chemicals to maintain a pH above 10 in the evaporation ponds.

Sodium hypochlorite oxidation is recommended as the treatment option for hydrogen sulfide as it is relatively inexpensive, does not produce hazardous solids, and is simpler to operate and automate than the other treatment options considered.

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1.0 INTRODUCTION

Amec Foster Wheeler Environment & Infrastructure, a division of Amec Foster Wheeler Americas Limited (Amec Foster Wheeler) has prepared this Draft Treatment Options Bench Testing Report (Report), on behalf of Wastren Advantage Inc., to describe the brine sampling results and bench-scale testing performed for the United States Department of the Interior Bureau of Reclamation (Reclamation) Colorado River Basin Salinity Control Project Paradox Valley Unit (PVU). Analytical testing was conducted in March 2016, and bench-scale testing for the removal of hydrogen sulfide gas from the brine was completed in early May 2016. This report presents the results from both efforts and provides recommendations for brine treatment design.

The final report planned for this study will include the preliminary design of the H2S treatment system, including drawings to describe the layout of the proposed system and to provide a basis for cost estimating. Evaluations will included a life-cycle cost using a 50-year project life. The final report will also include the recommended location for the H2S treatment system.

2.0 BACKGROUND

The Bureau of Reclamation's Paradox Valley Unit (PVU) is a component of the Colorado River Basin Salinity Control Program, a multi-works program to control the salinity of Colorado River water delivered to users in the United States and Mexico. The PVU currently intercepts 200 gpm of 260,000 mg/l brine and diverts it to a 16,000 foot deep injection well for disposal. The injection rate has been curtailed during the 20 year life of the well due mainly to induced seismic activity associated with the injection process. At the current rate, Reclamation prevents approximately 100,000 tons per year from entering the Colorado River system. The current collection well field is capable of producing 400 gpm. However, salinity control benefits may decrease when pumping in excess of 300 gpm. Therefore for the purposes of this study, the goal is to control up to 170,000 tons per year, or 300 gpm. Due to current and future limitations of the injection well, and long term salinity control considerations at Paradox, Reclamation is currently evaluating alternative methods of brine disposal of this produced brine. One of the long-term strategies being considered for brine disposal is diverting the brine to an evaporation pond or series of ponds.

This study investigates methods for controlling hydrogen sulfide in the brine. Hydrogen sulfide is a colorless, flammable, extremely hazardous gas with a "rotten egg" smell. Hydrogen sulfide is heavier than air and may travel along the ground and it will collect in low-lying and enclosed, poorly-ventilated areas. The primary route of human exposure is inhalation, and the gas is rapidly absorbed by the lungs. At a concentration in the air at or above 100 ppm, hydrogen sulfide gas is Immediately Dangerous to Life and Health (IDLH). OSHA Standards include a maximum exposure limit of 20 ppm in air over an 8-hour work shift. The American Conference of Governmental Industrial Hygienists (ACGIH) recommends a short-term exposure limit (STEL) of 5 ppm in air, which is the alarm setpoint for all H2S sensors at the PVU facilities. In addition, hydrogen sulfide is a highly flammable gas and gas/air mixtures can be explosive. If ignited, the gas burns to produce toxic vapors and gases, such as sulfur dioxide. Hydrogen sulfide is also corrosive to metals and concrete.

The brine produced at the PVU contains dissolved hydrogen sulfide at concentrations of approximately 50 to 125 per million (ppm). When the brine at PVU is exposed to the atmosphere, hydrogen sulfide readily volatilizes out of the brine and into the air, and concentrations in the air above the brine surface can exceed 500 ppm. This compound produces noxious odors, creates a corrosive environment, is flammable, and can be explosive at higher concentrations, and can be toxic if volatilized and inhaled at high concentrations. Therefore, Amec Foster Wheeler has been tasked with designing a brine treatment strategy to remove dissolved hydrogen sulfide prior to subsequently processing the brine into solid salt.

2.1 Baseline Sampling

To characterize the brine and provide a basis for brine treatment design, samples were collected in March 2016, in general accordance with the Sampling and Analysis Plan (SAP; Amec Foster Wheeler, 2016a). Two samples were collected from the existing brine evaporation pans, located at the Surface Treatment Facility (STF), and two samples were collected from the Brine Injection Facility (BIF), upstream of the equalization tank and filters. Field measurements of water quality parameters, turbidity, and dissolved sulfide were performed using the methods described in Section 3.0 below. The field and laboratory analytical results are summarized in Table 1. Laboratory reports are provided in Appendix A.

2.2 Bench-Scale Test Development

To evaluate potential hydrogen sulfide treatment alternatives, Amec Foster Wheeler reviewed a variety of removal technologies that utilize precipitation, oxidation, or equilibrium adjustment using elevated pH. We considered the following approaches to hydrogen sulfide control:

- *Oxidation:* Hydrogen sulfide in the brine is oxidized using various substances containing oxidants (in this case, sodium permanganate, sodium hypochlorite, and hydrogen peroxide). The oxidant causes the formation of sulfate compounds, completely destroying the hydrogen sulfide in the process. These reactions can be slow or fast depending on the reaction kinetics and the presence of any catalysts. In addition, other compounds in the brine may also be oxidized, slowing down the reaction or causing it to consume larger quantities of the oxidizing chemical.

- *Precipitation:* Precipitation uses chemical agents that, when combined with compounds in the water, form insoluble solids that become suspended in the solution and eventually settle or are removed by filtration. In this case, ferrous sulfate is added to the brine and reacts with the gaseous hydrogen sulfide to form solid iron sulfide. The iron sulfide is present as a solid and will eventually settle. This removes the gaseous hydrogen sulfide from the brine but does not destroy it. Precipitated solids will accumulate in the system and need to be removed periodically. In this particular case, the iron sulfide is a hazardous material and must be disposed appropriately.

- *Equilibrium:* Using a caustic solution, such as sodium hydroxide, the pH of the brine is raised sufficiently to push the equilibrium of sulfide species in favour of the ionized states

(HS^- and S^{2-}) and away from the gaseous state (H_2S). By maintaining an elevated pH, the ionized sulfide species can undergo natural oxidation, destroying them as described above. Once the sulfide species have been sufficiently oxidized, the pH can be lowered to a desired discharge limit without the risk of reforming hydrogen sulfide.

To evaluate these various treatment technologies, on-site bench-scale testing was performed at the PVU in May 2016. Bench-scale testing results provide information on design flow requirements for chemical addition and will be used to better understand the chemistry, effectiveness, and operating costs of various treatment alternatives during preliminary treatment system design.

3.0 MATERIALS AND METHODS

This section briefly summarizes methods used during baseline sampling and bench-scale testing. Baseline sampling was conducted in general accordance with the SAP (Amec Foster Wheeler, 2016a). Bench-scale testing was conducted in general accordance with the Draft Bench Testing Plan (Amec Foster Wheeler, 2016b).

3.1 Field Measurements

The following instrumentation was used for field measurements.

3.1.1 Hydrogen Sulfide

The concentration of sulfide in the untreated and treated brine samples was measured utilizing USEPA Method 8131 (Methylene Blue) and a Hach DR900 Colorimeter. This method measures total sulfides in a range of 0.01 to 0.70 milligram per liter (mg/L) as S^{2-} and is suitable for measuring sulfides in brines. The narrow range required dilutions of up to 1,000:1 on the untreated brines. To minimize volatilization of the hydrogen sulfide, dilutions were completed directly in the 25-milliliter (mL) vials used in the colorimeter test using deionized water or distilled water (depending on availability). Both the dilution water and the brine were added directly to the vials using adjustable pipettes (20- to 200-microliter [µL], 0.5- to 5.0-mL, and 1- to 10-mL capacities).

3.1.2 Water Quality Parameters

Water quality parameters were measured using a YSI 556 multi-probe system (MPS), calibrated daily in general accordance with the SAP (Amec Foster Wheeler, 2016a). Parameters measured were pH, oxidation reduction potential (ORP), temperature, specific conductance, and dissolved oxygen.

3.1.3 Turbidity

For the baseline sampling event, turbidity was measured using a Hach 2100Q portable turbidimeter with a 0.01 Nephelometric turbidity unit (NTU) lower detection limit. The turbidimeter was calibrated on-site in accordance with the manufacturer's instructions; each sample cell was cleaned and oiled lightly prior to calibration.

3.2 Laboratory Analyses

Baseline analytical samples were collected in dedicated sampling containers, in accordance with the SAP (Amec Foster Wheeler, 216a). Samples were submitted to ALS Environmental for analysis of the following:

- Total and dissolved metals
- Total phosphorus
- Ammonia
- Total Kjeldahl nitrogen
- Anions
- Total alkalinity
- Carbonate
- Bicarbonate
- Dissolved and suspended solids
- pH
- Conductivity
- Specific gravity
- Total and dissolved organic carbon
- Methane
- Total reduced sulfides

3.3 Bench-Scale Testing Methods

Bench-scale testing was performed over a period of six days at PVU utilizing the on-site laboratory located at the STF. All samples analyzed during bench-scale testing were collected from a sampling port located approximately one foot down the transfer pump discharge pipe. Samples were collected in one-liter polyethylene bottles immediately prior to performing each test. Head space was minimized to mitigate volatilization of the dissolved hydrogen sulfide. All brine sample handling was performed under an operating ventilation hood. Decontamination was similarly performed under the hood or outside.

3.3.1 Stirring Method

For the duration of each test, a six-paddle stirrer was used to ensure thorough, consistent mixing. The stirrer was positioned inside a drip pan, under the ventilation hood. A preliminary mixing test was performed using colored water to determine the mixing rate that would achieve thorough mixing with creating a vortex that promoted volatilization of the dissolved hydrogen sulfide gas. Based on the results, all tests were performed using a stir rate of approximately 50 rotations per minute (RPM), except as noted. All tests were performed using 2,000-mL glass beakers, with the exception of the evaporation pan tests described in Section 3.3.2.

On day one of bench-scale testing, the stirrer temporarily malfunctioned. This resulted in hand-stirring the second half of the pH increase titration test (described in Section 3.3.2 below). PVU's on-site electrician resolved the malfunction, and the stirrer was used for the duration of testing.

3.3.2 pH Increase and Hydrogen Sulfide Ionization using Sodium Hydroxide

Caustic addition affects the hydrogen sulfide available to strip off of the liquid by raising the pH above 10 to favor the equilibrium towards the ionized state of sulfide species (HS^- and S^{2-}) and

away from the dissolved gas form (H_2S). The ionized sulfide form would allow for natural oxidation to occur in the ponds, given adequate retention time.

Ionization of the dissolved hydrogen sulfide gas to dissolved HS^- and S^{2-} ions was carried out by adding 1,500-mL of untreated brine to a beaker and titrating a solution of sodium hydroxide and potassium hydroxide until the solution pH was greater than pH 12. This solution was a commercially available drain cleaner (Scotch Corporation Instant Power® Main Line Cleaner) that was used in place of lab-supplied sodium hydroxide when the lab shipment delivery was delayed beyond the testing start date. The solution contained 19% sodium hydroxide and 1% potassium hydroxide by weight, as measured by ALS Environmental in Fort Collins, Colorado.

Using the titration data, 4.0 L of brine collected directly from Well 3E was dosed with 76.8 mL of the hydroxide solution to increase the pH up to 12.3. The pH adjusted brine was then added to a 25.75-inch by 17.5-inch drip pan to an approximate depth of 0.75 inch to approximate the conditions in the proposed evaporation ponds. An identical volume of brine (including an extra 76.8-mL of brine to account for the extra volume in the test pan from the hydroxide solution) was added to a second control pan. The two pans were placed in an open area in the fenced compound of the STF, near the brine transfer pump and the existing evaporation pans. The brine in the pans was field tested daily for dissolved sulfide, pH, ORP, temperature, and dissolved oxygen. Note that these samples were collected when PVU was on their weekly shutdown on Wednesday morning, and the well pump was manually started to collect samples. The samples were placed in the pans at 12:30 on May 4, 2016.

3.3.3 pH Titration of Brine

A second titration of the brine was conducted to determine the pH titration curve for the brine from pH 2 to pH 12. A 1,500-mL sample of the untreated brine was added to a beaker and titrated using a solution of sodium hydroxide and potassium hydroxide to a pH greater than 12, as described in Section 3.3.2. The sample was then titrated backwards using hydrochloric acid to a pH of less than 7.

A third titration was conducted by titrating a 1,500-mL sample of untreated brine to below pH 2 using hydrochloric acid and then titrating back up to greater than pH 7 using the solution of sodium hydroxide and potassium hydroxide.

The hydrochloric acid solution was a commercially available pool cleaner/concrete etcher (Klean-Strip Green Muriatic Acid) that was used in place of lab-supplied acid when the lab shipment delivery was delayed beyond the testing start date. The solution contained 20% hydrochloric acid by weight (approximately 6.0 N hydrochloric acid).

3.3.4 Hydrogen Peroxide Oxidation

This treatment method uses a hydrogen peroxide solution to oxidize the hydrogen sulfide in the brine, destroying it in the process. In addition, hydrogen sulfide can react with hydrogen peroxide

to produce elemental sulfur and quite likely other partially oxidized sulfur compounds. The balance between these reactions will be determined by the reaction kinetics.

Either reaction can use iron as a catalyst to improve reaction times and reduce the required mixing and retention time of the full-scale system. The reactions are as follows:

$$4H_2O_2 + H_2S \xrightarrow{Fe} H_2SO_4 + 4H_2O$$

$$H_2O_2 + H_2S \xrightarrow{Fe} S^0(s) + 2H_2O$$

As shown in the first equation, the theoretical molar ratio of hydrogen sulfide to hydrogen peroxide is 1:4. For a brine hydrogen sulfide concentration of 80 mg/L, the theoretical requirement is 319 milligrams of hydrogen peroxide per litre of brine. Hydrogen peroxide is an oxidizer and is difficult to handle at high concentrations. For the purpose of the bench-scale testing, a 3% solution was used. At this concentration, the theoretical dose of hydrogen peroxide was 10.65 ml/L.

For each dose of hydrogen peroxide, an untreated control sample of the brine was also mixed and tested for dissolved hydrogen sulfide to quantify the amount of hydrogen sulfide lost during the test to volatilization. The test beaker and the control beaker were mixed a minimum of 30 minutes at 50 RPM or until the hydrogen sulfide reached 1 mg/L or less in the test beaker. The following three peroxide tests were conducted:

1. Peroxide oxidation at a neutral pH,
2. Peroxide oxidation at a neutral pH with a ferrous oxide catalyst, and
3. Peroxide oxidation at a pH greater than 10.

In order to keep the ferric oxide suspended, the mixer speed was increased to 95 RPM.

When conducting the peroxide oxidation at a pH greater than 10, the control beaker was also pH-adjusted to the same pH as the test beaker.

3.3.5 Sodium Hypochlorite Oxidation

This process works by oxidizing the sulfides to sulfates, destroying the dissolved hydrogen sulfide gas. The reaction is as follows:

$$H_2S + 4\,NaOCl \rightarrow H_2SO_4 + 4\,NaCl$$

As seen from the above reaction, the theoretical molar dosage rate is 4 moles of hypochlorite to 1 mole of hydrogen sulfide. At a hydrogen sulfide concentration of 80 mg/L, this corresponds to a theoretical dosage of 699 mg/L of NaOCl. Using common household bleach at a concentration of 8.25%, this is a theoretical dosing rate of approximately 8.47 ml/L (common household bleach is sold at 5.25% and sold as “concentrated” at 8.25%). The chlorine also oxidizes other compounds

in the water, including methane and some metals, resulting in a higher dose required to fully oxidize all hydrogen sulfide.

Sodium hypochlorite oxidation of the dissolved hydrogen sulfide was carried out by dosing 1,000 mL of untreated brine with various quantities of 8.25% sodium hypochlorite. For each dose of sodium hypochlorite, an untreated control sample of the brine was also mixed and tested for dissolved hydrogen sulfide to quantify the amount of hydrogen sulfide lost during the test to volatilization. The test beaker and the control beaker were mixed for 5 minutes at 50 RPM for each dose.

3.3.6 Sodium Permanganate Oxidation

In this process, a form of permanganate is added to the brine to oxidize the hydrogen sulfide, forming elemental sulfur and creating an alkaline condition in the pond. The hydrogen sulfide is destroyed in the process. Potassium permanganate and sodium permanganate are the two most common forms available. As sodium permanganate is safer to handle and easier to transport, it was selected for use in the bench-scale testing. The reaction at neutral pH proceeds as follows:

$$2\ NaMnO_4 + 3\ H_2S \rightarrow\ 3\ S + 2\ MnO_2 + 2\ NaOH + 2H_2O$$

As seen above, the theoretical molar ratio of H_2S to $NaMnO_4$ is 3:2. At a hydrogen sulfide concentration of 80 mg/L, the theoretical dosage required to oxidize all hydrogen sulfide in the brine is 222 mg/L $NaMnO_4$. Sodium permanganate is commonly available as a 40% solution, resulting in a theoretical dosing rate of 0.4 ml/L.

Sodium permanganate oxidation of the dissolved hydrogen sulfide was carried by dosing 1,000 mL of untreated brine with various quantities of 40% sodium permanganate. For each dose of sodium permanganate, an untreated control sample of the brine was also mixed and tested for dissolved hydrogen sulfide to quantify the amount of hydrogen sulfide lost during the test to volatilization. The test beaker and the control beaker were mixed for 5 minutes at 50 RPM for each dose.

3.3.7 Ferrous Sulfate Precipitation

This treatment method uses iron salts to precipitate iron sulfide from the brine, removing but not destroying the hydrogen sulfide. The reaction proceeds as follows:

$$FeSO_4 + H_2S \rightarrow\ FeS\ (s) + H_2SO_4$$

As shown above, the theoretical molar ratio of H_2S to $FeSO_4$ is 1:1. At a hydrogen sulfide concentration of 80 mg/L, the theoretical requirement for ferrous sulfate is 357 mg/L. Ferrous sulfate is widely available as both a powder and a dilute solution. A dosing rate of 357 mg/L will be used to precipitate the hydrogen sulfide.

Though originally proposed in the Draft Bench Testing Plan (Amec Foster Wheeler, 2016), ferrous sulfate precipitation testing was not completed due to possible issues with disposal of the precipitated iron sulfide (FeS) solids generated from both the lab tests and full-scale operation. Iron sulfide is pyrophoric and will rapidly and violently oxidize with air when dry. If left in HDPE-lined evaporation ponds, the solids would discolor the produced salts and could present both fire and asset risks to the liner. If the FeS solids were separated prior to the evaporation ponds, the concentrated FeS solid stream would be difficult and expensive to dispose of.

3.4 Hydrogen Sulfide Losses in Transfer Pipe

At the request of PVU staff, possible losses of hydrogen sulfide in the pipeline between the brine transfer pump at the STF and the equalization tank at the BIF were evaluated. Duplicate hydrogen sulfide colorimeter tests were completed for samples collected from:

- The STF transfer pump discharge pipe,
- The BIF sample port upstream of the equalization tank (same location sampled in March 2016), and
- The BIF sample port downstream of the equalization tank/upstream of the filters.

All of these samples were tested immediately after collecting samples from the sample port.

4.0 RESULTS AND DISCUSSION

Baseline and bench-scale laboratory and field testing results are described below and presented in Tables 1 through 5. Laboratory reports are provided in Appendix A.

4.1 Brine Well Variations and Water Quality Results

The brine tested during baseline sampling and during the duration of bench-scale testing may have varied slightly, as different pumps were operated by Wastren Advantage personnel at different times. However, dissolved sulfide results during bench-scale testing were consistently within the 70 to 100 mg/L range (Table 2). Duplicate tests performed on the same samples yielded similar results (see Section 4.7). Water quality parameters were similarly consistent (Table 2). Therefore, the effects on bench-scale testing results of periodically changing brine source wells were considered to be minimal.

4.2 Pond Operation without Hydrogen Sulfide Control

Amec Foster Wheeler does not recommend pumping the PVU brine into the evaporation ponds with no treatment process to remove hydrogen sulfide. As discussed in Section 2.0 of this report, the concentrations of hydrogen sulfide in the air above the brine when it is exposed to the atmosphere have been regularly measured above 100 ppm, which is the IDLH for hydrogen sulfide. Brine from some of the wells has been measured to produce hydrogen sulfide at greater than 500 ppm in the air when it is exposed to the atmosphere. Hydrogen sulfide is also denser than air and thus will stay near ground level under normal atmospheric conditions. The design of

the evaporation ponds will also likely increase rate of volatilization of hydrogen sulfide from the brine as the ponds will be shallow and have a very large surface area.

Hydrogen sulfide also presents additional risks because it is flammable, possibly explosive and has an objectionable rotten egg odor. The Lower Explosive Limit for hydrogen sulfide is 4.5% which may not normally be a risk under normal atmospheric conditions, but explosive environments could be formed if there are any low laying areas in the pond area (depression, manholes, etc.) where heavier-than-air hydrogen sulfide could displace air.

The H2S will create a significant health & safety risk in the vicinity of the evaporation ponds, likely requiring PVU staff to wear self-contained breathing devices when working at the ponds. It may also preclude having any sources of ignition near the ponds, unless the transfer of brine to the ponds has been stopped and monitoring devices indicate that the hydrogen concentrations are at safe levels.

There could also be off-site impacts due to the release of hydrogen sulfide from the evaporation ponds including nuisance odors and health impacts to local residents. Hydrogen sulfide can be sensed by humans at concentrations between 0.01 and 1.5 ppm in the air and thus it is likely that nuisance odours will reach residents, especially if the ponds are located at the Northwest Paradox site. At chronic exposures as low as 2 to 5 ppm in air, hydrogen sulfide may cause nausea, tearing, headaches, loss of sleep and breathing issues for asthma patients.

Another risk of releasing hydrogen sulfide from the evaporation ponds is the effects on wildlife. The U.S. Fish and Wildlife Service (USFWS) has proposed an ambient air benchmark for the protection of wildlife (mammals and birds) of 1 ppm. At 5 – 10 ppm, wildlife will avoid the area. Adverse, sub-lethal effects such as eye and mucus membrane irritation and agitation begin at 5 ppm for mammals and about 25 ppm for birds. Mortality in mammals begins at about 100 ppm, with median lethal concentrations to rodents at about 444 ppm.

Based on readings from H2S air sensors used to measure H2S in the air over the brine, there is high potential for H2S off-gassing from the PVU brine. We cannot use Henry's Law to estimate generation rate because of the high salt content of the brine, but from the pH adjustment bench test performed on the brine, the control pan started off with 40 mg/L of H2S and after 20 hours outdoors, there was no measureable H2S remaining in the liquid. Based on the dimensions of the pan, this equates out to an emission rate of 5.9 lbs H2S per acre per day. This is a conservatively low number since the two sample tests represented two daily tests and the H2S may have fully off-gassed much earlier than when we collected our 2nd sample for H2S testing. This test was also started during the weekly shutdown at PVU, so the brine sample was not fresh, and at half the normal H2S concentration. A higher initial H2S concentration would likely increase the emission rate as the brine would have been further from H2S air-liquid equilibrium

Our recommendation is based on a qualitative review of the many health & safety issues attributable to hydrogen sulfide release and is not based on detailed volatilization or atmospheric dispersion modelling of hydrogen sulfide generation and fate once released to the atmosphere

above the pond surface. Evaluating the operation of the ponds without hydrogen sulfide was not included in the scope of this project. However, it is likely that detailed atmospheric dispersion modelling of hydrogen sulfide will only confirm that operating the ponds without hydrogen sulfide control is high risk and potentially dangerous to worker health and safety and wildlife populations.

4.3 Hydrogen Sulfide Stripping

Air stripping or degasification is a method for hydrogen sulfide control where air is brought into contact with the brine to allow for controlled volatilization of the hydrogen sulfide. Air stripping is usually conducted in a tower with numerous trays that allow contact between air and brine to promote volatilization of hydrogen sulfide. For the concentrations of hydrogen sulfide in the PVU brine, natural aeration would not supply enough air and therefore an external source such as a blower would be required to provide enough air to fully strip the hydrogen sulfide from the brine. The blower would have to be big enough to ensure that there is enough air flowing through the stripper to keep the hydrogen sulfide concentration in the tower air stream to safely below the LEL. Adding packing material, such as various plastic media would increase the surface area for contact between the brine and air, and further reduce the size of the tower required. Since only the dissolved gas form of hydrogen sulfide, and not the ionized species, will volatilize in contact with air, the pH of the brine would also have to be decreased to below 6.0 to ensure that most of the sulfides are in the dissolved gas form.

For groundwater treatment systems where hydrogen sulfide is a nuisance odour and taste issue, the hydrogen sulfide concentration is low enough that emitting the air stream from the stripper untreated may be possible. For PVU, the air stream coming out of the air stripper would be fairly rich in hydrogen sulfide and emitting it to the atmosphere would be no different than pumping the brine to the ponds without hydrogen sulfide control. Therefore, the air stream from the stripper would have to be treated further using another technology such as thermal oxidation, or utilizing one of the chemical oxidation processes from our bench scale testing (likely in another packed tower with sodium hypochlorite).

Air stripping was considered as an option to remove hydrogen sulfide from the PVU brine, but was eliminated for several reasons related to the nature of the PVU brine. The main concern is the high dissolved solids content, and the high hydrogen sulfide content. Air stripping will increase water evaporation from the brine, affecting the solubility of the salts, and leading to frequent fouling of stripper internals, including trays, packing and nozzles for distributing the brine flow through the tower. This will require significant operator effort to maintain the operation of the stripper. Corrosion in the stripper can be managed by choosing fiberglass reinforced plastic (FRP) as the material of construction, and utilizing plastic packing media. The high chloride content of the brine, plus the addition of air means there is a high corrosion potential for metals, and their use in a stripper system would not be recommended. See Figure 6 for a diagram of a typical packed tower stripper.

The high concentration of hydrogen sulfide requires treatment of the air stream from the stripper, which can add another complex process to the overall hydrogen sulfide control system. Thermal oxidation would have a high capital requirement and would require temperatures exceeding 1000

°F to ensure complete conversion of the hydrogen sulfide to sulfur dioxide. Sulfur dioxide in the flue gas may have to be managed as well. If the air stream from the stripper is treated by chemical oxidation, then precipitated solids would create an issue with fouling or plugging in that reactor as well. As an alternative, packaged systems are commercially available which could scrub the hydrogen sulfide from the stripper air stream and then biologically oxidize the hydrogen sulfide to elemental sulfur solids, which could then be landfilled. However, it should also be noted that chemical or biological oxidation of the air stream would mean that the overall process includes a packed tower stripper to remove hydrogen sulfide from water, followed up by a packed tower that adds the hydrogen sulfide back to water so that it can be chemically or biologically oxidized. Direct chemical oxidation of the brine would be more cost efficient and easier to operate.

4.4 pH Increase and Hydrogen Sulfide Ionization using Sodium Hydroxide

As shown in the Titration 1 curve (Figure 1), the brine initially starts below pH 6.5 but only requires a small volume of the hydroxide solution to increase to approximately pH 9.5. pH then plateaus until it rises above pH 10, where the curve steeply climbs again. A final pH of 12.05 was reached after 30.1 mL of a solution of 5.7 N NaOH and 0.2 N KOH was added to 1,500 mL of brine.

For the 4.0-L samples tested in shallow pans (as described in Section 3.3.2), an immediate precipitation of white solids was observed when the hydroxide dose was added. The brine samples (collected directly from Well 3E) had an initial hydrogen sulfide concentration of 40 mg/L. The samples were placed in the pans at 12:30 on May 4, 2016.

When the test and control pans were tested at 10:30 on May 5, 2016, the hydrogen sulfide concentrations had decreased to below detection limits in the control pan and to 0.34 mg/L in the test pan. Approximately 25% of the water in the pans had evaporated during this time period. The pH in the test pan, which had started at 12.3, had decreased to 9.3 after 22 hours. The dissolved oxygen concentration in both pans was below 1.0 mg/L.

We could not test the brine in the test and control pans on the morning of May 6, 2016, as the water in the pans had mostly turned to a gel-like salt. There was little remaining water.

Controlled lab evaporation tests were performed as part of the pond optimization study (Study 2). Our bench test experiment was constructed to evaluate whether pH could be maintained in the pans, and if natural aeration could oxidize the sulfides. The two tests are not comparable.

We are unsure as to the exact mechanism of the rapid pH decrease in the pans. It could have been a combination of several effects, including carbon dioxide dissolving from the atmosphere, plus a loss of buffering capacity as some of the calcium and magnesium hydroxide salts precipitated due to the high initial pH and subsequent evaporation.

This test highlights possible issues with maintaining a pH above 10 in the proposed evaporation pond system. Adjustment of the brine to above pH 10 will ionize the dissolved hydrogen sulfide gas to both HS^- and S^{2-} ions, minimizing volatilization of hydrogen sulfide to the atmosphere from the pond. However, if the pH drops below 10, the sulfide equilibrium will shift towards dissolved

hydrogen sulfide gas and volatilization will occur. Since hydrogen sulfide is a noxious toxic gas volatilization is not desired. Based on the titration curve, maintaining a high pH in the brine entering the initial surge pond will not provide a significant safety factor for operation as the pH decreases rapidly from 12 to 10.

For the pH adjustment option to work, the ionic species of sulfide that exist when the pH is above 10 will have to be oxidized by dissolved oxygen from natural aeration through the pond surface. As the water evaporates, the water chemistry will change and the likelihood of the pH dropping below 10 will increase. Once the equilibrium starts switching towards dissolved H2S gas, it will begin to rapidly volatilize through the large surface area of the ponds, which will further drive the equilibrium towards dissolved H2S gas. This process can only work if the rate of oxidation is faster than the pH decrease. This can be remedied by increasing the sodium hydroxide dose to maintain a higher pH, but because of the large buffering capacity of the brine, it takes a large amount of sodium hydroxide to increase the pH from 9 to 10. Also, if the addition of high pH brine is stopped, there is a risk that the pH of the pond could decrease relatively quickly and start releasing H2S to the atmosphere.

pH adjustment of the brine is only a feasible long-term solution for hydrogen sulfide control if the pH can be maintained above 10 so that natural aeration and dissolved oxygen can oxidize the dissolved HS^- and S^{2-} ions. The large surface area and shallow depths of the evaporation pond system will ensure that the brine maintains a small dissolved oxygen concentration due to surface area transfer with atmospheric oxygen, preventing re-formation of sulfide species once they are oxidized.

Utilizing mechanical aeration to increase the dissolved oxygen concentration in the surge pond would likely enhance the volatilization rate of hydrogen sulfide from the pond before it enhanced the oxidation of hydrogen sulfide by dissolved oxygen. Additionally, mechanical aeration could only be achieved in the proposed deep centre well of the surge pond as the remainder of the pond would be too shallow to install any aeration systems. Care would also have to be taken in selecting materials of construction as the high chloride concentration in brine would likely eliminate most metals.

4.5 pH Titration of Brine

As shown in the hydroxide Titration 2 through 4 curves (Figures 1 and 2), there are three equivalency points in the titration curve for the brine in the pH range of 2 to 12. The brine displays behaviour similar to a triprotic acid (e.g., phosphoric acid). The Titration 2 curve (Figure 1) indicates a similar pattern as the Titration 1 curve, with the brine initially below pH 6.5, requiring small volumes to raise the pH to 9.5, and then requiring greater volumes to push the pH above approximately pH 10.2. pH then climbs again, requiring approximately 45 mL of sodium hydroxide to reach pH 12 in 1,500 mL of brine.

The Titration 3 curve showed similar inflection points, with pH shifts requiring substantial quantities of hydrochloric acid to push from approximately pH 10.2 to below about pH 9.5. A final pH of 6.75 was reached after adding 40 mL of 5N hydrochloric acid to 1,500 mL of brine.

The low pH titration curves shown in Figure 2 also indicated a range from approximately pH 2.2 to pH 4.6 in which very small quantities of titrant were required to shift the pH. Much smaller titrant volumes in general were required for the low pH titrations than for the high pH titrations. Only 2.0 mL of 5N hydrochloric acid were required to decrease the pH of 1,500 mL of brine from approximately 6.4 to 1.8. Similarly, only 1.6 mL of sodium hydroxide was required to increase the pH from 1.8 up to 6.6 in the same 1,500 mL of brine.

4.6 Hydrogen Peroxide Oxidation

Hydrogen peroxide oxidation results are presented in Table 3 and shown on Figure 3. The best performance for peroxide oxidation of the hydrogen sulfide occurred when the pH of the brine was increased above 10 and the peroxide dose was increased to a molar dose ratio of 4:1 moles hydrogen peroxide per mole of hydrogen sulfide. After 5 minutes, approximately 75% of the hydrogen sulfide had been oxidized, as indicated by the dissolved sulfide results (Table 3). Adding 0.8 gram of ferric oxide at the same dose and pH, did not improve the reaction rate. A white precipitate formed after both the dose of peroxide and the addition of hydroxide.

The white solids formed after addition of hydroxide were large and wispy, and were likely calcium hydroxide precipitated because of the increase in pH decreasing the solubility of calcium. The white solids formed after the addition of hydrogen peroxide were very fine, and were likely elemental sulfur, which is formed by the sulfide oxidation reaction with hydrogen peroxide. The production of elemental sulfur solids would be directly proportional to the concentration of hydrogen sulfide in the brine. At a peak hydrogen sulfide concentration of 125 mg/L, assuming all sulfide is oxidized to insoluble elemental sulfur, and not to highly soluble sulfate, the maximum solid generation rate would be 0.45 grams of elemental sulfur per gallon of PVU brine treated.

Peroxide oxidation followed what we would expect based on literature values, except for the ferric oxide catalyzed reaction. Without adjusting the pH of the brine, the initial rate of reaction increased as the peroxide dose was increased. At neutral pH and a molar dose ratio of 1:1 moles hydrogen peroxide per mole of hydrogen sulfide, the hydrogen sulfide in the treated sample had not decreased below 1 mg/L after a reaction time of 45 mins. We did not run the test beyond 45 minutes. This suggests that the reaction would require at least 60 minutes to fully remove hydrogen sulfide. The increase in peroxide dose only seemed to increase the initial reaction rate. Once the hydrogen sulfide concentration was below 10 mg/L, the reaction rate slowed considerably, regardless of the initial peroxide dose.

At neutral pH, the reaction that predominates is:

$$H_2O_2 + H_2S \rightarrow S^0(s) + 2H_2O$$

This reaction oxidizes the dissolved hydrogen sulfide to elemental sulfur, which precipitates out as a very fine white/yellow solid.

At pH greater than 9.2, the reaction that predominates is:

$$4H_2O_2 + H_2S \rightarrow H_2SO_4 + 4H_2O$$

This reaction oxidizes the dissolved hydrogen sulfide to dissolved sulfate, which would likely precipitate out in the proposed bittern pond as a calcium or magnesium salt. Oxidation to sulfate would be preferable, though this would require adjustment of the pH to 10 and a much higher dose of hydrogen peroxide. Results indicated that completing peroxide oxidation at the higher pH resulted in a higher reaction rate and more complete oxidation of the hydrogen sulfide. The control beaker in this test was pH adjusted to match the pH in the test beaker and, as a result, there was no discernible volatilization of hydrogen sulfide. Unlike the other peroxide tests, the pH-adjusted test actually oxidized all of the hydrogen sulfide present in the initial sample.

Catalytic peroxide oxidation testing was based on a paper by Ahmad *et al* (2009) that tested peroxide oxidation using ferric oxide powder as a catalyst. The ferric oxide used by Ahmad *et al* had a nominal size of less than 0.2 micrometer (µm). We obtained ferric oxide powder from Cole-Parmer that had a nominal size of less than 5 µm. Using this ferric oxide powder in conjunction with the paddle stirrer, we had difficulty keeping all of the ferric oxide catalyst in suspension, even at full speed. The best performance from the Ahmad *et al* experiment was at a dose of 1.5 grams per 500 mL of solution (3.0 grams per liter [g/L]), but we had difficulty even keeping 0.8 g/L in suspension.

The results from our tests run at neutral pH showed no improvement on the reaction rate, and actually appeared to slow down the peroxide reaction. The Ahmad *et al* tests were run at an initial pH of 11.2, which appears to have greatly increased the reaction rate. Other tests, including Levine *et al* (2004), used either ferric sulfate or ferric chloride to provide Fe^{3+} as a catalyst for peroxide addition. Based on our results for the catalytic oxidation test, we would recommend any further tests either be completed with a finer ferric oxide powder, mixed with a magnetic stirrer, and run at a pH greater than 10. Alternatively, additional tests could be run at a neutral pH using ferric sulfate or ferric chloride as the catalyst.

Any full-scale peroxide oxidation system would require either a reactor with a long residence time or the addition of secondary chemicals to either increase the pH or act as a catalyst. In order to eliminate expensive materials of construction, specialized equipment, and specialized handling procedures, the hydrogen peroxide would need to be shipped to site at a concentration of less than 30% by weight, which will significantly increase the chemical transportation costs. Alternatively, the peroxide could be shipped to site at 70% concentration by weight and diluted to less than 30% by weight for storage. This would require that at least part of the system be designed to handle 70% peroxide but would reduce transportation costs. However, the water required for dilution would likely have to be treated to remove solids and metals (filtration/ reverse osmosis) from river water in order to minimize peroxide loss.

4.7 Sodium Hypochlorite Oxidation

Sodium hypochlorite oxidation results are presented in Table 4 and shown on Figure 4. The sodium hypochlorite dose that achieved complete removal of hydrogen sulfide was actually less than the theoretical molar dose of 4 moles of sodium hypochlorite per mole of hydrogen sulphide. The dose was approximately 3.15 moles of sodium hypochlorite per mole of hydrogen sulphide. Slightly lower doses of sodium hypochlorite showed higher hydrogen sulfide concentrations, as well negative ORP values after 5 minutes of reaction (-212 millivolts [mV]). The ORP after 5 minutes of reaction time at the 3.15 molar dose was 480 mV. The pH dropped from 6.10 to 4.95 at the end of the 5-minute test. A white precipitate formed after the dose of sodium hypochlorite. The high positive ORP value is an indication that there is an excess of sodium hypochlorite in the beaker.

The final hydrogen sulfide concentration in the 3.15 molar dose was measured as 0.32 mg/L, but the color of the vial was a hazy yellow, not blue like the slightly lower doses had been. We conducted the hydrogen sulfide test at a 10:1 dilution to minimize this affect and allow for a reading. We do not believe that this is an actual measurement of the hydrogen sulfide. Rather, the yellow color likely was the effect of excess hypochlorite interacting with methylene blue color formation. The high ORP value of the treated sample suggested that no reduced sulfide compounds could exist.

Literature suggests that the presence of ammonia reduces the hypochlorite dose required to oxidize hydrogen sulfide, and there was approximately 15 mg/L of ammonia present in the untreated brine. This could be related to the formation of chloramines.

Sodium hypochlorite oxidation of hydrogen sulfide produces acid as a by-product, which depresses the pH of the treated brine. The bench test results indicated a pH decrease of approximately 1.5 pH units.

For a full-scale system, excess hypochlorite in the treated brine could lead to chlorine odor emanating from the evaporation ponds, and therefore small doses of reducing agents may be required. Depending on the reducing agent used, as well as the pH decrease caused by the hypochlorite oxidation, the system may also require the addition of an alkaline substance to raise the pH back to neutral.

Hypochlorite oxidation of hydrogen sulfide oxidizes the sulfide completely to dissolved sulfate, and thus no additional solids residuals are generated.

Sodium hypochlorite is commonly available as a 12.5% solution. However, the volumes are significant enough that transportation costs could be high. It may be more economical to generate sodium hypochlorite on-site from sodium chloride (a product of the evaporation ponds), water, and electricity. Commercial electrolytic generators exist with the capacity for the ranges of sodium hypochlorite required for this system.

4.8 Sodium Permanganate Oxidation

Sodium permanganate oxidation results are presented in Table 5 and shown on Figure 5. Sodium permanganate appeared highly effective at oxidizing hydrogen sulfide in the brine. The dose that achieved full removal of hydrogen sulfide was very close to the theoretical dose of 2 moles permanganate per 3 moles of hydrogen sulfide at a neutral pH. The color of the sodium permanganate (deep purple) acted as a visual indicator of the full removal of hydrogen sulfide. At doses lower than theoretical, there was no color in the test beaker, as all of the permanganate had reacted and been reduced to manganese dioxide. Once the hydrogen sulfide had been removed, there was excess permanganate in the beaker, and the purple color dominated.

Sodium permanganate is a very strong oxidizer but is also relatively expensive compared to other oxidizers. If operated at a higher pH, the permanganate oxidation rate increases by a factor of four. At the higher pH, the permanganate oxidation drives the sulfide to dissolved sulfate. Additionally, the high pH and strong oxidizer will also oxidize ferrous iron and lead to precipitation of ferric hydroxide.

At a neutral pH, the sulfides are oxidized to elemental sulfur, similar to peroxide oxidation at a neutral pH. The same issues with management of the elemental sulfur residual discussed with peroxide oxidation (Section 4.4) apply to permanganate oxidation, unless permanganate oxidation is operated at a higher pH. Additionally, permanganate oxidation at any pH produces significant amounts of manganese dioxide, which is a fine, insoluble, black solid that may discolor any salt products in the evaporation ponds. Manganese dioxide is considered a strong oxidizer and will react violently with combustible and reducing materials, which may restrict options for disposal.

Overdoses of sodium permanganate would leave the treated brine with a strong purple color, which may not be acceptable, requiring the addition of a reducing agent prior to discharge to the evaporation ponds. The color can be used as a dose indicator allowing the operator to reduce the permanganate dosing rate to achieve the desired results.

Sodium permanganate is available for shipment as a dissolved solution but is likely only economical if purchased as a solid salt and prepared as a solution on-site. Even then, sodium permanganate is likely to be more expensive than other options.

4.9 Regeneration of Hydrogen Sulfide after Treatment

Regeneration refers to hydrogen sulfide re-forming in the evaporation ponds after treatment. This is a concern with pH adjustment option tested in bench testing as that process does not eliminate the hydrogen sulfide – the process only adjusts the sulfide equilibrium away from the dissolved gas form. With this process, there is potential that the pH could drop in the ponds and drive the equilibrium towards the dissolved gas form, especially since the ionized sulfide species are oxidized relatively slowly by the dissolved oxygen concentration in the ponds.

Chemical oxidation processes transform the reduced sulfides to various oxidized forms of sulfur such as elemental sulfur or sulfates. Due to the shallow depth and large surface areas of the evaporation ponds, the ponds will be an oxidizing environment, thus precluding the formation of dissolved sulfur species such as hydrogen sulfide. Hydrogen sulfide would only be able to re-generate if the ponds were to become a strong reducing environment, which is unlikely since the ponds have a large surface area exposed to the atmosphere.

4.10 Potential for Residual Odors after Treatment

Similarly to section 4.9, the only treatment option that has significant potential to produce residual odours is pH adjustment, as the sulfide equilibrium could be shifted towards the dissolved gas form of hydrogen sulfide. Destruction of the hydrogen sulfide through chemical oxidation can be ensured by adding excess amounts of the chemical oxidizer, which will produce a strong oxidizing environment inside of the oxidizing reactor. There could be an issue with residual chlorine odor from the sodium hypochlorite process, but that can be managed by adding a small amount of a reducing agent to reduce the free chlorine to chlorides prior to discharge to the ponds. Common reducing agents used to remove free chlorine in water treatment include sodium bisulfite, sulfur dioxide and calcium thiosulfate.

Much like the current system at PVU, there always will be risk of fugitive hydrogen sulfide emissions from the system through leaks, vents, sampling processes, and maintenance procedures.

4.11 Hydrogen Sulfide Losses in Transfer Pipe

Hydrogen sulfide test results are presented in Table 2. For the duplicate samples analyzed during the comparison test, one result (90 mg/L) was consistent with previous data collected during bench-scale testing. One test gave a result that was determined to be erroneous (210 mg/L). This outlier has been attributed to a dilution error. Given the large dilutions required (1:1000); even a small error in dilutions can make a large difference in the measured result. A second set of duplicate samples was tested, and the results were again consistent with previous data (70 and 90 mg/L).

Duplicate sample results from the BIF upstream of the equalization tank were 60 mg/L and 90 mg/L. Duplicate sample results from the BIF downstream of the equalization tank were both 90 mg/L.

Based on these results, there does not seem to be a measurable degree of variability between the STF and BIF, given the accuracy of the colorimeter method (+/- 3% on the measurement alone, not including the standard errors in volumetric measurements).

5.0 CONCLUSIONS AND RECOMMENDATIONS

Based on the findings presented above, and Amec Foster Wheeler's experience with similar systems, it is recommended that a sodium hypochlorite treatment system be designed and implemented to treat the hydrogen sulfide at PVU.

Hypochlorite dosing systems are simpler to operate and automate than those associated with the other treatment methods evaluated during the bench testing. The systems are widely used in industrial wastewater treatment and can be designed to be semi- or fully automated. The reaction time was observed to be considerably quicker than the other options evaluated and there were no hazardous by-product solids produced.

The chemicals required by a hypochlorite dosing system are relatively safe to handle and are widely available. Hypochlorite is used in industrial processes for everything from wastewater treatment to sanitation, and many chemical handling companies offer bulk deliveries at discounted prices. To make delivery and handling easier and safer for PVU staff, the use of a high-capacity hypochlorite generator should be investigated. These units can generate large volumes of hypochlorite using on-site power and NaCl (salt). The salt required by these generators is inexpensive, easy to acquire in large volumes and has fewer operator health and safety risks associated with its handling.

6.0 REFERENCES

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TABLES

TABLE 1
BASELINE SAMPLING ANALYTICAL RESULTS
Colorado River Basin Salinity Control Project
Paradox Valley Unit, Bedrock, Colorado

Sample Location		Evaporation Pans at Surface Treatment Facility		Brine Injection Facility Main Line, Upstream of Tank & Filters	
Sample ID	Method	PVUEVAP 16031001 (1)	PVUEVAP 16031002 (2)	PVUBIF 16031001 (3)	PVUBIF 16031002 (4)
Date	--	10/03/2016	10/03/2016	10/03/2016	10/03/2016
Time	--	11:35	11:40	14:40	15:00
Field Analytical Results					
pH (s.u.)	YSI [5]	6.77	7.48	6.42	6.37
Temperature (°C)	YSI [5]	9.67	9.9	18.81	16.11
SEC (µS/cm)	YSI [5]	233,780	238,600	232,453	233,231
DO (mg/L)	YSI [5]	1.15	0.92	0.77	< 2.0
Turbidity (NTU)	2100Q [6]	12.3	23.4	0.67	0.81
H_2S (mg/L)	Field Kit [7]	0	0.1	5+	200
H_2S (mg/L as S^{2-})	DR900 [8]	<0.01	<0.01	61	125
Laboratory Analytical Results					
Non-Metals					
pH (s.u.)	150.1	7.18	7.15	6.32	6.29
SEC (µS/cm)	120.1	242,000	248,000	237,000	238,000
Specific Gravity	D5057-90	1.17	1.18	1.17	1.17
Bicarbonate (mg/L as $CaCO_3$)	310.1	91	100	200	200
Carbonate (mg/L as $CaCO_3$)	310.1	<20	<20	<20	<20
Total Alkalinity (mg/L as $CaCO_3$)	310.1	91	100	200	200
Ammonia (mg/L as N)	350.1	--	--	17	15
Bromide (mg/L)	300.0	--	--	86 J	83 J
Chloride (mg/L)	300.0	170,000	180,000	170,000	170,000
Fluoride (mg/L)	300.0	--	--	<50	<50
Total Kjeldahl Nitrogen (mg/L)	A4500-NH3	--	--	6.0	4.5
Nitrate (mg/L as N)	300.0	--	--	<100	<100
Nitrite (mg/L as N)	300.0	--	--	<50	<50
Orthophosphate (mg/L as P)	365.1	--	--	<0.25	0.43
Sulfate (mg/L)	300.0	7,500	7,700	7,100	6,800
Total Dissolved Solids (mg/L)	160.1	650,000	470,000	850,000	580,000
Total Suspended Solids (mg/L)	160.2	--	--	<20	<20
TOC (mg/L)	415.1	--	--	<1	<1
DOC (mg/L)	415.1	--	--	<1	<1
Dissolved Gases					
Methane (µg/L)	RSK-175	--	--	1,200	1,100
H_2S (mg/L)	Gas Chrom. [9]	--	--	57	53
Metals, Total					
Aluminum, Dissolved (µg/L)	SW6020	--	--	3,400 J	<5,000
Aluminum, Total (µg/L)	SW6020	--	--	<5,000	<5,000
Antimony, Dissolved (µg/L)	SW6020	--	--	<30	<30
Antimony, Total (µg/L)	SW6020	--	--	<30	<30
Arsenic, Dissolved (µg/L)	SW6020	--	--	<200	<200
Arsenic, Total (µg/L)	SW6020	--	--	<200	<200
Barium, Dissolved (µg/L)	SW6020	--	--	53 J	44 J
Barium, Total (µg/L)	SW6020	--	--	30 J	44 J
Beryllium, Dissolved (µg/L)	SW6020	--	--	<50	<50
Beryllium, Total (µg/L)	SW6020	--	--	<50	<50

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Sample ID	Method	PVUEVAP 16031001 (1)	PVUEVAP 16031002 (2)	PVUBIF 16031001 (3)	PVUBIF 16031002 (4)
Metals, Total (continued)					
Bismuth, Dissolved (µg/L)	SW6010	--	--	62 J	49 J
Bismuth, Total (µg/L)	SW6010	--	--	49 J	49 J
Boron, Dissolved (µg/L)	SW6020	--	--	10,000	11,000
Boron, Total (µg/L)	SW6020	--	--	11,000	11,000
Cadmium, Dissolved (µg/L)	SW6020	--	--	<30	<30
Cadmium, Total (µg/L)	SW6020	--	--	<30	<30
Calcium, Dissolved (µg/L)	SW6020	--	--	1,700,000	1,700,000
Calcium, Total (µg/L)	SW6020	1,600,000	1,800,000	1,700,000	1,700,000
Chromium, Dissolved (µg/L)	SW6020	--	--	<1,000	<1,000
Chromium, Total (µg/L)	SW6020	--	--	<1,000	<1,000
Cobalt, Dissolved (µg/L)	SW6020	--	--	<100	<100
Cobalt, Total (µg/L)	SW6020	--	--	<100	<100
Copper, Dissolved (µg/L)	SW6020	--	--	<1,000	<1,000
Copper, Total (µg/L)	SW6020	--	--	<1,000	<1,000
Iron, Dissolved (µg/L)	SW6020	--	--	<10,000	<10,000
Iron, Total (µg/L)	SW6020	<10,000	2,200 J	<10,000	<10,000
Lead, Dissolved (µg/L)	SW6020	--	--	<50	<50
Lead, Total (µg/L)	SW6020	--	--	<50	<50
Lithium, Dissolved (µg/L)	SW6020	--	--	410 J	420 J
Lithium, Total (µg/L)	SW6020	--	--	360 J	420 J
Magnesium, Dissolved (µg/L)	SW6020	--	--	1,900,000	2,000,000
Magnesium, Total (µg/L)	SW6020	1,800,000	2,100,000	1,900,000	2,000,000
Manganese, Dissolved (µg/L)	SW6020	--	--	610	620
Manganese, Total (µg/L)	SW6020	--	--	580	600
Mercury, Dissolved (µg/L)	7470A	--	--	<0.2	<0.2
Mercury, Total (µg/L)	7470A	--	--	<0.2	<0.2
Molybdenum, Dissolved (µg/L)	SW6020	--	--	<100	<100
Molybdenum, Total (µg/L)	SW6020	--	--	<100	<100
Nickel, Dissolved (µg/L)	SW6020	--	--	<500	<500
Nickel, Total (µg/L)	SW6020	--	--	<500	<500
Phosphorus, Dissolved (µg/L)	SW6010	--	--	520 J	530 J
Phosphorus, Total (µg/L)	SW6010	--	--	570 J	520 J
Phosphorus, Total (mg/L as P)	365.2	--	--	0.033 J	0.018 J
Potassium, Dissolved (µg/L)	SW6020	--	--	5,300,000	5,400,000
Potassium, Total (µg/L)	SW6020	5,000,000	5,700,000	5,300,000	5,400,000
Selenium, Dissolved (µg/L)	SW6020	--	--	<100	<100
Selenium, Total (µg/L)	SW6020	--	--	<100	<100
Silicon, Dissolved (µg/L)	SW6010	--	--	3,000	2,800
Silicon, Total (µg/L)	SW6010	--	--	2,700	2,600
Silver, Dissolved (µg/L)	SW6020	--	--	<10	<10
Silver, Total (µg/L)	SW6020	--	--	<10	<10
Sodium, Dissolved (µg/L)	SW6020	--	--	110,000,000	110,000,000
Sodium, Total (µg/L)	SW6020	93,000,000	98,000,000	100,000,000	94,000,000
Strontium, Dissolved (µg/L)	SW6020	--	--	32,000	32,000
Strontium, Total (µg/L)	SW6020	--	--	31,000	32,000
Thallium, Dissolved (µg/L)	SW6020	--	--	<20	<20

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Sample Location		Evaporation Pans at Surface Treatment Facility		Brine Injection Facility Main Line, Upstream of Tank & Filters	
Sample ID	Method	PVUEVAP 16031001 (1)	PVUEVAP 16031002 (2)	PVUBIF 16031001 (3)	PVUBIF 16031002 (4)
Metals, Total (continued)					
Thallium, Total (µg/L)	SW6020	--	--	<20	<20
Tin, Dissolved (µg/L)	SW6020	--	--	<500	<500
Tin, Total (µg/L)	SW6020	--	--	<500	<500
Titanium, Dissolved (µg/L)	SW6020	--	--	<2,000	<2,000
Titanium, Total (µg/L)	SW6020	--	--	<2,000	<2,000
Uranium, Dissolved (µg/L)	SW6020	--	--	<10	<10
Uranium, Total (µg/L)	SW6020	--	--	<10	<10
Vanadium, Dissolved (µg/L)	SW6020	--	--	<100	<100
Vanadium, Total (µg/L)	SW6020	--	--	<100	<100
Zinc, Dissolved (µg/L)	SW6020	--	--	<2,000	<2,000
Zinc, Total (µg/L)	SW6020	--	--	<2,000	<2,000
Zirconium, Dissolved (µg/L)	SW6020	--	--	<5	<5
Zirconium, Total (µg/L)	SW6020	--	--	<5	<5

Notes
1. Western of two brine evaporation pans; contains brine and groundwater to resemble diluted brine (also diluted with precipitation). Clear in turbidity vial.
2. Eastern of two brine evaporation pans; contains pure brine (diluted with precipitation). Clear in turbidity vial.
3. H_2S field kit and colorimeter tests diluted to achieve results.
4. Duplicate sample collected concurrently to sample PVUBIF16031002.
5. YSI 556 MPS hand-held water quality meter used to measure field pH, temperature, SEC, and DO.
6. Hach 2100Q hand-held meter used to measure field turbidity.
7. Hach H_2S Field Test Kit used to measure field H_2S via effervescence to determine dilution factors for colorimeter.
8. Hach DR900 colorimeter used to measure field H_2S.
9. Laboratory H_2S was measure by gas chromatograph equipped with a sulfur chemiluminescence detector.

Abbreviations
-- = not analyzed
< = non-detected value less than the indicated reporting limit
℃ = degree Celsius
µg/L = microgram per liter
µS/cm = microSiemen per centimeter
$CaCO_3$ = calcium carbonate
DO = dissolved oxygen
DOC = dissolved organic carbon
dup. = duplicate measurement
H_2S = hydrogen sulfide
J = estimated value less than the reporting limit but greater than the method detection limit
mg/L = milligram per liter
N = nitrogen
N/A = not applicable/not measured
NTU = nephelometric turbidity unit
P = phosphorus
s.u. = standard pH unit
SEC = specific electrical conductance
TOC = total organic carbon

TABLE 2
SUMMARY OF FIELD TEST RESULTS
Colorado River Basin Salinity Control Project
Paradox Valley Unit, Bedrock, Colorado

Measurement ID [1]	Date	Hydrogen Sulfide [2] (mg/L as S^{2-})	pH [3] (s.u.)	ORP [3] (mV)	Temperature [3] (°C)	SEC [3] (µS/cm)	DO [3] (mg/L)
Titration 1	03/05/2016	--	6.34	-270	17.8	231,000	0
Start of Day [4]	04/05/2016	60	--	--	--	--	--
Sodium Hypochlorite 1	04/05/2016	80	6.43	-312	17.4	--	--
Sodium Hypochlorite 2	04/05/2016	100	6.20	-316	17.0	--	--
Sodium Hypochlorite 3	04/05/2016	100	6.10	-320	18.6	--	--
Sodium Hypochlorite 4	04/05/2016	80	6.09	-305	18.3	--	--
Start of Day	05/05/2016	90	--	--	--	--	--
Sodium Permanganate 1	05/05/2016	80	6.57	-307	19.0	--	--
Sodium Permanganate 2	05/05/2016	80	6.58	-300	17.7	--	--
Sodium Permanganate 3	05/05/2016	90	6.59	-300	17.6	--	--
Sodium Permanganate 4	06/05/2016	70	6.35	-300	17.2	--	--
Sodium Permanganate 5	06/05/2016	70	6.35	-300	17.2	--	--
Hydrogen Peroxide 1	06/05/2016	80	6.45	-318	17.4	--	--
Hydrogen Peroxide 2	06/05/2016	80	6.36	-311	--	--	--
Hydrogen Peroxide 3	06/05/2016	70	6.36	-311	--	--	--
Hydrogen Peroxide 4	06/05/2016	80	6.34	-310	16.8	--	--
Hydrogen Peroxide 5	10/05/2016	70	6.57	-283	16.7	--	--
Comparison Test STF-2 [5]	10/05/2016	90	--	--	--	--	--
Comparison Test STF-3	10/05/2016	70	--	--	--	--	--
Comparison Test STF-4	10/05/2016	90	--	--	--	--	--
Comparison Test BIF-1	10/05/2016	60	--	--	--	--	--
Comparison Test BIF-2	10/05/2016	90	--	--	--	--	--
Comparison Test BIF-3	10/05/2016	90	--	--	--	--	--
Comparison Test BIF-4	10/05/2016	90	--	--	--	--	--
Titration 2	10/05/2016	--	6.63	-307	17.0	223,600	--
Titration 3	12/05/2016	--	6.43	-304	16.7	224,500	0.72
Minimum		60	6.09	-320	16.7	223,600	0
Mean		82	6.40	-304	17.5	226,400	0.36
Maximum		100	6.63	-270	19.0	231,000	0.72
Standard Deviation		10	0.16	12	0.7	3,300	0.36
Replicates		22	17	17	15	3	2
Uncertainty		2	0.04	3	0.2	1,900	0.25

Notes

1. All samples collected from sample port downstream of transfer pump at Surface Treatment Facility (STF) except the four Comparison Test BIF samples. Those were collected from the Brine Injection Facility upstream (BIF-1 and BIF-2) and downstream (BIF-3 and BIF-4) of the equalization tank..
2. Hach DR900 colorimeter used to measure field H_2S.
3. YSI 556 MPS hand-held water quality meter used to measure field pH, ORP, temperature, SEC, and DO.
4. Sample collected approximately 16 hours after shut-down of all pumps, not during regular operations, and was excluded from statistics.
5. Comparison Test STF-1 measured 210 mg/L and was considered anomalous due to suspected dilution error.

Abbreviations

°C = degree Celsius
µS/cm = microSiemen per centimeter
DO = dissolved oxygen
mg/L = milligram per liter
mV = millivolt
N/A = not applicable/not measured
ORP = oxidation reduction potential
s.u. = standard pH unit
SEC = specific electrical conductance

TABLE 3
HYDROGEN PEROXIDE OXIDATION TEST RESULTS
Colorado River Basin Salinity Control Project
Paradox Valley Unit, Bedrock, Colorado

Test 1			Test 2			Test 3			Test 4			Test 5		
pH 6.45, No Catalyst			pH 6.36, No Catalyst			pH 6.36, 0.75 g Fe_2O_3			pH 10.3, No Catalyst			pH 10.2, No Catalyst		
Dose = 5.6 mL 3% H_2O_2/L			Dose = 2.7 mL 3% H_2O_2/L			Dose = 2.7 mL 3% H_2O_2/L			Dose = 10.6 mL 3% H_2O_2/L			Dose = 10.6 mL 3% H_2O_2/L		
Time	Hydrogen Sulfide (mg/L as S^{2-})		Time	Hydrogen Sulfide (mg/L as S^{2-})		Time	Hydrogen Sulfide (mg/L as S^{2-})		Time	Hydrogen Sulfide (mg/L as S^{2-})		Time	Hydrogen Sulfide (mg/L as S^{2-})	
(min)	Test	Control	(min)	Test	Control	(min)	Test	Control	(min)	Test	Control	(min)	Test	Control
0	80	80	0	80	80	0	70	70	0	80	80	0	70	70
5	17	60	5	45	80	3	63	--	5	16	90	10	17	70
15	2.4	71	15	10	60	5	55	90	10	5	80	30	0.48	70
30	1.3	67	25	3	73	18	--	60	20	1.1	--			
45	1.1	61	35	1	64	25	15	60	30	0.14	80			
						35	10	53						
						45	7	48						
						60	4.6	40						

Notes
1. All samples collected from sample port downstream of transfer pump at Surface Treatment Facility.
2. Dose was added to the "Test" beaker. "Control" beaker did not receive H_2O_2 or catalyst but was pH adjusted for Tests 4 and 5.
3. Test 4 pH adjusted using 17 mL of sodium hydroxide solution.
4. Test 5 pH adjusted using 21 mL of sodium hydroxide solution.
5. Hach DR900 colorimeter used to measure field hydrogen sulfide.

Abbreviations
-- = not applicable/not measured
Fe_2O_3 = ferric oxide powder
H_2O_2 = hydrogen peroxide
L = liter
mg/L = milligram per liter
min = minutes
mL = milliliter

TABLE 4
SODIUM HYPOCHLORITE OXIDATION TEST RESULTS
Colorado River Basin Salinity Control Project
Paradox Valley Unit, Bedrock, Colorado

	pH (s.u.)		Temperature (°C)		ORP (mV)		Hydrogen Sulfide (mg/L as S^{2-})	
Test 1: Dose = 4.0 mL 8.25% NaOCl per L Brine								
	Test	**Control**	**Test**	**Control**	**Test**	**Control**	**Test**	**Control**
Initial:	6.43	6.43	17.4	17.4	-312	-312	80	80
Final:	5.51	6.41	18.6	18.2	-256	-312	15	60
Test 2: Dose = 5.0 mL 8.25% NaOCl per L Brine								
	Test	**Control**	**Test**	**Control**	**Test**	**Control**	**Test**	**Control**
Initial:	6.20	6.20	17.0	17.0	-316	-316	100	100
Final:	5.14	6.23	18.2	17.6	-229	-321	5	70
Test 3: Dose = 6.1 mL 8.25% NaOCl per L Brine								
	Test	**Control**	**Test**	**Control**	**Test**	**Control**	**Test**	**Control**
Initial:	6.10	6.10	18.6	18.6	-320	-320	100	100
Final:	4.95	6.18	18.9	18.4	480	-326	0.32	80
Test 4: Dose = 5.5 mL 8.25% NaOCl per L Brine								
	Test	**Control**	**Test**	**Control**	**Test**	**Control**	**Test**	**Control**
Initial:	6.09	6.09	18.3	18.3	-305	-305	80	80
Final:	5.02	6.16	18.4	18.4	-212	-310	2.3	80

Notes
1. All samples collected from sample port downstream of transfer pump at Surface Treatment Facility.
2. Dose was added to the "Test" beaker. "Control" beaker did not receive NaOCl.
3. Final results were measured after five minutes of stirring.
4. Hach DR900 colorimeter used to measure field H_2S.
5. YSI 556 MPS hand-held water quality meter used to measure field pH, temperature, and ORP.

Abbreviations
°C = degree Celsius
L = liter
mg/L = milligram per liter
mL = milliliter
mV = millivolt
NaOCl = sodium hypochlorite
ORP = oxidation reduction potential
s.u. = standard pH unit

TABLE 5
SODIUM PERMANGANATE OXIDATION TEST RESULTS
Colorado River Basin Salinity Control Project
Paradox Valley Unit, Bedrock, Colorado

	pH (s.u.)		Temperature (°C)		ORP (mV)		Hydrogen Sulfide (mg/L as S^{2-})	
Test 1: Dose = 3.4 mL $NaMnO_4$ per L Brine								
	Test	**Control**	**Test**	**Control**	**Test**	**Control**	**Test**	**Control**
Initial:	6.57	6.57	19.0	19.0	-307	-307	80	80
Final:	6.09	6.45	18.8	17.5	695	-302	<0.01	70
Test 2: Dose = 0.7 mL $NaMnO_4$ per L Brine								
	Test	**Control**	**Test**	**Control**	**Test**	**Control**	**Test**	**Control**
Initial:	6.58	6.58	17.7	17.7	-300	-300	80	80
Final:	6.18	6.44	18.4	18.1	675	-300	<0.01	70
Test 3: Dose = 0.2 mL $NaMnO_4$ per L Brine								
	Test	**Control**	**Test**	**Control**	**Test**	**Control**	**Test**	**Control**
Initial:	6.59	6.59	17.6	17.6	-300	-300	90	90
Final:	7.92	6.42	18.5	18.5	-359	-302	36	60
Test 4: Dose = 0.3 mL $NaMnO_4$ per L Brine								
	Test	**Control**	**Test**	**Control**	**Test**	**Control**	**Test**	**Control**
Initial:	6.35	6.35	17.2	17.2	-300	-300	70	70
Final:	6.39	--	18.6	--	-309	--	11	70
Test 5: Dose = 0.4 mL $NaMnO_4$ per L Brine								
	Test	**Control**	**Test**	**Control**	**Test**	**Control**	**Test**	**Control**
Initial:	6.35	--	17.2	--	-300	--	70	--
Final:	8.20	--	18.4	--	-236	--	0.7	--

Notes

1. All samples collected from sample port downstream of transfer pump at Surface Treatment Facility.
2. Dose was added to the "Test" beaker. "Control" beaker did not receive $NaMnO_4$.
3. Final results were measured after five minutes of stirring.
4. Hach DR900 colorimeter used to measure field H_2S.
5. YSI 556 MPS hand-held water quality meter used to measure field pH, temperature, and ORP.
6. Colorimeter interference was suspected for Test 1, 3.4 mL/L dose, due to purple color of residual $NaMnO_4$. Result indicated 1.0 mg/L as S^{2-}, but ORP indicated no dissolved sulfide could be present.

Abbreviations

°C = degree Celsius
L = liter
mg/L = milligram per liter
mL = milliliter
mV = millivolt
$NaMnO_4$ = sodium permanganate
ORP = oxidation reduction potential
s.u. = standard pH unit

FIGURES

FIGURE 1
HIGH pH TITRATION CURVES
Colorado River Basin Salinity Control Project
Paradox Valley Unit, Bedrock, Colorado

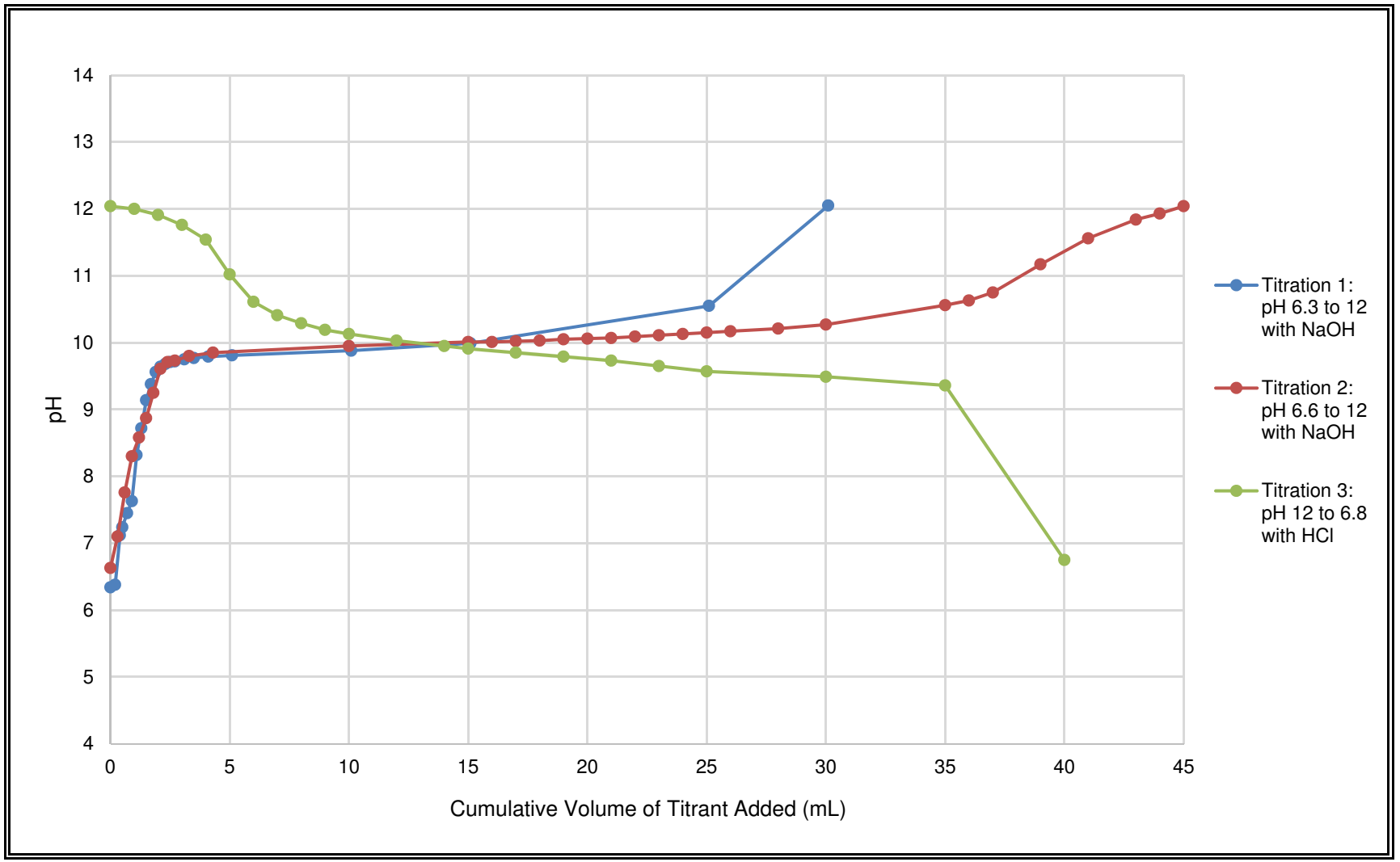


FIGURE 2
LOW pH TITRATION CURVES
Colorado River Basin Salinity Control Project
Paradox Valley Unit, Bedrock, Colorado

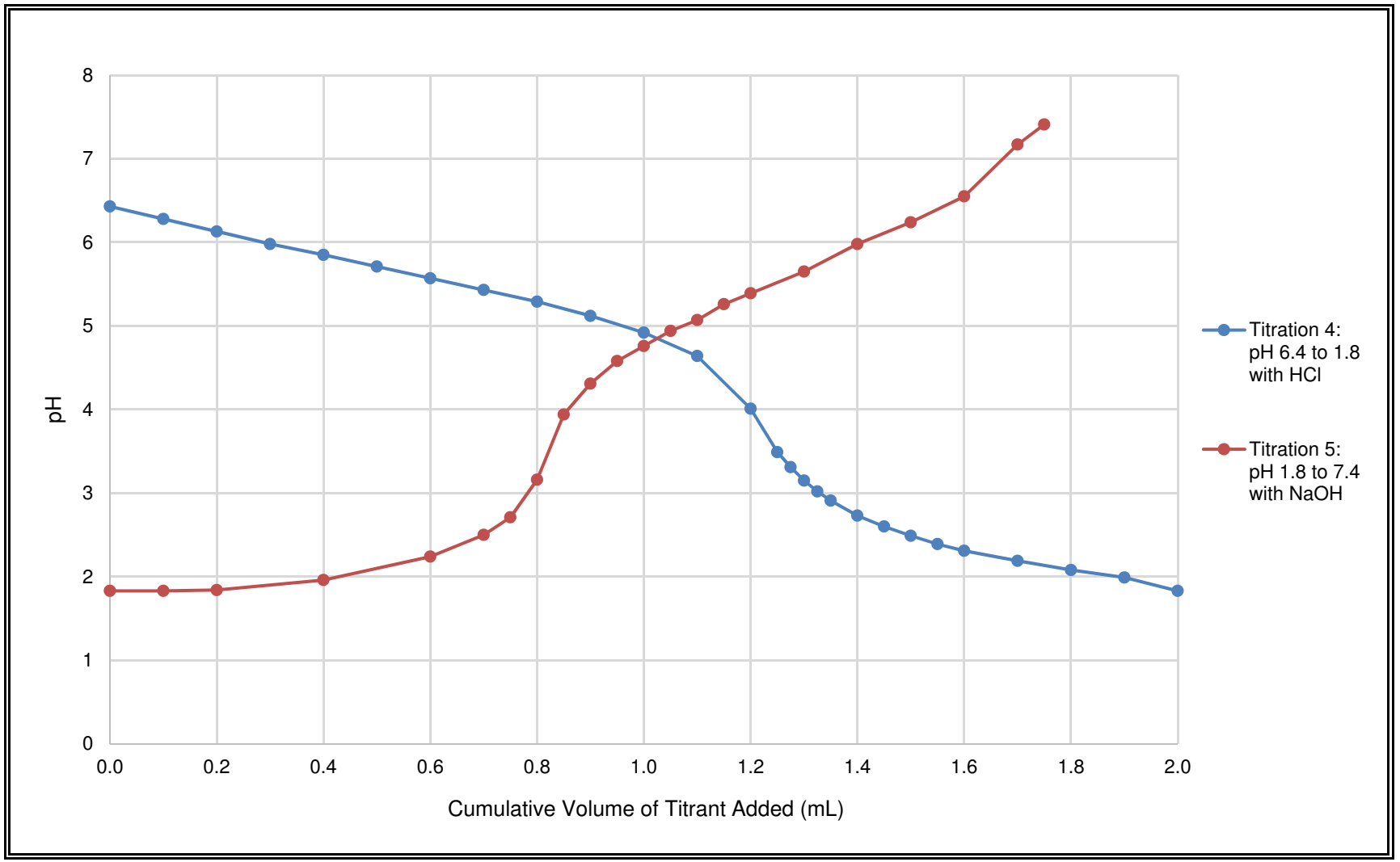


FIGURE 3
HYDROGEN PEROXIDE OXIDATION TEST RESULTS
Colorado River Basin Salinity Control Project
Paradox Valley Unit, Bedrock, Colorado

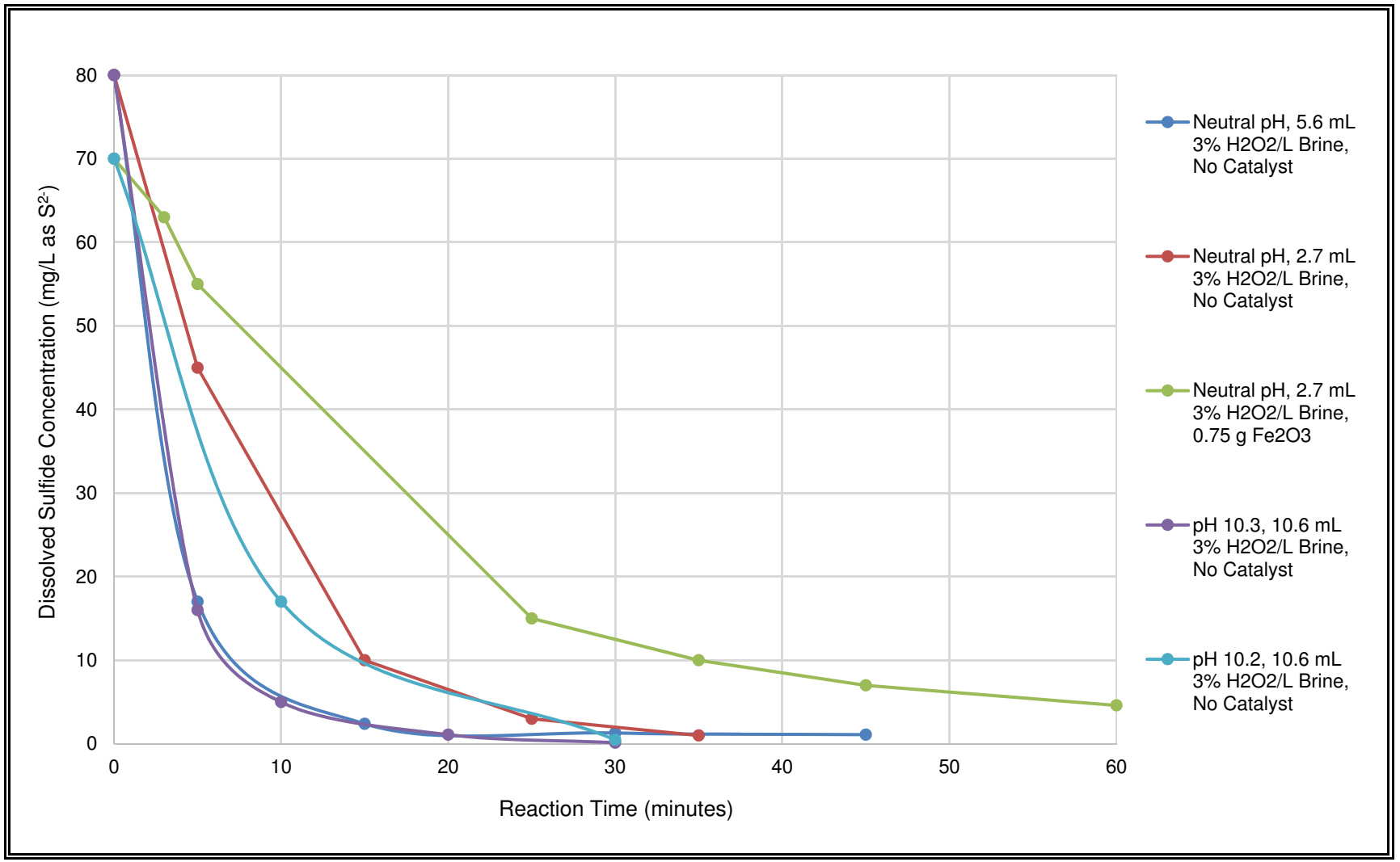


FIGURE 4
SODIUM HYPOCHLORITE OXIDATION TEST RESULTS
Colorado River Basin Salinity Control Project
Paradox Valley Unit, Bedrock, Colorado

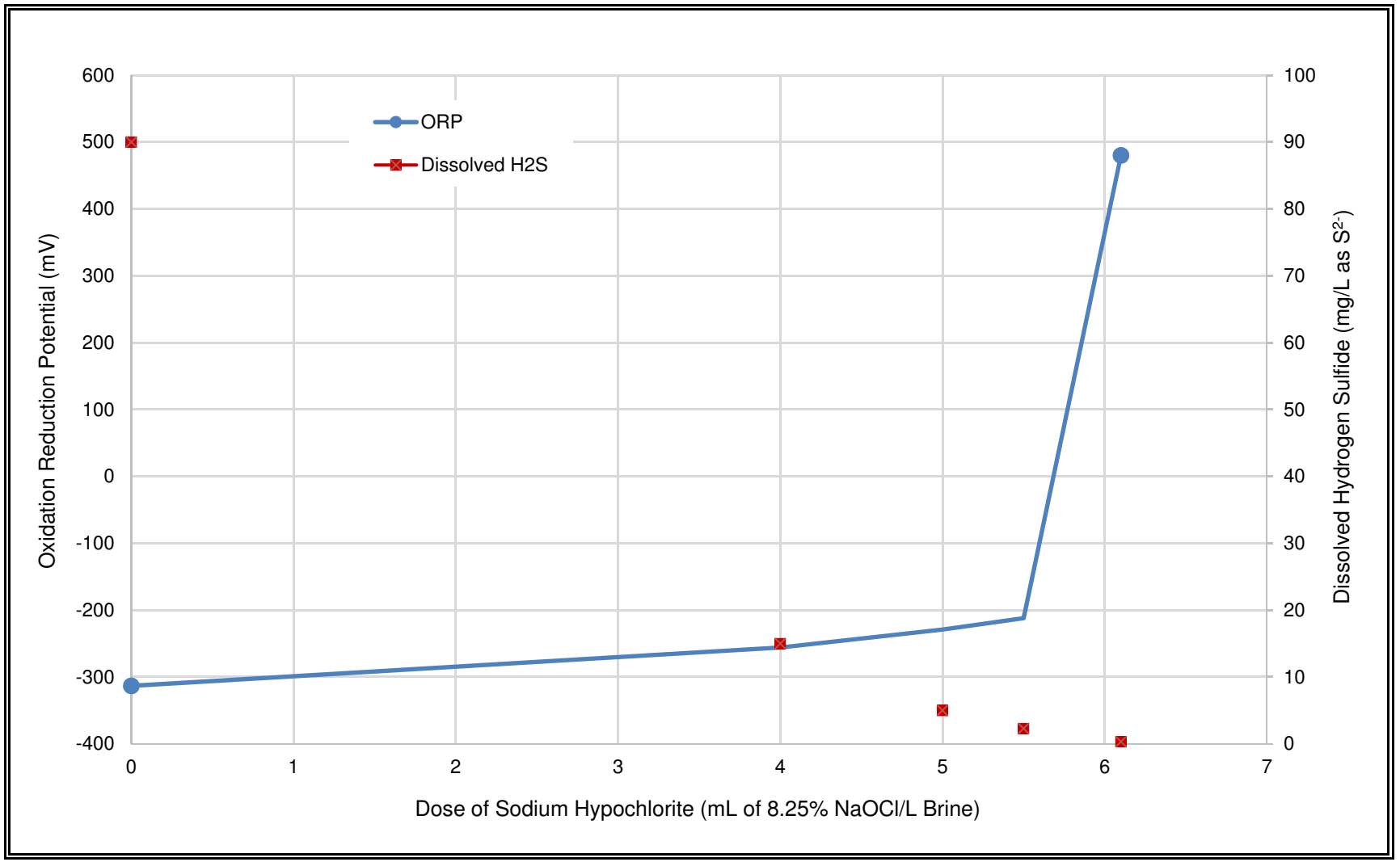


FIGURE 5
SODIUM PERMANGANATE OXIDATION TEST RESULTS
Colorado River Basin Salinity Control Project
Paradox Valley Unit, Bedrock, Colorado

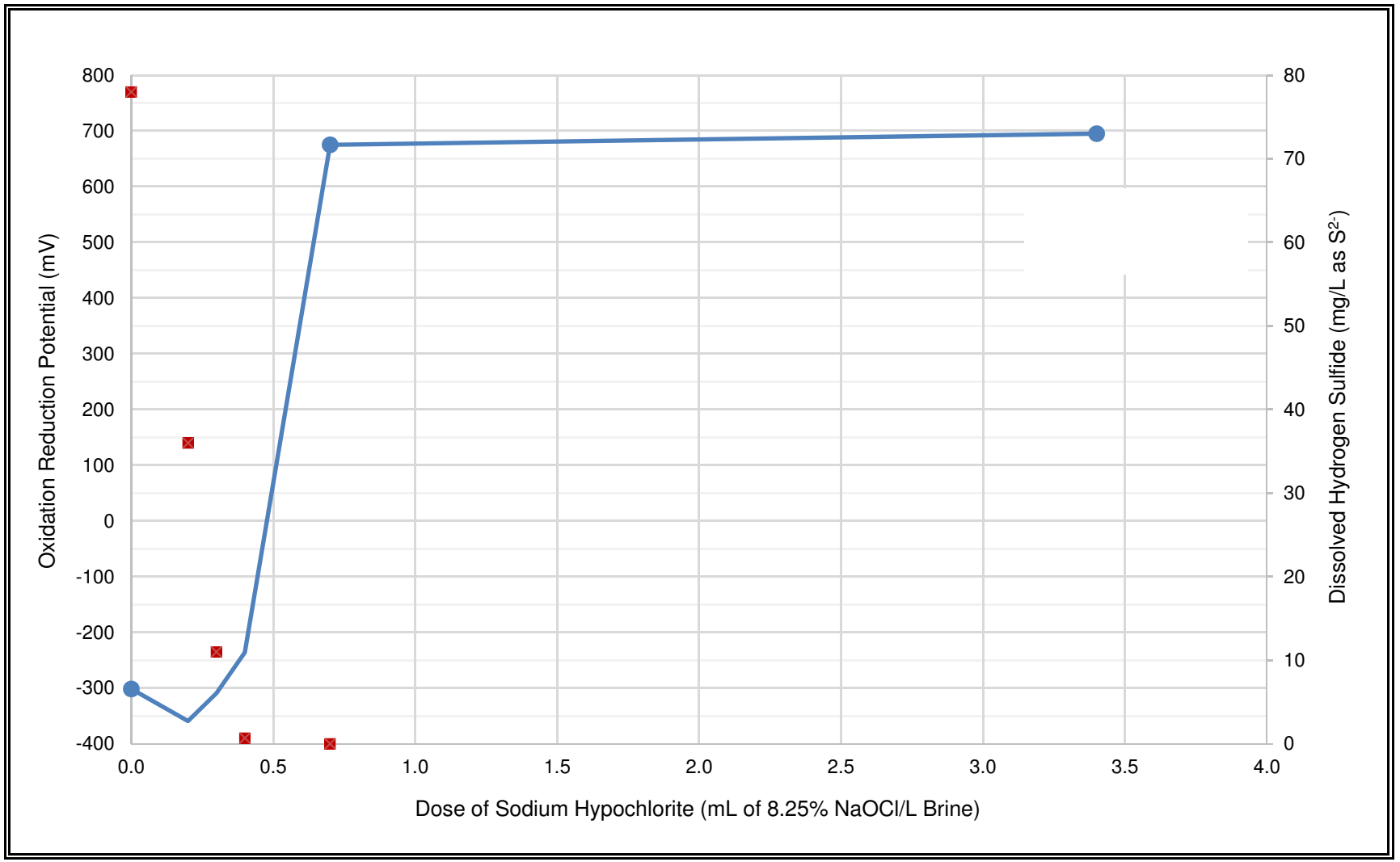
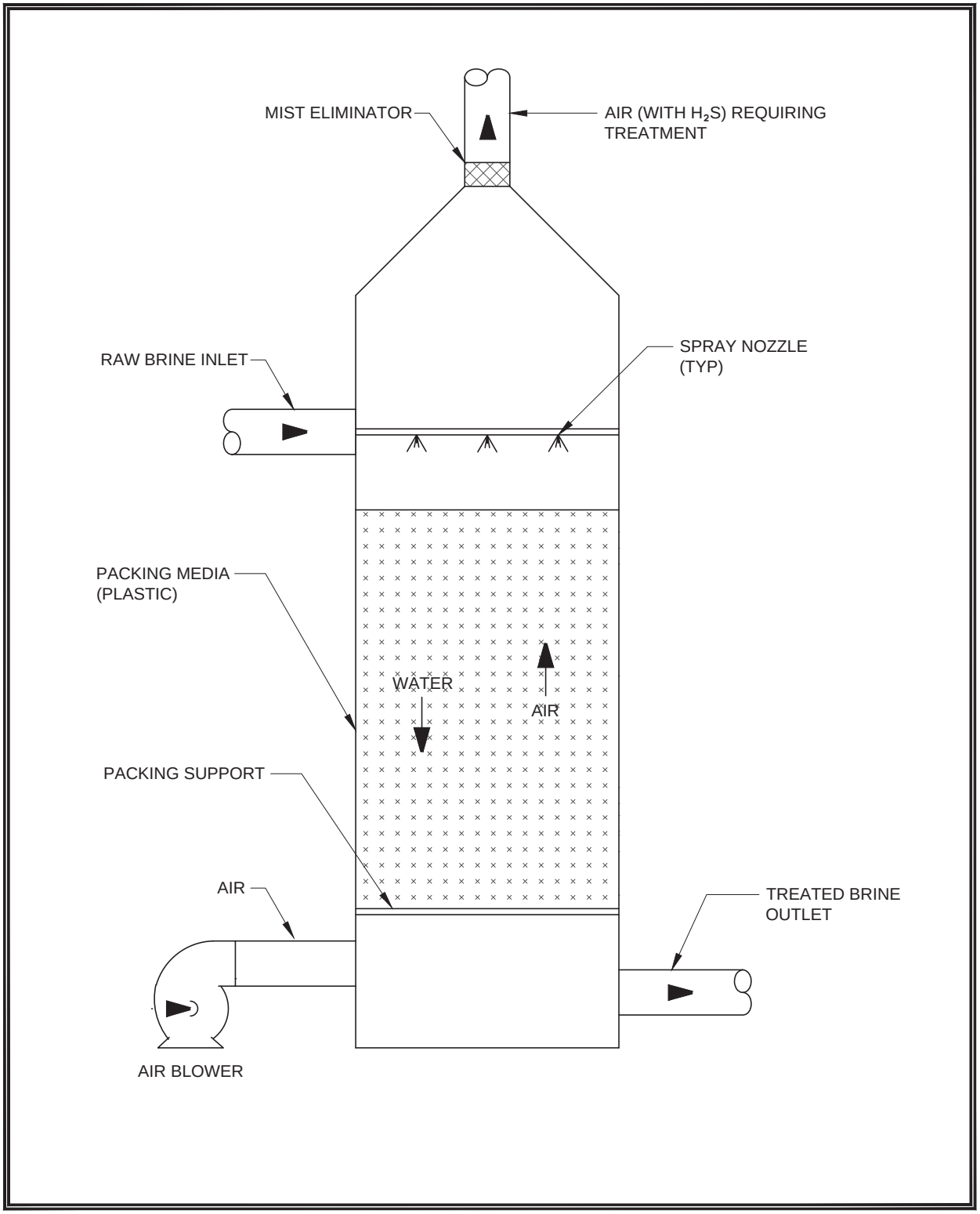


FIGURE 6
SCHEMATIC FOR TYPICAL PACKED TOWER STRIPPER
Colorado River Basin Salinity Control Project
Paradox Valley Unit, Bedrock, Colorado



APPENDIX A

Laboratory Analytical Reports

Saturday, March 26, 2016

Hallie Simpson
AMEC Foster Wheeler
9210 Sky Park Court, #200
San Diego, CA 92123

Re: ALS Workorder: 1603232
Project Name: PVU
Project Number: 1655500023

Dear Simpson:

Seven water samples were received from AMEC Foster Wheeler, on 3/12/2016. The samples were scheduled for the following analyses:

Dissolved Gasses
Inorganics
Metals
Dissolved and Total Organic Carbon
Specific Gravity, TKN, Anions Subcontract to ALS Holland, MI
Sulfur Compounds Subcontract to ALS Simi Valley, CA

The results for these analyses are contained in the enclosed reports.

The data contained in the following report have been reviewed and approved by the personnel listed below. In addition, ALS certifies that the analyses reported herein are true, complete and correct within the limits of the methods employed.

Thank you for your confidence in ALS Environmental. Should you have any questions, please call.

Sincerely,

ALS Environmental
Jeff R. Kujawa
Project Manager

Enclosure(s): Report

ALS Environmental – Fort Collins is accredited by the following accreditation bodies for various testing scopes in accordance with requirements of each accreditation body. All testing is performed under the laboratory management system, which is maintained to meet these requirement and regulations. Please contact the laboratory or accreditation body for the current scope testing parameters.

ALS Environmental – Fort Collins	
Accreditation Body	License or Certification Number
Alaska (AK)	UST-086
Alaska (AK)	CO01099
Arizona (AZ)	AZ0742
California (CA)	06251CA
Colorado (CO)	CO01099
Connecticut (CT)	PH-0232
Florida (FL)	E87914
Idaho (ID)	CO01099
Kansas (KS)	E-10381
Kentucky (KY)	90137
L-A-B (DoD ELAP/ISO 170250)	L2257
Louisiana (LA)	05057
Maryland (MD)	285
Missouri (MO)	175
Nebraska(NE)	NE-OS-24-13
Nevada (NV)	CO000782008A
New York (NY)	12036
North Dakota (ND)	R-057
Oklahoma (OK)	1301
Pennsylvania (PA)	68-03116
Tennessee (TN)	2976
Texas (TX)	T104704241
Utah (UT)	CO01099
Washington (WA)	C1280

1603232

TOC/DOC:
The samples were analyzed following the current revision of SOP 670 based on MCAWW procedures.

All acceptance criteria were met.

Dissolved Gasses:
The samples were prepared and analyzed according to method RSK-175 procedures and the current revision of SOP 449.

All acceptance criteria were met.

Metals:
The samples were analyzed following SW-846, 3rd Edition procedures. Analysis by Trace ICP followed method 6010B and the current revision of SOP 834. Analysis by ICPMS followed method 6020A and the current revision of SOP 827. Mercury analysis by CVAA followed method 7470A and the current revision of SOP 812.

All acceptance criteria were met.

Inorganics:
The samples were analyzed following MCAWW and EMSL procedures for the current revisions of the following SOPs and methods:

Analyte	Method	SOP #
Alkalinity	310.1	1106
Bicarbonate	310.1	1106
Carbonate	310.1	1106
Ammonia as N	350.1	1129
pH	150.1	1126
Specific conductance	120.1	1128
Total phosphorus	365.2	1119
TDS	160.1	1101
TSS	160.2	1100
Bromide	300.0 Revision 2.1	1113
Chloride	300.0 Revision 2.1	1113
Fluoride	300.0 Revision 2.1	1113

Nitrate as N	300.0 Revision 2.1	1113
Nitrite as N	300.0 Revision 2.1	1113
Orthophosphate as P	300.0 Revision 2.1	1113
Sulfate	300.0 Revision 2.1	1113

The samples were prepared and analyzed within the established hold time for each analysis with the exception of samples 1603232-3, -4 and -5 for nitrate as N, nitrite as N and orthophosphate as P. The samples were received with no hold time remaining.

The samples were diluted as necessary for the anion analysis, due to high salts concentration.

All remaining acceptance criteria were met.

ALS Environmental -- FC

Sample Number(s) Cross-Reference Table

OrderNum: 1603232
Client Name: AMEC Foster Wheeler
Client Project Name: PVU
Client Project Number: 1655500023
Client PO Number:

Client Sample Number	Lab Sample Number	COC Number	Matrix	Date Collected	Time Collected
PVUEVAP16031001	1603232-1		WATER	10-Mar-16	11:35
PVUEVAP16031002	1603232-2		WATER	10-Mar-16	11:40
PVUBIF16031001	1603232-3		WATER	10-Mar-16	14:40
PVUBIF16031002	1603232-4		WATER	10-Mar-16	15:00
Trip Blank	1603232-5		WATER	10-Mar-16	
PVUBIF16031001	1603232-6		WATER	10-Mar-16	14:40
PVUBIF16031002	1603232-7		WATER	10-Mar-16	15:00

ALS Environmental

225 Commerce Drive, Fort Collins, Colorado 80524
TF: (800) 443-1511 PH: (970) 490-1511 FX: (970) 490-1522

Chain-of-Custody

Turnaround time for samples received after 2 p.m. will be calculated beginning from the next business day.

Turnaround time for samples received Saturday will be calculated beginning from the next business day.

ALS WORKORDER #	
1603232	
PAGE	1 of 2
DISPOSAL	(BY LAB) or RETURN

TURNAROUND TIME	RUSH	SAMPLER	Hallie B. Simpson
SITE ID			
EDD FORMAT	Excel, X-tab & Flat file		
PURCHASE ORDER	N/A		
BILL TO COMPANY	Amec Foster Wheeler		
INVOICE ATTN TO	Carla Scheidlinger		
ADDRESS	9210 Sky Park Ct, Ste 200		
CITY / STATE / ZIP	San Diego, CA 92123		
PHONE	858-300-4311		
FAX			
E-MAIL	carla.scheidlinger@amecfw.com		
CC:	hallie.simpson@amecfw.com		

	PROJECT NAME	PROJECT No.	COMPANY NAME	SEND REPORT TO	ADDRESS	CITY / STATE / ZIP	PHONE	FAX	E-MAIL	CC:
	PVU	165550000023	Amec Foster Wheeler	Hallie Simpson	PO Box 3781	Telluride, CO 81435	720-284-4043	—	hallie.simpson@amecfw.com	greg.harmer@amecfw.com

PARAMETER/METHOD REQUEST FOR ANALYSIS

A	Total Metals + Hg – 6010/6020/7470
B	Dissolved Metals + Hg – 6010/6020/7470
C	Total Phosphorus – 365.2
D	Ammonia – 350.1
E	Anions – 300.0
F	Alkalinity – 310.1
G	TDS – 160.1
H	TSS – 160.2
I	pH – 150.1
J	Specific Conductance – 120.1

LAB ID	FIELD ID	MATRIX	SAMPLE DATE	SAMPLE TIME	# OF BOTTLES	PRESERVATIVE	QC	A	B	C	D	E	F	G	H	I	J	SEE NOTES SECTION
(1)	PVUEVAP160310001	W	3/10/16	11:35	3	HNO_3 (2)		X				X	X	X		X	X	*
(2)	PVUEVAP160310002	W	3/10/16	11:40	3	HNO_3 (2)		X				X	X	X		X	X	*
(3)	PVUBIF160310001	W	3/10/16	14:40	11	1,2,3		X	X	X	X	X	X	X	X	X	X	*
(4)	PVUBIF160310002	W	3/10/16	15:00	11	1,2,3		X	X	X	X	X	X	X	X	X	X	*
(5)	TRIP BLANK	W			5	1,2		X	X			X						

*Time Zone (Circle): EST CST (MST) PST Matrix: O = oil S = soil NS = non-soil solid W = water L = liquid E = extract F = filter

NOTES

* Sample may contain dissolved H_2S. Open bottles under hood or in well-ventilated area!

REPORT LEVEL / QC REQUIRED	
	Summary (Standard QC)
	LEVEL II (Standard QC)
	LEVEL III (Std QC + forms)
	LEVEL IV (Std QC + forms + raw

PRESERVATION KEY 1-HCl 2-HNO3 3-H2SO4 4-NaOH 5-NaOH/ZnAcetate 6-NaHSO4 7-4°C 8-Other

Form 202r9

	SIGNATURE	PRINTED NAME	DATE	TIME
RELINQUISHED BY		Hallie B. Simpson	3/11/16	~~12:00~~ 1500 (1438)
RECEIVED BY		Scott Malby	3-12-16	0930
RELINQUISHED BY				
RECEIVED BY				
RELINQUISHED BY				
RECEIVED BY				

ALS Environmental

225 Commerce Drive, Fort Collins, Colorado 80524
TF: (800) 443-1511 PH: (970) 490-1511 FX: (970) 490-1522

Chain-of-Custody

Turnaround time for samples received after 2 p.m. will be calculated beginning from the next business day.

Turnaround time for samples received Saturday will be calculated beginning from the next business day.

ALS WORKORDER # 1603232

PAGE 2 of 2

DISPOSAL (BY LAB) or RETURN

PROJECT NAME	PVA	TURNAROUND TIME	RUSH
PROJECT No.	1655500023	SAMPLER	Hallie B. Simpson
COMPANY NAME	Amec Foster Wheeler	SITE ID	
SEND REPORT TO	See Page 1	EDD FORMAT	
ADDRESS	See Page 1	PURCHASE ORDER	See Page 1
CITY / STATE / ZIP	See Page 1	BILL TO COMPANY	See Page 1
PHONE	See Page 1	INVOICE ATTN TO	See Page 1
FAX		ADDRESS	See Page 1
E-MAIL		CITY / STATE / ZIP	See Page 1
		PHONE	See Page 1
		FAX	See Page 1
		E-MAIL	See Page 1

PARAMETER/METHOD REQUEST FOR ANALYSIS

A	TOC – 415.1
B	DOC – 415.1
C	Methane – RSK-175
D	~~Total Kjeldahl Nitrogen – SM4500~~ (HBS)
E	~~Specific Gravity – ASTMD5057-90~~ (HBS)
F	
G	
H	
I	
J	

LAB ID	FIELD ID	MATRIX	SAMPLE DATE	SAMPLE TIME	# OF BOTTLES	PRESERVATIVE	QC	A	B	C	D	E	F	G	H	I	J	SEE NOTES SECTION
1	PVUEVAP160310001	W	3/10/16	11:35	3	2						X						*
2	PVUEVAP160310002	W	3/10/16	11:40	3	2						X						*
3	PVUBIF160310001	W	3/10/16	14:40	11	1,2,3		X	6 X	X	X	X						*
4	PVUBIF160310002	W	3/10/16	15:00	11	1,2,3		X	6 X	X	X	X						*
5	TRIP BLANK	W			5	1,2			4 X									

(HBS)

*Time Zone (Circle): EST CST MST PST Matrix: O = oil S = soil NS = non-soil solid W = water L = liquid E = extract F = filter

NOTES

* Sample may contain dissolved H_2S. Open bottles under hood or in well-ventilated area!

7 of 38

REPORT LEVEL / QC REQUIRED	
	Summary (Standard QC)
	LEVEL II (Standard QC)
	LEVEL III (Std QC + forms)
	LEVEL IV (Std QC + forms + raw

PRESERVATION KEY: 1-HCl 2-HNO3 3-H2SO4 4-NaOH 5-NaOH/ZnAcetate 6-NaHSO4 7-4°C 8-Other

Form 202r9

	SIGNATURE	PRINTED NAME	DATE	TIME
RELINQUISHED BY		Hallie B. Simpson	3/11/16	~~12:00~~ (HBS) 1500
RECEIVED BY		Scott Malloy	3-12-16	0930
RELINQUISHED BY				
RECEIVED BY				
RELINQUISHED BY				
RECEIVED BY				

ALS Environmental - Fort Collins
CONDITION OF SAMPLE UPON RECEIPT FORM

Client: Anec Workorder No: 1603232

Project Manager: SDM 3-12-16 LRS JRK Initials: SDM Date: 3-12-16

1.	Does this project require any special handling in addition to standard ALS procedures?		YES	(NO)
2.	Are custody seals on shipping containers intact?	NONE	(YES)	NO
3.	Are Custody seals on sample containers intact?	(NONE)	YES	NO
4.	Is there a COC (Chain-of-Custody) present or other representative documents?		(YES)	NO
5.	Are the COC and bottle labels complete and legible?		(YES)	NO
6.	Is the COC in agreement with samples received? (IDs, dates, times, no. of samples, no. of containers, matrix, requested analyses, etc.)		YES	(NO)
7.	Were airbills / shipping documents present and/or removable?	DROP OFF	(YES)	NO
8.	Are all aqueous samples requiring preservation preserved correctly? (excluding volatiles)	N/A	YES	NO
9.	Are all aqueous non-preserved samples pH 4-9?	N/A	YES	NO
10.	Is there sufficient sample for the requested analyses?		(YES)	NO
11.	Were all samples placed in the proper containers for the requested analyses?		(YES)	NO
12.	Are all samples within holding times for the requested analyses?		(YES)	NO
13.	Were all sample containers received intact? (not broken or leaking, etc.)		(YES)	NO
14.	Are all samples requiring no headspace (VOC, GRO, RSK/MEE, Rx CN/S, radon) headspace free? Size of bubble: X < green pea ____ > green pea	N/A	YES	(NO)
15.	Do any water samples contain sediment? Amount Amount of sediment: ____ dusting ____ moderate ____ heavy	N/A	YES	(NO)
16.	Were the samples shipped on ice?		(YES)	NO
17.	Were cooler temperatures measured at 0.1-6.0°C? IR gun used*: #2 #4	RAD ONLY	(YES)	NO

Cooler #:	1							
Temperature (°C):	5.1							
No. of custody seals on cooler:	2							
DOT Survey/ Acceptance Information — External µR/hr reading:	10							
Background µR/hr reading:	9							

Were external µR/hr readings ≤ two times background and within DOT acceptance criteria? (YES) / NO / NA (If no, see Form 008.)

Additional Information: PROVIDE DETAILS BELOW FOR A NO RESPONSE TO ANY QUESTION ABOVE, EXCEPT #1 AND #16.

6.) Sample 1 & 2 ⇒ COC says 3 bottles shipped ⇒ only received 2.
Sample 3 & 4 ⇒ COC says 11 bottles shipped ⇒ only received 9 bottles for each Sample.

14.) Sample 3 & 4 bottles 5, 6, & 7 have headspace < green pea.

If applicable, was the client contacted? YES / NO (NA) Contact: _____ Date/Time: _____

Project Manager Signature / Date: 3-14-16

*IR Gun #2: Oakton, SN 29922500201-0066
*IR Gun #4: Oakton, SN 2372220101-0002

After printing this label:
1. Use the 'Print' button on this page to print your label to your laser or inkjet printer.
2. Fold the printed page along the horizontal line.
3. Place label in shipping pouch and affix it to your shipment so that the barcode portion of the label can be read and scanned.

Warning: Use only the printed original label for shipping. Using a photocopy of this label for shipping purposes is fraudulent and could result in additional billing charges, along with the cancellation of your FedEx account number.
Use of this system constitutes your agreement to the service conditions in the current FedEx Service Guide, available on fedex.com.FedEx will not be responsible for any claim in excess of $100 per package, whether the result of loss, damage, delay, non-delivery,misdelivery,or misinformation, unless you declare a higher value, pay an additional charge, document your actual loss and file a timely claim.Limitations found in the current FedEx Service Guide apply. Your right to recover from FedEx for any loss, including intrinsic value of the package, loss of sales, income interest, profit, attorney's fees, costs, and other forms of damage whether direct, incidental,consequential, or special is limited to the greater of $100 or the authorized declared value. Recovery cannot exceed actual documented loss.Maximum for items of extraordinary value is $1,000, e.g. jewelry, precious metals, negotiable instruments and other items listed in our ServiceGuide. Written claims must be filed within strict time limits, see current FedEx Service Guide.

Client:	AMEC Foster Wheeler	**Date:**	*22-Mar-16*
Project:	1655500023 PVU	**Work Order:**	1603232
Sample ID:	PVUEVAP16031001	**Lab ID:**	1603232-1
Legal Location:		**Matrix:**	WATER
Collection Date:	3/10/2016 11:35	**Percent Moisture:**	

Analyses	Result	Qual	Report Limit	Units	Dilution Factor	MDL	Date Analyzed
ALKALINITY AS CALCIUM CARBONATE			**EPA310.1**		Prep Date: **3/17/2016**		PrepBy: **CBA**
BICARBONATE AS CaCO3	**91**		**20**	**MG/L**	1		3/17/2016
CARBONATE AS CaCO3	ND		20	MG/L	1		3/17/2016
TOTAL ALKALINITY AS CaCO3	**91**		**20**	**MG/L**	1		3/17/2016
ICPMS METALS			**SW6020**		Prep Date: **3/15/2016**		PrepBy: **CDR**
CALCIUM	**1600000**		**100000**	**UG/L**	100	6100	3/18/2016 14:35
IRON	ND		10000	UG/L	100	530	3/18/2016 14:35
POTASSIUM	**5000000**		**100000**	**UG/L**	100	32000	3/18/2016 14:35
MAGNESIUM	**1800000**		**10000**	**UG/L**	100	2000	3/18/2016 14:35
SODIUM	**9.3E+07**		**100000**	**UG/L**	100	19000	3/21/2016 14:25
ION CHROMATOGRAPHY			**EPA300.0**		Prep Date: **3/14/2016**		PrepBy: **SDW**
CHLORIDE	**170000**		**2000**	**MG/L**	10000	600	3/14/2016 16:17
SULFATE	**7500**		**500**	**MG/L**	500	150	3/14/2016 11:15
PH			**EPA150.1**		Prep Date: **3/14/2016**		PrepBy: **CBA**
PH	**7.18**		**0.1**	**pH**	1		3/14/2016
SPECIFIC CONDUCTANCE IN WATER			**EPA120.1**		Prep Date: **3/14/2016**		PrepBy: **CBA**
SPECIFIC CONDUCTIVITY	**242000**		**1**	**umhos/cm**	1		3/14/2016
TOTAL DISSOLVED SOLIDS			**EPA160.1**		Prep Date: **3/16/2016**		PrepBy: **CBA**
TOTAL DISSOLVED SOLIDS	**650000**		**2000**	**MG/L**	1		3/17/2016

Client:	AMEC Foster Wheeler	**Date:**	*22-Mar-16*
Project:	1655500023 PVU	**Work Order:**	1603232
Sample ID:	PVUEVAP16031002	**Lab ID:**	1603232-2
Legal Location:		**Matrix:**	WATER
Collection Date:	3/10/2016 11:40	**Percent Moisture:**	

Analyses	Result	Qual	Report Limit	Units	Dilution Factor	MDL	Date Analyzed
ALKALINITY AS CALCIUM CARBONATE			**EPA310.1**		Prep Date: **3/17/2016**		PrepBy: **CBA**
BICARBONATE AS CaCO3	**100**		**20**	**MG/L**	1		3/17/2016
CARBONATE AS CaCO3	ND		20	MG/L	1		3/17/2016
TOTAL ALKALINITY AS CaCO3	**100**		**20**	**MG/L**	1		3/17/2016
ICPMS METALS			**SW6020**		Prep Date: **3/15/2016**		PrepBy: **CDR**
CALCIUM	**1800000**		**100000**	**UG/L**	100	6100	3/18/2016 14:38
IRON	**2200**	J	**10000**	**UG/L**	100	530	3/18/2016 14:38
POTASSIUM	**5700000**		**100000**	**UG/L**	100	32000	3/18/2016 14:38
MAGNESIUM	**2100000**		**10000**	**UG/L**	100	2000	3/18/2016 14:38
SODIUM	**9.8E+07**		**100000**	**UG/L**	100	19000	3/21/2016 14:28
ION CHROMATOGRAPHY			**EPA300.0**		Prep Date: **3/14/2016**		PrepBy: **SDW**
CHLORIDE	**180000**		**2000**	**MG/L**	10000	600	3/14/2016 16:02
SULFATE	**7700**		**500**	**MG/L**	500	150	3/14/2016 11:00
PH			**EPA150.1**		Prep Date: **3/14/2016**		PrepBy: **CBA**
PH	**7.15**		**0.1**	**pH**	1		3/14/2016
SPECIFIC CONDUCTANCE IN WATER			**EPA120.1**		Prep Date: **3/14/2016**		PrepBy: **CBA**
SPECIFIC CONDUCTIVITY	**248000**		**1**	**umhos/cm**	1		3/14/2016
TOTAL DISSOLVED SOLIDS			**EPA160.1**		Prep Date: **3/16/2016**		PrepBy: **CBA**
TOTAL DISSOLVED SOLIDS	**470000**		**2000**	**MG/L**	1		3/17/2016

Client: AMEC Foster Wheeler **Date:** *22-Mar-16*
Project: 1655500023 PVU **Work Order:** 1603232
Sample ID: PVUBIF16031001 **Lab ID:** 1603232-3
Legal Location: **Matrix:** WATER
Collection Date: 3/10/2016 14:40 **Percent Moisture:**

Analyses	Result	Qual	Report Limit	Units	Dilution Factor	MDL	Date Analyzed
ALKALINITY AS CALCIUM CARBONATE			**EPA310.1**		Prep Date: **3/17/2016**		PrepBy: **CBA**
BICARBONATE AS CaCO3	**200**		**20**	**MG/L**	1		3/17/2016
CARBONATE AS CaCO3	ND		20	MG/L	1		3/17/2016
TOTAL ALKALINITY AS CaCO3	**200**		**20**	**MG/L**	1		3/17/2016
AMMONIA AS N			**EPA350.1**		Prep Date: **3/14/2016**		PrepBy: **BAS**
AMMONIA AS N	**17**		**2.5**	**MG/L**	25	0.75	3/14/2016 13:42
DISSOLVED GASSES			**RSK175**		Prep Date: **3/17/2016**		PrepBy: **JFN**
METHANE	**1200**		**1**	**UG/L**	1	1	3/17/2016 13:30
ICP METALS			**SW6010**		Prep Date: **3/15/2016**		PrepBy: **CDR**
BISMUTH	**49**	J	**200**	**UG/L**	1	46	3/16/2016 13:14
PHOSPHORUS	**570**	J	**2000**	**UG/L**	1	110	3/16/2016 13:14
SILICON	**2700**		**500**	**UG/L**	1	290	3/16/2016 13:14
ICPMS METALS			**SW6020**		Prep Date: **3/15/2016**		PrepBy: **CDR**
SILVER	ND		10	UG/L	100	3.9	3/18/2016 14:41
ALUMINUM	ND		5000	UG/L	100	1400	3/18/2016 14:41
ARSENIC	ND		200	UG/L	100	18	3/18/2016 14:41
BORON	**11000**		**5000**	**UG/L**	100	1200	3/18/2016 14:41
BARIUM	**30**	J	**100**	**UG/L**	100	23	3/18/2016 14:41
BERYLLIUM	ND		50	UG/L	100	27	3/18/2016 14:41
CALCIUM	**1700000**		**100000**	**UG/L**	100	6100	3/18/2016 14:41
CADMIUM	ND		30	UG/L	100	9.9	3/18/2016 14:41
COBALT	ND		100	UG/L	100	7	3/18/2016 14:41
CHROMIUM	ND		1000	UG/L	100	110	3/18/2016 14:41
COPPER	ND		1000	UG/L	100	110	3/18/2016 14:41
IRON	ND		10000	UG/L	100	530	3/18/2016 14:41
POTASSIUM	**5300000**		**100000**	**UG/L**	100	32000	3/18/2016 14:41
LITHIUM	**360**	J	**1000**	**UG/L**	100	210	3/18/2016 14:41
MAGNESIUM	**1900000**		**10000**	**UG/L**	100	2000	3/18/2016 14:41
MANGANESE	**580**		**200**	**UG/L**	100	30	3/18/2016 14:41
MOLYBDENUM	ND		100	UG/L	100	41	3/18/2016 14:41
SODIUM	**1E+08**		**100000**	**UG/L**	100	19000	3/21/2016 14:50
NICKEL	ND		500	UG/L	100	420	3/18/2016 14:41
LEAD	ND		50	UG/L	100	16	3/18/2016 14:41
ANTIMONY	ND		30	UG/L	100	8.4	3/18/2016 14:41
SELENIUM	ND		100	UG/L	100	66	3/18/2016 14:41
TIN	ND		500	UG/L	100	130	3/21/2016 14:50
STRONTIUM	**31000**		**100**	**UG/L**	100	31	3/18/2016 14:41
TITANIUM	ND		2000	UG/L	100	1400	3/18/2016 14:41
THALLIUM	ND		20	UG/L	100	1.4	3/18/2016 14:41
URANIUM	ND		10	UG/L	100	2.7	3/18/2016 14:41
VANADIUM	ND		100	UG/L	100	58	3/18/2016 14:41
ZINC	ND		2000	UG/L	100	910	3/18/2016 14:41

Client: AMEC Foster Wheeler **Date:** *22-Mar-16*
Project: 1655500023 PVU **Work Order:** 1603232
Sample ID: PVUBIF16031001 **Lab ID:** 1603232-3
Legal Location: **Matrix:** WATER
Collection Date: 3/10/2016 14:40 **Percent Moisture:**

Analyses	Result	Qual	Report Limit	Units	Dilution Factor	MDL	Date Analyzed
ZIRCONIUM	ND		5	UG/L	10	5	3/22/2016 14:17
ION CHROMATOGRAPHY			**EPA300.0**		Prep Date: **3/14/2016**		PrepBy: **SDW**
BROMIDE	**86**	J	**100**	**MG/L**	500	30	3/14/2016 10:44
CHLORIDE	**170000**		**2000**	**MG/L**	10000	600	3/14/2016 15:47
FLUORIDE	ND		50	MG/L	500	15	3/14/2016 10:44
NITRATE AS N	ND		100	MG/L	500	30	3/14/2016 10:44
NITRITE AS N	ND		50	MG/L	500	15	3/14/2016 10:44
ORTHOPHOSPHATE AS P	ND		250	MG/L	500	30	3/14/2016 10:44
SULFATE	**7100**		**500**	**MG/L**	500	150	3/14/2016 10:44
MERCURY			**SW7470**		Prep Date: **3/14/2016**		PrepBy: **NAQ**
MERCURY	ND		0.2	UG/L	1	0.06	3/15/2016 14:37
ORGANIC CARBON			**EPA415.1**		Prep Date: **3/17/2016**		PrepBy: **SDW**
TOTAL ORGANIC CARBON	ND		1	MG/L	1	0.3	3/17/2016 14:11
PH			**EPA150.1**		Prep Date: **3/14/2016**		PrepBy: **CBA**
PH	**6.32**		**0.1**	**pH**	1		3/14/2016
SPECIFIC CONDUCTANCE IN WATER			**EPA120.1**		Prep Date: **3/14/2016**		PrepBy: **CBA**
SPECIFIC CONDUCTIVITY	**237000**		**1**	**umhos/cm**	1		3/14/2016
TOTAL DISSOLVED SOLIDS			**EPA160.1**		Prep Date: **3/16/2016**		PrepBy: **CBA**
TOTAL DISSOLVED SOLIDS	**850000**		**2000**	**MG/L**	1		3/17/2016
TOTAL PHOSPHORUS AS P			**EPA365.2**		Prep Date: **3/22/2016**		PrepBy: **TWK**
TOTAL PHOSPHORUS	**0.033**	J	**0.05**	**MG/L**	1	0.015	3/22/2016
TOTAL SUSPENDED SOLIDS			**EPA160.2**		Prep Date: **3/14/2016**		PrepBy: **TWK**
TOTAL SUSPENDED SOLIDS	ND		20	MG/L	1		3/15/2016

Client: AMEC Foster Wheeler **Date:** *22-Mar-16*
Project: 1655500023 PVU **Work Order:** 1603232
Sample ID: PVUBIF16031002 **Lab ID:** 1603232-4
Legal Location: **Matrix:** WATER
Collection Date: 3/10/2016 15:00 **Percent Moisture:**

Analyses	Result	Qual	Report Limit	Units	Dilution Factor	MDL	Date Analyzed
ALKALINITY AS CALCIUM CARBONATE			**EPA310.1**		Prep Date: **3/17/2016**		PrepBy: **CBA**
BICARBONATE AS CaCO3	**200**		**20**	**MG/L**	1		3/17/2016
CARBONATE AS CaCO3	ND		20	MG/L	1		3/17/2016
TOTAL ALKALINITY AS CaCO3	**200**		**20**	**MG/L**	1		3/17/2016
AMMONIA AS N			**EPA350.1**		Prep Date: **3/14/2016**		PrepBy: **BAS**
AMMONIA AS N	**15**		**2.5**	**MG/L**	25	0.75	3/14/2016 12:14
DISSOLVED GASSES			**RSK175**		Prep Date: **3/17/2016**		PrepBy: **JFN**
METHANE	**1100**		**1**	**UG/L**	1	1	3/17/2016 13:33
ICP METALS			**SW6010**		Prep Date: **3/15/2016**		PrepBy: **CDR**
BISMUTH	**49**	J	**200**	**UG/L**	1	46	3/16/2016 13:18
PHOSPHORUS	**520**	J	**2000**	**UG/L**	1	110	3/16/2016 13:18
SILICON	**2600**		**500**	**UG/L**	1	290	3/16/2016 13:18
ICPMS METALS			**SW6020**		Prep Date: **3/15/2016**		PrepBy: **CDR**
SILVER	ND		10	UG/L	100	3.9	3/18/2016 14:44
ALUMINUM	ND		5000	UG/L	100	1400	3/18/2016 14:44
ARSENIC	ND		200	UG/L	100	18	3/18/2016 14:44
BORON	**11000**		**5000**	**UG/L**	100	1200	3/18/2016 14:44
BARIUM	**44**	J	**100**	**UG/L**	100	23	3/18/2016 14:44
BERYLLIUM	ND		50	UG/L	100	27	3/18/2016 14:44
CALCIUM	**1700000**		**100000**	**UG/L**	100	6100	3/18/2016 14:44
CADMIUM	ND		30	UG/L	100	9.9	3/18/2016 14:44
COBALT	ND		100	UG/L	100	7	3/18/2016 14:44
CHROMIUM	ND		1000	UG/L	100	110	3/18/2016 14:44
COPPER	ND		1000	UG/L	100	110	3/18/2016 14:44
IRON	ND		10000	UG/L	100	530	3/18/2016 14:44
POTASSIUM	**5400000**		**100000**	**UG/L**	100	32000	3/18/2016 14:44
LITHIUM	**420**	J	**1000**	**UG/L**	100	210	3/18/2016 14:44
MAGNESIUM	**2000000**		**10000**	**UG/L**	100	2000	3/18/2016 14:44
MANGANESE	**600**		**200**	**UG/L**	100	30	3/18/2016 14:44
MOLYBDENUM	ND		100	UG/L	100	41	3/18/2016 14:44
SODIUM	**9.4E+07**		**100000**	**UG/L**	100	19000	3/21/2016 14:53
NICKEL	ND		500	UG/L	100	420	3/18/2016 14:44
LEAD	ND		50	UG/L	100	16	3/18/2016 14:44
ANTIMONY	ND		30	UG/L	100	8.4	3/18/2016 14:44
SELENIUM	ND		100	UG/L	100	66	3/18/2016 14:44
TIN	ND		500	UG/L	100	130	3/21/2016 14:53
STRONTIUM	**32000**		**100**	**UG/L**	100	31	3/18/2016 14:44
TITANIUM	ND		2000	UG/L	100	1400	3/18/2016 14:44
THALLIUM	ND		20	UG/L	100	1.4	3/18/2016 14:44
URANIUM	ND		10	UG/L	100	2.7	3/18/2016 14:44
VANADIUM	ND		100	UG/L	100	58	3/18/2016 14:44
ZINC	ND		2000	UG/L	100	910	3/18/2016 14:44

Client:	AMEC Foster Wheeler	**Date:**	*22-Mar-16*
Project:	1655500023 PVU	**Work Order:**	1603232
Sample ID:	PVUBIF16031002	**Lab ID:**	1603232-4
Legal Location:		**Matrix:**	WATER
Collection Date:	3/10/2016 15:00	**Percent Moisture:**	

Analyses	Result	Qual	Report Limit	Units	Dilution Factor	MDL	Date Analyzed
ZIRCONIUM	ND		5	UG/L	10	5	3/22/2016 14:39
ION CHROMATOGRAPHY			**EPA300.0**		Prep Date: **3/14/2016**		PrepBy: **SDW**
BROMIDE	**83**	J	**100**	**MG/L**	500	30	3/14/2016 10:29
CHLORIDE	**170000**		**2000**	**MG/L**	10000	600	3/14/2016 15:31
FLUORIDE	ND		50	MG/L	500	15	3/14/2016 10:29
NITRATE AS N	ND		100	MG/L	500	30	3/14/2016 10:29
NITRITE AS N	ND		50	MG/L	500	15	3/14/2016 10:29
ORTHOPHOSPHATE AS P	ND		250	MG/L	500	30	3/14/2016 10:29
SULFATE	**6800**		**500**	**MG/L**	500	150	3/14/2016 10:29
MERCURY			**SW7470**		Prep Date: **3/14/2016**		PrepBy: **NAQ**
MERCURY	ND		0.2	UG/L	1	0.06	3/15/2016 14:43
ORGANIC CARBON			**EPA415.1**		Prep Date: **3/17/2016**		PrepBy: **SDW**
TOTAL ORGANIC CARBON	ND		1	MG/L	1	0.3	3/17/2016 14:19
PH			**EPA150.1**		Prep Date: **3/14/2016**		PrepBy: **CBA**
PH	**6.29**		**0.1**	**pH**	1		3/14/2016
SPECIFIC CONDUCTANCE IN WATER			**EPA120.1**		Prep Date: **3/14/2016**		PrepBy: **CBA**
SPECIFIC CONDUCTIVITY	**238000**		**1**	**umhos/cm**	1		3/14/2016
TOTAL DISSOLVED SOLIDS			**EPA160.1**		Prep Date: **3/16/2016**		PrepBy: **CBA**
TOTAL DISSOLVED SOLIDS	**580000**		**2000**	**MG/L**	1		3/17/2016
TOTAL PHOSPHORUS AS P			**EPA365.2**		Prep Date: **3/22/2016**		PrepBy: **TWK**
TOTAL PHOSPHORUS	**0.018**	J	**0.05**	**MG/L**	1	0.015	3/22/2016
TOTAL SUSPENDED SOLIDS			**EPA160.2**		Prep Date: **3/14/2016**		PrepBy: **TWK**
TOTAL SUSPENDED SOLIDS	ND		20	MG/L	1		3/15/2016

Client: AMEC Foster Wheeler **Date:** *22-Mar-16*
Project: 1655500023 PVU **Work Order:** 1603232
Sample ID: Trip Blank **Lab ID:** 1603232-5
Legal Location: **Matrix:** WATER
Collection Date: 3/10/2016 **Percent Moisture:**

Analyses	Result	Qual	Report Limit	Units	Dilution Factor	MDL	Date Analyzed
DISSOLVED GASSES			**RSK175**		Prep Date: **3/17/2016**		PrepBy: **JFN**
METHANE	ND		1	UG/L	1	1	3/17/2016 13:14
ICP METALS			**SW6010**		Prep Date: **3/15/2016**		PrepBy: **CDR**
BISMUTH	ND		200	UG/L	1	46	3/16/2016 13:23
PHOSPHORUS	**520**	J	**2000**	**UG/L**	1	110	3/16/2016 13:23
SILICON	**440**	J	**500**	**UG/L**	1	290	3/16/2016 13:23
ICPMS METALS			**SW6020**		Prep Date: **3/15/2016**		PrepBy: **CDR**
SILVER	ND		10	UG/L	100	3.9	3/18/2016 14:47
ALUMINUM	ND		5000	UG/L	100	1400	3/18/2016 14:47
ARSENIC	ND		200	UG/L	100	18	3/18/2016 14:47
BORON	ND		5000	UG/L	100	1200	3/18/2016 14:47
BARIUM	ND		100	UG/L	100	23	3/18/2016 14:47
BERYLLIUM	ND		50	UG/L	100	27	3/18/2016 14:47
CALCIUM	ND		100000	UG/L	100	6100	3/18/2016 14:47
CADMIUM	ND		30	UG/L	100	9.9	3/18/2016 14:47
COBALT	ND		100	UG/L	100	7	3/18/2016 14:47
CHROMIUM	ND		1000	UG/L	100	110	3/18/2016 14:47
COPPER	ND		1000	UG/L	100	110	3/18/2016 14:47
IRON	ND		10000	UG/L	100	530	3/18/2016 14:47
POTASSIUM	ND		100000	UG/L	100	32000	3/18/2016 14:47
LITHIUM	ND		1000	UG/L	100	210	3/18/2016 14:47
MAGNESIUM	ND		10000	UG/L	100	2000	3/18/2016 14:47
MANGANESE	ND		200	UG/L	100	30	3/18/2016 14:47
MOLYBDENUM	ND		100	UG/L	100	41	3/18/2016 14:47
SODIUM	**81000**	J	**100000**	**UG/L**	100	19000	3/21/2016 14:56
NICKEL	ND		500	UG/L	100	420	3/18/2016 14:47
LEAD	ND		50	UG/L	100	16	3/18/2016 14:47
ANTIMONY	ND		30	UG/L	100	8.4	3/18/2016 14:47
SELENIUM	ND		100	UG/L	100	66	3/18/2016 14:47
TIN	ND		500	UG/L	100	130	3/21/2016 14:56
STRONTIUM	ND		100	UG/L	100	31	3/18/2016 14:47
TITANIUM	ND		2000	UG/L	100	1400	3/18/2016 14:47
THALLIUM	ND		20	UG/L	100	1.4	3/18/2016 14:47
URANIUM	ND		10	UG/L	100	2.7	3/18/2016 14:47
VANADIUM	ND		100	UG/L	100	58	3/18/2016 14:47
ZINC	ND		2000	UG/L	100	910	3/18/2016 14:47
ZIRCONIUM	ND		5	UG/L	10	5	3/22/2016 14:41
ION CHROMATOGRAPHY			**EPA300.0**		Prep Date: **3/14/2016**		PrepBy: **SDW**
BROMIDE	ND		0.2	MG/L	1	0.06	3/14/2016 10:14
CHLORIDE	**0.63**		**0.2**	**MG/L**	1	0.06	3/14/2016 10:14
FLUORIDE	ND		0.1	MG/L	1	0.03	3/14/2016 10:14
NITRATE AS N	ND		0.2	MG/L	1	0.06	3/14/2016 10:14
NITRITE AS N	ND		0.1	MG/L	1	0.03	3/14/2016 10:14

Client:	AMEC Foster Wheeler	**Date:**	*22-Mar-16*
Project:	1655500023 PVU	**Work Order:**	1603232
Sample ID:	Trip Blank	**Lab ID:**	1603232-5
Legal Location:		**Matrix:**	WATER
Collection Date:	3/10/2016	**Percent Moisture:**	

Analyses	Result	Qual	Report Limit	Units	Dilution Factor	MDL	Date Analyzed
ORTHOPHOSPHATE AS P	ND		0.5	MG/L	1	0.06	3/14/2016 10:14
SULFATE	**0.31**	J	**1**	**MG/L**	1	0.3	3/14/2016 10:14
MERCURY			**SW7470**		Prep Date: **3/14/2016**		PrepBy: **NAQ**
MERCURY	ND		0.2	UG/L	1	0.06	3/15/2016 14:45

Client: AMEC Foster Wheeler **Date:** *22-Mar-16*
Project: 1655500023 PVU **Work Order:** 1603232
Sample ID: PVUBIF16031001 **Lab ID:** 1603232-6
Legal Location: **Matrix:** WATER
Collection Date: 3/10/2016 14:40 **Percent Moisture:**

Analyses	Result	Qual	Report Limit	Units	Dilution Factor	MDL	Date Analyzed
ICP METALS			**SW6010**		Prep Date: **3/15/2016**		PrepBy: **CDR**
BISMUTH	**62**	J	**200**	**UG/L**	1	46	3/16/2016 13:26
PHOSPHORUS	**520**	J	**2000**	**UG/L**	1	110	3/16/2016 13:26
SILICON	**3000**		**500**	**UG/L**	1	290	3/16/2016 13:26
ICPMS METALS			**SW6020**		Prep Date: **3/15/2016**		PrepBy: **CDR**
SILVER	ND		10	UG/L	100	3.9	3/18/2016 14:50
ALUMINUM	**3400**	J	**5000**	**UG/L**	100	1400	3/18/2016 14:50
ARSENIC	ND		200	UG/L	100	18	3/18/2016 14:50
BORON	**10000**		**5000**	**UG/L**	100	1200	3/18/2016 14:50
BARIUM	**53**	J	**100**	**UG/L**	100	23	3/18/2016 14:50
BERYLLIUM	ND		50	UG/L	100	27	3/18/2016 14:50
CALCIUM	**1700000**		**100000**	**UG/L**	100	6100	3/18/2016 14:50
CADMIUM	ND		30	UG/L	100	9.9	3/18/2016 14:50
COBALT	ND		100	UG/L	100	7	3/18/2016 14:50
CHROMIUM	ND		1000	UG/L	100	110	3/18/2016 14:50
COPPER	ND		1000	UG/L	100	110	3/18/2016 14:50
IRON	ND		10000	UG/L	100	530	3/18/2016 14:50
POTASSIUM	**5300000**		**100000**	**UG/L**	100	32000	3/18/2016 14:50
LITHIUM	**410**	J	**1000**	**UG/L**	100	210	3/18/2016 14:50
MAGNESIUM	**1900000**		**10000**	**UG/L**	100	2000	3/18/2016 14:50
MANGANESE	**610**		**200**	**UG/L**	100	30	3/18/2016 14:50
MOLYBDENUM	ND		100	UG/L	100	41	3/18/2016 14:50
SODIUM	**1.1E+08**		**100000**	**UG/L**	100	19000	3/21/2016 14:59
NICKEL	ND		500	UG/L	100	420	3/18/2016 14:50
LEAD	ND		50	UG/L	100	16	3/18/2016 14:50
ANTIMONY	ND		30	UG/L	100	8.4	3/18/2016 14:50
SELENIUM	ND		100	UG/L	100	66	3/18/2016 14:50
TIN	ND		500	UG/L	100	130	3/21/2016 14:59
STRONTIUM	**32000**		**100**	**UG/L**	100	31	3/18/2016 14:50
TITANIUM	ND		2000	UG/L	100	1400	3/18/2016 14:50
THALLIUM	ND		20	UG/L	100	1.4	3/18/2016 14:50
URANIUM	ND		10	UG/L	100	2.7	3/18/2016 14:50
VANADIUM	ND		100	UG/L	100	58	3/18/2016 14:50
ZINC	ND		2000	UG/L	100	910	3/18/2016 14:50
ZIRCONIUM	ND		5	UG/L	10	5	3/22/2016 14:42
MERCURY			**SW7470**		Prep Date: **3/14/2016**		PrepBy: **NAQ**
MERCURY	ND		0.2	UG/L	1	0.06	3/15/2016 14:47
ORGANIC CARBON			**EPA415.1**		Prep Date: **3/17/2016**		PrepBy: **SDW**
DISSOLVED ORGANIC CARBON	ND		1	MG/L	1	0.3	3/17/2016 14:30

Client: AMEC Foster Wheeler **Date:** *22-Mar-16*
Project: 1655500023 PVU **Work Order:** 1603232
Sample ID: PVUBIF16031002 **Lab ID:** 1603232-7
Legal Location: **Matrix:** WATER
Collection Date: 3/10/2016 15:00 **Percent Moisture:**

Analyses	Result	Qual	Report Limit	Units	Dilution Factor	MDL	Date Analyzed
ICP METALS			**SW6010**		Prep Date: **3/15/2016**		PrepBy: **CDR**
BISMUTH	**49**	J	**200**	**UG/L**	1	46	3/16/2016 13:31
PHOSPHORUS	**530**	J	**2000**	**UG/L**	1	110	3/16/2016 13:31
SILICON	**2800**		**500**	**UG/L**	1	290	3/16/2016 13:31
ICPMS METALS			**SW6020**		Prep Date: **3/15/2016**		PrepBy: **CDR**
SILVER	ND		10	UG/L	100	3.9	3/18/2016 14:53
ALUMINUM	ND		5000	UG/L	100	1400	3/18/2016 14:53
ARSENIC	ND		200	UG/L	100	18	3/18/2016 14:53
BORON	**11000**		**5000**	**UG/L**	100	1200	3/18/2016 14:53
BARIUM	**44**	J	**100**	**UG/L**	100	23	3/18/2016 14:53
BERYLLIUM	ND		50	UG/L	100	27	3/18/2016 14:53
CALCIUM	**1700000**		**100000**	**UG/L**	100	6100	3/18/2016 14:53
CADMIUM	ND		30	UG/L	100	9.9	3/18/2016 14:53
COBALT	ND		100	UG/L	100	7	3/18/2016 14:53
CHROMIUM	ND		1000	UG/L	100	110	3/18/2016 14:53
COPPER	ND		1000	UG/L	100	110	3/18/2016 14:53
IRON	ND		10000	UG/L	100	530	3/18/2016 14:53
POTASSIUM	**5400000**		**100000**	**UG/L**	100	32000	3/18/2016 14:53
LITHIUM	**420**	J	**1000**	**UG/L**	100	210	3/18/2016 14:53
MAGNESIUM	**2000000**		**10000**	**UG/L**	100	2000	3/18/2016 14:53
MANGANESE	**620**		**200**	**UG/L**	100	30	3/18/2016 14:53
MOLYBDENUM	ND		100	UG/L	100	41	3/18/2016 14:53
SODIUM	**1.1E+08**		**100000**	**UG/L**	100	19000	3/21/2016 15:02
NICKEL	ND		500	UG/L	100	420	3/18/2016 14:53
LEAD	ND		50	UG/L	100	16	3/18/2016 14:53
ANTIMONY	ND		30	UG/L	100	8.4	3/18/2016 14:53
SELENIUM	ND		100	UG/L	100	66	3/18/2016 14:53
TIN	ND		500	UG/L	100	130	3/21/2016 15:02
STRONTIUM	**32000**		**100**	**UG/L**	100	31	3/18/2016 14:53
TITANIUM	ND		2000	UG/L	100	1400	3/18/2016 14:53
THALLIUM	ND		20	UG/L	100	1.4	3/18/2016 14:53
URANIUM	ND		10	UG/L	100	2.7	3/18/2016 14:53
VANADIUM	ND		100	UG/L	100	58	3/18/2016 14:53
ZINC	ND		2000	UG/L	100	910	3/18/2016 14:53
ZIRCONIUM	ND		5	UG/L	10	5	3/22/2016 14:43
MERCURY			**SW7470**		Prep Date: **3/14/2016**		PrepBy: **NAQ**
MERCURY	ND		0.2	UG/L	1	0.06	3/15/2016 14:50
ORGANIC CARBON			**EPA415.1**		Prep Date: **3/17/2016**		PrepBy: **SDW**
DISSOLVED ORGANIC CARBON	ND		1	MG/L	1	0.3	3/17/2016 14:40

Client:	AMEC Foster Wheeler	**Date:**	*22-Mar-16*
Project:	1655500023 PVU	**Work Order:**	1603232
Sample ID:	PVUBIF16031002	**Lab ID:**	1603232-7
Legal Location:		**Matrix:**	WATER
Collection Date:	3/10/2016 15:00	**Percent Moisture:**	

Analyses	Result	Qual	Report Limit	Units	Dilution Factor	MDL	Date Analyzed

Explanation of Qualifiers

Radiochemistry:

U or ND - Result is less than the sample specific MDC.

Y1 - Chemical Yield is in control at 100-110%. Quantitative yield is assumed.

Y2 - Chemical Yield outside default limits.

W - DER is greater than Warning Limit of 1.42

* - Aliquot Basis is 'As Received' while the Report Basis is 'Dry Weight'.
# - Aliquot Basis is 'Dry Weight' while the Report Basis is 'As Received'.

G - Sample density differs by more than 15% of LCS density.

D - DER is greater than Control Limit

M - Requested MDC not met.

LT - Result is less than requested MDC but greater than achieved MDC.

M3 - The requested MDC was not met, but the reported activity is greater than the reported MDC.

L - LCS Recovery below lower control limit.

H - LCS Recovery above upper control limit.

P - LCS, Matrix Spike Recovery within control limits.

N - Matrix Spike Recovery outside control limits

NC - Not Calculated for duplicate results less than 5 times MDC

B - Analyte concentration greater than MDC.

B3 - Analyte concentration greater than MDC but less than Requested MDC.

Inorganics:

B - Result is less than the requested reporting limit but greater than the instrument method detection limit (MDL).

U or ND - Indicates that the compound was analyzed for but not detected.

E - The reported value is estimated because of the presence of interference. An explanatory note may be included in the narrative.

M - Duplicate injection precision was not met.

N - Spiked sample recovery not within control limits. A post spike is analyzed for all ICP analyses when the matrix spike and or spike duplicate fail and the native sample concentration is less than four times the spike added concentration.

Z - Spiked recovery not within control limits. An explanatory note may be included in the narrative.

* - Duplicate analysis (relative percent difference) not within control limits.

S - SAR value is estimated as one or more analytes used in the calculation were not detected above the detection limit.

Organics:

U or ND - Indicates that the compound was analyzed for but not detected.

B - Analyte is detected in the associated method blank as well as in the sample. It indicates probable blank contamination and warns the data user.

E - Analyte concentration exceeds the upper level of the calibration range.

J - Estimated value. The result is less than the reporting limit but greater than the instrument method detection limit (MDL).

A - A tentatively identified compound is a suspected aldol-condensation product.

X - The analyte was diluted below an accurate quantitation level.

* - The spike recovery is equal to or outside the control criteria used.

+ - The relative percent difference (RPD) equals or exceeds the control criteria.

G - A pattern resembling gasoline was detected in this sample.

D - A pattern resembling diesel was detected in this sample.

M - A pattern resembling motor oil was detected in this sample.

C - A pattern resembling crude oil was detected in this sample.

4 - A pattern resembling JP-4 was detected in this sample.

5 - A pattern resembling JP-5 was detected in this sample.

H - Indicates that the fuel pattern was in the heavier end of the retention time window for the analyte of interest.

L - Indicates that the fuel pattern was in the lighter end of the retention time window for the analyte of interest.

Z - This flag indicates that a significant fraction of the reported result did not resemble the patterns of any of the following petroleum hydrocarbon products:
- gasoline
- JP-8
- diesel
- mineral spirits
- motor oil
- Stoddard solvent
- bunker C

Batch ID: **HC160317-9-1** Instrument ID **MEE-1** Method: **RSK175**

LCS Sample ID: **HC160317-9** Units: **UG/L** Analysis Date: **3/17/2016 13:00**

Client ID: Run ID: **HC160317-9AA** Prep Date: **3/17/2016** DF: **1**

Analyte	Result	ReportLimit	SPK Val	SPK Ref Value	%REC	Control Limit	Decision Level	RPD Ref	RPD	RPD Limit	Qual
METHANE	145	1	142		102	80-120				25	

LCSD Sample ID: **HC160317-9** Units: **UG/L** Analysis Date: **3/17/2016 13:46**

Client ID: Run ID: **HC160317-9AA** Prep Date: **3/17/2016** DF: **1**

Analyte	Result	ReportLimit	SPK Val	SPK Ref Value	%REC	Control Limit	Decision Level	RPD Ref	RPD	RPD Limit	Qual
METHANE	154	1	142		108	80-120		145	6	25	

MB Sample ID: **HC160317-9** Units: **UG/L** Analysis Date: **3/17/2016 13:03**

Client ID: Run ID: **HC160317-9AA** Prep Date: **3/17/2016** DF: **1**

Analyte	Result	ReportLimit	SPK Val	SPK Ref Value	%REC	Control Limit	Decision Level	RPD Ref	RPD	RPD Limit	Qual
METHANE	ND	1									

QC BATCH REPORT

Batch ID: **HC160317-9-3** Instrument ID **MEE-1** Method: **RSK175**

DUP Sample ID: **1603232-5** Units: **UG/L** Analysis Date: **3/17/2016 13:17**
Client ID: **Trip Blank** Run ID: **HC160317-9AA** Prep Date: **3/17/2016** DF: **1**

Analyte	Result	ReportLimit	SPK Val	SPK Ref Value	%REC	Control Limit	Decision Level	RPD Ref	RPD	RPD Limit	Qual
METHANE	ND	1							1	25	

LCS Sample ID: **HC160317-9** Units: **UG/L** Analysis Date: **3/17/2016 13:00**
Client ID: Run ID: **HC160317-9AA** Prep Date: **3/17/2016** DF: **1**

Analyte	Result	ReportLimit	SPK Val	SPK Ref Value	%REC	Control Limit	Decision Level	RPD Ref	RPD	RPD Limit	Qual
METHANE	145	1	142		102	80-120				25	

LCSD Sample ID: **HC160317-9** Units: **UG/L** Analysis Date: **3/17/2016 13:46**
Client ID: Run ID: **HC160317-9AA** Prep Date: **3/17/2016** DF: **1**

Analyte	Result	ReportLimit	SPK Val	SPK Ref Value	%REC	Control Limit	Decision Level	RPD Ref	RPD	RPD Limit	Qual
METHANE	154	1	142		108	80-120		145	6	25	

MB Sample ID: **HC160317-9** Units: **UG/L** Analysis Date: **3/17/2016 13:03**
Client ID: Run ID: **HC160317-9AA** Prep Date: **3/17/2016** DF: **1**

Analyte	Result	ReportLimit	SPK Val	SPK Ref Value	%REC	Control Limit	Decision Level	RPD Ref	RPD	RPD Limit	Qual
METHANE	ND	1									

The following samples were analyzed in this batch: 1603232-3 1603232-4 1603232-5

QC BATCH REPORT

Batch ID: **MO160317-1-1** Instrument ID **TOC1** Method: **EPA415.1**

LCS Sample ID: **MO160317-1** Units: **MG/L** Analysis Date: **3/17/2016 13:02**
Client ID: Run ID: **MO160317-1A1** Prep Date: **3/17/2016** DF: **1**

Analyte	Result	ReportLimit	SPK Val	SPK Ref Value	%REC	Control Limit	Decision Level	RPD Ref	RPD	RPD Limit	Qual
DISSOLVED ORGANIC CARBON	15.4	1	15		103	85-115				20	

LCSD Sample ID: **MO160317-1** Units: **MG/L** Analysis Date: **3/17/2016 13:13**
Client ID: Run ID: **MO160317-1A1** Prep Date: **3/17/2016** DF: **1**

Analyte	Result	ReportLimit	SPK Val	SPK Ref Value	%REC	Control Limit	Decision Level	RPD Ref	RPD	RPD Limit	Qual
DISSOLVED ORGANIC CARBON	15.4	1	15		102	85-115		15.4	0	20	

MB Sample ID: **MO160317-1** Units: **MG/L** Analysis Date: **3/17/2016 12:43**
Client ID: Run ID: **MO160317-1A1** Prep Date: **3/17/2016** DF: **1**

Analyte	Result	ReportLimit	SPK Val	SPK Ref Value	%REC	Control Limit	Decision Level	RPD Ref	RPD	RPD Limit	Qual
DISSOLVED ORGANIC CARBON	ND	1									

The following samples were analyzed in this batch: 1603232-6 1603232-7

QC BATCH REPORT

Batch ID: **MO160317-1-2** Instrument ID **TOC1** Method: **EPA415.1**

LCS Sample ID: **MO160317-1** Units: **MG/L** Analysis Date: **3/17/2016 13:02**
Client ID: Run ID: **MO160317-2A1** Prep Date: **3/17/2016** DF: **1**

Analyte	Result	ReportLimit	SPK Val	SPK Ref Value	%REC	Control Limit	Decision Level	RPD Ref	RPD	RPD Limit	Qual
TOTAL ORGANIC CARBON	15.4	1	15		103	85-115				20	

LCSD Sample ID: **MO160317-1** Units: **MG/L** Analysis Date: **3/17/2016 13:13**
Client ID: Run ID: **MO160317-2A1** Prep Date: **3/17/2016** DF: **1**

Analyte	Result	ReportLimit	SPK Val	SPK Ref Value	%REC	Control Limit	Decision Level	RPD Ref	RPD	RPD Limit	Qual
TOTAL ORGANIC CARBON	15.4	1	15		102	85-115		15.4	0	20	

MB Sample ID: **MO160317-1** Units: **MG/L** Analysis Date: **3/17/2016 12:43**
Client ID: Run ID: **MO160317-2A1** Prep Date: **3/17/2016** DF: **1**

Analyte	Result	ReportLimit	SPK Val	SPK Ref Value	%REC	Control Limit	Decision Level	RPD Ref	RPD	RPD Limit	Qual
TOTAL ORGANIC CARBON	ND	1									

The following samples were analyzed in this batch: 1603232-3 1603232-4

QC BATCH REPORT

Batch ID: **HG160314-1-1** Instrument ID **CETAC7500** Method: **SW7470**

LCS Sample ID: **HG160314-1** Units: **UG/L** Analysis Date: **3/15/2016 12:43**
Client ID: Run ID: **HG160315-1A10** Prep Date: **3/14/2016** DF: **1**

Analyte	Result	ReportLimit	SPK Val	SPK Ref Value	%REC	Control Limit	Decision Level	RPD Ref	RPD	RPD Limit	Qual
MERCURY	1.1	0.2	1		110	80-120				20	

MB Sample ID: **HG160314-1** Units: **UG/L** Analysis Date: **3/15/2016 12:39**
Client ID: Run ID: **HG160315-1A10** Prep Date: **3/14/2016** DF: **1**

Analyte	Result	ReportLimit	SPK Val	SPK Ref Value	%REC	Control Limit	Decision Level	RPD Ref	RPD	RPD Limit	Qual
MERCURY	ND	0.2									

The following samples were analyzed in this batch:

1603232-3	1603232-4	1603232-5
1603232-6	1603232-7	

QC BATCH REPORT

Batch ID: **IP160315-2-5** Instrument ID **ICPMS2** Method: **SW6020**

LCS Sample ID: **IM160315-2** Units: **UG/L** Analysis Date: **3/18/2016 13:48**

Client ID: Run ID: **IM160318-12A6** Prep Date: **3/15/2016** DF: **10**

Analyte	Result	ReportLimit	SPK Val	SPK Ref Value	%REC	Control Limit	Decision Level	RPD Ref	RPD	RPD Limit	Qual
ALUMINUM	5110	50	5000		102	80-120				20	
ANTIMONY	30.6	0.3	30		102	80-120				20	
ARSENIC	107	2	100		107	80-120				20	
BARIUM	110	1	100		110	80-120				20	
BERYLLIUM	53.9	0.5	50		108	80-120				20	
BORON	1030	50	1000		103	80-120				20	
CADMIUM	30.1	0.3	30		100	80-120				20	
CALCIUM	10300	1000	10000		103	80-120				20	
CHROMIUM	499	10	500		100	80-120				20	
COBALT	101	1	100		101	80-120				20	
COPPER	1050	10	1000		105	80-120				20	
IRON	5120	100	5000		102	80-120				20	
LEAD	50.2	0.5	50		100	80-120				20	
LITHIUM	1100	10	1000		110	80-120				20	
MAGNESIUM	9940	100	10000		99	80-120				20	
MANGANESE	100	2	100		100	80-120				20	
MOLYBDENUM	100	1	100		100	80-120				20	
NICKEL	506	5	500		101	80-120				20	
POTASSIUM	5000	1000	5000		100	80-120				20	
SELENIUM	109	1	100		109	80-120				20	
SILVER	10.5	0.1	10		105	80-120				20	
STRONTIUM	99.8	1	100		100	80-120				20	
THALLIUM	2.23	0.2	2		112	80-120				20	
TIN	533	5	500		107	80-120				20	
TITANIUM	2050	20	2000		102	80-120				20	
URANIUM	11.2	0.1	10		111	80-120				20	
VANADIUM	103	1	100		103	80-120				20	
ZINC	2050	20	2000		102	80-120				20	

QC BATCH REPORT

Batch ID: **IP160315-2-5** Instrument ID **ICPMS2** Method: **SW6020**

MB Sample ID: **IP160315-2** Units: **UG/L** Analysis Date: **3/18/2016 13:45**

Client ID: Run ID: **IM160318-12A6** Prep Date: **3/15/2016** DF: **10**

Analyte	Result	ReportLimit	SPK Val	SPK Ref Value	%REC	Control Limit	Decision Level	RPD Ref	RPD	RPD Limit	Qual
ALUMINUM	35	50									J
ANTIMONY	ND	0.3									
ARSENIC	ND	2									
BARIUM	ND	1									
BERYLLIUM	ND	0.5									
BORON	ND	50									
CADMIUM	ND	0.3									
CALCIUM	ND	1000									
CHROMIUM	ND	10									
COBALT	ND	1									
COPPER	-1.6	10									J
IRON	ND	100									
LEAD	ND	0.5									
LITHIUM	ND	10									
MAGNESIUM	ND	100									
MANGANESE	ND	2									
MOLYBDENUM	ND	1									
NICKEL	ND	5									
POTASSIUM	ND	1000									
SELENIUM	ND	1									
SILVER	ND	0.1									
STRONTIUM	ND	1									
THALLIUM	ND	0.2									
TIN	ND	5									
TITANIUM	ND	20									
URANIUM	ND	0.1									
VANADIUM	ND	1									
ZINC	ND	20									

The following samples were analyzed in this batch:

1603232-1	1603232-2	1603232-3
1603232-4	1603232-5	1603232-6
1603232-7		

QC BATCH REPORT

Batch ID: **IP160315-2-5** Instrument ID **ICPMS2** Method: **SW6020**

LCS Sample ID: **IM160315-2** Units: **UG/L** Analysis Date: **3/21/2016 14:04**
Client ID: Run ID: **IM160321-11A3** Prep Date: **3/15/2016** DF: **10**

Analyte	Result	ReportLimit	SPK Val	SPK Ref Value	%REC	Control Limit	Decision Level	RPD Ref	RPD	RPD Limit	Qual
SODIUM	10600	1000	10000		106	80-120				20	

MB Sample ID: **IP160315-2** Units: **UG/L** Analysis Date: **3/21/2016 14:01**
Client ID: Run ID: **IM160321-11A3** Prep Date: **3/15/2016** DF: **10**

Analyte	Result	ReportLimit	SPK Val	SPK Ref Value	%REC	Control Limit	Decision Level	RPD Ref	RPD	RPD Limit	Qual
SODIUM	ND	1000									

The following samples were analyzed in this batch:

1603232-1	1603232-2	1603232-3
1603232-4	1603232-5	1603232-6
1603232-7		

QC BATCH REPORT

Batch ID: **IP160315-2-5** Instrument ID **ICPMS2** Method: **SW6020**

LCS Sample ID: **IM160315-2** Units: **UG/L** Analysis Date: **3/22/2016 14:06**
Client ID: Run ID: **IM160322-10A4** Prep Date: **3/15/2016** DF: **10**

Analyte	Result	ReportLimit	SPK Val	SPK Ref Value	%REC	Control Limit	Decision Level	RPD Ref	RPD	RPD Limit	Qual
ZIRCONIUM	10.7	0.5	10		107	80-120				20	

MB Sample ID: **IP160315-2** Units: **UG/L** Analysis Date: **3/22/2016 14:05**
Client ID: Run ID: **IM160322-10A4** Prep Date: **3/15/2016** DF: **10**

Analyte	Result	ReportLimit	SPK Val	SPK Ref Value	%REC	Control Limit	Decision Level	RPD Ref	RPD	RPD Limit	Qual
ZIRCONIUM	ND	0.5									

The following samples were analyzed in this batch:

1603232-1	1603232-2	1603232-3
1603232-4	1603232-5	1603232-6
1603232-7		

QC BATCH REPORT

Batch ID: **IP160315-2-7** Instrument ID **ICP6500** Method: **SW6010**

LCS Sample ID: **IP160315-2** Units: **UG/L** Analysis Date: **3/16/2016 12:04**
Client ID: Run ID: **IP160316-1A10** Prep Date: **3/15/2016** DF: **1**

Analyte	Result	ReportLimit	SPK Val	SPK Ref Value	%REC	Control Limit	Decision Level	RPD Ref	RPD	RPD Limit	Qual
BISMUTH	511	20	500		102	80-120				20	
PHOSPHORUS	10900	200	10000		109	80-120				20	
SILICON	1040	50	1000		104	80-120				20	

MB Sample ID: **IP160315-2** Units: **UG/L** Analysis Date: **3/16/2016 11:55**
Client ID: Run ID: **IP160316-1A10** Prep Date: **3/15/2016** DF: **1**

Analyte	Result	ReportLimit	SPK Val	SPK Ref Value	%REC	Control Limit	Decision Level	RPD Ref	RPD	RPD Limit	Qual
BISMUTH	ND	20									
PHOSPHORUS	80	200									J
SILICON	ND	50									

The following samples were analyzed in this batch:

1603232-3	1603232-4	1603232-5
1603232-6	1603232-7	

Batch ID: **AK160317-1-1** Instrument ID **Balance** Method: **EPA310.1**

DUP Sample ID: **1603232-1** Units: **MG/L** Analysis Date: **3/17/2016**
Client ID: **PVUEVAP16031001** Run ID: **AK160317-1A1** Prep Date: **3/17/2016** DF: **1**

Analyte	Result	ReportLimit	SPK Val	SPK Ref Value	%REC	Control Limit	Decision Level	RPD Ref	RPD	RPD Limit	Qual
BICARBONATE AS CaCO3	95.9	20						91		15	
CARBONATE AS CaCO3	ND	20						20		15	
TOTAL ALKALINITY AS CaCO3	95.9	20						91		15	

LCS Sample ID: **AK160317-1** Units: **MG/L** Analysis Date: **3/17/2016**
Client ID: Run ID: **AK160317-1A1** Prep Date: **3/17/2016** DF: **1**

Analyte	Result	ReportLimit	SPK Val	SPK Ref Value	%REC	Control Limit	Decision Level	RPD Ref	RPD	RPD Limit	Qual
TOTAL ALKALINITY AS CaCO3	101	5	100		101	85-115				15	

MB Sample ID: **AK160317-1** Units: **MG/L** Analysis Date: **3/17/2016**
Client ID: Run ID: **AK160317-1A1** Prep Date: **3/17/2016** DF: **1**

Analyte	Result	ReportLimit	SPK Val	SPK Ref Value	%REC	Control Limit	Decision Level	RPD Ref	RPD	RPD Limit	Qual
BICARBONATE AS CaCO3	ND	5									
CARBONATE AS CaCO3	ND	5									
TOTAL ALKALINITY AS CaCO3	ND	5									

The following samples were analyzed in this batch: 1603232-1 1603232-2 1603232-3 1603232-4

QC BATCH REPORT

Batch ID: **IC160314-1-1** Instrument ID **IC-2** Method: **EPA300.0**

LCS Sample ID: **IC160314-1** Units: **MG/L** Analysis Date: **3/14/2016 09:29**
Client ID: Run ID: **ic160314-1A4** Prep Date: **3/14/2016** DF: **1**

Analyte	Result	ReportLimit	SPK Val	SPK Ref Value	%REC	Control Limit	Decision Level	RPD Ref	RPD	RPD Limit	Qual
FLUORIDE	1.91	0.1	2		95	90-110				15	
CHLORIDE	5.07	0.2	5		101	90-110				15	
NITRITE AS N	2.04	0.1	2		102	90-110				15	
BROMIDE	4.87	0.2	5		97	90-110				15	
NITRATE AS N	5.1	0.2	5		102	90-110				15	
ORTHOPHOSPHATE AS P	2	0.5	2		100	90-110				15	
SULFATE	20.8	1	20		104	90-110				15	

LCSD Sample ID: **IC160314-1** Units: **MG/L** Analysis Date: **3/14/2016 09:44**
Client ID: Run ID: **ic160314-1A4** Prep Date: **3/14/2016** DF: **1**

Analyte	Result	ReportLimit	SPK Val	SPK Ref Value	%REC	Control Limit	Decision Level	RPD Ref	RPD	RPD Limit	Qual
FLUORIDE	1.86	0.1	2		93	90-110		1.91	3	15	
CHLORIDE	4.89	0.2	5		98	90-110		5.07	4	15	
NITRITE AS N	1.98	0.1	2		99	90-110		2.04	3	15	
BROMIDE	4.7	0.2	5		94	90-110		4.87	3	15	
NITRATE AS N	4.94	0.2	5		99	90-110		5.1	3	15	
ORTHOPHOSPHATE AS P	1.88	0.5	2		94	90-110		2	7	15	
SULFATE	20.1	1	20		101	90-110		20.8	3	15	

MB Sample ID: **IC160314-1** Units: **MG/L** Analysis Date: **3/14/2016 09:14**
Client ID: Run ID: **ic160314-1A4** Prep Date: **3/14/2016** DF: **1**

Analyte	Result	ReportLimit	SPK Val	SPK Ref Value	%REC	Control Limit	Decision Level	RPD Ref	RPD	RPD Limit	Qual
FLUORIDE	ND	0.1									
CHLORIDE	ND	0.2									
NITRITE AS N	ND	0.1									
BROMIDE	ND	0.2									
NITRATE AS N	ND	0.2									
ORTHOPHOSPHATE AS P	ND	0.5									
SULFATE	ND	1									

The following samples were analyzed in this batch:

1603232-1	1603232-2	1603232-3
1603232-4	1603232-5	

QC BATCH REPORT

Batch ID: **NH160314-1-1** Instrument ID **GALLERY** Method: **EPA350.1**

LCS Sample ID: **NH160314-1** Units: **MG/L** Analysis Date: **3/14/2016 11:36**
Client ID: Run ID: **NH160314-1A2** Prep Date: **3/14/2016** DF: **1**

Analyte	Result	ReportLimit	SPK Val	SPK Ref Value	%REC	Control Limit	Decision Level	RPD Ref	RPD	RPD Limit	Qual
AMMONIA AS N	1.02	0.1	1		102	90-110				20	

MB Sample ID: **NH160314-1** Units: **MG/L** Analysis Date: **3/14/2016 11:34**
Client ID: Run ID: **NH160314-1A2** Prep Date: **3/14/2016** DF: **1**

Analyte	Result	ReportLimit	SPK Val	SPK Ref Value	%REC	Control Limit	Decision Level	RPD Ref	RPD	RPD Limit	Qual
AMMONIA AS N	ND	0.1									

The following samples were analyzed in this batch: 1603232-4

QC BATCH REPORT

Batch ID: **PH160314-1-1** Instrument ID **pH-1** Method: **EPA150.1**

DUP Sample ID: **1603232-1** Units: **pH** Analysis Date: **3/14/2016**

Client ID: **PVUEVAP16031001** Run ID: **PH160314-1A1** Prep Date: **3/14/2016** DF: **1**

Analyte	Result	ReportLimit	SPK Val	SPK Ref Value	%REC	Control Limit	Decision Level	RPD Ref	RPD	RPD Limit	Qual
PH	7.18	0.1						7.18		0.2	

The following samples were analyzed in this batch: 1603232-1 1603232-2 1603232-3 1603232-4

QC BATCH REPORT

Batch ID: **SC160314-1-1** Instrument ID **pH-2** Method: **EPA120.1**

DUP Sample ID: **1603232-1** Units: **umhos/cm** Analysis Date: **3/14/2016**

Client ID: **PVUEVAP16031001** Run ID: **SC160314-1A1** Prep Date: **3/14/2016** DF: **1**

Analyte	Result	ReportLimit	SPK Val	SPK Ref Value	%REC	Control Limit	Decision Level	RPD Ref	RPD	RPD Limit	Qual
SPECIFIC CONDUCTIVITY	242000	1						242000	0	10	

The following samples were analyzed in this batch: 1603232-1 1603232-2 1603232-3 1603232-4

QC BATCH REPORT

Batch ID: **TD160316-2-2** Instrument ID **Balance** Method: **EPA160.1**

DUP Sample ID: **1603232-1** Units: **MG/L** Analysis Date: **3/17/2016**
Client ID: **PVUEVAP16031001** Run ID: **TD160316-1A1** Prep Date: **3/16/2016** DF: **1**

Analyte	Result	ReportLimit	SPK Val	SPK Ref Value	%REC	Control Limit	Decision Level	RPD Ref	RPD	RPD Limit	Qual
TOTAL DISSOLVED SOLIDS	650000	2000						650000	1	5	

LCS Sample ID: **TD160316-2** Units: **MG/L** Analysis Date: **3/17/2016**
Client ID: Run ID: **TD160316-1A1** Prep Date: **3/16/2016** DF: **1**

Analyte	Result	ReportLimit	SPK Val	SPK Ref Value	%REC	Control Limit	Decision Level	RPD Ref	RPD	RPD Limit	Qual
TOTAL DISSOLVED SOLIDS	386	20	400		97	85-115				5	

LCSD Sample ID: **TD160316-2** Units: **MG/L** Analysis Date: **3/17/2016**
Client ID: Run ID: **TD160316-1A1** Prep Date: **3/16/2016** DF: **1**

Analyte	Result	ReportLimit	SPK Val	SPK Ref Value	%REC	Control Limit	Decision Level	RPD Ref	RPD	RPD Limit	Qual
TOTAL DISSOLVED SOLIDS	403	20	400		101	85-115		386	4	5	

MB Sample ID: **TD160316-2** Units: **MG/L** Analysis Date: **3/17/2016**
Client ID: Run ID: **TD160316-1A1** Prep Date: **3/16/2016** DF: **1**

Analyte	Result	ReportLimit	SPK Val	SPK Ref Value	%REC	Control Limit	Decision Level	RPD Ref	RPD	RPD Limit	Qual
TOTAL DISSOLVED SOLIDS	ND	20									

The following samples were analyzed in this batch: 1603232-1 1603232-2 1603232-3 1603232-4

QC BATCH REPORT

Batch ID: **TP160322-1-2** Instrument ID **Spec** Method: **EPA365.2**

LCS Sample ID: **TP160322-1** Units: **MG/L** Analysis Date: **3/22/2016**
Client ID: Run ID: **TP160322-1A4** Prep Date: **3/22/2016** DF: **1**

Analyte	Result	ReportLimit	SPK Val	SPK Ref Value	%REC	Control Limit	Decision Level	RPD Ref	RPD	RPD Limit	Qual
TOTAL PHOSPHORUS	0.494	0.05	0.5		99	80-120				20	

MB Sample ID: **TP160322-1** Units: **MG/L** Analysis Date: **3/22/2016**
Client ID: Run ID: **TP160322-1A4** Prep Date: **3/22/2016** DF: **1**

Analyte	Result	ReportLimit	SPK Val	SPK Ref Value	%REC	Control Limit	Decision Level	RPD Ref	RPD	RPD Limit	Qual
TOTAL PHOSPHORUS	ND	0.05									

The following samples were analyzed in this batch: 1603232-3 1603232-4

QC BATCH REPORT

Batch ID: **TS160314-1-3** Instrument ID **Balance** Method: **EPA160.2**

LCS Sample ID: **TS160314-1** Units: **MG/L** Analysis Date: **3/15/2016**
Client ID: Run ID: **TS160314-1** Prep Date: **3/14/2016** DF: **1**

Analyte	Result	ReportLimit	SPK Val	SPK Ref Value	%REC	Control Limit	Decision Level	RPD Ref	RPD	RPD Limit	Qual
TOTAL SUSPENDED SOLIDS	503	20	528		95	85-115				5	

LCSD Sample ID: **TS160314-1** Units: **MG/L** Analysis Date: **3/15/2016**
Client ID: Run ID: **TS160314-1** Prep Date: **3/14/2016** DF: **1**

Analyte	Result	ReportLimit	SPK Val	SPK Ref Value	%REC	Control Limit	Decision Level	RPD Ref	RPD	RPD Limit	Qual
TOTAL SUSPENDED SOLIDS	504	20	522		97	85-115		503	0	5	

MB Sample ID: **TS160314-1** Units: **MG/L** Analysis Date: **3/15/2016**
Client ID: Run ID: **TS160314-1** Prep Date: **3/14/2016** DF: **1**

Analyte	Result	ReportLimit	SPK Val	SPK Ref Value	%REC	Control Limit	Decision Level	RPD Ref	RPD	RPD Limit	Qual
TOTAL SUSPENDED SOLIDS	ND	4									

The following samples were analyzed in this batch: 1603232-3 1603232-4

15-Mar-2016

Jeff Kujawa
ALS Environmental
225 Commerce Dr
Fort Collins, CO 80524

Re: **1603232** Work Order: **1603682**

Dear Jeff,

ALS Environmental received 4 samples on 12-Mar-2016 for the analyses presented in the following report.

The analytical data provided relates directly to the samples received by ALS Environmental and for only the analyses requested.

Sample results are compliant with NELAP standard requirements and QC results achieved laboratory specifications. Any exceptions are noted in the Case Narrative, or noted with qualifiers in the report or QC batch information. Should this laboratory report need to be reproduced, it should be reproduced in full unless written approval has been obtained from ALS Environmental. Samples will be disposed in 30 days unless storage arrangements are made.

The total number of pages in this report is 13.

If you have any questions regarding this report, please feel free to contact me.

Sincerely,

Electronically approved by: Tom Beamish

Tom Beamish
Client Services Coordinator

Certificate No: MN 532786

ADDRESS 3352 128th Avenue Holland, Michigan 49424-9263 | PHONE (616) 399-6070 | FAX (616) 399-6185
ALS GROUP USA, CORP Part of the ALS Laboratory Group A Campbell Brothers Limited Company

ALS Group USA, Corp

Date: 15-Mar-16

Client: ALS Environmental
Project: 1603232
Work Order: **1603682**

Work Order Sample Summary

Lab Samp ID	Client Sample ID	Matrix	Tag Number	Collection Date	Date Received	Hold
1603682-01	PVUEVAP16031001	Water		3/10/2016 11:35	3/12/2016 14:20	☐
1603682-02	PVUEVAP16031002	Water		3/10/2016 11:40	3/12/2016 14:20	☐
1603682-03	PVUBIF16031001	Water		3/10/2016 14:40	3/12/2016 14:20	☐
1603682-04	PVUBIF16031002	Water		3/10/2016 15:00	3/12/2016 14:20	☐
1603682-04	PVUBIF16031002	Water		3/10/2016 15:00	3/12/2016 14:20	☐

ALS Group USA, Corp

Date: 15-Mar-16

Client: ALS Environmental
Project: 1603232
WorkOrder: **1603682**

QUALIFIERS, ACRONYMS, UNITS

Qualifier	Description
*	Value exceeds Regulatory Limit
a	Not accredited
B	Analyte detected in the associated Method Blank above the Reporting Limit
E	Value above quantitation range
H	Analyzed outside of Holding Time
J	Analyte is present at an estimated concentration between the MDL and Report Limit
n	Not offered for accreditation
ND	Not Detected at the Reporting Limit
O	Sample amount is > 4 times amount spiked
P	Dual Column results percent difference > 40%
R	RPD above laboratory control limit
S	Spike Recovery outside laboratory control limits
U	Analyzed but not detected above the MDL
X	Analyte was detected in the Method Blank between the MDL and PQL, sample results may exhibit background or reagent contamination at the observed level.

Acronym	Description
DUP	Method Duplicate
LCS	Laboratory Control Sample
LCSD	Laboratory Control Sample Duplicate
LOD	Limit of Detection (see MDL)
LOQ	Limit of Quantitation (see PQL)
MBLK	Method Blank
MDL	Method Detection Limit
MS	Matrix Spike
MSD	Matrix Spike Duplicate
PQL	Practical Quantitation Limit
RPD	Relative Percent Difference
TDL	Target Detection Limit
TNTC	Too Numerous To Count
A	APHA Standard Methods
D	ASTM
E	EPA
SW	SW-846 Update III

Units Reported	Description
mg/L	Milligrams per Liter
none	

ALS Group USA, Corp

Date: 15-Mar-16

Client: ALS Environmental
Project: 1603232
Work Order: 1603682

Case Narrative

Sample Comments:

Batch R183353, Method PO4_365.1_W, Sample 1603682-03A: Sample had to be run and reported at a dilution due to matrix interference.

Batch R183353, Method PO4_365.1_W, Sample 1603682-04A: Sample had to be run and reported at a dilution due to matrix interference.

QC Comments:

Batch R183368, Method IC_300.0_WW, Sample 1603682-03A MS: The MS and/or MSD recovery was below the lower control limit. The corresponding result in the parent sample may be biased low for Nitrite.

ALS Group USA, Corp

Date: *15-Mar-16*

CLIENT: ALS Environmental
Project: 1603232

Work Order: 1603682

Lab ID: 1603682-01A
Collection Date: 3/10/2016 11:35:00 AM
Client Sample ID: PVUEVAP16031001
Matrix: WATER

Analyses	Result	Report Limit	MDL	Qual	Units	Dilution Factor	Date Analyzed
SPECIFIC GRAVITY			**D5057-90**				Analyst: **KF**
Specific Gravity	**1.17**		**0**		**none**	1	3/14/2016 12:58 PM

Lab ID: 1603682-02A
Collection Date: 3/10/2016 11:40:00 AM
Client Sample ID: PVUEVAP16031002
Matrix: WATER

Analyses	Result	Report Limit	MDL	Qual	Units	Dilution Factor	Date Analyzed
SPECIFIC GRAVITY			**D5057-90**				Analyst: **KF**
Specific Gravity	**1.18**		**0**		**none**	1	3/14/2016 12:58 PM

Lab ID: 1603682-03A
Collection Date: 3/10/2016 2:40:00 PM
Client Sample ID: PVUBIF16031001
Matrix: WATER

Analyses	Result	Report Limit	MDL	Qual	Units	Dilution Factor	Date Analyzed
ANIONS BY ION CHROMATOGRAPHY			**E300.0**				Analyst: **EE**
Nitrogen, Nitrate	ND	100	27		mg/L	1000	3/12/2016 05:53 PM
Nitrogen, Nitrite	ND	100	23		mg/L	1000	3/12/2016 05:53 PM
PHOSPHORUS, ORTHO-P (AS P)			**E365.1 R2.0**				Analyst: **JJG**
Phosphorus, Ortho-P (As P)	ND	0.25	0.040		mg/L	5	3/12/2016 03:56 PM
SPECIFIC GRAVITY			**D5057-90**				Analyst: **KF**
Specific Gravity	**1.17**		**0**		**none**	1	3/14/2016 12:58 PM

Lab ID: 1603682-03B
Collection Date: 3/10/2016 2:40:00 PM
Client Sample ID: PVUBIF16031001
Matrix: WATER

Analyses	Result	Report Limit	MDL	Qual	Units	Dilution Factor	Date Analyzed
NITROGEN, TOTAL KJELDAHL			**A4500-NH3 G-97**				Analyst: **JB**
Nitrogen, Total Kjeldahl	**6.0**	**1.0**	**0.34**		**mg/L**	1	3/15/2016 10:49 AM

Qualifiers:

ND - Not Detected at the Reporting Limit
J - Analyte detected below quantitation limits
B - Analyte detected in the associated Method Blank
* - Value exceeds Maximum Contaminant Level
S - Spike Recovery outside accepted recovery limits
P - Dual Column results RPD > 40%
E - Value above quantitation range
H - Analyzed outside of Hold Time

ALS Group USA, Corp

Date: *15-Mar-16*

CLIENT: ALS Environmental
Project: 1603232

Work Order: 1603682

Lab ID: 1603682-04A
Client Sample ID: PVUBIF16031002

Collection Date: 3/10/2016 3:00:00 PM
Matrix: WATER

Analyses	Result	Report Limit	MDL	Qual	Units	Dilution Factor	Date Analyzed
ANIONS BY ION CHROMATOGRAPHY			**E300.0**				Analyst: **EE**
Nitrogen, Nitrate	ND	100	27		mg/L	1000	3/12/2016 06:54 PM
Nitrogen, Nitrite	ND	100	23		mg/L	1000	3/12/2016 06:54 PM
PHOSPHORUS, ORTHO-P (AS P)			**E365.1 R2.0**				Analyst: **JJG**
Phosphorus, Ortho-P (As P)	**0.43**	**0.25**	**0.040**		**mg/L**	5	3/12/2016 03:56 PM
SPECIFIC GRAVITY			**D5057-90**				Analyst: **KF**
Specific Gravity	**1.17**		**0**		**none**	1	3/14/2016 12:58 PM

Lab ID: 1603682-04B
Client Sample ID: PVUBIF16031002

Collection Date: 3/10/2016 3:00:00 PM
Matrix: WATER

Analyses	Result	Report Limit	MDL	Qual	Units	Dilution Factor	Date Analyzed
NITROGEN, TOTAL KJELDAHL			**A4500-NH3 G-97**				Analyst: **JB**
Nitrogen, Total Kjeldahl	**4.5**	**1.0**	**0.34**		**mg/L**	1	3/15/2016 10:49 AM

Qualifiers:

ND - Not Detected at the Reporting Limit
J - Analyte detected below quantitation limits
B - Analyte detected in the associated Method Blank
* - Value exceeds Maximum Contaminant Level
S - Spike Recovery outside accepted recovery limits
P - Dual Column results RPD > 40%
E - Value above quantitation range
H - Analyzed outside of Hold Time

QC BATCH REPORT

Batch ID: **83508** Instrument ID **LACHAT** Method: **A4500-NH3 G-97**

MBLK Sample ID: **MBLK-83508-83508** Units: **mg/L** Analysis Date: **3/15/2016 10:49 AM**
Client ID: SeqNo: **3733881** Prep Date: **3/14/2016**

Analyte	Result	PQL	SPK Val	SPK Ref Value	%REC	Control Limit	RPD Ref Value	%RPD	RPD Limit	Qual
Nitrogen, Total Kjeldahl	ND	1.0								

LCS Sample ID: **LCS-83508-83508** Units: **mg/L** Analysis Date: **3/15/2016 10:49 AM**
Client ID: SeqNo: **3733882** Prep Date: **3/14/2016**

Analyte	Result	PQL	SPK Val	SPK Ref Value	%REC	Control Limit	RPD Ref Value	%RPD	RPD Limit	Qual
Nitrogen, Total Kjeldahl	9.345	1.0	10	0	93.4	90-110	0			

MS Sample ID: **1603510-01A MS** Units: **mg/L** Analysis Date: **3/15/2016 10:49 AM**
Client ID: SeqNo: **3733885** Prep Date: **3/14/2016**

Analyte	Result	PQL	SPK Val	SPK Ref Value	%REC	Control Limit	RPD Ref Value	%RPD	RPD Limit	Qual
Nitrogen, Total Kjeldahl	7.332	1.0	10	0.04602	72.9	75-125	0			S

MSD Sample ID: **1603510-01A MSD** Units: **mg/L** Analysis Date: **3/15/2016 10:49 AM**
Client ID: SeqNo: **3733886** Prep Date: **3/14/2016**

Analyte	Result	PQL	SPK Val	SPK Ref Value	%REC	Control Limit	RPD Ref Value	%RPD	RPD Limit	Qual
Nitrogen, Total Kjeldahl	7.622	1.0	10	0.04602	75.8	75-125	7.332	3.88	30	

LCS2 Sample ID: **LCS2-83508-83508**
Client ID:

Analyte	Result	PQL	SPK Val	SPK Ref Value	%REC	Control Limit	RPD Ref Value	%RPD	RPD Limit	Qual
Nitrogen, Total Kjeldahl	9.476	1.0	10	0	94.8	90-110	0			

The following samples were analyzed in this batch: 1603682-03B 1603682-04B

Note: See Qualifiers Page for a list of Qualifiers and their explanation.

Client: ALS Environmental
Work Order: 1603682
Project: 1603232

QC BATCH REPORT

Batch ID: **R183353** Instrument ID **LACHAT2** Method: **E365.1 R2.0**

MBLK Sample ID: **MBLK-R183353** Units: **mg/L** Analysis Date: **3/12/2016 03:56 PM**
Client ID: Run ID: **LACHAT2_160312A** SeqNo: **3731143** Prep Date: DF: **1**

Analyte	Result	PQL	SPK Val	SPK Ref Value	%REC	Control Limit	RPD Ref Value	%RPD	RPD Limit	Qual
Phosphorus, Ortho-P (As P)	ND	0.050								

LCS Sample ID: **LCS-R183353** Units: **mg/L** Analysis Date: **3/12/2016 03:56 PM**
Client ID: Run ID: **LACHAT2_160312A** SeqNo: **3731144** Prep Date: DF: **1**

Analyte	Result	PQL	SPK Val	SPK Ref Value	%REC	Control Limit	RPD Ref Value	%RPD	RPD Limit	Qual
Phosphorus, Ortho-P (As P)	1.06	0.050	1	0	106	90-110	0			

MS Sample ID: **1603682-03A MS** Units: **mg/L** Analysis Date: **3/12/2016 03:56 PM**
Client ID: **PVUBIF16031001** Run ID: **LACHAT2_160312A** SeqNo: **3731150** Prep Date: DF: **5**

Analyte	Result	PQL	SPK Val	SPK Ref Value	%REC	Control Limit	RPD Ref Value	%RPD	RPD Limit	Qual
Phosphorus, Ortho-P (As P)	0.9365	0.25	1	0.03285	90.4	90-110	0			

MSD Sample ID: **1603682-03A MSD** Units: **mg/L** Analysis Date: **3/12/2016 03:56 PM**
Client ID: **PVUBIF16031001** Run ID: **LACHAT2_160312A** SeqNo: **3731151** Prep Date: DF: **5**

Analyte	Result	PQL	SPK Val	SPK Ref Value	%REC	Control Limit	RPD Ref Value	%RPD	RPD Limit	Qual
Phosphorus, Ortho-P (As P)	0.942	0.25	1	0.03285	90.9	90-110	0.9365	0.586	20	

The following samples were analyzed in this batch: 1603682-03A 1603682-04A

Note: See Qualifiers Page for a list of Qualifiers and their explanation.

Client: ALS Environmental
Work Order: 1603682
Project: 1603232

QC BATCH REPORT

Batch ID: **R183368** Instrument ID **IC3** Method: **E300.0**

MBLK Sample ID: **CCB/MBLK-R183368** Units: **mg/L** Analysis Date: **3/12/2016 05:13 PM**
Client ID: Run ID: **IC3_160312A** SeqNo: **3731537** Prep Date: DF: **1**

Analyte	Result	PQL	SPK Val	SPK Ref Value	%REC	Control Limit	RPD Ref Value	%RPD	RPD Limit	Qual
Nitrogen, Nitrate	ND	0.10								
Nitrogen, Nitrite	ND	0.10								

LCS Sample ID: **LCS-R183368** Units: **mg/L** Analysis Date: **3/12/2016 05:33 PM**
Client ID: Run ID: **IC3_160312A** SeqNo: **3731538** Prep Date: DF: **1**

Analyte	Result	PQL	SPK Val	SPK Ref Value	%REC	Control Limit	RPD Ref Value	%RPD	RPD Limit	Qual
Nitrogen, Nitrate	1.971	0.10	2	0	98.6	90-110	0			
Nitrogen, Nitrite	2.002	0.10	2	0	100	90-110	0			

MS Sample ID: **1603682-03A MS** Units: **mg/L** Analysis Date: **3/12/2016 06:13 PM**
Client ID: **PVUBIF16031001** Run ID: **IC3_160312A** SeqNo: **3731540** Prep Date: DF: **1000**

Analyte	Result	PQL	SPK Val	SPK Ref Value	%REC	Control Limit	RPD Ref Value	%RPD	RPD Limit	Qual
Nitrogen, Nitrate	1944	100	2000	20.7	96.2	80-120	0			
Nitrogen, Nitrite	1546	100	2000	0	77.3	80-120	0			S

MSD Sample ID: **1603682-03A MSD** Units: **mg/L** Analysis Date: **3/12/2016 06:33 PM**
Client ID: **PVUBIF16031001** Run ID: **IC3_160312A** SeqNo: **3731541** Prep Date: DF: **1000**

Analyte	Result	PQL	SPK Val	SPK Ref Value	%REC	Control Limit	RPD Ref Value	%RPD	RPD Limit	Qual
Nitrogen, Nitrate	1939	100	2000	20.7	95.9	80-120	1944	0.273	20	
Nitrogen, Nitrite	1542	100	2000	0	77.1	80-120	1546	0.233	20	S

The following samples were analyzed in this batch: 1603682-03A 1603682-04A

Note: See Qualifiers Page for a list of Qualifiers and their explanation.

Client: ALS Environmental
Work Order: 1603682
Project: 1603232

QC BATCH REPORT

Batch ID: **R183442** Instrument ID **WETCHEM** Method: **D5057-90**

DUP Sample ID: **1603682-01A DUP** Units: **none** Analysis Date: **3/14/2016 12:58 PM**
Client ID: **PVUEVAP16031001** Run ID: **WETCHEM_160314N** SeqNo: **3733177** Prep Date: DF: **1**

Analyte	Result	PQL	SPK Val	SPK Ref Value	%REC	Control Limit	RPD Ref Value	%RPD	RPD Limit	Qual
Specific Gravity	1.171	0	0	0	0	0-0	1.171	0.0171	0	

The following samples were analyzed in this batch:

1603682-01A 1603682-02A 1603682-03A
1603682-04A

Note: See Qualifiers Page for a list of Qualifiers and their explanation.

ALS Environmental

225 Commerce Drive, Fort Collins, Colorado 80524
TF: (800) 443-1511 PH: (970) 490-1511 FX: (970) 490-1522

Chain-of-Custody

Turnaround time for samples received after 2 p.m. will be calculated beginning from the next business day.
Turnaround time for samples received Saturday will be calculated beginning from the next business day.

ALS WORKORDER # 1603582

TURNAROUND TIME	RUSH	SAMPLER	Hallie B. Simpson	PAGE	1 of 1
PROJECT NAME	PVU	SITE ID		DISPOSAL	BY LAB or RETURN
PROJECT No.	165550000023	EDD FORMAT	See Fort Collins Co.	PARAMETER/METHOD REQUEST FOR ANALYSIS	
		PURCHASE ORDER		A	TKN – SM4500
COMPANY NAME	Amec Foster Wheeler	BILL TO COMPANY		B	Specific Gravity – ASTMD5057-90
SEND REPORT TO	Hallie B. Simpson	INVOICE ATTN TO		C	Anions – Nitrate/Nitrite, O-phosphate
ADDRESS	PO Box 3781	ADDRESS		D	
CITY / STATE / ZIP	Telluride, CO 81435	CITY / STATE / ZIP		E	
PHONE	720-284-4093	PHONE		F	
FAX		FAX		G	
E-MAIL	hallie.simpson@amecfw.com	E-MAIL		H	
CC	greg.harmon@amecfw.com			I	
				J	

LAB ID	FIELD ID	MATRIX	SAMPLE DATE	SAMPLE TIME	# OF BOTTLES	PRESERVATIVE	QC	A	B	C	D	E	F	G	H	I	J	SEE NOTES SECTION
	PVUEVAP160310001	W	3/10/16	11:35	2	3			X									*
	PVUEVAP160310002	W	3/10/16	11:40	2	3			X									*
	PVUBIF160310001	W	3/10/16	14:40	2	3		X	X	X								*
	PVUBIF160310002	W	3/10/16	15:00	2	3		X	X	X								*

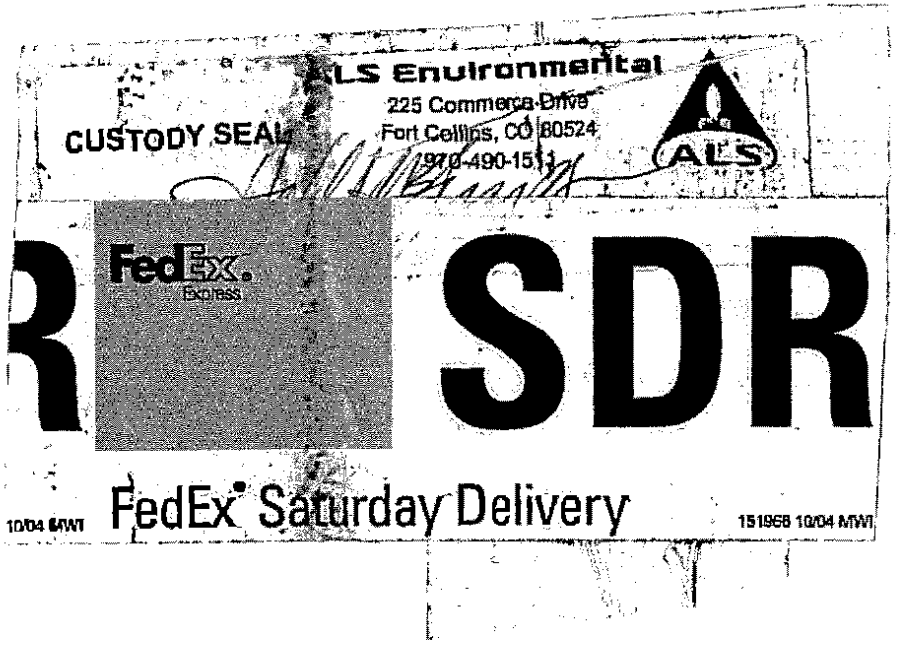
*Time Zone (Circle): EST CST MST PST Matrix: O = oil S = soil NS = non-soil solid W = water L = liquid E = extract F = filter

NOTES	REPORT LEVEL / QC REQUIRED
* Samples contain dissolved H_2S. Open bottles under hood are in well-ventilated area! 2.26	Summary (Standard QC)
	LEVEL II (Standard QC)
	LEVEL III (Std QC + forms)
	LEVEL IV (Std QC + forms + raw)

PRESERVATION KEY: 1-HCl 2-HNO3 3-H2SO4 4-NaOH 5-NaOH/ZnAcetate 6-NaHSO4 7-4°C 8-Other

Form 202r9

	SIGNATURE	PRINTED NAME	DATE	TIME
RELINQUISHED BY		Hallie B. Simpson	3/11/16	15:00
RECEIVED BY		JOE RIBAR	3/12/16	1420
RELINQUISHED BY				
RECEIVED BY				
RELINQUISHED BY				
RECEIVED BY				


ALS Environmental
225 Commerce Drive
Fort Collins, CO 80524
(970-490-1511
CUSTODY SEAL
ALS
FedEx Express
R
SDR
FedEx Saturday Delivery
10/04 MWI
151968 10/04 MWI

ALS Group USA, Corp

Sample Receipt Checklist

Client Name: **ALS - FORT COLLINS** Date/Time Received: **12-Mar-16 14:20**

Work Order: **1603682** Received by: **JR**

Checklist completed by Joseph Ribar (eSignature) 12-Mar-16 (Date) Reviewed by: Tom Bramish (eSignature) 14-Mar-16 (Date)

Matrices: water
Carrier name: FedEx

Shipping container/cooler in good condition?	Yes ☑	No ☐	Not Present ☐
Custody seals intact on shipping container/cooler?	Yes ☑	No ☐	Not Present ☐
Custody seals intact on sample bottles?	Yes ☐	No ☐	Not Present ☑
Chain of custody present?	Yes ☑	No ☐	
Chain of custody signed when relinquished and received?	Yes ☑	No ☐	
Chain of custody agrees with sample labels?	Yes ☑	No ☐	
Samples in proper container/bottle?	Yes ☑	No ☐	
Sample containers intact?	Yes ☑	No ☐	
Sufficient sample volume for indicated test?	Yes ☑	No ☐	
All samples received within holding time?	Yes ☑	No ☐	
Container/Temp Blank temperature in compliance?	Yes ☑	No ☐	
Sample(s) received on ice?	Yes ☑	No ☐	
Temperature(s)/Thermometer(s):	2.0c/2.0c	SR2	
Cooler(s)/Kit(s):			
Date/Time sample(s) sent to storage:	3/12/2016 3:43:39 PM		
Water - VOA vials have zero headspace?	Yes ☐	No ☐	No VOA vials submitted ☑
Water - pH acceptable upon receipt?	Yes ☑	No ☐	N/A ☐
pH adjusted?	Yes ☐	No ☑	N/A ☐
pH adjusted by:	-		

Login Notes:

Client Contacted: Date Contacted: Person Contacted:

Contacted By: Regarding:

Comments:

CorrectiveAction:

2655 Park Center Dr., Suite A
Simi Valley, CA 93065
T: +1 805 526 7161
F: +1 805 526 7270
www.alsglobal.com

LABORATORY REPORT

March 23, 2016

Amy Wolf
ALS Laboratory Group
225 Commerce Drive
Fort Collins, CO 80524

RE: PVU / 1655500023

Dear Amy:

Enclosed are the results of the samples submitted to our laboratory on March 12, 2016. For your reference, these analyses have been assigned our service request number P1601303.

All analyses were performed according to our laboratory's NELAP and DoD-ELAP-approved quality assurance program. The test results meet requirements of the current NELAP and DoD-ELAP standards, where applicable, and except as noted in the laboratory case narrative provided. For a specific list of NELAP and DoD-ELAP-accredited analytes, refer to the certifications section at www.alsglobal.com. Results are intended to be considered in their entirety and apply only to the samples analyzed and reported herein.

If you have any questions, please call me at (805) 526-7161.

Respectfully submitted,

ALS | Environmental

By Sue Anderson at 4:01 pm, Mar 23, 2016

For Samantha Henningsen
Project Manager

2655 Park Center Dr., Suite A
Simi Valley, CA 93065
T: +1 805 526 7161
F: +1 805 526 7270
www.alsglobal.com

Client: ALS Laboratory Group
Project: PVU / 1655500023

Service Request No: P1601303

CASE NARRATIVE

The samples were received intact under chain of custody on March 12, 2016 and were stored in accordance with the analytical method requirements. Please refer to the sample acceptance check form for additional information. The results reported herein are applicable only to the condition of the samples at the time of sample receipt.

Sulfur Analysis

The samples were analyzed for twenty sulfur compounds using a gas chromatograph equipped with a sulfur chemiluminescence detector (SCD). All compounds with the exception of hydrogen sulfide and carbonyl sulfide are quantitated against the initial calibration curve for methyl mercaptan. This method is not included on the laboratory's NELAP, DoD-ELAP, or AIHA-LAP scope of accreditation.

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ALS Environmental – Simi Valley

CERTIFICATIONS, ACCREDITATIONS, AND REGISTRATIONS

Agency	Web Site	Number
AIHA	http://www.aihaaccreditedlabs.org	101661
Arizona DHS	http://www.azdhs.gov/lab/license/env.htm	AZ0694
DoD ELAP	http://www.pjlabs.com/search-accredited-labs	L15-398
Florida DOH (NELAP)	http://www.doh.state.fl.us/lab/EnvLabCert/WaterCert.htm	E871020
Maine DHHS	http://www.maine.gov/dhhs/mecdc/environmental-health/water/dwp-services/labcert/labcert.htm	2014025
Minnesota DOH (NELAP)	http://www.health.state.mn.us/accreditation	977273
New Jersey DEP (NELAP)	http://www.nj.gov/dep/oqa/	CA009
New York DOH (NELAP)	http://www.wadsworth.org/labcert/elap/elap.html	11221
Oregon PHD (NELAP)	http://public.health.oregon.gov/LaboratoryServices/EnvironmentalLaboratoryAccreditation/Pages/index.aspx	4068-001
Pennsylvania DEP	http://www.depweb.state.pa.us/labs	68-03307 (Registration)
Texas CEQ (NELAP)	http://www.tceq.texas.gov/field/qa/env_lab_accreditation.html	T104704413-15-6
Utah DOH (NELAP)	http://www.health.utah.gov/lab/labimp/certification/index.html	CA016272015-5
Washington DOE	http://www.ecy.wa.gov/programs/eap/labs/lab-accreditation.html	C946

Analyses were performed according to our laboratory's NELAP and DoD-ELAP approved quality assurance program. A complete listing of specific NELAP and DoD-ELAP certified analytes can be found in the certifications section at www.alsglobal.com, or at the accreditation body's website.

Each of the certifications listed above have an explicit Scope of Accreditation that applies to specific matrices/methods/analytes; therefore, please contact the laboratory for information corresponding to a particular certification.

ALS ENVIRONMENTAL

DETAIL SUMMARY REPORT

Client: ALS Laboratory Group
Project ID: PVU / 1655500023
Service Request: P1601303

Date Received: 3/12/2016
Time Received: 10:45

Client Sample ID	Lab Code	Matrix	Date Collected	Time Collected	Sulfur Liq - Sulfur
PVUBIF16031001	P1601303-001	Water	3/10/2016	14:40	X
PVUBIF16031002	P1601303-002	Water	3/10/2016	15:00	X

ALS Environmental

225 Commerce Drive, Fort Collins, Colorado 80524
TF: (800) 443-1511 PH: (970) 490-1511 FX: (970) 490-1522

Chain-of-Custody

Turnaround time for samples received after 2 p.m. will be calculated beginning from the next business day.

Turnaround time for samples received Saturday will be calculated beginning from the next business day.

ALS WORKORDER # PI601303

TURNAROUND TIME	RUSH	SAMPLER	Hallie B. Simpson	PAGE	1 of 1
SITE ID				DISPOSAL	(BY LAB) or RETURN
EDD FORMAT	Excel, X-tab & flat file			PARAMETER/METHOD REQUEST FOR ANALYSIS	
PURCHASE ORDER	N/A			A	Reduced Sulfur Compounds – ASTM D5504-12
BILL TO COMPANY	Amec Foster Wheeler			B	
INVOICE ATTN TO	Carla Scheidlinger			C	
ADDRESS	9210 Sky Park Ct, Ste 200			D	
CITY / STATE / ZIP	San Diego, CA 92123			E	
PHONE	858-300-4311			F	
FAX				G	
E-MAIL	carla.scheidlinger@amecfw.com			H	
CC:	hallie.simpson@amecfw.com			I	
				J	

PROJECT NAME	PVU
PROJECT No.	16555000023
COMPANY NAME	Amec Foster Wheeler
SEND REPORT TO	Hallie Simpson
ADDRESS	PO Box 3781
CITY / STATE / ZIP	Telluride, CO 81435
PHONE	720 284 4043
FAX	
E-MAIL	hallie.simpson@amecfw.com
CC:	greg.harmer@amecfw.com

LAB ID	FIELD ID	MATRIX	SAMPLE DATE	SAMPLE TIME	# OF BOTTLES	PRESERVATIVE	QC	A	B	C	D	E	F	G	H	I	J	SEE NOTES SECTION
1	PVUBIF160310001	W	3/10/16	14:40	3	None		X										*
2	PVUBIF160310002	W	3/10/16	15:00	3	None		X										*

5 of 10

*Time Zone (Circle): EST CST MST PST Matrix: O = oil S = soil NS = non-soil solid W = water L = liquid E = extract F = filter

Wet ice 3°C

NOTES

* Samples contain dissolved H_2S. Open VOAs under hood or in well-ventilated area.

REPORT LEVEL / QC REQUIRED	
	Summary (Standard QC)
	LEVEL II (Standard QC)
	LEVEL III (Std QC + forms)
	LEVEL IV (Std QC + forms + raw

PRESERVATION KEY: 1-HCl 2-HNO3 3-H2SO4 4-NaOH 5-NaOH/ZnAcetate 6-NaHSO4 7-4°C 8-Other

Form 202r9

	SIGNATURE	PRINTED NAME	DATE	TIME
RELINQUISHED BY		Hallie B. Simpson	3/11/16	12:00
RECEIVED BY		Kelly Horiuchi	3/12/16	1045am
RELINQUISHED BY				
RECEIVED BY				
RELINQUISHED BY				
RECEIVED BY				

ALS Environmental
Sample Acceptance Check Form

Client: ALS Laboratory Group Work order: P1601303

Project: PVU / 1655500023

Sample(s) received on: 3/12/16 Date opened: 3/12/16 by: ADAVID

Note: This form is used for all samples received by ALS. The use of this form for custody seals is strictly meant to indicate presence/absence and not as an indication of compliance or nonconformity. Thermal preservation and pH will only be evaluated either at the request of the client and/or as required by the method/SOP.

		Yes	No	N/A
1	Were **sample containers** properly marked with client sample ID?	☒	☐	☐
2	Did **sample containers** arrive in good condition?	☒	☐	☐
3	Were **chain-of-custody** papers used and filled out?	☒	☐	☐
4	Did **sample container labels** and/or tags agree with custody papers?	☒	☐	☐
5	Was **sample volume** received adequate for analysis?	☒	☐	☐
6	Are samples within specified holding times?	☒	☐	☐
7	Was proper **temperature** (thermal preservation) of cooler at receipt adhered to?	☒	☐	☐
	Cooler Temperature: 3° C Blank Temperature: ° C **Wet Ice**			
8	Were **custody seals** on outside of cooler/Box/Container?	☒	☐	☐
	Location of seal(s)? Sealing lid of cooler Sealing Lid?	☒	☐	☐
	Were signature and date included?	☒	☐	☐
	Were seals intact?	☒	☐	☐
9	Do containers have appropriate **preservation**, according to method/SOP or Client specified information?	☒	☐	☐
	Is there a client indication that the submitted samples are **pH** preserved?	☐	☐	☒
	Were **VOA vials** checked for presence/absence of air bubbles?	☒	☐	☐
	Does the client/method/SOP require that the analyst check the sample pH and if necessary alter it?	☒	☐	☐
10	**Tubes:** Are the tubes capped and intact?	☐	☐	☒
11	**Badges:** Are the badges properly capped and intact?	☐	☐	☒
	Are dual bed badges separated and individually capped and intact?	☐	☐	☒

Lab Sample ID	Container Description	Required pH *	Received pH	Adjusted pH	VOA Headspace (Presence/Absence)	Receipt / Preservation Comments
P1601303-001.01	40mL VOA NP		7	1	A	MC 3/22/2016
P1601303-001.02	40mL VOA NP				A	
P1601303-001.03	40mL VOA NP				A	
P1601303-002.01	40mL VOA NP		7	1	A	MC 3/22/2016
P1601303-002.02	40mL VOA NP				A	
P1601303-002.03	40mL VOA NP				A	

Explain any discrepancies: (include lab sample ID numbers):

RSK - MEEPP, HCL (pH<2); RSK - CO2, (pH 5-8); Sulfur (pH>4)

ALS ENVIRONMENTAL

RESULTS OF ANALYSIS

Client: **ALS Laboratory Group**
Client Sample ID: **PVUBIF16031001**
Client Project ID: **PVU / 1655500023**

ALS Project ID: P1601303
ALS Sample ID: P1601303-001

Test Code: GC/SCD Reduced Sulfur Analysis
Instrument ID: Agilent 6890A/GC13/SCD
Analyst: Mike Conejo
Sample Type: Water
Test Notes:

Date Collected: 3/10/16
Date Received: 3/12/16
Date Analyzed: 3/22/16
Liquid Amount: 10.0 ml(s)
Purge Volume: 0.30 Liter(s)
Injection Volume(s): 0.050 ml(s)

CAS #	Compound	Result µg/L	MRL µg/L	Data Qualifier
7783-06-4	Hydrogen Sulfide	**57,000**	17	
463-58-1	Carbonyl Sulfide	ND	29	
74-93-1	Methyl Mercaptan	ND	24	
75-08-1	Ethyl Mercaptan	ND	30	
75-18-3	Dimethyl Sulfide	ND	30	
75-15-0	Carbon Disulfide	ND	19	
75-33-2	Isopropyl Mercaptan	ND	37	
75-66-1	tert-Butyl Mercaptan	ND	44	
107-03-9	n-Propyl Mercaptan	ND	37	
624-89-5	Ethyl Methyl Sulfide	ND	37	
110-02-1	Thiophene	ND	41	
513-44-0	Isobutyl Mercaptan	ND	44	
352-93-2	Diethyl Sulfide	ND	44	
109-79-5	n-Butyl Mercaptan	ND	44	
624-92-0	Dimethyl Disulfide	ND	23	
616-44-4	3-Methylthiophene	ND	48	
110-01-0	Tetrahydrothiophene	ND	43	
638-02-8	2,5-Dimethylthiophene	ND	55	
872-55-9	2-Ethylthiophene	ND	55	
110-81-6	Diethyl Disulfide	ND	30	

ND = Compound was analyzed for, but not detected above the laboratory reporting limit.
MRL = Method Reporting Limit - The minimum quantity of a target analyte that can be confidently determined by the referenced method.

ALS ENVIRONMENTAL

RESULTS OF ANALYSIS

Client: **ALS Laboratory Group**
Client Sample ID: **PVUBIF16031002**
Client Project ID: **PVU / 1655500023**

ALS Project ID: P1601303
ALS Sample ID: P1601303-002

Test Code: GC/SCD Reduced Sulfur Analysis
Instrument ID: Agilent 6890A/GC13/SCD
Analyst: Mike Conejo
Sample Type: Water
Test Notes:

Date Collected: 3/10/16
Date Received: 3/12/16
Date Analyzed: 3/22/16
Liquid Amount: 10.0 ml(s)
Purge Volume: 0.30 Liter(s)
Injection Volume(s): 0.050 ml(s)

CAS #	Compound	Result µg/L	MRL µg/L	Data Qualifier
7783-06-4	Hydrogen Sulfide	**53,000**	17	
463-58-1	Carbonyl Sulfide	ND	29	
74-93-1	Methyl Mercaptan	ND	24	
75-08-1	Ethyl Mercaptan	ND	30	
75-18-3	Dimethyl Sulfide	ND	30	
75-15-0	Carbon Disulfide	ND	19	
75-33-2	Isopropyl Mercaptan	ND	37	
75-66-1	tert-Butyl Mercaptan	ND	44	
107-03-9	n-Propyl Mercaptan	ND	37	
624-89-5	Ethyl Methyl Sulfide	ND	37	
110-02-1	Thiophene	ND	41	
513-44-0	Isobutyl Mercaptan	ND	44	
352-93-2	Diethyl Sulfide	ND	44	
109-79-5	n-Butyl Mercaptan	ND	44	
624-92-0	Dimethyl Disulfide	ND	23	
616-44-4	3-Methylthiophene	ND	48	
110-01-0	Tetrahydrothiophene	ND	43	
638-02-8	2,5-Dimethylthiophene	ND	55	
872-55-9	2-Ethylthiophene	ND	55	
110-81-6	Diethyl Disulfide	ND	30	

ND = Compound was analyzed for, but not detected above the laboratory reporting limit.
MRL = Method Reporting Limit - The minimum quantity of a target analyte that can be confidently determined by the referenced method.

ALS ENVIRONMENTAL

RESULTS OF ANALYSIS

Client: **ALS Laboratory Group**
Client Sample ID: **Method Blank** ALS Project ID: P1601303
Client Project ID: **PVU / 1655500023** ALS Sample ID: P160322-MB

Test Code:	GC/SCD Reduced Sulfur Analysis	Date Collected:	NA
Instrument ID:	Agilent 6890A/GC13/SCD	Date Received:	NA
Analyst:	Mike Conejo	Date Analyzed:	3/22/16
Sample Type:	Water	Liquid Amount:	10.0 ml(s)
Test Notes:		Purge Volume:	0.30 Liter(s)
		Injection Volume(s):	1.0 ml(s)

CAS #	Compound	Result µg/L	MRL µg/L	Data Qualifier
7783-06-4	Hydrogen Sulfide	ND	0.84	
463-58-1	Carbonyl Sulfide	ND	1.5	
74-93-1	Methyl Mercaptan	ND	1.2	
75-08-1	Ethyl Mercaptan	ND	1.5	
75-18-3	Dimethyl Sulfide	ND	1.5	
75-15-0	Carbon Disulfide	ND	0.93	
75-33-2	Isopropyl Mercaptan	ND	1.9	
75-66-1	tert-Butyl Mercaptan	ND	2.2	
107-03-9	n-Propyl Mercaptan	ND	1.9	
624-89-5	Ethyl Methyl Sulfide	ND	1.9	
110-02-1	Thiophene	ND	2.1	
513-44-0	Isobutyl Mercaptan	ND	2.2	
352-93-2	Diethyl Sulfide	ND	2.2	
109-79-5	n-Butyl Mercaptan	ND	2.2	
624-92-0	Dimethyl Disulfide	ND	1.2	
616-44-4	3-Methylthiophene	ND	2.4	
110-01-0	Tetrahydrothiophene	ND	2.2	
638-02-8	2,5-Dimethylthiophene	ND	2.8	
872-55-9	2-Ethylthiophene	ND	2.8	
110-81-6	Diethyl Disulfide	ND	1.5	

ND = Compound was analyzed for, but not detected above the laboratory reporting limit.
MRL = Method Reporting Limit - The minimum quantity of a target analyte that can be confidently determined by the referenced method.

ALS ENVIRONMENTAL

LABORATORY CONTROL SAMPLE / DUPLICATE LABORATORY CONTROL SAMPLE SUMMARY

Client: **ALS Laboratory Group**
Client Sample ID: **Duplicate Lab Control Sample** ALS Project ID: P1601303
Client Project ID: **PVU / 1655500023** ALS Sample ID: P160322-DLCS

Test Code: GC/SCD Reduced Sulfur Analysis
Instrument ID: Agilent 6890A/GC13/SCD
Analyst: Mike Conejo
Sample Type: Water
Test Notes:

Date Collected: NA
Date Received: NA
Date Analyzed: 3/22/16
Liquid Amount: 10.0 ml(s)
Purge Volume: 0.30 Liter(s)
Injection Volume: 0.20 ml(s)

CAS #	Compound	Spike Amount LCS / DLCS ug/L	Result LCS ug/L	Result DLCS ug/L	% Recovery LCS	% Recovery DLCS	ALS Acceptance Limits	RPD	RPD Limit	Data Qualifier
7783-06-4	Hydrogen Sulfide	418	306	314	**73**	**75**	45-151	3	28	
463-58-1	Carbonyl Sulfide	737	591	591	**80**	**80**	43-154	0	28	
74-93-1	Methyl Mercaptan	590	438	449	**74**	**76**	38-153	3	28	