GW - 4

WORK PLANS

5/21/2007

Chevron

Matthew P. Hudson
Remediation Project Manager

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RECEIVED

MAY 25 2007

Oil Conservation Division
Environmental Bureau

May 21, 2007

Mr. Wayne Price
New Mexico Oil Conservation Division
1220 South St. Francis Dr.
Santa Fe, NM 87505

RE: Permit Modification for the Eunice North Gas Plant (GW-004), Lea County, New Mexico

Dear Mr. Price:

Chevron Environmental Management Company *(CEMC)* is pleased to provide the enclosed *In-Situ Pilot Study Work Plan for the Eunice North Gas Plant* (Work Plan) to comply with the requirements in the Discharge Plan Application to modify the existing discharge permit for the Eunice North Gas Plant (GW-004) in Lea County, New Mexico. The attached Work Plan was prepared by SECOR International Incorporated (SECOR) on behalf of CEMC.

Specific details of the following application line items are described in the attached Work Plan and cross-referenced below:

1. *See Permit Application.*

2. *See Permit Application.*

3. *See Permit Application*

4. Attach the name, telephone number and address of the landowner of the facility site.
   Section 1.0 fourth paragraph

5. Attach the description of the facility with a diagram indicating location of fences, pits, dikes and tanks on the facility.
   Section 1.0 and Figure 2, Figure 3

6. Attach a description of all materials stored or used at the facility.
   Section 2.0, Appendix B

7. Attach a description of present sources of effluent and waste solids. Average quality and daily volume of waste water must be included.
   Section 1.1-chromium plume present, no further discharge.

8. Attach a description of current liquid and solid waste collection/treatment/disposal procedures.
   Sections 3.4

9. Attach a description of proposed modifications to existing collection/treatment/disposal systems.
   Section 1.1 and Appendix A

10. Attach a routine inspection and maintenance plan to ensure permit compliance.
    Section 3.1, 3.2, 3.5, and 3.6

11. Attach a contingency plan for reporting and clean-up of spills or releases.
    Section 3.8

12. Attach geological/hydrological information for the facility. Depth to and quality of ground water must be included.
    Section 1.2

13. Attach a facility closure plan, and other information as is necessary to demonstrate compliance with any other OCD rules, regulations and/or orders.
    Section 4.0

CEMC has also developed the following public notice that will be used to comply with the New Mexico Public Notice and Participation regulations (Part 20.6.2.3108):

(GW-004) Chevron U.S.A., Inc., Keith Hall, Facilities Engineering Manager, 11111 South Wilcrest, Houston, Texas, 77099 (Phone: (281) 561-3582), has submitted a discharge plan modification application for the previously approved discharge plan for the North Eunice Gas Plant, located in the SE/4 NE/4 of Section 28, Township 21 South, Range 37 East, Lea County, New Mexico. Groundwater impacted with dissolved chromium will be remediated through the injection of two treatment chemicals: calcium polysulfide and sodium acetate. The treatment chemicals will be stored on-site and the groundwater most likely to be affected by a spill, leak, or accidental discharge to the surface is at a depth of approximately 37 to 73 feet with a total dissolved solids concentration of approximately 5,000 mg/l. The discharge plan addresses how the treatment chemicals will be handled, stored, and injected - including how spills, leaks, and other accidental discharges to the surface will be managed in order to protect fresh water.

Should you have any questions regarding the enclosed application, or the public notice language, please contact me at 281-561-3466.

Sincerely,

Matthew P. Hudson

Attachments: Discharge Plan Application
In-Situ Pilot Study Work Plan for the Eunice North Gas Plant

cc:
Glenn von Gonten, NMOCD
Scott Olivier, SECOR

District I
1625 N. French Dr., Hobbs, NM 88240
District II
1301 W. Grand Avenue, Artesia, NM 88210
District III
1000 Rio Brazos Road, Aztec, NM 87410
District IV
1220 S. St. Francis Dr., Santa Fe, NM 87505

State of New Mexico
Energy Minerals and Natural Resources

Oil Conservation Division
1220 South St. Francis Dr.
Santa Fe, NM 87505

Revised June 10, 2003

Submit Original
Plus 1 Copy
to Santa Fe
1 Copy to Appropriate
District Office

DISCHARGE PLAN APPLICATION FOR SERVICE COMPANIES,GAS PLANTS, REFINERIES, COMPRESSOR, GEOTHERMAL FACILITES AND CRUDE OIL PUMP STATIONS

(Refer to the OCD Guidelines for assistance in completing the application)

☐ New ☐ Renewal ☒ Modification

1. Type: Eunice North Gas Plant (GW-004)

2. Operator: Chevron U.S.A. Inc.

Address: 11111 South Wilcrest, Houston, TX 77099

Contact Person: Matt Hudson Phone: (281) 561-3653

3. Location: NE /4 SE /4 Section 28 Township 21-S Range 37-E
Submit large scale topographic map showing exact location.

4. Attach the name, telephone number and address of the landowner of the facility site.

5. Attach the description of the facility with a diagram indicating location of fences, pits, dikes and tanks on the facility.

6. Attach a description of all materials stored or used at the facility.

7. Attach a description of present sources of effluent and waste solids. Average quality and daily volume of waste water must be included.

8. Attach a description of current liquid and solid waste collection/treatment/disposal procedures.

9. Attach a description of proposed modifications to existing collection/treatment/disposal systems.

10. Attach a routine inspection and maintenance plan to ensure permit compliance.

11. Attach a contingency plan for reporting and clean-up of spills or releases.

12. Attach geological/hydrological information for the facility. Depth to and quality of ground water must be included.

13. Attach a facility closure plan, and other information as is necessary to demonstrate compliance with any other OCD rules, regulations and/or orders.

14. CERTIFICATION I hereby certify that the information submitted with this application is true and correct to the best of my knowledge and belief.

Name: MATT HUDSON Title: PROJECT MANAGER

Signature: Date: 05/21/07

E-mail Address: MHKW@CHEVRON.COM

FINAL

IN-SITU PILOT STUDY WORK PLAN FOR THE EUNICE NORTH GAS PLANT

Chevron Environmental Management Company

May 21, 2007
89CH.49526.07

Prepared by:

Jeremy Rasmussen, P.E.
Senior Engineer

Submitted by:

D. Scott Olivier

David Scott Olivier
Senior Project Manager

Reviewed by:

Daniel Oberle

Dan Oberle, P.E.
Principal Engineer

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1.0 INTRODUCTION

On behalf of Chevron Environmental Management Company (CEMC), SECOR International Incorporated (SECOR) has prepared this In-Situ Pilot Study Work Plan for the Eunice North Gas Plant (Site). The Eunice North Gas Plant is located in Lea County, New Mexico, approximately 0.25 miles north of the town of Eunice. The legal description is the south half (S/2) of the southeast quarter (SE/4) of the northeast quarter (NE/4) of Section 28, Township 21 South (T-21-S), Range 37 East (R-37-E). A Site Location Map is presented on Figure 1.

The Eunice North Gas Plant was originally constructed in the 1940s, and was owned and operated by Texaco from the 1940s through the 1980s. The gas plant was constructed and modified to operate as a turbo expander type natural gas processing plant for extraction of NGLC natural gas liquids.

Ownership transferred to Versado LLP (Versado), and gas plant operations have ceased and the operational equipment has been partially dismantled with much of the equipment shut-in. There are several buildings, structures, and tanks across the Site, including sumps, the compressor building, and the cooling tower.

The plant is currently operated as a natural gas compressor station under an agreement with Chevron. Targa Midstream Services, L.P. (Targa) operates two compressors in the northwest portion of the Site for Versado. The address is State Highway 207 (Eunice-Hobbs Highway), Eunice, New Mexico, 88231. The gas plant operator, Lewis Tarin, can be reached at (505) 394-3452.

1.1 Background

Impacts to the soil within the plant boundaries, as well as groundwater impacts in the area of the plant, were discovered when Texaco was renewing the New Mexico Oil Conservation Division (NMOCD) Groundwater Discharge Plan for the plant in the early 1990s. In August 1996, the NMOCD required an initial investigation to evaluate the integrity of process area sumps at the Site. Dissolved benzene and dissolved chromium were detected in groundwater above standards, which was documented in the *Subsurface Environmental Assessment Report* (Highlander, 1996). The source of the chromium was speculated to be cooling tower blowdown discharged to the surface southwest of the plant.

Several soil and groundwater investigations were conducted between 1996 and 2003, with semi-annual groundwater monitoring beginning in 2004. Based on the groundwater investigations, the three primary groundwater constituents of concern (COCs) for this Site are:

- Metals (specifically chromium and hexavalent chromium) in the groundwater that have migrated beyond the plant boundaries toward Monument Draw;
- Dissolved solids (represented by chloride concentrations) in the groundwater south and east of the plant; and
- Petroleum hydrocarbons in groundwater in the vicinity of an old sump inside the plant.

In addition to dissolved-phase concentrations in groundwater, hydrocarbons in the soil and groundwater at the Site are mainly located within a limited area inside the plant boundary. The source of the hydrocarbons has been removed. Two wells in the plant area (MW005 and MW006) historically exhibited the presence of phase-separated hydrocarbon (PSH) accumulations.

Beginning in 2003, remedial efforts for chromium impacts began through In-Situ Reactive Zone (IRZ) treatment at a "study area" consisting of three injection wells near the area of the highest chromium concentrations. This was followed by an array of 14 injection wells at the distal end of the chromium plume (distal array). The IRZ process used a carbohydrate-based electron donor (molasses) to stimulate reducing conditions in the subsurface to convert hexavalent chromium to trivalent chromium. IRZ was discontinued in September 2005 based on the bench-scale test results detailed below.

A bench-scale treatability study was performed in 2005 by SECOR to optimize the in-situ treatment reagent. The November 2005 study, entitled *Reductive Treatment Bench-Scale Testing Evaluation for Chevron Environmental Management Company Eunice North Gas Plant Eunice, New Mexico* (Appendix A), evaluated two biological reducing agents (molasses and sodium acetate) and two chemical reducing agents (sodium metabisulfite and calcium polysulfide). The results of the study indicate that calcium polysulfide treatment provided the optimum reduction of hexavalent chromium to trivalent chromium, and subsequent precipitation of the trivalent chromium from solution, at the lowest chemical dosage. Although the dosage rates are higher and the kinetics slower, the study also indicated that alternate electron donors could be successfully used. Alkanoic salts like sodium acetate could provide pH buffering to prevent excessive pH drops in the groundwater during biological degradation processes.

The remedial approach selected for future in-situ treatment of the hexavalent chromium groundwater plume is injection of an inorganic reducing agent (calcium polysulfide) along with an electron donor (sodium acetate). The calcium polysulfide will provide rapid reduction of hexavalent chromium within the injection area, while the sodium acetate will create a reducing zone through biological activity capable of treating hexavalent chromium migrating into the injection area. Additional bench-scale testing was performed in January 2007 to optimize chemical injection rates and minimize solids generation to prevent well clogging issues, as described in Section 3.0.

A Site Map, including locations of the study area, medial array, and distal array injection wells along with the associated monitoring wells is included as Figure 2.

1.2 Geologic Setting

The regional geology and hydrogeology is referenced from the *Groundwater Investigation and Remediation Activities Report 2004* (ARCADIS, 2005). Monument Draw is the major surface drainage feature in southern Lea County, and runs north to south slightly over two miles east of the Site. The overall topography in the area of the Site slopes gently toward Monument Draw at an approximate slope of 35 feet per mile. Small closed basins or playas exist on this sloping surface.

The geologic formations of interest at the Site include the Triassic Chinle, Cretaceous undifferentiated, Tertiary Ogallala and Quaternary eolian sedimentation, designated the Blackwater Draw. Of particular interest with regard to the impact of hexavalent chromium released to groundwater are the Tertiary Ogallala and Quaternary Blackwater Draw.

The lower Tertiary Ogallala formation is composed of fluvial sediments of the Miocene-Pliocene epochs. It is a heterogeneous combination of clay, silt, sand, and gravel of braided-stream deposits interbedded with, and overlain by, eolian sediments deposited as sand sheets and loess resting directly upon an erosional surface carved into the Triassic Chinle Formation under the Site. The fluvial sediments were deposited on a sloping plain in the form of coalescing alluvial fans, by streams that originated in the Rocky Mountains to the west and northwest. The Ogallala Formation was deposited in laterally restricted lenses of material, predominantly medium to yellowish-gray conglomeratic sandstone and fine to medium-grained well-sorted sandstone. The primary fresh water-bearing formation under and in the vicinity of the Site is the Ogallala.

In contrast to the fluvial deposition of the lower Ogallala sediments, the upper part of the Ogallala and all of the Blackwater Draw Formation overlying the Ogallala are composed of windblown (eolian) deposits. The very fine sand facies of the upper Ogallala are thick, ranging up to 125 feet and capped by the Caprock caliche or calcrete, marking the top of the Ogallala.

The Blackwater Draw Formation occurs as a mantle of Quaternary eolian sediment locally as thick as 100 feet, covering an area of the South High Plains of northeastern Texas and eastern New Mexico. Throughout the depositional time of the Blackwater Draw Formation, laterally restricted lenticular layers of eolian and playa or lacustrine facies were formed. The Blackwater Draw Formation occurs near the ground surface at the Site and contains reddish sediments composed of up to six well-developed buried soils with similar lithology and morphology. The soil development occurred during periods of landscape stability, separated by intermittent periods of deposition or by deflation that stripped surface horizons from newly developed soils.

The primary source of freshwater at the Site is the Ogallala Formation, which is hydraulically unconfined in the area of the Site. It is bounded on the base of the aquifer by an eroded surface of a firm red silty clay of the Chinle Formation. The base of the Ogallala is composed of a 5 to 10-foot interval of gravel/sand/clay, which is termed the "deep" water-bearing zone. The gravel unit is overlain by a red to yellow sand that exhibits vertical heterogeneity with alternating layers of loose and well-consolidated sand. This overlying unit constitutes the "shallow" water-bearing zone. Wells screened in the gravel unit have 40 to 50 feet of hydraulic head. Wells screened in the shallow water-bearing zone have screens that intersect the groundwater table and typically have 10 to 45 feet of saturation. Overall depth to groundwater varies with local topography and ranges from 37 to 73 feet below ground surface (bgs).

Regionally, the groundwater gradient was to the southeast in the area of the Site. However, a mounding effect now exists south of the plant, due to lawn watering within the City of Eunice. This mounding effect creates variable hydraulic gradient directions that tend towards southwest, west, northwest, north, and northeast trends. The elevations of the groundwater in the shallow and deep zones are similar, indicating there is hydraulic continuity between the zones.

1.3 Purpose

This work plan is intended to provide detailed information on the specifications and procedures to be followed to perform a pilot study of in-situ treatment of chromium-impacted groundwater. This pilot study will be performed on select wells in the medial array. The pilot study area is shown in Figure 3. The results of the injection activities described in this work plan will be used to develop a full-scale remediation plan.

Selected injection and monitoring wells, injection and sampling frequency, analytes and analytical methods, quality control (QC) procedures, groundwater injection and sampling procedures, and reporting requirements are described in the subsequent sections.

2.0 CHEMICAL INFORMATION AND STORAGE

Three chemicals (calcium polysulfide, sodium bicarbonate, and acetic acid) will be used in the in-situ pilot study. Acetic acid is an alkanoic acid, and when combined with sodium bicarbonate forms an alkanoic salt (sodium acetate). Information on these chemicals, along with the handling and storage procedures, is detailed in the following sections.

2.1 Chemical Information

2.1.1 Calcium Polysulfide

The following reference list presents documents describing where calcium polysulfide injection has been used in-situ to treat hexavalent chromium impacts in groundwater at other sites throughout the United States, including Arizona and California:

- Storch, P., A. Messer, D. Palmer and R. Pyrih. "Pilot Test for In-Situ Geochemical Fixation of Chromium (VI) Using Calcium Polysulfide" in A.R. Gavaskar and A.S.C. Chen (eds), Proceedings of the Third International Conference on Remediation of Chlorinated and Recalcitrant Compounds, May 2002, Battelle Press.
- Rouse, J., I Davies, A. DeSantis, and J. Hutton, "In-situ Hexavalent Chromium Reduction and Geochemical Fixation in Varied Geohydrological Regines", Best Sulfur Products Technical Paper, 2000.
- Storch, P. A. Messer, M. Barone, and R. Pyrih, "In Situ Geochemical Fixation of Cr(VI) in Soil Using Calcium Polysulfide, in A.R. Gavaskar and A.S.C. Chen (eds), Proceedings of the Fourth International Conference on Remediation of Chlorinated and Recalcitrant Compounds, May 2004, Battelle Press.
- Thomasser, R. and J. Rouse, "In-Situ Remediation of Chromium Contamination of Soil and Groundwater", Best Sulfur Products Technical Paper, 2000.
- Rouse, J and R. Thomasser, "Hexavalent Chromium Remediation by Bore-Hole Placed Reactive Barriers and Monitored Natural Attenuation", Proceedings from the Third International Conference on Oxidation and Reduction Technologies for In-situ Treatment of Soil and Groundwater, October, 2004.
- Zawislanski, P., J. Beatty and W. Carlson, "Long-Term Stability of Metals Following In-situ Treatment of Acidic Groundwater Using Calcium Polysulfide", Proceedings from the Third International Conference on Oxidation and Reduction Technologies for In-situ Treatment of Soil and Groundwater, October, 2004.
- Yu, G. and J. Tremaine, "Pilot Test Using Cascade to Treat Cr(VI) In Groundwater of A Carbonate Aquifer", Proceedings from the Second International Conference on Oxidation and Reduction Technologies for In-situ Treatment of Soil and Groundwater, November 2002.

A 29% calcium polysulfide solution will be used during the pilot study, and the calcium polysulfide material safety data sheet (MSDS) is included in Appendix B. Some minimal hydrogen sulfide (H_2S) odor is distinguishable when the calcium polysulfide is exposed to air. The chemical is stable because it is pH amended so the vapor concentrations are low. Airborne concentrations will quickly dissipate. Monitoring equipment will be used during mixing and handling as a safety precaution.

There should not be concerns with the residual following injection of calcium polysulfide. Calcium polysulfide is a commonly used treatment chemical approved for use in drinking water by the National Sanitation Foundation (NSF International) and also becoming widely used for in-situ treatment of hexavalent chromium, as well as other metals, in groundwater. Calcium polysulfide oxidizes under aerobic conditions to form calcium, sulfate, and elemental sulfur.

Calcium polysulfide has been recently used more frequently as a reducing agent for hexavalent chromium owing to its ability to reduce hexavalent chromium to trivalent chromium without the need for acidification. Sulfur atoms have the ability to catenate into linear chains of sulfur atoms to create a polysulfide salt when reacted with a metal. When sulfur is reacted with calcium metal, a calcium polysulfide salt is formed that contains anywhere from 2 sulfur atoms (CaS_2) to 7 sulfur atoms (CaS_7). The average amount of sulfur in the polysulfide salts is 5 sulfur atoms per calcium atom. Therefore, calcium polysulfide is often written with the chemical formula CaS_5. When the polysulfide anion (S_5^{-2}) reacts with hexavalent chromium in the groundwater, the last sulfur atom on the polysulfide chain (which is a sulfide anion) is converted from a -2 oxidation state to a zero oxidation state, thus releasing two moles of electrons for each mole of polysulfide anion reacted. The CaS_5 reduction reaction with hexavalent chromium in the form of the dissolved chromate anion (CrO_4^{-2}) therefore occurs as shown in the reaction below:

$$\underset{\text{hydrogen}}{10H^+_{(aq)}} + \underset{\text{chromate}}{2CrO_4{}^{2-}{}_{(aq)}} + \underset{\text{calcium polysulfide}}{3CaS_{5(aq)}} \rightarrow \underset{\text{chromium hydroxide}}{2Cr(OH)_{3(s)}} + \underset{\text{calcium}}{3Ca^{2+}_{(aq)}} + \underset{\text{water}}{2H_2O_{(l)}} + \underset{\text{elemental sulfur}}{15S^0_{(s)}}$$

Following injection, the polysulfide will reduce the hexavalent chromium to trivalent chromium, causing the trivalent chromium to precipitate out of solution as chromium hydroxide [$Cr(OH)_3$]. Chromium hydroxide is a solid; therefore, it will remain in the soil matrix instead of the groundwater. Bench-scale testing with groundwater from the Site indicates there should be no pH issues related to calcium polysulfide treatment. As long as the pH of the aquifer remains above 6.0, the trivalent chromium will remain sorbed to the soil matrix and not soluble. The pH will remain above 6.0 using bicarbonate buffering (described in Section 2.1.2) to keep the trivalent chromium in its solid form once it is reduced.

The trivalent chromium is also thermodynamically stable and will not revert back to hexavalent chromium following calcium polysulfide injection. The only potential mechanism for trivalent chromium to revert back to hexavalent chromium is the introduction of a strong oxidant into the aquifer, such as permanganate or persulfate. Long term remediation plans at the Site do not involve the use of these strong oxidants. Thermodynamic calculations also indicate that dissolved oxygen within the aquifer will not cause trivalent chromium to revert back to hexavalent chromium.

Calcium will also precipitate out of the groundwater when it reacts with natural carbonate and sulfate in the groundwater. The maximum concentration of calcium to remain in solution is dependant upon pH and solubility. Typically, it will reach a maximum of 500 to 600 mg/l at neutral pH values, which is typical of hard-water aquifers. The remaining elemental sulfur from the calcium polysulfide is insoluble; therefore, it will precipitate out of solution and also remain in the soil matrix.

Calcium polysulfide will also react with minerals in the soil such as iron and manganese. Because of this reaction, it expends itself in the soil matrix before it can travel too far downgradient. It is anticipated that this reaction will occur within the first 50 feet of distance based on existing Site data and an understanding of the local soil chemistry.

2.1.2 Sodium Acetate

The use of sodium acetate as a terminal electron donor for biological reduction of chromium has been documented in the following literature sources:

- Dermou. E, A. Velissariou, D. Xenos, D.V. Vayena, *Biological Removal of Hexavalent Chromium in Trickling Filters Operating with Different Media Types*, Desalination, 211, pp. 156-163, 2007.
- Marsh, T.L. and M.J. McInerney, Relationship of Hydrogen Bioavailability to Chromate Red Sediments, Applied Environmental Microbiology, 67(4), pp. 1517-1521, April 2001.
- McLean, J. and T.J. Beveridge, *Chromate Reduction by a Pseudomonad isolated from a Site Contaminated with Chromated Copper Arsenate*, Applied and Environmental Microbiology, 67, pp. 1076-1084, March 2003.
- Pattanapipitpaisal, P, N.L. Brown and L.E. Macaskie, *Chromate Reduction and 16S Identifiaction of Bacteria Isolated from a Cr(VI)-Contaminated Site*, Applied Microbiology Biotechnology, 57, pp. 257-261, 2001.
- SECOR International Inc., *Reductive Treatment Bench-Scale Testing Evaluation for Chevron Environmental Management Company, Eunice North Gas Plant – Eunice, New Mexico*, January 23, 2006.
- Williams, S.M., C.S. Criddle and M.J. Dybas, *Assessing the Potential for Biological Cr(VI) Reduction in an Aquifer Contaminated with Mixed Wastes*, in Chromium (VI) Handbook, 348-356 (James A. Jacobs, et al. eds., 2005), CRC Press.

Sodium acetate has been used extensively across the United States as an electron donor for in-situ groundwater treatment applications. Native bacteria within the aquifer utilize the electron donor as a carbon source, thereby creating reducing conditions which beneficially reduce contaminants such as hexavalent chromium through the biological activity. In-situ bioremediation of groundwater with sodium acetate has been documented in New Mexico. Sodium acetate was used in Mountainview, New Mexico for the in-situ treatment of nitrates *(In-Situ Groundwater Bio-Denitrification, McQuillan, Faris, New Mexico Environment Department).*

Sodium acetate ($NaC_2H_3O_2$) is an alkanoic salt that is commonly used as a food preservative or additive. It is a colorless, odorless salt that readily dissolves in water (solubility > 50%). When dissolved in water, the acetate anion can be used as a terminal electron donor for the biological reduction of hexavalent chromium as shown in the simplified reaction below.

$$\underset{\text{acetate}}{3\,CH_3CO_2^-{}_{(aq)}} + \underset{\text{chromate}}{8\,CrO_4^{2-}{}_{(aq)}} + \underset{\text{water}}{17\,H_2O_{(l)}} \rightarrow \underset{\text{chromium hydroxide}}{8Cr(OH)_{3(s)}} + \underset{\text{bicarbonate}}{6HCO_3^-{}_{(aq)}} + \underset{\text{hydroxide}}{13OH^-{}_{(aq)}}$$

Sodium acetate and calcium polysulfide have alkaline pH values when dissolved in water. Since groundwater will be re-circulated as part of the pilot treatment, it is important to buffer the pH of the re-circulated groundwater to prevent the precipitation of dissolved calcium from the groundwater as calcium carbonate as shown in the reaction below:

$$\underset{\text{bicarbonate}}{HCO_3^-{}_{(aq)}} + \underset{\text{hydroxide}}{OH^-{}_{(aq)}} + \underset{\text{calcium}}{Ca^{+2}{}_{(aq)}} \rightarrow \underset{\text{calcium carbonate}}{CaCO_{3(s)}} + \underset{\text{water}}{H_2O_{(l)}}$$

To prevent calcium carbonate precipitation from occurring (which leads to well fouling), the sodium acetate solution will be prepared on-site by adding sodium bicarbonate ($NaHCO_3$) and acetic acid (CH_3COOH) to re-circulated groundwater flow. This will create dissolved sodium acetate and dissolved carbon dioxide (in the form of weak carbonic acid) that creates stable bicarbonate equilibrium as shown in the reaction below:

$$\underset{\text{sodium bicarbonate}}{NaHCO_{3(aq)}} + \underset{\text{acetic acid}}{CH_3COOH_{(aq)}} \rightarrow \underset{\text{sodium acetate}}{NaC_2H_3O_{2(aq)}} + \underset{\text{carbonic acid}}{H_2CO_{3(aq)}}$$

Calcium carbonate cannot precipitate from solution under a balanced bicarbonate system since excess alkalinity in the form of hydroxide reacts with carbonic acid to form bicarbonate instead of carbonate. Therefore, calcium remains in solution instead of precipitating, which would result in excessive well fouling.

$$\underset{\text{carbonic acid}}{H_2CO_{3(aq)}} + \underset{\text{hydroxide}}{OH^-{}_{(aq)}} + \underset{\text{calcium}}{Ca^{+2}{}_{(aq)}} \rightarrow \underset{\text{calcium}}{Ca^{+2}{}_{(aq)}} + \underset{\text{bicarbonate}}{HCO_3^-{}_{(aq)}} + \underset{\text{water}}{H_2O_{(l)}}$$

Handling and storage procedures for use of the sodium bicarbonate and acetic acid to create a pH-buffered sodium acetate solution are detailed in the following sections.

2.1.2.1 Sodium Bicarbonate

Sodium bicarbonate (better known as baking soda) is a white, odorless salt commonly used in preparation of baked goods. A 5% sodium bicarbonate solution will be used during the pilot study, and the sodium bicarbonate MSDS is included in Appendix B. The chemical is stable under ordinary conditions of use and storage. Conditions to avoid include heat, moisture, and incompatible materials such as strong acids; therefore, the sodium bicarbonate will be stored on a wooden pallet away from other materials and will be kept covered. A dust mask and goggles will be worn when preparing the sodium bicarbonate solution (prepared by adding 50-lb bags of the salt into a mix tank with Site groundwater) to prevent minor irritation that occurs when the salt contacts the eyes or mucous membranes. The pH of the salt and solution is near neutral.

2.1.2.2 Acetic Acid

A 56% acetic acid solution will be used during the pilot study, and the acetic acid MSDS is included in Appendix B. Acetic acid is stable, but should be stored in a cool, dry environment and kept away from sources of ignition, heat, and oxidizing agents. Skin contact and inhalation should be avoided as acetic acid is a mild acid. Gloves and chemical goggles should be worn when handling the chemical. Acetic acid is readily biodegradable and is safe for discharge when diluted; therefore, should not result in a residual issue.

2.2 Chemical Storage and Delivery

Containers of 29% (10.6 lbs/gallon) calcium polysulfide and 56% acetic acid (8.5 lbs/gallon) will be delivered and stored on-site in 55-gallon drums. The chemicals will be set up and stored on separate secondarily-contained spill containment pallets. Sodium bicarbonate will be delivered in 50-lb bags, and will be stored on a wooden pallet. A total of two drums of calcium polysulfide, five drums of acetic acid, and 33 bags of sodium bicarbonate will be required. The chemical storage area will be within the fenced exclusion zone. A Pilot Study Layout Map is presented on Figure 4, and Pilot Study Detail Map, including specific tank locations and containment layout, is presented on Figure 5.

3.0 PILOT STUDY ACTIVITIES

Eleven injection wells are situated in the medial array (approximate 50-foot spacing), which bisects the chromate plume in a north-south orientation, perpendicular to the groundwater flow direction. Two of these wells (IW024 and IW025), as well as a nearby monitoring well (MW090SA) were selected for the pilot study. In-situ injection of calcium polysulfide, sodium bicarbonate, and acetic acid to reduce hexavalent chromium to trivalent chromium will be conducted following the procedures outlined below.

3.1 Health and Safety

To ensure safe completion of pilot study activities, the site-specific Health and Safety Plan (HASP) will be updated and task-specific job safety analyses (JSAs) will be created or updated, as necessary, prior to commencing fieldwork. SECOR will perform dry-runs on each activity (gauging, sampling, etc.) to ensure any gaps in the JSAs are filled. Two SECOR personnel will be on-site during activities. Daily health and safety briefings will be conducted at the start of each day and after lunch, to detail upcoming hazards and lessons learned from the previous day's events. Applicable JSAs will be reviewed daily at the two tailgate meetings and whenever field personnel change tasks.

As the pilot study will be conducted for nine days in a row for 24 hours a day, there will be several personnel working on-site in rotation. Personnel will work in teams of two for shifts of approximately eight to ten hours, and there will be enough personnel dedicated to the job that no one will work more than five days in a row. Meetings will be held between the changing shifts to make sure all pertinent information is passed between the teams.

3.2 Baseline Groundwater Sampling

Prior to the pilot study, baseline groundwater elevations will be measured in five wells: IW023, IW024, IW025, IW026, and MW090SA and recorded on the Groundwater Sampling Field Data Sheet (Appendix C). Well locations are detailed on Figure 4 and well details are summarized below:

Well ID	Surveyed Measuring Point Elevation (ft AMSL)	Surveyed Ground Elevation (ft AMSL)	Screened Interval (ft bgs)	Completed Well Depth (ft bgs)
IW023	3426.05	3423.49	34-98	99
IW024	3426.63	3424.06	41-101	103
IW025	3427.62	3425.06	41-101	103
IW026	3428.01	3425.53	37-102	105
MW090SA	3428.33	3425.63	36-101	103

Groundwater samples will also be collected at these five wells using either a bailer or low-flow sampling procedures. If using low-flow procedures, the bladder pump intake will be lowered into the well to the midpoint of the well screen. The pump will be started at its lowest speed setting and speed will be slowly increased until discharge occurs.

During well purging, indicator field parameters will be measured using a multi-meter with flow-through-cell and recorded on the Groundwater Sampling Field Data Sheet (Appendix C) every two to five minutes. Purging is considered complete and sampling will begin when three consecutive parameter readings are stable, within the following limits:

- Dissolved oxygen (DO) - 10%
- Conductivity - 3%
- Temperature - 3%
- pH - ± 0.1 unit
- Oxidation reduction potential (ORP) - ± 10 millivolts

Sample containers will be filled by allowing the pump discharge to flow gently down the inside of the container with minimal turbulence. Groundwater samples collected for dissolved metals analysis will be field filtered into pre-preserved containers using high-capacity, 0.45-μm disposable filters and a small pump. If a sample can not be filtered in the field, the chain of custody will be marked "Filter at Lab" and an unpreserved bottle will be used.

Following collection, groundwater samples will be labeled, logged on a laboratory chain of custody, and placed on ice in an insulated cooler to maintain a temperature of approximately 4°C. Water samples will be transmitted via FedEx to the analytical laboratory. Proper chain of custody documentation will be maintained throughout the sampling and analysis process.

Groundwater samples will be sent for analysis to Lancaster Laboratories in Lancaster, Pennsylvania, a CEMC-approved analytical laboratory. Samples will be analyzed for dissolved chromium, hexavalent chromium, total organic carbon (TOC), and sodium.

After collection of the groundwater samples, the pump tubing will either be properly discarded or dedicated to the well for re-sampling. To decontaminate sampling equipment, an Alconox-water solution will be pumped from buckets through the pump and associated equipment. The equipment will then be rinsed thoroughly with deionized water pumped from buckets. One-time use disposable equipment will not be decontaminated, but packaged for appropriate disposal.

Additional details on groundwater sampling procedures can be found in the *Sampling and Analysis Plan for the Eunice North Gas Plant* dated June 5, 2006.

3.3 Incorporation of Lessons Learned

Historical pump testing data and in-situ treatment data from the Site was evaluated to determine anticipated pumping rates from extraction wells, injection rates at injection wells, injection back-pressure, and radius of influence.

Constant-rate 48-hour pump tests were performed at RW004A, RW002, and RW003 in 2001 (ARCADIS, 2004). RW004A is screened in the deep Ogallala zone (95 to 115 feet bgs), RW002 is screened in the shallow Ogallala zone (48 to 68 feet bgs), and RW003 is also screened in the shallow Ogallala zone (45 to 65 feet bgs). A summary of the pump test data valuable to the pilot study design is provided in the following table:

Pumping Well	Flow Rate (gpm)	Maximum Drawdown at Pumping Well (ft)	Maximum Drawdown at Observation Well (ft)	Distance from Pumping Well to Observation Well (ft)
RW004A	3.3	32	6	25
RW002	9.25	10	1	23
RW003	7.2	10	1	19

The data suggests a pumping rate of at least 5 gallons per minute (gpm) could be expected at a 4-inch well screened across the shallow and deep Ogallala. The data also suggests a radius of influence of greater than 20 feet can be expected from the extraction effort.

Data from past molasses injection efforts were also evaluated. Molasses injections occurred between 2003 and 2005 at three study area injection wells (RW004A, IW001, and IW002), and between 2004 and 2005 at 14 distal array injection wells (IW003 through IW016). All injection wells except RW004A had a 4-inch diameter. During an injection event, 250 to 1,000 gallons of a 5 to 15% molasses solution was injected into the subsurface. On average, the injections occurred every month. The injection pressure and flow rate data are summarized in the following table:

Area	Average Injection Pressure (psi)	Range of Average Injection Pressures (psi)	Average Injection Flow Rate (gpm)	Range of Average Injection Flow Rates (gpm)
Study Area	7.9	6.6-10.2	11.7	10.0-14.0
Distal Array	3.0	0.0-8.7	18.2	7.3-27.7

The data suggest an injection rate of at least 10 gpm could be expected at a 4-inch well screened across the shallow and deep Ogallala, at a pressure less than 10 psi.

Groundwater elevation data from monitoring wells in the vicinity of study area injection wells indicate measurable mounding effects from the injections. The monitoring wells are located at distances between 15 and 40 feet from the injection wells. Although the hydraulic effects were immediate during the injection period, analytical monitoring data indicate changes in groundwater chemistry took several weeks to occur.

Monitoring well clusters adjacent to injection wells IW016 and IW014 were used to monitor changes in groundwater chemistry due to injections at the distal array. For IW016, changes in groundwater chemistry at the nearest monitoring well (10 feet away) took 7 days to occur. For IW014, changes in groundwater chemistry at the nearest monitoring well (10 feet away) took 41 days to occur. The distal array injection wells are spaced approximately 100 feet apart.

To increase the radial influence of treatment and ensure contact with the treatment chemicals, groundwater recirculation versus batch injections is proposed for the medial array pilot study. Groundwater will be extracted from IW024 and MW090SA at a combined flow rate of approximately 10 gpm, amended with treatment chemicals, and then injected into IW025 at a flow rate of approximately 10 gpm and a pressure less than 10 psi.

3.4 Pilot Study Activities

A Pilot Study Detail Map is provided as Figure 5. A Process Flow Diagram is included as Figure 6, and a Piping and Instrumentation Diagram is included as Figure 7. The following sections provide detail on groundwater extraction, treatment chemical addition, and injection of the amended groundwater.

3.4.1 Groundwater Extraction

Groundwater will be extracted from IW024 and MW090SA using ½-HP stainless steel submersible pumps (Grundfos, Model #16S05-5) capable of delivering 10 gpm against 125 feet of total dynamic head (TDH). The anticipated 5 gpm from each well will be routed to a secondarily contained 1,100-gallon polyethylene mixing tank. The anticipated pH of the extracted groundwater is 7.0 to 7.2. In-line pitot tube style acrylic flowmeters (BlueWhite, Model #F-30100PR) will be installed to monitor the flow rate from each extraction well. Sample ports will also be installed as shown on Figure 7. Using a bypass line, a portion of the extracted groundwater (475 gallons per batch) will be occasionally routed to the 550-gallon polyethylene mix tank for creating batches of 5% sodium bicarbonate.

The pilot study design requires one pore volume exchange within the vicinity of IW025. Assuming a saturated thickness of 15 feet (deep zone only), a radius of influence of 35 feet (distance to nearest well IW024), and a porosity of 30%, the volume of injected groundwater will be approximately 130,000 gallons. At a groundwater extraction/injection rate of 10 gpm, this equates to a nine-day, 24-hour per day pilot study. The desired concentration of treatment chemicals in the pore volume is 1,500 mg/l sodium bicarbonate; 1,000 mg/l acetic acid; and 250 mg/l calcium polysulfide. The mixture of sodium bicarbonate and acetic acid creates a 1,600 mg/l sodium acetate solution within the mix tank. The total mass of chemicals required is therefore 1,625 lbs of sodium bicarbonate; 1,083 lbs of acetic acid; and 267 lbs of calcium polysulfide. Chemical addition is described in greater detail in the following sections.

3.4.2 Sodium Bicarbonate Addition

The generation of solids is a significant consideration with any in-situ groundwater treatment technology. Sodium bicarbonate and acetic acid were chosen for the pilot study to help eliminate the generation of solids during groundwater extraction and injection activities. Solids generated could foul injection wells and result in a significant mass of sludge to handle and properly dispose of. Solids handling would increase the complexity and cost of the remedial approach.

Recent bench-scale testing suggests that when extracted groundwater (pH of 7.0 to 7.2) is treated with 1,000 mg/l acetic acid and 1,500 mg/l sodium bicarbonate, the resulting solution has a well-buffered pH in the range of 5.8 to 6.0 and a sodium acetate concentration of

1,600 mg/l. The pH needs to be maintained above 5.0 to prevent stripping of H_2S (from the subsequent calcium polysulfide addition), and below 6.8 to prevent calcium carbonate fouling. Bench-scale testing was also performed to evaluate pre-treatment with caustic (sodium hydroxide) to precipitate calcium carbonate out of solution prior to the mix tank. This would result in the accumulation of up to 4% of the groundwater volume as sludge, or approximately 5,000 gallons of sludge having 2% solids content.

Batches of 5% sodium bicarbonate will be made within a secondarily contained 550-gallon polyethylene batch tank. Four 50-lb bags of sodium bicarbonate will be added to the batch tank along with 475 gallons of make-up water (groundwater). The solution will have a pH near neutral, with a small submersible pump within the tank continually mixing the contents. From the batch tank, the sodium bicarbonate solution will be pumped by metering pump (LMI, Model #C741-36, 20 gallons per hour [gph] max) into the 1,100-gallon mix tank. To ensure the pH stays in the specified range of 5.8 to 6.0, pH will be monitored in the mix tank using a portable YSI 63 pH/Conductivity meter. Adjustments will be made to the chemical metering pump, as necessary, to maintain the desired pH range.

At an injection rate of 10 gpm, the 5% sodium bicarbonate will be added at a rate of 17.4 gph to create a 1,500 mg/l sodium bicarbonate solution in the mix tank. A total of 1,625 lbs of sodium bicarbonate will be required for the pilot study. A total of 3,750 gallons of 5% sodium bicarbonate will be required, which equates to nearly one batch a day of treatment chemical. Polyethylene tubing (1/2-inch OD) will be used to deliver the treatment chemical.

3.4.3 Acetic Acid Addition

Acetic acid (56%) will be pumped from secondarily contained 55-gallon drums to the mix tank. A chemical metering pump (LMI, Model #B741-313SI, 7 gph maximum) will be used to deliver the chemical. At an injection rate of 10 gpm, the 56% acetic acid will be added at a rate of 1.05 gph to create a 1,000 mg/l solution. A total of 1,083 lbs of acetic acid will be required, with equates to 228 gallons at a 56% concentration and density of 8.5 lbs/gallon. Polyvinylidene fluoride (PVDF) tubing (1/2-inch OD) will be used to deliver the treatment chemical. To ensure process control and proper mixing, the hydraulic retention time (HRT) in the mix tank will be at least 50 minutes (100 minutes is provided at 10 gpm).

3.4.4 Injection

The chemically-amended groundwater (1,600 mg/l sodium acetate, pH of 5.8 to 6.0) will be pumped from the mix tank to injection well IW025 at a rate of 10 gpm. A stainless steel centrifugal pump (Goulds, Model #IMSIC4E4) will be used to transfer the groundwater. The injection pump has been sized to deliver 30 gpm against 50 feet TDH. A one-micron bag filter (Polyline, Model #FLT4202) will be installed upstream of the injection well to capture any residual solids. Prior to the bag filter, there will be a re-circulation line back to the mix tank to aid in mixing.

An in-line totalizer and flowmeter (7/8-inch NuFlo, 3-30 gpm range, 1-inch MT ends, MCII analyzer) will be installed after the bag filter. A pressure gauge installed at the wellhead will be used to monitor injection pressure, with a target maximum of 10 psi established for the pilot study. Additional pressure gauges and sample ports will be installed as shown on Figure 7.

Rebecca Melendez with the Office of the State Engineer in Roswell, New Mexico indicated that no permits would be required for the 130,000-gallon pilot study since it is a short term, one time event. However, a permanent full-scale remedial system requiring extraction and injection of groundwater would require additional paperwork through the Office of the State Engineer. New Mexico is a Clean Water Act primacy state. Therefore, a class 5 injection well permit may be required by the New Mexico Environment Department (NMED). The state of New Mexico would then likely report to the United States Environmental Protection Agency (USEPA) on the injection. All applicable permits and notification required by the State of New Mexico (NMOCD, NMED, Office of the State Engineer) and the USEPA will be acquired prior to implementation of this work plan.

3.4.5 Calcium Polysulfide Addition

The final treatment chemical, a 29% calcium polysulfide solution, will be injected in-line at the wellhead versus at the mix tank. The calcium polysulfide is injected in-line to avoid H_2S stripping from solution and to mitigate any health and safety issues associated with handling calcium polysulfide. The calcium polysulfide solution has a pH of 11.3 to 11.5. A chemical metering pump (LMI, Model #B741-313SI, 7 gph maximum) will be used to pump the calcium polysulfide from 55-gallon drums to IW025. At an injection rate of 10 gpm, the 29% calcium polysulfide will be added at a rate of 0.4 gph to create a 250 mg/l solution. A total of 267 lbs, or 87 gallons at a 29% concentration and density of 10.6 lbs/gallon, of calcium polysulfide will be required. Polyethylene tubing (1/2-inch OD) will be used to deliver the treatment chemical.

The target dose for calcium polysulfide is 250 mg/l, as testing shows higher concentrations could precipitate out too much elemental sulfur. This dosage rate will increase the pH of the groundwater to between 6.2 and 6.3, with a final alkalinity of 1,400 mg/l. This solution is stable and will not precipitate calcium carbonate from solution, thereby minimizing clogging of the well screen and formation. The alkalinity sequesters H_2S and, along with the in-line injection technique, keeps it from stripping from solution. The alkalinity also prevents the groundwater from going acidic at a later date as the acetate is consumed biologically to create reducing conditions.

3.5 Pilot Study Data Collection

During pilot study activities, groundwater elevation and indicator field parameters (conductivity, ORP, pH, DO, and temperature) will be monitored at IW023, IW024, IW026, and MW090SA to determine the influence of the injection activities and recorded on the Groundwater Field Log (Appendix D).

In addition, to confirm the presence of calcium polysulfide at the wells adjacent to IW025 (IW023, IW024, IW026, and MW090SA), a field titration will be performed daily. The field titration procedure is included in Appendix E. A Hach test kit will also be used to monitor hexavalent chromium concentrations in the field daily.

3.6 Confirmation Groundwater Sampling

Following the pilot study, confirmation groundwater samples will be collected from five wells (IW023, IW024, IW025, IW026, and MW090SA) and analyzed for dissolved chromium, hexavalent chromium, TOC, and sodium. Groundwater sampling activities and field data collection will follow the same procedures detailed in Section 3.2 for baseline sample collection.

3.7 Investigative Derived Waste Management

The only waste expected to be generated during the pilot study is purge water from sampling activities. Purge water will be pumped from the wells into a 500-gallon polyethylene tank during sampling activities, and later pumped into an on-site disposal well.

The pilot study will also generate waste that can be disposed of at a municipal landfill. This includes empty chemical drums (which will be properly rinsed out prior to disposal), empty chemical bags, and pallets.

3.8 Spill Contingency

Piping will be inspected daily during the pilot study to detect any weak points or leaks in the system. Should a spill or leak of the acetic acid or calcium polysulfide solutions occur within one of the spill containment pallets, it will be pumped out and returned to a new 55-gallon drum for re-use. Any material in leaking drums will be pumped into a new drum and the damaged drum removed from the Site. All mixing and pumping of the sodium bicarbonate solution will be conducted within a fiberglass containment basin (7 feet wide, 8 feet long, 18 inches deep, 500 gallon capacity). The 1,100-gallon mix tank, injection pump, and bag filter will also be placed within a fiberglass containment basin (8 feet wide, 10 feet long, 20 inches deep, 1,000 gallon capacity).

Any spill or leak outside of the containment areas will be remediated, per the MSDS and the product label, to protect human health and minimize any effects to the environment. Sand, or other appropriate absorbent material, shall be used to contain a spill. At no time shall acidic substances be used to remedy a spill. Absorbent material that comes in contact with any spilled solution will be containerized for proper disposal. Following removal of the absorbent material, chase water will be applied to the ground surface to further dilute the spilled solution and expedite its infiltration into the geologic formation. Any spill volume that poses immediate danger to human health or the environment or that is greater than or equal to 55 gallons shall be reported, within 24 hours, to the NMED (emergencies: 505-827-9329, non-emergencies: 866-428-6535). A 55-gallon spill kit will be located within the exclusion zone, as shown on Figure 5.

Further reference should be made to the MSDS and the product label prior to commencing any handling or transport of the sodium bicarbonate, acetic acid, and calcium polysulfide.

3.9 Utilities

Water provided by the City of Eunice will be used for general housekeeping activities and will also supply a portable eye wash & shower in the chemical storage area, as shown on Figure 5.

To power the system (three metering pumps, one centrifugal pump, two extraction pumps, one mixing pump, and temporary lighting), a temporary 120-volt electrical drop will be installed at a nearby power pole. In the event this option cannot be implemented in the field, a gas powered generator could be used or power could be routed from the fenced aboveground storage tank (AST) area (approximately 1,000 feet).

4.0 SCHEDULE AND COMPLIANCE

Per 20.6.2.3108 Public Notice and Participation, the NMOCD should approve the Groundwater Discharge Permit Renewal Application within 75 days of receipt from CEMC. The Public Notice requirements must also be completed by CEMC within this time period. SECOR will initiate the pilot study activities within 45 days of receiving NMOCD approval of the application. Therefore, four months will likely elapse between the time the application is submitted and the pilot study is initiated.

Initially, baseline groundwater sampling of the five wells will be completed prior to commencement of injection activities, as discussed in Section 3.2. Pilot study activities are expected to last for a 14-day duration, which includes time for mobilization, set-up, 9-day pilot test, and demobilization. Following the pilot study, confirmation groundwater sampling of the five wells will be completed as described in Section 3.6.

Following the pilot study activities and confirmation groundwater sampling, results will be reviewed and presented in a letter report. This information will be used to develop a full-scale remedial approach for the Site.

5.0 STATEMENT OF LIMITATIONS

The recommendations contained in this work plan are based upon professional opinions with regard to the subject matter. These opinions have been arrived at in accordance with currently accepted hydrogeologic and engineering standards and practices applicable to this location, and are subject to the following limitations:

1. The data and findings presented are valid as of the dates when the investigations were performed. The passage of time, manifestation of latent conditions, or occurrence of future events may require further exploration at the Site, analysis of the data, and reevaluation of the findings, observations, and conclusions expressed in the report.

2. The data reported and the findings, observations, and conclusions expressed are limited by the Scope of Work. The Scope of Work was defined by the request of the client, the time and budgetary constraints imposed by the client, and availability of access to the Site. SECOR cannot verify the accuracy of data provided by previous consultants.

3. Because of the limitations stated above, the findings, observations, and conclusions expressed by SECOR are not, and should not be, considered an opinion concerning the compliance of any past or present owner or operator of the Site with any federal, state, or local law or regulation.

4. No warranty or guarantee, whether expressed or implied, is made with respect to the data or the reported findings, observations, and conclusions, which are based solely upon Site conditions in existence at the time of the investigations.

5. SECOR reports present professional opinions and findings of a scientific and technical nature. While attempts were made to relate the data and findings to applicable environmental laws and regulations, the report shall not be constructed to offer legal opinion or representations as to the requirements of, nor the compliance with, environmental laws, rules, regulations, or policies of federal, state, or local governmental agencies. Any use of this report constitutes acceptance of the limits of SECOR's liability. SECOR's liability extends only to its client and not to any other parties who may obtain the report. Appropriate legal counsel should review issues raised by the report.

6.0 REFERENCES

6.1 General

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6.2 Calcium Polysulfide

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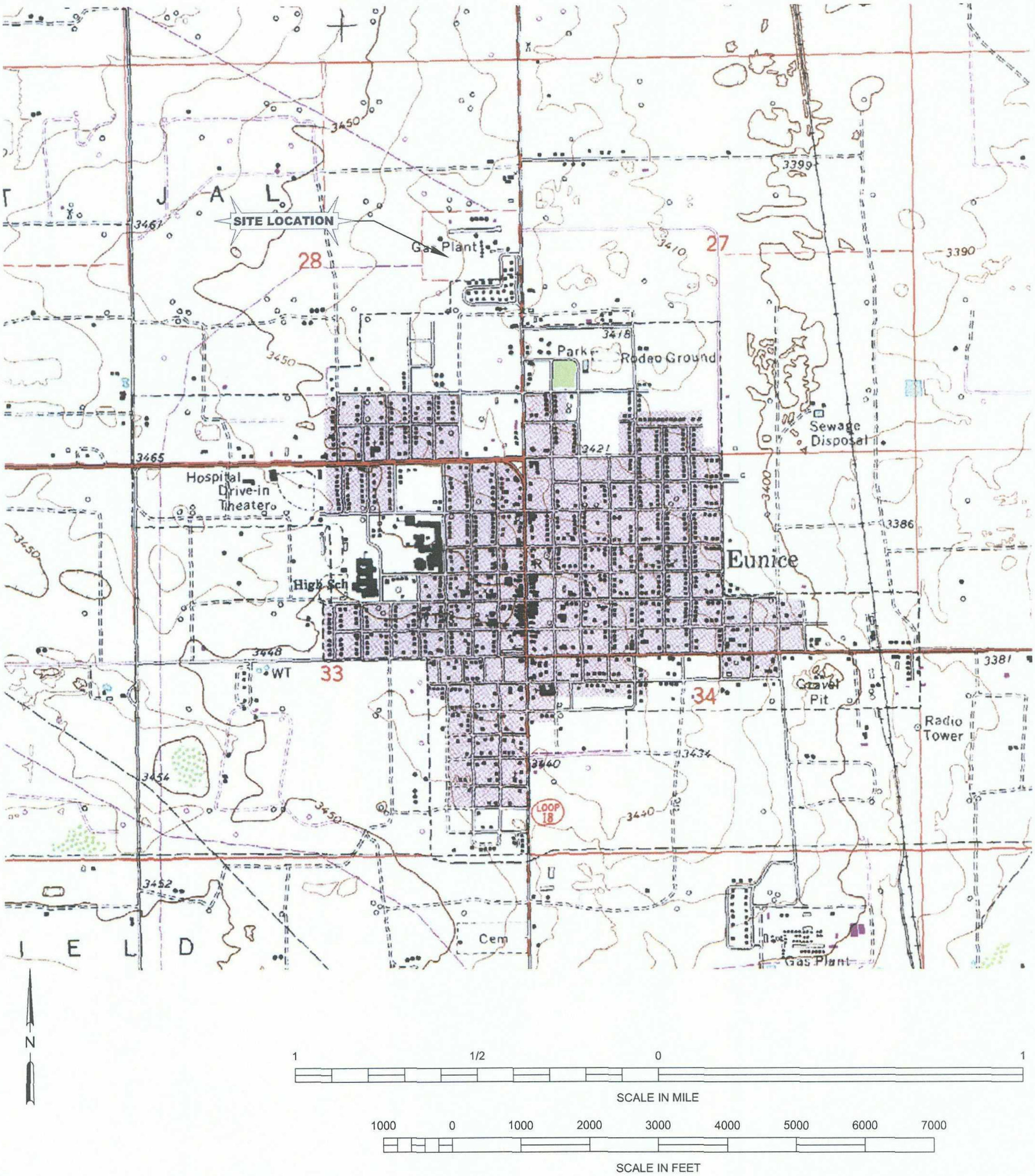

REFERENCE: USGS 7.5 MINUTE QUADRANGLE; EUNICE AND RATTLESNAKE CANYON, NEW MEXICO

Eunice N[illegible] Site Location Map.dwg

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FOR:

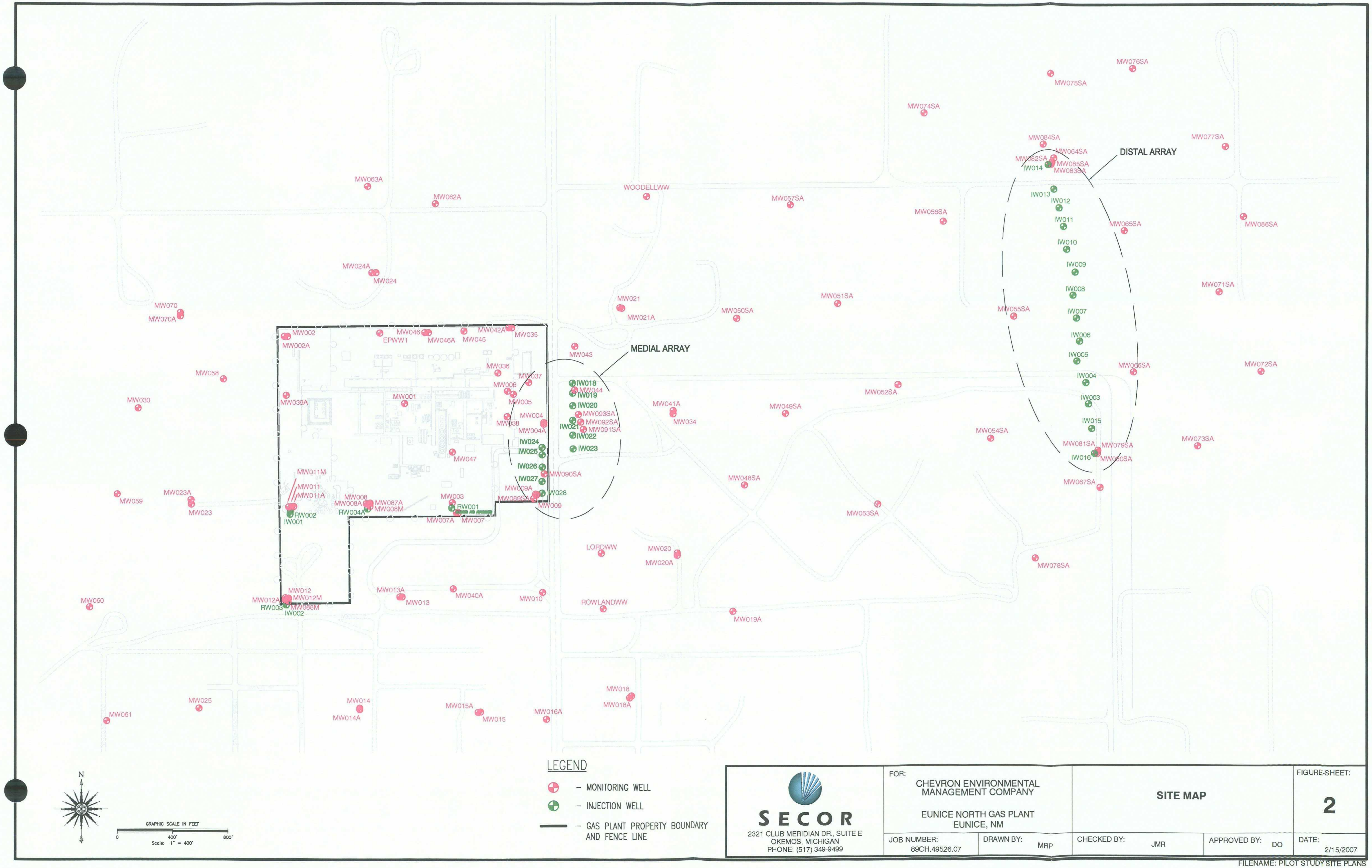
CHEVRON
EUNICE NORTH GAS PLANT

EUNICE, NEW MEXICO

SITE LOCATION MAP

FIGURE:
1

JOB NUMBER:	DRAWN BY:	CHECKED BY:	APPROVED BY:	DATE:
89CH.49410.01	ERM	RDT	RDT	10/21/05



LEGEND

- ● – MONITORING WELL
- ● – INJECTION WELL
- ▬ – GAS PLANT PROPERTY BOUNDARY AND FENCE LINE

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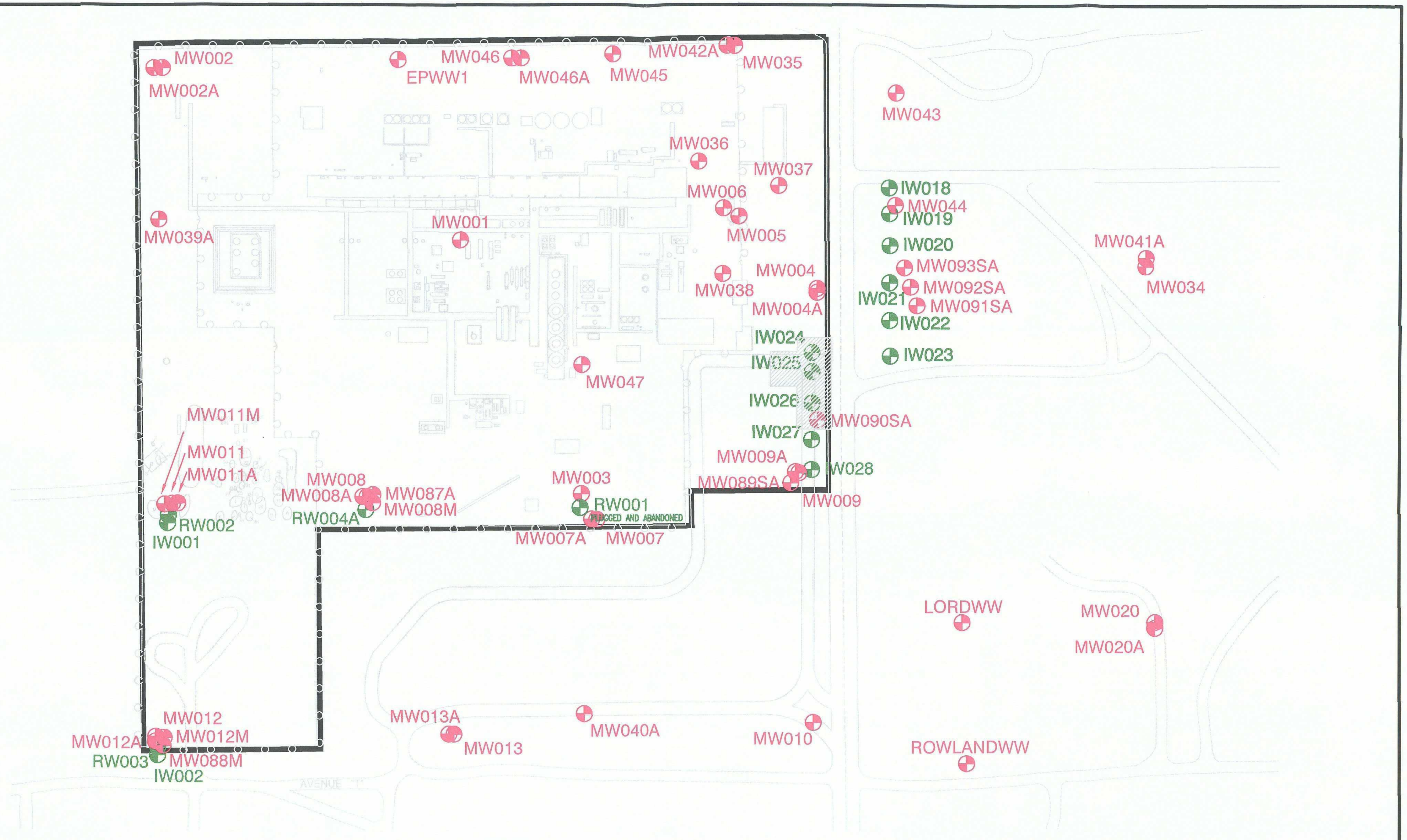
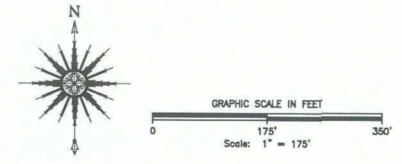
FOR: CHEVRON ENVIRONMENTAL MANAGEMENT COMPANY EUNICE NORTH GAS PLANT EUNICE, NM		SITE MAP	FIGURE-SHEET: 2
JOB NUMBER: 89CH.49526.07	DRAWN BY: MRP	CHECKED BY: JMR	APPROVED BY: DO	DATE: 2/15/2007

FILENAME: PILOT STUDY SITE PLANS





LEGEND

- 🔴 – MONITORING WELL
- 🟢 – INJECTION WELL
- ▬ – GAS PLANT PROPERTY BOUNDARY AND FENCE LINE
- ▨ – PILOT STUDY AREA

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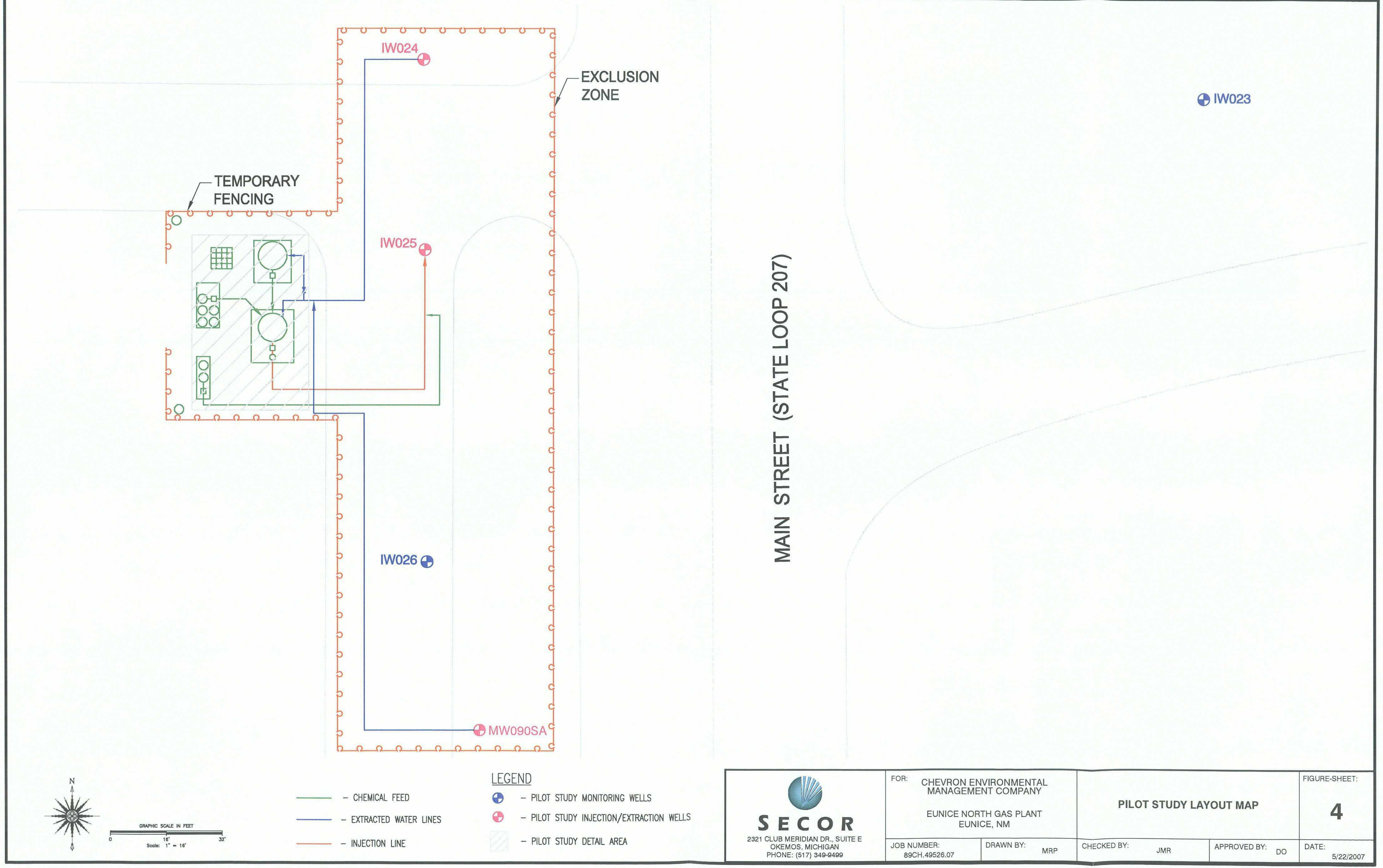
FOR: CHEVRON ENVIRONMENTAL MANAGEMENT COMPANY EUNICE NORTH GAS PLANT EUNICE, NM		EXPANDED SITE MAP		FIGURE-SHEET: 3
JOB NUMBER: 89CH.49526.07	DRAWN BY: MRP	CHECKED BY: JMR	APPROVED BY: DO	DATE: 5/22/2007

FILENAME: PILOT STUDY SITE PLA



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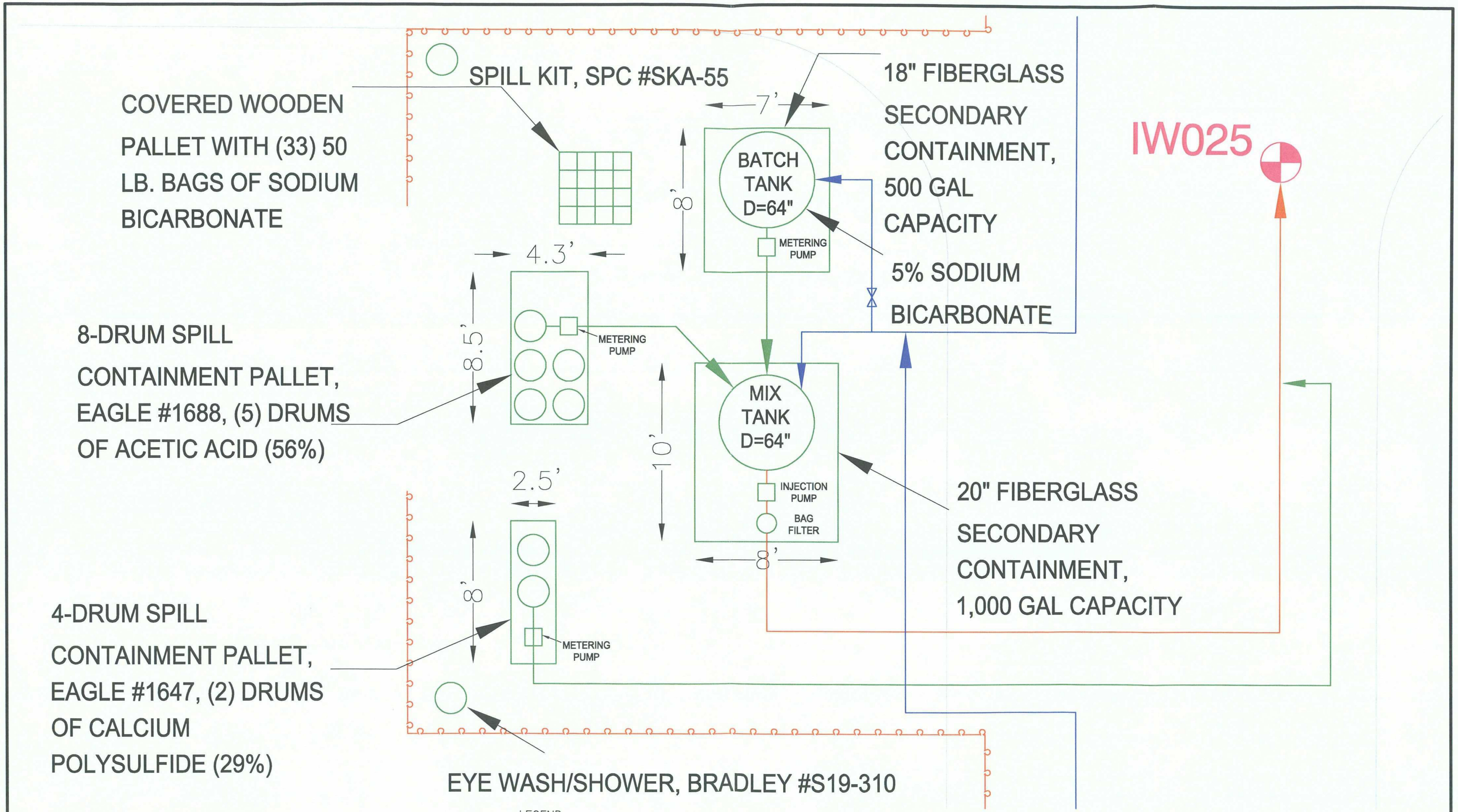
EUNICE NORTH GAS PLANT
EUNICE, NM

PILOT STUDY LAYOUT MAP

FIGURE-SHEET: 4

JOB NUMBER: 89CH.49526.07
DRAWN BY: MRP
CHECKED BY: JMR
APPROVED BY: DO
DATE: 5/22/2007

FILENAME: PILOT STUDY SITE PLAN



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FOR: CHEVRON ENVIRONMENTAL MANAGEMENT COMPANY EUNICE NORTH GAS PLANT EUNICE, NM		PILOT STUDY DETAIL MAP		FIGURE-SHEET: 5
JOB NUMBER: 89CH.49526.07	DRAWN BY: MRP	CHECKED BY: JMR	APPROVED BY: DO	DATE: 2/15/2007

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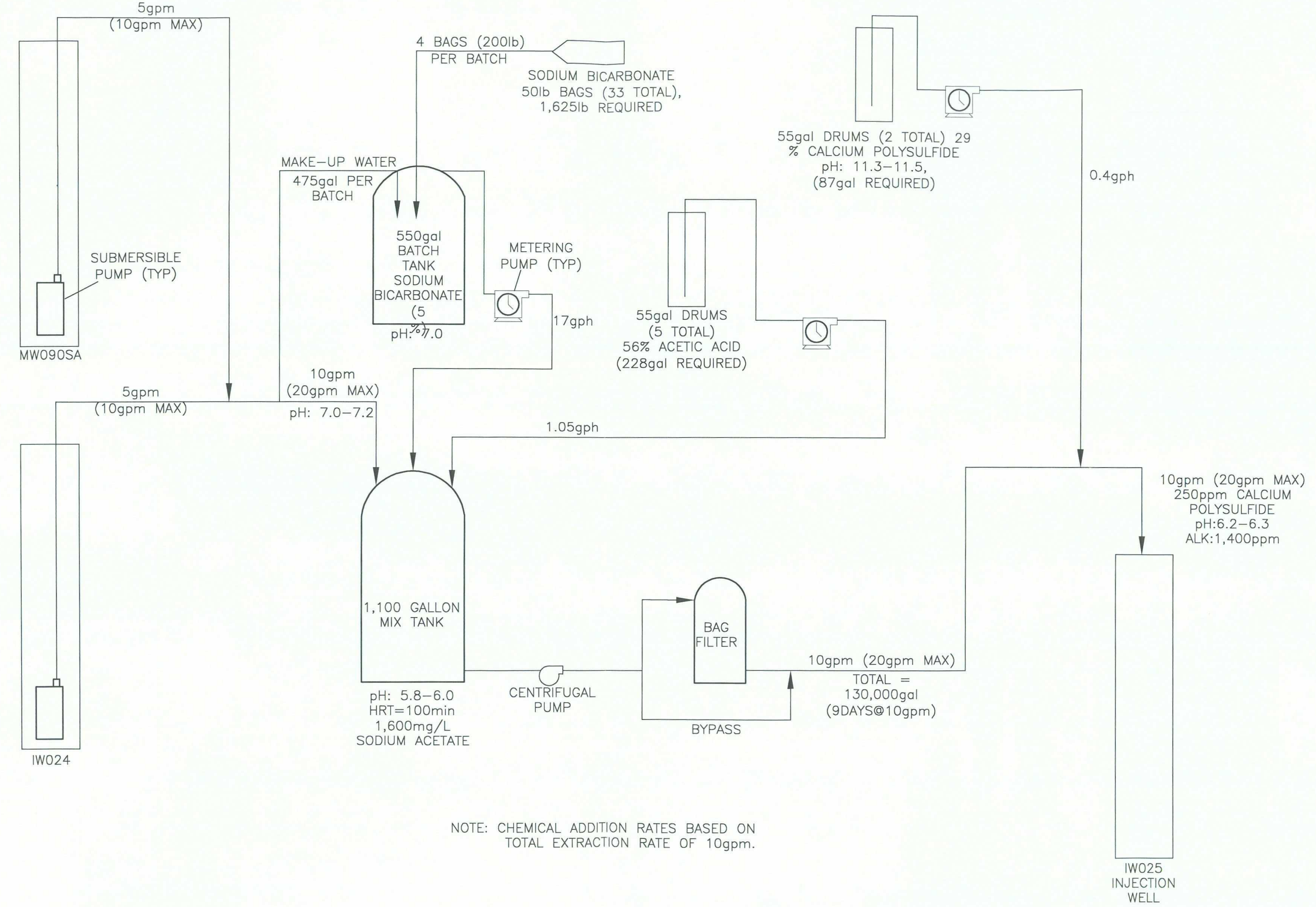

NOTE: CHEMICAL ADDITION RATES BASED ON
TOTAL EXTRACTION RATE OF 10gpm.

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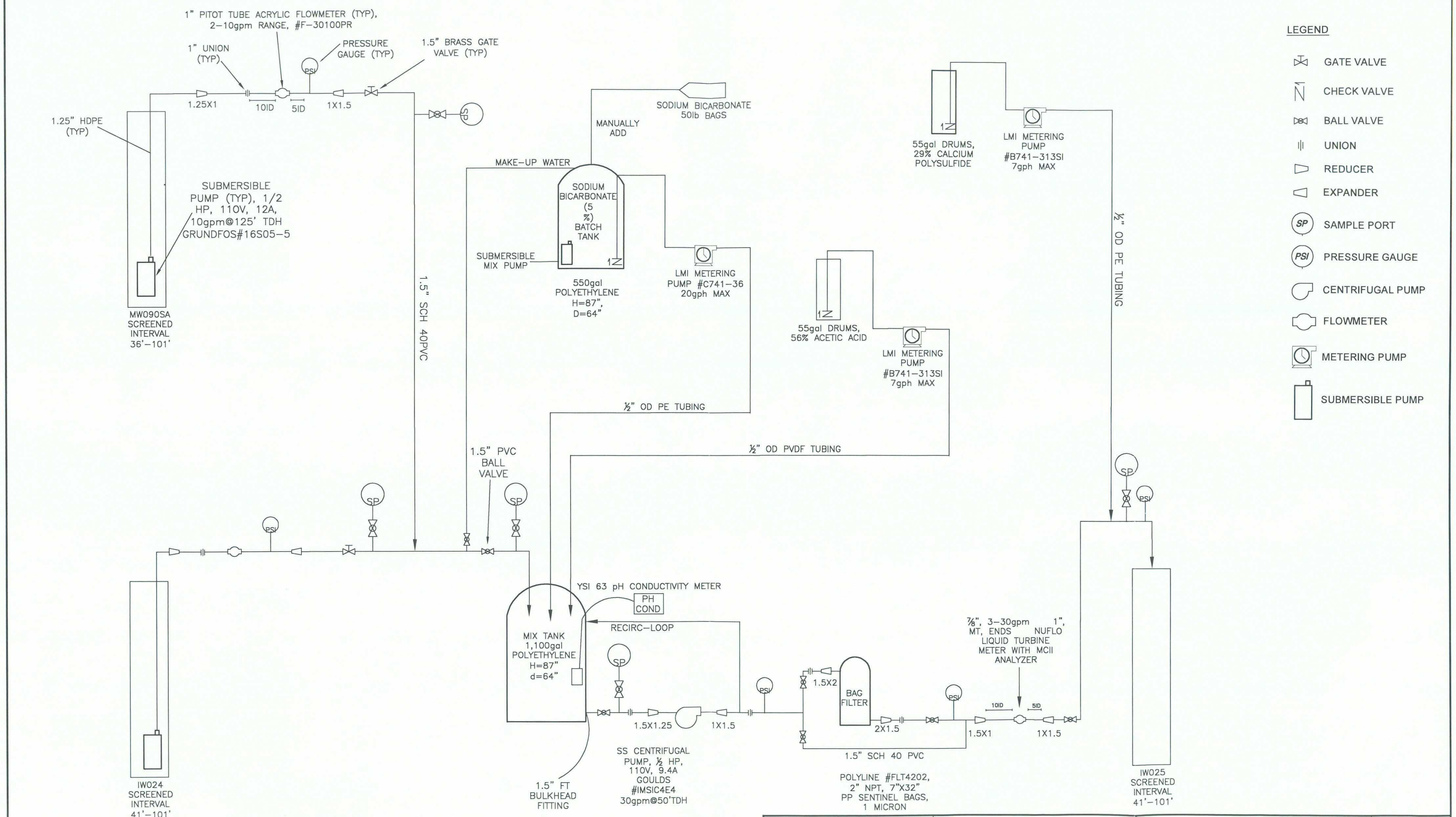
EUNICE, NEW MEXICO

JOB NUMBER: 89CH.49410.01
DRAWN BY: KJD
CHECKED BY: JMR
APPROVED BY: JMR

PROCESS FLOW DIAGRAM

FIGURE: 6
DATE: 05/22/07

FILEPATH:



Note: Chemical Addition Rates Based on Total Extraction Rate of 10gpm.

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FOR:
CHEVRON
EUNICE NORTH GAS PLANT
EUNICE, NEW MEXICO

PIPING AND INSTRUMENTATION DIAGRAM

FIGURE: 7

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APPENDIX A
REDUCTIVE TREATMENT BENCH-SCALE TESTING EVALUATION

In-Situ Pilot Study Work Plan
for the Eunice North Gas Plant

Chevron Environmental Management Company
89CH.49526.07
May 21, 2007

FINAL

REDUCTIVE TREATMENT BENCH-SCALE TESTING EVALUATION FOR

CHEVRON ENVIRONMENTAL MANAGEMENT COMPANY

Eunice North Gas Plant - Eunice, New Mexico

January 23, 2006
89CH.49410.06

Prepared by:

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Reviewed by:

Jeremy Rasmussen, P.E.
Senior Engineer

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EXECUTIVE SUMMARY

Three different treatment reagents were tested at the bench-scale level to determine if the reagents could provide similar or better treatment results for hexavalent chromium when compared to the current molasses treatment. The results of the study showed sodium acetate, sodium metabisulfite, and calcium polysulfide were all effective reagents for chromium reduction. Sodium metabisulfite and calcium polysulfide are inorganic reducing reagents that directly treat the hexavalent chromium by chemical reduction. Sodium acetate is an electron donor that stimulates subsurface biological activity which leads to the reduction of chromium.

Although all of the reagents tested showed promise as reducing agents for chromium, the treatment of hexavalent chromium *in-situ* is a two-step process and both steps must be successful for effective treatment. In the first step of treatment, the chromium is reduced from the hexavalent state to the trivalent state. In the second step, the trivalent chromium must precipitate from solution so the amount of chromium remaining in the groundwater is below MCLs.

Each of the reagents was tested to determine how they performed in the second step of the chromium treatment process. The results showed that the calcium polysulfide provided the fastest reduction kinetics and best consistent removal efficiency for chromium from groundwater (> 98% removal). Sodium metabisulfite and sodium acetate also provided good removal efficiencies for chromium (91.4 to > 98%) but higher dosages of treatment chemical were required. The samples treated with molasses were the only samples that did not achieve MCLs during the testing. Although molasses was able to quickly reduce the chromium to its trivalent state, the fermentation of the molasses significantly lowered the pH and prevented the chromium from precipitating out of solution. The total removal efficiency of total dissolved chromium by the molasses treatment was only 20 percent.

The results of this study suggest that molasses treatment will lower the pH of groundwater during treatment and that chelating effects could suspend metals in solution. Site data collected by Arcadis shows groundwater pH values as low as 4.37 and dissolved calcium concentrations in excess of 3,000 mg/L. These are consistent with the results of bench-scale testing. Based on these findings, it is recommended that the treatment chemical for in-situ chromium treatment be changed from molasses to calcium polysulfide.

1.0 INTRODUCTION

The Chevron Eunice #2 North Plant (the site) is a former natural gas processing plant that operated just north of Eunice, New Mexico. Chromate biocides were used in the plant's cooling tower operations when the plant was in operation. Hexavalent chromium impacts have been detected in the groundwater beneath the facility at concentrations exceeding 1,000 ug/L. A plume of hexavalent chromium exceeding 100 ug/L extends approximately 4,000 feet down-gradient of the original source area.

A pilot remedial program was conducted in 2004 and 2005 by Arcadis at the distal end of the chromate plume to evaluate molasses treatment for the reduction and precipitation of chromium. The program included 14 pilot injection wells screened into the deep zone. Once per month, each injection well is injected with between 400 to 800 gallons of 30 percent molasses solution followed by a chase solution of 250 gallons of city water.

In September 2005, Arcadis installed a row of medial array wells within the central portion of the plume along route NM-18, with SECOR providing oversight. Groundwater at this location is approximately 42 feet below grade. Samples of soil were collected from depth intervals of 42 feet, 60 feet and 90 feet below grade during installation of well IW-022. Water samples were collected from the well after it was completed.

The soil and groundwater samples were shipped to SECOR's treatability testing laboratory in Sylvania, Ohio on September 30, 2005 for *in-situ* chemical reduction bench-scale testing. The bench-scale testing compared the effectiveness of molasses treatment with other reduction technologies for hexavalent chromium treatment. The treatment reagents evaluated as part of the study included calcium polysulfide, sodium acetate, and sodium metabisulfite. Bench scale testing with the soil and groundwater samples began on October 3, 2005.

2.0 TREATABILITY STUDY APPROACH

2.1 Test Objectives and Rationale

The objectives of the treatability testing were to:

- Determine if the addition of non-carbohydrate organics to the groundwater would induce *in-situ* reductive treatment of chromium;
- Determine if sodium metabisulfite could be utilized to reduce and precipitate hexavalent chromium *in-situ* and how pH affects the kinetics of the reaction;
- Determine if calcium polysulfide could be utilized for *in-situ* reduction of hexavalent chromium in a soil/water system without interference from reactions with the soil; and
- Compare the effectiveness of each treatment reagent to the current reagent (molasses) and a comparative group to determine which reductive treatment(s) will be most effective for on-going site operations.

2.2 Experimental Design and Procedures

The procedures used for testing are summarized in the sections below.

2.2.1 Testing for Biological Activity

When the site groundwater samples arrived at the laboratory, a sample was immediately tested and found to contain approximately 0.3 mg/L hexavalent chromium. This value is below the value that is typically toxic to bacteria, thus indicating that biologically-driven reducing reactions were a feasible treatment technology for the site. For confirmation, testing was performed on the water sample to identify and quantify baseline populations of indigenous heterotrophic aerobic and anaerobic bacteria.

This testing was performed using a BART^{TM} biological activity reaction test kit manufactured by Droycon Bioconcepts, Inc. Fifteen milliliters of site groundwater were added to the test kit chamber and the chamber was inverted for 30 seconds to dissolve a culture medium into the groundwater. The reaction chamber was then placed upright, out of the sunlight, for a five-day incubation period.

During this period, bacteria present in the groundwater were allowed to multiply within the test chamber. The test chamber included an interceding device to restrict diffusion of oxygen into the groundwater to produce different environments for biological activity. The interceding device created an aerobic zone at the surface of the reaction chamber to support aerobic biological activity and an anaerobic zone at the bottom of the reaction chamber to support anaerobic biological activity. The use of a biodegradable indicator die allowed for a visual determination of whether the predominant bacteria were aerobic or anaerobic based on the location in the chamber in which the indicator die was consumed. The rate in which the die is consumed provides information that is used to determine the initial population of bacteria in the groundwater.

2.2.2 Batch Reaction Tests

Four treatment reagent combinations were evaluated for in-situ chemical reduction testing. The reagents included calcium polysulfide, sodium acetate, sodium metabisulfite (at two pH values), and molasses. The testing was conducted using different concentrations of each reagent. Control samples were also prepared for baseline comparison. Each one-liter glass jar for the batch reaction testing was amended with 200 grams of site soil and 600 milliliters of site groundwater. The treatment reagents were added to each test group at different concentrations and the pH and ORP of the samples were monitored as a function of time after preparation.

Water samples were also tested for hexavalent chromium as a function of time to evaluate reaction kinetics with respect to the chemical reduction of hexavalent chromium. Post treatment samples were then tested for total dissolved chromium to determine the overall effectiveness of each treatment with respect to total removal of chromium from the groundwater. The preparation of each reagent test group is described below.

2.2.2.1 Sodium Acetate

The addition of organics to stimulate chromium reduction is dependant upon biological processes. Bacteria in the soil and groundwater consume organics while using electron acceptors in the groundwater to metabolize them. The loss of electron acceptors causes a decrease in the oxidation-reduction potential (ORP) in the groundwater. This change in geochemistry facilitates the chemical reduction of chromium, especially if ferrous iron dissolves into the groundwater from soil as part of the reduced conditions or biological activity.

The type of organic placed into the subsurface affects the rate at which the chromium will be reduced. For example, simple sugar carbohydrates like molasses degrade quickly which results in rapid reduction of chromium. However, these sugars degrade by fermentation which releases acid into the groundwater and lowers the groundwater pH. The reduced groundwater pH may prevent the necessary second step of chromium treatment which involves precipitating the chromium from solution.

To overcome the problems with carbohydrate fermentation, alkanoic salts such as sodium acetate and sodium lactate may be used as the organic food source for the bacteria. These organics degrade slower than carbohydrates and produce only minor pH effects during degradation, thus allowing the chromium to precipitate out of the groundwater. For this bench-scale test, sodium acetate was selected as the non-carbohydrate, organic food source for stimulation of biological activity. Sodium acetate is the sodium salt of vinegar and is a food grade product. The sodium acetate was evaluated at two different dosages (1,000 mg/L and 2,000 mg/L) in test samples containing 200 grams of site soil and 600 milliliters of site groundwater.

2.2.2.2 Molasses

Molasses is a by-product of the sugar refining process. When sugar cane is harvested, it is mashed and boiled to extract the sugar. After the crystallized sucrose is removed from the boiled-down solution, the remaining by-product is referred to as unsulfured molasses. If the sugar cane is too green, it is often treated with sulfur dioxide to assist in the sugar extraction process. The product of this treatment is referred to as sulfured molasses. Sugar cane is typically extracted in a three-step process. The final by-product from the last extraction is referred to as "blackstrap molasses."

Blackstrap molasses still contains a large amount of sugar, but the economics of extracting the sugar exceeds its market value. The blackstrap molasses is a dark, viscous liquid that typically contains around 20 percent sucrose, 20 percent reducing sugars, 20 percent water, 10 percent organic non-sugars, and 10 percent dissolved solids. The elevated dissolved solids and dissolved organics in the molasses give it a high fluid density of approximately 12.5 pounds per gallon. The dissolved solids in the molasses consist primarily of potassium (3 to 4 percent by weight) and calcium (1 to 2 percent by weight). However, it is also a natural chelating agent and contains many other dissolved metals. These include magnesium at around 3,000 mg/L, iron at around 300 mg/L, sodium at about 800 mg/L, copper at about 30 mg/L, zinc at about 15 mg/L, and selenium at about 0.3 mg/L.

Because of its rich nutrients and carbohydrates, blackstrap molasses is often used in cattle feed. It can usually be purchased inexpensively for less than $0.10 per pound. Because of its low price, molasses is sometimes used as an inexpensive organic food source for biological treatments to produce reducing conditions in groundwater as is currently being performed at the site. The blackstrap molasses for this bench-scale test was evaluated at three different dosages (500 mg/L, 1,000 mg/L and 2,000 mg/L) in test samples containing 200 grams of site soil and 600 milliliters of site groundwater.

2.2.2.3 Calcium Polysulfide

Sulfur atoms have the ability to catenate into linear chains of sulfur atoms to create a polysulfide salt when reacted with a metal. When sulfur is reacted with calcium metal, a calcium polysulfide salt is formed that contains anywhere from two sulfur atoms (CaS_2) to seven sulfur atoms (CaS_7) per calcium atom. The average amount of sulfur is four to five sulfur atoms per calcium atom. This material is called calcium polysulfide.

Calcium polysulfide is a NSF International approved reagent for drinking water treatment. It is a nontoxic reagent that has recently received attention as a reducing reagent for hexavalent chromium due to its ability to quickly reduce chromium without the need for acidification. When the polysulfide anion (S_5^{2-}) reacts with hexavalent chromium in the groundwater, the sulfide converts from the -2 oxidation state to the zero oxidation state, thus releasing two moles of electrons for each mole of polysulfide anion reacted.

Three test samples were prepared to evaluate calcium polysulfide as a reducing agent in a site-specific soil/groundwater system at dosages of 10, 25 and 50 mg/L. The samples were prepared using 200 grams of site soil and 600 milliliters of site groundwater.

2.2.2.4 Sodium Metabisulfite

Sodium metabisulfite is a reducing agent that is commonly used to reduce hexavalent chromium to trivalent chromium in water treatment applications. However, the reactions typically require acidic pH values to achieve reasonable kinetics. Sodium metabisulfite was tested with and without sodium hydroxide amendment at two different concentrations (250 mg/L and 500 mg/L) to determine how the pH of the groundwater would affect reaction kinetics and chromium precipitation. The test samples contained 200 grams of site soil and 600 milliliters of site groundwater.

2.2.3 Testing for Hexavalent Chromium and Total Chromium

Water samples from each of the above groups were tested for hexavalent chromium after 3, 7 and 14 days using a Hach Chromium 6^+ Test Kit. After 14 days, a water sample was removed from each sample at the highest dosage for analysis of total dissolved chromium. The samples were filtered with a 0.45-micron filter to remove any precipitated solids, and the filtered water was placed into four-ounce plastic sample containers preserved with nitric acid. The samples were then placed in a cooler on ice and shipped to Merit Laboratories in East Lansing, Michigan for total dissolved chromium analysis.

After four weeks of reaction time, additional water samples were collected from each reactor. The samples were filtered with a 0.45-micron filter, and shipped to Merit Laboratories for a final analysis of total dissolved chromium. The total dissolved chromium tests were performed to evaluate overall effectiveness of each treatment technology in removing chromium from solution.

2.3 Equipment and Materials

The following equipment/instruments were used during the treatability study:

- Ohaus GT480 Laboratory Balance
- Labconco laboratory fume hood
- 70-mm plastic weigh boats
- Stainless steel spatula
- Oakton pH meter
- Oakton ORP meter
- One-liter glass jars
- BD 10-ml Disposable Syringes
- Cole-Parmer Syringe Filter, pore size 0.45-micron
- 4-oz Nalgene HDPE wide mouth jar preserved with nitric acid
- HACH Chromium 6^+ Test Kit

The following solutions were used in the treatability study:

- Distilled water
- Calcium polysulfide (28% weight: weight)
- Sodium hydroxide (2% weight)

- Sodium metabisulfite (100% pure)
- Sodium acetate (100% pure)
- Unsulfured Blackstrap Molasses
- YSI 3682 Zobell ORP standard
- Oakton pH 7 buffer standards

3.0 RESULTS AND DISCUSSION

3.1 Test Results for Biological Activity

The site groundwater sample tested positive for anaerobic heterotrophs. The biological activity reaction chamber indicated that the initial microbial count in the groundwater was between 7,000 and 50,000 heterotrophic bacteria counts per milliliter. This shows that the groundwater and soil were not sterilized by the presence of hexavalent chromium. Therefore, electron-donor amendments may be used at this site for purposes of stimulating biological processes that result in secondary reduction of chromium.

3.2 Batch Reaction Tests for Chromium Reduction

The pH and ORP of the groundwater in the batch reaction tests were monitored over a one-month testing period. During this time-frame, samples were collected periodically from the batch reaction tests for analyses of hexavalent chromium until the results were below detection limits of 0.05 mg/L. On the 14th day and 28th day of the test, samples were analyzed for total dissolved chromium to evaluate total chromium removal efficiency. The results of the testing are summarized below with respect to each of the test groups.

3.2.1 Sodium Acetate

The sodium acetate solutions slowly degraded as a result of biological activity over the 28-day test period. The most notable drop in ORP occurred during the first 14 days of the test, with the ORP stabilizing in the range of -50 to -100 mV thereafter. The ORP of the sodium acetate solutions are shown as a function of time in Table 1 and are illustrated in Figure 1. The decrease in ORP was noted to occur slightly faster with increased dosage. As the acetate degraded, a sour odor developed in the samples. The pH of the sodium acetate systems decreased only slightly during the testing period, starting at an original pH of approximately 7.0 and ending at a pH value of approximately 6.7. The pH data for the sodium acetate test groups are shown in Table 2 and are illustrated in Figure 2.

Little reduction of hexavalent chromium was initially observed in the sodium acetate samples during biological acclimation. However, the concentrations began to decrease around the 7th day of the study. Hexavalent chromium was reduced to 0.1 mg/L by the 14th day of the study, and the concentrations were below detection limits of 0.05 mg/L by the 28th day of the study. The hexavalent chromium concentrations as a function of time are summarized in Table 3 and are illustrated in Figure 3. Assuming a first-order reaction for reductive kinetics, the data suggests that the hexavalent chromium was being reduced at a pseudo first order reaction rate constant of 0.047 days^{-1} which is equivalent to a half life of approximately 15 days.

The sample containing 1,000 mg/L sodium acetate maintained a clear appearance throughout the study. The 2,000 mg/L sodium acetate turned slightly turbid during the last week of the study. Both samples had a slightly sour odor but did not contain any suspended solids as a result of the treatment.

3.2.2 Molasses

The solutions of molasses degraded very quickly after they were placed into the batch reaction containers. This is not unexpected since molasses is rich in carbohydrates, and carbohydrates are degraded rapidly by many types of bacteria. The ORP of all three test groups dropped to below -100 mV within the first week of the study and remained in this highly negative range throughout the duration of the test. The ORP of the molasses solutions are shown as a function of time in Table 4 and are illustrated in Figure 4. The ORP decrease occurred slightly faster with increased dosage. As the molasses degraded, all three test samples turned dark brown in color and developed a strong sewage odor. White gelatinous solids (presumably biosolids) became suspended within all three test samples with the amount of solids increasing proportionally with dosage.

As the molasses degraded, a notable drop in the pH of the samples was observed. The samples originally started at a pH of approximately 7.0, but ended pH values in the range of 5.42 to 5.92. The pH of the solutions decreased proportional to the dosage of molasses addition. The pH data for the molasses test groups are shown in Table 5 and are illustrated in Figure 5.

Hexavalent chromium reduction occurred quickly in the samples dosed with molasses. The hexavalent chromium concentrations were all below the detection limits of 0.05 mg/L when analyzed on the third day of the test. The fast kinetics are likely partially due to the high concentrations of dissolved iron in the molasses. Assuming a first-order reaction for reductive kinetics, the data suggest that hexavalent chromium was being reduced at a pseudo first order reaction rate constant in excess of 0.4 days^{-1}.

3.2.3 Calcium Polysulfide

The solutions treated with low dosages of calcium polysulfide showed gradual reduction in ORP over time. The gradual reduction in ORP suggested possible under-dosage. However, when samples of the water were tested for hexavalent chromium on the third day of the test, all three samples were below detection limits of 0.05 mg/L. The concentration of hexavalent chromium over time in the calcium polysulfide group is shown in Figure 13. A sample collected on the 14th day of the test from the 50 mg/L dosage sample also showed that the total chromium in the sample had been reduced to 0.006 mg/L. These results are shown as a function of time in Figure 12. This shows that the calcium polysulfide serves as a very effective treatment reagent despite the fact that significant ORP decreases were not observed in the test water at low dosages. The ORP of the calcium polysulfide solutions are shown as a function of time in Table 6 and are illustrated in Figure 6. Assuming a first order reaction for reductive kinetics, the calcium polysulfide reduced hexavalent chromium at a pseudo first order reaction rate constant that exceeded 0.4 days^{-1}. The calcium polysulfide samples remained translucent throughout the study without the formation of odors or solids in the samples. The pH of the samples were monitored over the course of the testing. The pH's of the samples versus time is shown graphically in Figure 14. There was no significant change in pH over the time of testing.

3.2.4 Sodium Metabisulfite

Sodium metabisulfite was tested at two different pH values to determine how both pH and concentration would affect the results. The sodium metabisulfite at pH 7 slowly reduced the ORP of the test systems. The lowest dosage of sodium metabisulfite produced the fastest drop in ORP. The ORP of the metabisulfite samples at pH 7 are shown as a function of time in Table 7 and are illustrated in Figure 7.

The sodium metabisulfite at pH 10 had a more dramatic decrease in ORP which was likely the result of the higher pH values. The ORP of the metabisulfite samples at pH 10 also approached negative values by the end of the study. These data are shown as a function of time in Table 8 and are illustrated in Figure 8. No significant difference was noted as a function of sample dosage.

The reduction of hexavalent chromium in the sodium metabisulfite samples occurred slowly over time. The reaction kinetics were a function of both dosage and pH. Higher concentrations of sodium metabisulfite provided faster kinetics as did lower pH values. Although the kinetics were somewhat slow, each of the sodium metabisulfite test groups were able to reduce the concentrations of hexavalent chromium to below detection limits of 0.05 mg/L by the end of the study. The hexavalent chromium concentrations for the sodium metabisulfite samples at pH 7 and 10 are shown in Tables 9 and 10, respectively. The data are also illustrated graphically in Figures 9 and 10.

Assuming a first order reaction for reductive kinetics, the data suggest that the hexavalent chromium was being reduced at a pseudo first order reaction rate constant of 0.08 days^{-1} at pH 7 with a dosage of 250 mg/L. The reaction rate constant increased to 0.17 days^{-1} when the dosage was increased to 500 mg/L. The test samples at pH 10 had similar kinetics with a pseudo first order reaction rate constant of approximately 0.04 days^{-1}. The samples treated with sodium metabisulfite remained translucent throughout the study without the formation of odors or solids in the samples.

3.3 Total Chromium Removal Evaluation

In-situ treatment of hexavalent chromium requires a two-step process. In the first step, the chromium must be reduced from its hexavalent state to its trivalent state. As the bench-scale testing demonstrates, many different types of chemicals can achieve the first step. However, the second step is equally important. In the second step, the trivalent chromium must precipitate from solution to reduce the concentration of dissolved chromium in the groundwater. If the treatment only reduces chromium but does not remove it from solution, then no real progress has been made with respect to achieving maximum contaminant levels (MCLs).

After 14 days of testing, a water sample was removed from each of the test groups (except the sodium acetate group) from the sample group's highest dosed sample for analyses of total dissolved chromium. These samples were collected to provide a mid-test view of how each treatment reagent was performing with respect to achieving MCLs. The sodium acetate group was not sampled as part of this test because the hexavalent chromium analyses indicated that the hexavalent chromium was still above the MCLs.

The water samples were each filtered with a 0.45-micron filter, and the filtrate was placed into a four-ounce plastic sampling container preserved with nitric acid. The samples were shipped to Merit Laboratories on ice for analyses of total dissolved chromium. The results of the analyses are shown in Table 11.

The results showed that the calcium polysulfide treatment at 50 mg/L had already achieved chromium removal to well below the MCLs. However, none of the other samples had achieved MCLs during the initial 14-day test period. The metabisulfite samples had removed between 42 to 55 percent of the total chromium from the groundwater after 14 days and the molasses treatment had removed only 11 percent of the total dissolved chromium.

After 28 days of testing, samples of water were removed from all of the samples in each test group for analyses. The samples were filtered with a 0.45-micron filter and the filtrates were placed into four-ounce, nitric-preserved, plastic containers. The samples were placed on ice inside a cooler and shipped to Merit Laboratories for analyses of total dissolved chromium. The results of these analyses are shown in Table 12.

Most of the samples tested after 28 days showed good removal for chromium from the groundwater. The three calcium polysulfide samples had reduced the total concentration of chromium in solution to between 0.006 and 0.015, well below the MCL of 0.1 mg/L. The sodium metabisulfite samples and sodium acetate samples also performed well, producing total dissolved chromium numbers ranging from less than detection limits of 0.005 mg/L to 0.062 mg/L. Of the samples tested, only the molasses appeared to perform poorly for removal of total chromium. The total chromium concentrations in the samples treated with molasses ranged from 0.129 to 0.25 mg/L total chromium. All of the values were above the MCLs, and the data showed that the amount of dissolved chromium in the groundwater increased with increased dosages of molasses. This effect is likely the result of acidity released by the fermentation of the molasses.

Table 13 shows a summary of the treatment efficiencies for the highest dosage of each treatment chemical evaluated. The results are also illustrated graphically in Figure 11. The results show that the sodium metabisulfite, calcium polysulfide and sodium acetate treatments were all able to provide greater than 95 percent removal efficiency for total chromium from the groundwater. The molasses, however, was only able to remove 20 percent of the total dissolved chromium. Since hexavalent chromium testing showed that the molasses was very successful in reducing the chromium from its hexavalent state to its trivalent state, the elevated chromium concentrations are likely the result of groundwater acidification and possible chelating effects.

3.4 Cost Analysis

The results of the testing show that calcium polysulfide and sodium metabisulfite are the most effective methods of treatment. The cost of each of these chemicals is between $2.00 and $2.50 per pound depending on the vendor. Because the cost of each chemical is relatively the same, it is important to look at the concentrations of the chemicals needed to for effective treatment. Sodium metabisulfite effective as low as 250 ppm would cost between $4,170 and $5,210 per million gallons of water treated. Calcium polysulfide at its most effective concentration of 50 ppm would cost between $830 and $1045 per million gallons of water treated. The 10 ppm concentration of calcium polysulfide also lowed hexavalent chromium below detection limits of 0.05 mg/L and total chromium to 0.015 mg/L, below the standard of 0.1 mg/L, would cost between $166 and $209 per million gallons of water treated.

4.0 CONCLUSIONS AND RECOMMENDATONS

The following conclusions can be drawn from the treatability testing:

- Non-carbohydrate organics, such as sodium lactate, can be used in place of molasses to achieve effective in-situ reduction of chromium by creating biologically-induced reducing conditions;
- Alkanoic salts like sodium acetate and sodium lactate can also provide pH buffering to prevent the groundwater pH from falling too low during biodegradation processes;
- Metabisulfite can be utilized to reduce and precipitate hexavalent chromium *in-situ*, and reduced kinetics at higher pH values can be overcome by the use of increased dosage concentrations;
- Calcium polysulfide provided the best treatment results at the lowest chemical dosage without significant interference from reactions with the soil;
- Calcium polysulfide and molasses provided the fastest reaction kinetics for chromium reduction, but sodium metabisulfite and sodium acetate were also able to complete reduce the hexavalent chromium with 28 days at dosages of 500 mg/L and 2,000 mg/L, respectively; and
- A low pH developed in the molasses-treated samples from the fermentation of the molasses. The low pH and possible chelating effects of the molasses prevented the chromium from precipitating from solution, thus resulting in a total dissolved chromium removal efficiency of only 20 percent.

The following recommendations can be drawn from the conclusions of this study:

- Molasses treatment should be discontinued since bench-testing indicates that it will reduce the pH of the groundwater and retain dissolved metals in solution. Site data collected by Arcadis showing site groundwater pH values as low 4.37 and dissolved calcium concentrations in excess of 3,000 mg/L corroborate with this observation; and
- Treatment with calcium polysulfide is recommended in place of the molasses treatment since it provides rapid and economic treatment kinetics while increasing the alkalinity of the groundwater to effectively remove dissolved chromium from solution.

Table 1: Sodium Acetate Test Group - ORP (mV)

Day	1,000 mg/l	2,000 mg/l
0	155	155
3	125	112
7	50	25
14	-53	-90
28	-42	< -100

Table 2: Sodium Acetate Test Group - pH versus Time

Day	1,000 mg/l	2,000 mg/l
0	6.97	6.97
3	6.84	7.02
7	6.85	6.93
14	6.82	6.82
28	6.73	6.7

Table 3: Sodium Acetate Test Group - Hex Chrome (mg/l)

Day	1,000 mg/l	2,000 mg/l
0	0.3	0.3
3	0.3	0.3
7	0.25	0.2
14	0.15	0.15
28	< 0.05	< 0.05

Table 4: Molasses Test Group - ORP (mV)

Day	500 mg/l	1,000 mg/l	2,000 mg/l
0	155	155	155
3	-40	-80	-101
7	< -100	< -100	< -100
14	< -100	< -100	< -100
28	< -100	< -100	< -100

Table 5: Molasses Test Group - pH versus Time

Day	500 mg/l	1,000 mg/l	2,000 mg/l
0	6.97	6.97	6.97
3	6.85	6.67	6.43
7	6.55	6.34	6.13
14	5.98	5.77	5.46
28	5.92	5.67	5.42

Table 6: Calcium Polysulfide Test Group - ORP (mV)

Day	10 mg/l	25 mg/l	50 mg/l
0	155	155	155
3	137	141	125
7	90	96	101
14	74	75	73
28	40	36	34

Table 7: Metabisulfite @ pH 7 Test Group - ORP (mV)

Day	250 mg/l	500 mg/l
0	155	155
3	72	154
7	60	104
14	60	72
28	49	52

Table 8: Metabisulfite @ pH 10 Test Group - ORP (mV)

Day	250 mg/l	500 mg/l
0	155	155
3	72	107
7	60	82
14	11	8
28	2	-1

Table 9: Metabisulfite @ pH 7 Test Group - Hex Chrome (mg/l)

Day	250 mg/l	500 mg/l
0	0.3	0.3
3	0.25	0.15
7	0.1	< 0.05
14	< 0.05	< 0.05

Table 10: Metabisulfite @ pH 10 Test Group - Hex Chrome (mg/l)

Day	250 mg/l	500 mg/l
0	0.3	0.3
3	0.3	0.15
7	0.15	0.1
14	0.1	0.1
28	< 0.05	< 0.05

Table 11: 14-Day Test Results for Total Chromium

Sample I.D.	Dissolved Cr (mg/l)
Control	0.313
Calcium Polysulfide	0.006
Molasses	0.278
Sodium Metabisulfite (pH 7)	0.14
Sodium Metabisulfite (pH 10)	0.18

Table 12: 28-Day Test Results for Total Chromium

Sample I.D.	Reagent Dose (mg/l)	Dissolved Cr (mg/l)
Sodium Metabisulfite (pH 7)	250	0.062
Sodium Metabisulfite (pH 7)	500	< 0.005
Sodium Metabisulfite (pH 10)	250	0.048
Sodium Metabisulfite (pH 10)	500	0.027
Molasses	500	0.129
Molasses	1000	0.199
Molasses	2000	0.25
Calcium Polysulfide	10	0.015
Calcium Polysulfide	25	0.01
Calcium Polysulfide	50	0.006
Sodium Acetate	1000	0.033
Sodium Acetate	2000	0.011

Highlighted samples exceed the MCL of 0.1 mg/l Cr

Table 13: Treatment Efficiency for Total Chromium Removal

Sample I.D.	**Reagent Dose (mg/l)**	**Removal Efficiency**
Sodium Metabisulfite (pH 7)	500	98.4%
Sodium Metabisulfite (pH 10)	500	91.4%
Molasses	2000	20.1%
Calcium Polysulfide	50	98.1%
Sodium Acetate	2000	96.5%

Figure 1

Sodium Acetate Test Group - ORP versus Time

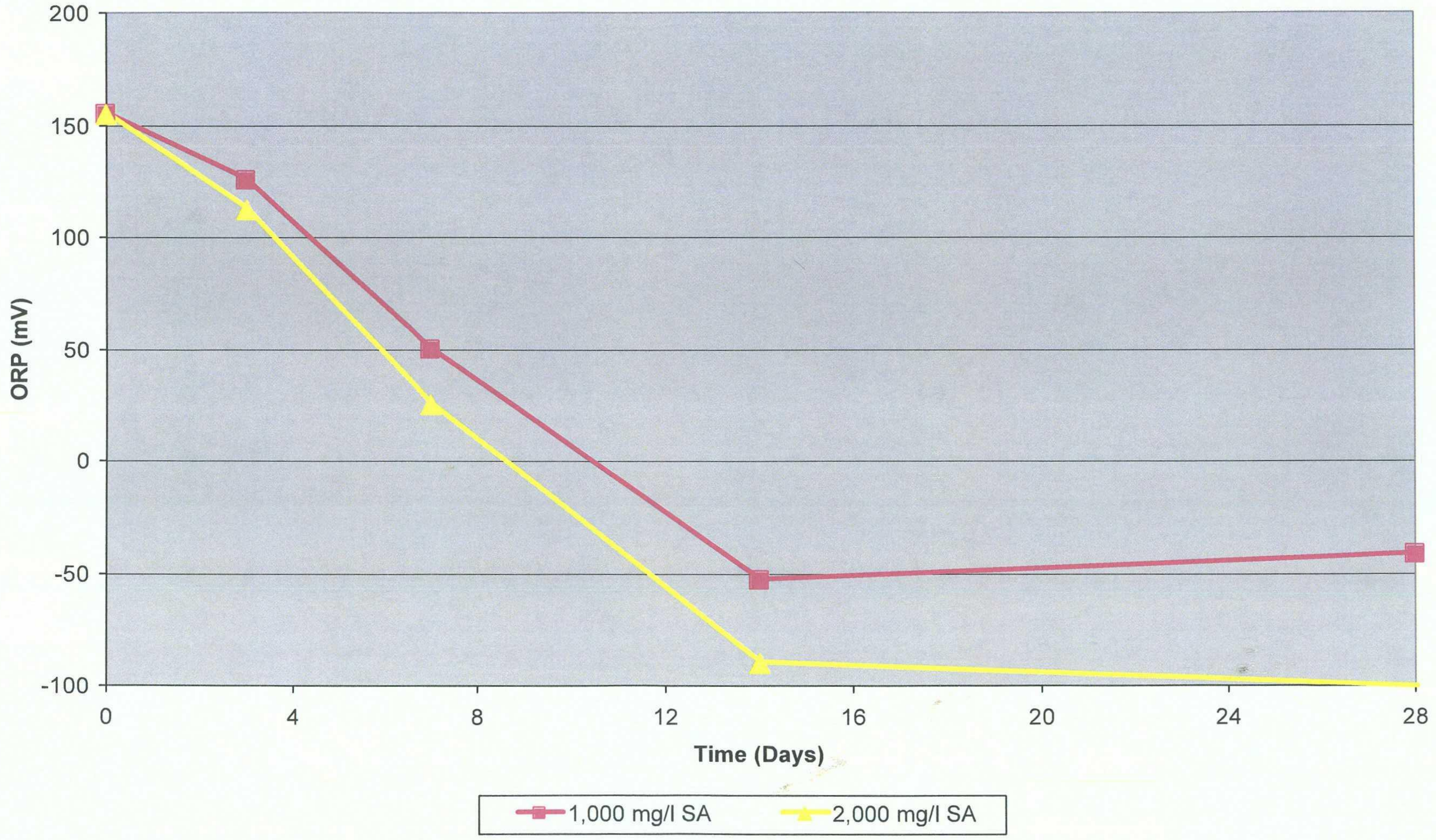


Figure 2
Sodium Acetate Test Group - pH versus Time

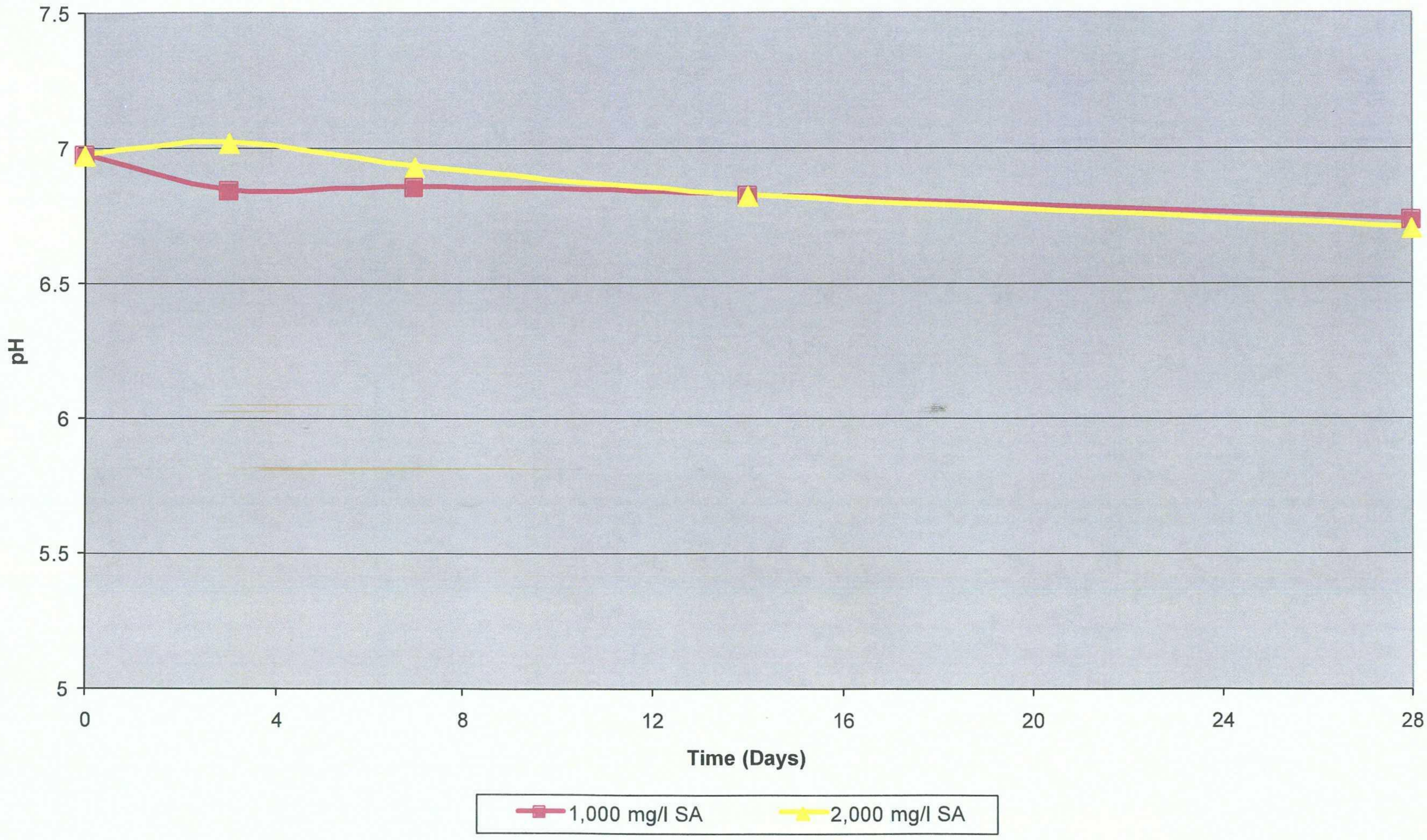


Figure 3

Sodium Acetate Test Group

Hex Chrome Concentration versus Time

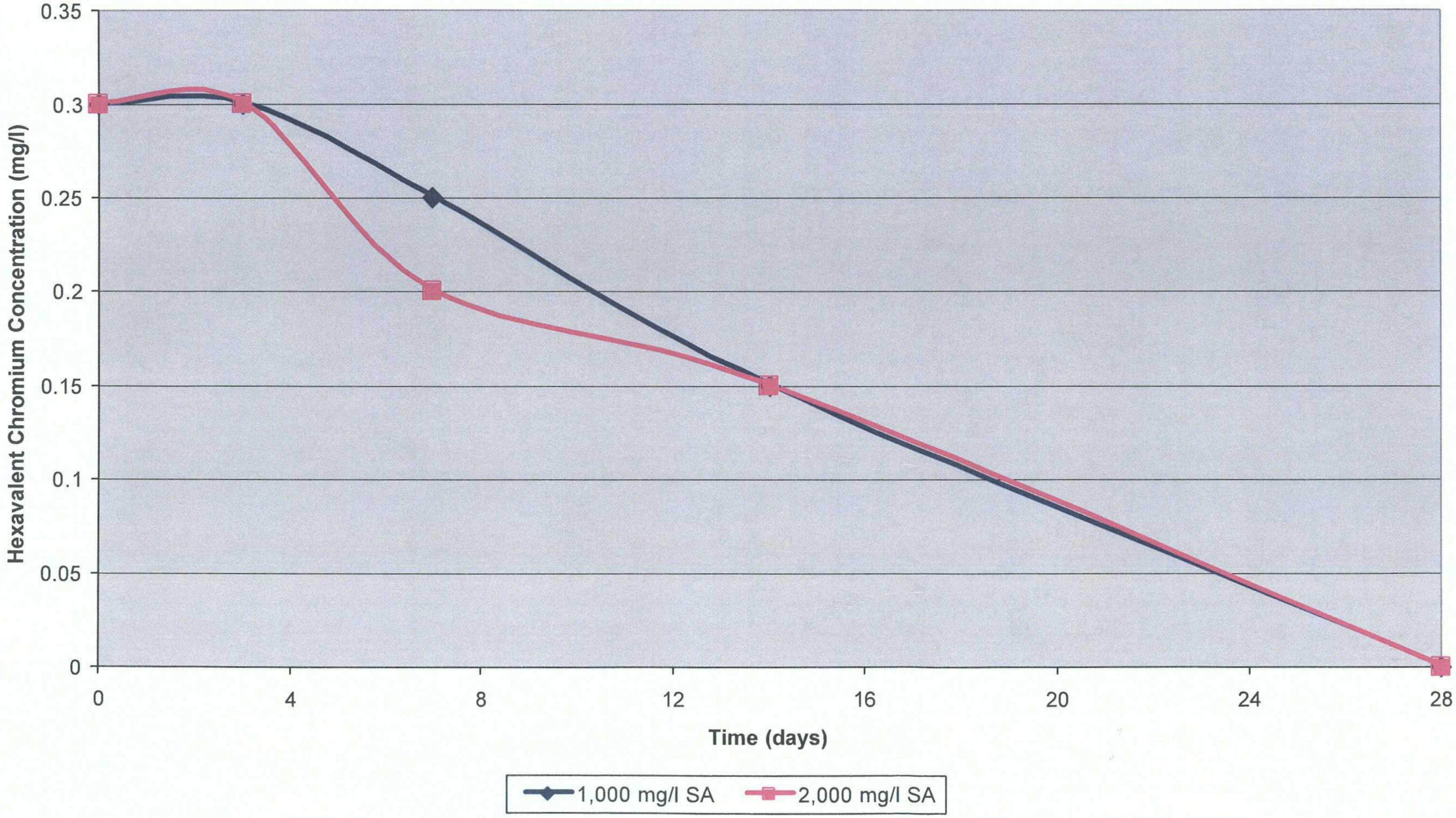


Figure 4

Molasses Test Group - ORP versus Time

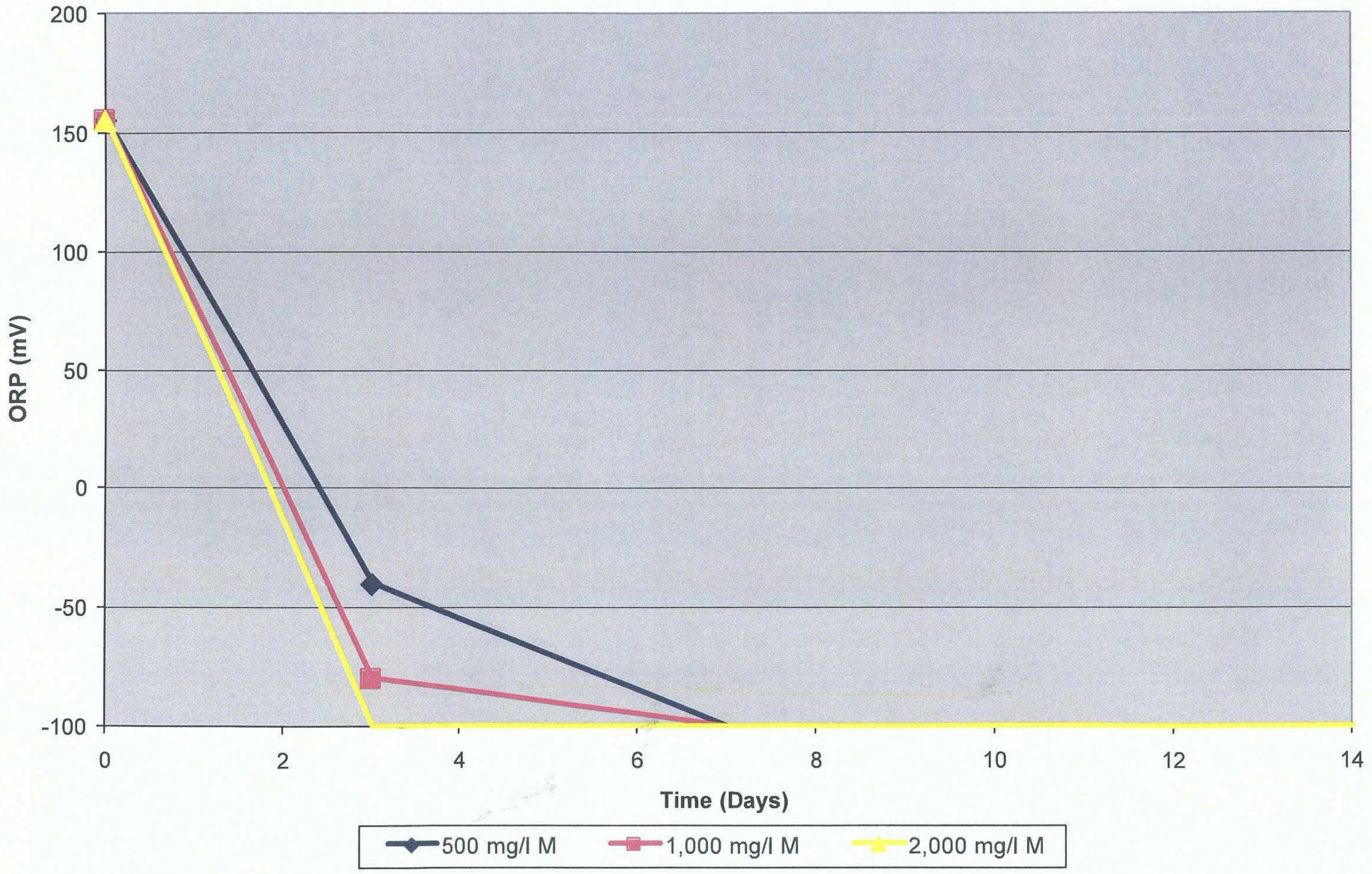


Figure 5

Molasses Test Group - pH versus Time

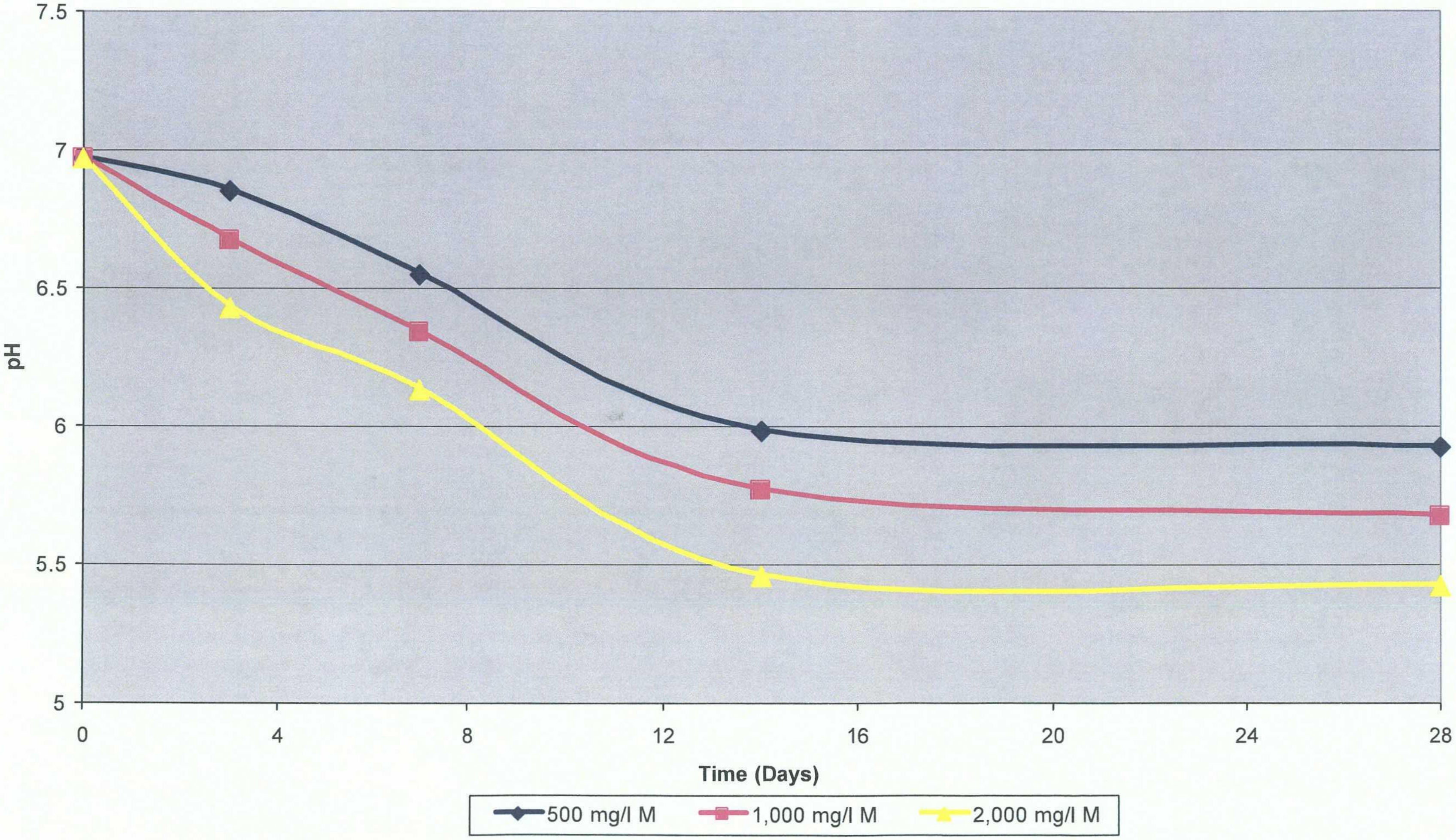


Figure 6

Calcium Polysulfide Test Group - ORP versus Time

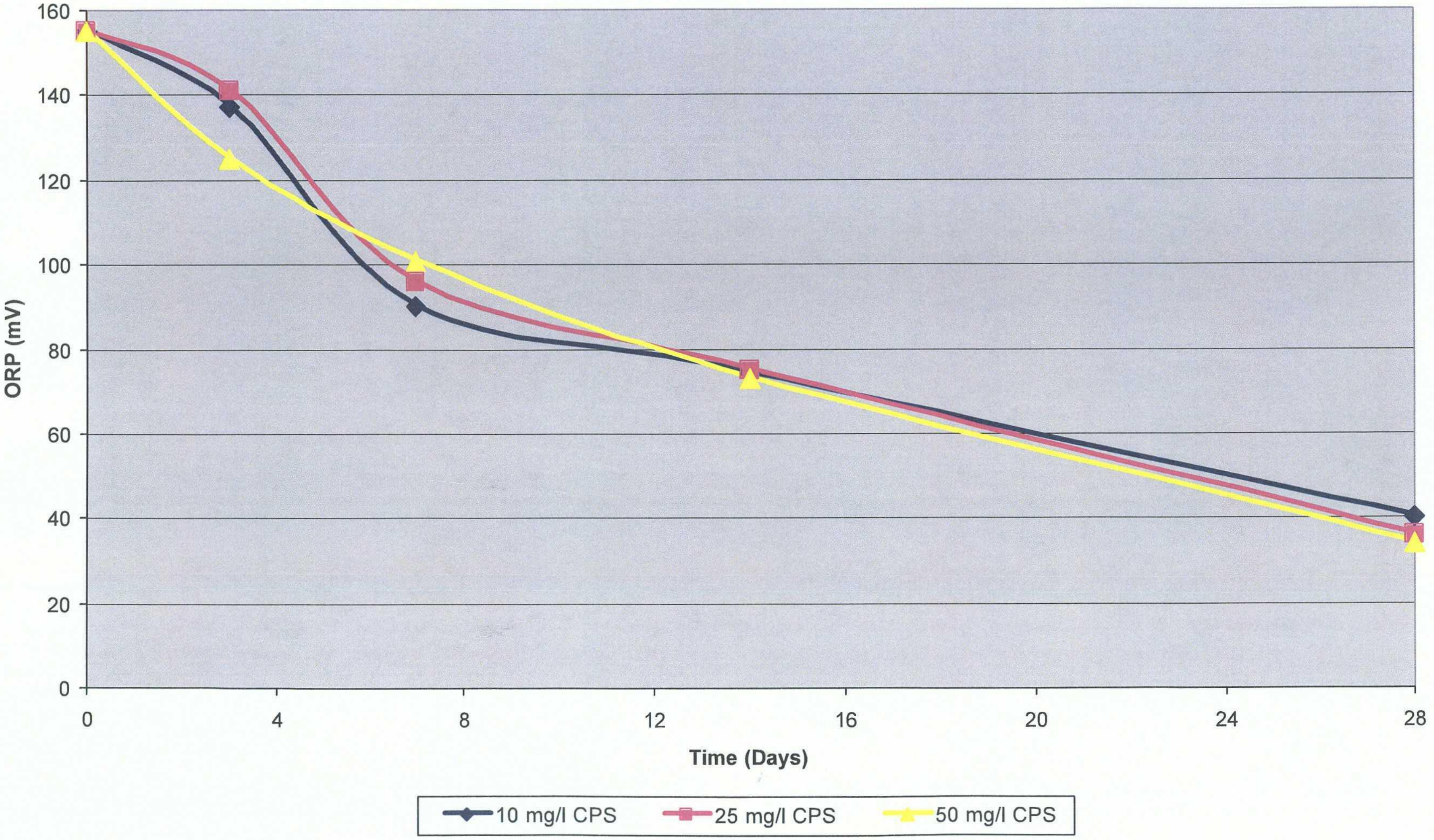


Figure 7

Metabisulfite Test Group @ pH 7 - ORP versus Time

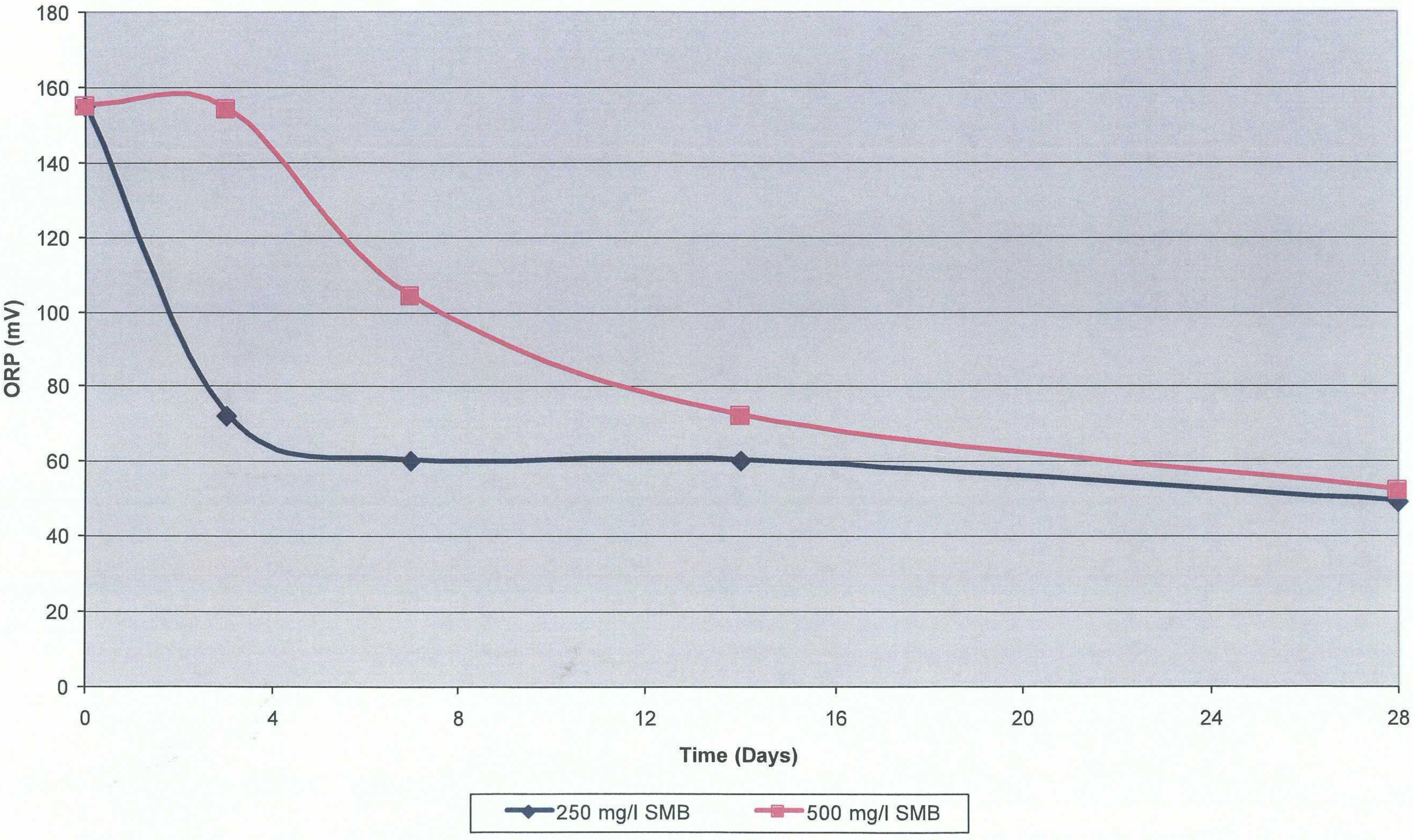


Figure 8

Metabisulfite Test Group @ pH 10 - ORP versus Time

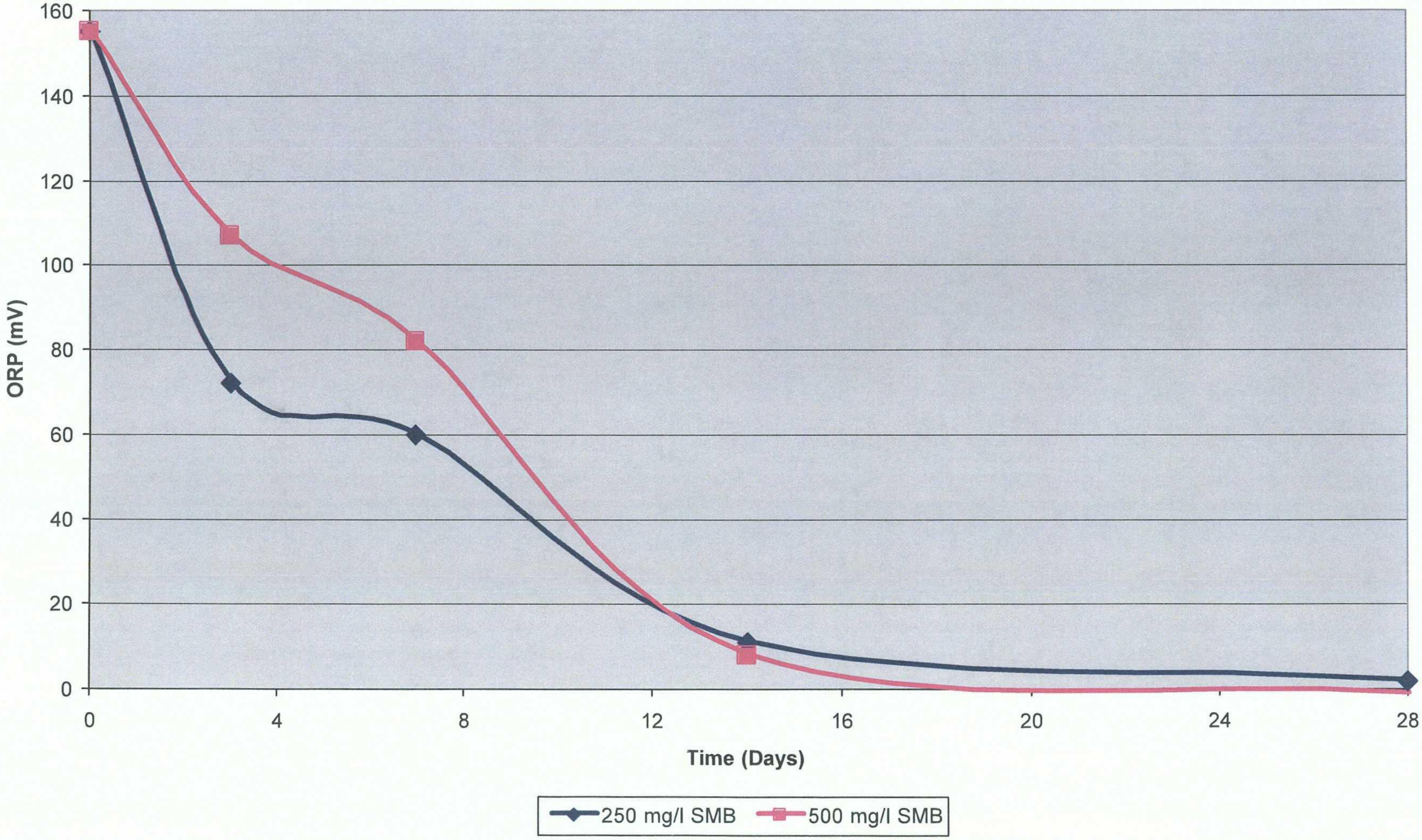


Figure 9

Metabisulfate at pH 7 Test Group
Hex Chrome Concentration verus Time

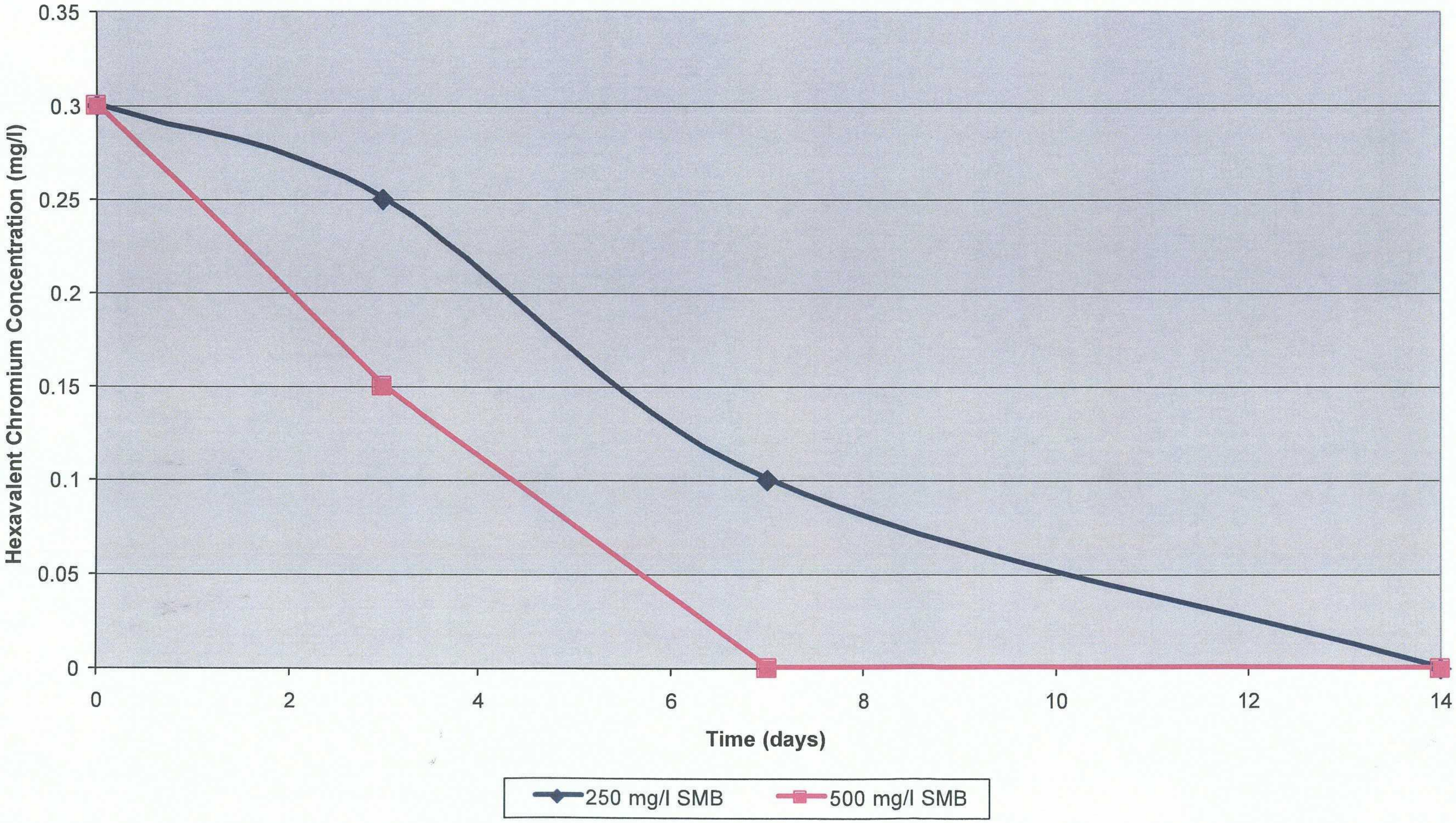


Figure 10

Metabisulfate at pH 10 Test Group
Hex Chrome Concentration verus Time

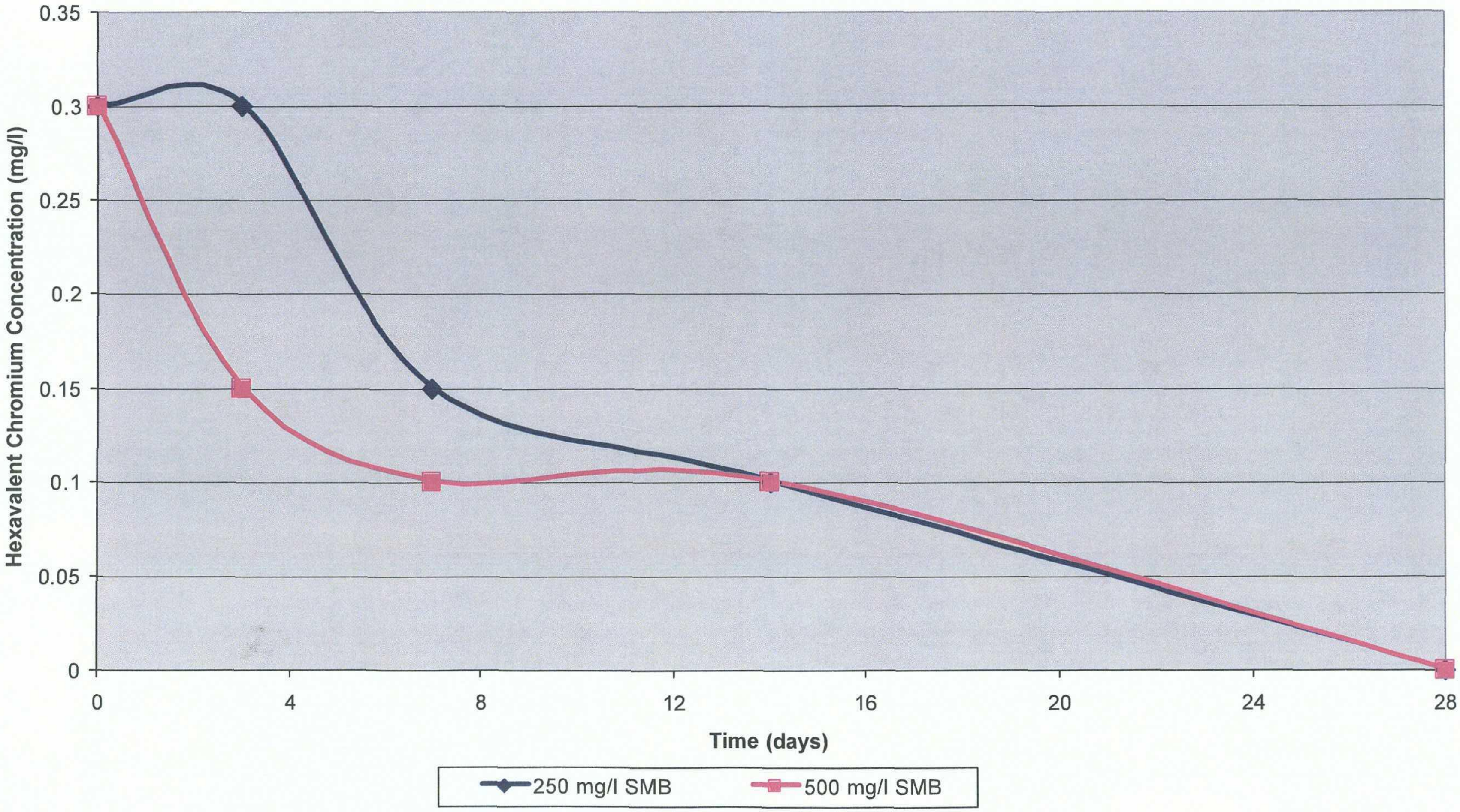


Figure 11

Treatment Efficiency for Total Chromium Removal

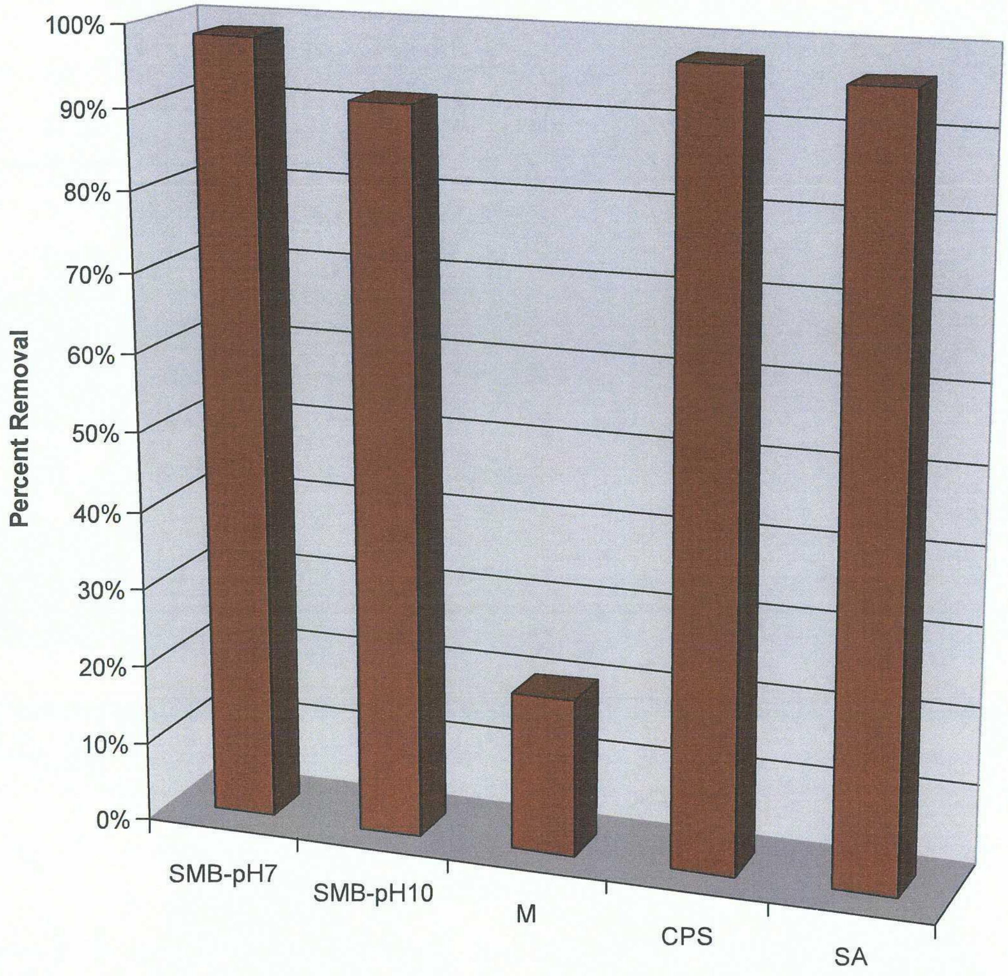


Figure 12
Calcium Polysulfide Test Group
Total Chrome Concentraion versus Time

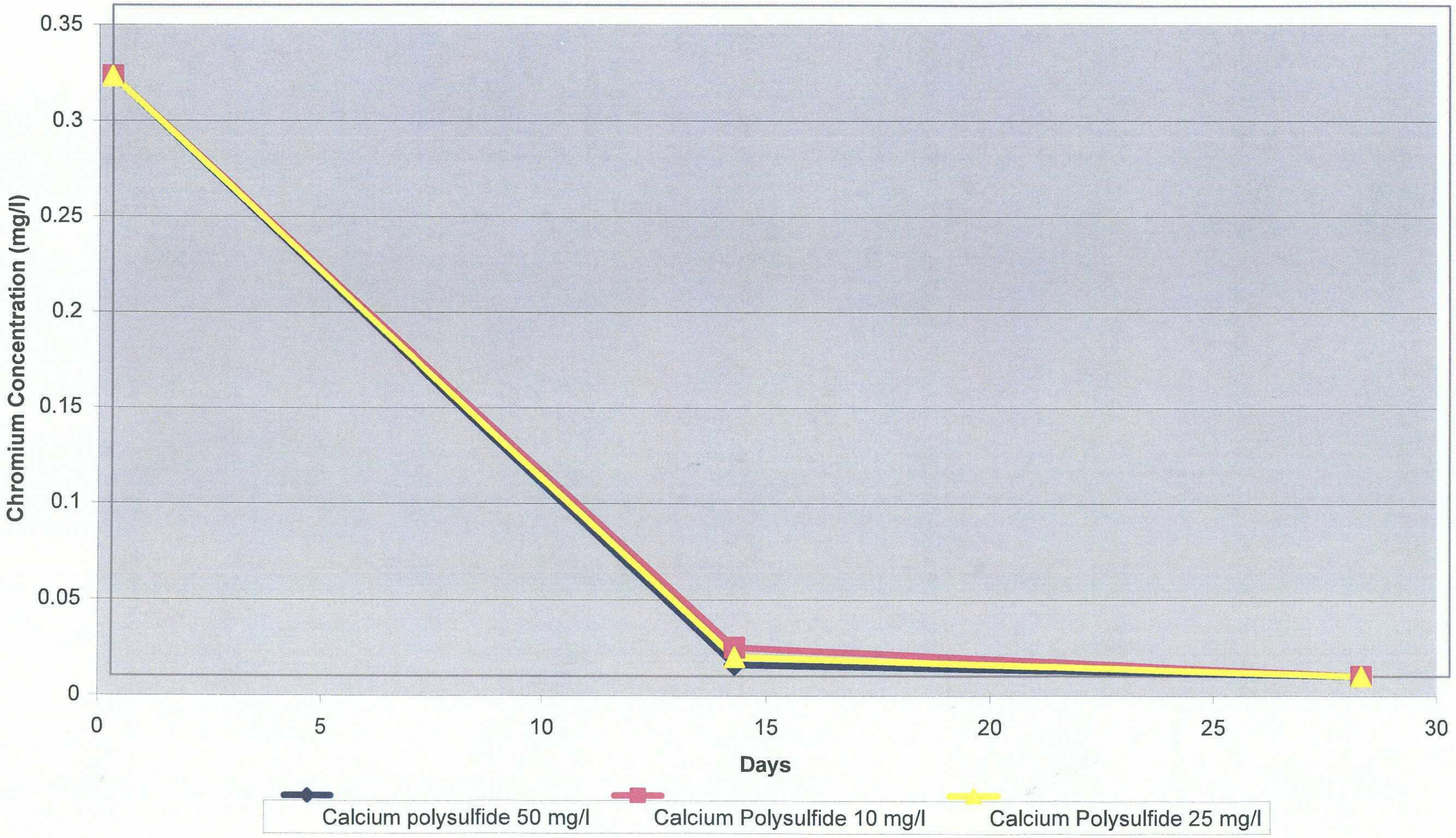


Figure 13
Calcium Polysulfide Test Group
Hex Chrome Concentration versus Time

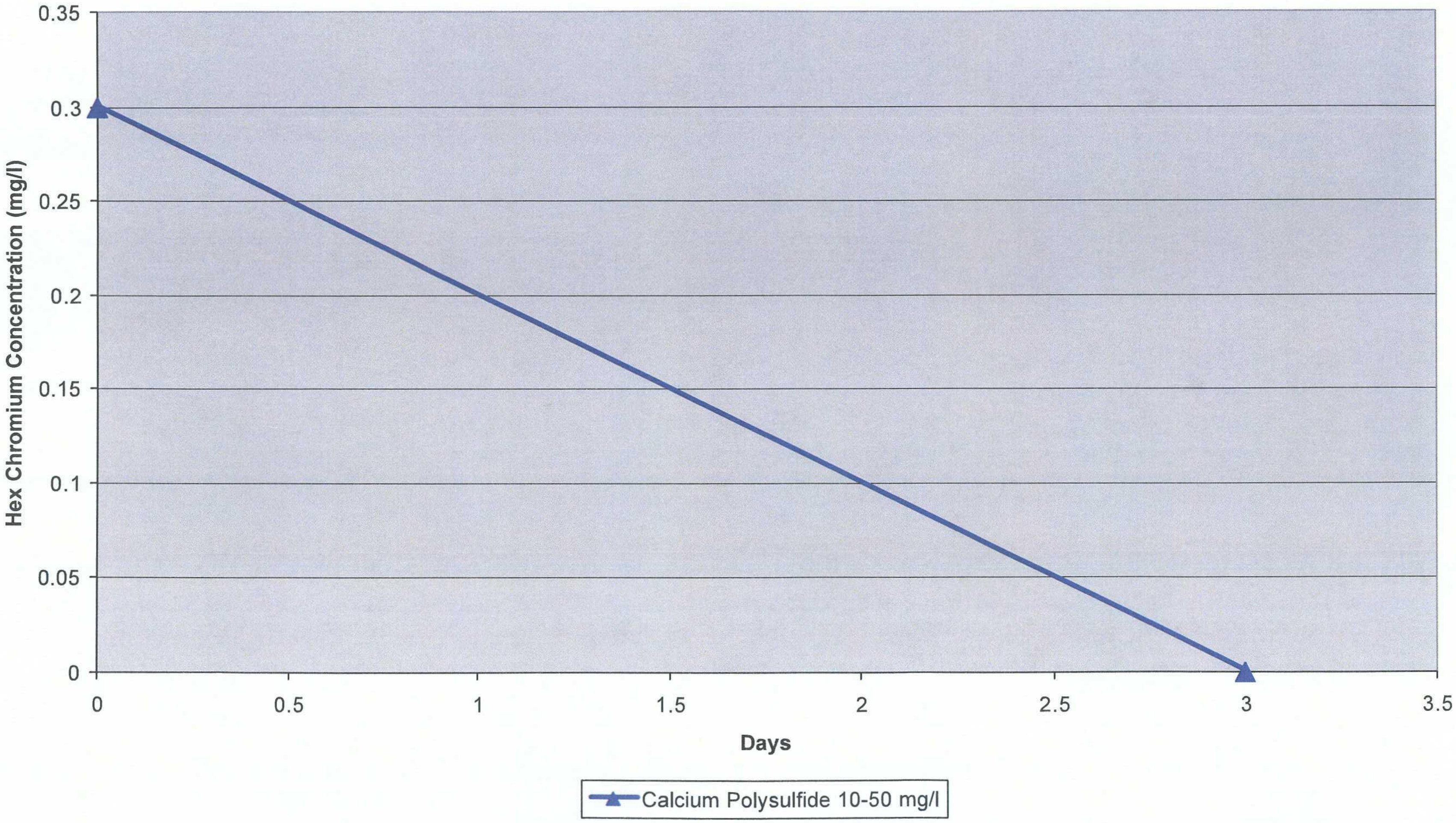
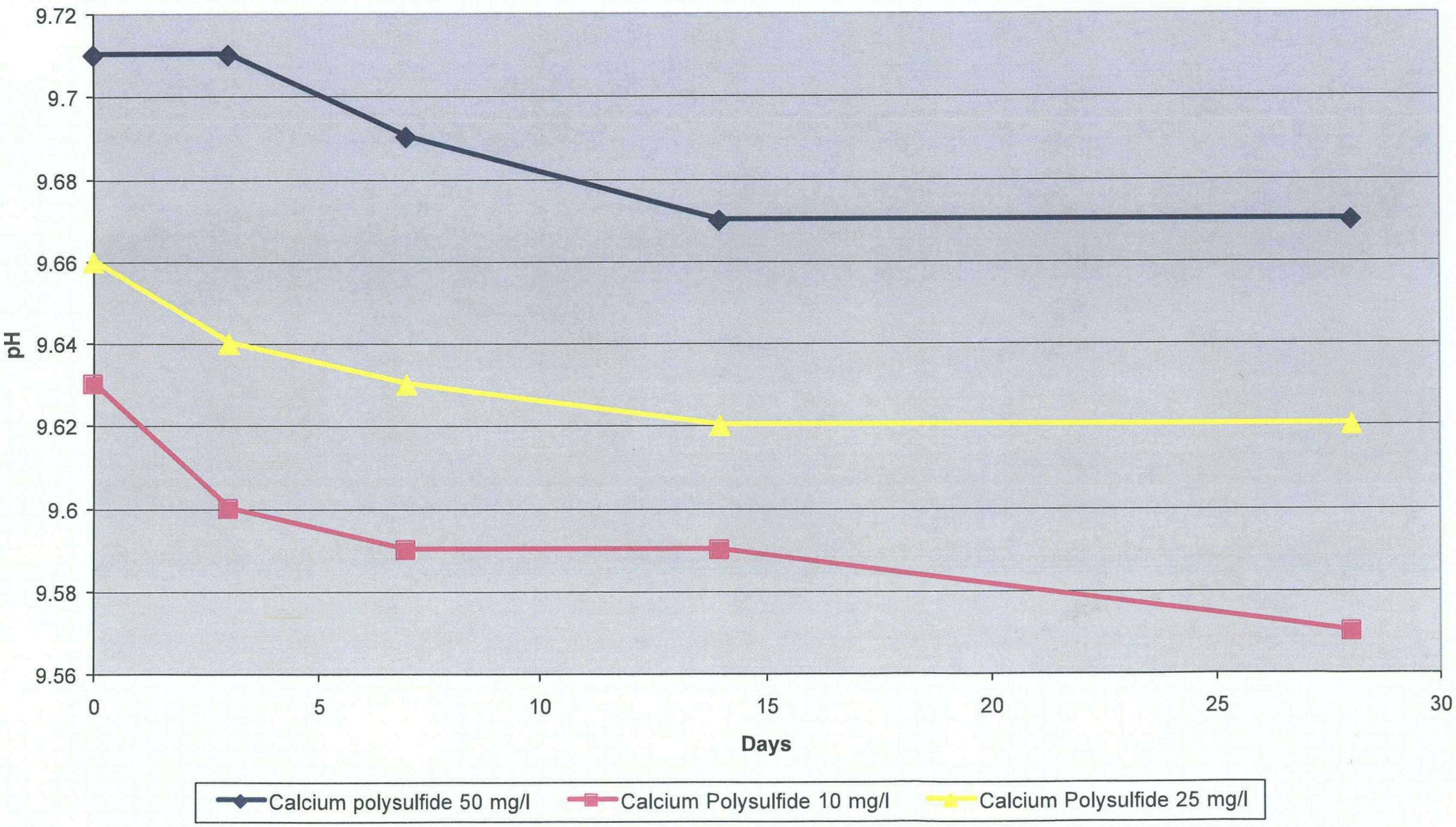


Figure 14
Calcium Polysulfide Test Group
pH versus Time



APPENDIX B
MSDS SHEETS

In-Situ Pilot Study Work Plan
for the Eunice North Gas Plant

Chevron Environmental Management Company
89CH.49526.07
May 21, 2007

MSDS Number: **S2954** * * * * * *Effective Date:* ***05/23/06*** * * * * * *Supercedes:* ***09/12/03***

MSDS *Material Safety Data Sheet*

24 Hour Emergency Telephone: 908-859-2151
CHEMTREC: 1-800-424-9300

National Response in Canada
CANUTEC: 613-996-6666

Outside U.S. and Canada
Chemtrec: 703-527-3887

NOTE: CHEMTREC, CANUTEC and National Response Center emergency numbers to be used only in the event of chemical emergencies involving a spill, leak, fire, exposure or accident involving chemicals.

From: Mallinckrodt Baker, Inc.
222 Red School Lane
Phillipsburg, NJ 08865

Mallinckrodt CHEMICALS

J.T.Baker

All non-emergency questions should be directed to Customer Service (1-800-582-2537) for assistance.

SODIUM BICARBONATE

1. Product Identification

Synonyms: Sodium hydrogen carbonate; sodium acid carbonate; baking soda; bicarbonate of soda
CAS No.: 144-55-8
Molecular Weight: 84.01
Chemical Formula: $NaHCO_3$
Product Codes:
J.T. Baker: 3506, 3508, 3509, 3510
Mallinckrodt: 7285, 7396, 7397, 7412, 7749, 7903

2. Composition/Information on Ingredients

Ingredient	CAS No	Percent	Hazardous
Sodium Bicarbonate	144-55-8	99 - 100%	No

3. Hazards Identification

Emergency Overview

As part of good industrial and personal hygiene and safety procedure, avoid all unnecessary exposure to the chemical substance and ensure prompt removal from skin, eyes and clothing.

SAF-T-DATA$^{(tm)}$ Ratings (Provided here for your convenience)

Health Rating: 1 - Slight
Flammability Rating: 1 - Slight
Reactivity Rating: 1 - Slight
Contact Rating: 1 - Slight
Lab Protective Equip: GOGGLES; LAB COAT
Storage Color Code: Green (General Storage)

Potential Health Effects

Inhalation:
High concentrations of dust may cause coughing and sneezing.
Ingestion:
Extremely large oral doses may cause gastrointestinal disturbances.
Skin Contact:
No adverse effects expected.
Eye Contact:
Contact may cause mild irritation, redness, and pain.
Chronic Exposure:
No information found.
Aggravation of Pre-existing Conditions:
No information found.

---

4. First Aid Measures

Inhalation:
Remove to fresh air. Get medical attention for any breathing difficulty.
Ingestion:
Give several glasses of water to drink to dilute. If large amounts were swallowed, get medical advice.
Skin Contact:
Not expected to require first aid measures.

Eye Contact:
Wash thoroughly with running water. Get medical advice if irritation develops.

5. Fire Fighting Measures

Fire:
Not considered to be a fire hazard.
Explosion:
Not considered to be an explosion hazard.
Fire Extinguishing Media:
Use any means suitable for extinguishing surrounding fire.
Special Information:
Use protective clothing and breathing equipment appropriate for the surrounding fire.

6. Accidental Release Measures

Ventilate area of leak or spill. Wear appropriate personal protective equipment as specified in Section 8. Spills: Sweep up and containerize for reclamation or disposal. Vacuuming or wet sweeping may be used to avoid dust dispersal. Small amounts of residue may be flushed to sewer with plenty of water.

7. Handling and Storage

Keep in a well closed container stored under cold to warm conditions, 2 to 40 C, (36 to 104F). Protect against physical damage. Containers of this material may be hazardous when empty since they retain product residues (dust, solids); observe all warnings and precautions listed for the product.

8. Exposure Controls/Personal Protection

Airborne Exposure Limits:
None established.
Ventilation System:
In general, dilution ventilation is a satisfactory health hazard control for this substance. However, if conditions of use create discomfort to the worker, a local exhaust system should be considered.
Personal Respirators (NIOSH Approved):
For conditions of use where exposure to dust or mist is apparent and engineering controls

are not feasible, a particulate respirator (NIOSH type N95 or better filters) may be worn. If oil particles (e.g. lubricants, cutting fluids, glycerine, etc.) are present, use a NIOSH type R or P filter. For emergencies or instances where the exposure levels are not known, use a full-face positive-pressure, air-supplied respirator. WARNING: Air-purifying respirators do not protect workers in oxygen-deficient atmospheres.

Skin Protection:

Wear protective gloves and clean body-covering clothing.

Eye Protection:

Use chemical safety goggles. Maintain eye wash fountain and quick-drench facilities in work area.

9. Physical and Chemical Properties

Appearance:

White crystalline powder.

Odor:

Odorless.

Solubility:

7.8g/100g water @ 18C (64F).

Density:

2.2

pH:

8.3 (0.1 molar @ 25C (77F))

% Volatiles by volume @ 21C (70F):

0

Boiling Point:

Not applicable.

Melting Point:

60C (140F)

Vapor Density (Air=1):

No information found.

Vapor Pressure (mm Hg):

No information found.

Evaporation Rate (BuAc=1):

No information found.

10. Stability and Reactivity

Stability:

Stable under ordinary conditions of use and storage.

Hazardous Decomposition Products:

Gaseous carbon dioxide.

Hazardous Polymerization:

Will not occur.
Incompatibilities:
Reacts with acids to form carbon dioxide. Dangerous reaction with monoammonium phosphate or a sodium-potassium alloy.
Conditions to Avoid:
Heat, moisture, incompatibles.

11. Toxicological Information

Investigated as a mutagen, reproductive effector. Oral rat LD50: 4220 mg/kg. Irritation data: human,skin, 30mg/3D-I mild, rabbit,eye, 100 mg/30 S, mild.

--------\Cancer Lists\---

	---NTP Carcinogen---		
Ingredient	Known	Anticipated	IARC Category
Sodium Bicarbonate (144-55-8)	No	No	None

12. Ecological Information

Environmental Fate:
No information found.
Environmental Toxicity:
No information found.

13. Disposal Considerations

Whatever cannot be saved for recovery or recycling should be managed in an appropriate and approved waste disposal facility. Processing, use or contamination of this product may change the waste management options. State and local disposal regulations may differ from federal disposal regulations. Dispose of container and unused contents in accordance with federal, state and local requirements.

14. Transport Information

Not regulated.

15. Regulatory Information

--------\Chemical Inventory Status - Part 1\--------------------------------

Ingredient	TSCA	EC	Japan	Australia
Sodium Bicarbonate (144-55-8)	Yes	Yes	Yes	Yes

--------\Chemical Inventory Status - Part 2\--------------------------------

		--Canada--		
Ingredient	Korea	DSL	NDSL	Phil.
Sodium Bicarbonate (144-55-8)	Yes	Yes	No	Yes

--------\Federal, State & International Regulations - Part 1\----------------

	-SARA 302-		------SARA 313------	
Ingredient	RQ	TPQ	List	Chemical Catg.
Sodium Bicarbonate (144-55-8)	No	No	No	No

--------\Federal, State & International Regulations - Part 2\----------------

		-RCRA-	-TSCA-
Ingredient	CERCLA	261.33	8(d)
Sodium Bicarbonate (144-55-8)	No	No	No

Chemical Weapons Convention: No TSCA 12(b): No CDTA: No
SARA 311/312: Acute: No Chronic: No Fire: No Pressure: No
Reactivity: No (Pure / Solid)

Australian Hazchem Code: None allocated.
Poison Schedule: None allocated.
WHMIS:
This MSDS has been prepared according to the hazard criteria of the Controlled Products Regulations (CPR) and the MSDS contains all of the information required by the CPR.

16. Other Information

NFPA Ratings: Health: **1** Flammability: **0** Reactivity: **0**
Label Hazard Warning:
As part of good industrial and personal hygiene and safety procedure, avoid all unnecessary exposure to the chemical substance and ensure prompt removal from skin, eyes and clothing.
Label Precautions:
None.
Label First Aid:
Not applicable.
Product Use:
Laboratory Reagent.
Revision Information:
No Changes.
Disclaimer:
****

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****

Prepared by: Environmental Health & Safety
Phone Number: (314) 654-1600 (U.S.A.)

Comet Chemical Company Ltd.
3463 Thomas Street Innisfil ,ON L9S 3W4
Tel: (705) 436-5580 Fax: (705) 436-7194

Materials Safety Data - **ACETIC ACID, 56% Solution**

	UN - 2790
Shipping Name	ACETIC ACID SOLUTION
Transport of Dangerous Goods Class	Class 8 ; Packing Group III
WHMIS Class	B 3; E
Material Use	acidifying & neutralising, solvent, food additive

1. HAZARDOUS INGREDIENTS

	CAS NUMBER	%	TWAEV (ppm)	LD_{50} ORAL	(mg/kg) SKIN	LC_{50} ppm INHALATION
Acetic Acid	64-19-7	56%	10	3310	1110	5620

2. PHYSICAL CHARACTERISTICS

Odour & Appearance	clear, colourless, liquid with very pungent vinegar odour
Odour Threshold	0.1 ppm - well below TWAEV
Vapour Pressure	17 mmHg (20°C)
Vapour Density (air = 1)	2
Boiling Point	102°C
Freezing Point	-24°C
Specific Gravity	1.062 (20°C)
Water Solubility	complete
pH	1 - highly acid

3. FLAMMABILITY & REACTIVITY

Flash Point	85°C	*(56% acetic acid)*
Autoignition Temperature	465°C	*(glacial acetic acid)*
Flammable Limits	4% - 16%	*(glacial acetic acid)*
Hazardous Combustion Products	carbon monoxide, nitrogen oxides, smoke, irritating fumes	
Firefighting Precautions	foam, dry chemical, water fog, water spray to cool, firefighters must wear SCBA	
Sensitivity to Static Discharge	not sensitive	
Sensitivity to Mechanical Impact	not sensitive	
Chemical Stability	stable; will not polymerize	
Reactive With	strong oxidising agents; vigorous heat producing reaction with alkalies	
Dangerous Decomposition Products	none apart from "Hazardous Combustion Products"	

4. TOXICOLOGY

EFFECTS OF ACUTE EXPOSURE

Skin Contact	causes burns and pain
Skin Absorption	yes; but extensive skin "burns" resulting from contact threaten health more than absorption of the substance into the blood would
Eye Contact	highly irritating; permanent damage likely
Inhalation	irritating; may cause choking, coughing and laboured breathing; absorption by inhalation may change the pH of the blood causing loss of consciousness
Ingestion	pain and burning; gradually dissolves tissues on contact causing severe damage, eventually perforating the digestive tract and resulting in haemorrhage

EFFECTS OF CHRONIC EXPOSURE

General	brown or yellow stains; irritation and dermatitis
Sensitising	no
Carcinogenic	experimental mutagen by RTECS criteria; no effects documented in humans
Reproductive Effect	reproductive toxin by RTECS criteria; no effects documented in humans
Synergistic With	not known
Estimated LD_{50}	6900 mg/kg (oral, rat); 2000 mg/kg (skin, rabbit)
Estimated LC_{50}	10,000 ppm (inhalation, mouse)

5. PROTECTIVE EQUIPMENT

Hands butyl rubber, "Viton", "Saranex" or "Responder" gloves

NOTE: Various other protective materials may also resist 56% acetic acid well.

Eyes	chemical goggles AND a face shield are highly recommended
Respirator	not required if ventilation is adequate (see TWAEV, (1) above), or use organic vapour cartridge
Clothing	impermeable (above) apron , boots, long sleeves are required

6. ENVIRONMENT

Leak Precaution	dyke to control spillage and prevent environmental contamination
Handling Spill	ventilate contaminated area; recover free liquid with suitable pumps; absorb residue on a suitable sorbent (dry sand, earth) and store in closed containers for disposal
Waste Disposal	may be incinerated in approved facility; acetic acid is readily biodegradeable and may be flushed to sewer **if diluted by at least 1:50**; may be neutralised (with soda ash), diluted by at least 1:10 and flushed to sewer

7. STORAGE & HANDLING

Store and use in a cool dry environment. Although fire is not a principal hazard, keep away from sources of ignition, heat and oxidising agents. Vapour inhalation may alter blood pH causing loss of consciousness. Use with adequate mechanical ventilation. Do not cut, drill, weld or grind on or near this container. Avoid all contact with skin and wash work clothes frequently. An eye bath and safety shower must be available near the workplace.

8. FIRST AID

SKIN:	Wash with soap and plenty of water. Remove contaminated clothing and do not reuse until thoroughly cleaned or laundered.
EYES:	Wash eyes with plenty of water, holding eyelids open. Seek medical assistance promptly if there is any irritation.
INHALATION:	Remove from contaminated area promptly. **CAUTION: Rescuer must not endanger himself!** If breathing stops, administer artificial respiration and seek medical aid promptly.
INGESTION:	Give plenty of water to dilute product. Do not induce vomiting (NOTE below). Keep victim quiet. If vomiting occurs, keep victim's head below hips to prevent inhalation of vomited material. Seek medical help promptly.

NOTE: Inadvertent inhalation of vomited material may seriously damage the lungs. The risk and danger of this is greater than the risk of poisoning through absorption of this product. The stomach should be emptied under medical supervision, after the installation of an airway to protect the lungs.

Emergency telephone numbers	- weekdays from 8:00 - 5:00	(705) 436-5580
	at all other times	(800) 567-7455 (Philip Environmental)

Prepared for Comet Chemical Co. Ltd., by ***Nicholas Morgan, August 2002, Revised August 2005***

The information herein is given in good faith but no warranty, expressed or implied is made.

PLEASE ENSURE THAT THIS **MSDS** *IS GIVEN TO AND* **EXPLAINED** *TO THE PERSON USING THIS PRODUCT.*

Material Safety Data Sheet

Calcium polysulfide solution

MSDS Number 6100 (Revised: 1/14/05) 6 Pages

Section 1: CHEMICAL PRODUCT and COMPANY IDENTIFICATION

1.1 **Product Name** .... **Calcium polysulfide solution**
Chemical Family .... Inorganic salt solution
Synonyms .... Calcium polysulfide, CaPS, calcium sulfide, lime sulphur
Formula .... CaS_x

1.2 **Manufacturer** .... Tessenderlo Kerley Inc.
2255 N. 44th Street, Suite 300
Phoenix, Arizona 85008-3279
Information .... (602) 889-8300

1.3 **Emergency Contact** .... (800) 877-1737 (Tessenderlo Kerley)
(800) 424-9300 (CHEMTREC)

Section 2: COMPOSITION, INFORMATION ON INGREDIENTS

2.1 **Chemical Ingredients (% by wt.)**

Calcium polysulfide	CAS #:1344-81-6	24 - 29%
Water	CAS #:7732-18-5	71 - 76%

(See Section 8 for exposure guidelines)

Section 3: HAZARDS IDENTIFICATION

NFPA: **Health - 2** **Flammability - 0** **Reactivity - 1**

EMERGENCY OVERVIEW

Warning:
Avoid inhalation of product fumes (hydrogen sulfide) near openings on storage container. Release of the product to the environment may cause the evolution of highly toxic hydrogen sulfide vapors. Product solution is alkaline and may cause irritation to the skin. Eye contact will cause eye irritation and possible corneal damage. Ingestion will result in irritation of tissues and the release of hydrogen sulfide in the gastrointestinal tract.

Section 3: HAZARDS IDENTIFICATION (Cont.)

3.1 POTENTIAL HEALTH EFFECTS

EYE: Contact with the eyes by product mist or solution will cause irritation and a burning sensation. Eye contact may result in severe corneal injury.

SKIN CONTACT: Contact with product mist or solution will cause skin irritation and may result in corrosion of the skin.

SKIN ABSORPTION: Absorption is unlikely to occur.

INGESTION: Ingestion of product solution will cause irritation and corrosion of the gastrointestinal tract to include nausea, vomiting and diarrhea. Contact with stomach acid will cause highly toxic hydrogen sulfide to evolve.

INHALATION: Inhalation of product vapors (hydrogen sulfide) may cause dizziness and unconsciousness possibly resulting in serious falls from elevated positions..

CHRONIC EFFECTS/CARCINOGENICITY: Not listed as a carcinogen by NTP, IARC or OSHA.

Section 4: FIRST AID MEASURES

4.1 EYES: Immediately flush with large quantities of water for 15 minutes. Hold eyelids apart during irrigation to insure thorough flushing of the entire area of the eye and lids. Obtain immediate medical attention.

4.2 SKIN: Immediately flush with large quantities of water. Remove contaminated clothing under a safety shower. Obtain immediate medical attention.

4.3 INGESTION: DO NOT INDUCE VOMITING. If victim is conscious, immediately give large quantities of water. If vomiting does occur, continue to give fluids. Obtain immediate medical attention.

4.4 INHALATION: Remove victim from contaminated atmosphere. If breathing is labored, administer oxygen. If breathing has ceased, clear airway and start mouth to mouth resuscitation. If heart has stopped beating, external heart massage should be applied. Obtain immediate medical attention.

Section 5: FIRE FIGHTING MEASURES

5.1 FLAMMABLE PROPERTIES

FLASH POINT: Not flammable (See Section 5.4) **METHOD USED:** NA

5.2 FLAMMABLE LIMITS H_2S **LFL**: 4% **UFL**: 44%

5.3 EXTINGUISHING MEDIA: Water spray or foam or as appropriate for combustibles involved in fire.

Section 5: FIRE FIGHTING MEASURES (Cont.)

5.4 FIRE & EXPLOSIVE HAZARDS: When heated or diluted, hydrogen sulfide vapors will evolve. This gas may form explosive mixtures with air. (See Section 5.2) Keep containers/storage vessels in fire area cooled with water spray.

5.5 FIRE FIGHTING EQUIPMENT: Because of the possible presence of toxic gases and the irritating nature of the product, wear self-contained breathing apparatus, positive pressure, (MSHA/NIOSH approved or equivalent) and full protective gear.

Section 6: ACCIDENTAL RELEASE MEASURES

6.1 Small releases: Confine and absorb small releases on sand, earth or other inert absorbent. Released material may contain residual sulfides. Spray with weak (~5%) hydrogen peroxide to oxidize sulfides.

6.2 Large releases: Confine area to qualified personnel. Wear proper protective equipment. Shut off release if safe to do so. Dike spill area to prevent runoff into sewers, drains (possible toxic or explosive mixtures) or surface waterways (potential aquatic toxicity). Spray product vapors with fine water spray or mist. Recover as much of the solution as possible. Treat remaining material as a small release (above).

Section 7: HANDLING and STORAGE

7.1 Handling: Handle in enclosed containers to avoid breathing product. Avoid contact with skin and eyes. Dilute only in enclosed containers. Use in a well ventilated area. Wash thoroughly after handling.

7.2 Storage: Store in well ventilated areas in enclosed containers. Do not store combustibles in the area of storage vessels. Keep away from any sources of heat or flame. Store tote, drums and small containers out of direct sunlight at moderate temperatures [<90°F (32°C)]. (See Section 10.4 for materials of construction)

Section 8: EXPOSURE CONTROLS, PERSONAL PROTECTION

8.1 RESPIRATORY PROTECTION: Wear self-contained breathing apparatus, positive pressure, MSHA/NIOSH (approved or equivalent).

8.2 SKIN PROTECTION: Gloves, boots, and chemical suit should be worn to prevent liquid contact. Wash contaminated clothing prior to reuse. Contaminated shoes cannot be cleaned and should be discarded

8.3 EYE PROTECTION: Chemical goggles and a full face shield.

8.4 EXPOSURE GUIDELINES:

	OSHA		ACGIH	
	TWA	STEL	TLV	STEL
Hydrogen sulfide	20 ppm (ceiling)		10 ppm (ceiling)	

8.5 ENGINEERING CONTROLS: Use adequate exhaust ventilation to prevent inhalation of product vapors. Maintain eyewash/safety shower in areas where chemical is handled.

Section 9: PHYSICAL and CHEMICAL PROPERTIES

9.1 APPEARANCE:	Ruby red liquid
9.2 ODOR:	Strong order of rotten eggs
9.3 BOILING POINT:	Not determined
9.4 VAPOR PRESSURE:	Not determined (Believed to be minimal)
9.5 VAPOR DENSITY:	Not determined
9.6 SOLUBILITY IN WATER:	Dissolves with precipitation of elemental sulfur.
9.7 SPECIFIC GRAVITY:	1.20 - 1.27 (10.0 - 10.6 lbs/gal)
9.8 FREEZING POINT:	Not determined
9.9 pH:	10.0 - 11.7
9.10 VOLATILE:	Not applicable

Section 10: STABILITY and REACTIVITY

10.1 STABILITY: This is a stable material

10.2 HAZARDOUS POLYMERIZATION: Will not occur.

10.3 HAZARDOUS DECOMPOSITION PRODUCTS: Heating this product will evolve hydrogen sulfide vapors. Continued heating will also cause oxides of sulfur to be released.

10.4 INCOMPATIBILITY: Strong oxidizers such as nitrates, nitrites or chlorates can cause explosive mixtures if heated to dryness. Acids, acidic materials or dilution with water will cause the release of hydrogen sulfide, a highly toxic gas.

Section 11: TOXICOLOGICAL INFORMATION

11.1 ORAL: Data not available

11.2 DERMAL: Data not available

11.3 INHALATION: INH-Rat LC_{50}: 3.6 mg/L (4 Hr. Exposure)

11.4 CHRONIC/CARCINOGENICITY: No evidence available

11.5 TERATOLOGY: Data not available

11.6 REPRODUCTION: Data not available

11.7 MUTAGENICITY: Data not available

Section 12: ECOLOGICAL INFORMATION

No data available.

Section 13: DISPOSAL CONSIDERATIONS

If released to the environment for other than its intended purpose, this product should be checked to see it meets the criteria of a reactive sulfides D003, Reactive waste.

Section 14: TRANSPORT INFORMATION

14.1 DOT Shipping Name: Calcium Polysulfide solution

14.2 DOT Hazard Class: NA

14.3 UN/NA Number: NA

14.4 Packing Group: NA

14.5 DOT Placard: NA

14.6 DOT Label(s): NA

14.7 IMO Shipping Name: Not Determined

14.8 RQ (Reportable Quantity): NA

14.9 RR STCC Number: Not Determined

Section 15: REGULATORY INFORMATION

15.1 OSHA: This product is listed as a hazardous material under criteria of the Federal OSHA Hazard Communication Standard, 29 CFR 1910.1200.

15.2 SARA TITLE III:

a. **EHS** (Extremely Hazardous Substance) List: No

b. Section 311/312, (Tier I,II) Categories:

Immediate (acute)	Yes
Fire	No
Sudden release	No
Reactivity	Yes
Delayed (chronic)	No

c. Section 313 (Toxic Release Reporting-Form R): No

Chemical Name	CAS Number	Concentration

d. **TPQ** (Threshold Planning Quantity): No

15.3 CERCLA/SUPERFUND: RQ (Reportable Quantity) No

15.4 TSCA (Toxic Substance Control Act) Inventory List: Yes

Section 15: REGULATORY INFORMATION (Cont.)

15.5 RCRA (Resource Conservation and Recovery Act) Status:	Possible D003 (See Section 13)
15.6 WHMIS (Canada) Hazard Classification:	NA
15.7 DOT Hazardous Material: (See Section 14)	No
15.8 CAA Hazardous Air Pollutant (HAP)	No

Section 16: OTHER INFORMATION

REVISIONS: The entire MSDS was reformatted to comply to ANSI Standard Z400.1-1993, by Technical Services-Tessenderlo Kerley, Inc.

Address updated, 4/30/99
Section 8.3, Eye Protection revised and logo revised, 4/29/02
Revised Section 2.1, Ingredients, 3, Hazard Identification, 9,Physical characteristics, 11, Toxicological Information, 14, Transportation, 1/14/05

APPENDIX C
GROUNDWATER SAMPLING FIELD DATA SHEETS

In-Situ Pilot Study Work Plan
for the Eunice North Gas Plant

Chevron Environmental Management Company
89CH.49526.07
May 21, 2007

SECOR
GROUNDWATER SAMPLING FIELD DATA SHEET

SECOR PROJECT NUMBER: ______________________ DATE: __________ WELL NO. __________

FACILITY NAME: ______________________________ TEMPERATURE: __________ °F or °C

FIELD PERSONNEL: ______________________ WEATHER: ______________________

FIELD MEASUREMENTS:

A. Static Water Level (SWL) below top of casing/piezometer: __________ FT. or IN.

B. Thickness of Free Product, if present: ________ Inches __________ FT. or IN.

C. Total Depth of well (TD) from top of casing/piezometer: __________ FT. or IN.

D. Height of Water Column in casing (h = TD - SWL): __________ FT. or IN.

E. **Useful approximate Purge Volumes (PV) per foot of water column for common casing sizes:**

	3 Well Vols.	5 Well Vols.			
2" Diameter =	0.5 gals/ft	0.82 gals/ft	x feet of water________	=	__________PV (Gal)
4" Diameter =	2.0 gals/ft	3.25 gals/ft	x feet of water________	=	__________PV (Gal)
6" Diameter =	4.4 gals/ft	7.35 gals/ft	x feet of water________	=	__________PV (Gal)

PURGING METHOD: ______________________ DURATION: ______________

OBSERVATIONS:

Cum. PV (Gal)	Time	Turbidity	DO	ORP	pH	Temp.	Conduct.	SWL

TOTAL VOLUME OF WATER PURGED FROM WELL: ______________________

PURGE WATER STORED/DISPOSED OF WHERE/HOW: ______________________

SAMPLES COLLECTED: Depth to Water at time of sample collection: ______________________

Sample Number(s)	Time	Size/Number of Container(s)	Preservative

COMMENTS:

____

____

Casing Capacities:
2-inch hole.........0.16 gal/lin ft.
4-inch hole.........0.65 gal/lin ft.
6.5-inch hole.......1.70 gal/lin ft.
8-inch hole.........2.60 gal/lin ft.
10-inch hole........4.10 gal/lin ft.

Recharge Calculation at Time of Sample Collection:

Total Depth of Well:
Original Water Column: ________ x 0.80 = -- (________)
Collect sample when Depth to Water measures
Less than or equal to:

Signature: ______________________

SECOR
GROUNDWATER SAMPLING FIELD DATA SHEET

SECOR PROJECT NUMBER: ____________________ DATE: __________ WELL NO. __________

FACILITY NAME: ______________________________ TEMPERATURE: ________ °F or °C

FIELD PERSONNEL: ____________________ WEATHER: ____________________

FIELD MEASUREMENTS:

A. Static Water Level (SWL) below top of casing/piezometer: ________ FT. or IN.
B. Thickness of Free Product, if present: ________ Inches ________ FT. or IN.
C. Total Depth of well (TD) from top of casing/piezometer: ________ FT. or IN.
D. Height of Water Column in casing (h = TD - SWL): ________ FT. or IN.
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	3 Well Vols.	5 Well Vols.			
2" Diameter =	0.5 gals/ft	0.82 gals/ft	x feet of water________	=	________PV (Gal)
4" Diameter =	2.0 gals/ft	3.25 gals/ft	x feet of water________	=	________PV (Gal)
6" Diameter =	4.4 gals/ft	7.35 gals/ft	x feet of water________	=	________PV (Gal)

PURGING METHOD: ______________________________ DURATION: ____________________

OBSERVATIONS:

Cum. PV (Gal)	Time	Turbidity	DO	ORP	pH	Temp.	Conduct.	SWL

TOTAL VOLUME OF WATER PURGED FROM WELL: ______________________________

PURGE WATER STORED/DISPOSED OF WHERE/HOW: ______________________________

SAMPLES COLLECTED: Depth to Water at time of sample collection: ____________________

Sample Number(s)	Time	Size/Number of Container(s)	Preservative

COMMENTS:

____

____

Casing Capacities:
2-inch hole.........0.16 gal/lin ft.
4-inch hole.........0.65 gal/lin ft.
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8-inch hole.........2.60 gal/lin ft.
10-inch hole........4.10 gal/lin ft.

Recharge Calculation at Time of Sample Collection:

Total Depth of Well:
Original Water Column: ________ **x** 0.80 = -- (________)
Collect sample when Depth to Water measures
Less than or equal to:

Signature: ______________________________

SECOR

GROUNDWATER SAMPLING FIELD DATA SHEET

SECOR PROJECT NUMBER: ____________________ DATE: __________ WELL NO. __________

FACILITY NAME: ____________________ TEMPERATURE: __________ °F or °C

FIELD PERSONNEL: ____________________ WEATHER: ____________________

FIELD MEASUREMENTS:

A. Static Water Level (SWL) below top of casing/piezometer: __________ FT. or IN.

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6" Diameter =	4.4 gals/ft	7.35 gals/ft	x feet of water________	= __________PV (Gal)

PURGING METHOD: ____________________ DURATION: ____________________

OBSERVATIONS:

Cum. PV (Gal)	Time	Turbidity	DO	ORP	pH	Temp.	Conduct.	SWL

TOTAL VOLUME OF WATER PURGED FROM WELL: ____________________

PURGE WATER STORED/DISPOSED OF WHERE/HOW: ____________________

SAMPLES COLLECTED: Depth to Water at time of sample collection: ____________________

Sample Number(s)	Time	Size/Number of Container(s)	Preservative

COMMENTS:

____

____

Casing Capacities:
2-inch hole.........0.16 gal/lin ft.
4-inch hole.........0.65 gal/lin ft.
6.5-inch hole.......1.70 gal/lin ft.
8-inch hole.........2.60 gal/lin ft.
10-inch hole........4.10 gal/lin ft.

Recharge Calculation at Time of Sample Collection:

Total Depth of Well:
Original Water Column: ________ **x** 0.80 = -- (________)
Collect sample when Depth to Water measures
Less than or equal to:

Signature: ____________________

SECOR
GROUNDWATER SAMPLING FIELD DATA SHEET

SECOR PROJECT NUMBER: ______________________ DATE: __________ WELL NO. ____________

FACILITY NAME: ______________________________________ TEMPERATURE: __________ °F or °C

FIELD PERSONNEL: __________________________ WEATHER: ______________________

FIELD MEASUREMENTS:

A. Static Water Level (SWL) below top of casing/piezometer: __________ FT. or IN.
B. Thickness of Free Product, if present: ________ Inches __________ FT. or IN.
C. Total Depth of well (TD) from top of casing/piezometer: __________ FT. or IN.
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6" Diameter =	4.4 gals/ft	7.35 gals/ft	x feet of water ________	=	________ PV (Gal)

PURGING METHOD: ______________________________ DURATION: ____________________

OBSERVATIONS:

Cum. PV (Gal)	Time	Turbidity	DO	ORP	pH	Temp.	Conduct.	SWL

TOTAL VOLUME OF WATER PURGED FROM WELL: ______________________________

PURGE WATER STORED/DISPOSED OF WHERE/HOW: ______________________________

SAMPLES COLLECTED: Depth to Water at time of sample collection: ______________________________

Sample Number(s)	Time	Size/Number of Container(s)	Preservative

COMMENTS:

____

____

Casing Capacities:
2-inch hole.........0.16 gal/lin ft.
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Recharge Calculation at Time of Sample Collection:

Total Depth of Well:
Original Water Column: ________ **x** 0.80 = -- (________)
Collect sample when Depth to Water measures
Less than or equal to:

Signature: ______________________________

SECOR
GROUNDWATER SAMPLING FIELD DATA SHEET

SECOR PROJECT NUMBER: ______________ DATE: ________ WELL NO. ________

FACILITY NAME: ______________ TEMPERATURE: ________ °F or °C

FIELD PERSONNEL: ______________ WEATHER: ______________

FIELD MEASUREMENTS:

A. Static Water Level (SWL) below top of casing/piezometer: ________ FT. or IN.

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6" Diameter =	4.4 gals/ft	7.35 gals/ft	x feet of water________	=	________PV (Gal)

PURGING METHOD: ______________ DURATION: ______________

OBSERVATIONS:

Cum. PV (Gal)	Time	Turbidity	DO	ORP	pH	Temp.	Conduct.	SWL

TOTAL VOLUME OF WATER PURGED FROM WELL: ______________

PURGE WATER STORED/DISPOSED OF WHERE/HOW: ______________

SAMPLES COLLECTED: Depth to Water at time of sample collection: ______________

Sample Number(s)	Time	Size/Number of Container(s)	Preservative

COMMENTS:

____

____

Casing Capacities:
2-inch hole.........0.16 gal/lin ft.
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8-inch hole.........2.60 gal/lin ft.
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Recharge Calculation at Time of Sample Collection:

Total Depth of Well:
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Less than or equal to:

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SECOR

GROUNDWATER SAMPLING FIELD DATA SHEET

SECOR PROJECT NUMBER: ______________________ DATE: __________ WELL NO. __________

FACILITY NAME: ______________________________ TEMPERATURE: ________ °F or °C

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FIELD MEASUREMENTS:

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PURGING METHOD: ______________________ DURATION: ______________________

OBSERVATIONS:

Cum. PV (Gal)	Time	Turbidity	DO	ORP	pH	Temp.	Conduct.	SWL

TOTAL VOLUME OF WATER PURGED FROM WELL: ______________________

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Sample Number(s)	Time	Size/Number of Container(s)	Preservative

COMMENTS:

____

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Less than or equal to:

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SECOR

GROUNDWATER SAMPLING FIELD DATA SHEET

SECOR PROJECT NUMBER: ______________________ DATE: __________ WELL NO. __________

FACILITY NAME: ______________________________ TEMPERATURE: __________ °F or °C

FIELD PERSONNEL: ______________________ WEATHER: ______________________

FIELD MEASUREMENTS:

A. Static Water Level (SWL) below top of casing/piezometer: __________ FT. or IN.

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6" Diameter =	4.4 gals/ft	7.35 gals/ft	x feet of water__________	=	__________PV (Gal)

PURGING METHOD: ______________________ DURATION: ______________________

OBSERVATIONS:

Cum. PV (Gal)	Time	Turbidity	DO	ORP	pH	Temp.	Conduct.	SWL

TOTAL VOLUME OF WATER PURGED FROM WELL: ______________________

PURGE WATER STORED/DISPOSED OF WHERE/HOW: ______________________

SAMPLES COLLECTED: Depth to Water at time of sample collection: ______________________

Sample Number(s)	Time	Size/Number of Container(s)	Preservative

COMMENTS:

____

____

Casing Capacities:
2-inch hole.........0.16 gal/lin ft.
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6.5-inch hole.......1.70 gal/lin ft.
8-inch hole.........2.60 gal/lin ft.
10-inch hole........4.10 gal/lin ft.

Recharge Calculation at Time of Sample Collection:

Total Depth of Well:

Original Water Column: _________ x 0.80 = -- (_______)

Collect sample when Depth to Water measures

Less than or equal to:

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SECOR

GROUNDWATER SAMPLING FIELD DATA SHEET

SECOR PROJECT NUMBER: ____________ DATE: ________ WELL NO. ________

FACILITY NAME: ____________ TEMPERATURE: ________ °F or °C

FIELD PERSONNEL: ____________ WEATHER: ____________

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PURGING METHOD: ____________ DURATION: ____________

OBSERVATIONS:

Cum. PV (Gal)	Time	Turbidity	DO	ORP	pH	Temp.	Conduct.	SWL

TOTAL VOLUME OF WATER PURGED FROM WELL: ____________

PURGE WATER STORED/DISPOSED OF WHERE/HOW: ____________

SAMPLES COLLECTED: Depth to Water at time of sample collection: ____________

Sample Number(s)	Time	Size/Number of Container(s)	Preservative

COMMENTS:

____

____

Casing Capacities:
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Recharge Calculation at Time of Sample Collection:

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Original Water Column: ________ x 0.80 = -- (________)
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SECOR
GROUNDWATER SAMPLING FIELD DATA SHEET

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PURGING METHOD: ____________ DURATION: ____________

OBSERVATIONS:

Cum. PV (Gal)	Time	Turbidity	DO	ORP	pH	Temp.	Conduct.	SWL

TOTAL VOLUME OF WATER PURGED FROM WELL: ____________

PURGE WATER STORED/DISPOSED OF WHERE/HOW: ____________

SAMPLES COLLECTED: Depth to Water at time of sample collection: ____________

Sample Number(s)	Time	Size/Number of Container(s)	Preservative

COMMENTS:

____

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Recharge Calculation at Time of Sample Collection:

Total Depth of Well:
Original Water Column: ________ x 0.80 = -- (________)
Collect sample when Depth to Water measures
Less than or equal to:

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SECOR

GROUNDWATER SAMPLING FIELD DATA SHEET

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PURGING METHOD: ______________________ DURATION: ______________________

OBSERVATIONS:

Cum. PV (Gal)	Time	Turbidity	DO	ORP	pH	Temp.	Conduct.	SWL

TOTAL VOLUME OF WATER PURGED FROM WELL: ______________________

PURGE WATER STORED/DISPOSED OF WHERE/HOW: ______________________

SAMPLES COLLECTED: Depth to Water at time of sample collection: ______________________

Sample Number(s)	Time	Size/Number of Container(s)	Preservative

COMMENTS:

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Casing Capacities:
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SECOR

GROUNDWATER SAMPLING FIELD DATA SHEET

SECOR PROJECT NUMBER: ______________________ DATE: __________ WELL NO. __________

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PURGING METHOD: ______________________________ DURATION: ____________________

OBSERVATIONS:

Cum. PV (Gal)	Time	Turbidity	DO	ORP	pH	Temp.	Conduct.	SWL

TOTAL VOLUME OF WATER PURGED FROM WELL: ______________________________

PURGE WATER STORED/DISPOSED OF WHERE/HOW: ______________________________

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Sample Number(s)	Time	Size/Number of Container(s)	Preservative

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Recharge Calculation at Time of Sample Collection:

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Less than or equal to:

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SECOR

GROUNDWATER SAMPLING FIELD DATA SHEET

SECOR PROJECT NUMBER: ______________________ DATE: __________ WELL NO. __________

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PURGING METHOD: ______________________ DURATION: __________

OBSERVATIONS:

Cum. PV (Gal)	Time	Turbidity	DO	ORP	pH	Temp.	Conduct.	SWL

TOTAL VOLUME OF WATER PURGED FROM WELL: ______________________

PURGE WATER STORED/DISPOSED OF WHERE/HOW: ______________________

SAMPLES COLLECTED: Depth to Water at time of sample collection: ______________________

Sample Number(s)	Time	Size/Number of Container(s)	Preservative

COMMENTS:

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Casing Capacities:
2-inch hole.........0.16 gal/lin ft.
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6.5-inch hole.......1.70 gal/lin ft.
8-inch hole.........2.60 gal/lin ft.
10-inch hole........4.10 gal/lin ft.

Recharge Calculation at Time of Sample Collection:

Total Depth of Well:
Original Water Column: __________ **x** 0.80 = -- (__________)
Collect sample when Depth to Water measures
Less than or equal to:

Signature: ______________________

SECOR
GROUNDWATER SAMPLING FIELD DATA SHEET

SECOR PROJECT NUMBER: ______________________ DATE: __________ WELL NO. __________

FACILITY NAME: ______________________________ TEMPERATURE: __________ °F or °C

FIELD PERSONNEL: __________________________ WEATHER: ______________________

FIELD MEASUREMENTS:

A. Static Water Level (SWL) below top of casing/piezometer: __________ FT. or IN.

B. Thickness of Free Product, if present: ________ Inches __________ FT. or IN.

C. Total Depth of well (TD) from top of casing/piezometer: __________ FT. or IN.

D. Height of Water Column in casing (h = TD - SWL): __________ FT. or IN.

E. **Useful approximate Purge Volumes (PV) per foot of water column for common casing sizes:**

	3 Well Vols.	5 Well Vols.			
2" Diameter =	0.5 gals/ft	0.82 gals/ft	x feet of water________	=	___________PV (Gal)
4" Diameter =	2.0 gals/ft	3.25 gals/ft	x feet of water________	=	___________PV (Gal)
6" Diameter =	4.4 gals/ft	7.35 gals/ft	x feet of water________	=	___________PV (Gal)

PURGING METHOD: ______________________________ DURATION: ____________________

OBSERVATIONS:

Cum. PV (Gal)	Time	Turbidity	DO	ORP	pH	Temp.	Conduct.	SWL

TOTAL VOLUME OF WATER PURGED FROM WELL: ______________________________

PURGE WATER STORED/DISPOSED OF WHERE/HOW: ____________________________

SAMPLES COLLECTED: Depth to Water at time of sample collection: ____________________

Sample Number(s)	Time	Size/Number of Container(s)	Preservative

COMMENTS:

____

____

Casing Capacities:
2-inch hole.........0.16 gal/lin ft.
4-inch hole.........0.65 gal/lin ft.
6.5-inch hole.......1.70 gal/lin ft.
8-inch hole.........2.60 gal/lin ft.
10-inch hole........4.10 gal/lin ft.

Recharge Calculation at Time of Sample Collection:

Total Depth of Well:
Original Water Column: ________ **x** 0.80 = -- (______)
Collect sample when Depth to Water measures
Less than or equal to:

Signature: ______________________________

APPENDIX D
GROUNDWATER FIELD LOG

In-Situ Pilot Study Work Plan
for the Eunice North Gas Plant

Chevron Environmental Management Company
89CH.49526.07
May 21, 2007

Pilot Study Groundwater Field Log
Eunice North Gas Plant

Well ID	Date	Time	Depth to Water (feet)	Conductivity (mS/cm)	ORP (mV)	pH	DO (mg/L)	Temperature (Degree C)
IW023								
IW023								
IW023								
IW023								
IW023								
IW023								
IW023								
IW023								
IW023								
IW023								

Well ID	Date	Time	Depth to Water (feet)	Conductivity (mS/cm)	ORP (mV)	pH	DO (mg/L)	Temperature (Degree C)
IW024								
IW024								
IW024								
IW024								
IW024								
IW024								
IW024								
IW024								
IW024								
IW024								

Well ID	Date	Time	Depth to Water (feet)	Conductivity (mS/cm)	ORP (mV)	pH	DO (mg/L)	Temperature (Degree C)
IW026								
IW026								
IW026								
IW026								
IW026								
IW026								
IW026								
IW026								
IW026								
IW026								

Well ID	Date	Time	Depth to Water (feet)	Conductivity (mS/cm)	ORP (mV)	pH	DO (mg/L)	Temperature (Degree C)
MW090SA								
MW090SA								
MW090SA								
MW090SA								
MW090SA								
MW090SA								
MW090SA								
MW090SA								
MW090SA								
MW090SA								

APPENDIX E
CALCIUM POLYSULFIDE FIELD TITRATION

In-Situ Pilot Study Work Plan
for the Eunice North Gas Plant

Chevron Environmental Management Company
89CH.49526.07
May 21, 2007

Calcium Polysulfide (CaS_xS) Field Titration

Prepare NaOCl Titrant
Weigh out 5.7 grams of 6% NaOCl (Clorox bleach) and dilute it in a volumetric flask to one liter to produce a 340 mg/l NaOCl solution.

Testing of a Groundwater Sample
Put 100 milliliters of groundwater into a beaker with a N,N-diethyl-P-phenylenediamine (DPD) indicator, preferably a DPD No. 1 Free Chlorine Test Tablet manufactured by Bio-Lab, Inc. of Decatur, Georgia. DPD has the molecular formula $C_{10}H_{16}N_2$. Place the tablet into the groundwater sample and swirl the sample until the DPD tablet dissolves. Titrate the groundwater sample using the NaOCl titrant until the color changes to yellow. If the water is yellow before titrating (from high concentrations of CaS_xS), then the sample will turn from yellow, to white, and then back to yellow. The sample may begin to pick up a grey color before it turns yellow. The titration should continue through this phase until a yellow color develops. The titration works by the hypochlorite (ClO^-) reacting with available polysulfide ions as shown in the reaction below:

$$CaS_xS + NaOCl + H_2O \rightarrow CaS_x + S^0 + Na^+ + Cl^- + 2OH^-$$

After the CaS_xS is reacted, the ClO^- will react with sulfide complexes of DPD to produce a yellow color which shows that all of the CaS_xS has been consumed.

$$\underset{\text{DPD}}{2\,C_{10}H_{16}N_2} + S^{-2} + ClO^- \rightarrow \underset{\text{Yellow Color}}{(C_{10}H_{15}N_2Cl)_2S} + OH^-$$

If the CaS_xS concentrations are below 10 ppm, then the water may start out with a clear to cloudy appearance before the titration, and it may develop into a light reddish-orange color instead of a yellow color at the titration point. This occurs because not all of the DPD is reacted with sulfide ions, so the hypochlorite reacts directly with the DPD and produces a red color. The mixture of red and yellow color indicators makes the color slightly reddish-orange. This is considered the titration point at low concentrations.

Each milliliter of titrant using this method is equivalent to 10 ppm CaS_xS in the water sample. Adding too much of the titrant will make the yellow color disappear as DPD is oxidized by excess ClO^-, so do not over-titrate the sample.