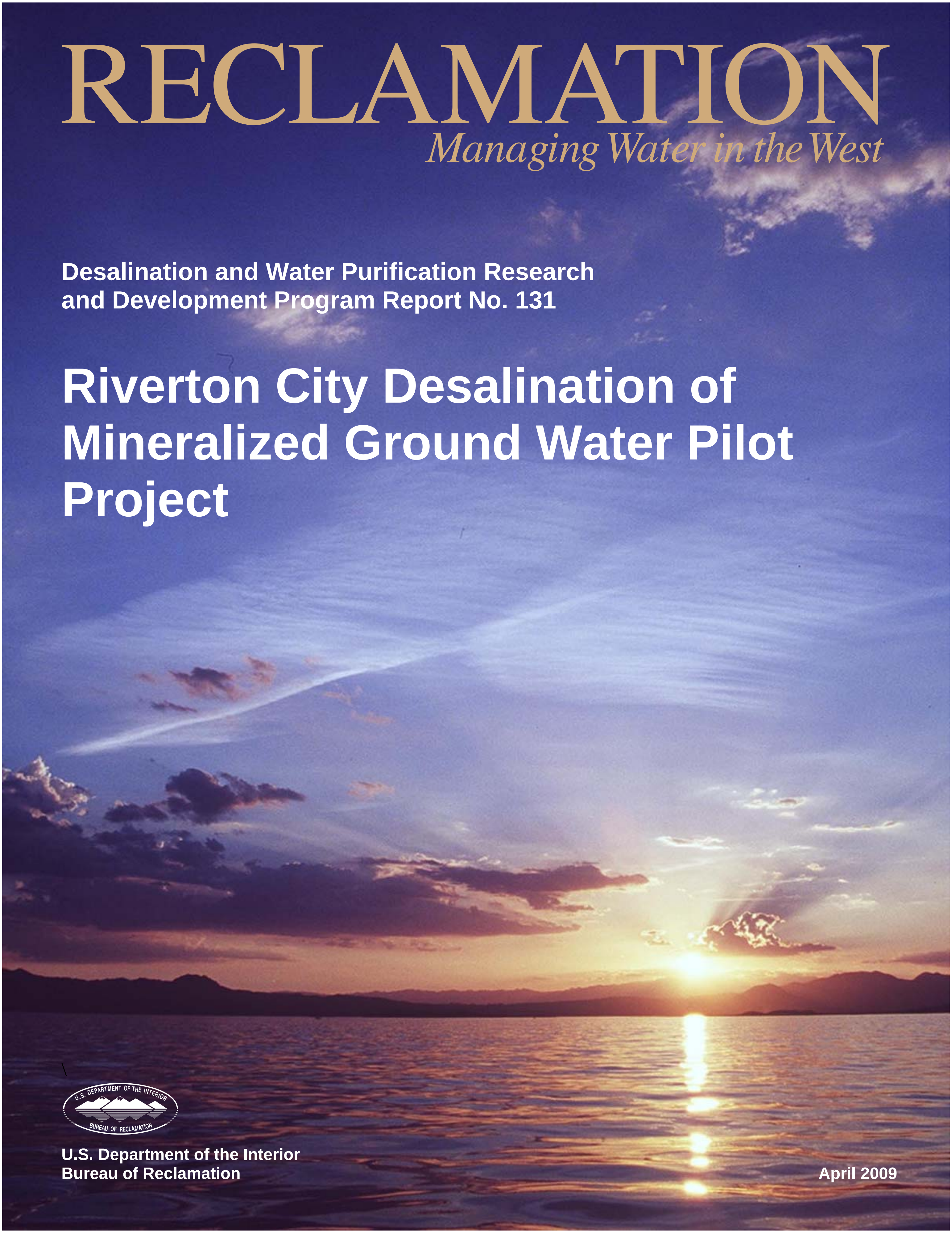

RECLAMATION

Managing Water in the West

Desalination and Water Purification Research
and Development Program Report No. 131

Riverton City Desalination of Mineralized Ground Water Pilot Project

U.S. Department of the Interior
Bureau of Reclamation

April 2009

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)* April 2009	**2. REPORT TYPE** Final	**3. DATES COVERED** *(From - To)* October 2003 – May 2008

4. TITLE AND SUBTITLE
Riverton City Desalination of Mineralized Ground Water Pilot Project

5a. CONTRACT NUMBER
Agreement No. 04-FC-81-1063

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
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5d. PROJECT NUMBER

5e. TASK NUMBER
Task E

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
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8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Department of the Interior,
Bureau of Reclamation, Denver Federal Center,
PO Box 25007, Denver CO 80225-0007

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)
DWPR Report No. 131

12. DISTRIBUTION / AVAILABILITY STATEMENT
Available from the National Technical Information Service (NTIS),
Operations Division, 5285 Port Royal Road, Springfield VA 22161

13. SUPPLEMENTARY NOTES
Report can be downloaded from Reclamation Web site: http://www.usbr.gov/pmts/water/publications/reports.html

14. ABSTRACT ***(Maximum 200 words)***

Riverton City's (City) ground water potable drinking water sources are high in total dissolved solids (TDS). During certain periods of the year, blending with purchased water is required to improve the palatability of the drinking water. To reduce its dependence on outside suppliers, the City completed pilot testing of two desalination methods: electrodialysis reversal (EDR) and reverse osmosis (RO). The primary goal of the pilot testing was to evaluate the performance of each technology at reducing the naturally occurring TDS levels in the ground water, from over 900 milligrams per liter (mg/L), on average, to below the secondary maximum contaminant level of 500 mg/L or less. Pilot testing of each technology occurred simultaneously for a period of 3 months. Based on the pilot test results, both technologies achieved a blended concentration of 500 mg/L. To achieve this concentration, 87 percent of the City's water supply would have to be treated by EDR or 65 percent of the water supply would have to be treated by RO. Lastly, treatment capital and operation costs were developed based on the observed data from the pilot testing.

15. SUBJECT TERMS
Desalination, electrodialysis reversal, reverse osmosis, total dissolved solids, brackish ground water

16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON** Robert Jurenka
a. REPORT U	**b. ABSTRACT** U	**c. THIS PAGE** U	SAR (same as report)	188	**19b. TELEPHONE NUMBER** *(include area code)* 303-445-2254

Standard Form 298 (Rev. 8/98)
Prescribed by ANSI Std. 239-18

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Prepared for Reclamation Under Agreement No. 04-FC-81-1063

by

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Bureau of Reclamation
Technical Service Center
Water and Environmental Resources Division
Water Treatment Engineering Research Team
Denver, Colorado

April 2009

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Acknowledgments

We would like to thank the Riverton City Council, Riverton City Water Department personnel, the pilot vendors, and those individuals who assisted in the execution of this project. This research project was sponsored by the Bureau of Reclamation through the Desalination and Water Purification Research and Development Program. We extend our appreciation to them for making this project possible.

Disclaimer

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Abbreviations and Acronyms

BTU	British Thermal Units
$CaCO_3$	calcium carbonate
City	Riverton City
District	Jordan Valley Water Conservation District
EC	electrical conductivity
ED	electrodialysis
EDR	electrodialysis reversal
EPA	U.S. Environmental Protection Agency
Epic	Epic Engineering
ETV	equipment testing verification
GE	GE Infrastructure/Ionics
Gpm	gallons per minute
Gpd	gallons per day
HCl	hydrochloric acid (also referred to as muriatic acid)
HP	horsepower
mgd	million gallons per day
mg/L	milligrams per liter
NTU	nephelometric turbidity units
ppb	parts per billion
ppm	parts per million
psi	pounds per square inch gradient
PVC	polyvinyl chloride
Reclamation	Bureau of Reclamation
RO	reverse osmosis
SDI	silt density index
SiO_4	reactive silica
TOC	total organic carbon
TDS	total dissolved solids
µmhos/cm	micromhos per centimeter
µS/cm	microsiemens per centimeter

1. Executive Summary

Riverton City's (City) ground water supplies for its culinary water system are high in total dissolved solids (TDS). The high TDS affects the palatableness of the water. During certain periods of the year, the City blends water from a wholesale supplier. This blending changes the taste of the water by reducing the TDS level. The high TDS also causes excessive scaling in the water distribution system extending into the end user's water heaters and household piping, creating an undetermined loss of energy. These effects may be counteracted through the application of desalination technology in a water treatment plant. Deconcentration of the mineralized ground water supplies will reduce the City's dependence on outside supplies of high-quality potable water, thus increasing the City's ability to continue to provide adequate water to its growing service base. Additional benefits may include lower maintenance and operating costs of the City's potable water infrastructure downstream of the desalination treatment and lower water heating costs for end users because damaging scaling will be reduced.

With partial funding assistance through the Bureau of Reclamation's Desalination and Water Purification Research and Development Program, the City recently completed pilot testing of two desalination treatment methods: electrodialysis reversal (EDR) and reverse osmosis (RO). Pilot testing of each system was performed for a period of 3 months at three of the City's well sites. Pilots were run on the same water source (wells) for the same duration to provide a side-by-side comparison of each technology's effectiveness in accomplishing the City's treatment desires.

The primary goal for the pilot testing was to evaluate the performance of each technology at reducing naturally occurring TDS in the source ground water to desired target levels. Both technologies were successful at reducing TDS levels in the source water, from over 900 milligrams per liter (mg/L), on average, to below the target level of 500 milligrams per liter (mg/L) (from the U.S. Environmental Protection Agency's secondary drinking water standards). Both pilot units used a four-stage membrane process. Fewer stages of treatment were not investigated due to budget and time limitations. On average, the RO pilot reduced TDS levels to below 20 mg/L, while EDR reduced levels below 330 mg/L.

Based on results from the pilot testing, to achieve a blended ratio of 500 mg/L, 65 percent of all the City's well water would have to be treated with RO and 87 percent with EDR. The RO pilot achieved a recovery of 74 percent as operated, and the EDR pilot achieved an average of 73 percent. The EDR unit did exhibit higher recovery rates between electrode polarity reversal, with some periods as high as 82 percent. RO reduced TDS by 98 percent, and EDR reduced TDS by 63 percent.

Treatment capital and operational cost estimates were developed based upon the observed data from the pilot operation. Both vendors reviewed the data and participated in development of the cost estimates. For a central water treatment facility with a capacity of 10.5 million gallons per day (mgd) capacity, it is estimated that a reverse osmosis plant could be constructed for $7.9 million, plus distribution and disposal improvements. Similarly, an EDR plant of the same capacity could be constructed for $12.8 million. Operational costs are estimated at $216 per acre-foot for RO and $298 per acre-foot for EDR. These costs are based upon 2005 dollar estimates and do not include a contingency. The recommended contingency is 20 percent since the estimates are for budgeting purposes.

2. Introduction

Support for this project began when the Riverton City (City) Water Department was exposed to electrodialysis reversal (EDR). City personnel visited a site in Magna, Utah, where an EDR demonstration unit was operating on a public supply underground water well. The well water being treated at that particular project was similar in total dissolved solids (TDS) concentration to the City's well supplies. The EDR demonstration unit was operating on a continuous basis, producing treated water with a significantly reduced TDS concentration. Sparked by the results of the EDR, the City's Water Department became interested in investigating technologies to reduce TDS concentrations in their public drinking water underground sources.

2.1 Project Funding

In order to pursue investigating EDR, the City budgeted $40,000 to conduct an EDR pilot test on their well water. The City retained Epic Engineering, P.C. (Epic) as their consultant to manage the piloting. Epic prescreened additional technologies for TDS reduction and recommended reverse osmosis (RO) as another potential viable process. Prescreening efforts indicated that RO could compete with EDR, both in terms of economics and finished water quality. Therefore, it was recommended to the City that both technologies be piloted in order to provide a comparison.

Reclamation's Desalination and Water Purification Research and Development Program was identified as a source of additional project funding. Epic submitted a funding proposal on behalf of the City in order to fund piloting of both EDR and RO. The project budget was identified as $93,754 and was to be funded equally between Riverton City and Reclamation.

2.2 Project Definition

The project includes the pilot testing of two treatment methods for reducing TDS: EDR and RO. Pilot testing of each system was performed for a 3-month period in order to provide a 2,000-hour (22 hours per day on average) operating basis for reliability and sustainability. The pilots were run on the same water source during the same period in order to provide a side-by-side comparison. Source water quality was continuously monitored and recorded, as was the effluent water quality from each pilot. Water quality data from the source water, permeate, and concentrate streams were used to evaluate each technology's effectiveness in reducing TDS and were the basis for a 20-year present worth comparison. This final technical report is provided to document the findings of the project and fulfill the cooperative agreement requirements with Reclamation.

2.3 Project Team

The pilot project team included the City's Water Department, Epic, Goldeneye Solutions, Inc., and GE Infrastructure/Ionics (GE). The City's Water Department oversaw the pilot project and provided day-to-day monitoring, data recording, and sampling of the EDR and RO pilots. Water Department personnel also helped set up, move, and dismantle pilot equipment. Epic provided technical support and coordination between the City, Goldeneye Solutions, Inc., and GE. Engineers from Epic helped troubleshoot operational difficulties, evaluated pilot data, and provided project coordination. Goldeneye Solutions, Inc., provided the RO pilot equipment. GE provided the EDR pilot equipment. Both pilot vendors trained City personnel in operation of their pilot unit and provided technical assistance during pilot operation. In addition, the pilot vendors provided assistance to Epic in developing capital cost and operational costs of full-scale treatment plants.

Project team members can be contacted at:

Riverton City Water Department, 12830 South 1700 West, Riverton City,
Utah 84065

Epic Engineering P.C., 4000 West 3341 South, West Valley City, Utah 84120

Goldeneye Solutions, Inc., 502 NW 13th Avenue, Little Falls, Minnesota
56345

GE Infrastructure/Ionics, Water & Process Technologies, 65 Grove Street,
Watertown, Massachusetts 02472

2.4 Project Objectives

The primary objective of the project is to evaluate the performance of EDR and RO at reducing TDS in the City's drinking water wells and to determine each process's treatment capital and operational costs per acre-foot. In order to accomplish this goal, the pilot units were operated at the City's Gedge well, Hill well, and Maynard well. Sampling and testing of feed water, brine, and treated water were done to gather data that could be analyzed to determine the effectiveness of each process. Samples were tested for TDS, pH, turbidity, and conductivity. Target constituents were monitored, as well, and included total silica, reactive silica, sulfate, arsenic, iron, total organic carbon (TOC), hardness, and alkalinity. The pilot project was performed to provide a baseline evaluation that would serve the City in planning its future water supply and treatment goals.

3. Pilot Equipment Description

3.1 Reverse Osmosis Pilot

The main components of the RO pilot unit were the 4-inch, spiral-wound membranes. The membranes were manufactured by Dow. The pilot unit required 18 Dow/Filmtec BW30LE-4040 membranes. The pilot was configured in four stages, arranged in a 2 by 2 by 1 by 1 array of three membrane elements each. The pilot was constructed on two moveable skids. The primary skid consisted of the high-pressure booster feed pump, the RO elements, the pilot programmable logic controller and control panel, sampling ports, and instrumentation. The other skid held the permeate storage tank, feed pump, and two feed valves.

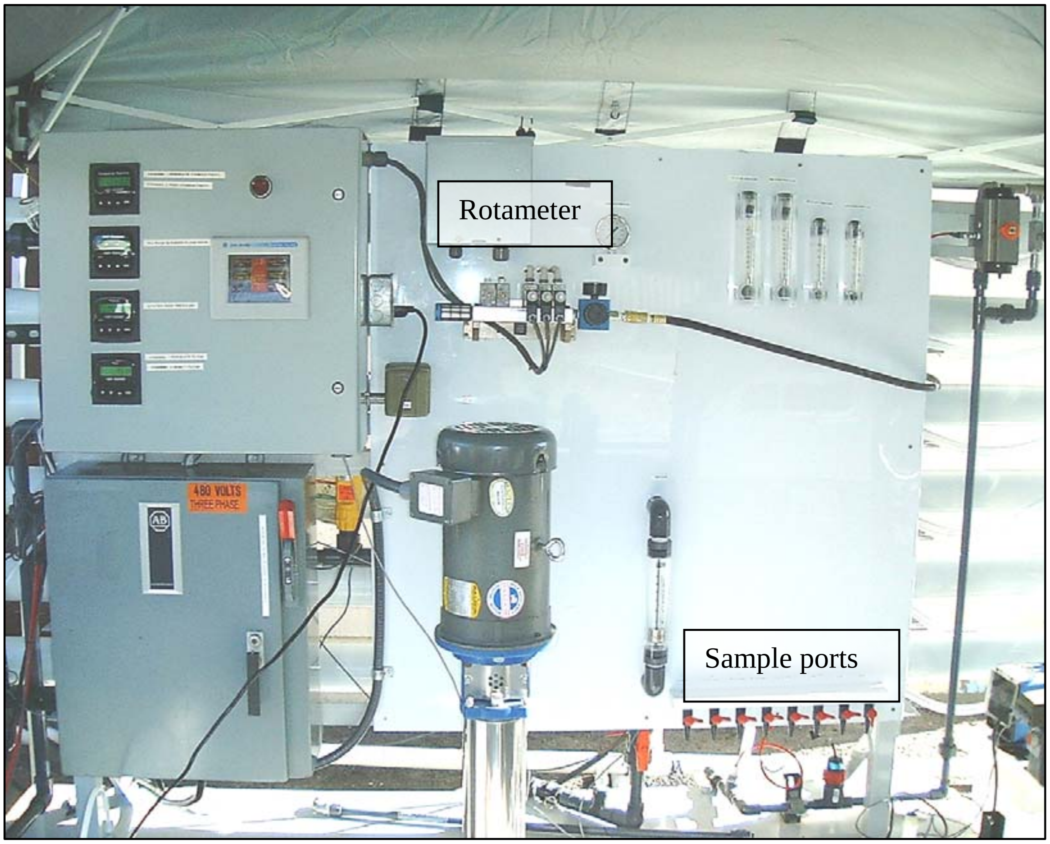

Figure 3-1. RO pilot skid.

The RO pilot was covered with a temporary cover to protect polyvinyl chloride (PVC) components from excessive sunlight and electrical components from precipitation. The pilot required a 480-volt, 30-amperes, three-phase power connection and had a footprint of 16 feet by 10 feet.

The Dow BW30LE-4040 RO membrane element is designed for treating brackish water in light industrial applications. The BW30LE-4040 is 4 inches in diameter and 40 inches long; has an active membrane area of 82 square feet; a permeate flow rate of 2,300 gallons per day (gpd) at 150 pounds per square inch (psi) applied pressure; and a stabilized salt rejection of 99.0 percent based on standard test ratings. The membrane is made from a polyamide thin-film composite material. It is rated for a maximum operating temperature of 113 degrees Fahrenheit (˚F); a maximum operating pressure of 600 psi; a maximum pressure drop of 15 psi per element; a pH range between 2 and 11; a maximum feed silt density index (SDI) of 5; and a free chlorine tolerance less than 0.1 part per million (ppm).

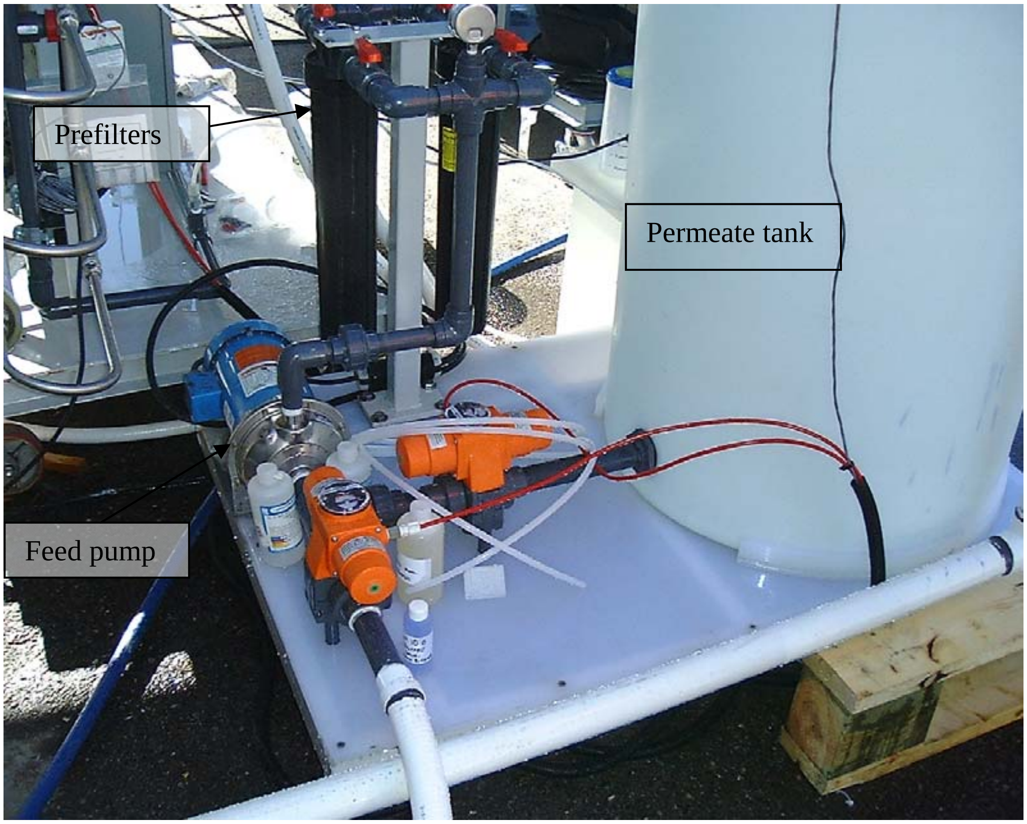

Figure 3-2. Prefilters and feed pump.

Feed water for the RO pilot is pressurized by a feed pump before it is sent through two 20-inch-high, 5-micron cartridge filters. The feed pump has a 2-horsepower motor and delivered feed water at an average pressure between 70 and 80 psi to the prefilters. The feed pump was installed adjacent to a permeate collection tank from which permeate water could be pumped through the RO membranes for cleaning. The process change was accomplished using two air-actuated valves.

The prefilters consisted of two 20-inch-high, 5-micron disposable cartridges installed in parallel in the feed water piping. Following the prefilters, the feed water pressure is boosted by a multistage, centrifugal, high-pressure pump. The high-pressure pump has a 7.5-horsepower motor and was used to boost the feed pressure to a value ranging between 150 and 180 psi.

Figure 3-3. Chemical injection system.

A chemical injection system for anti-scalant was provided with the pilot. It consisted of a small high-density polyethylene tank with a level sensor and a diaphragm metering pump. The RO membrane elements are protected by a hard shell exterior that is designed to withstand higher pressure drops, which are experienced in multiple element configurations.

The feed water flows through the membranes as a result of the pressure difference created between the feed water and product water. The product side of the membrane is near atmospheric pressure. The remaining feed water continues through the pressurized side of the RO element. The feed water is now called concentrate because it contains a higher concentration of constituents. The major energy requirement is for the initial pressurization of the feed water. As the product water passes through the membrane, the remaining feed water and brine solution becomes more and more concentrated. To reduce the concentration of dissolved salts remaining, a portion of this concentrated feed water-brine solution is withdrawn from the container. Without this discharge, the concentration of dissolved salts in the feed water would continue to increase, requiring ever-increasing energy inputs to overcome the naturally increased osmotic pressure.

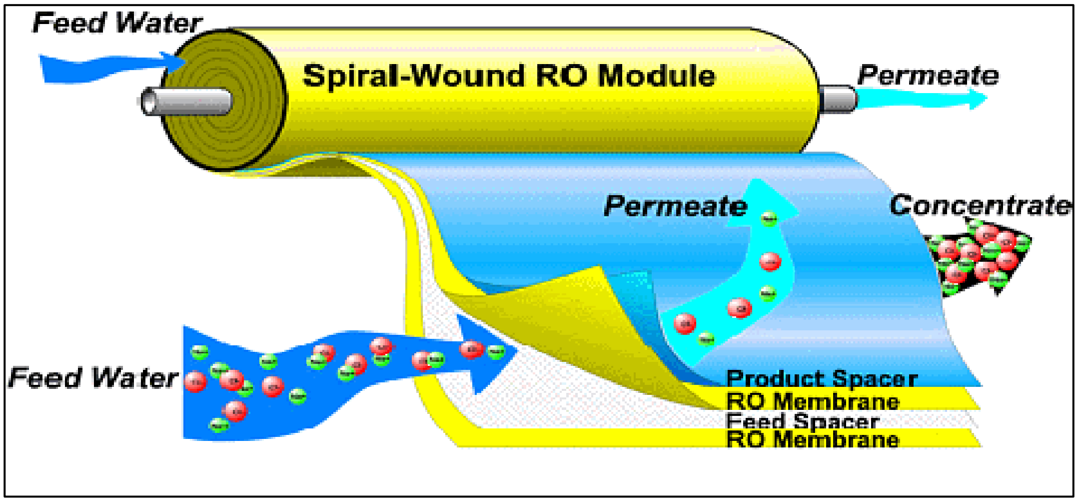

Figure 3-4. RO membrane element.

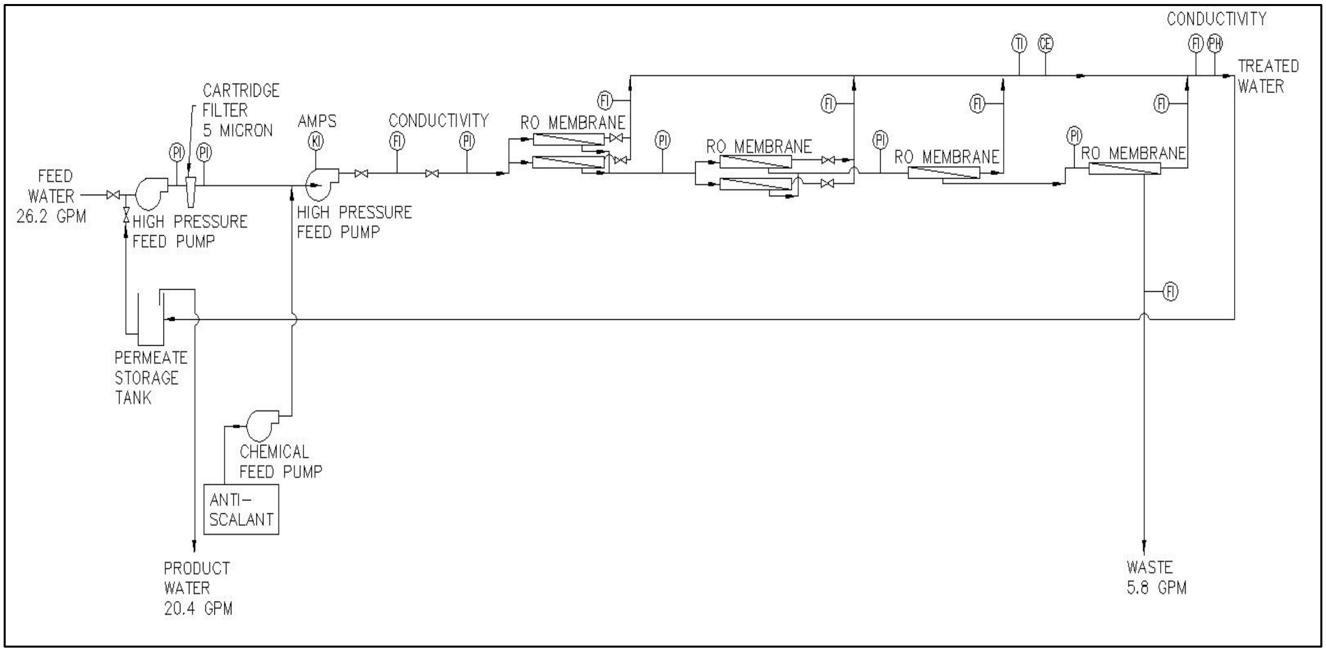

Figure 3-5. RO flow diagram.

3.2 Electrodialysis Reversal Pilot

The EDR pilot was an Aquamite V-M manufactured by Ionics, Inc. The pilot unit is considered to be a four-stage EDR stack. The membrane stack has two electrical stages, and each electrical stage contains two hydraulic stages. The cell pair orientation in the pilot membrane stack is 90/60//90/60. The pilot membrane sheets are 18 inches by 40 inches each and are paired in sets consisting of one cation selective membrane and one anion selective membrane. The first-stage hydraulic stage contained 90 cell pairs, the second stage contained 60 cell pairs, and so on. This staging is diagrammed in figure 3-12, which appears later in this report.

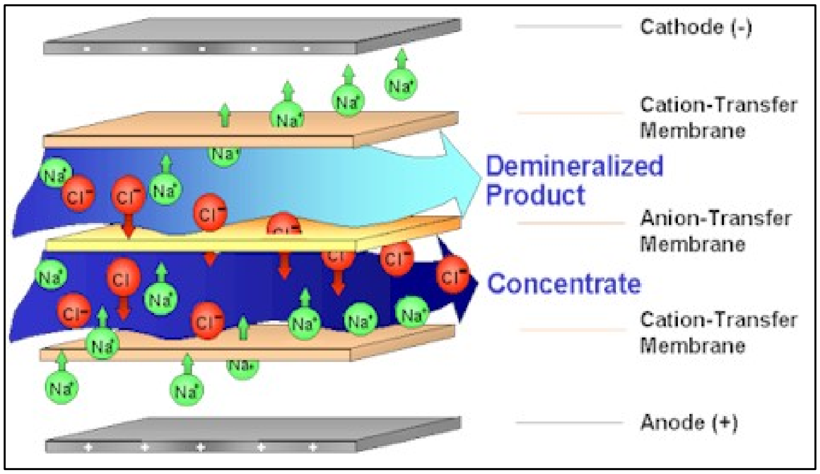

Figure 3-6. EDR membrane stack.

This unit was selected by GE because of its ability to closely duplicate the performance of a full-sized EDR 2020 system, in terms of product water quality and the concentrated level of brine, which recirculates within the EDR system. The ED membranes provided in the unit were not new. GE estimated their age at 15 years.

The process of EDR is very similar to electrodialysis (ED) in that it utilizes electrical current as the main driving force in separating matter. The charged particles must be mobile, and the separation media must be able to transfer the electrical current with relatively low resistance; as such, water is a good medium for ED. Where ED draws the ions to the anodes and cathodes by separating them, EDR adds ion selective membranes to prevent migrating cations and anions from reaching the electrodes. The semipermeable barriers are commonly known as ion-exchange, ion-selective, or EDR membranes. In order to allow water to flow between the ion-selective membranes, they are assembled with spacers between them that help direct the waterflow and create turbulence.

Like other membrane processes, one problem in water desalination with the ED process is that the membranes and other active surfaces tend to become "fouled" or "scaled" over time by organic and inorganic substances present in the water. The fouling is removed by chemical soaks and flushing. EDR was developed to extend the time between chemical cleans on ED membranes. By reversing the electrical current and exchanging the fresh product water and the concentrate wastewater streams within the membrane stack several times per hour, fouling and scaling constituents that build up on the membrane surface in one cycle are removed in the next reversing cycle. This is the main difference between ED and EDR. The efficiency of the EDR process depends largely on the direct current voltage levels in the stacks. It is important to note that the two electrodes in a stack are kept separated from the processed solutions.

Figure 3-7. EDR pilot unit trailer.

The EDR pilot unit arrived in a trailerized configuration, which made transportation easy but proved to be difficult to work in when repairs to the pilot had to be made. The trailer was approximately 8 feet wide by 12 feet tall by 24 feet long. The trailer required a 480-volt, 50-amperes, three-phase power connection to power the internal pumps, electric actuated valves, electronic controller, and EDR rectifier. The flow diagram for the pilot unit, as supplied by GE, shows how the water is routed through the EDR stack.

The pilot unit is designed to boost feed water with a 2-horsepower motor and 15-gallon-per-minute (gpm) pump. The motor requires 480-volt, three-phase electricity. The trailer is equipped with a feed water pump, so it can utilize water from an open top reservoir, at atmospheric pressure, and pressurize the water in order to push it through a 10-micron, disposable cartridge prefilter. The feed pump was not needed in this test because the water pressure provided by the well pumps was more than adequate to accomplish this. However, the controller logic in the pilot unit could not reasonably be changed to delete the pump from the control circuit, so the feed pump boosted the feed pressure, again, to a pressure greater than required by the pilot unit. To compensate for this additional pressure, GE installed a manual pressure-reducing valve downstream of the feed pump and prior to the 10-micron filter.

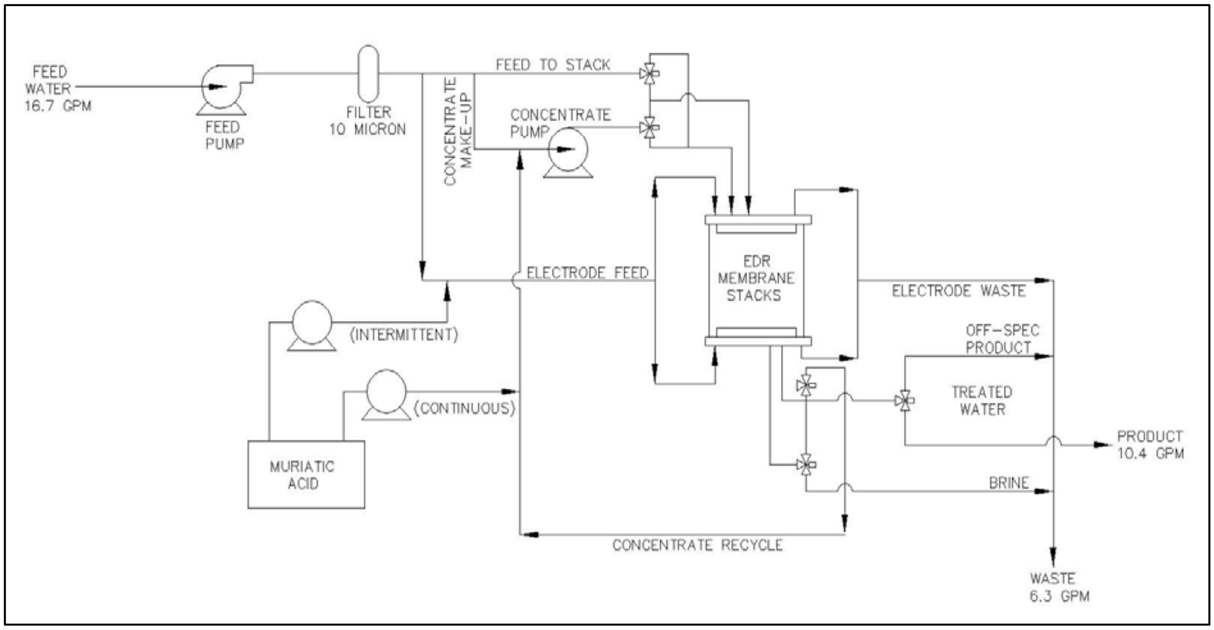

Figure 3-8. EDR flow diagram.

The target feed flow rate was 14 gpm. Actual feed water flows varied from 11 to 18 gpm during the piloting. New cartridge filters were installed at the beginning of the pilot testing and were not replaced during pilot operations. Inlet pressures to the prefilter ranged from 62 to 75 psi. The prefilter cartridge holder was large enough to stack two cartridges on top of each other, effectively providing for parallel flow of the feed water through them.

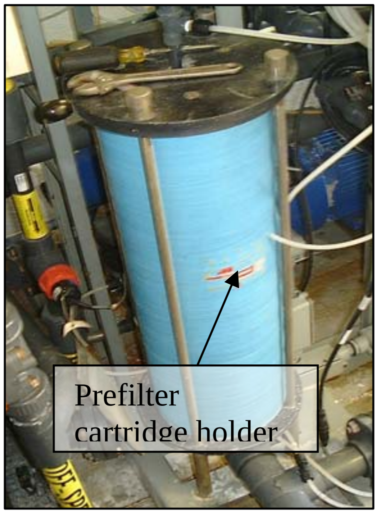

Figure 3-9. Prefilter.

Feed water was divided into several streams before entering the EDR stack. These streams are the main stack feed, electrode feed, and concentrate make-up water. The main stack feed was controlled by monitoring the dilute (or product flow) from the EDR unit with a rotameter and an electronic flowmeter. Theoretically, under steady state conditions, these flows would be the same; however, in practice, the EDR membrane stack continually leaked a small amount of water. The amount of leaked water was not measured during the pilot study but, by observation, appeared to be less than 1 percent of the feed flow. A dilute flow rate of 12.5 gpm was the goal for the pilot.

Electrode feed was measured using two rotameters: one for the top and bottom electrodes in the stack, and one for the center electrodes. Electrode target flows of 1 gpm each were desired during the pilot. The target concentrate make-up flow rate was 0.6 gpm.

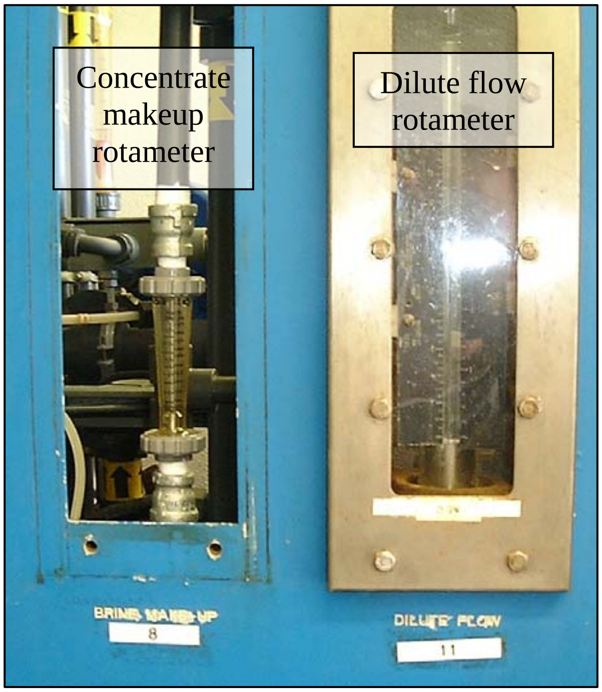

Figure 3-10. EDR rotameters.

Waterflows to the electrodes are not continuous during operation. The flows alternate between the sets of electrodes. The top and bottom electrodes have flow around them during the negative electrode polarity phase, and the middle electrodes have flow around them during the positive electrode polarity phase.

During polarity phase changes, which occurred every 15 minutes of pilot operation, the electrode flows both fell to zero while the cycling actuated valves changed position.

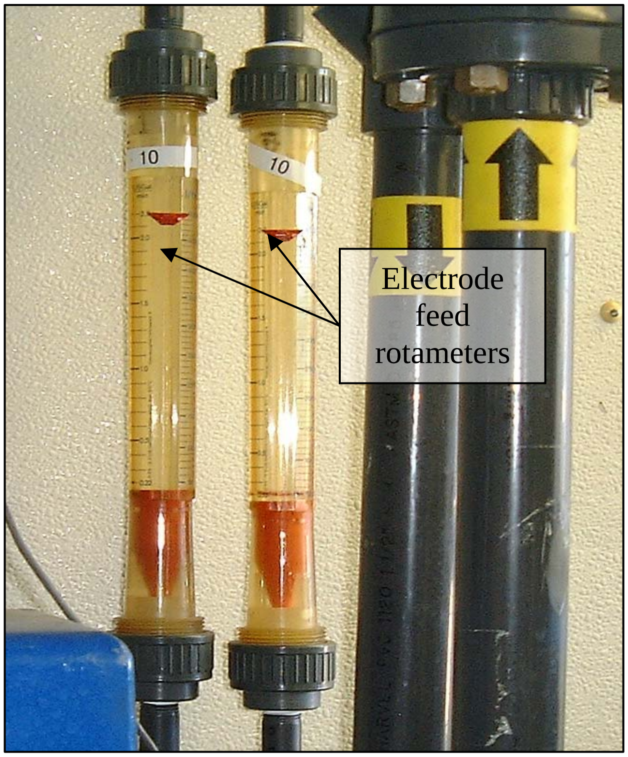

Figure 3-11. Electrode feed rotameters.

Feed water routed through the EDR membrane stack passes through the cell pairs in various stages. Understanding the internal stages to the pilot unit can be difficult; therefore, figure 3-12 illustrates the various hydraulic and electrical stages. A full-scale 2020 EDR membrane stack does not share electrical stages with hydraulic stages the way the pilot unit does. Because of this, a full-scale EDR plant is expected to achieve slightly better ion separation than the pilot unit. Dilute (permeate) water from each hydraulic stage flows onto the next stage, where the flow divides and passes through the next stage's cell pairs. Concentrate, also referred to as brine, is drawn off from each hydraulic stage. The majority of the concentrate is sent to waste, and a small stream is pumped back to the start of the EDR stack and recycled.

When viewing the EDR stack, it is easy to see the two electrical stages as they are separated by the plates forming the middle electrodes. The hydraulic stages in the pilot cannot be visually seen from viewing the exterior of the EDR stack. Understanding the hydraulic stages in the EDR stack is made easier by illustrating them in a simplified sketch of the stack (figure 3-12). The collected water from the stack is often referred to as dilute because it has a lower concentration of ions present than the stack feed water. The dilute is collected and sent on as product water or off-spec product. During an electrical current reversal of the electrodes, dilute water and concentrate streams exchange within the membrane stack. This cycling helps remove fouling and scaling constituents that build up on the membrane surfaces. The stack of ion-selective membranes is clamped together in a manner to squeeze them one on top of the other. This assembled configuration helps minimize the leakage of water from the spacers and membranes. The stack is protected with plastic sides that can be easily removed for access and maintenance. The plastic shields protect operators from inadvertently touching the electrodes and getting shocked. The electrode voltage during the pilot operation ranged between 48 and 56 volts direct current. Amperage in the electrodes varied from 1.2 amperes to 6.6 amperes.

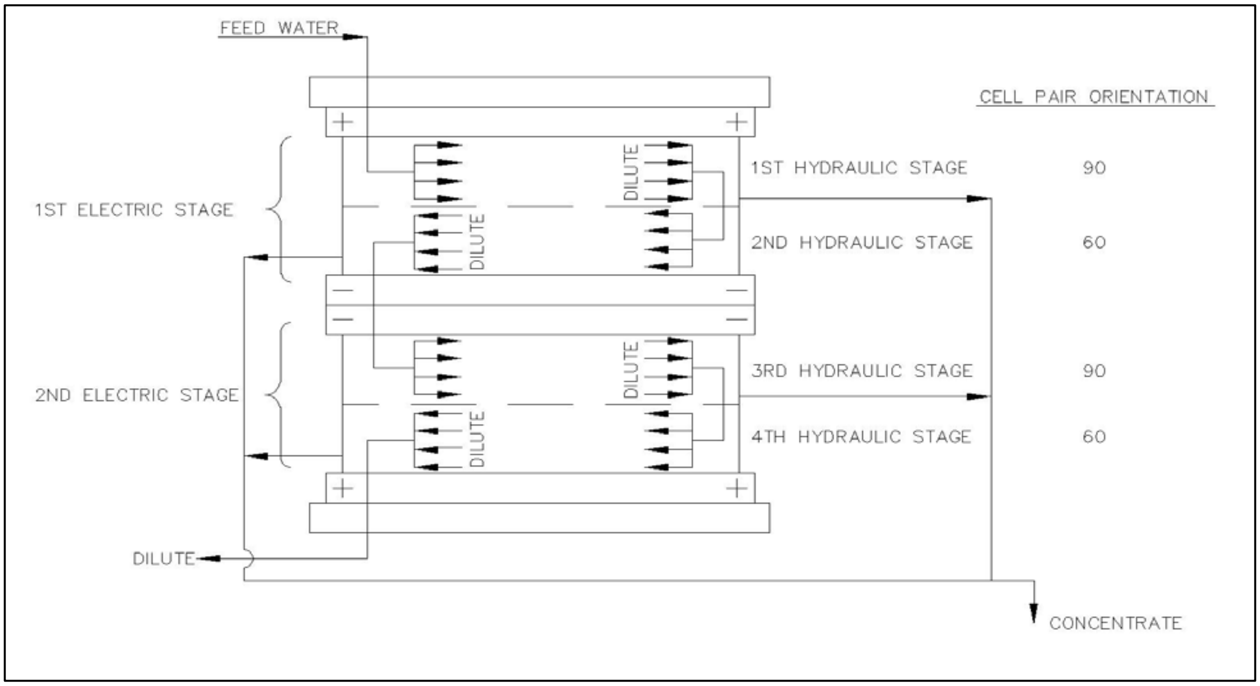

Figure 3-12. EDR stages.

Figure 3-13. EDR unit.

The bottom of the stack has a tray that collects water that seeps from the stack. The water that seeps from the stack is sent to waste. We noted during the pilot testing that the drain line on the tray tended to clog rather easily. We attribute this to the high concentration of TDS in the feed water and the likelihood that the water coming off of the stack was a combination of dilute and concentrate, effectively providing a small stream with hardness equal to the feed water.

Figure 3-14. EDR stack.

To ensure that feed water is not contaminated within the stack, the pilot piping is configured to maintain a higher pressure on the dilute streams compared to the brine streams. The pilot accomplishes this using PVC pipe mounted to the outside of the trailer. The dilute stream is pushed through a higher standpipe relative to the other streams before it gravity flows away from the unit.

The EDR pilot produces several streams, all of which must be properly managed to maintain proper operation. These streams include product water, off-spec product, concentrate recycle, brine-blowdown, and electrode waste. Management of these streams is mainly accomplished by monitoring multiple pressure gauges mounted on the pilot and by varying manual flow control valves. The process is tedious and somewhat difficult. We found that even after the 3 days of initial training and three subsequent followup visits by GE personnel, operation of the EDR pilot improved but was not perfect. GE informs us that a new full-scale plant would be equipped with automated equipment to control each series of EDR membrane stacks and that these improvements simplify the operation of the technology.

Figure 3-15. EDR piping.

The top two gauges provided the feed water pressure before and after the prefilter cartridge. The middle left gauge indicated the feed water pressure after the feed pump. Note that due to the circumstance with the water system pressure from the wells, a pressure reducing valve was installed between the feed pump and the prefilter cartridge to reduce pressure. The middle right gauge indicated the water pressure at the EDR stack inlet and outlet. The lower left gauge indicated the water pressure going to the electrodes, and the lower right gauge indicated the stack inlet differential pressure and the stack outlet differential pressure.

The stack inlet differential pressure is a measurement between the raw feed water entering the stack and the brine concentrate. The stack outlet differential pressure is measured between the product (dilute) water and the brine concentrate stream.

Figure 3-16. EDR gauges.

4. Feed Water Quality

The analysis of the feed water quality for the pilot testing was critical in order to determine the effectiveness of each method in treating the source water from Riverton City's wells. Several constituents were tested including TDS, pH, turbidity, and conductivity. Target constituents such as total silica, reactive silica, sulfate, arsenic, iron, TOC, hardness, and alkalinity were monitored as well. Critical water quality parameters for the RO process include silica, water temperature, and TDS. Critical water quality parameters for the EDR process include water hardness, water temperature, and TDS.

4.1 Silt Density Index

The fouling potential of suspended solids in the feed water was measured by performing a SDI test. A sample line was run from a tap on the feed water piping to a SDI test kit, which was used to analyze the feed water. The unit included a ball valve, pressure regulator (set to 30 psi), pressure gauge, filter disk holder, and filter papers. A standard SDI test estimates the decay (plugging) flow rate of colloidal particles through a 47-millimeter-diameter, 0.45-micrometer pore size membrane and is used to assess the suitability of membrane processes like EDR and RO. The rate of plugging is converted to an SDI value and used as a guide for determining pretreatment/prefiltration requirements. SDI values of less than five do not require prefiltration according to the manufacturers of RO and EDR membranes. SDI values were measured upstream of the prefilter cartridges and for each of the wells. The results are:

Gedge well = 2.0, Hill well = 0.5, Maynard well = 0.1

The formula used to determine the SDI value is:

$$\mathrm{SDI} = \frac{\left(1 - \frac{t_i}{t_f}\right) \times 100}{T}$$

The well water, as expected, measured very low SDI. The Gedge well had the highest SDI, which was consistent with the observations made on the replaced prefilter cartridges. While it was relatively little in volume, the Gedge well did produce the largest amount of sand of the three wells.

4.2 Turbidity

Turbidity refers to how clear the water is. The greater the amount of total suspended solids in the water, the murkier it appears and the higher the measured turbidity will be. High concentrations of particulate matter can modify light penetration, as particles of silt, clay, and other materials stay dispersed in the water. Fine particulate material, if not removed by pretreatment, can also clog or damage sensitive membranes and potentially interfere with membrane removal efficiencies. Very high levels of turbidity for a short period of time may not be significant and may even be less of a problem than a lower level that persists longer.

The well water from all three wells measured relatively low. The results for each of the wells are:

	NTU			**No. of Samples**
	Minimum	**Maximum**	**Average**	
Gedge well	0.05	0.30	0.14	5
Hill well	0.06	0.20	0.11	4
Maynard well	0.05	0.06	0.05	5

Note: NTU = nephelometric turbidity units.

4.3 Water Temperature

As expected, the temperature of the water from the wells remained fairly constant during the duration of the test. It was anticipated that all of the ground water would be very close in temperature given the proximity of the wells to one another. The actual average feed water temperature from each well to the pilot units was:

	° F			**No. of Samples**
	Minimum	**Maximum**	**Average**	
Gedge well	56	74	61	16
Hill well	50	62	58	15
Maynard well	50	64	57	22

4.4 pH of Water

The ground water sources evaluated in the pilot project had a stable pH reading very near neutral. The pH of pure water, when exposed to the atmosphere, can be lowered by the absorption of carbon dioxide from a pH of 7 to as low as 5.7. The pH of water also lowers as temperature increases. Most substances have a pH between 0 and 14; because of this, the pH scale is said to range from 0 to 14. Values below 7 are considered acidic, and values above 7 are basic. Drinking water should have a pH between 6.5 and 8.5.

	pH			No. of Samples
	Minimum	Maximum	Average	
Gedge well	7.18	8.48	7.29	45
Hill well	7.30	7.82	7.47	31
Maynard well	7.04	7.54	7.50	43

4.5 Total Organic Carbon

Total organic carbon is a measurement of the degree of organic contamination within the water. The main sources of TOC are natural organic substances, insecticides, herbicides, and other agricultural chemicals. Riverton City's wells are protected from contamination by their Drinking Water Source Protection Plan. Implementation of this plan does not guarantee the wells will not be contaminated, but it is the best management practice available to the City. Laboratory measurements of the TOC from each of the studied wells are provided below. The minimum regulated level for surface waters (or ground water under the direct influence of surface water) that use conventional filtration is greater than 2.0 mg/L. Only the Maynard well exhibited TOC levels above this value, but there is no evidence to suggest that the Maynard well is (or has been) under the direct influence of surface water. In addition, the wells are not chlorinated; therefore, the interaction of disinfectants with TOC does not occur. For these reasons, the permeate water from each pilot was not tested.

	Mg/L			No. of Samples
	Minimum	Maximum	Average	
Gedge well	1.5	1.5	1.5	1
Hill well	1.6	1.6	1.6	1
Maynard well	2.3	2.3	2.3	1

4.6 Total Dissolved Solids

Dissolved solids can be organic or inorganic in nature. Inorganic constituents are the most common dissolved solids in water, and they typically exist as ions in solution. The most common of these ions are calcium, magnesium, sodium, iron, manganese, bicarbonate, chloride, sulfate, nitrate, and carbonate. These electrically charged dissolved particles make ordinary natural water a good conductor of electricity. It is a common practice to measure the conductivity of water to use as an indicator of TDS concentration. The TDS concentration can be related to the conductivity of the water, but the empirical relationship is not a constant. The relationship between TDS and conductivity is a function of the type and nature of the dissolved cations and anions in the water and possible the nature of any suspended materials. The TDS in ppm (mg/L) usually range from 0.5 to 1.0 times the electrical conductivity (EC) in microsiemens per centimeter (µS/cm).

The concentration of the dissolved ions may cause the water to be corrosive, have a salty or brackish taste, tend to deposit scale formations, and interfere and decrease efficiency of hot water heaters. Also, high TDS levels can be a warning for elevated concentrations of health related ions such as nitrate, arsenic, aluminum, copper, lead, etc. For these reasons, the EPA has set a secondary standard of 500 mg/L for drinking water. However, many communities in the United States tolerate levels as high as 1,200 mg/L.

The average TDS concentrations of the well source waters, as measured during the pilot test period from laboratory samples, are:

	mg/L			**No. of Samples**
	Minimum	**Maximum**	**Average**	
Gedge well	746	920	857	38
Hill well	682	1,060	960	34
Maynard well	878	1,030	970	42

4.7 Conductivity

Electrical conductivity estimates the amount of TDS (salts) or the total amount of dissolved ions in the water. Absolute pure water with no ions will not conduct an electrical current. EC increases with increasing water temperature and is commonly corrected to a standard value of 25 degrees Celsius (°C). At this standard temperature, the values are referred to as specific EC. The geology of the surrounding rocks contributes to the chemistry composition of the water, and this can have an influence on the conductivity of the water. For example, limestone leads to higher EC because of the dissolution of carbonate minerals in the water. The size of the contributing watershed can also influence the conductivity of water. For example, a bigger watershed surface area means relatively more water draining into the lake and more contact with soil and rocks before reaching the collection basin. This can allow more time for dissolving ions into the water. Other sources, mainly pollutants from wastewater, urban runoff, and pesticides can also affect conductivity. For these reasons, a consistent and direct relationship between TDS and conductivity cannot be established for all cases. However, for small studies, an average empirical relationship is often used to identify “normal” conditions and for monitoring because conductivity can easily be measured in the field, whereas measuring TDS is a more time-consuming activity and is most often done in a laboratory setting.

The average conductivity measurements of the well source waters, as measured in the field with a handheld instrument during the pilot test period, are:

	µS/cm			No. of Samples
	Minimum	Maximum	Average	
Gedge well	774	1,332	1,292	69,178
Hill well	400	1,603	1,452	61,912
Maynard well	1,395	1,518	1,499	54,965

The correlating empirical relationship for each well is as follows, where TDS is in mg/L and EC is in µS/cm:

Gedge well	0.66 = TDS/EC
Hill well	0.66 = TDS/EC
Maynard well	0.65 = TDS/EC

4.8 Arsenic

The EPA lowered the maximum contaminant level for arsenic from 50 parts per billion (ppb) to 10 ppb in January 2006. The potential health effects from exposure to elevated levels of arsenic can be skin damage, circulatory system complications, and increased risk of cancer. A common source of arsenic contamination in drinking water is erosion of natural deposits in geological formations. Industrial sources of arsenic include runoff from mining activities and electronic production waste. Waters that have a high natural concentration of fluoride can contribute to higher levels of arsenic because of fluoride's affinity for the element. The average arsenic concentrations in the well water are:

	ppb			No. of Samples
	Minimum	Maximum	Average	
Gedge well	2.5	5.2	4.4	7
Hill well	1.0	6.3	5.0	7
Maynard well	6.2	8.5	7.4	10

4.9 Sulfate

Sulfate, like TDS, is not regulated by the EPA under national primary drinking water standards. However, sulfates degrade the taste of drinking water, similar to TDS, and EPA recommends a secondary standard of 250 mg/L. In combination with calcium, barium, or strontium, sulfate can be a cause of scaling in RO membranes. The average concentrations of sulfate in the wells are:

	mg/L			No. of Samples
	Minimum	Maximum	Average	
Gedge well	138	145	140	7
Hill well	140	168	159	7
Maynard well	151	162	159	10

4.10 Alkalinity

Naturally occurring alkalinity is a natural buffer in water that will react with small doses of strong acids to produce relatively small changes in pH. Alkalinity is comprised primarily of carbon dioxide, bicarbonate, carbonate, and hydroxides. Carbon dioxide and bicarbonate are in a balance between the pH range of 4.4 and 8.2. At a pH of 4.4 or lower, all alkalinity is in the form of carbon dioxide. At a pH of 8.2, there is negligible carbon dioxide and all alkalinity is bicarbonate. Bicarbonate and carbonate are in balance between the pH range of 8.2 and 9.6. At a pH of 9.6, there is no carbon dioxide or bicarbonate and all alkalinity is carbonate. As the pH increases above 9.6, hydroxyl alkalinity starts to occur due to the presence of hydroxide ions.

Alkalinity is commonly reported in $CaCO_3$ equivalents. Levels of 20 to 200 mg/L are typical of fresh water. A total alkalinity level between 100 and 200 mg/L is considered well buffered. Levels below 10 mg/L indicate that the water is poorly buffered and is very susceptible to changes in pH from natural or human-caused sources.

The alkalinity levels in the three wells are:

	mg/L as $CaCO_3$			No. of Samples
	Minimum	Maximum	Average	
Gedge well	290	300	298	7
Hill well	330	380	366	7
Maynard well	360	370	368	10

4.11 Water Hardness

The hardness of water is defined as the sum of polyvalent cations dissolved in the water. The most common cations are calcium and magnesium, although iron, strontium, and manganese may contribute. Hardness is usually reported as an equivalent quantity of $CaCO_3$. The calculation for hardness, is in milli-equivalents per liter $CaCO_3$ = ([Ca, mg/L]*2.497) + ([Mg, mg/L]*4.116. The following classification for hardness is used in the water industry.

Classification	mg/L or ppm	Grains/Gallon
Soft	0-17.1	0-1
Slightly hard	17.1-60	1-3.5
Moderately hard	60-120	3.5-7.0
Hard	120-180	7.0-10.5
Very Hard	180 and over	10.5 and over

The well water tested is all very hard. Magnesium is highly soluble and usually represents a third or less of the total hardness and is usually not a contributor to scaling on membranes. Calcium, on the other hand, can be a large contributor to scaling. The hardness levels in each of the three wells are:

	mg/L as $CaCO_3$			No. of Samples
	Minimum	Maximum	Average	
Gedge well	435	531	471	7
Hill well	482	614	563	7
Maynard well	365	529	494	10

4.12 Total Silica and Reactive Silica

Total silica refers to the total concentration of silica without identifying the silica compounds. Total silica content of water is composed of reactive silica and unreactive silica. Reactive silica (SiO_4) is dissolved silica that is slightly ionized and has not been polymerized into a long chain. Unreactive silica is polymerized, colloidal, or suspended silica (e.g., sand). High levels of suspended silica are not recommended for membranes; hence, the SDI limit of five for RO and EDR. In the colloidal form, silica can be removed by modern RO membranes, but it can cause fouling of the RO membrane. Silica passes through the EDR process, essentially unaffected.

The relative insolubility of silica can cause ill effects on RO membranes as the feed water becomes more concentrated. At a pH of 7, the solubility of silica is 120 mg/L at 77 ˚F. Multistage RO units, which concentrate the feed water, can reach this limit and cause precipitation of silica, thereby clogging the membrane. An example is a feed water having a silica concentration of 30 mg/L in an RO system trying to achieve a 75-percent recovery.

Reactive silica can be removed within an ion-exchange softening process. Silica can be removed easier in such a pretreatment process if a large percentage of it is reactive silica, thus preventing silica fouling of the RO membrane.

The silica concentrations in the three Riverton City wells are as follows:

	Reactive Silica (mg/L)			Total Silica (mg/L)			No. of Samples
	Minimum	**Maximum**	**Average**	**Minimum**	**Maximum**	**Average**	
Gedge well	31	33	32	31	38	34	7
Hill well	32	39	37	34	44	40	7
Maynard well	43	46	45	44	50	47	10

5. Pilot Operation

One of the implied goals of the pilot testing project was to acquire 2,000 hours of operational performance from each technology. That is the reason for choosing a 12-week study period. If the pilots ran continuously, 24 hours per day, 7 days per week for this period, they would have logged 2,016 hours each. Realistically, we expected to achieve a result somewhat less than this for the following reasons:

1. The 12-week study period was the maximum study duration due to budget restraints.
2. The 12 weeks included a small number of days for setup, training, and relocating of the pilot equipment from one well location to the next for the three studied wells.
3. Some minor "hiccups" in operating the pilots were expected.

5.1 Study Period

The pilot equipment was set up on August 31, 2005, and began operation on the same day under the supervision of the vendors. Training of the Riverton City personnel began on the same day and ensued for the next 3 days. The vendors shared the available training time each day, with each vendor providing 4 hours of training each day. During the remaining hours in the day, the vendor pilot technicians fine-tuned the operation of the pilots and prepared training lessons for the City operators.

The last day of pilot operation was December 7, 2005. The pilots were in operation for a gross period of 14 weeks (98 days). The additional 2 weeks of rental were provided by the vendors on gratis. The following table provides a detailed breakdown of the pilot operations at each well.

5.2 EDR Operation

As can be seen from the data in the previous table, the EDR pilot saw significant downtime while at the Gedge well and Hill well. The experience of trying to run the EDR pilot was unpleasant during the first 2 months of operation, when the EDR unit was operating at the Gedge and Hill wells. The Field Notebook outlines the problems experienced with the EDR pilot during this period of time, but it does not fill in all of the gaps. In general, the main problem in operating the EDR unit stemmed from not completely understanding how the pilot operated. This basic deficiency manifested itself as a failure of the concentrate recycle pump. Multiple visits by GE technicians to clean and adjust the pilot, as well as to provide additional training, still did not compensate for the complexity of the pilot. The issue of complexity is one related to process piping, valving, and location of instrumentation. The overall concept of EDR was well understood.

Table 5.1. Pilot Operations

Pilot	Gedge Well				Hill Well				Maynard Well			
	Start and finish dates	No. of days onsite	No. of days opera-tional	% on-line	Start and finish dates	No. of days onsite	No. of days opera-tional	% on-line	Start and finish dates	No. of days onsite	No. of days opera-tional	% on-line
EDR	08/31/05–10/12/05	42	19	45%	10/12/05–11/07/05	26	19	73%	11/07/05–12/07/05	30	30	100%
RO	08/31/05–10/12/05	42	41	98%	10/12/05-11/07/05	26	26	100%	11/07/05–12/07/05	30	30	100%

Pilot	Gedge Well, Hill Well, and Maynard Well			
	Total days onsite	Total days operational	Total % online	Total estimated operating hours
EDR	98	68	69%	1,536
RO	98	97	99%	2,232

The age and condition of the EDR pilot was the second cause of problems associated with operating the unit. Electrical shorts associated with the emergency stop button on the EDR pilot caused multiple shutdowns of the unit for no apparent reason. PVC piping within the pilot was aged and brittle. This caused a piping failure that required repair during the time the brine concentrate pump was malfunctioning. Also, we know that the GE technician worked on several motor operated valves on the pilot during field visits to correct their operation. The details of the maintenance work done on the EDR pilot equipment was not recorded by GE's technician and, hence, is not a part of this report. However, after the last site visit by the technician on October 28, 2005, the EDR pilot operated successfully for the remainder of the study.

It is not our intent to imply that the EDR process is inherently plagued with problems but, rather, to present the actual problems experienced with our particular EDR demo unit. In all fairness, the process of EDR has been proven in various other applications, and it should not be assumed that EDR equipment will demonstrate the difficulties we experienced. We caution the reader to be mindful of this and want to make it clear that the comments in this report are applicable only to this particular study.

Weather conditions changed during the course of the pilot study from warm 70 °F days in September to cold 32 °F days in late November and early December. Night-time temperatures dipped as low 22 °F. The trailerized enclosure of the EDR pilot equipment served as a shelter from rain and snow.

Two small (1,500-watt) electric resistance heaters were used inside the trailer to keep temperatures above freezing.

5.2.1 EDR Performance

Recorded measurements of field and laboratory results (where applicable) were evaluated to determine the percent rejection that the EDR equipment achieved. The analysis was done on the results for each individual well. The overall results were combined to provide a time-weighted average for the pilot study. The terms "rejection" and "reduction" are used synonymously in this report.

Table 5-2. EDR Rejection Rate

Rejection Rate for EDR				
Well Name	**Gedge (%)**	**Hill (%)**	**Maynard (10%)**	**Weighted Average**
TDS	73.9	57.3	62.6	64.3
Conductivity	72.2	42.2	65.7	59.7
Hardness	86.7	92.2	90.3	89.9
Alkalinity	59.2	68.4	62.2	63.5
Sulfate	95.7	97.3	97.2	96.8
Reactive silica	0.5	0.0	1.4	0.5
Total silica	0.0	0.4	1.4	0.3
Arsenic	88.4	83.3	85.0	85.3

The results show that the EDR pilot could successfully reduce TDS in the well water by approximately two-thirds of initial values. The removal of alkalinity tracked very closely with that of TDS, which, given the pH of our feed water, indicates that the majority of alkalinity in the well water is due to bicarbonates. The unit performed exceptionally well at reducing water hardness. This shows EDR is capable of high rejection rates of calcium and magnesium (the main contributors of hardness in the City's wells). Sulfate removal was the highest of the measured parameters, and all of the treated well water achieved greater than 95-percent rejection. Arsenic, while low in initial concentrations, still exhibited very significant rejection by the EDR, with an average reduction of 85 percent. As expected, the EDR unit showed little to no effect on silica concentrations in the water. Therefore, the presence of silica in water has little to no effect on the fouling of EDR membranes and seemingly passes through without effect to the membranes or equipment.

5.2.2 EDR Projections vs. Actual Results

The accuracy of the computer-generated models used in the EDR industry, compared to actual performance in the field, is of important interest to the City. City officials must consider the impacts that water recovery rates and treatment efficiency may have on planning budgets. If it can be shown that projections are indeed accurate with real-life results, the planners can have a high level of confidence that planned improvements will accomplish their desired goals. GE ran a projection for the EDR pilot on the Gedge well prior to pilot startup. The projection was based upon water quality sample data taken from the well 2 years previously. That projection is presented hereafter and compared to actual results for specific parameters.

Table 5.3. EDR Model Projections

EDR Computer Model Projections for the Gedge Well									
	Feed Water			**Product Water**			**Concentrate Water**		
Description	**Projection**	**Actual**	**Variance**	**Projection**	**Actual**	**Variance**	**Projection**	**Actual**	**Variance**
Flow	15.4	16.7	1.3	12.0	10.4	-1.6	3.4	6.3	2.9
TDS	1,108.1	857	-251.1	313.0	225.5	-87.8	7,675.8	2,142.1	-5,533.7
Conductivity	1,472.8	1,292	-180.8	398.5	358.5	-40.0	8,543.0	3,243.9	-5,299.1
Hardness	502.4	471	-31.4	93.4	63.0	-30.4	3,882.9	1,280.8	-2,602.1
pH	7.60	7.29	-0.31	7.16	6.90	-0.26	8.23	6.58	-1.65
Sulfate	160.0	140	-20.0	19.43	6.0	-13.4	1,321.7	407.1	-914.6
Total silica	48.0	34	-14.0	48.0	34.0	-14.0	48.0	32.6	-15.4
Recovery	78%	61%	-17%						
Temperature	60 ˚F	61 ˚F	1 ˚F						

At the Gedge well, the largest deviation from the projection was found in the recovery percentage and concentrate TDS levels. The EDR pilot did not achieve the flow recovery anticipated or the concentration of dissolved solids in the brine stream. This variance is attributed to improper acid feed settings during operation at the well. Hydrochloric acid was fed into the feed water in order to acidify the water, so that scale-forming calcium and magnesium ions would remain in solution as the water flowed through the EDR process. Our pilot protocol did not establish a feed water pH target level. Rather, we relied on GE to provide guidance on establishing the acid feed rate for the study. In retrospect, the feed water should have been conditioned to provide a pH of 6 or less, as this likely would have helped prevent the disruptive scaling experienced early on in the study.

The City operator responsible for the pilot experienced numerous occasions where instrumentation settings could not be achieved on the pilot, specifically stack differential pressures. Whatever the cause of this was, it is attributed to the condition of the EDR unit, as evidenced by the repair work performed each time GE's field technician visited the pilot operation and to training provided by GE.

By the end of the pilot operation, the overall recovery percentage of the EDR unit was 73 percent. Recovery percentages gradually increased over time and at each of the well sites. Adjustments to the EDR pilot by GE seemed to be the biggest factor in improving recovery. The individual recovery at each well was: Gedge well = 61 percent, Hill well = 78 percent, and Maynard well = 79 percent.

Optimizing recovery to try and achieve an 85-percent recovery rate (as indicated possible by GE prior to the beginning of the pilot operation) was not a focus during the pilot operation. GE recommended the pilot be run at a conservative recovery rate to demonstrate the technology and insisted that a full-scale EDR plant would be a more efficient plant, both in terms of recovery and effectiveness. On several occasions, Riverton City informed GE that the EDR pilot needed to stay in operation during the demonstration or, if it could not, that the equipment was to be removed. Thus, GE focused on having the unit online as opposed to trying to push its capabilities for fear of an offline condition occurring.

5.3 RO Operation

The experience of operating the RO pilot equipment evokes the thought "simple and reliable," as problems were few and not difficult to solve. Initially, some of the instrumentation on the RO pilot appeared to be recording data incorrectly. Specifically, the data logger was recording oscillating amperage readings on the booster pump and lower than actual concentrate flows. These items were corrected while at the Gedge well and did not significantly impact operation of the unit.

A second small problem we experienced operating the pilot was that the antiscalant solution tank formed a mucous-looking substance in it, which affected the operation of the level sensor in the tank. The mucous-looking substance was formed by sunlight exposure and caused the level sensor to send a false signal that the chemical tank was empty, which, in turn, triggered the programmable logic controller to shut down the RO unit. This was solved by draining the chemical tank, rinsing it with water, and cleaning the level sensor. To avoid the problem in the future, Goldeneye Solutions instructed us to add sodium benzoate to the antiscalant solution at a concentration of 2 tablespoons per 16 gallons.

The RO unit was mounted on mobile skids with casters and did not have a weather enclosure. Although we erected a patio-type tarp cover over it to protect it from sunlight and precipitation, the weather caused a metering pump (diaphragm style) to malfunction during the pilot operation. It was determined that rain damaged the pump controls. This caused the unit to be inoperable for 1 day. The condition was fixed temporarily with a spare pump and permanently when Goldeneye Solutions provided a replacement pump a few days later. After the initial failure, the metering pump was protected from precipitation by placing a small plastic bag over it.

During the colder months of November and December, the RO pilot equipment was wrapped with a tarp and kept above freezing temperature with two portable propane heaters (15,000 British thermal units [BTU] and 25,000 BTU, respectively). Freezing of the unit did not occur, except at the sample port, where SDI measurements were being made.

Figure 5-1. RO Pilot Tarp Enclosure.

The main breaker in the RO power center tripped on two separate occasions, which necessitated a restart of the unit on each occasion. However, the downtime was relatively insignificant and did not promulgate any other conditions or problems with the RO equipment. Keeping the equipment from freezing was the main concern for the City's operator responsible for monitoring the RO pilot. The other aspects of running the RO equipment required very little attention or adjustment.

5.3.1 RO Performance

The overall performance of the RO unit was evaluated by using recorded measurements from field and laboratory sample testing. The results were combined into rejection averages. For comparison, the results are presented alongside those of the EDR.

Table 5-4. RO Versus EDR Comparison

Rejection Comparison		
	RO (%)	EDR (%)
TDS	97.9	64.3
Conductivity	98.4	59.7
Hardness	100.0	89.9
Alkalinity	99.8	63.5
Sulfate	100.0	96.8
Reactive silica	99.1	0.5
Total silica	99.0	0.3
Arsenic	97.3	85.3

Rejection by the RO membranes was greater than the EDR ion-selective membranes. The RO membrane represents a physical barrier through which water is forced, removing constituents that are too large to pass through the membrane. This approach of removing impurities in water appears to be a more effective method than the EDR process of drawing ions out of the feed water stream.

The implications of this include potential benefits; most notably, the ability to treat a smaller side stream to produce the desired blended water quality and the reduction in energy costs associated with treating the smaller stream. However, the RO membranes are subjected to greater concentrations of constituents in the brine stream, which can lead to back-side fouling and scaling. RO also effectively eliminates alkalinity in the treated water, thus removing any natural buffering capacity against strong acids, and lowers its pH to undesirable levels.

5.3.2 RO Projections vs. Actual Results

The accuracy of the computer projection for the RO pilot was more accurate than that for the EDR. Specifically, the recovery projection of 75 percent was almost achieved, as the pilot’s actual recovery rate was 74 percent. The recovery of the RO pilot could be improved by adjusting the outlet pressure control valve. The valve position was not changed during the pilot test. The projection provided by the RO vendor did not include a forecast for conductivity. The largest deviation in the projection was that for TDS. The projection included a higher than actual TDS concentration, which correlated to a higher calculated concentration of TDS in the brine than what was actually achieved. This deviation was increased by a higher residual TDS in the product water than forecasted.

Table 5-5. RO Model Projections

RO Computer Model Projections for the Gedge Well									
	Feed Water			Product Water			Concentrate Water		
Description	Projection	Actual	Variance	Projection	Actual	Variance	Projection	Actual	Variance
Flow	26.67	26.19	-0.48	20.0	20.44	0.44	6.67	5.75	-0.92
TDS	938.8	857	-81.8	17.9	29.0	11.0	3,697.7	3,031.2	-666.5
Conductivity		1,292			15.2			4,885	
Hardness	488.2	471	-17.2	7.5	0.3	-7.2	1,928.4	1,736.4	-192.1
pH	7.10	7.25	0.15	5.45	5.63	0.18	7.75	7.72	-0.03
Sulfate	141.0	140	-1.0	1.50	0.0	-1.5	558.9	519.3	-39.6
Total silica	34.7	34	-0.7	1.2	0.3	-1.0	135.0	123.7	-11.3
Recovery	76%	74%	-1%						
Temperature	60 ˚F	61 ˚F	1 ˚F						

6.0 Quality Control of Data

One of the keys to successfully completing the pilot project was reviewing the collected data for errors in accuracy and analyzing it for precision and confidence. The goal was to achieve a high level of quality assurance by following procedures adapted from the National Science Foundation/Environmental Protection Agency Equipment Testing Verification (ETV) protocol.

Data was recorded by Riverton City personnel in most cases, and reviewed by supervising personnel from Epic. This procedure was developed to identify inaccuracies in data recording and to reduce human-induced errors in the dataset. Field measurements of conductivity and pH were taken with a Myron L handheld meter that was calibrated on a weekly basis using reagent solutions provided by the manufacturer. Electronic flowmeter measurements were checked against flow rotameters for noticeable deviations in each pilot. The vendors did not provide current calibrations on the pilot instrumentation; however, we feel that the devices provided a reasonable degree of accuracy.

6.1 Precision and Confidence Intervals

The degree of mutual agreement among individual measurements provides an estimate of random error and is referred to as precision. This report analyzes the precision of the recorded data from the pilot operation by calculating the standard deviation, coefficient of variance, and 95-percent confidence interval for nine different parameters on the feed water and treated water from each pilot. For a normally distributed set of data, 68 percent of the values will be within one standard deviation of the mean, 95 percent will be within two standard deviations, and 99.7 percent will be within three. The coefficient of variance is the ratio of the standard deviation to the mean and is a dimensionless number that can be used to compare the amount of variance between data sets with different means. The coefficient of variance is expressed as a percentage. A low percentage indicates a close distribution of data, and a high percentage indicates a spread data set.

6.1.1 Feed Water Quality

Seven of the nine parameters at both the Gedge and Maynard wells were found to have a 95-percent confidence interval within one standard deviation. The Hill well feed water exhibited the most variation in water quality data. This data variation is illustrated in the water quality charts derived from the Hill dataset. During the pilot test, it was determined that the fluctuations in water quality were a direct result of two conditions acting together.

The Hill well pump station incorporates a metering connection between Riverton City and Jordan Valley Water Conservancy District (District) that meters water the City purchases from the District. The water purchased from the District mixes immediately with water pumped from the Hill well. When the Hill well pump is operating, well water displaces water from the District at the point of connection to the RO and EDR pilots. After the well shuts off, water purchased from the District begins to fill the pump station piping as the pilots continue to draw water from the system. The water quality from the District is significantly different from the underground water from the well. The most noticeable difference is in TDS concentration. The District water has an approximate TDS concentration of 250 mg/L.

Table 6-1. Statistical Analysis of Feed Water Quality Data

Feed Water Quality	Gedge Well		CV	No. of samples	95% Confidence Interval			Units
	Average	s			Student's $t_{0.05}$	Lower Limit	Upper Limit	
TDS	857.3	34.2	4%	38	1.686	847.9	866.7	mg/L
Conductivity	1,292	22	2%	69,178	1.6448	1,292	1292	µmhos/cm
Hardness	471	25	5%	7	1.943	453	490	mg/L
Alkalinity	298	3	1%	7	1.943	296	300	mg/L
Sulfate	141	1	1%	7	1.943	140	142	mg/L
Reactive silica	32	1	3%	7	1.943	31	32	mg/L
Total silica	34	2	7%	7	1.943	32	35	mg/L
Arsenic	0.0044	0.0016	37%	7	1.943	0.0032	0.0055	mg/L
pH	7.3	0.17	2%	45	1.678	7.25	7.33	

Feed Water Quality	Hill Well		CV	No. of samples	95% Confidence Interval			Units
	Average	s			Student's $t_{0.05}$	Lower Limit	Upper Limit	
TDS	960.3	98.4	10%	34	1.691	931.7	988.8	mg/L
Conductivity	1,452	234	16%	61,912	1.6448	1,450	1,453	µmhos/cm
Hardness	563	62	11%	7	1.943	518	608	mg/L
Alkalinity	366	23	6%	7	1.943	349	383	mg/L
Sulfate	159	14	9%	7	1.943	149	170	mg/L
Reactive silica	37	3	9%	7	1.943	34	39	mg/L
Total silica	40	5	12%	7	1.943	37	44	mg/L
Arsenic	0.0050	0.0017	33%	7	1.943	0.0038	0.0063	mg/L
pH	7.5	0.08	1%	31	1.698	7.44	7.50	

Table 6-1. Statistical Analysis of Feed Water Quality Data (continued)

Feed Water Quality	Maynard Well		CV	No. of samples	95% Confidence Interval			Units
	Average	s			Student's $t_{0.05}$	Lower Limit	Upper Limit	
TDS	970.1	34.0	4%	42	1.68	961.3	978.9	mg/L
Conductivity	1,499	20	1%	54,965	1.6448	1,498	1,499	µmhos/cm
Hardness	494	41	8%	10	1.833	470	517	mg/L
Alkalinity	368	3	1%	10	1.833	366	370	mg/L
Sulfate	159	4	3%	10	1.833	156	161	mg/L
Reactive silica	45	1	2%	10	1.833	44	45	mg/L
Total silica	47	2	4%	10	1.833	46	48	mg/L
Arsenic	0.0074	0.0008	10%	10	1.833	0.0070	0.0078	mg/L
pH	7.5	0.08	1%	43	1.685	7.48	7.52	

6.1.2 RO Product Quality

Statistically analyzing the RO product water reveals the flowthrough membrane's ability to significantly reduce the TDS, hardness, and alkalinity of the feed water. Permeate water from the RO pilot consistently had a TDS concentration between 5 and 34 mg/L. Hardness was virtually removed, with no readings above 1 mg/L as $CaCO_3$. Likewise, alkalinity was reduced to a level averaging 1 mg/L. The coefficient of variance for many of the parameters is high (greater than 50 percent) but the averages and standard deviations for each are relatively small compared to feed water conditions. We conclude from this that the RO membranes are highly effective at removing dissolved solids; however, a proper design needs to accommodate the lower band of expected performance.

The high variation in TDS in product water from the Hill well indicates water purchased from the District influenced the water quality samples. The treated water from the Hill site has a significantly lower average TDS than the other two locations.

Table 6-2. Statistical Analysis of RO Product Water Quality

RO Product Water	Gedge Well		CV	No. of samples	95% Confidence Interval			Units
	Average	s			Student's $t_{0.05}$	Lower Limit	Upper Limit	
TDS	29.0	14.4	49%	27	1.706	24.3	33.7	mg/L
Conductivity	21.78	1.11	5%	43,680	1.6448	21.77	21.79	µmhos/cm
Hardness	0.30	0.45	149%	5	2.132	0	0.73	mg/L
Alkalinity	0.80	0.84	105%	5	2.132	0	1.60	mg/L
Sulfate	0	0	0%	5	2.132	0	0.00	mg/L
Reactive silica	0.12	0.16	137%	5	2.132	0	0.28	mg/L

RO Product Water	Gedge Well		CV	No. of samples	95% Confidence Interval			Units
	Average	S			Student's $t_{0.05}$	Lower Limit	Upper Limit	
Total silica	0.26	0.09	34%	5	2.132	0	0.35	mg/L
Arsenic	0.00044	0.00098	224%	5	2.132	0	0.0014	mg/L
pH	6.5	1.05	16%	27	1.706	6.13	6.81	

RO Product Water	Hill Well		CV	No. of samples	95% Confidence Interval			Units
	Average	s			Student's $t_{0.05}$	Lower Limit	Upper Limit	
TDS	8.1	7.0	87%	18	1.74	5.2	11.0	mg/L
Conductivity	18.19	4.58	25%	34,930	1.6448	18.15	18.23	µmhos/cm
Hardness	0	0	0%	4	2.353	0	0	mg/L
Alkalinity	0	0	0%	4	2.353	0	0	mg/L
Sulfate	0	0	0%	4	2.353	0	0	mg/L
Reactive silica	0.18	0.17	98%	4	2.353	0	0.38	mg/L
Total silica	0.15	0.13	86%	4	2.353	0	0.30	mg/L
Arsenic	0	0	0%	4	2.353	0	0	mg/L
pH	5.8	0.52	9%	17	1.746	5.61	6.05	

RO Product Water	Maynard Well		CV	No. of samples	95% Confidence Interval			Units
	Average	s			Student's $t_{0.05}$	Lower Limit	Upper Limit	
TDS	22.3	11.3	51%	20	1.729	17.9	26.7	mg/L
Conductivity	30.12	4.04	13%	27,539	1.6448	20.08	30.16	µmhos/cm
Hardness	0.21	0.44	211%	5	2.132	0	0.63	mg/L
Alkalinity	1.40	1.14	81%	5	2.132	0.31	2.49	mg/L
Sulfate	0	0	0%	5	2.132	0	0	mg/L
Reactive silica	0.72	0.18	25%	5	2.132	0.55	0.89	mg/L
Total silica	0.78	0.04	6%	5	2.132	0.74	0.82	mg/L
Arsenic	0	0	0%	5	2.132	0	0	mg/L
pH	6.8	0.87	13%	21	1.725	6.50	7.16	

6.1.3 EDR Product Quality

The data collected from analyzing the EDR product water must be interpreted with care. The EDR process is a cycling process; when the pilot equipment switched electrode phases, its efficiency fluctuated by ramping down and up until a steady-state treatment was achieved again. Operators were instructed to take water quality samples and tests during the middle of the 15-minute cycle to ensure steady-state conditions. However, this proved to be more difficult in practice than anticipated. Some of the data results and samples may have been taken at a time when the EDR unit was producing “off-spec” product water. This report does not separate “off-spec” product data, if any was collected, as the procedures used in place did not adequately address the condition.

In general, the EDR unit produced treated water with significantly higher levels of TDS, conductivity, hardness, alkalinity, sulfate, silica, and arsenic when compared to RO treated water. Measured pH levels were also slightly higher. Likewise, the standard deviation for each monitored parameter was significantly greater when compared to the RO results.

Of particular interest is the result for TDS reduction at the Gedge well. Here it is well documented that the EDR unit was malfunctioning during much of the test period for the well. Nonetheless, the laboratory data for TDS indicated a lower average, standard deviation, and coefficient of variance. This data is misleading because it appears that the unit operated with a high degree of effectiveness at that site when, in fact, its water recovery was the lowest of the three test sites. Being unfamiliar with the intricacies of the EDR equipment, it is difficult to explain this condition. That is why we are emphasizing the need to look at the collected data side by side with the actual performance and operation. Only by considering all the information together can a complete picture be presented.

It is our opinion that the best operational data from the EDR pilot is that from the testing at the Hill and Maynard wells because it is taken during a time when the equipment was properly adjusted and ran consistently. The data from the Gedge well is considered noncharacteristic of EDR and should be weighted accordingly. Operation difficulties experienced early on with the EDR have skewed the data during that time, so any use of it for planning purposes should be done with caution.

Table 6-3 Statistical Analysis of EDR Product Water Quality

EDR Product Water	Gedge Well		CV	No. of samples	95% Confidence Interval			Units
	Average	s			Student's $t_{0.05}$	Lower Limit	Upper Limit	
TDS	225.5	51.7	23%	11	1.812	197.2	253.8	mg/L
Conductivity	358	124	34%	25,498	1.6448	357	360	mg/L
Hardness	63	62	98%	2	6.314	0	337	mg/L
Alkalinity	123	67	55%	2	6.314	0	422	mg/L
Sulfate	6	6	94%	2	6.314	0	31	mg/L
Reactive silica	32	0.2	1%	2	6.314	30.6	32.5	mg/L
Total silica	34	3	9%	2	6.314	20	48	mg/L
Arsenic	0.0005	0.00071	141%	2	6.314	0	0.0037	mg/L
pH	6.9	2.13	31%	15	1.761	5.88	7.82	

EDR Product Water	Maynard Well		CV	No. of samples	95% Confidence Interval			Units
	Average	s			Student's $t_{0.05}$	Lower Limit	Upper Limit	
TDS	407	530.3	130%	16	1.753	174.6	639.4	mg/L
Conductivity	834	317	38%	26,982	1.6448	831	838	µmhos/cm
Hardness	44	4	10%	3	2.92	37	51	mg/L
Alkalinity	116	29	25%	3	2.92	66	166	mg/L
Sulfate	4	0.6	13%	3	2.92	3.4	5.3	mg/L
Reactive silica	37	3	8%	3	2.92	32	42	mg/L
Total silica	40	5	12%	3	2.92	32	48	mg/L
Arsenic	0.00093	0.00042	45%	3	2.92	0.00023	0.0016	mg/L
pH	7.3	0.17	2%	14	1.771	7.22	7.38	

EDR Product Water	Hill Well		CV	No. of samples	95% Confidence Interval			Units
	Average	s			Student's $t_{0.05}$	Lower Limit	Upper Limit	
TDS	363.5	396.4	109%	22	1.721	218.1	508.9	mg/L
Conductivity	512	105	21%	27,425	1.6448	511	513	µmhos/cm
Hardness	47	4	9%	5	2.132	42	51	mg/L
Alkalinity	140	21	15%	5	2.132	120	160	mg/L
Sulfate	4	0.9	20%	5	2.132	3.5	5.3	mg/L
Reactive silica	44	0.6	1%	5	2.132	43.5	44.6	mg/L
Total silica	47	2	4%	5	2.132	45	49	mg/L
Arsenic	0.0011	0.00016	15%	5	2.132	0.00096	0.0013	mg/L
pH	7.1	0.30	4%	22	1.721	6.98	7.20	

7.0 Concentrate Disposal

An issue that must be addressed in any RO or EDR project is the disposal of the concentrate. We offer some general comments in this report that outline Riverton City's perspective and our recommended management practices regarding concentrate disposal. First, it must be remembered that in the overall scheme, mass balance of constituents is achieved. Concentrating the TDS levels from the 900-mg/L range (927 mg/L was the feed water average) to near 3,300 mg/L (3,368 mg/L was calculated concentrate average) is a significant increase and should raise the question "what is to be done with this water?".

In the City's case, their existing pressure irrigation system is capable of accepting the concentrate and putting it to beneficial use. The main source of water for the City's pressure irrigation system is canal water from Utah Lake. This source has TDS levels that range between 300 and 4,000 mg/L, with an average TDS for a 1-year study period during the years 1990-91 of just over 1,200 mg/L[1] If the City irrigation system did not utilize the concentrate water, another alternative for the City would be to discharge the brine stream into the Jordan River, which would convey it into the Great Salt Lake. The lake has a TDS concentration that varies between 100,000 mg/L and 240,000 mg/L, depending on the volume of the lake.

Concentrate disposal costs are not included in the cost estimates within this report.

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[1] (Utah Department of Environmental Quality, "Utah Lake," http://www.waterquality.utah.gov/watersheds/lakes/UTAHLAKE.pdf).

8.0 Pilot Project Evaluation

The pilot project test protocol stated very specific goals for the study period. The purpose of these goals was to document the success, or lack of success, of each technology's ability to attain TDS reduction in the well water, and provide a basis for determining capital and operational costs related to implementing the technology on a production basis at one or more of the City's wells. While many of the goals were achieved, not all were. The largest influencing factors that affected our ability to accomplish the goals are:

1. Multiple occasions of failure and shutdown of the EDR demonstration unit. Managing the problems associated with the EDR equipment taxed personnel resources on this project by requiring their time and effort to try and keep the unit running. We soon found ourselves without time to adjust and monitor variables that we would like to have done.

2. A change in the experimental plan from testing one well site to testing three. Initially, the protocol was intended for one well; however, it was decided to test three individual wells because of the differences in water quality, specifically TDS and silica concentration. Moving the pilots from well to well required time and personnel that otherwise could have spent time monitoring the impacts of desired adjustments in the protocol.

3. Lack of vendor support on the EDR. We found the customer service and technical support from GE lacking during the pilot study. Specifically, when we asked GE for recommendations for adjusting electrode voltage we were informed that they would not vary the pilot electrode voltage because it was already at the optimal setting.

4. Bare rental of the pilot equipment. The decision to lease the equipment bare and operate it was made early on in the project schedule. Hindsight has provided us with the knowledge that monitoring and adjusting the pilots to accomplish all the goals written in the experimental plan required more personnel time than was budgeted in the project. Also, our lack of operating experience caused us to spend more time troubleshooting the pilots than an experienced technician would require.

8.1 Test Objectives

Test objectives were divided into two categories: primary and secondary. There were 2 primary objectives and 16 secondary objectives.

8.1.1 Primary Objectives and Conclusions

1. **Evaluate the performance of each technology at reducing naturally occurring TDS in the source ground water to desired target levels.**

   Overall, the pilot test accomplished this goal, as can be seen in the observed data. Actual blending was originally intended at the time of writing of the pilot protocol. However, we soon realized that the results for TDS in blended samples would not be known for some time if they were collected and sent to the lab, so we removed actual blending from the test. Instead, we recognized that calculated values, based on pilot data, could easily predict the required target blending ratios. The target level was selected as 500 mg/L TDS based upon the EPA's secondary drinking water standard. In order to achieve a blended ratio of 500, 65 percent of all the City's well water would have to be treated with RO and 87 percent with EDR. RO has the advantage of having to treat less water than EDR to achieve the same blended water TDS levels.

2. **Determine the treatment capital and operational costs per acre-foot for each technology.**

   Costs estimates were developed based upon the observed data from the pilot operation. Both vendors reviewed the data and participated in the development of the cost estimates. For a central water treatment facility of 10.5-mgd capacity, it is estimated that a reverse osmosis plant could be constructed for $7.9 million, plus distribution system improvements. Similarly, an EDR plant of the same capacity could be constructed for $12.8 million. O&M costs are estimated at $184 for RO and $237 for EDR per acre-foot. These costs are based upon 2005 dollar estimates and do not include contingency. The recommended contingency is 20 percent, since the estimates are for budgeting purposes. These estimates are included in this report as appendix F.

   The costs for the disposal of the brine stream are considered the same for the City's situation, regardless of whether RO or EDR was implemented. Therefore, we did not include them in the cost analysis.

8.1.2 Secondary Objectives

1. **Conduct 12-week pilot operation to provide 2,000 hours of "on-line" time.**

   The RO equipment met the operational goal, operating an estimated 2,200 hours while the EDR was online an estimated 1,500 hours.

2. **Determine the optimal number of stages and blending ratios to reduce TDS concentration levels to 700, 600, and 500 mg/L.**

   Both pilots used a four-stage membrane process. Fewer stages of treatment were not investigated. During the pilot study, concentrations of blended water above 500 mg/L were considered undesirable and, hence, no longer considered. Laboratory sampling and field measurements focused on the permeate water quality after the fourth stage of membrane processing. No data was collected from interstage locations for TDS. During the pilot study, it was realized that in order to accomplish this goal that the number of laboratory samples and operator time required to do so would increase dramatically and drive the project costs beyond the established city budget. The vendors provided calculated projections for one well (Gedge).

3. **Take daily sampling of TDS of feed, brine, treated, and blended water.**

   Water samples for TDS were taken for the feed and treated water. It was determined that the brine and blended water could be calculated, so the costs of laboratory testing were avoided.

4. **Take weekly sampling in accordance with the “Sampling Matrix” from the pilot test protocol.**

   The matrix was followed, except that brine and blended water were not sampled because they could be calculated using mass balance.

5. **Determine the optimal flow recovery and TDS reduction for each well.**

   Flow recovery percentages were determined based upon pilot performance during the study. RO achieved a recovery of 74 percent, and EDR achieved an average of 73 percent, with some periods as high as 82 percent. RO reduced TDS by 98 percent, and EDR reduced TDS by 63 percent. The highest recovery percentages are the most desirable. The technologies were very close in this regard, but the latter performance of the EDR indicates it may be able to achieve higher recovery rates than RO.

6. **Data log multiple instrument readings every 15 minutes.**

   Data logging of several items was accomplished on a 1-minute resolution. The higher resolution actually showed the difference between the cycling of the EDR and the steady operation of the RO. The following items were automatically logged by computer: current, feed water conductivity, product water conductivity, feed water flow rate, treated water flow rate, RO brine flow rate, RO feed pressure, and feed water pH.

The following items were logged once a day: EDR electrode voltage, feed water temperature, and brine pH.

The vendors required that specific data to each pilot be recorded on a daily basis beyond that shown in the pilot protocol. This was done and provided to the vendors at the completion of the study. Examples are antiscalant tank level, acid tank level, electrode flow, RO first stage flow, etc.

7. **Compare actual flow recoveries to anticipated recoveries.**

Neither pilot achieved actual recoveries higher than those anticipated. The RO achieved 99 percent of its anticipated recovery, and the EDR achieved 86 percent.

8. **Monitor and record actual chemical usages for each process.**

The vendors did not provide estimated quantities of chemical usage as requested. Actual usages were determined and compared against those commonly found in similar type applications. Actual consumption is as shown below:

	Dosage (mg/L)	**Solution (gpd)**	**Total Solution Used (gallons)**
RO – antiscalant	2.3	2.5	242.5
EDR – acid_1	31.9	2	76
EDR – acid_2	63.8	4	120
EDR – acid_{ave}	46	2.9	196

The antiscalant was ATF-200 provided by Alpine Technical Services. The antiscalant solution was formed by mixing ATF-200 with well water at a ratio of 1:32. The acid solution used for the EDR was 31.45 percent muriatic acid (HCl) bought locally from a nearby hardware store. The dosage rate on the EDR was changed from 2 to 4 gpd to avoid scale deposits in the brine (concentrate) stream. The dosage change occurred on October 28, 2005, as directed by GE.

Actual expenses incurred by the City for chemicals were $1.34 per day for antiscalant and $8.95 per day for muriatic acid. The cost disparity for chemicals between the EDR and RO apparently diminishes for large-scale operations. Industry-provided figures for chemicals show EDR chemical consumption costs only 25 percent more than RO.

9. Evaluate the impact of high silica ground water on water recovery.

Silica showed no impact on the EDR process. The provided antiscalant dosage in the RO system proved to adequately prevent silica fouling of the RO membranes.

10. Evaluate membrane recovery after each clean in place.

The RO membranes that were tested were installed new, and a clean in place was not performed on them. No noticeable degradation of the membrane performance was observed. The EDR ion-selective membranes were in used condition. They did show signs of scaling while at the Gedge well; however, subsequent maintenance performed by GE technicians did remove the scaling. Following the scaling incident at the Gedge well, the EDR equipment continued to improve in performance.

11. Investigate energy input vs. effective TDS reduction.

This goal of the pilot project was not accomplished.

12. Determine the ideal configuration of EDR and RO systems to meet the TDS goals established.

The pilot equipment vendors both recommended four-stage membrane configurations for the feed water.

13. Develop full-scale plant process design criteria.

The pilot project provided the following full-scale design criteria: recovery rate, TDS rejection, chemical dosage rates, brine TDS concentration, and blending ratios. This data would be the foundation of a large plant design.

14. Determine the upper limit of effectiveness of EDR and RO.

This goal was not achieved. Process parameters were not varied under controlled conditions and monitored as required in order to define any limits. The only apparent limit was that of scaling in the EDR caused perhaps by dosing muriatic acid at a level that was too low (~30 mg/L).

15. Maintain testing quality assurance by limiting sampling to steady-state conditions.

This goal was accomplished. The only questionable data is that of the EDR during the initial few weeks at the Gedge well, and it is questionable, not because of recording accuracy, but because of operating conditions.

16. Summarize the findings of the pilot test operation.

This report is a compilation of findings from the pilot test period and is being provided as documentation to Riverton City for their use.

See appendices for additional data.

Appendix A

Projections

WATSYS FOR WINDOWS DESIGN PROGRAM
ProjName: Riverton Utah Gedge Well
By: ERR, Epic Engineering
Cell Pair Configuration // 90/60 // 90/60 //
Monday, August 22, 2005

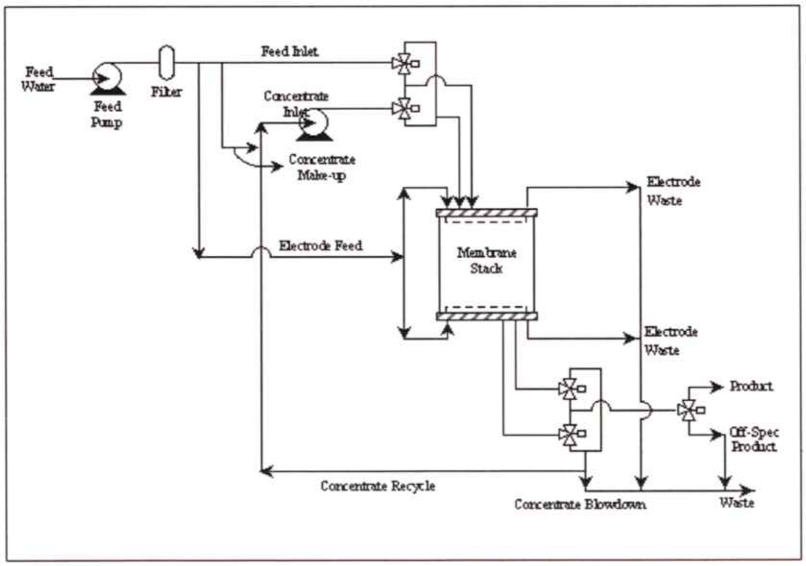
IONICS

# of Lines	1		
System	Aquamite V		
Anion Membrane	AR204SXZL		
Cation Membrane	CR67HMR		
Spacer	3G Mark III Retrofit		
Net Production Rate (1)	12.00	USGPM	
Dilute In Flow (2)	12.85	USGPM	
Dilute Flow Losses (3)	0.35	USGPM	
Dilute Out Flow (4)	12.50	USGPM	
Off-Spec Product (5)	0.50	USGPM	4% OSP
EDR Feed (6)	15.38	USGPM	
Conc. Pump Flow (7)	9.76	USGPM	
Electrode Waste (8)	1.37	USGPM	
Conc. Makeup Flow (9)	1.16	USGPM	
Total System Feed (10)	15.38	USGPM	
Total System Waste (11)	3.38	USGPM	22% Waste
Conc. Blowdown (12)	1.51	USGPM	
Minimum Velocity	6.6	cm/s	
Stack Inlet Pressure	33.7	psi	
Stack Outlet Pressure	0.0	psi	
Temperature	60.0	F	
Pumping Power	10.9	kWh/kgal	
DC Power	0.7	kWh/kgal	
Total Power	11.7	kWh/kgal	
Total KVA	1	KVA	

	Feed	Product	BBD	Waste
Calcium (mg/L)	140.00	24.71	1092.78	548.77
Magnesium (mg/L)	37.00	7.67	279.36	140.98
Sodium (mg/L)	119.19	39.02	781.74	403.44
Potassium (mg/L)	8.20	2.06	58.90	29.95
Strontium (mg/L)	0.93	0.07	8.01	3.97
Barium (mg/L)	0.06	0.01	0.47	0.24
Ammonia (mg/L)	0.00	0.00	0.00	0.00
Bicarbonate (mg/L)	380.00	137.17	2386.73	1240.94
Sulphate (mg/L)	160.00	19.43	1321.69	658.39
Chloride (mg/L)	200.00	32.58	1583.59	793.60
Fluoride (mg/L)	0.20	0.07	1.27	0.66
Nitrate (mg/L)	14.50	2.55	113.25	56.87
Total PO4 (mg/L)	0.00	0.00	0.00	0.00
HPO4= (mg/L)	0.00	0.00	0.00	0.00
H2PO4- (mg/L)	0.00	0.00	0.00	0.00
Silica (mg/L)	48.00	48.00	48.00	48.00
TDS (mg/L)	1108.1	313.3	7675.8	3925.8
Conductivity (uS/cm)	1472.8	398.5	8543.0	4720.2
pH	7.60	7.16	8.23	7.99
CaSO4 %Sat	9.53	1.04	80.79	40.10
BaSO4 %Sat	149.27	0.00	563.50	378.23
SrSO4 %Sat	15.75	0.00	56.25	40.16
CaF2 %Sat	21.34	0.00	144.75	74.36
CaHPO4 %Sat	0.00	0.00	0.00	0.00
Ca3(PO4)2 %Sat	0.00	0.00	0.00	0.00
LI	0.53	-1.04	2.79	1.98
Flow Rate	15.4	12.0	1.5	3.4
Total Hardness	502.4	93.4	3882.9	1952.7

Electrical Stages	1	2
Voltage	57	62
Current	4.4	2.8
Surge Amps	11	14

Hydraulic Stages	1	2	3	4
% Polarization	28.9	30.0	35.0	40.0
Cut	0.284	0.266	0.339	0.343
Current Efficiency	0.89	0.89	0.85	0.85
% Burning	3.9	4.4	4.3	5.3



This Design Case exceeds Design Limit.
Consult Ionics Watertown before using this design.
Langelier Index exceeds design limit of 2.1

System Summary

Feed Flow to Stage 1	26.67 gpm	Permeate Flow	20.00 gpm
Raw Water Flow to System	26.67 gpm	Recovery	74.97 %
Feed Pressure	207.96 psig	Feed Temperature	60.00 F
Fouling Factor	0.85	Feed TDS	938.83 mg/l
Chem. Dose (100%)	0.00 mg/l	Number of Elements	18
Total Active Area	1476.00 ft2	Average System Flux	19.51 gfd
Water Classification	RO Permeate SDI < 1		

Stage	Element	#PV	#Ele	Feed Flow (gpm)	Feed Press (psig)	Recirc Flow (gpm)	Conc Flow (gpm)	Conc Press (psig)	Perm Flow (gpm)	Avg Flux (gfd)	Perm Press (psig)	Boost Press (psig)	Perm TDS (mg/l)
1	BW30LE-4040	2	3	26.67	202.96	0.00	18.72	181.70	7.95	23.27	0.00	0.00	10.02
2	BW30LE-4040	2	3	18.72	176.70	0.00	11.87	164.52	6.85	20.05	0.00	0.00	16.31
3	BW30LE-4040	1	3	11.87	159.52	0.00	8.99	140.66	2.88	16.83	0.00	0.00	25.98
4	BW30LE-4040	1	3	8.99	135.66	0.00	6.67	123.09	2.32	13.58	0.00	0.00	39.80

(mg/l, except pH)	Raw Water	Adj Feed	Permeate	Concentrate
NH4	0.00	0.00	0.00	0.00
K	4.50	4.50	0.18	17.44
Na	82.00	82.00	1.87	322.04
Mg	36.10	36.10	0.38	143.11
Ca	136.00	136.00	2.36	536.37
Sr	0.57	0.57	0.01	2.24
Ba	0.06	0.06	0.00	0.22
HCO3	310.00	310.00	7.39	1216.54
CO3	0.07	0.07	0.00	0.28
NO3	2.90	2.90	0.16	11.10
Cl	150.00	190.93	2.84	754.42
F	0.00	0.00	0.00	0.00
SO4	141.00	141.00	1.50	558.92

7.5 mg/L

1928.4 mg/L

HARDNESS CALCULATION

$EQ_{CaCO_3} = 136(2.497) + 36.1(4.116)$

$= 488.2$ mg/L

SiO2	34.70	34.70	1.22	134.99
CO2	37.75	37.75	37.75	37.75
TDS	897.90	938.83	17.92	3697.66
pH	7.10	7.10	5.45	7.75

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Reverse Osmosis System Analysis for FILMTEC(TM) Membranes ROSA v5.02
Project: Riverton Gedge Well Site Case: 1
Mike Gold, Goldeneye Solutions, Inc. 8/29/2005

Design Warnings

-None-

Solubility Warnings

Langelier Saturation Index > 0
Stiff & Davis Stability Index > 0
BaSO4 (% Saturation) > 100 %
SiO2 (% Saturation) > 100 %
Antiscalants may be required. Consult your antiscalant manufacturer for dosing and maximum allowable system recovery.

Scaling Calculations

	Raw Water	Adj Feed	Concentrate
pH	7.10	7.10	7.75
Langelier Saturation Index	0.74	0.74	1.70
Stiff & Davis Stability Index	1.17	1.17	1.60
Ionic Strength (Molal)	0.02	0.02	0.08

TDS (mg/l)	897.90	897.90	3697.66
HCO3	310.00	310.00	1216.54
CO2	37.75	37.75	37.75
CO3	0.07	0.07	0.28
CaSO4 (% Saturation)	4.08	4.08	31.13
BaSO4	370.09	370.09	1254.99
SrSO4	1.23	1.23	5.95
CaF2	0.00	0.00	0.00
SiO2	32.70	32.70	127.21

To balance: 40.93 mg/l Cl added to feed.

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Reverse Osmosis System Analysis for FILMTEC(TM) Membranes — ROSA v5.02
Project: Riverton Gedge Well Site — Case: 1
Mike Gold, Goldeneye Solutions, Inc. — 8/29/2005

Array Details

Stage 1	Element	Recov.	Perm Flow (gpm)	Perm TDS (mg/l)	Feed Flow (gpm)	Feed TDS (mg/l)	Feed Press (psig)
	1	0.10	1.38	8.68	13.34	938.83	202.96
	2	0.11	1.32	9.97	11.95	1046.59	194.68
	3	0.12	1.27	11.54	10.63	1175.61	187.63
Stage 2	Element	Recov.	Perm Flow (gpm)	Perm TDS (mg/l)	Feed Flow (gpm)	Feed TDS (mg/l)	Feed Press (psig)
	1	0.13	1.18	13.68	9.36	1333.37	176.70
	2	0.14	1.14	16.13	8.18	1524.51	171.77
	3	0.16	1.10	19.32	7.03	1769.08	167.74
Stage 3	Element	Recov.	Perm Flow (gpm)	Perm TDS (mg/l)	Feed Flow (gpm)	Feed TDS (mg/l)	Feed Press (psig)

	1	0.09	1.02	22.83	11.87	2093.42	159.52
	2	0.09	0.96	25.94	10.85	2287.07	152.40
	3	0.09	0.90	29.55	9.90	2505.69	146.14

Stage 4	Element	Recov.	Perm Flow (gpm)	Perm TDS (mg/l)	Feed Flow (gpm)	Feed TDS (mg/l)	Feed Press (psig)
	1	0.09	0.82	34.67	8.99	2754.39	135.66
	2	0.09	0.77	39.70	8.18	3026.59	130.87
	3	0.10	0.73	45.68	7.40	3338.18	126.70

Appendix B

Field Notebook

RIVERTON CITY RO PILOT PROJECT FIELD NOTEBOOK

GEDGE WELL Page 1 of 3

DATE	DESCRIBE FIELD OBSERVATIONS OF SIGNIFICANCE; OPERATING PARAMETERS; CHANGES IN SETTINGS; OR OTHER SIGNIFICANT DETAILS
9/4/05	The system was shut down, I cleared all alarms that were on the screen and restarted the system. Now the system is up and running. *D.G.*
9/12/05	The system was shutdown, the relay 2 light was on. The system feed pressure gauge and air valve would not hold air pressure "compressor continually running". I unplugged the airline and reset the alarms. I plugged the airline back in and restarted the system. Looking back at data logger, the system went down about 0300 on 9/10/05. Now everything is running ok. *D.G.*
9/12/05	Channel 2 reject flow was at 6.69 gpm. vs. data logger that was at 3.46 gpm. This is inconsistent data and needs to be explained. The motor amp reading varies from 0 to 4.4 amps over minutes. This also appears to be incorrect. *T.W.*
	Taigon came out today to burn the data to a disk, but he did not have everything he needed to download the data. He said that he would return tomorrow to retrieve the data. *S.R.*
9/13/05	I shutdown the RO to change out the C.T. to the updated style sent by Mike Gold. Mike Horan found the C.T. that was sent did not have the correct signal to receive the data we needed. I called Mike Gold, but he wasn't available today. Then I called Taigon and he said to run the RO without the correct C.T. until we get the right parts in. *J.R.*
9/14/05	I changed out both filters because the difference between the pressures was close to 10 psi. The filters appeared to be really dirty. *J.R.*
9/15/05	I changed the C.T. jumper from 0-50 to 0-20 giving us the correct reading now. Taigon came today and downloaded the data to a CD. *J.R.*
9/16/05	I added 8 gallons of the anti-scalent solution and took a weekly sampler in to be tested. *J.R.*
9/20/05	There was an alarm occurring, but it didn't trip the unit. The alarm was the low anti-scalant level. I just canceled the alarm and it continues to run. *J.R.*
9/23/05	The pre-filter inlet pressure was at 82 psi and the outlet pressure was at 67 psi. I changed the filters and there was still 11 psi difference. I took filters out and the pressure still did not change. I reinstalled the new filters and the pressure on the pre-filter inlet is 77 psi. and the outlet is 66 psi. The filters that I took out were not as dirty as the first one's Jeremy changed. I increased the feed flow to 27.0 gallons and added 8 gallons of anti-scalent solution. *D.G.*

DATE	**DESCRIBE FIELD OBSERVATIONS OF SIGNIFICANCE; OPERATING PARAMETERS; CHANGES IN SETTINGS; OR OTHER SIGNIFICANT DETAILS**
9/23/05	PLC reject flow shows 7.21 gpm vs. the data logger shows 3.62 gpm. I need to reconcile the downloaded RO data. *T.W* Note: PLC data is correct.
9/26/05	Power failure shut down the unit and I restarted it. *J.R.*
9/28/05	The data logger shut down last night. It's getting harder to start it over again. The program needs to be debugged. *J.R.*
9/30/05	I added 7 gallons of anti-scalant to the tank. *J.R.*
	I downloaded the R.O. data. The feed rotometer was reading 26.5 gpm. The permeate rotometer sum is 20.25 gpm. P_1 is 9.5 gpm., P_2 is 7.5 gpm., P_3 is 2.0 gpm., and P_4 is 1.25 gpm. The data logger reject flow is 3.84 gpm. This does not agree with PLC flow 7.7 gpm. PLC flow is more accurate than the other one. I notified Goldeneye of this problem two days ago. I also noticed the sample data on brine conductivity seems incorrect. I will address this issue with Jeremy. I spoke with Jeremy and it was concluded that the handheld conductivity meter is reading correctly and samples are being taken at the right spot, but meter is limited to 1999υm/cm. I will contact the meter manufacture Myron L Company, Model ARH1, Serial # T405997 *T.W.* PLC reject flow is correct. Meter display changes above 2000 υm/cm but meter is good to 20,000 υm/cm
10/5/05	I noticed that the display on the anti-scalent pump is starting to weather. I am going to cover it with plastic. *J.R.*
10/6/05	I downloaded the data from data logger. The anti-scalant metering pump was pulsing ~1.5 times/sec. with the pump unplugged. It appears moisture has damaged the pump controls. I notified Goldeneye Solutions about this problem. The anti-scalant system is offline. *T.W.*
	I replaced the pump with a spare one. Mike is sending a new one with settings. The pump temporary settings are: 100% stroke length and 35% frequent operate in hand position. *J.R.*
	I calibrated the hand held meter. *J.R.*
10/7/05	The data logger wasn't current today. *J.R.*
10/10/05	I got the replacement for the anti-scalant pump today. I am going to wait until Wednesday to install at the new site. The data logger has gone down and I can't get it

back up. I talked with Mike he said he would address the problem on Wednesday. The program has failed debugging. *J.R.*

RIVERTON CITY **EDR PILOT PROJECT** **FIELD NOTEBOOK**

GEDGE WELL **Page 1 of 3**

DATE	DESCRIBE FIELD OBSERVATIONS OF SIGNIFICANCE; OPERATING PARAMETERS; CHANGES IN SETTINGS; OR OTHER SIGNIFICANT DETAILS
9/2/05	Two alarms tripped today the first was a critical alarm that led to concentrate pump failure. The second was a non-critical alarm that was high conductivity. *J.R.*
9/3/05	Alarm shut down summary: • Current critical alarm – 11/02 17:04:43 o Unit 1 emergency stop button pressed • Current non-critical alarm 11/03 03:38:40 o High product conductivity I restarted and adjusted stack in. The differential pressure is down to 60 psi. It was at 100 psi.*D.G.*
9/4/05	I readjusted the stack in and the differential pressure is down from over 100 psi. to 60 psi. Pressure gauge was pegged out at over 100 psi. The data logger was keeping up current time but is reading all NA's. I reset the logger and it is now working fine. *D.G.*
9/6/05	The value used to get the stack differential and the adjustment is not working in the rear gauge. Concentrate discharge pump is not working either. *J.R.*
9/7/05	I called Taigon and made him aware of the problems mentioned above, he was going to consult G.E. and get back to me. *J.R.*
9/9/05	I had a conference call with Taigon and Bernardo. There were a lot of "could be solutions" but there was no definite solution. Taigon is going to come out Monday 9/12/05 to asses the problems. *J.R.*
	I adjusted the dilute flow in and the brine make up both had dropped 2 gpm. Low (0.4+12 dilute in) product, pH has gone up to 8.1. *J.R.*
9/12/05	The concentrate pump burned up. The rotor is locked. *T.W.*
	The concentrate pump failure caused the EDR to shutdown. Samples and readings will no longer be taken until fixed. Taigon and I left messages with Eugene Reel. *J.R.*
9/16/05	I spoke with Bernardo, he had not heard what was next. I left a message with Eugene Reel on 9/15/05 with no reply. Taigon still is making arrangements to get elevated feed tank as requested by Bernardo. *J.R.*
9/21/05	I called Taigon he had heard nothing yet about the status of getting the EDR fixed. He was going to call G.E. again and get back with me. Mike Horan installed C.T. on the EDR. *J.R.*

DATE	**DESCRIBE FIELD OBSERVATIONS OF SIGNIFICANCE; OPERATING PARAMETERS; CHANGES IN SETTINGS; OR OTHER SIGNIFICANT DETAILS**
9/23/05	Bernardo was here at 7:30 am. and began removing discharge pump. He though it was just scaled buildup on the impellers, but now he has decided the motor burned up. He is trying to find a new pump and motor. Taigon went over trouble shooting with Bernardo. *J.R.*
9/26/05	EDR is running again and I took samples. The data logger had shut its self down but it is up and running. *J.R.*
9/30/05	I downloaded the EDR data. Brine TDS samples are beyond the range of the meter (see RO notes). I shutdown the unit and started to hook up a tap for the SDI sample. T.W.
	I added 4 gallons of acid; the level is just above 10 gallons for the weekend. Taigon is taking the SDI sample. *J.R.*
10/3/05	EDR tripped and the emergency stop button was pressed. Non-critical alarm warned of high product conductivity. I started it back up and added 2 gallons of muriatic acid. *J.R.*
10/4/05	Duane took the TOC sample today. I added 1 gallon of acid to the brine pump reservoir. I took the voltage on the stack it was low at 3 and 4 volts. The gasket on the discharge side of the brine pump failed. I fixed it and now it's running. *J.R.*
10/5/05	The EDR tripped due to the discharge brine motor failure. I called Taigon we are going to have a meeting to see what we can figure out. Taigon called Delco to come and trouble shoot the motor. We noticed when it's running air comes out. It was also arching to its frame. *J.R.*
10/6/05	Brandon from Delco came out, we took voltage on pump and he figured it was burned up. He suggested it wasn't the right or the best style of pump for this type of water application. He is going to try to return today to install new pump. No EDR samples were taken on 10/5 or 10/6 due to motor failure. Flange and gasket on the discharge side of brine pump were in poor condition and we had to replace them. I calibrated the hand held meter. *J.R.*
	The EDR pilot remains shutdown. I downloaded the data from the data loggers. Data logger program reached excel limit of 65536 rows. I deleted all row data beyond row 200. I restarted the data logger after saving the program data. The data logger is working, but the pilot is down. *T.W.*

DATE	DESCRIBE FIELD OBSERVATIONS OF SIGNIFICANCE; OPERATING PARAMETERS; CHANGES IN SETTINGS; OR OTHER SIGNIFICANT DETAILS
10/7/05	I received a message from Taigon on Thursday 10/6. The motor was being shipped but not until first of next week. The ETA is five days, but he was going to try and speed it up. *J.R.*
10/10/05	I spoke to Taigon but he had not heard anything since Friday 10/7. He thinks we have enough data to move onto the next site. *J.R.*

RIVERTON CITY RO PILOT PROJECT FIELD NOTEBOOK

HILL WELL Page 1 of 1

DATE	DESCRIBE FIELD OBSERVATIONS OF SIGNIFICANCE; OPERATING PARAMETERS; CHANGES IN SETTINGS; OR OTHER SIGNIFICANT DETAILS
10/12/05	Moved the pilot to the Hill Well and now it's all back up and running. *J.R.*
10/14/05	The RO tripped due to a power failure. *J.R.*
10/17/05	I started adding sodium benzoate at 2 tablespoons per 16 gallons. *J.R.*
10/21/05	I took a sample of off-spec concentrate of TDS and Selenium. *J.R.*
10/24/05	I changed the filters today and got the pressure back to a difference of 10 psi. The filters appear dirty and appear to have exceeded their lifespan. *J.R.*
10/27/05	Duane took the TOC sample form Hill well today. *J.R.*
11/3/05	The breaker tripped in RO's Junction box, I reset it and now it's running fine.
11/4/05	The selenium and TDS concentrate was sampled today. *J.R.*
11/7/05	I downloaded the pilot data. *T.W.*

RIVERTON CITY EDR PILOT PROJECT FIELD NOTEBOOK

HILL WELL Page 1 of 2

DATE	DESCRIBE FIELD OBSERVATIONS OF SIGNIFICANCE; OPERATING PARAMETERS; CHANGES IN SETTINGS; OR OTHER SIGNIFICANT DETAILS
10/12/05	The pilot was moved to Hill Well. The EDR is still not running and the motor is scheduled to be installed Monday 10/17. *J.R.*
10/17/05	Brandon from Delco installed the new pump and motor. I started the EDR up, but the pump has a little leak. I talked to Taigon he said to run it. The EDR appears to be running well. The readings and samples look good. *J.R.*
10/18/05	The EDR tripped and the emergency stop button pressed. I restarted the EDR at 8:30 am. *J.R.* I noticed water running out of the stack into drain. It was wet before, but not this wet. *J.R.* The EDR tripped again and the emergency stop button was pushed. *J.R.* The EDR tripped again at 8:00 pm. The emergence stop was pressed. I restarted the EDR. *J.R.*
10/19/05	The EDR tripped again at 8:30 am. It was the same problem as before. I restarted the EDR. *J.R.* The stack out differential pressure is > 100 when the rectifier is enabled. It cannot be pulled down to 30-60" range. When rectifier is off differential pressure is 28". • Rectifier off stack differential in is 50", the stack differential out is 26" • Rectifier enabled stack differential in is > 100, stack differential out is >100 T.W. The EDR tripped between 1:00 and 4:00 pm. The emergency stop was pressed and the EDR was restarted. *J.R.*
10/21/05	The EDR tripped last night and the emergency stop button was pressed. It tripped again and the alarm said that the valve did not close. I restarted the EDR and it has been running ever since. *J.R.* We sampled off spec, the concentrate TDS and Selenium. *J.R.*
10/24/05	The EDR tripped this past weekend some time. It was either late Friday or early Saturday morning. I started the EDR on Monday (10/24). In the morning it tripped again and the problem is the valve is not closing. I found it in the operations book, but there is not enough info to pin point witch switch has gone bad. *J.R.*

DATE	**DESCRIBE FIELD OBSERVATIONS OF SIGNIFICANCE; OPERATING PARAMETERS; CHANGES IN SETTINGS; OR OTHER SIGNIFICANT DETAILS**
10/25/05	The EDR failed again due to a valve not closing. *J.R.*
	At 2:52 pm. it failed again, I started it back up. *J.R.*
10/26/05	I came in and it was tripped again. The emergency stop was pressed. I restarted at 8:23 am. *J.R.*
10/27/05	The EDR tripped again and the emergency stop was pressed. I restarted it. Duane took the TOC sample from Hill today. *J.R.*
10/28/05	GE is in town and they are working on the EDR. They made repairs to the stack, feed line and discharge line. The repairs included a plugged hose and they torque the stack to 120 lbs. The emergency stop switch was unhooked, the electrode tubes were cleaned and the acid was adjusted for more intake. Russell's phone # 602-437-2392. No CIP acid in drain to cause concern. *J.R.*
10/30/05	The EDR tripped again and the emergency stop was pressed. *J.R.*
11/1/05	I spoke to Russell and informed him that the EDR is still tripping on the emergency stop button. *J.R.*
11/4/05	I took a concentrate sample today; it was of selenium and TDS. *J.R.*
11/7/05	I downloaded the pilot data. T.W.

RIVERTON CITY **RO PILOT PROJECT** **FIELD NOTEBOOK**

MAYNARD WELL **Page 1 of 1**

DATE	**DESCRIBE FIELD OBSERVATIONS OF SIGNIFICANCE; OPERATING PARAMETERS; CHANGES IN SETTINGS; OR OTHER SIGNIFICANT DETAILS**
11/11/05	I sampled the waste for selenium and TDS. *J.R.*
11/15/05	I took TOC samples today; last night the RO had a problem because the breaker on pic tripped. The RO is now up and running. *J.R.*
11/18/05	I downloaded the RO data from data logger, all of the readings looked well. The main feed pump is 2 hp 480-volt motor. *T.W.*
11/28/05	I changed the filters today. *J.R.*
11/30/05	I sampled the waste for selenium and TDS. *J.R.*

RIVERTON CITY　EDR PILOT PROJECT　FIELD NOTEBOOK

MAYNARD WELL

Page 1 of 1

DATE	DESCRIBE FIELD OBSERVATIONS OF SIGNIFICANCE; OPERATING PARAMETERS; CHANGES IN SETTINGS; OR OTHER SIGNIFICANT DETAILS
11/8/05	I started reading the water at the Maynard Well. The site condition is 1480 + pH 7.51. *J.R.*
11/11/05	I sampled the waste for selenium and TDS. *J.R.*
11/15/05	The data logger failed and it said the system has recovered from a serious error. I got it back up and running. *J.R.*
11/16/05	I took a TOC sample today. J.R.
11/18/05	I downloaded the data from the data logger. I noticed the permeate conductivity meter signal had failed. The previous 3 weeks permeate conductivity readings are no good. I pulled the end cap off of the instrument and rewired to fix the shorts on the leads. This fixed the signal readings. *T.W.*
11/30/05	I sampled the waste today for selenium and TDS. *J.R.*

Appendix C

Gedge Well Charts

Figure C-1
Gedge Well RO Recovery

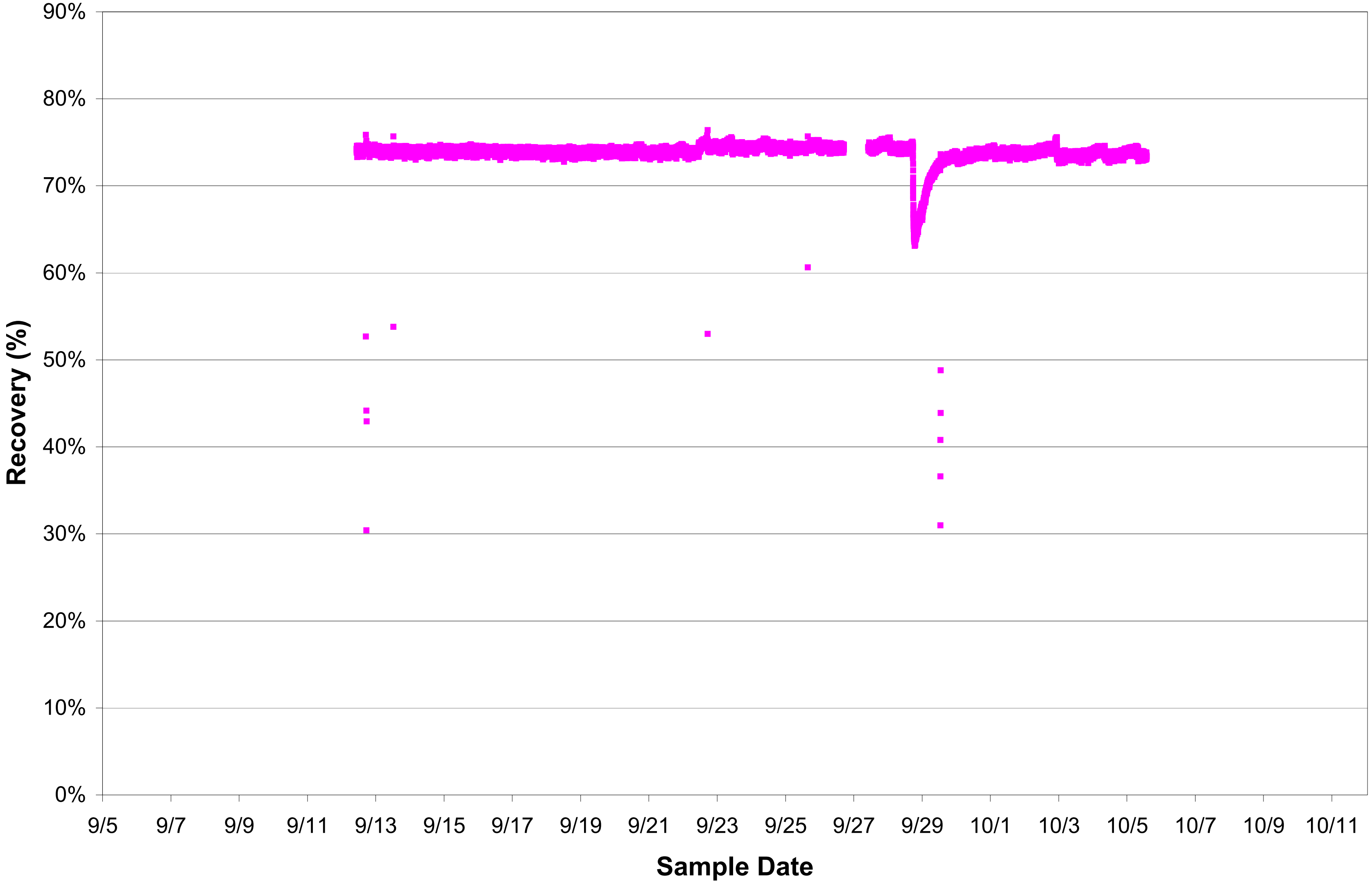


Figure C-2
Gedge Well EDR Recovery

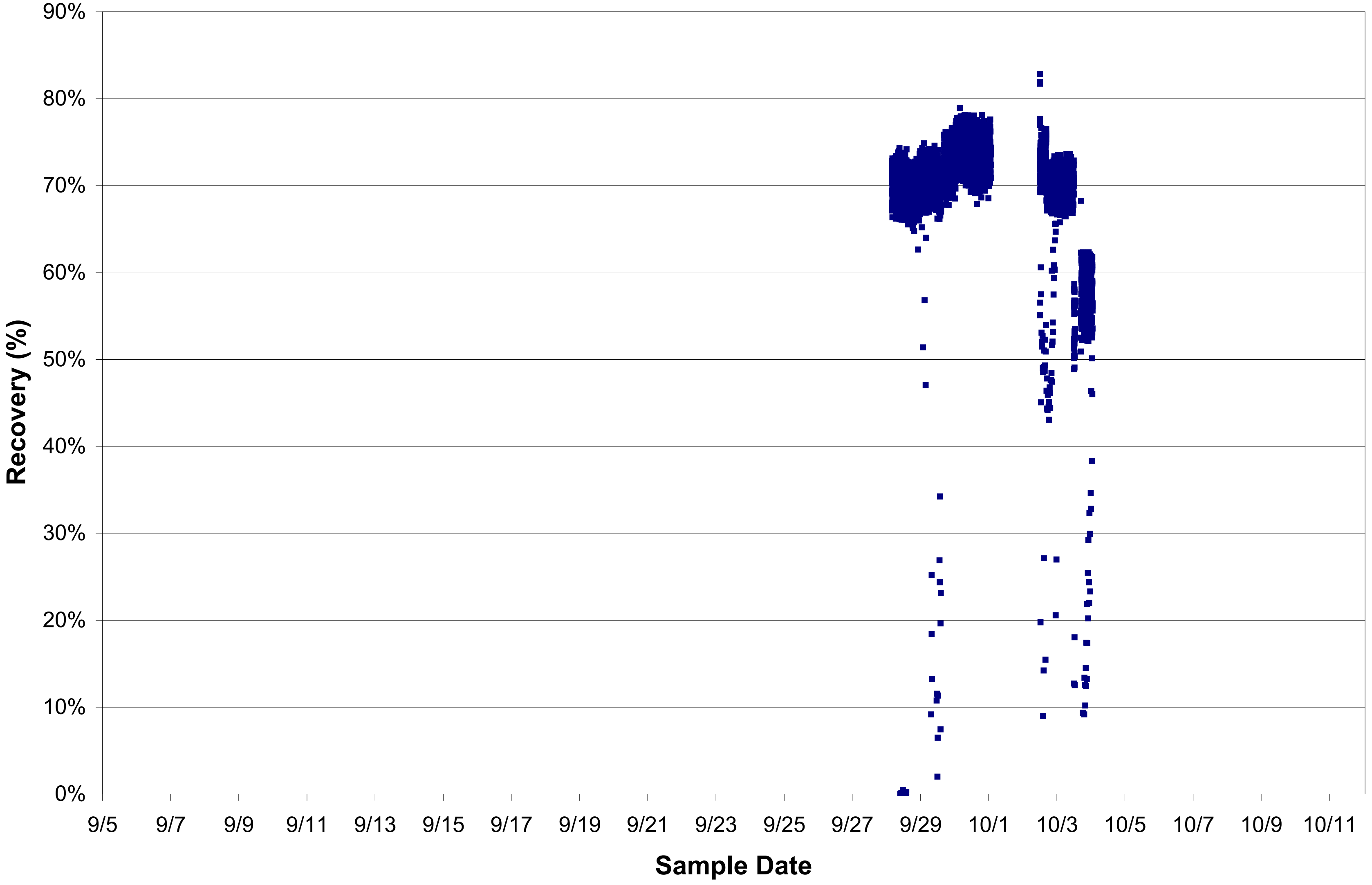


Figure C-3

Gedge Well Conductivity

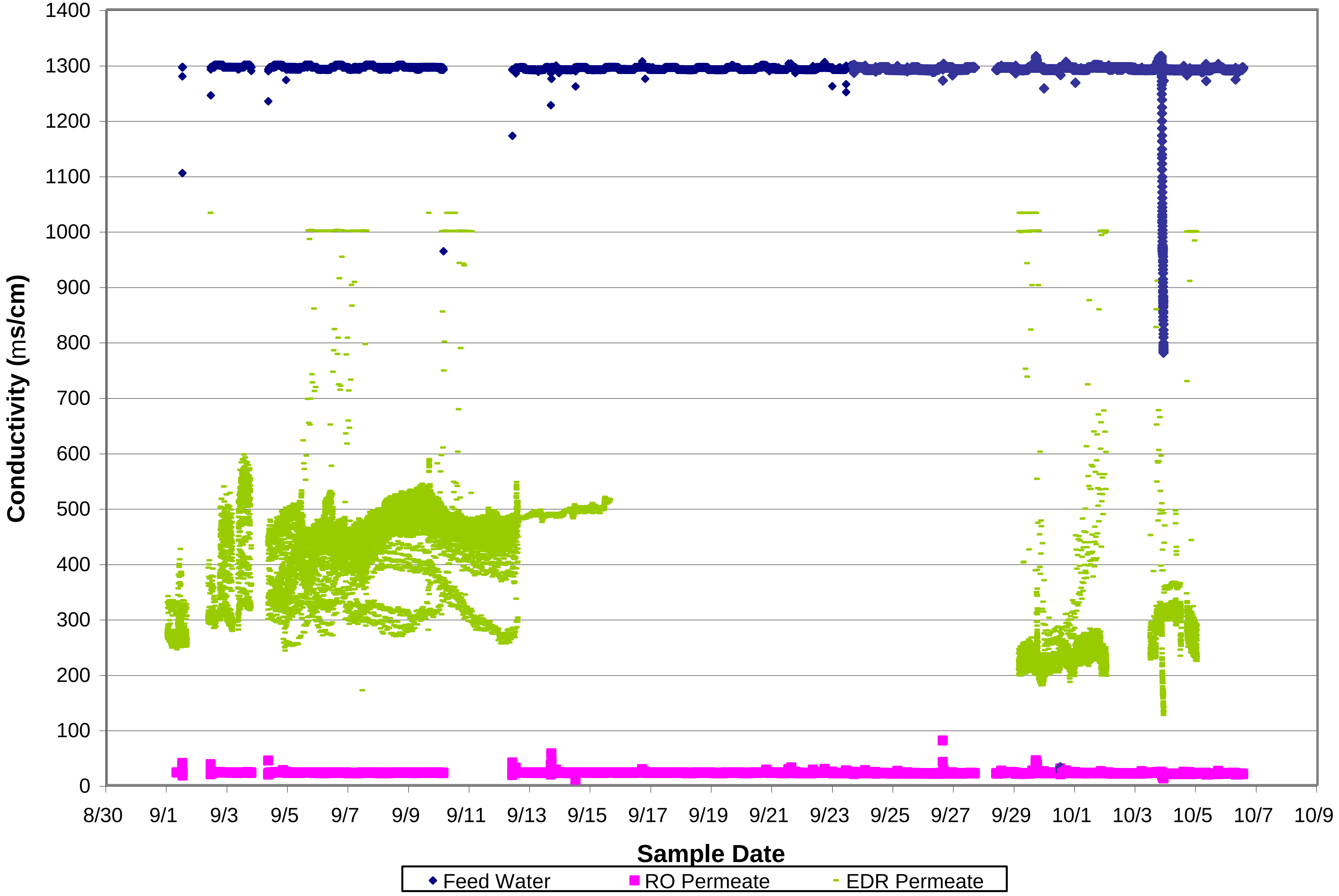


Figure C-4

Gedge Well RO TDS

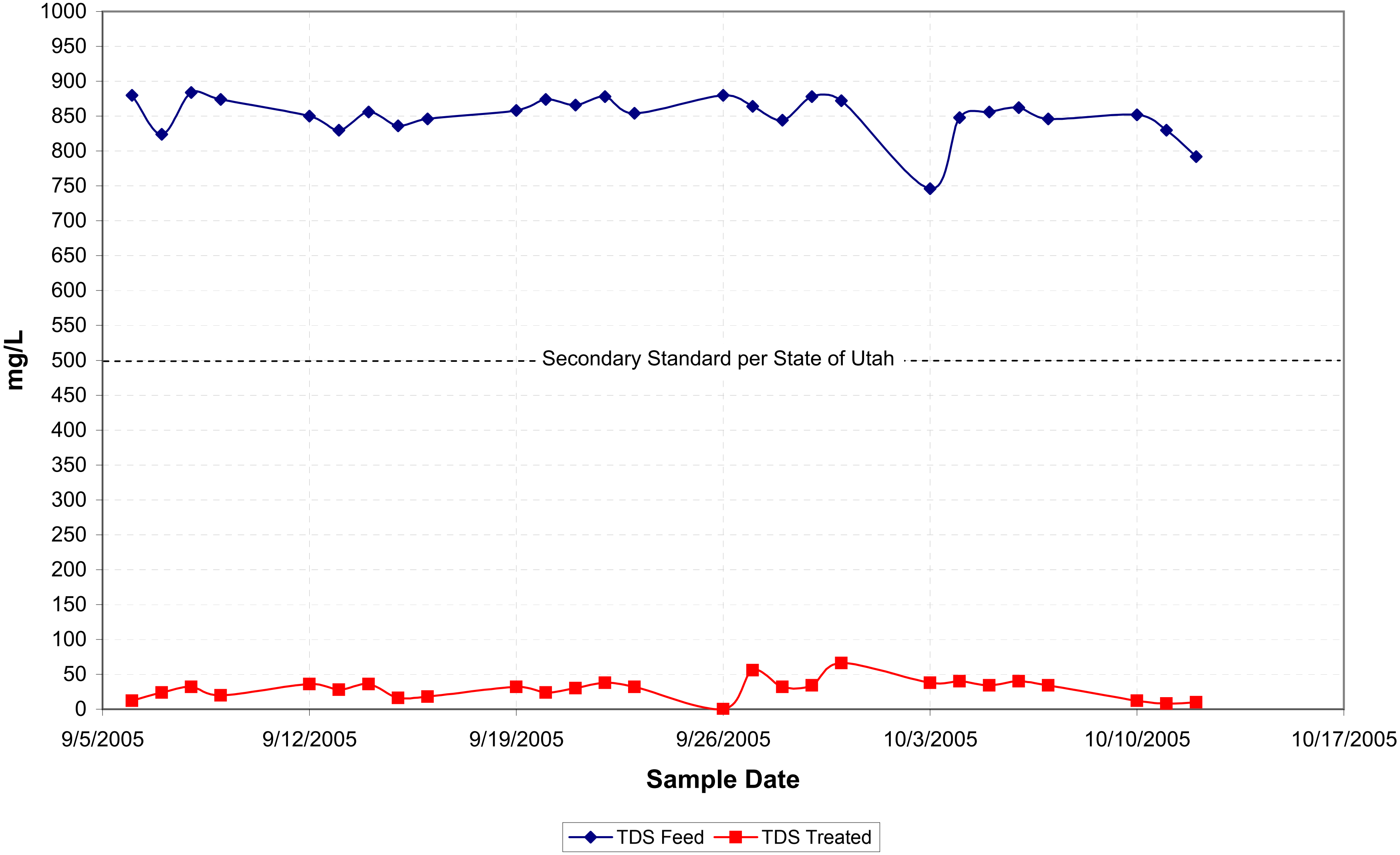


Figure C-5

Gedge Well RO Hardness ($CaCO_3$), Calcium, Magnesium

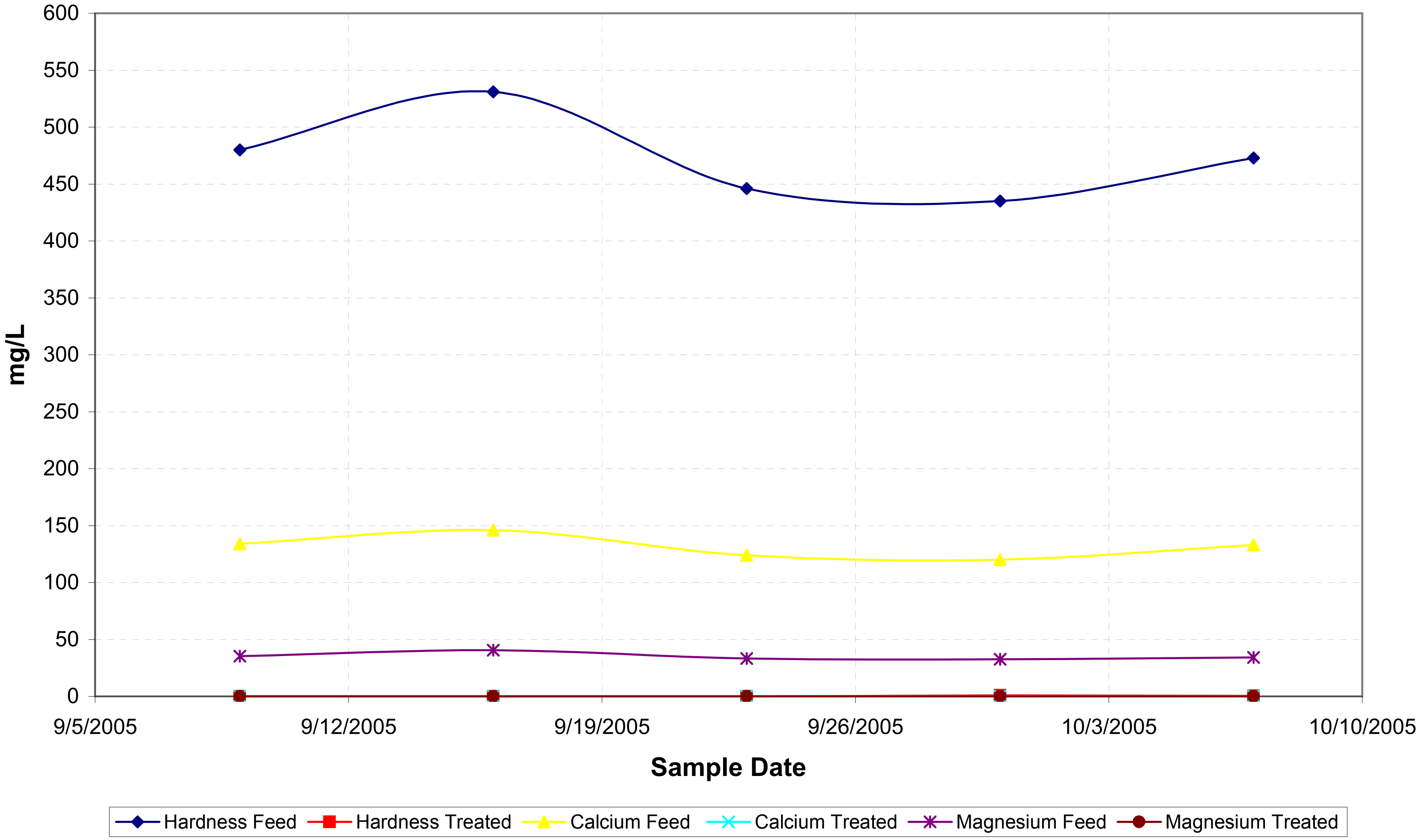


Figure C-6
Gedge Well RO Alkalinity

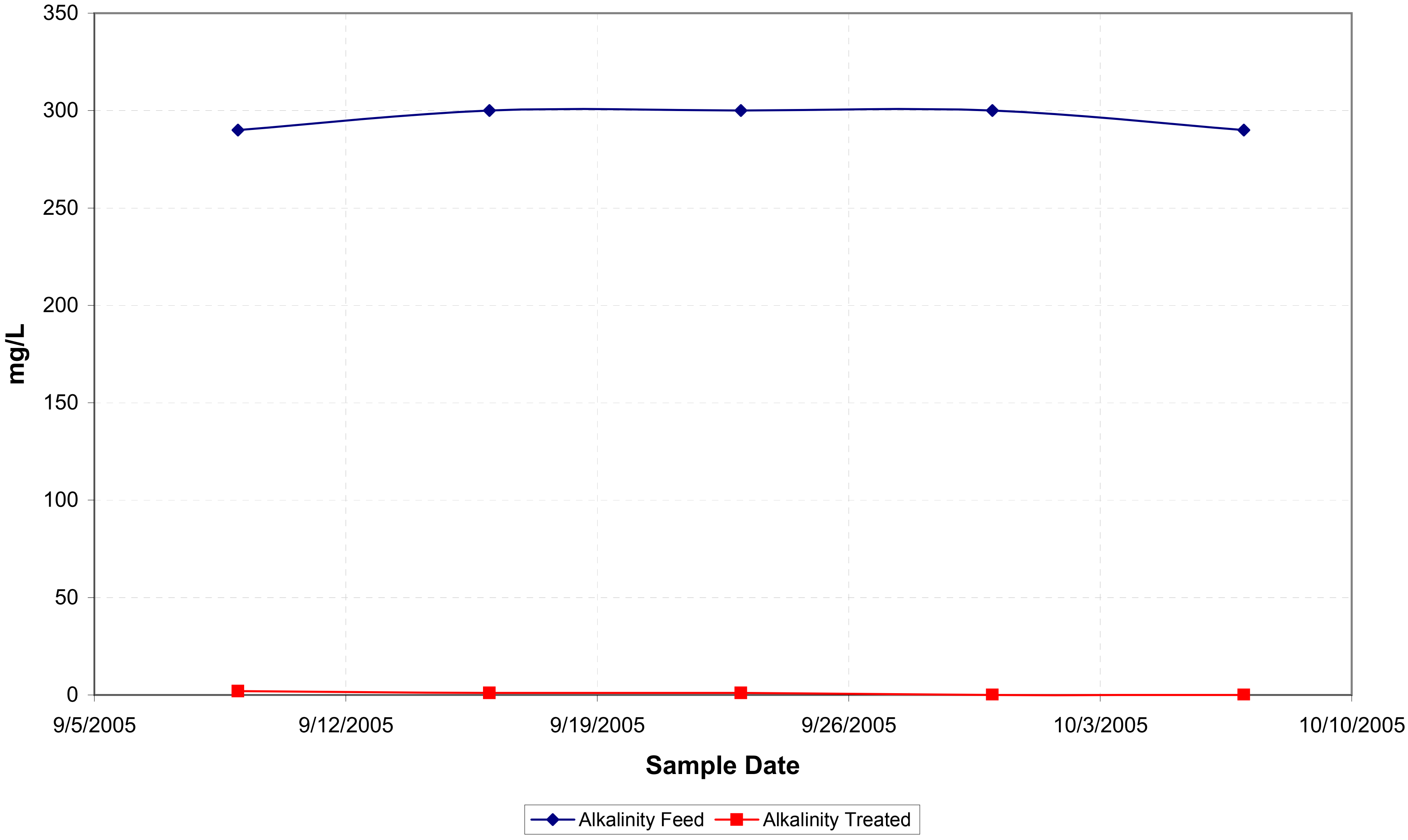


Figure C-7
Gedge Well RO Silica Total, Silica Reactive

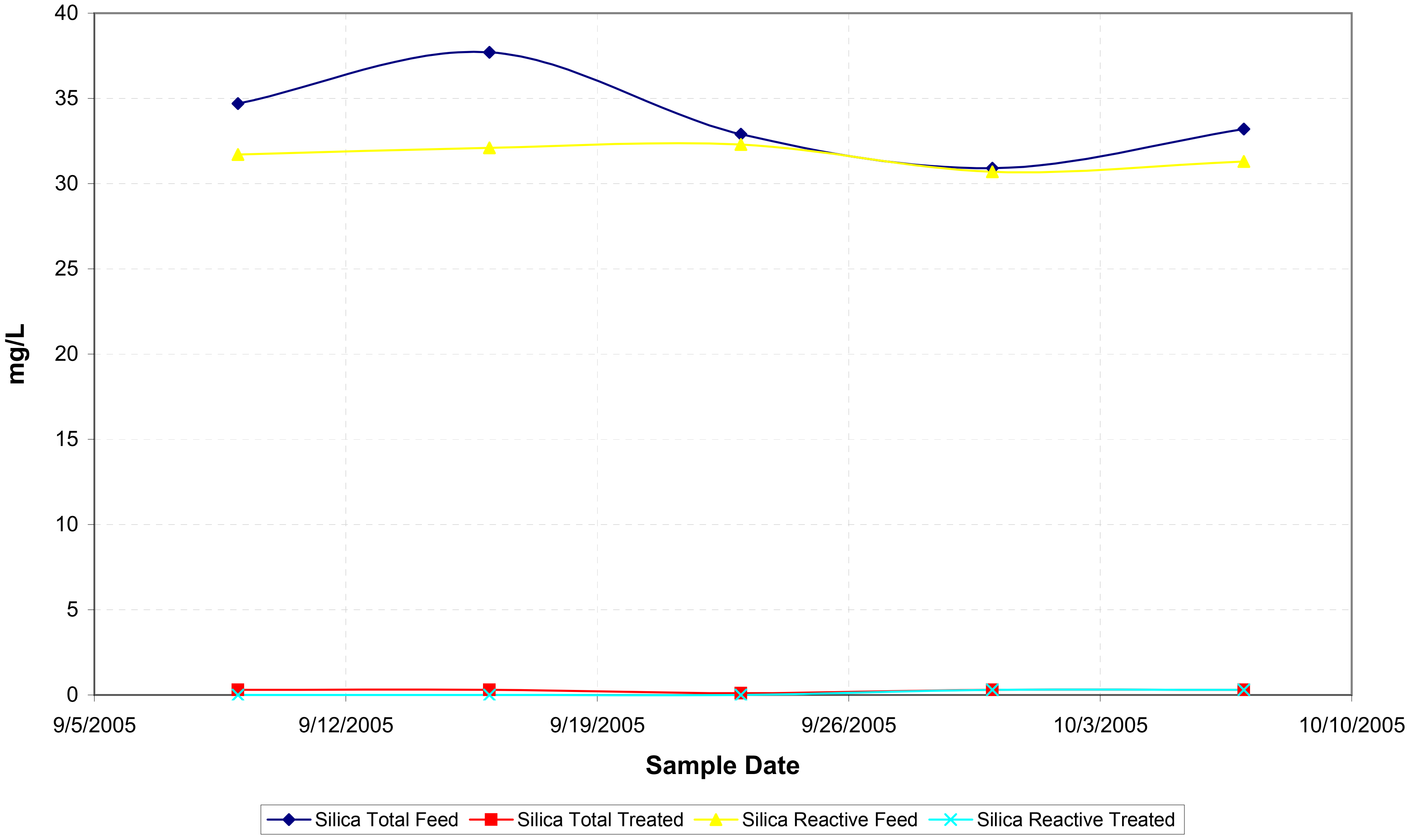


Figure C-8

Gedge Well RO Arsenic

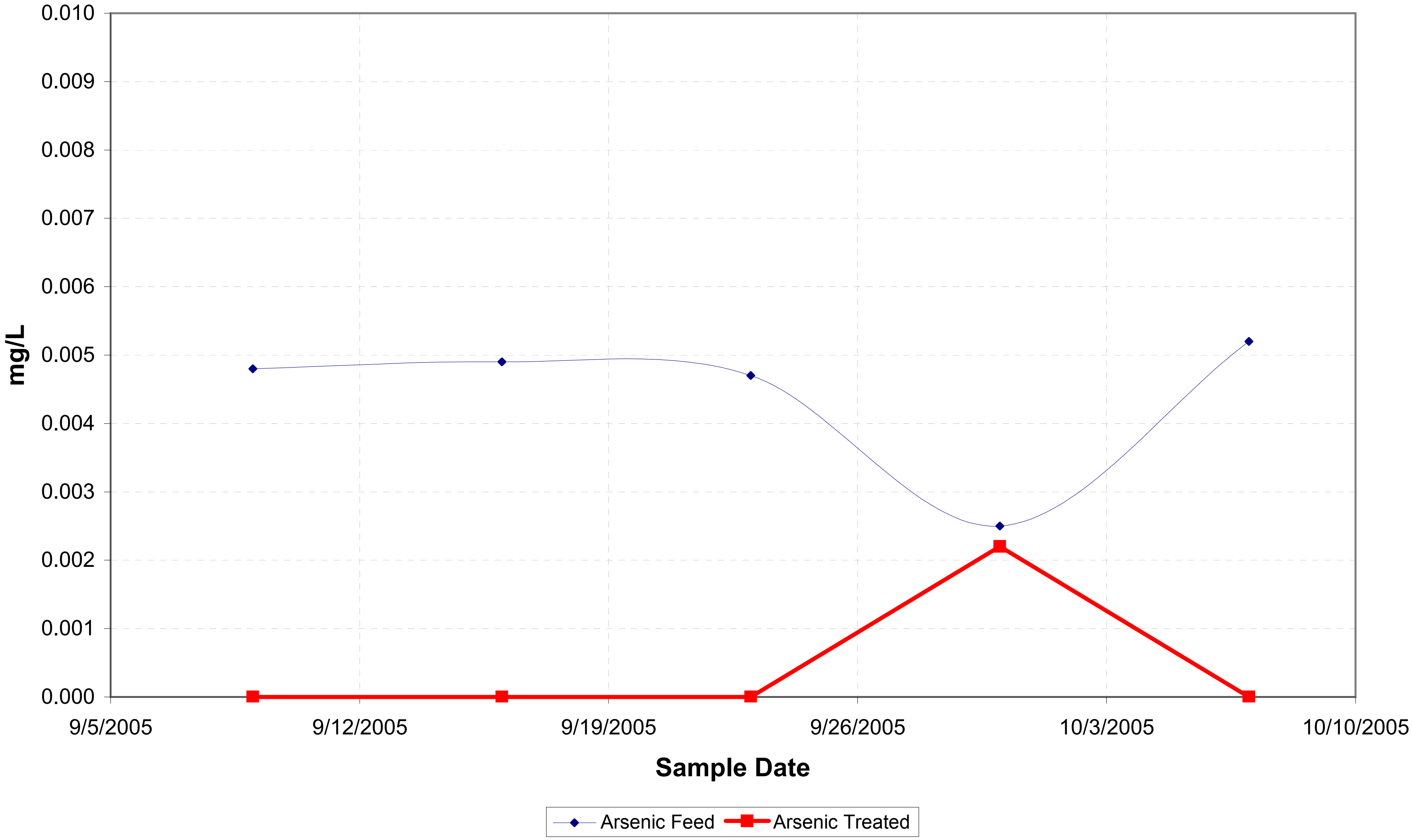


Figure C-9
Gedge Well RO Sulfate

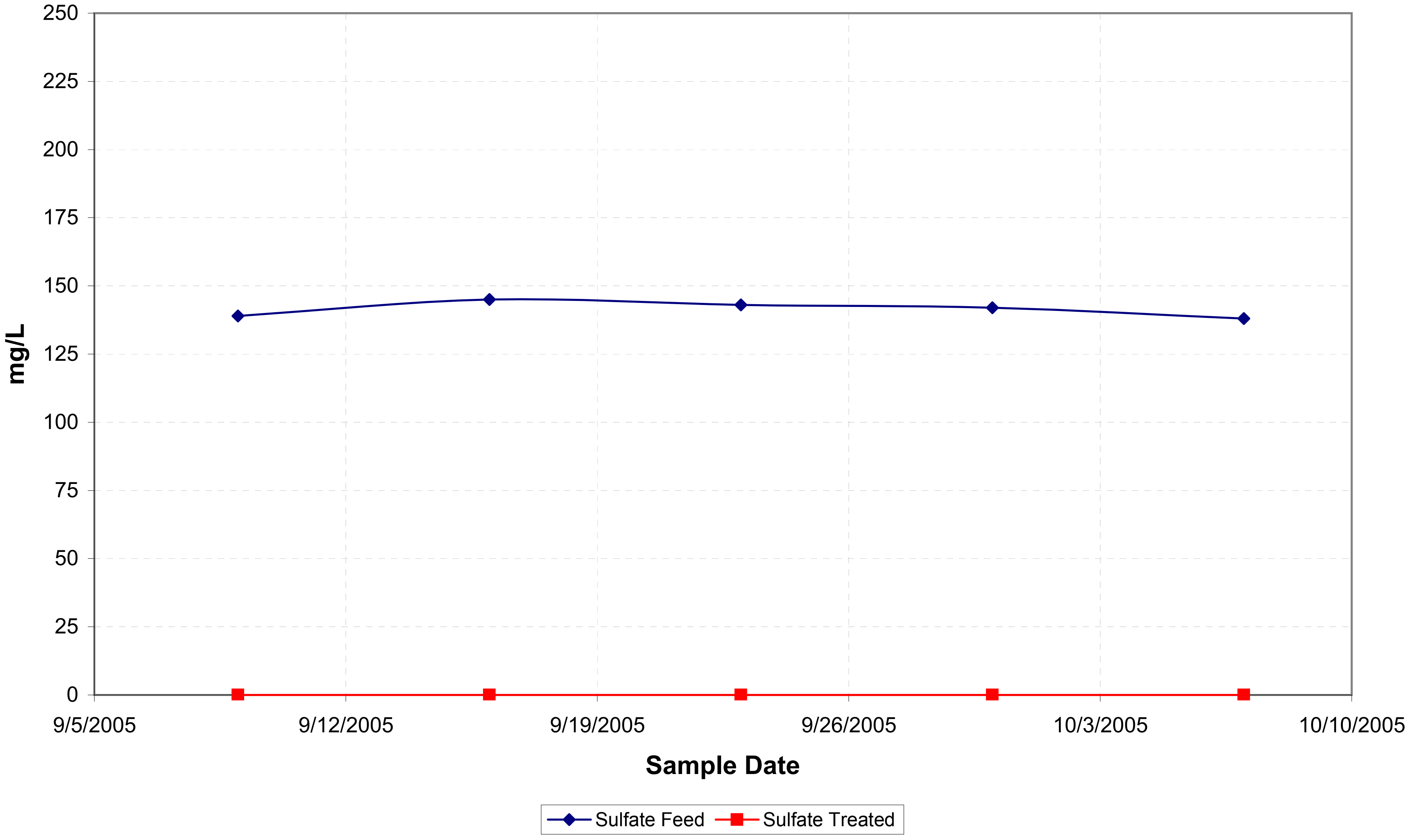


Figure C-10
Gedge Well RO Turbidity

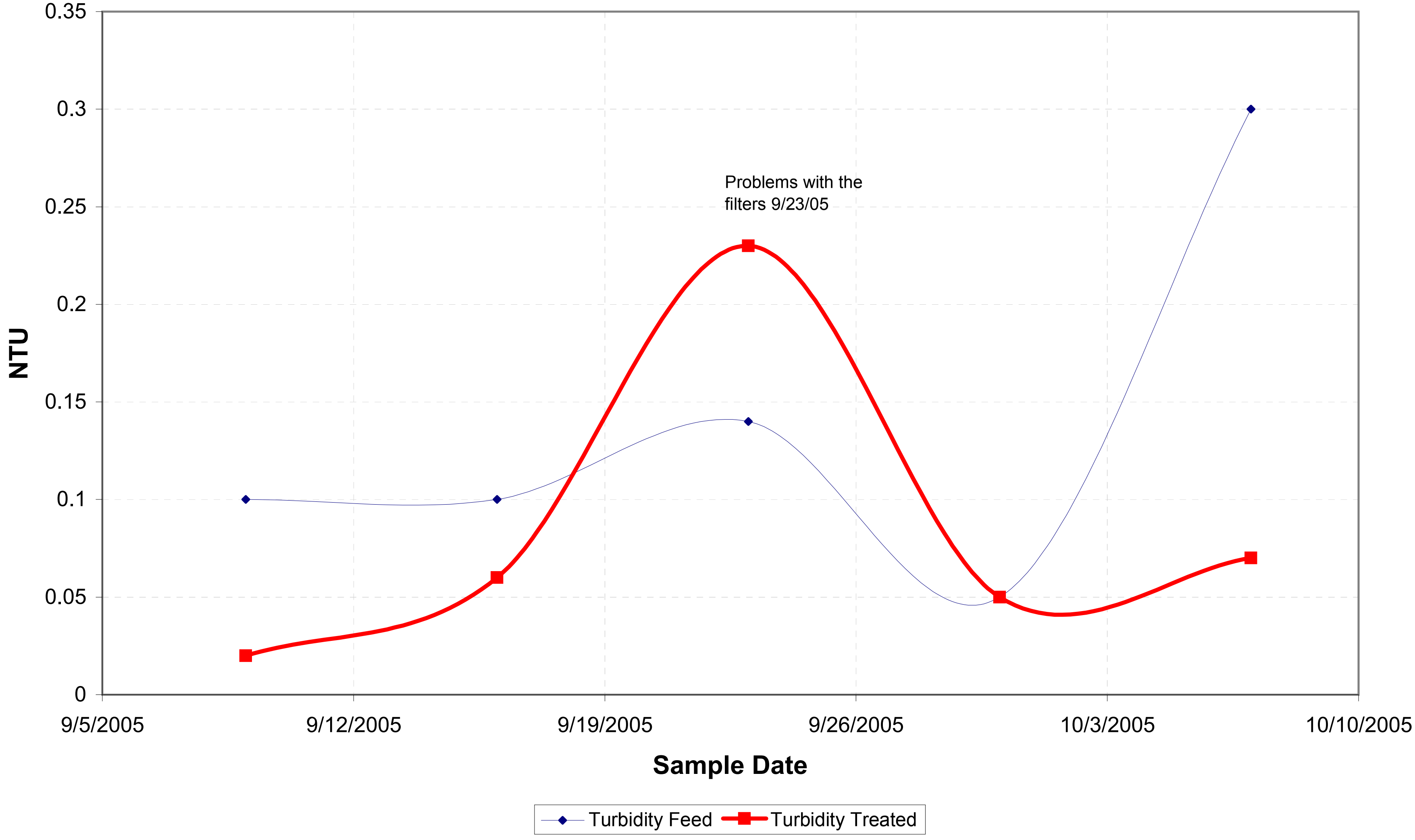


Figure C-11
Gedge Well EDR TDS

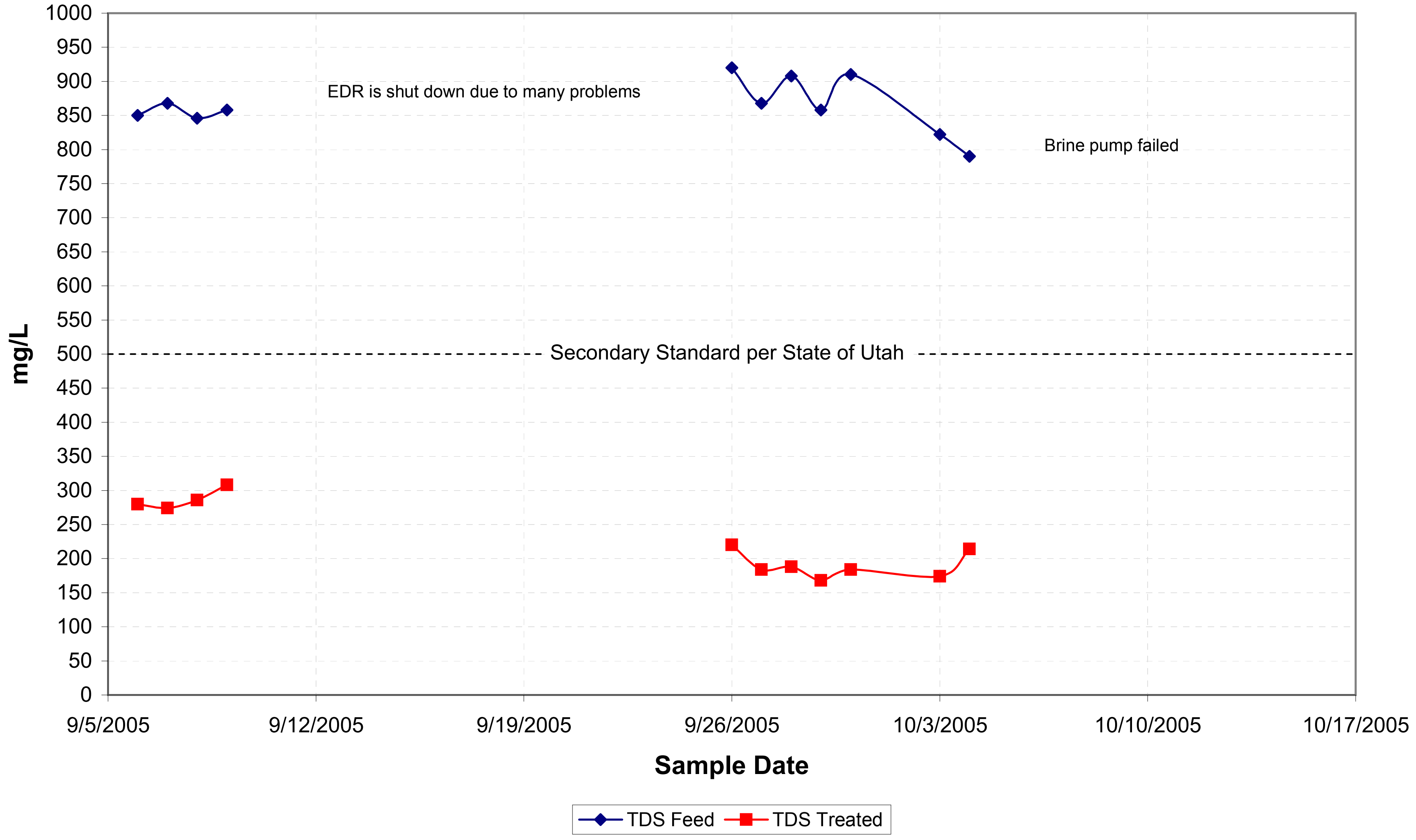


Figure C-12

Gedge Well EDR Hardness ($CaCO_3$), Calcium, Magnesium

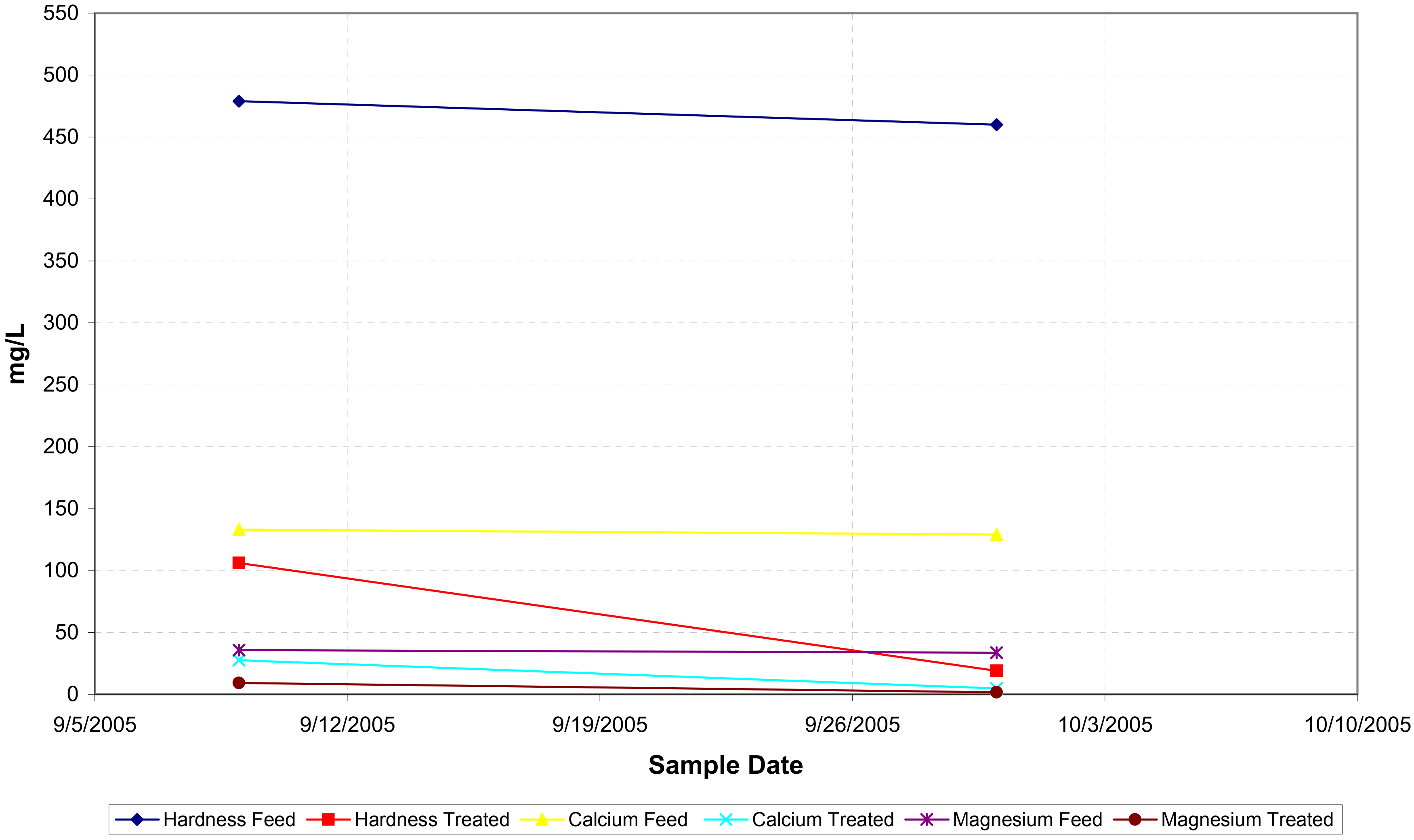


Figure C-13

Gedge Well EDR Alkalinity

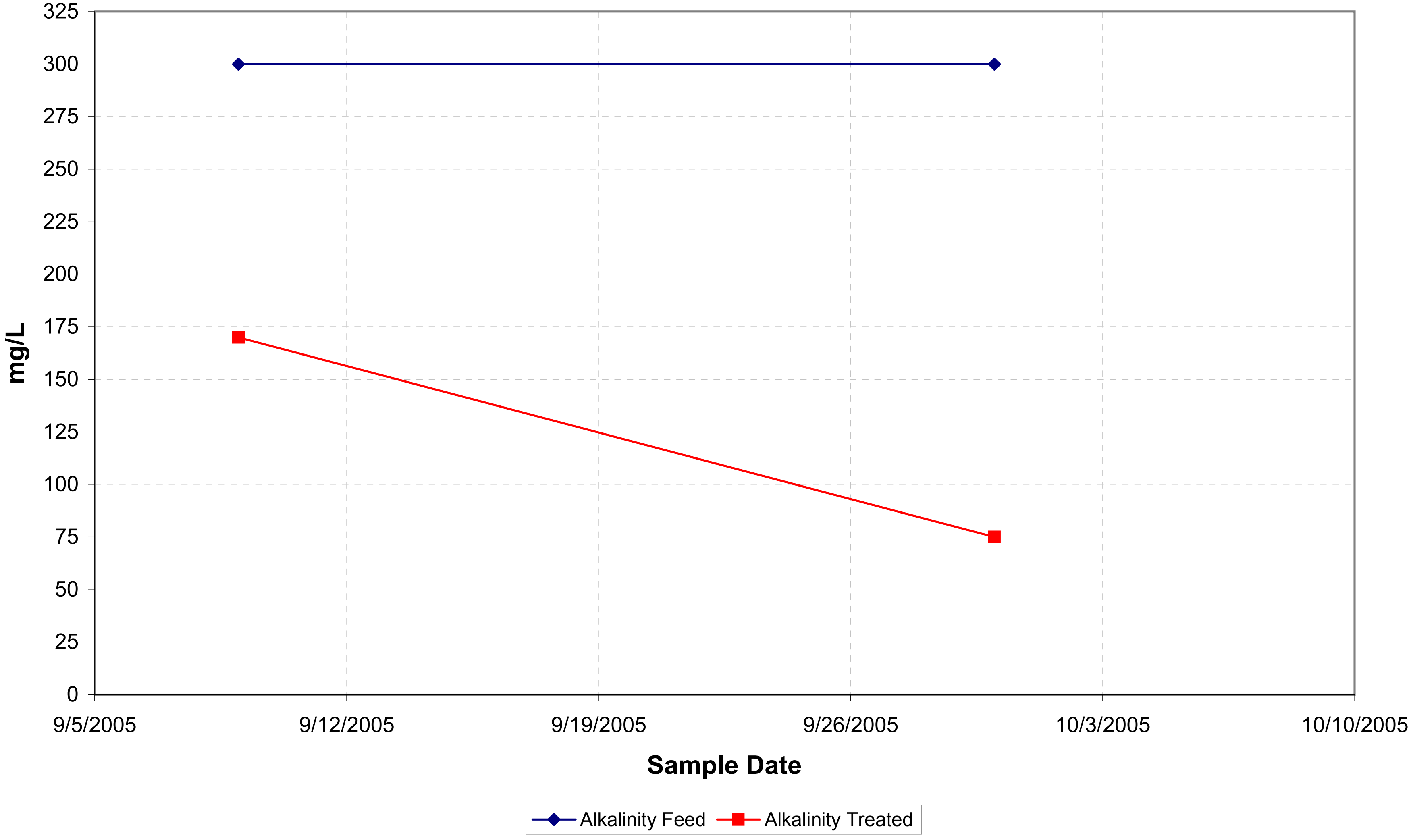


Figure C-14

Gedge Well EDR Silica Total, Silica Reactive

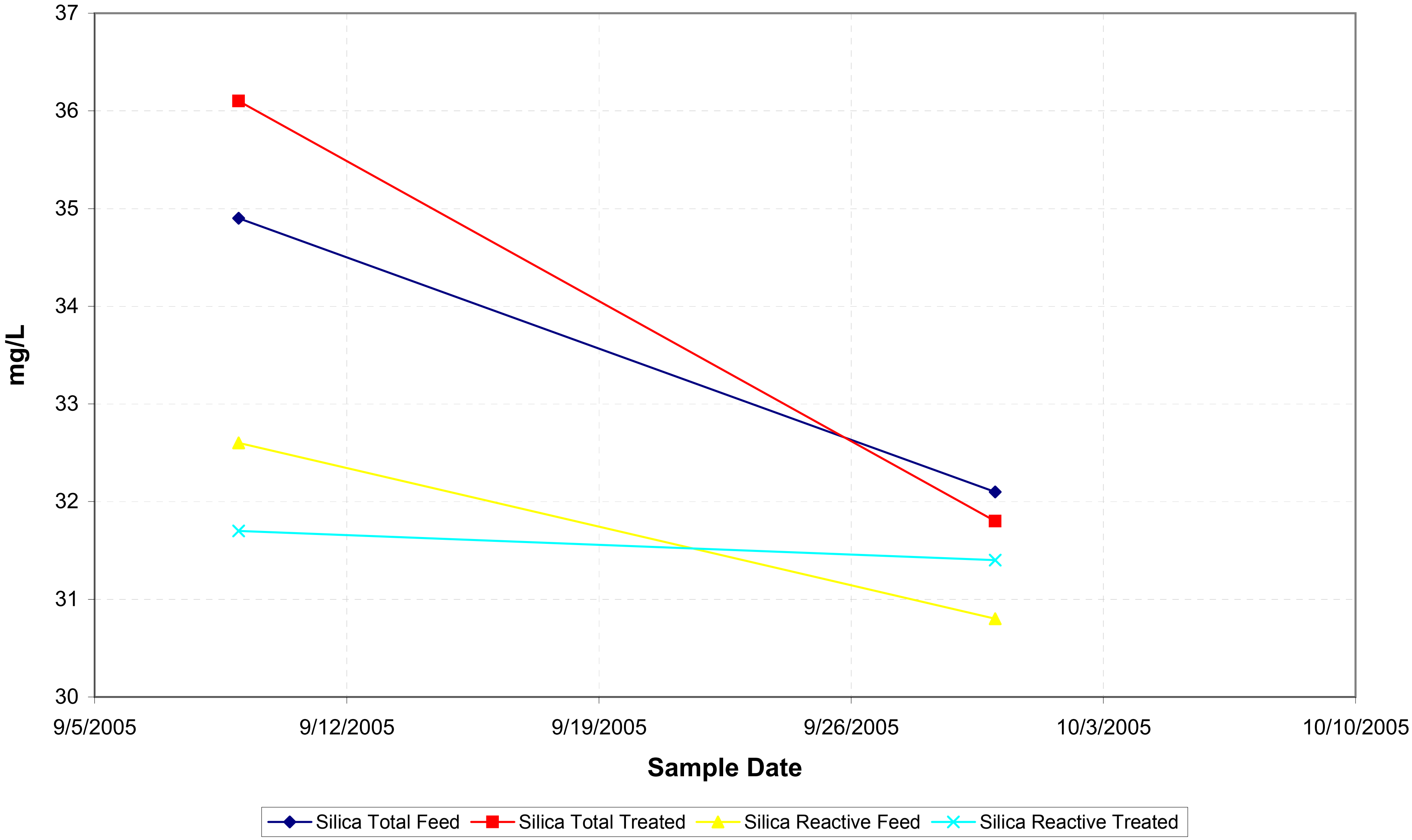


Figure C-15

Gedge Well EDR Arsenic

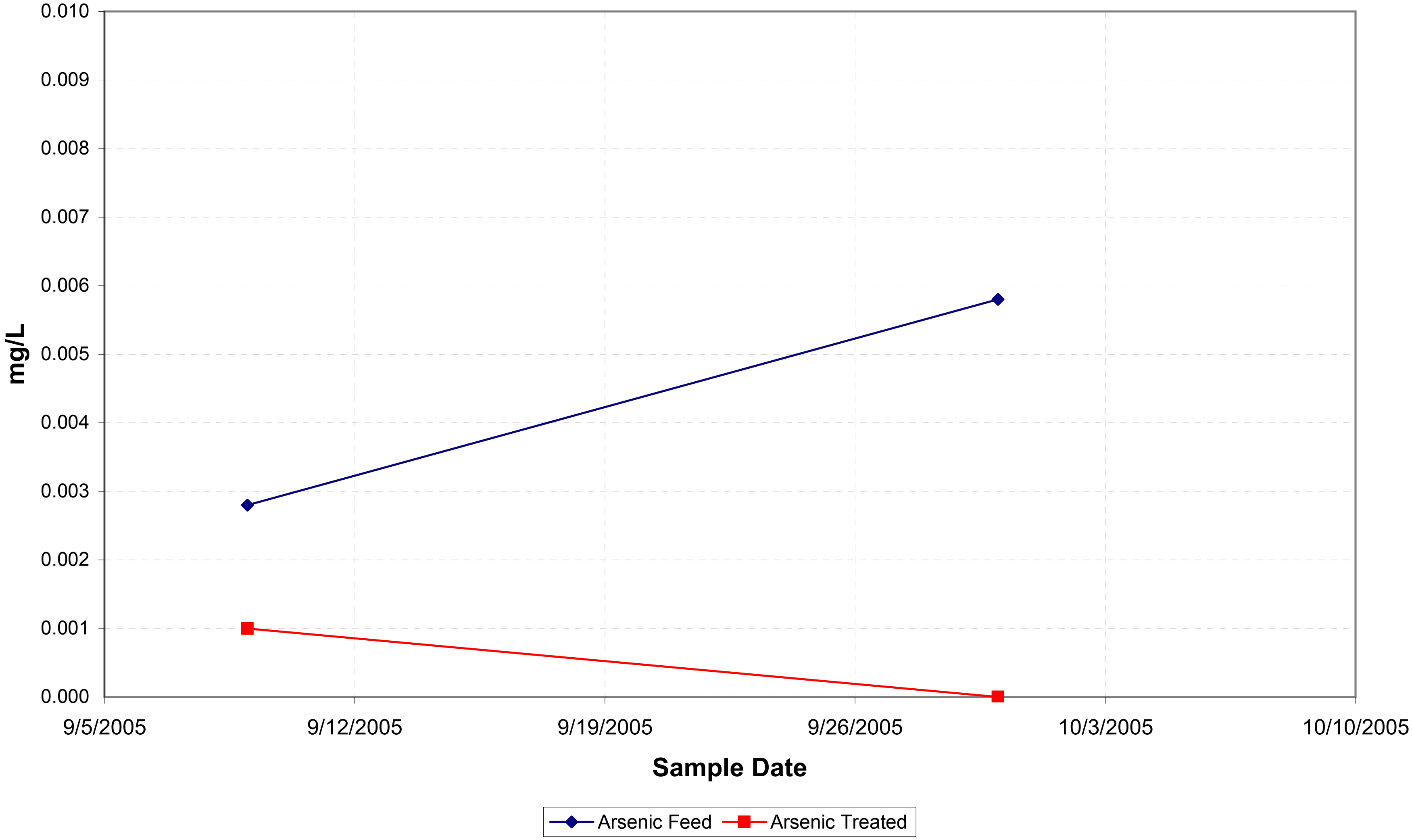


Figure C-16

Gedge Well EDR Sulfate

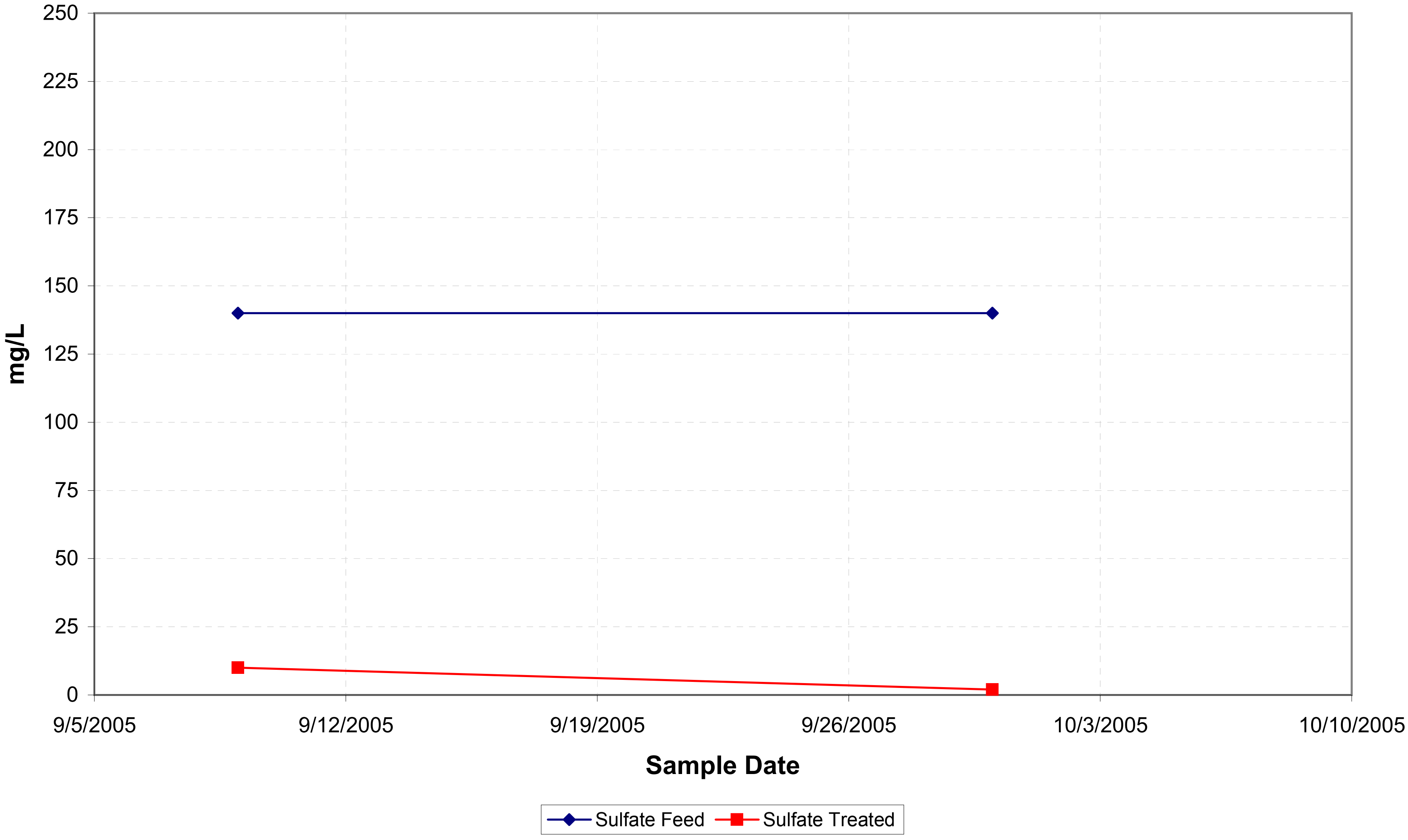
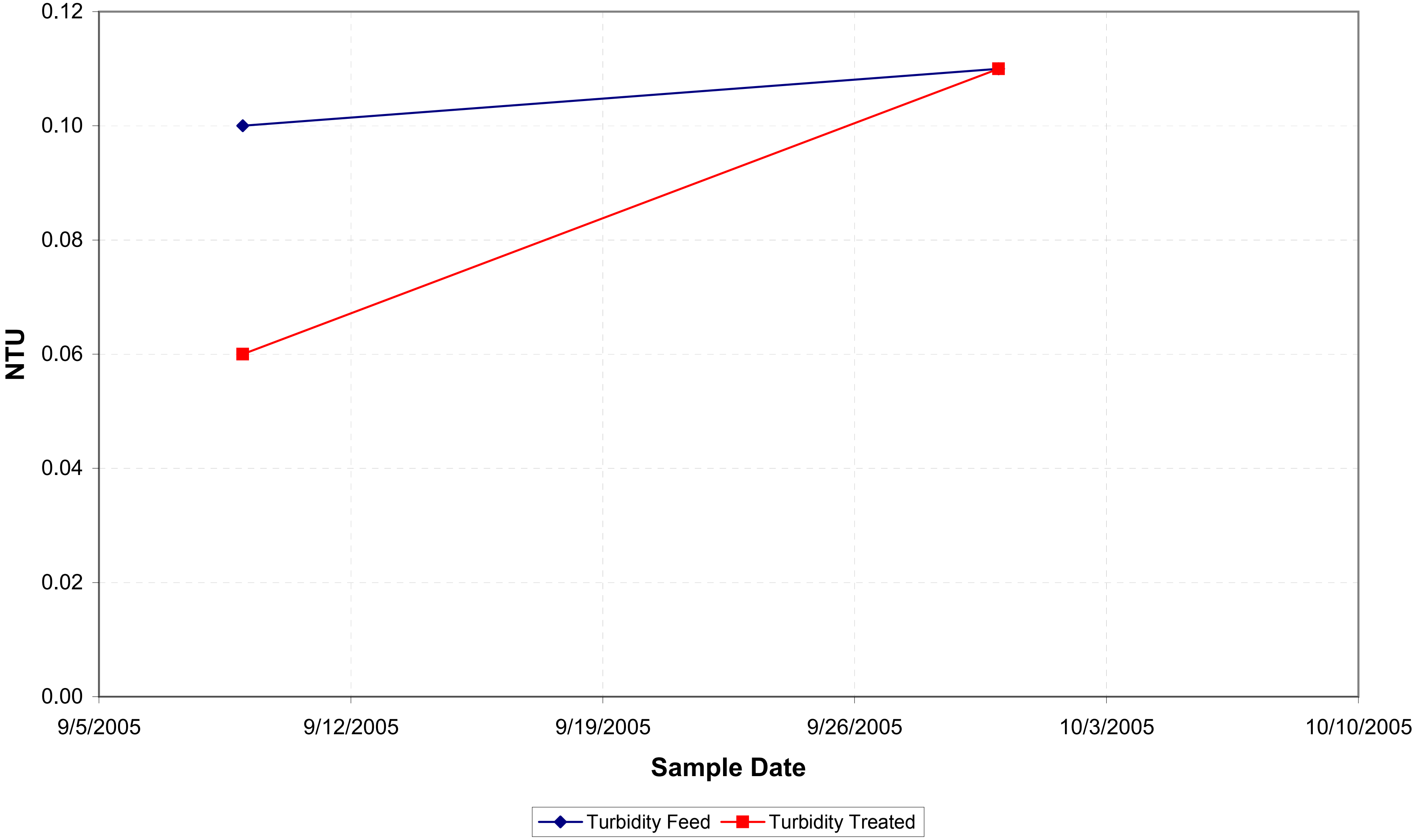


Figure C-17

Gedge Well EDR Turbidity



Appendix D

Hill Well Charts

Figure D-1
Hill Well RO Recovery

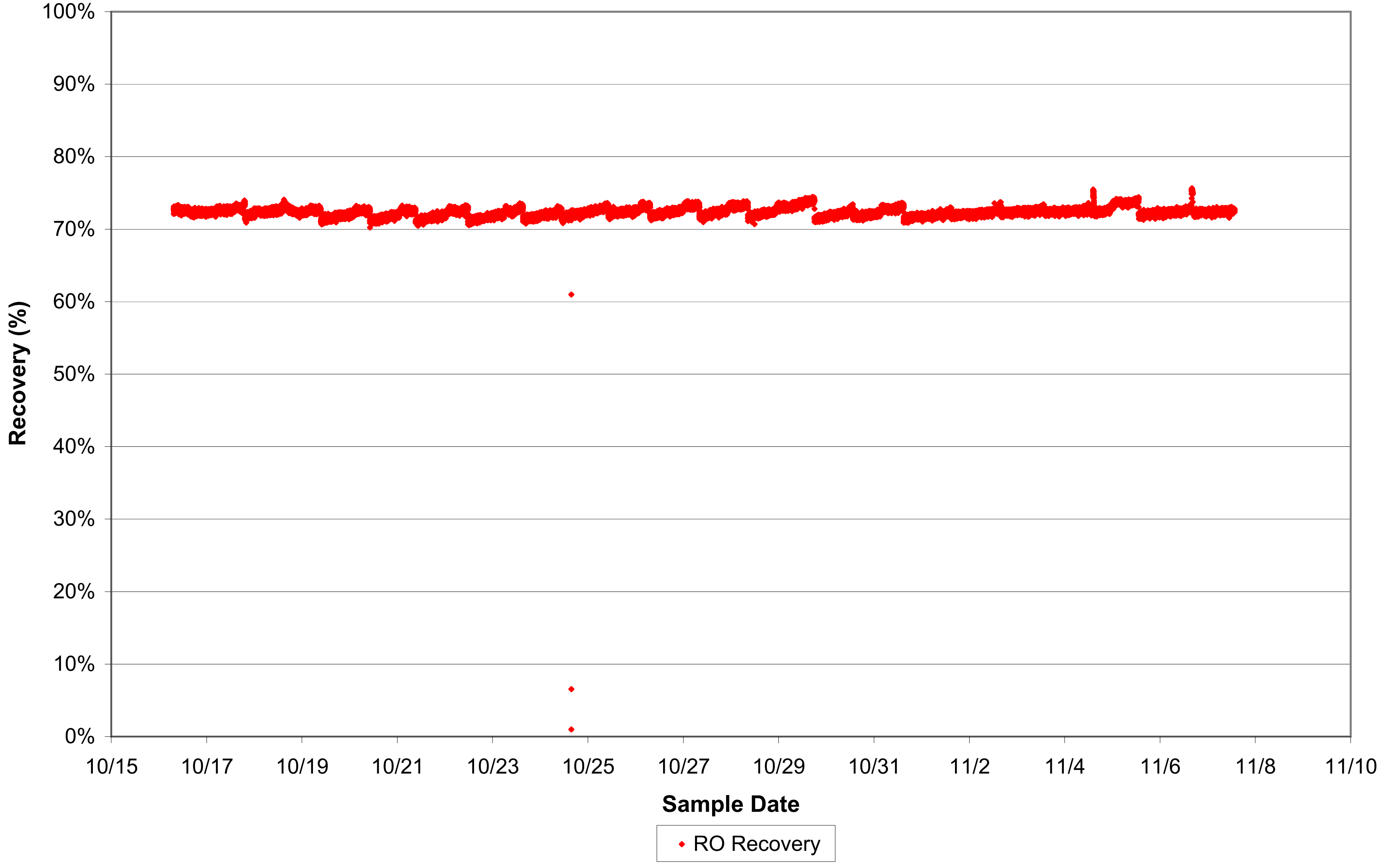


Figure D-2

Hill Well EDR Recovery

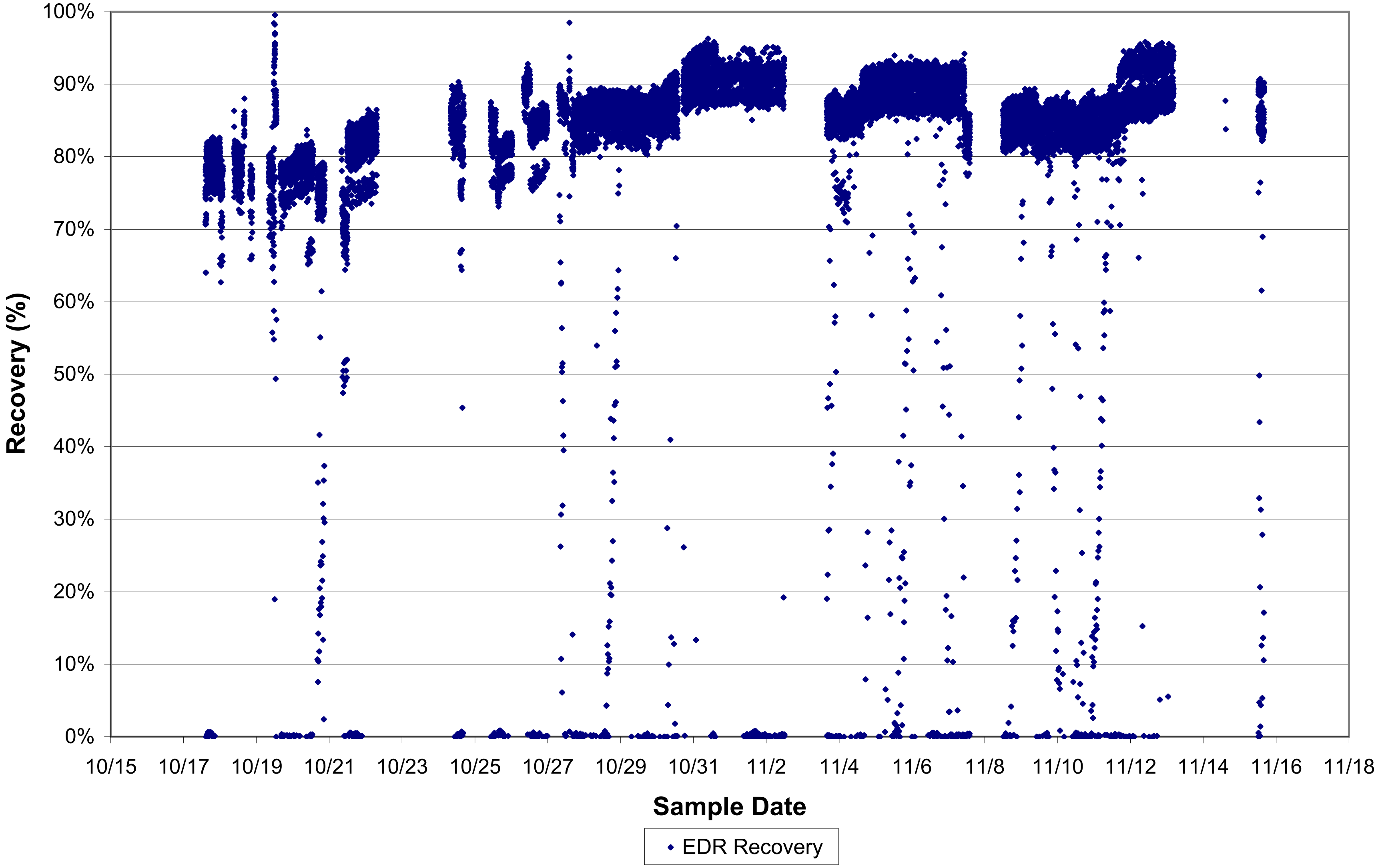


Figure D-3
Hill Well Conductivity

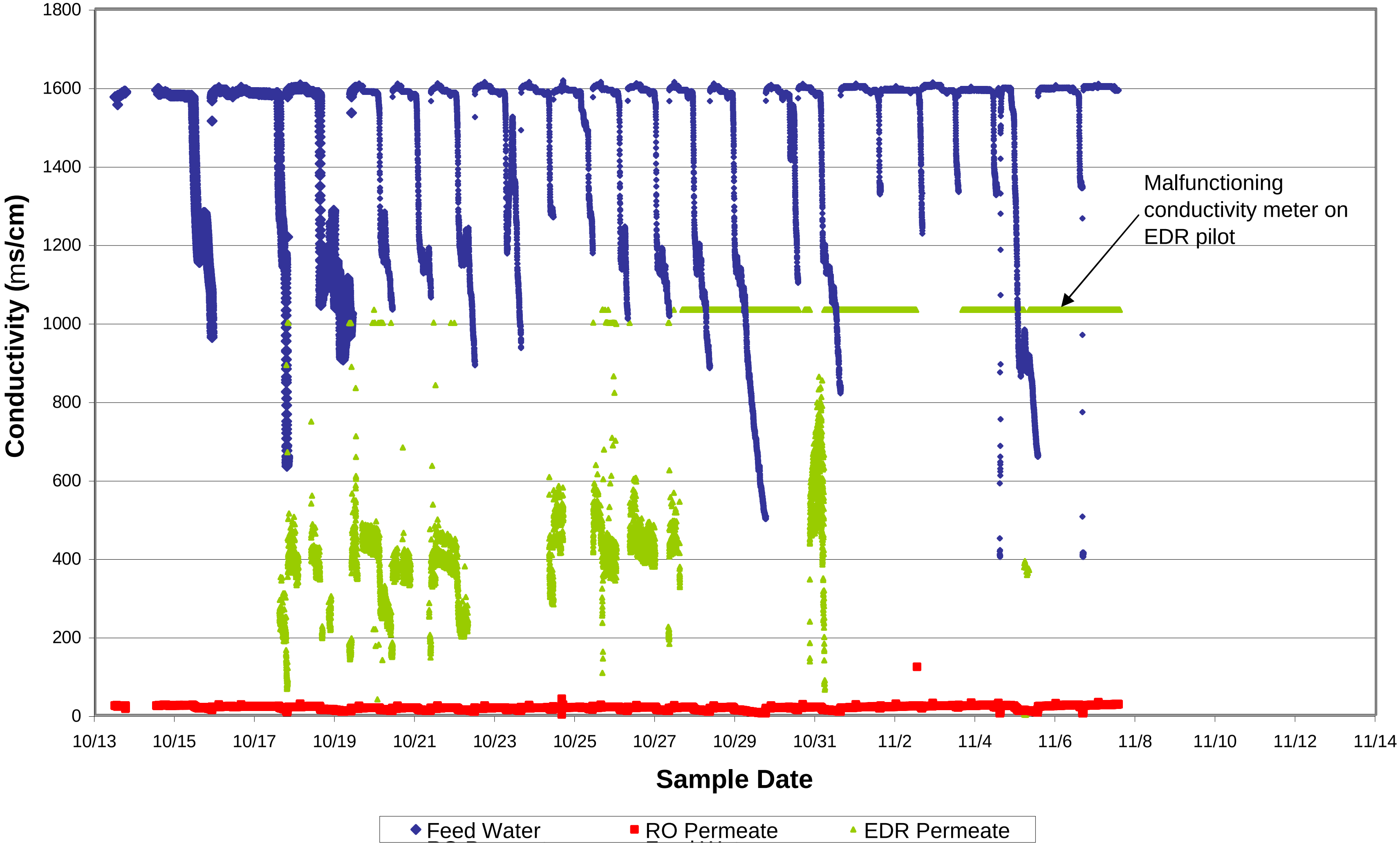


Figure D-4
Hill Well RO TDS

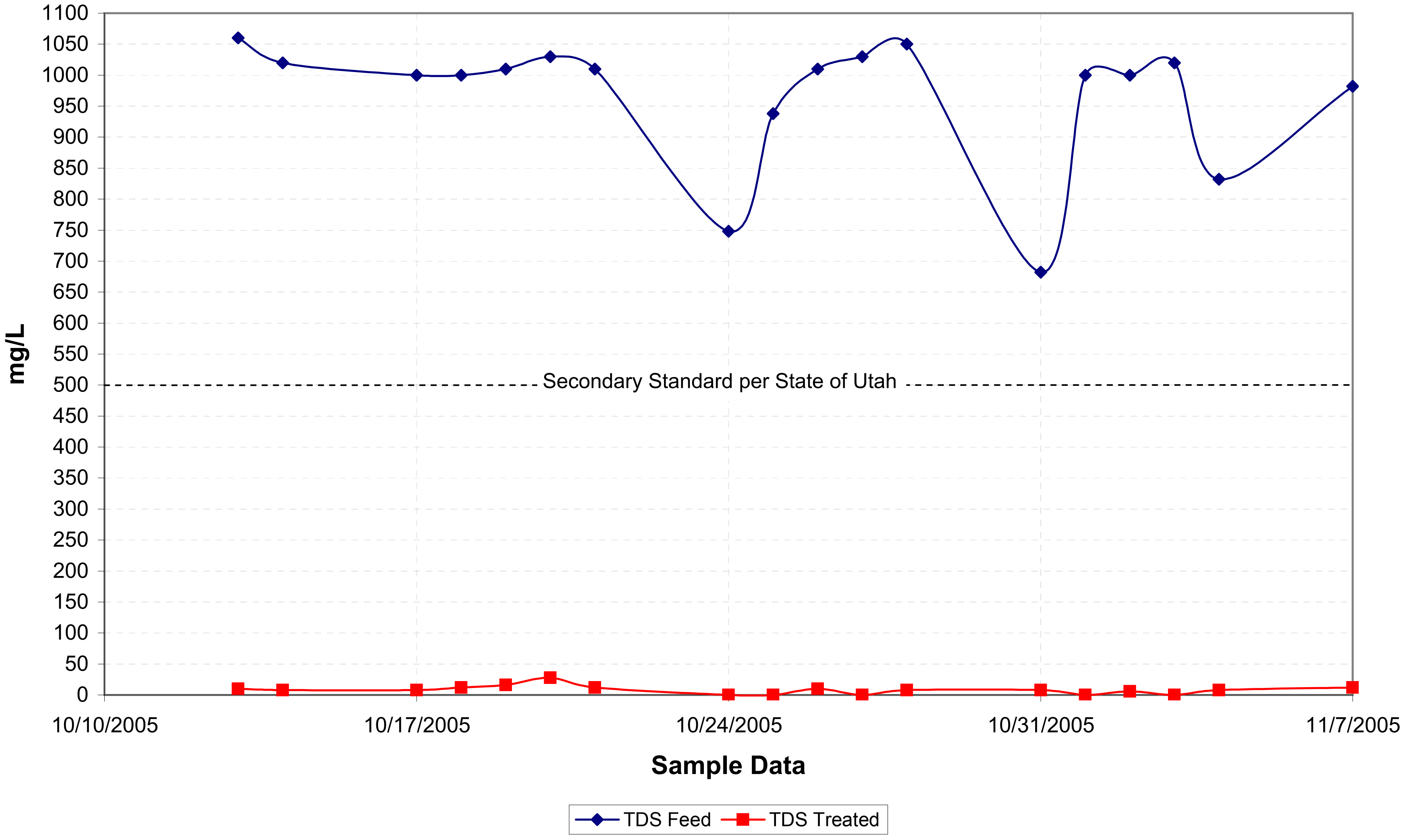


Figure D-5
Hill Well RO Hardness ($CaCO_3$), Calcium, Magnesium

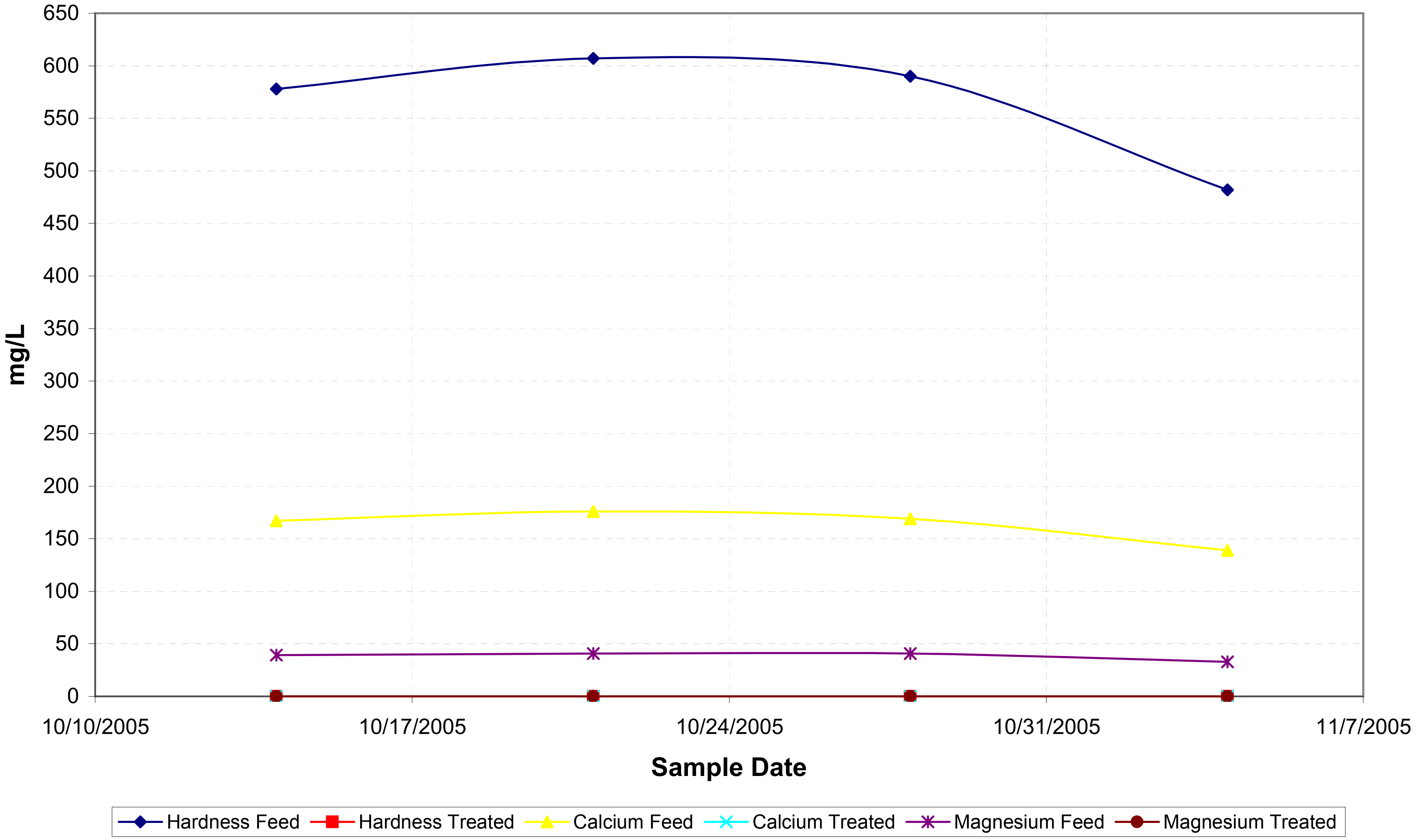


Figure D-6
Hill Well RO Alkalinity

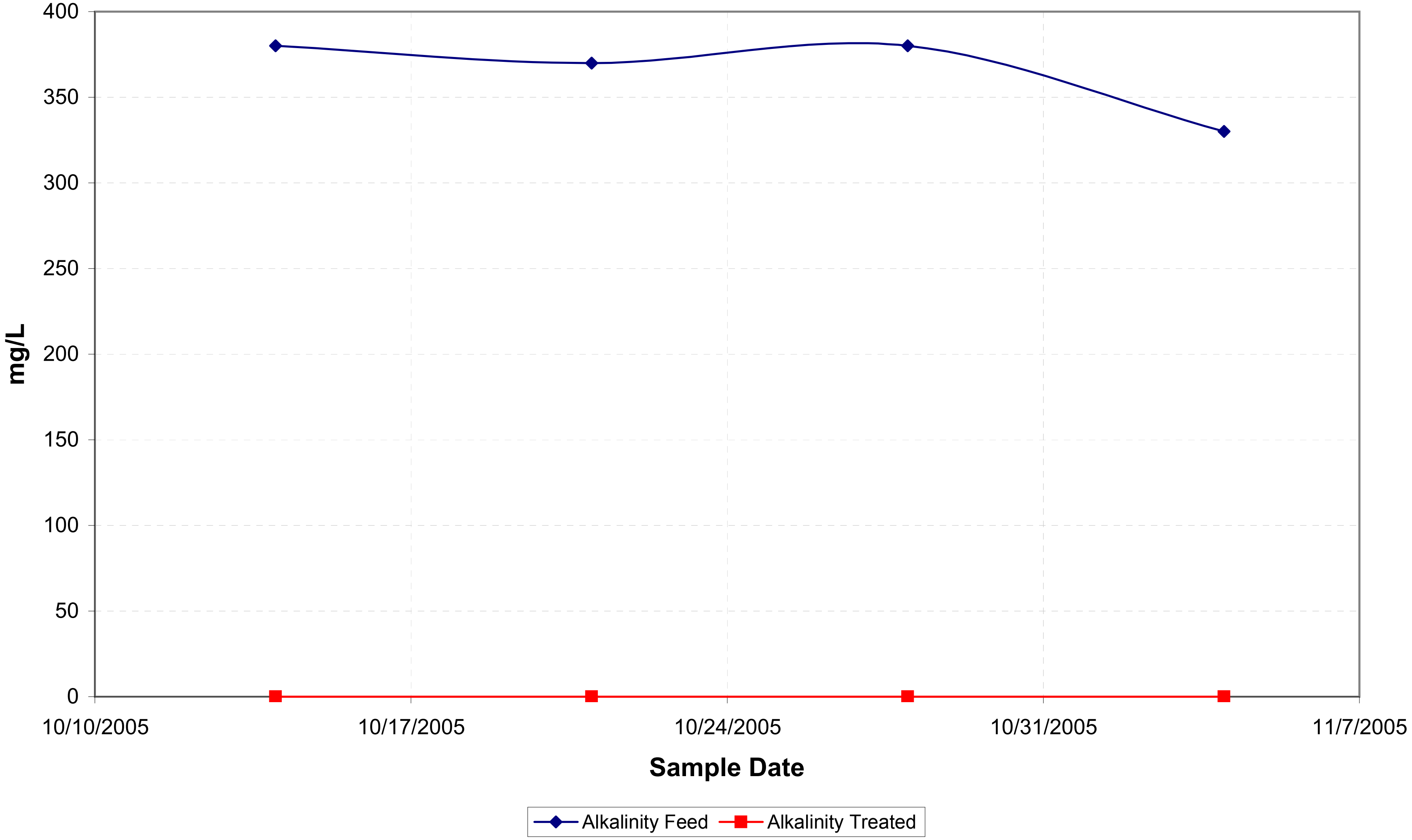


Figure D-7
Hill Well RO Silica Total, Silica Reactive

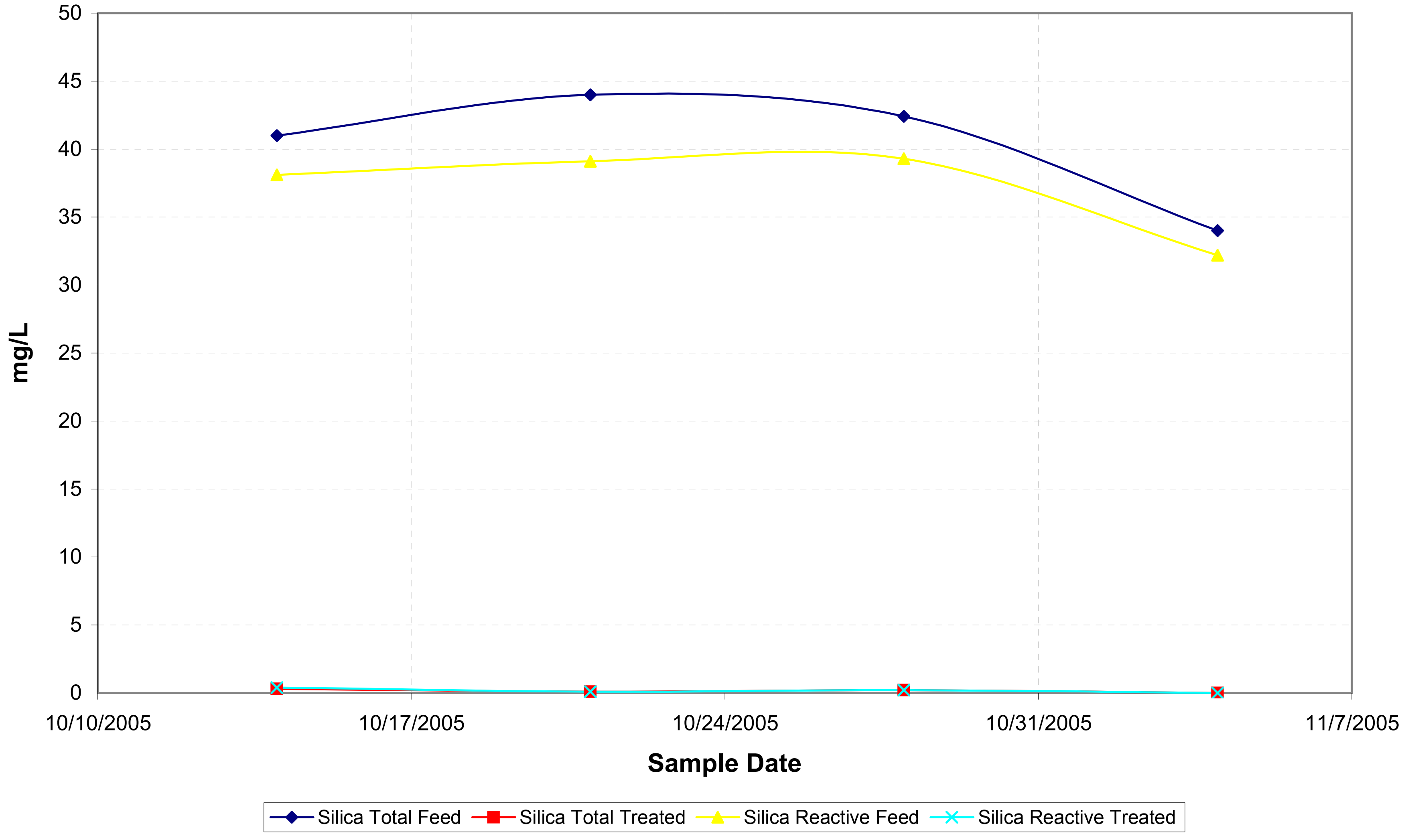


Figure D-8
Hill Well RO Arsenic

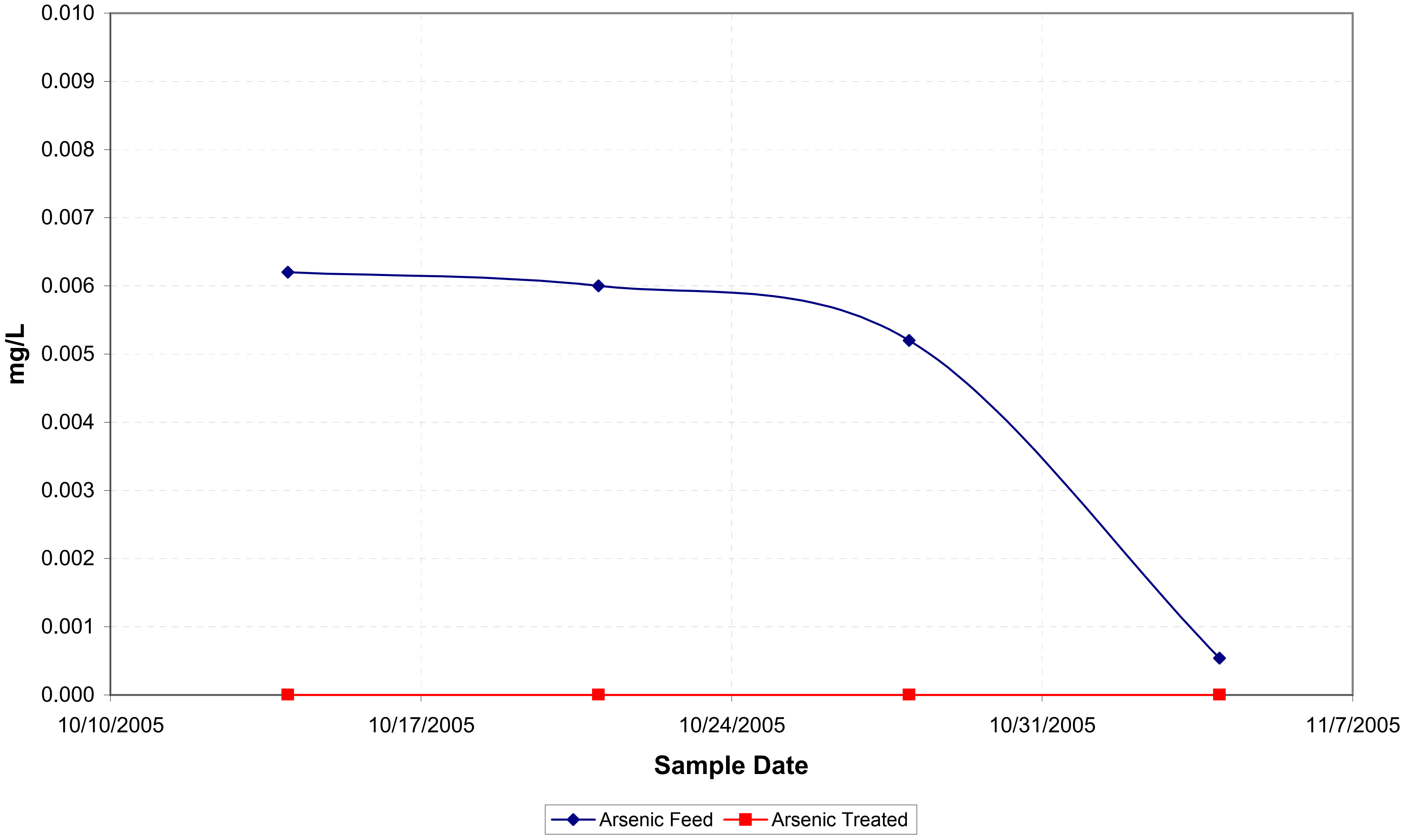


Figure D-9
Hill Well RO Sulfate

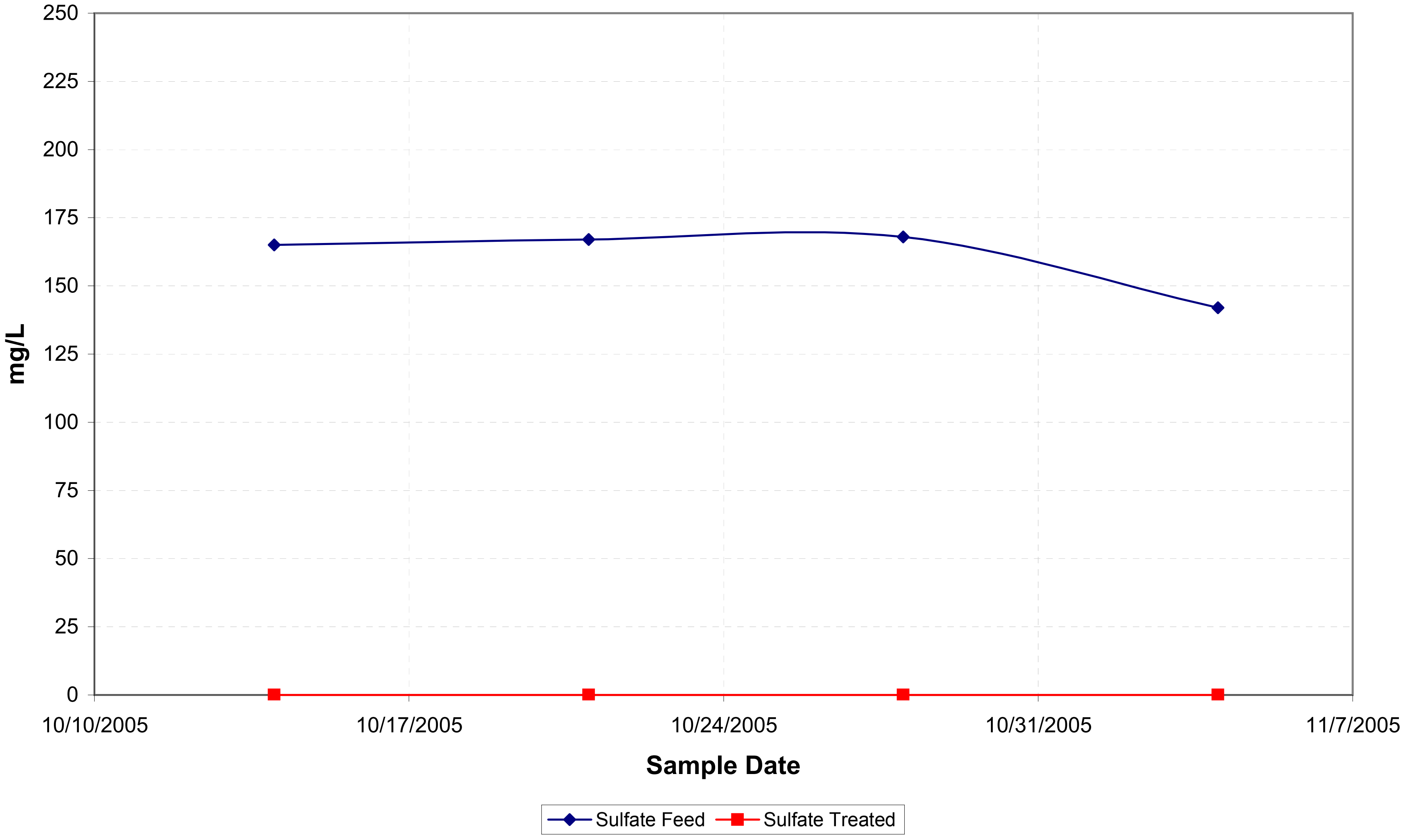


Figure D-10

Hill Well RO Turbidity

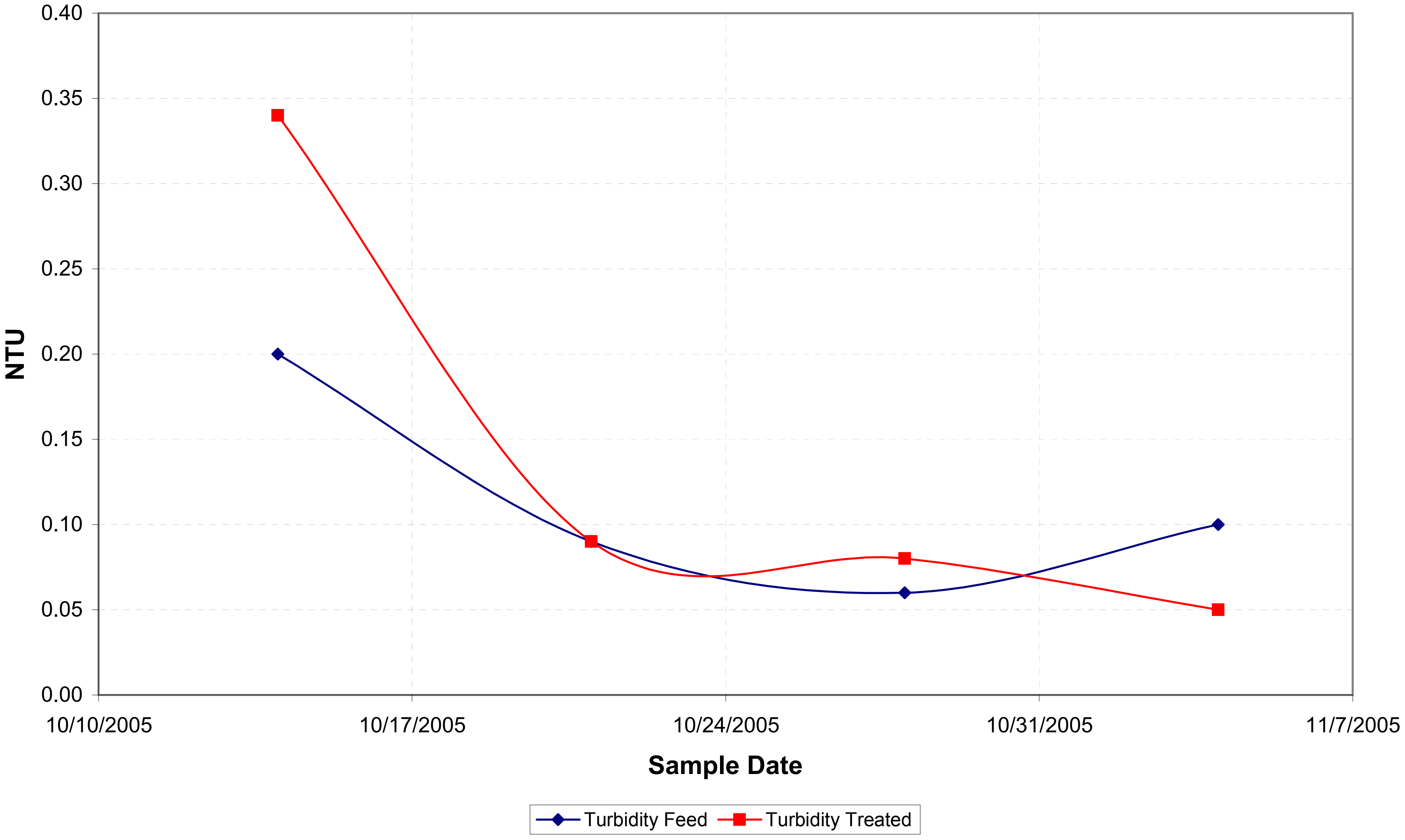


Figure D-11
Hill Well EDR TDS

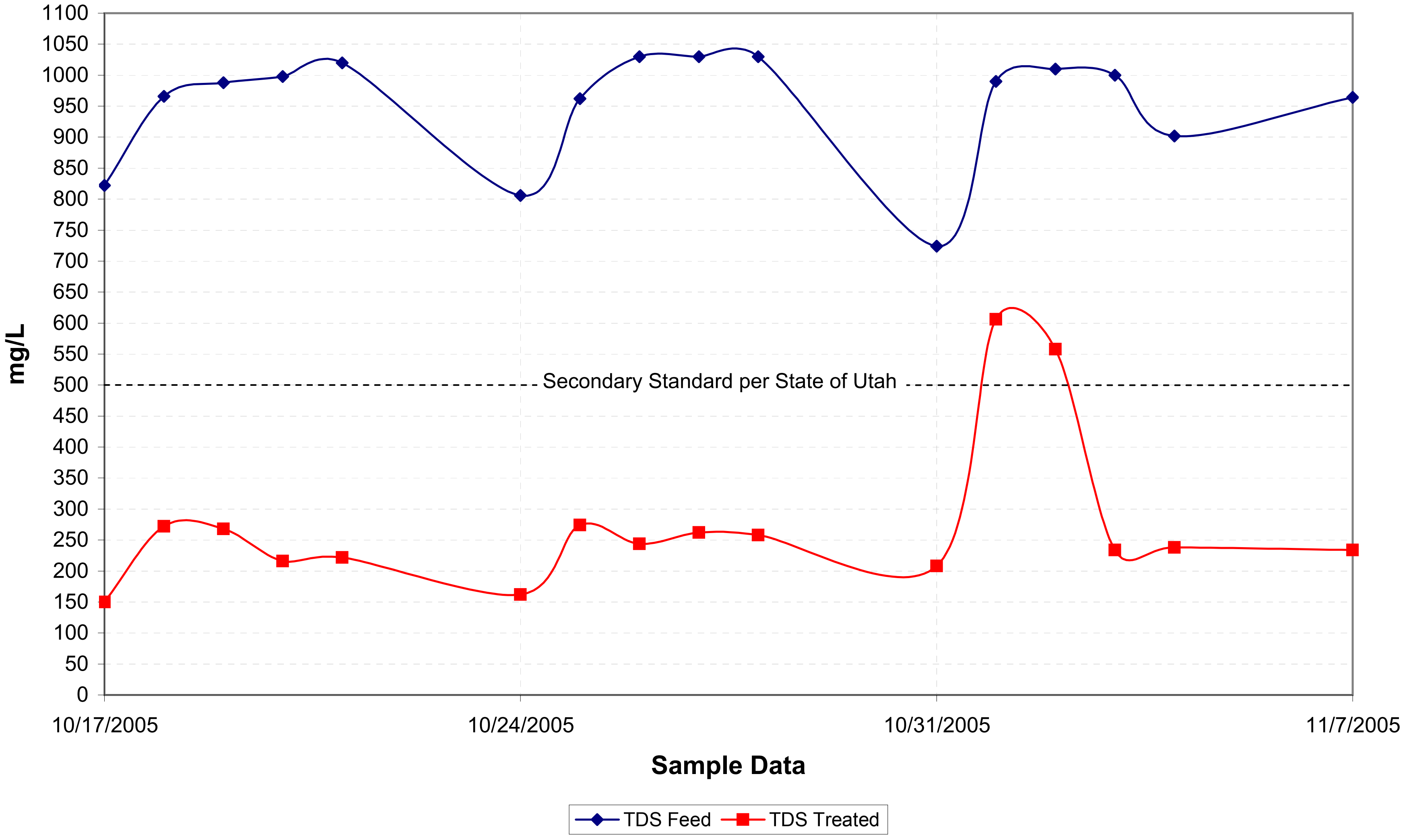


Figure D-12

Hill Well EDR Hardness ($CaCO_3$), Calcium, Magnesium

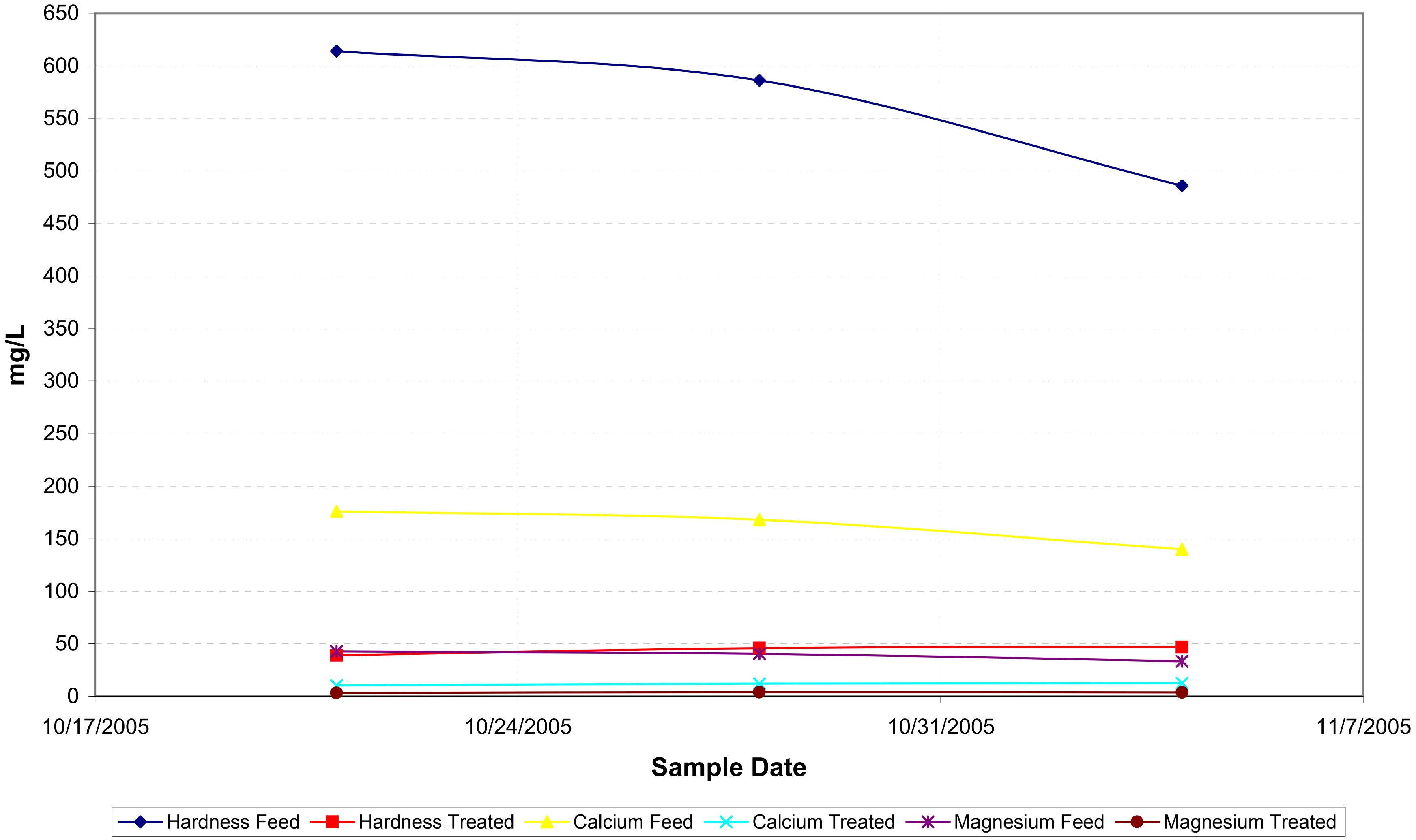


Figure D-13

Hill Well EDR Alkalinity

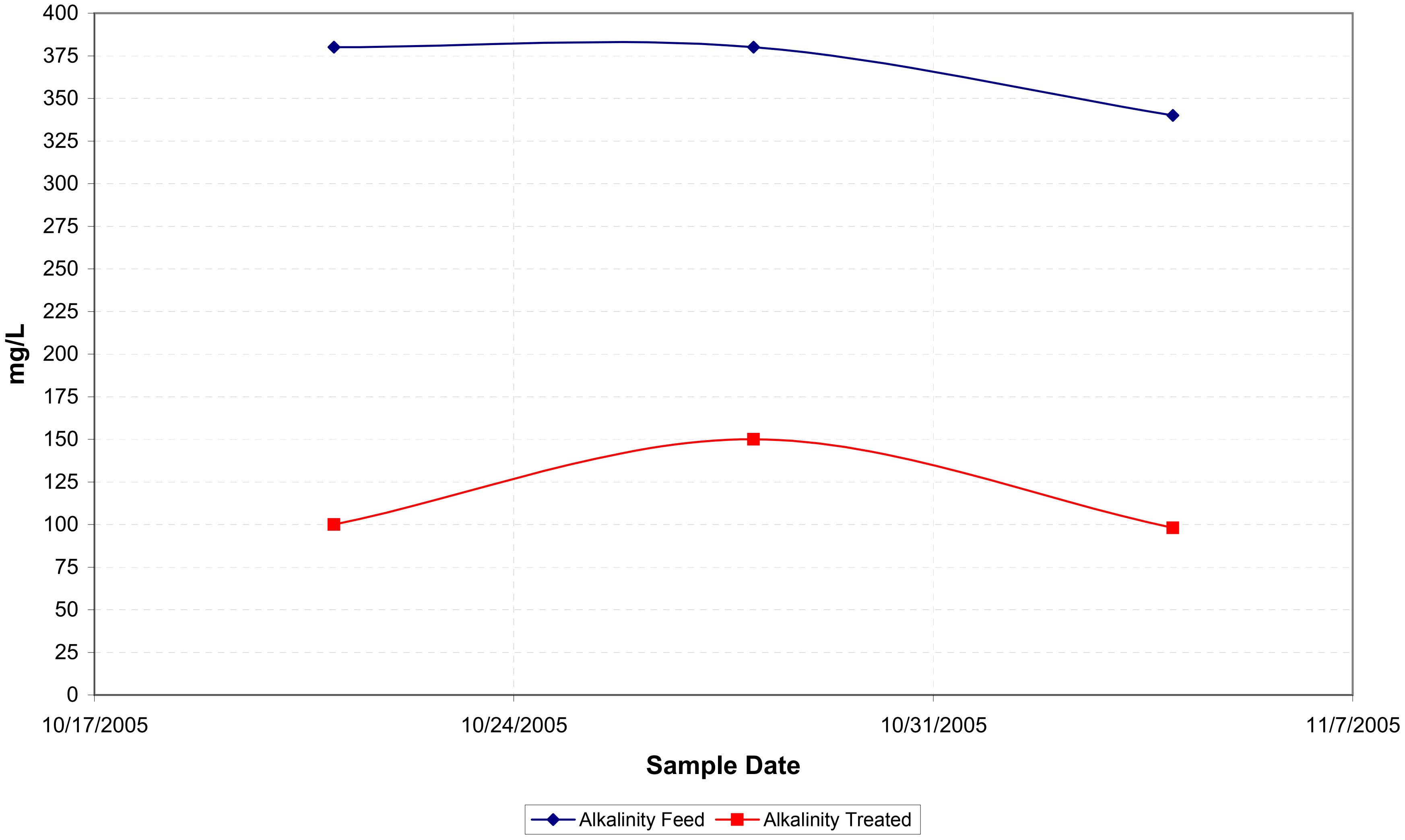


Figure D-14
Hill Well EDR Silica Total, Silica Reactive

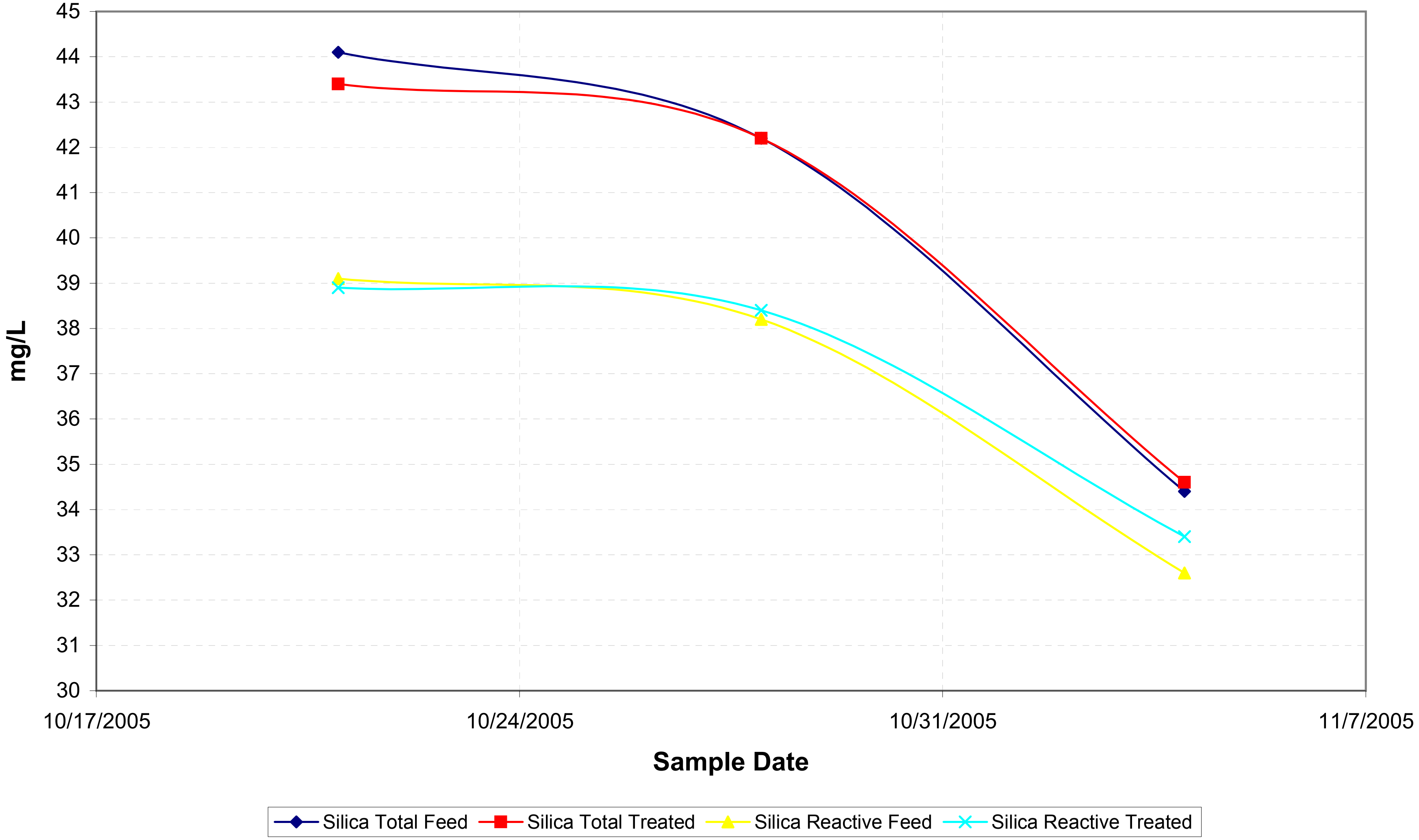


Figure D-15

Hill Well EDR Arsenic

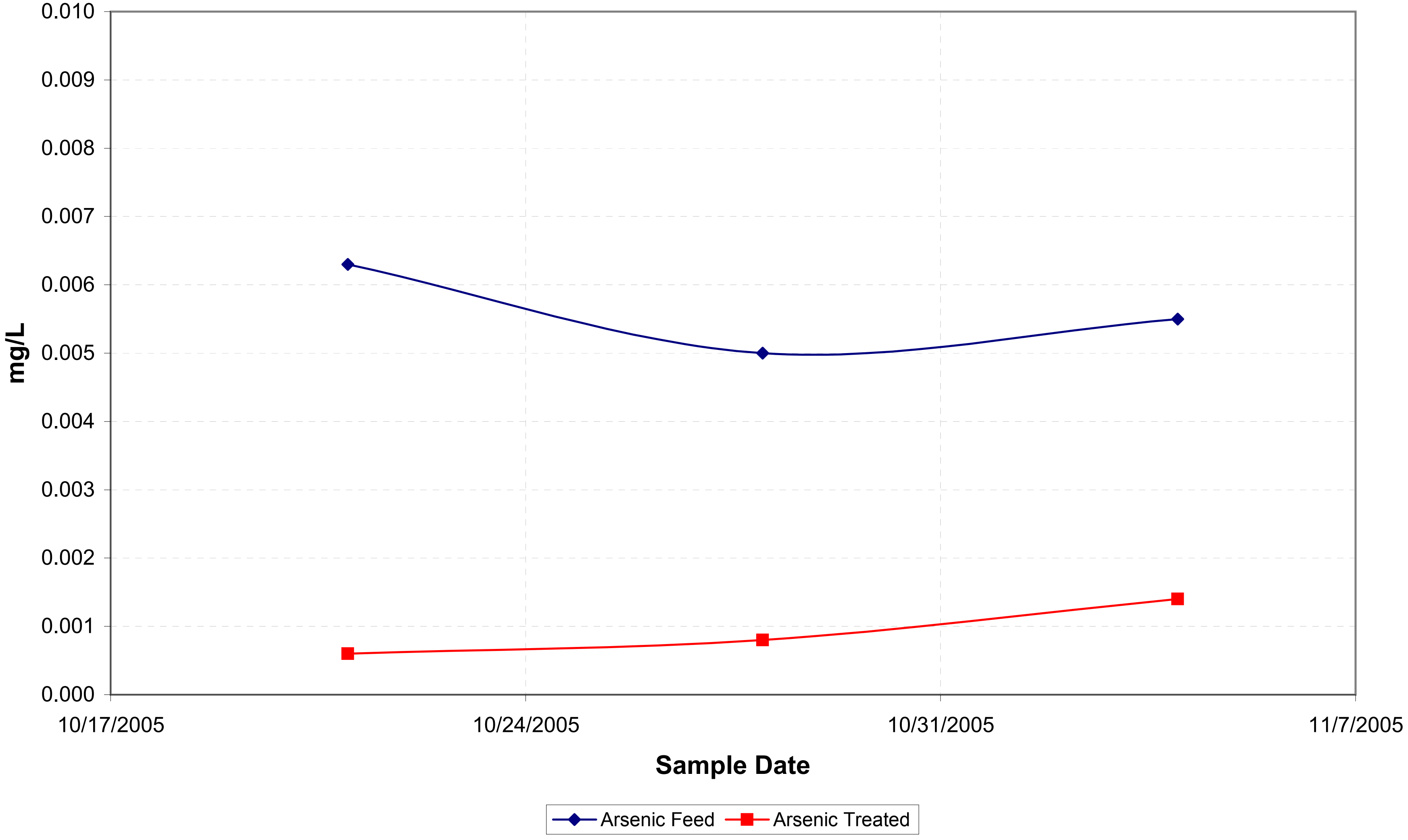


Figure D-16
Hill Well EDR Sulfate

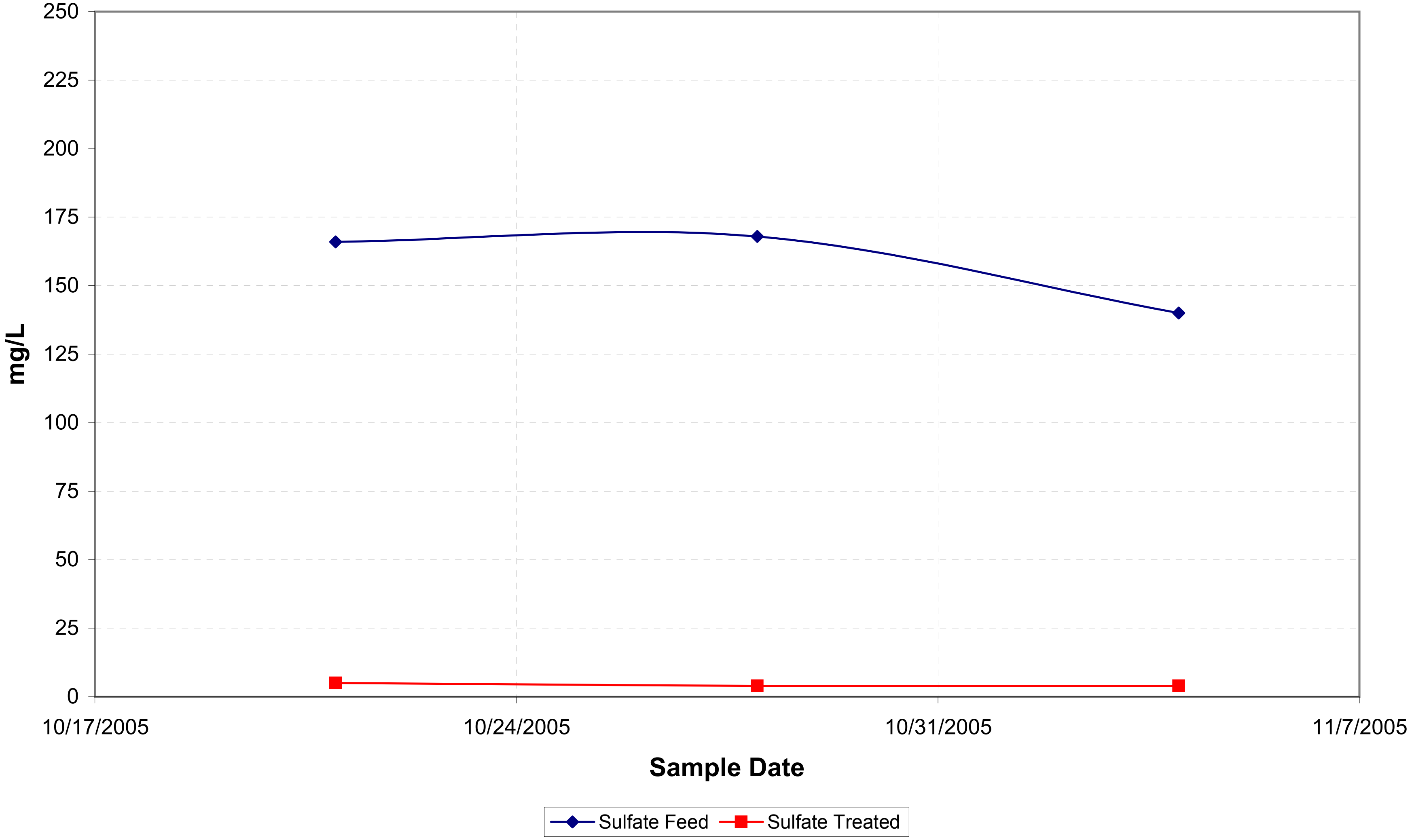
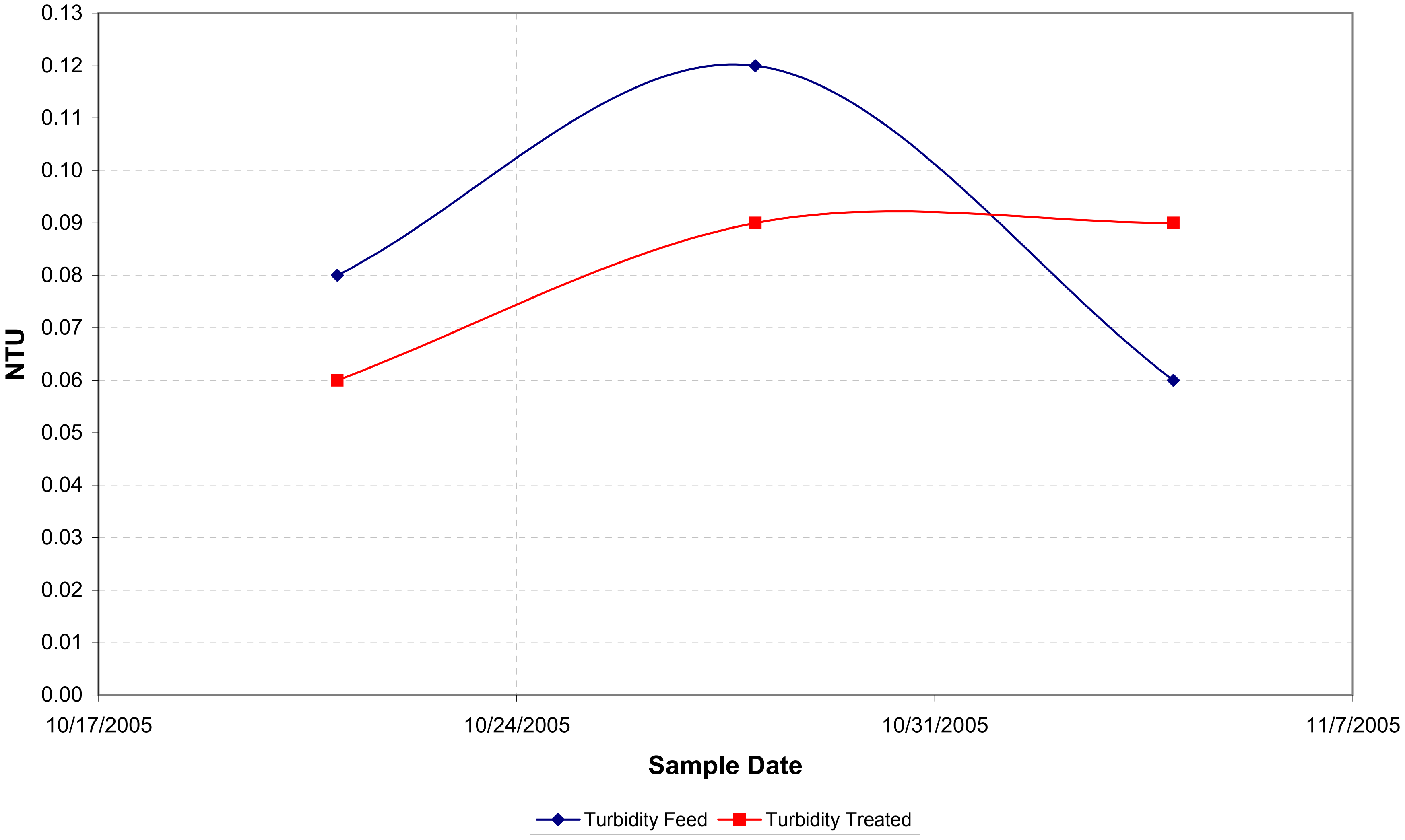


Figure D-17
Hill Well EDR Turbidity



Appendix E

Maynard Well Charts

Figure E-1
Maynard Well RO Recovery

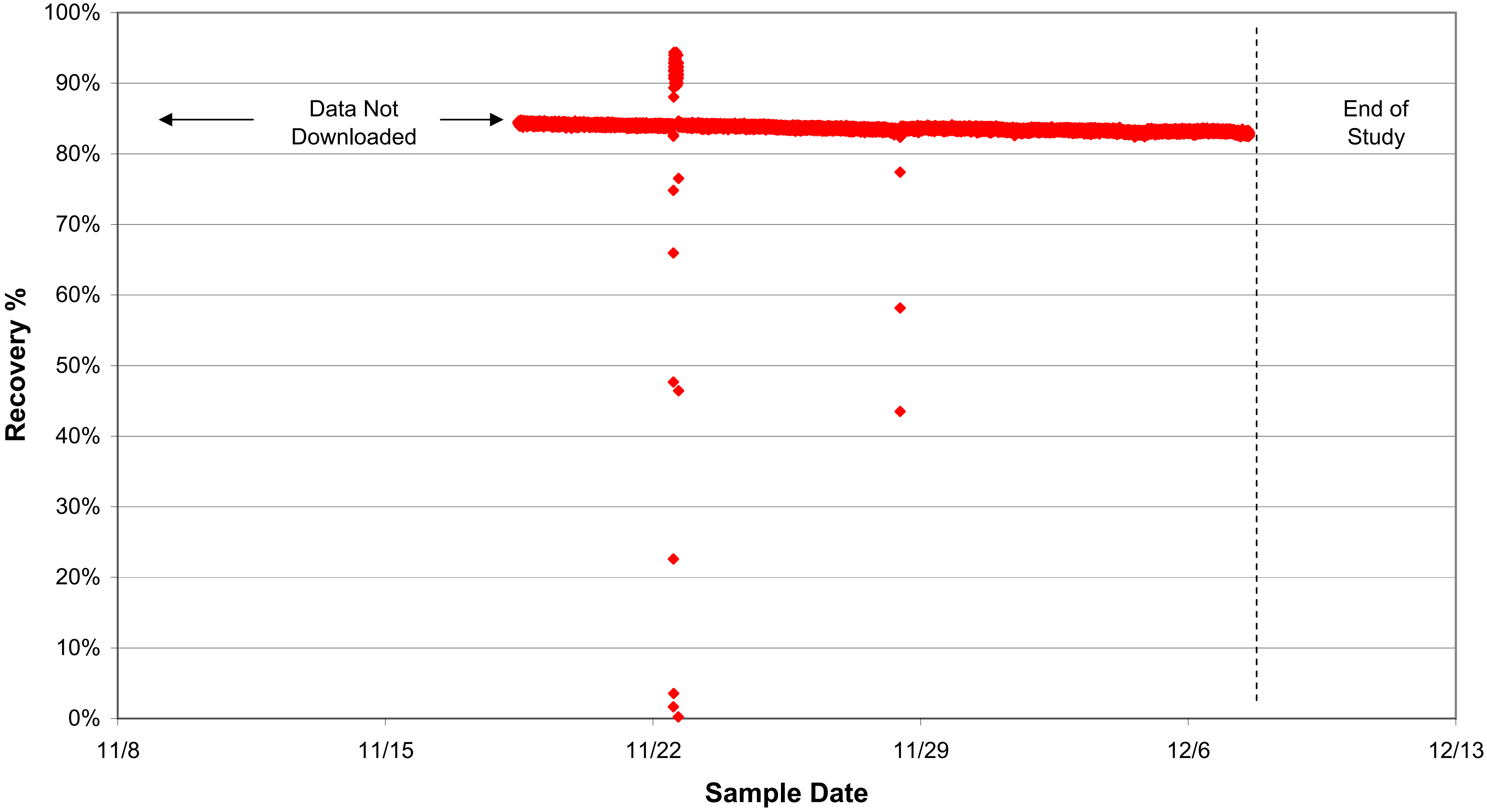


Figure E-2
Maynard Well EDR Recovery

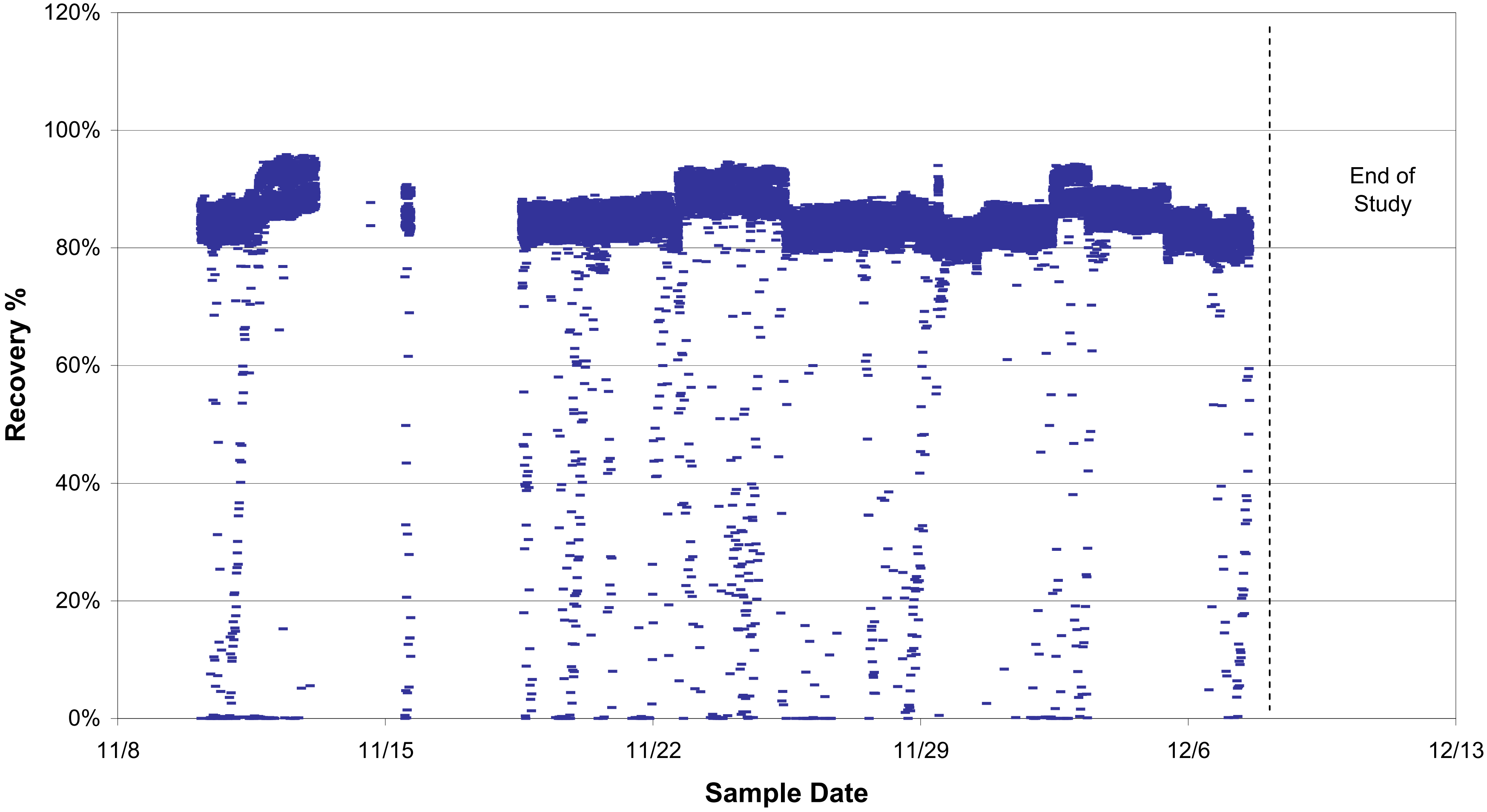


Figure E-3
Maynard Well Conductivity

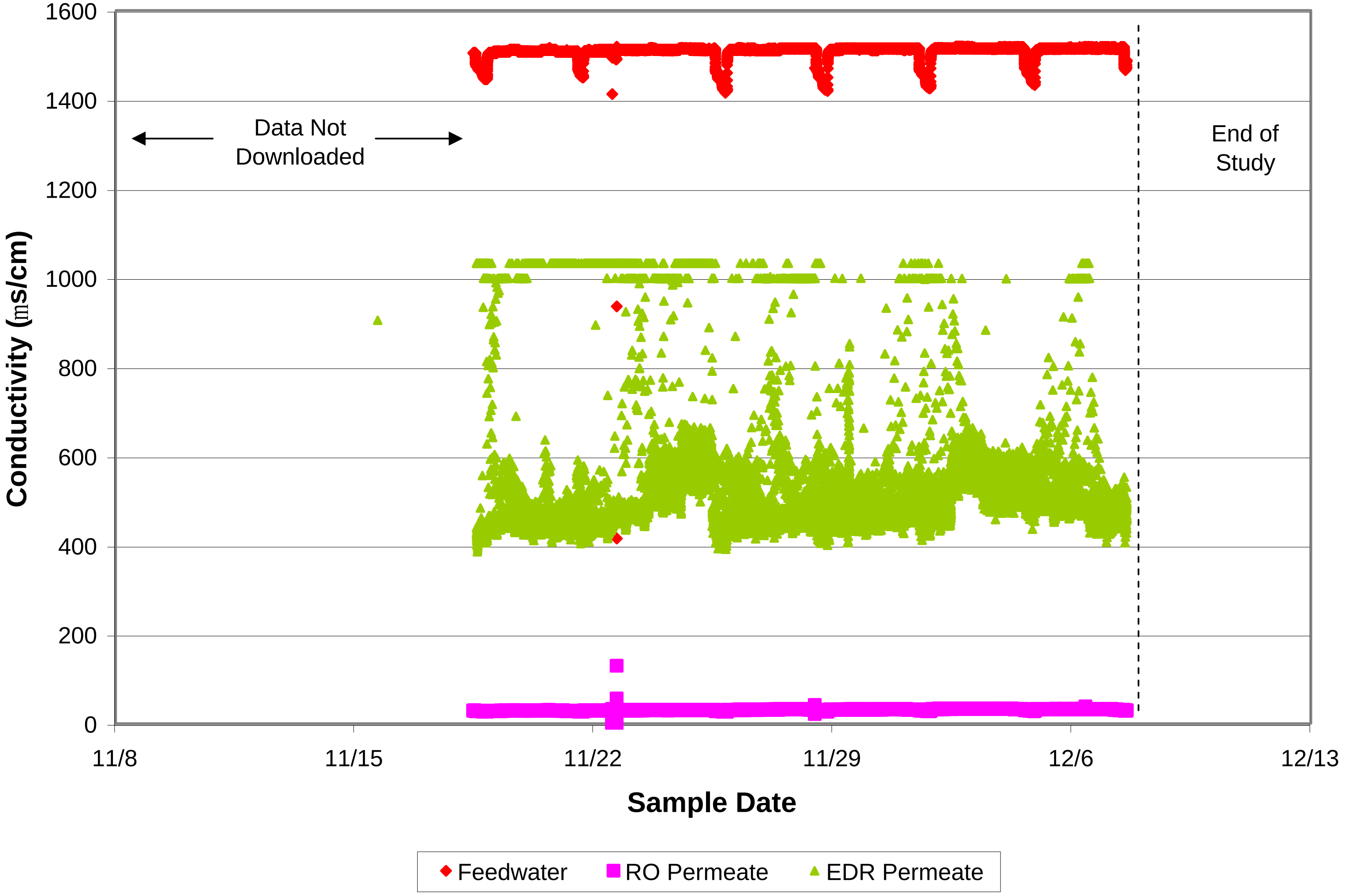


Figure E-4
Maynard Well RO TDS

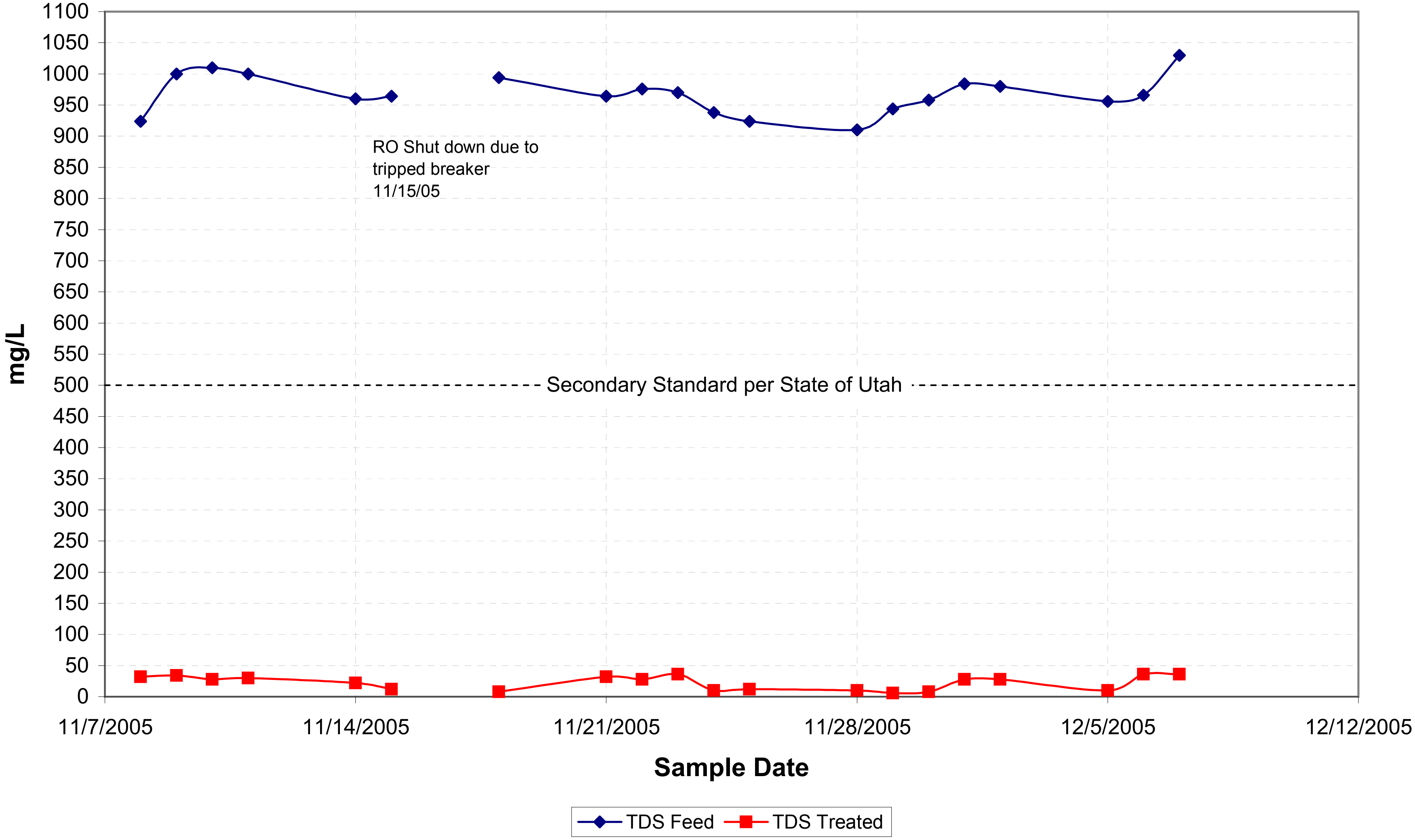


Figure E-5

Maynard Well RO Hardness ($CaCO_3$), Calcium, Magnesium

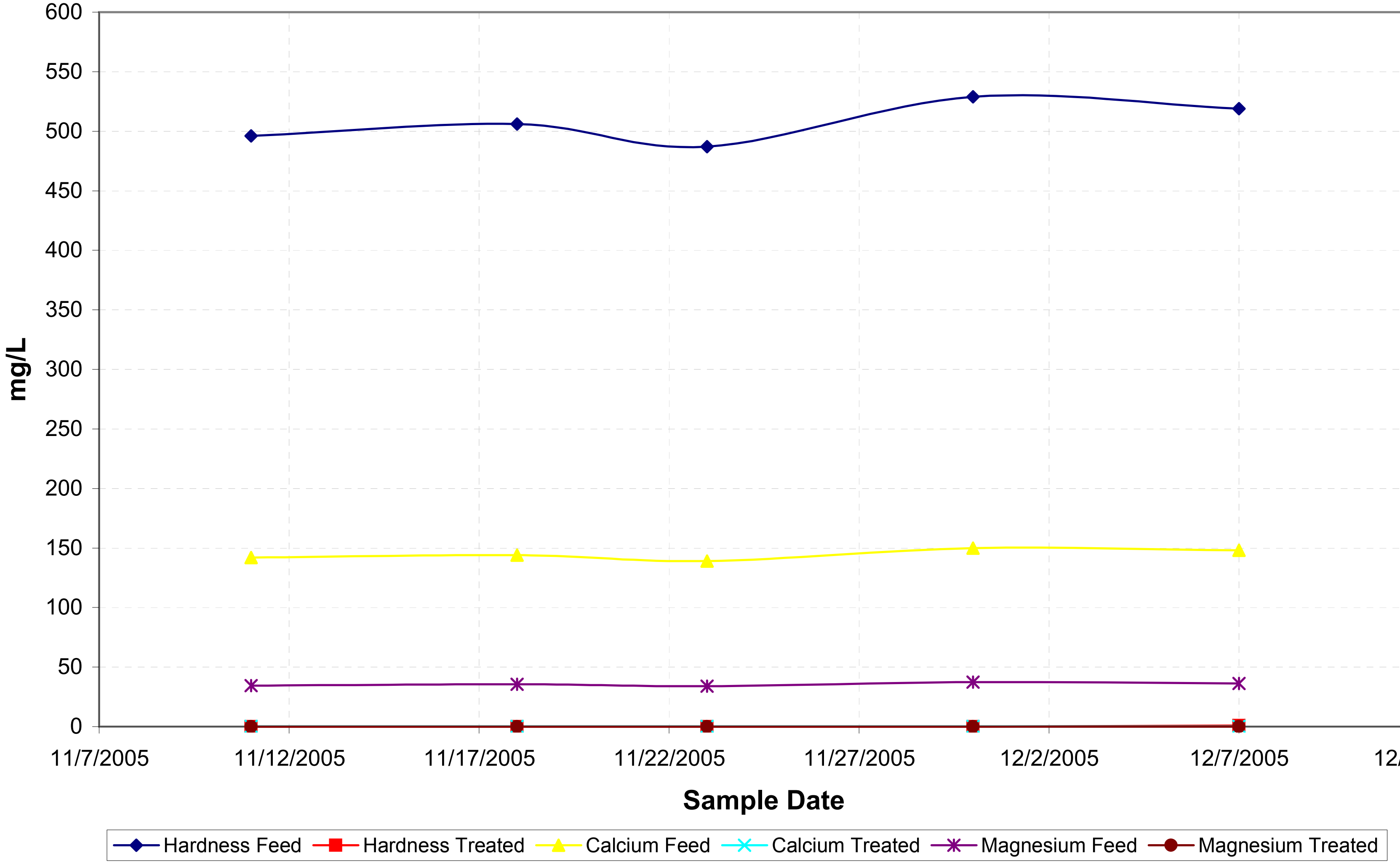


Figure E-6

Maynard Well RO Alkalinity

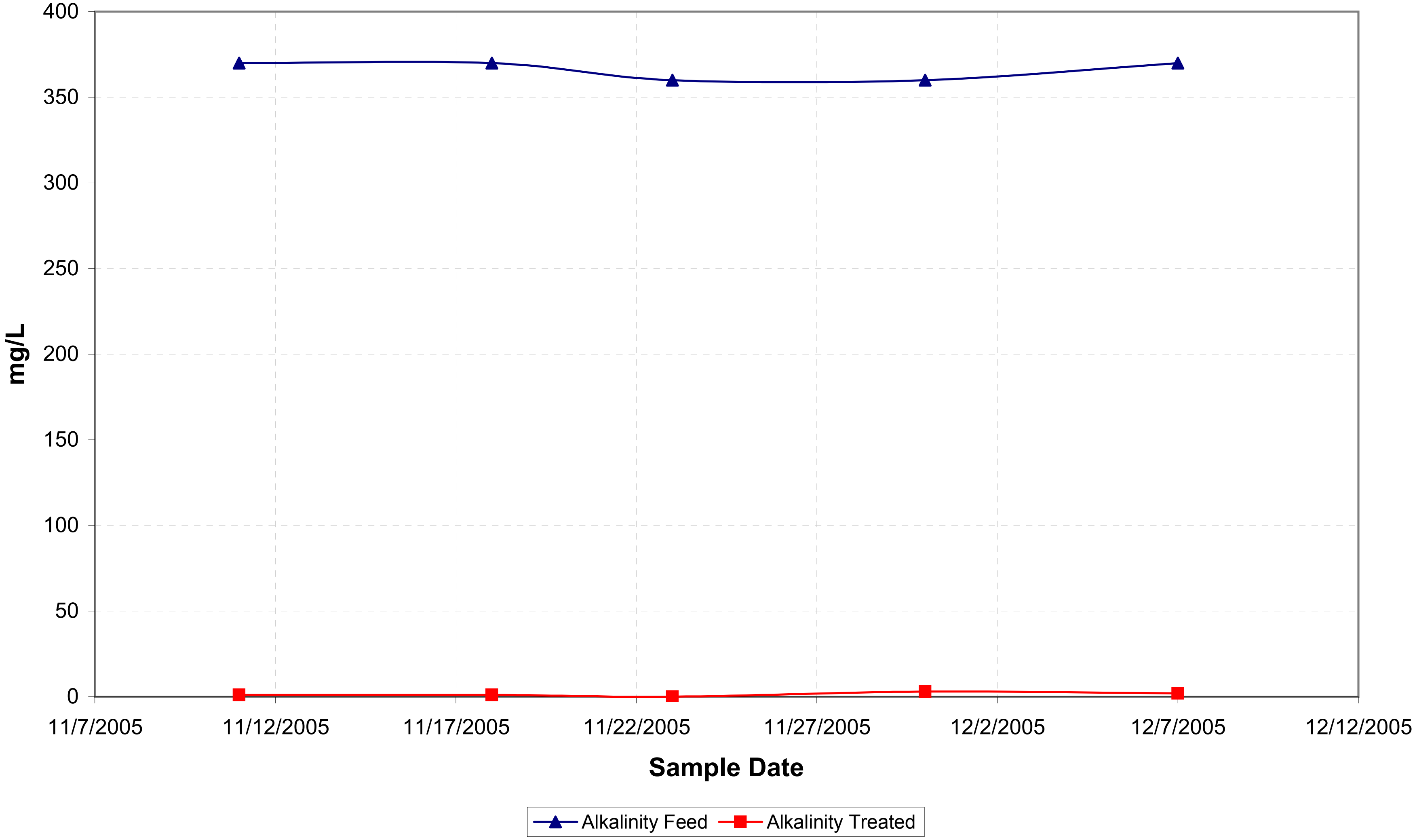


Figure E-7
Maynard Well RO Silica Total, Silica Reactive

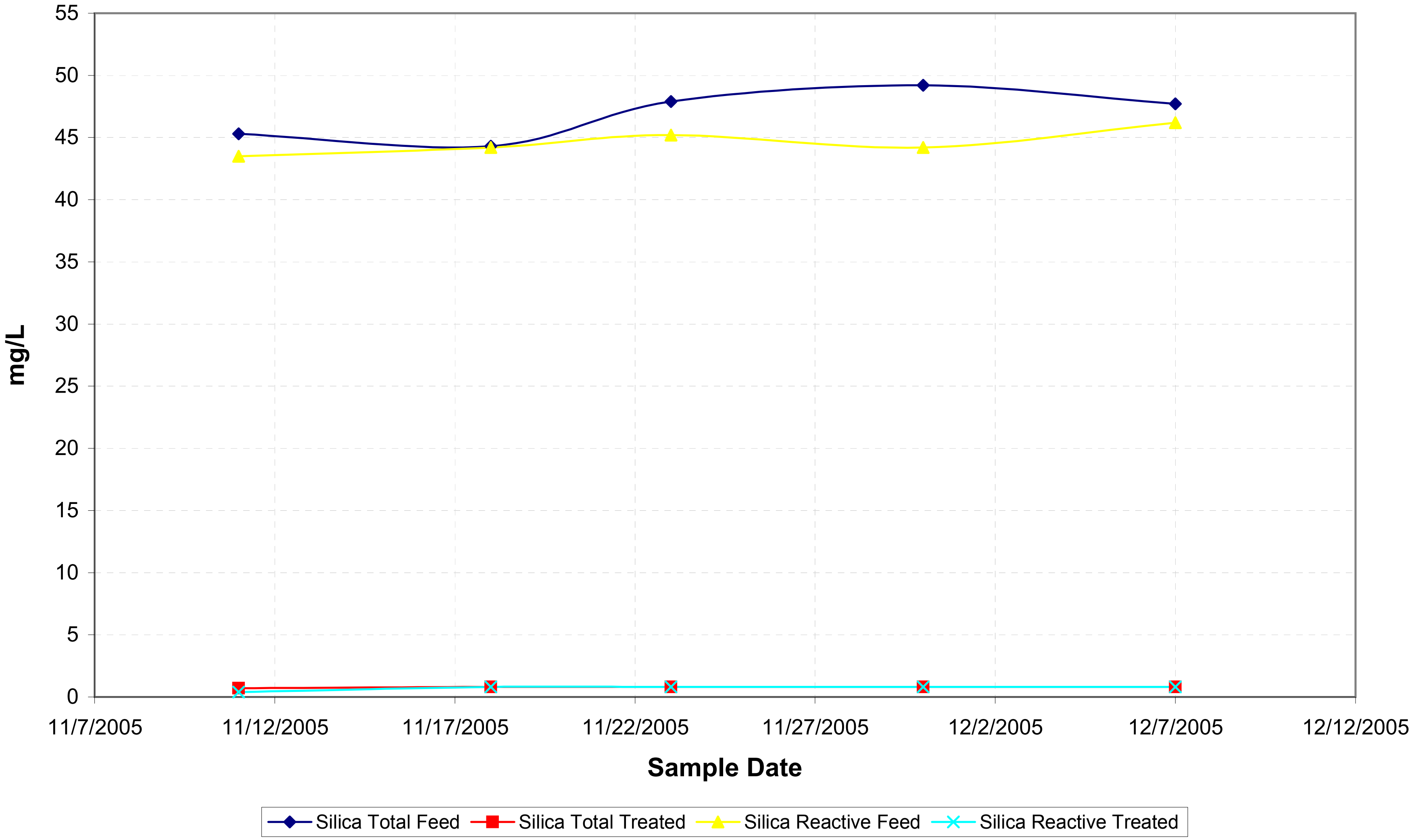


Figure E8
Maynard Well RO Arsenic

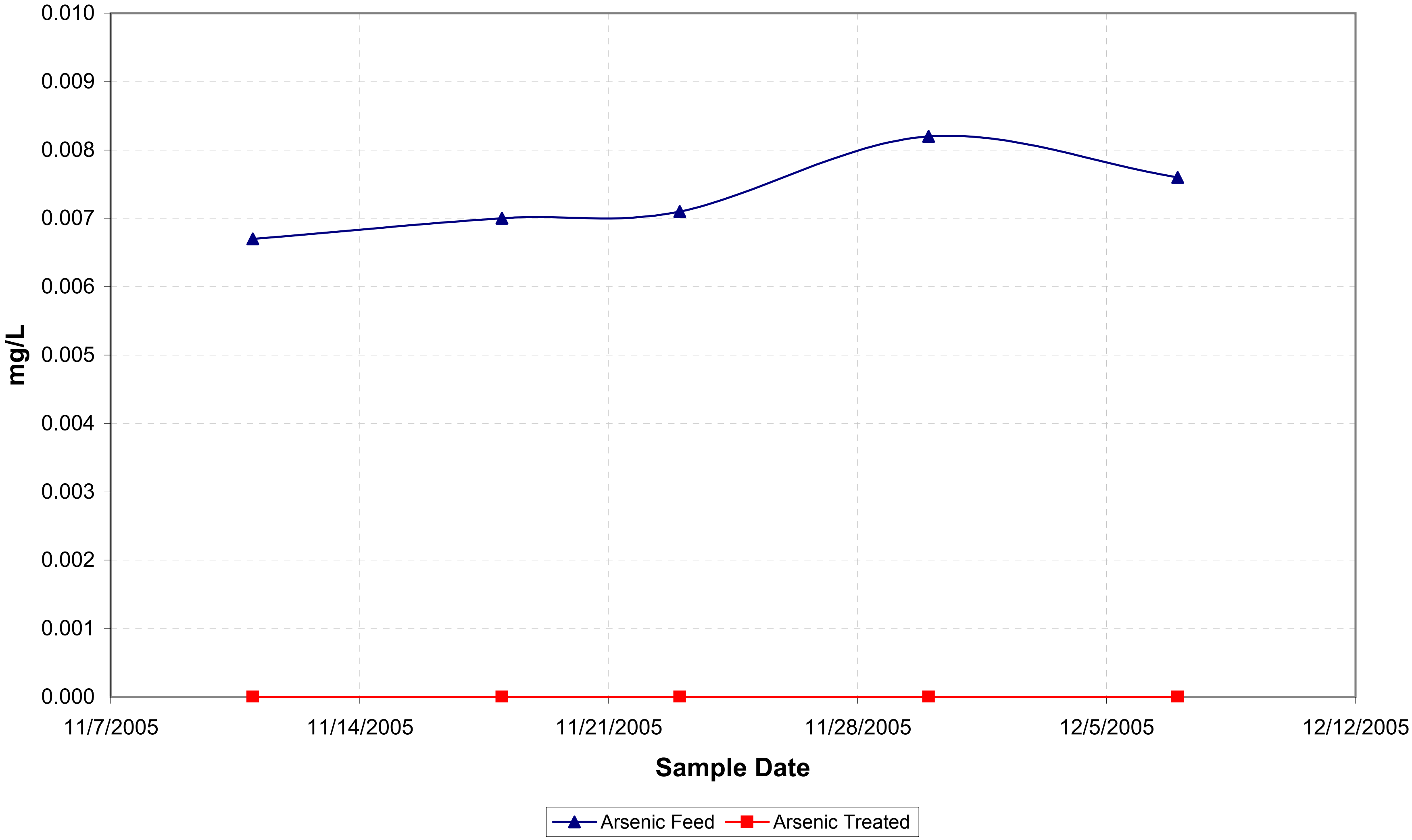


Figure E-9
Maynard Well RO Sulfate

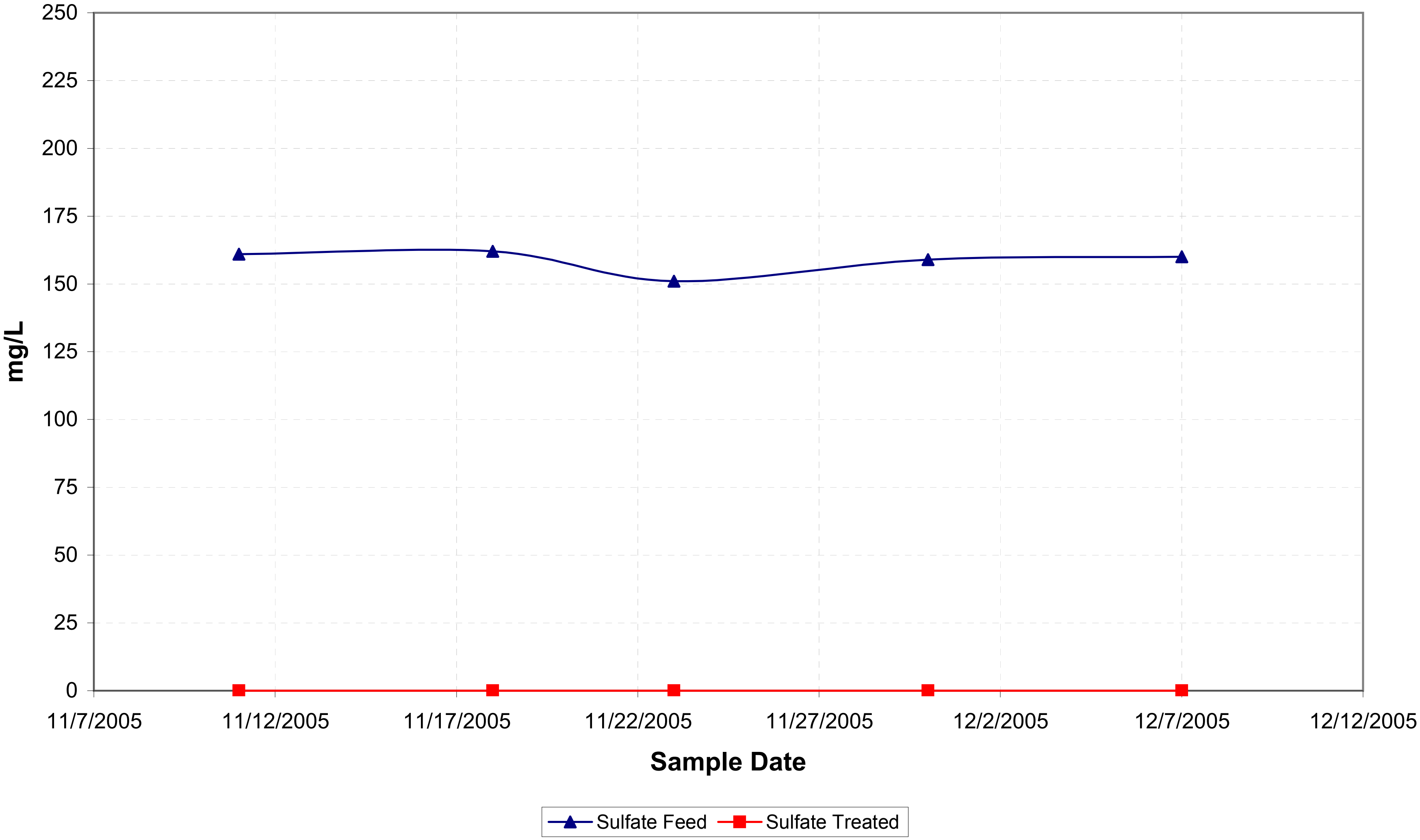


Figure E-10

Maynard Well RO Turbidity

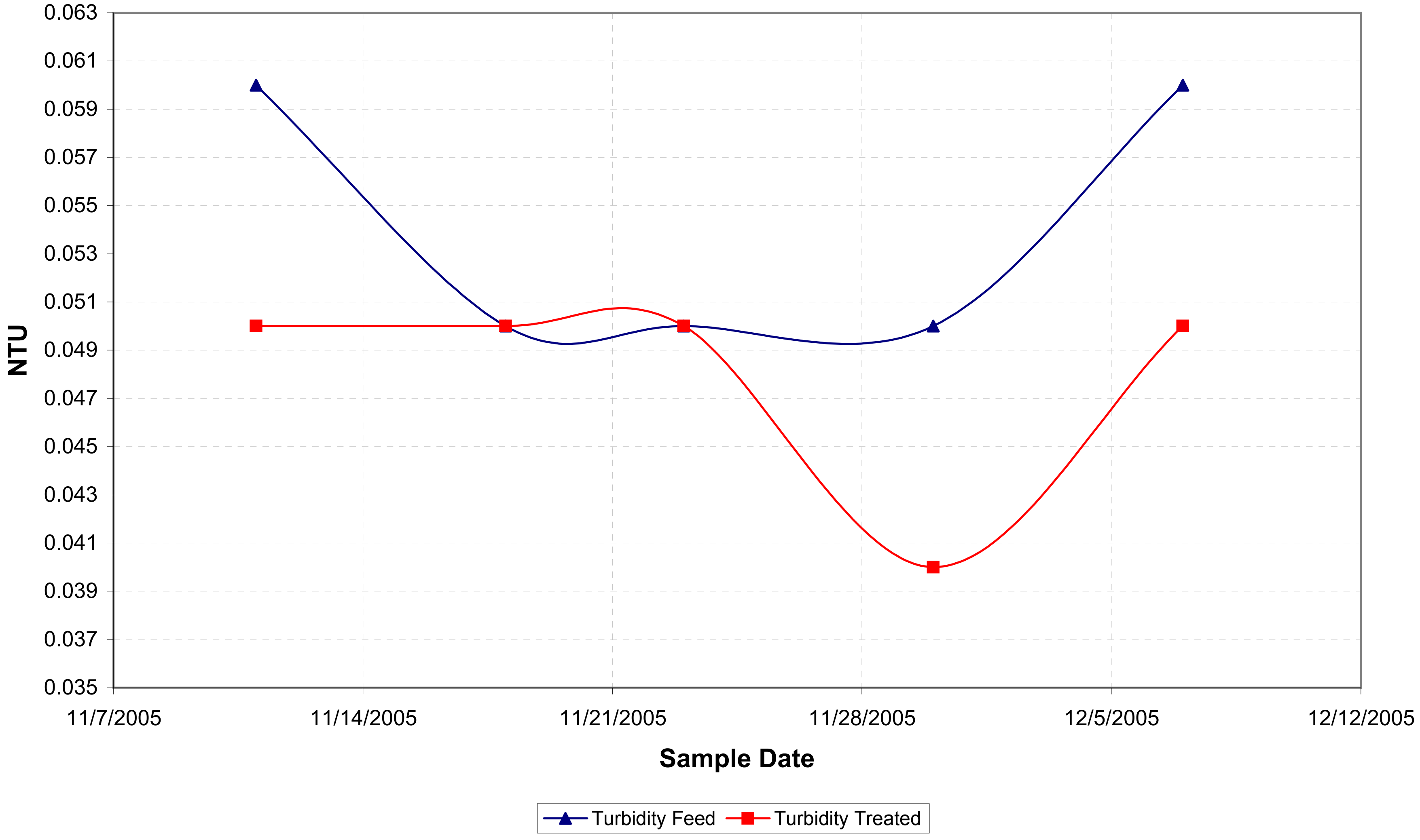


Figure E-11
Maynard Well EDR TDS

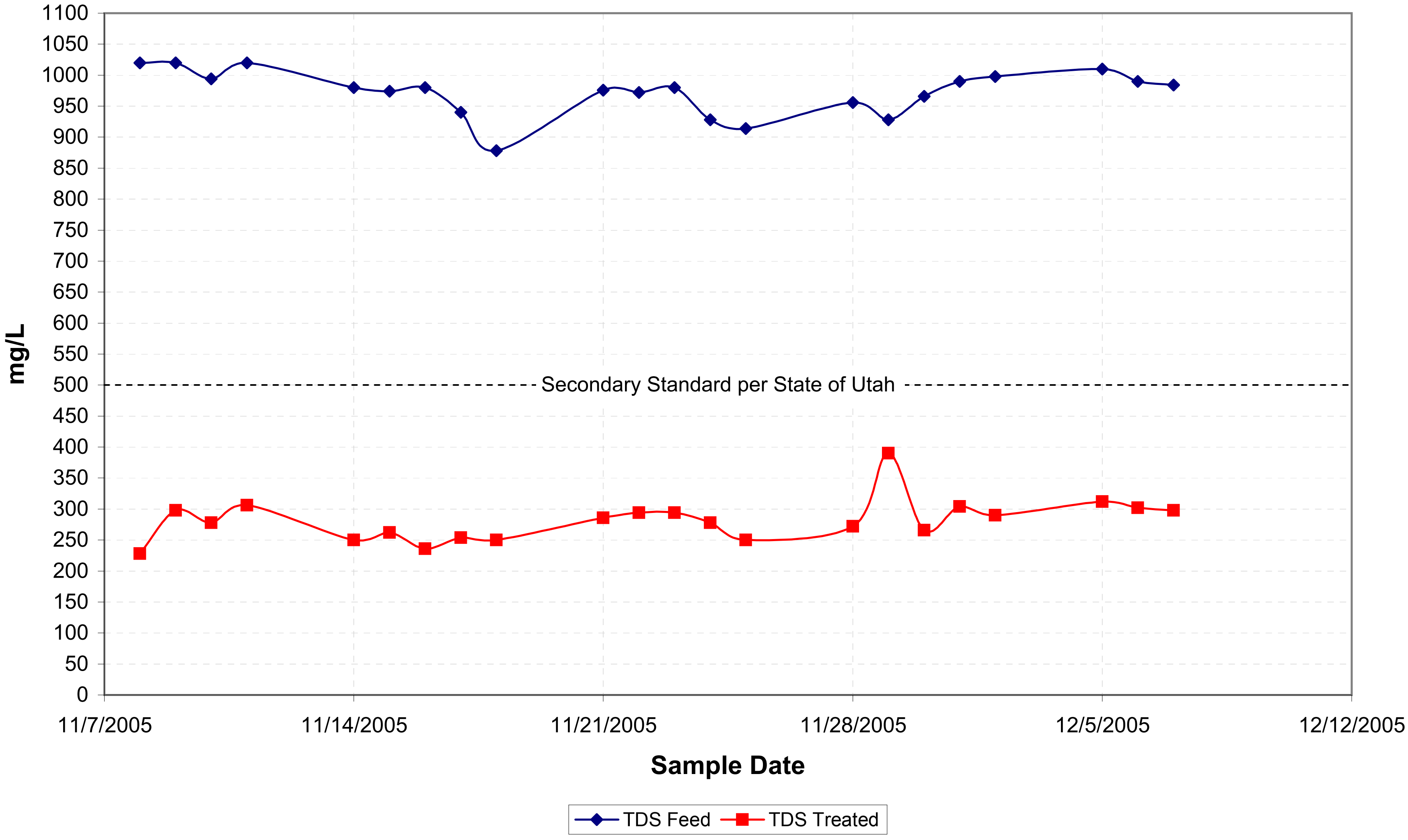


Figure E-12

Maynard Well EDR Hardness ($CaCO_3$), Calcium, Magnesium

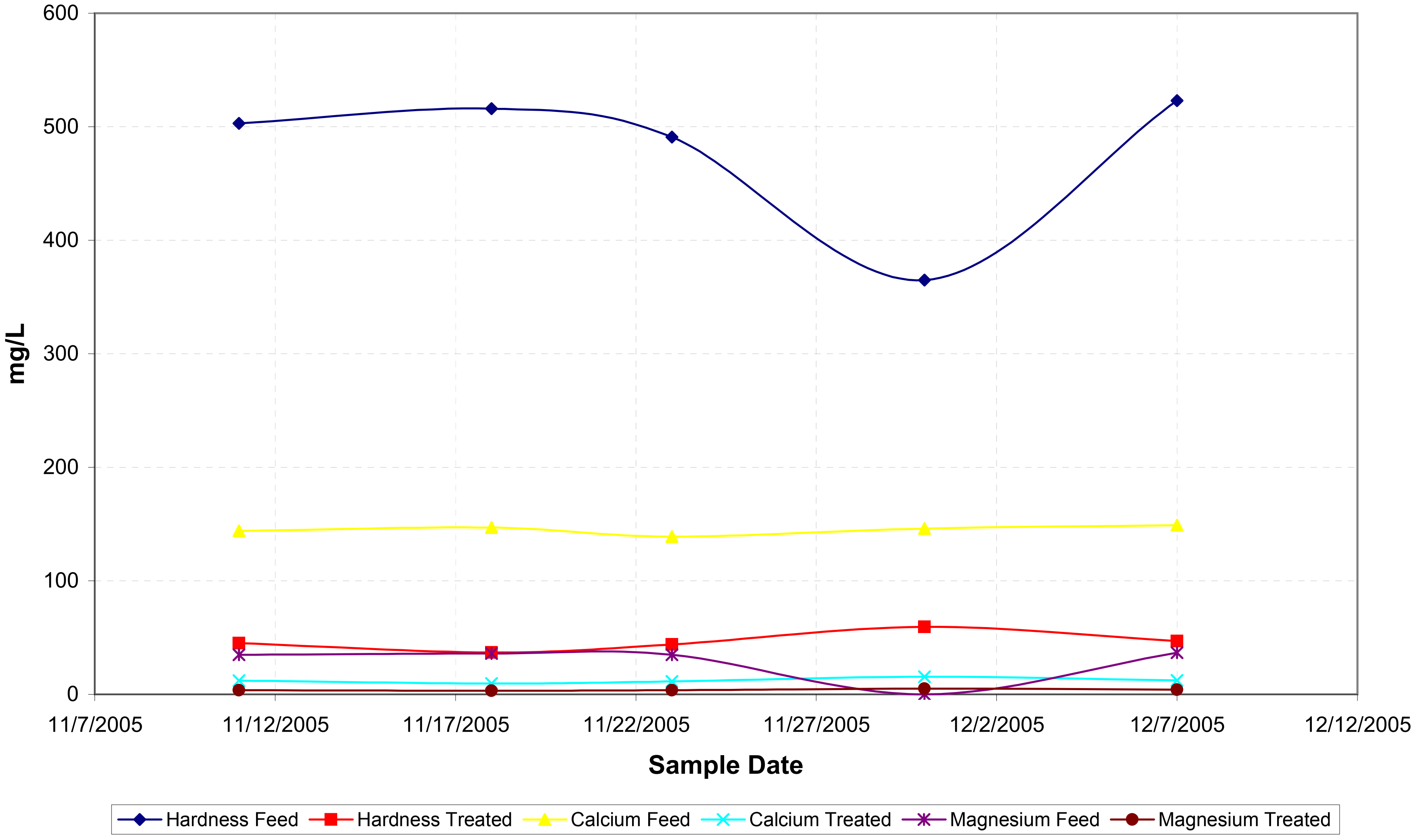


Figure E-13
Maynard Well EDR Alkalinity

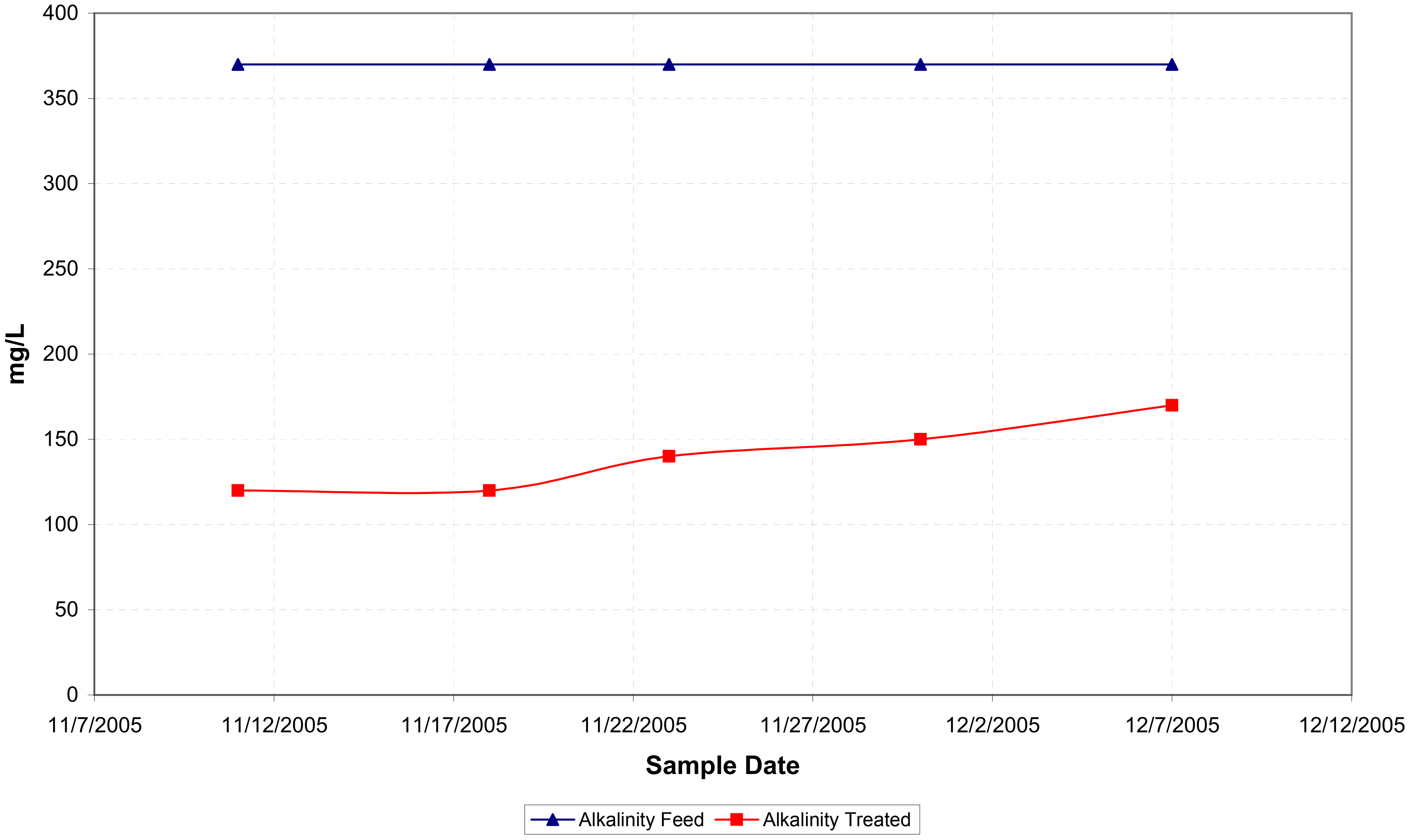


Figure E-14

Maynard Well EDR Silica Total, Silica Reactive

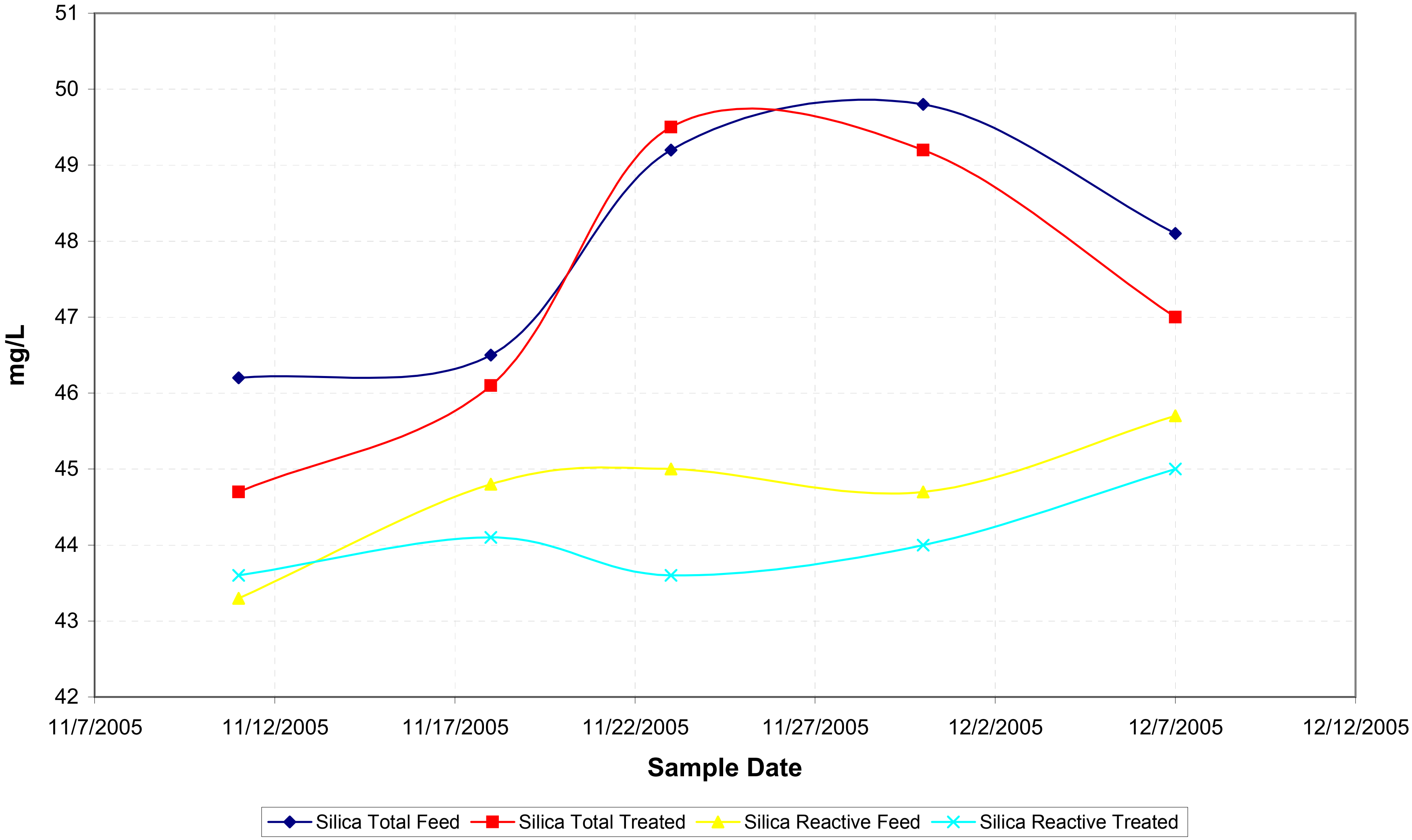


Figure E-15
Maynard Well EDR Arsenic

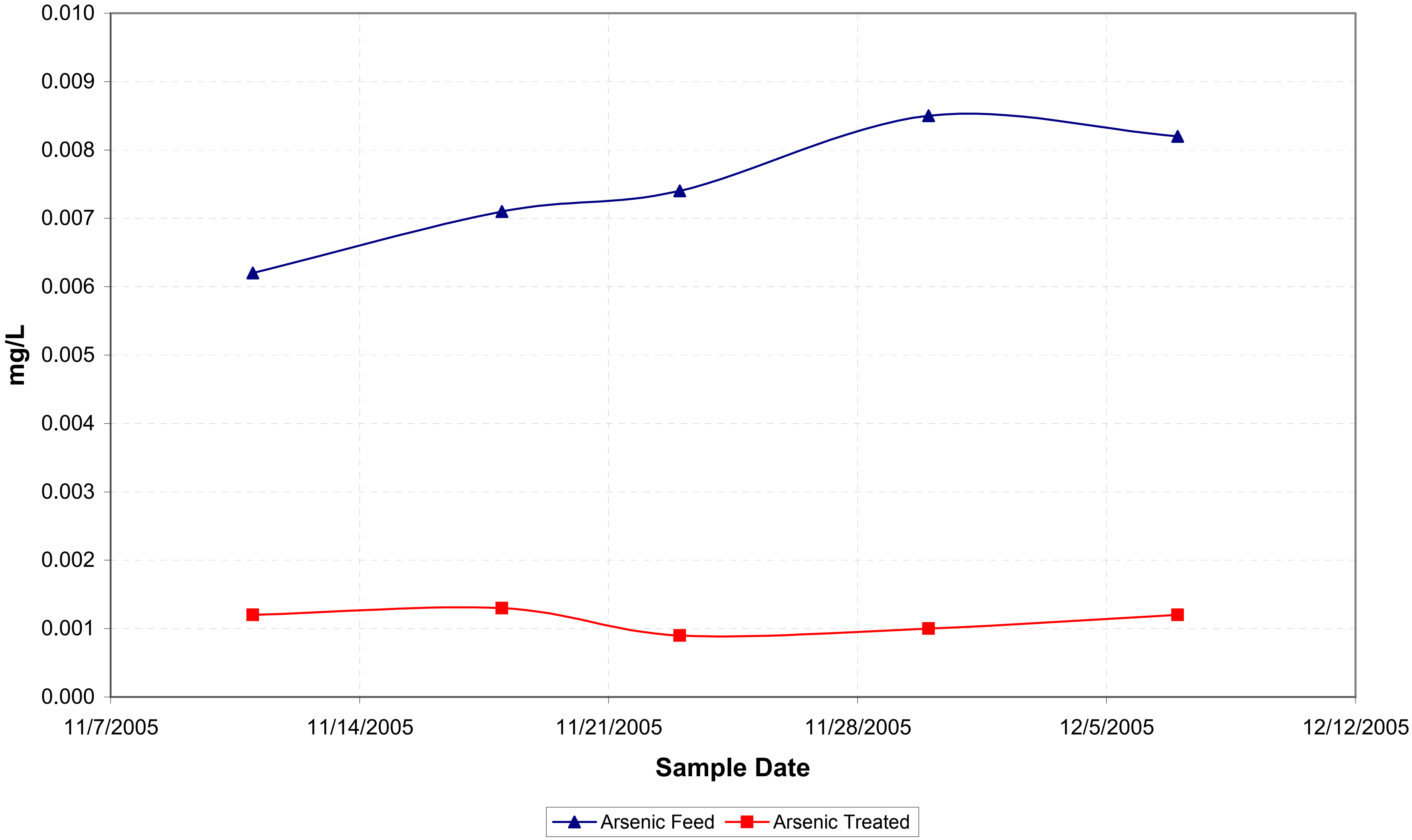


Figure E-16

Maynard Well EDR Sulfate

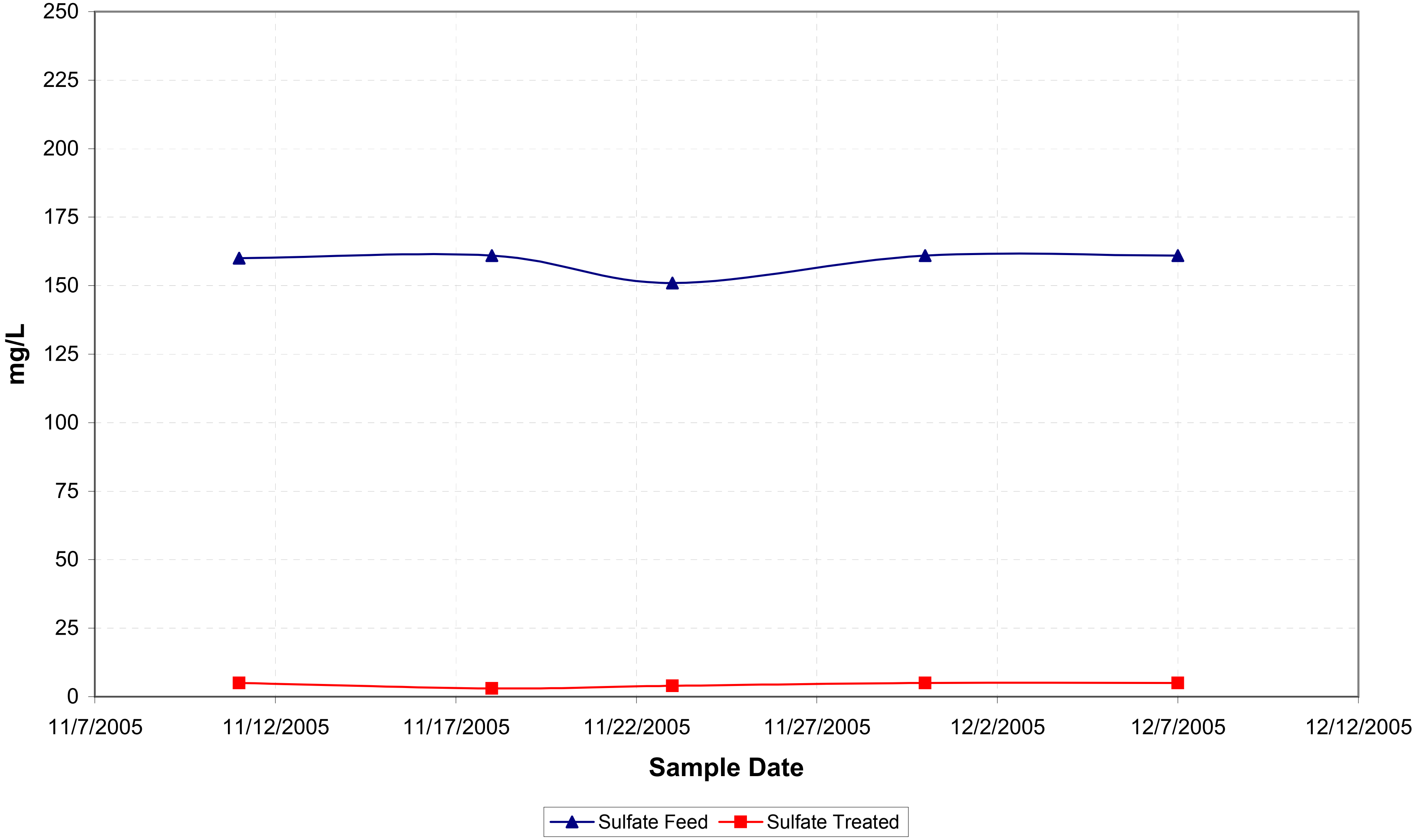
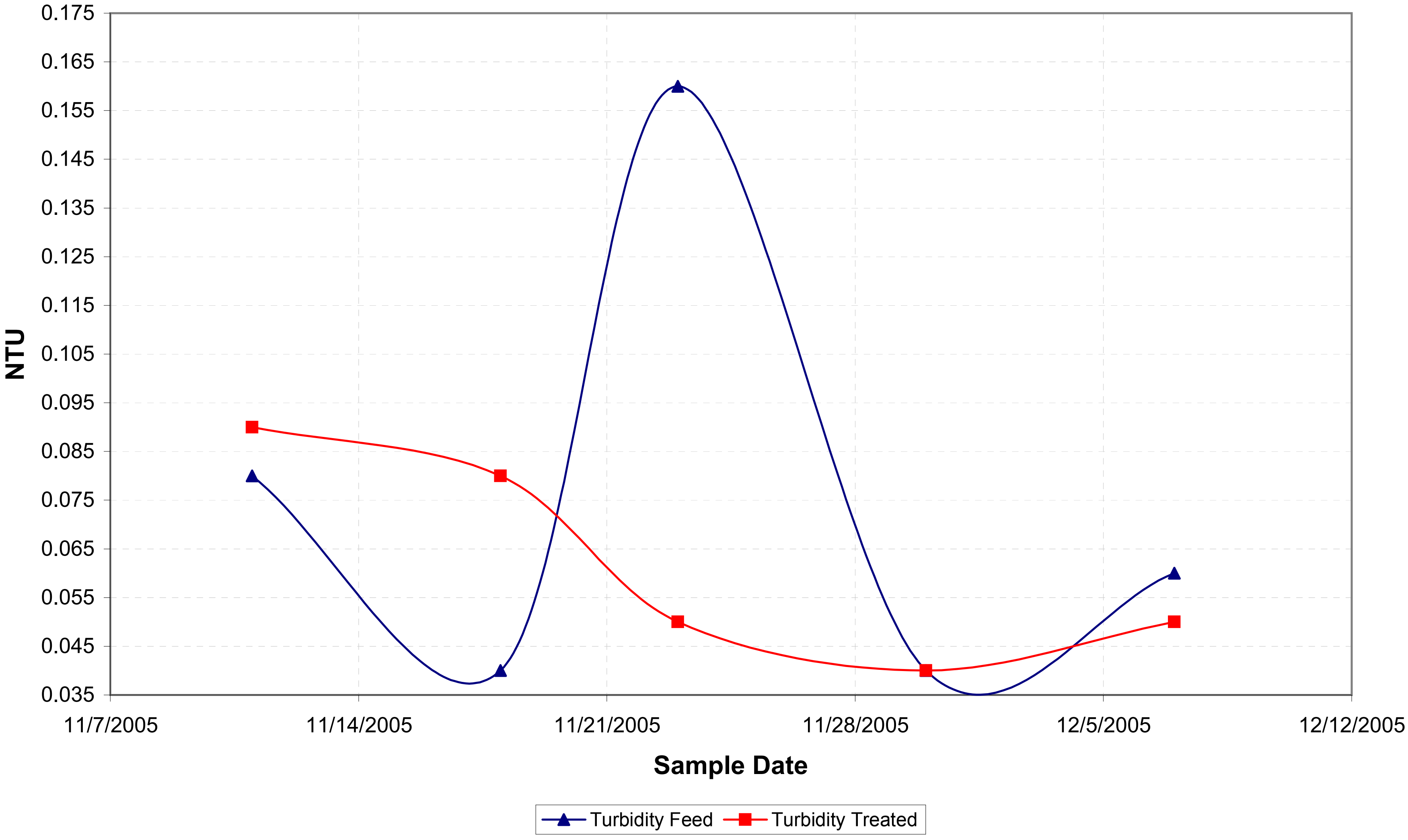


Figure E-17

Maynard Well EDR Turbidity



Appendix F

Cost Estimates

Epic Engineering, P.C.
Civil Municipal Project Management Water Resources

4000 West 3341 South
West Valley, Utah 84120

January 17, 2006

Scott Hill
Water Dept. Director
12830 South 1700 West
Riverton City, UT 84065

SUBJECT: BUDGET ESTIMATES FOR RO & EDR TREATMENT

Dear Mr. Hill,

The project cost estimates include estimated capital costs and operational & maintenance costs. They have been developed for each well site independently and for a combined central treatment facility. Capital costs have been calculated on an acre-ft basis and O&M costs have been calculated on a kgal basis and converted to acre-ft. A summary is shown on the last page of the calculations.

Since we have operated pilots for the two technologies on three of the wells (Gedge, Hill, Maynard), we have included actual operating data for: RO recovery, EDR recovery, RO power consumption, EDR power consumption, and blending ratios. The data from the three tested wells has been applied on an average basis to the calculations.

Budget estimates for treatment and process equipment are based upon equipment costs received from GE/Ionics and Harn RO. The cost estimates assume that each well site have adequate property to house the process equipment. For the central wtp, it was assumed it would be sited north of the Hill well site on the 10-acre parcel currently owned by the City. Transmission pipeline costs to deliver untreated well water to and from a central wtp are not included in these estimates. It is likely that the existing distribution system could be utilized/converted to provide a portion of this need.

Respectfully,
Epic Engineering, P.C.

Taigon Worthen, P.E.
Project Engineer

/att

N:\PROJ\Riverton-City\05-RV-013 EDR and RO Pilot Project\Correspondence with Riverton City\Epic letter 1_17_06 budget estimates.doc

Epic Engineering, P.C.
CIVIL MUNICIPAL PROJECT MANAGEMENT WATER RESOURCES

Date: 1/15/2006
Page: 1 of 9
By: T. WORTHEN
Subject: RIVERTON CITY
RO & EDR TREATMENT COSTS

WELL NAME	Q_W	$[TDS]_N$	$[TDS]_G$
HILL	2400 GPM	1248 PPM	500 PPM
GEDGE	2400 GPM	1113 PPM	500 PPM
MAYNARD	880 GPM	1289 PPM	500 PPM
HAMILTON	800 GPM	1060 PPM	500 PPM
GARAMANDI	480 GPM	950 PPM	500 PPM
STEFFENOFF	380 GPM	1150 PPM	500 PPM
CENTRAL WTP	*7340 GPM*	*1164 PPM*	*500 PPM*

WHERE:
$Q_{SIDESTREAM}$ = PERMEATE FLOW
Q_W = WELL FLOW
$[TDS]_N$ = NORMAL WELL TDS
$[TDS]_P$ = PERMEATE TDS
$[TDS]_G$ = BLENDED WATER TDS GOAL

SYSTEM	$[TDS]_P$	RECOVERY %
RO	20 PPM	76%
EDR	359 PPM	73%

RO BLENDING RATIO CALCULATIONS ($Q_{SIDESTREAM}:Q_W$)

WELL NAME	$[TDS]_P$ X REC%	Q_W X $[TDS]_N$ + $[TDS]_G$ X Q_W	$Q_{SIDESTREAM}$	RATIO
HILL	-1112.8	-1795200	1613 GPM	67%
GEDGE	-977.8	-1471200	1505 GPM	63%
MAYNARD	-1153.8	-694320	602 GPM	68%
HAMILTON	-924.8	-448000	484 GPM	61%
GARAMANDI	-814.8	-216000	265 GPM	55%
STEFFENOFF	-1014.8	-247000	243 GPM	64%
CENTRAL WTP	*-1028.5221*	*-4871720*	*4736.62174*	*65%*

EDR BLENDING RATIO CALCULATIONS ($Q_{SIDESTREAM}:Q_W$)

WELL NAME	$[TDS]_P$ X REC%	Q_W X $[TDS]_N$ + $[TDS]_G$ X Q_W	$Q_{SIDESTREAM}$	RATIO
HILL	-850.93	-1795200	2110 GPM	88%
GEDGE	-715.93	-1471200	2055 GPM	86%
MAYNARD	-891.93	-694320	778 GPM	88%
HAMILTON	-662.93	-448000	676 GPM	84%
GARAMANDI	-552.93	-216000	391 GPM	81%
STEFFENOFF	-752.93	-247000	328 GPM	86%
CENTRAL WTP	*-766.65207*	*-4871720*	*6354.53837*	*87%*

Epic Engineering, P.C.
CIVIL MUNICIPAL PROJECT MANAGEMENT WATER RESOURCES

Date: 1/15/2006
Page: 2 of 9
By: T. WORTHEN
Subject: RIVERTON CITY
RO & EDR TREATMENT COSTS

HILL WELL

CAPITAL COSTS	RO SYSTEM		EDR SYSTEM	
MEMBRANES & PROCESS EQUIP	1,150,000		1,900,000	
INSTALLATION COSTS	230,000	(20%)	437,000	(23%)
ANTISCALANT FEED SYSTEM	100,000			
DECARBONATION SYSTEM	100,000			
ACID FEED SYSTEM			100,000	
BUILDING	656,250	(3750 SF)	1,233,750	(7050 SF)
ENGINEERING & CM @15%	335,438		550,613	
LEGAL & ADMINISTRATION @2%	44,725		73,415	
TOTAL	2,616,413		4,294,778	
COST PER GALLON CAPACITY	$ 0.90		$ 1.63	
COST PER ACRE-FT PRODUCED*	$ 44.46		$ 75.98	

*BASED ON 20 YEAR LIFE

O & M COSTS (PER 1000 GAL)	RO SYSTEM		EDR SYSTEM	
ELECTRICITY @ 6.5 CENTS / KW-H	$ 0.27		$ 0.46	
CHEMICALS	$ 0.04		$ 0.05	
PREFILTER CARTRIDGES	$ 0.04		$ 0.03	
MEMBRANES	$ 0.08	(5-YEAR LIFE)	$ 0.07	(15-YEAR LIFE)
OTHER EQUIPMENT	$ 0.06		$ 0.04	
TOTAL	$ 0.49		$ 0.65	
LABOR @ $35 PER HOUR	$ 54,600	(0.75 FTE)	$ 54,600	(0.75 FTE)
COST PER ACRE-FT	$ 178		$ 231	

GEDGE WELL

CAPITAL COSTS	RO SYSTEM		EDR SYSTEM	
MEMBRANES & PROCESS EQUIP	1,150,000		1,900,000	
INSTALLATION COSTS	230,000	(20%)	437,000	(23%)
ANTISCALANT FEED SYSTEM	100,000			
DECARBONATION SYSTEM	100,000			
ACID FEED SYSTEM			100,000	
BUILDING	656,250	(3750 SF)	1,233,750	(7050 SF)
ENGINEERING & CM @15%	335,438		550,613	
LEGAL & ADMINISTRATION @2%	44,725		73,415	
TOTAL	2,616,413		4,294,778	
COST PER GALLON CAPACITY	$ 0.89		$ 1.62	
COST PER ACRE-FT PRODUCED*	$ 44.46		$ 75.98	

*BASED ON 20 YEAR LIFE

O & M COSTS (PER 1000 GAL)	RO SYSTEM		EDR SYSTEM	
ELECTRICITY @ 6.5 CENTS / KW-H	$ 0.27		$ 0.46	
CHEMICALS	$ 0.04		$ 0.05	
PREFILTER CARTRIDGES	$ 0.04		$ 0.03	
MEMBRANES	$ 0.08	(5-YEAR LIFE)	$ 0.07	(15-YEAR LIFE)
OTHER EQUIPMENT	$ 0.06		$ 0.04	
TOTAL	$ 0.49		$ 0.65	
LABOR @ $35 PER HOUR	$ 54,600	(0.75 FTE)	$ 54,600	(0.75 FTE)
COST PER ACRE-FT	$ 178		$ 231	

Date: 1/15/2006
Page: 4 of 9
By: T. WORTHEN
Subject: RIVERTON CITY
RO & EDR TREATMENT COSTS

MAYNARD WELL

CAPITAL COSTS		RO SYSTEM			EDR SYSTEM	
MEMBRANES & PROCESS EQUIP		421,667			696,667	
INSTALLATION COSTS		84,333	(20%)		160,233	(23%)
ANTISCALANT FEED SYSTEM		36,667				
DECARBONATION SYSTEM		36,667				
ACID FEED SYSTEM					36,667	
BUILDING		240,625			452,375	
ENGINEERING & CM @15%		122,994			201,891	
LEGAL & ADMINISTRATION @2%		16,399			26,919	
TOTAL		959,351			1,574,752	
COST PER GALLON CAPACITY	$	0.91		$	1.63	
COST PER ACRE-FT PRODUCED*	$	44.46		$	75.98	
*BASED ON 20 YEAR LIFE						

O & M COSTS (PER 1000 GAL)		RO SYSTEM			EDR SYSTEM	
ELECTRICITY @ 6.5 CENTS / KW-H	$	0.27		$	0.46	
CHEMICALS	$	0.04		$	0.05	
PREFILTER CARTRIDGES	$	0.04		$	0.03	
MEMBRANES	$	0.08	(5-YEAR LIFE)	$	0.07	(15-YEAR LIFE)
OTHER EQUIPMENT	$	0.06		$	0.04	
TOTAL	$	0.49		$	0.65	
LABOR @ $35 PER HOUR	$	54,600	(0.75 FTE)	$	54,600	(0.75 FTE)
COST PER ACRE-FT	$	210		$	264	

HAMILTON WELL

CAPITAL COSTS	RO SYSTEM		EDR SYSTEM	
MEMBRANES & PROCESS EQUIP	383,333		633,333	
INSTALLATION COSTS	76,667	(20%)	145,667	(23%)
ANTISCALANT FEED SYSTEM	33,333			
DECARBONATION SYSTEM	33,333			
ACID FEED SYSTEM			33,333	
BUILDING	218,750		411,250	
ENGINEERING & CM @15%	111,813		183,538	
LEGAL & ADMINISTRATION @2%	14,908		24,472	
TOTAL	872,138		1,431,593	
COST PER GALLON CAPACITY	$ 0.89		$ 1.61	
COST PER ACRE-FT PRODUCED*	$ 44.46		$ 75.98	

*BASED ON 20 YEAR LIFE

O & M COSTS (PER 1000 GAL)	RO SYSTEM		EDR SYSTEM	
ELECTRICITY @ 6.5 CENTS / KW-H	$ 0.27		$ 0.46	
CHEMICALS	$ 0.04		$ 0.05	
PREFILTER CARTRIDGES	$ 0.04		$ 0.03	
MEMBRANES	$ 0.08	(5-YEAR LIFE)	$ 0.07	(15-YEAR LIFE)
OTHER EQUIPMENT	$ 0.06		$ 0.04	
TOTAL	$ 0.49		$ 0.65	
LABOR @ $35 PER HOUR	$ 54,600	(0.75 FTE)	$ 54,600	(0.75 FTE)
COST PER ACRE-FT	$ 215		$ 270	

GARAMANDI WELL

CAPITAL COSTS		RO SYSTEM			EDR SYSTEM	
MEMBRANES & PROCESS EQUIP		230,000			380,000	
INSTALLATION COSTS		46,000	(20%)		87,400	(23%)
ANTISCALANT FEED SYSTEM		20,000				
DECARBONATION SYSTEM		20,000				
ACID FEED SYSTEM					20,000	
BUILDING		131,250			246,750	
ENGINEERING & CM @15%		67,088			110,123	
LEGAL & ADMINISTRATION @2%		8,945			14,683	
TOTAL		523,283			858,956	
COST PER GALLON CAPACITY	$	0.87		$	1.59	
COST PER ACRE-FT PRODUCED*	$	44.46		$	75.98	
*BASED ON 20 YEAR LIFE						

O & M COSTS (PER 1000 GAL)		RO SYSTEM			EDR SYSTEM	
ELECTRICITY @ 6.5 CENTS / KW-H	$	0.27		$	0.46	
CHEMICALS	$	0.04		$	0.05	
PREFILTER CARTRIDGES	$	0.04		$	0.03	
MEMBRANES	$	0.08	(5-YEAR LIFE)	$	0.07	(15-YEAR LIFE)
OTHER EQUIPMENT	$	0.06		$	0.04	
TOTAL	$	0.49		$	0.65	
LABOR @ $35 PER HOUR	$	54,600	(0.75 FTE)	$	54,600	(0.75 FTE)
COST PER ACRE-FT	$	252		$	308	

STEFFENOFF WELL

CAPITAL COSTS	RO SYSTEM		EDR SYSTEM	
MEMBRANES & PROCESS EQUIP	182,083		300,833	
INSTALLATION COSTS	36,417	(20%)	69,192	(23%)
ANTISCALANT FEED SYSTEM	15,833			
DECARBONATION SYSTEM	15,833			
ACID FEED SYSTEM			15,833	
BUILDING	103,906		195,344	
ENGINEERING & CM @15%	53,111		87,180	
LEGAL & ADMINISTRATION @2%	7,081		11,624	
TOTAL	414,265		680,006	
COST PER GALLON CAPACITY	$ 0.89		$ 1.62	
COST PER ACRE-FT PRODUCED*	$ 44.46		$ 75.98	

*BASED ON 20 YEAR LIFE

O & M COSTS (PER 1000 GAL)	RO SYSTEM		EDR SYSTEM	
ELECTRICITY @ 6.5 CENTS / KW-H	$ 0.27		$ 0.46	
CHEMICALS	$ 0.04		$ 0.05	
PREFILTER CARTRIDGES	$ 0.04		$ 0.03	
MEMBRANES	$ 0.08	(5-YEAR LIFE)	$ 0.07	(15-YEAR LIFE)
OTHER EQUIPMENT	$ 0.06		$ 0.04	
TOTAL	$ 0.49		$ 0.65	
LABOR @ $35 PER HOUR	$ 54,600	(0.75 FTE)	$ 54,600	(0.75 FTE)
COST PER ACRE-FT	$ 277		$ 334	

CENTRAL WTP

CAPITAL COSTS	RO SYSTEM		EDR SYSTEM	
MEMBRANES & PROCESS EQUIP	3,517,083		5,810,833	
INSTALLATION COSTS	703,417	(20%)	1,336,492	(23%)
ANTISCALANT FEED SYSTEM	305,833			
DECARBONATION SYSTEM	305,833			
ACID FEED SYSTEM			305,833	
BUILDING	1,925,000	(11000 SF)	3,500,000	(20000 SF)
ENGINEERING & CM @15%	1,013,575		1,642,974	
LEGAL & ADMINISTRATION @2%	135,143		219,063	
TOTAL	7,905,885		12,815,195	
COST PER GALLON CAPACITY	$ 0.89		$ 1.58	
COST PER ACRE-FT PRODUCED*	$ 44		$ 74	

*BASED ON 20 YEAR LIFE

O & M COSTS (PER 1000 GAL)	RO SYSTEM		EDR SYSTEM	
ELECTRICITY @ 6.5 CENTS / KW-H	$ 0.27		$ 0.46	
CHEMICALS	$ 0.04		$ 0.05	
PREFILTER CARTRIDGES	$ 0.04		$ 0.03	
MEMBRANES	$ 0.08	(5-YEAR LIFE)	$ 0.07	(15-YEAR LIFE)
OTHER EQUIPMENT	$ 0.06		$ 0.04	
TOTAL	$ 0.49		$ 0.65	
LABOR @ $35 PER HOUR	$ 109,200	(1.5 FTE)	$ 109,200	(1.5 FTE)
COST PER ACRE-FT	$ 172		$ 224	

Date: 1/15/2006
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By: T. WORTHEN
Subject: RIVERTON CITY
RO & EDR TREATMENT COSTS

SUMMARY

WELL NAME	RO $/ACRE-FT	EDR $/ACRE-FT
HILL	$223	$307
GEDGE	$223	$307
MAYNARD	$255	$340
HAMILTON	$260	$346
GARAMANDI	$297	$384
STEFFENOFF	$321	$410
CENTRAL WTP	*$216*	*$298*

Appendix G

Field Collected Data

Table G-1 Gedge Well - RO

Date	Prefilter Inlet PSI	Prefilter Outlet PSI	1st Stage Permeate Flow	2nd Stage Permeate Flow	3rd Stage Permeate Flow	4th Stage Permeate Flow	1st Stage PSI	2nd Stage PSI	3rd Stage PSI	4th Stage PSI	Feed PSI	Permeate Flow	Concentrate Flow
09/03/05	80	72	9.0	7.0	2.2	1.4	150	115	100	78	156.0	20.1	6.8
09/04/05	80	72	9.2	7.2	2.2	1.4	152	118	100	75	159.7	20.2	6.7
09/05/05	79	75	9.0	7.0	2.2	1.5	150	110	100	75	154.9	19.9	6.9
09/06/05	80	76	8.9	7.0	2.2	1.5	150	112	100	80	154.9	20.1	6.9
09/07/05	80	74	8.9	7.0	2.2	1.5	150	111	100	77	154.6	19.8	7.0
09/08/05	80	74	8.9	7.0	2.2	1.5	150	105	100	75	154.7	19.9	7.0
09/09/05	80	75	8.9	7.0	2.1	1.5	150	107	100	75	155.1	19.7	7.0
09/12/05	80	74	8.9	7.0	2.2	1.5	150	119	100	80	155.9	19.8	6.9
09/13/05	80	74	8.9	7.0	2.2	1.5	150	112	100	80	154.8	20.1	7.0
09/14/05	80	72	9.0	7.0	2.3	1.4	150	113	100	79	154.6	20.0	7.0
09/15/05	80	71	8.9	7.0	2.2	1.2	149	111	100	80	153.8	19.9	7.0
09/16/05	80	70	8.9	7.0	2.2	1.5	150	110	100	80	154.9	20.1	7.1
09/19/05	80	69	8.9	7.0	2.2	1.4	150	113	100	75	153.8	19.7	7.1
09/20/05	80	69	8.8	7.0	2.2	1.5	149	110	100	80	153.7	19.9	7.0
09/21/05	82	72	8.8	7.0	2.2	1.5	150	110	100	75	154.7	20.2	7.1
09/22/05	82	67	8.8	7.0	2.3	1.5	148	115	100	78	154.3	19.7	7.1
9/23/2005	77	66	9.4	7.5	2.4	1.6	160	125	109	85	167.1	21.6	7.3
9/26/2005	75	65	9.2	7.5	2.5	1.5	155	120	105	75	166.0	21.4	7.3
9/27/2005	75	65	9.2	7.5	2.5	1.5	156	130	110	79	166.0	21.3	7.3
9/27/2005	79	65	9.2	7.3	2.5	1.5	160	130	110	78	166.4	21.2	7.3
9/29/2005	79	64	9.3	7.5	2.4	1.6	160	125	109	85	166.3	21.1	7.3
9/30/2005	80	65	9.8	7.4	1.9	1.0	158	140	107	90	170.5	20.5	7.7
10/3/2005	78	64	9.5	7.6	2.1	1.6	160	130	110	74	163.9	20.7	7.3
10/4/2005	78	68	9.1	7.2	2.2	1.5	161	130	110	80	168.5	20.8	7.5
10/5/2005	80	65	9.1	7.2	2.3	1.6	160	130	110	90	169.1	20.6	7.5
10/6/2005	79	65	9.1	7.1	2.5	1.5	160	130	111	90	169.2	20.9	7.6
10/7/2005	78	65	9.0	7.1	2.3	1.5	160	130	110	90	168.8	20.8	7.6
10/10/2005	78	60	9.2	7.1	2.15	1.5	160	129	110	79	165.7	21.0	7.4
10/11/2005	79	65	9.0	7.1	2.1	1.5	161	130	111	90	169.8	20.6	7.4
10/12/2005	80	65	9.0	7.1	2.4	1.3	160	130	111	95	169.5	20.4	6.0

Table G-2 Hill Well - RO

Date	Prefilter Inlet PSI	Prefilter Outlet PSI	1st Stage Permeate Flow	2nd Stage Permeate Flow	3rd Stage Permeate Flow	4th Stage Permeate Flow	1st Stage PSI	2nd Stage PSI	3rd Stage PSI	4th Stage PSI	Feed PSI	Permeate Flow	Concentrate Flow
10/14/05	70	54	9.0	7.1	2.4	1.2	170	130	115	89	175.8	20.3	7.4
10/17/05	70	59	8.8	7.1	2.4	1.5	170	130	125	90	175.4	20.4	7.7
10/18/05	76	53	9.0	7.4	2.2	1.4	170	130	125	90	174.7	20.5	7.8
10/19/05	77	59	8.6	7.1	2.4	1.5	170	140	120	92	181.1	20.0	8.0
10/20/05	76	55	8.9	7.1	2.5	1.6	165	130	110	88	171.7	21.0	7.8
10/21/05	75	58	8.9	7.0	2.2	1.4	170	135	120	80	179.3	20.3	8.1
10/24/05	70	57	9.0	7.2	2.4	1.4	156	131	110	88	171.2	20.8	7.8
10/25/05	75	62	9.0	7.1	2.2	1.4	170	135	120	90	179.1	21.0	8.1
10/26/05	75	62	9.0	7.2	2.5	1.2	172	133	120	90	179.7	20.8	8.0
10/27/05	72	62	9.0	7.4	2.4	1.4	171	135	120	90	179.7	20.4	8.0
10/27/05	70	60	9.0	7.1	2.2	1.4	170	130	120	90	178.2	20.5	8.0
10/31/05	70	59	9.0	7.4	2.5	1.5	170	130	110	88	173.0	21.2	7.9
11/01/05	70	58	9.1	7.4	2.3	1.5	170	130	115	80	175.4	21.0	8.0
11/02/05	70	58	9.1	7.4	2.3	1.4	169	130	111	89	173.8	21.1	8.0
11/03/05	74	60	9.1	7.4	2.4	1.4	170	130	112	90	175.5	21.3	8.0
11/04/05	70	58	9.1	7.4	2.4	1.4	167	130	121	80	173.0	20.9	7.9
11/7/2005	70	58	9.4	7.4	2.2	1.1	165	130	110	88	171.9	20.8	7.9

Table G-3 Maynard Well - RO

Date	Prefilter Inlet PSI	Prefilter Outlet PSI	1st Stage Permeate Flow	2nd Stage Permeate Flow	3rd Stage Permeate Flow	4th Stage Permeate Flow	1st Stage PSI	2nd Stage PSI	3rd Stage PSI	4th Stage PSI	Feed PSI	Permeate Flow	Concentrate Flow
11/08/05	70	58	9.4	7.4	2.4	1.4	166	129	110	85	170.2	21.3	7.9
11/09/05	70	58	9.4	7.6	2.4	1.2	165	128	110	75	169.9	21.1	7.8
11/10/05	70	57	9.6	7.6	2.4	1.2	162	125	110	85	169.6	21.0	7.8
11/11/05	70	56	9.2	7.4	2.2	1.2	161	125	110	80	169.4	21.0	7.7
11/14/05	70	56	9.4	7.6	2.4	1.2	169	129	120	85	171.0	21.1	7.8
11/15/05	70	58	9.4	7.6	2.4	1.2	169	129	110	80	171.8	21.1	7.9
11/16/05	70	58	9.4	7.6	2.4	1.2	165	135	110	85	171.2	21.2	7.9
11/17/05													
11/18/05	70	54	9.5	7.6	2.4	1.2	165	125	108	84	171.2	21.2	7.8
11/21/05	70	56	9.2	7.4	2.4	1.2	170	130	110	85	174.8	20.7	7.9
11/22/05	71	55	9.1	7.4	2.2	1.2	170	127	110	85	175.1	20.9	7.9
11/23/05	71	54	9.1	7.4	2.4	1.0	170	128	109	85	175.2	20.4	7.8
11/24/05	71	52	9.2	7.4	2.4	1.0	170	125	109	85	175.6	20.7	7.9
11/25/05	72	52	9.0	7.4	2.2	1.0	170	129	110	85	177.2	20.1	8.0
11/28/05	71	61	9.0	7.6	2.4	1.0	180	130	110	79	185.2	20.2	8.0
11/29/05	71	61	9.0	7.6	2.4	1.0	180	130	110	78	185.0	20.3	8.0
11/30/05	72	61	8.8	7.6	2.2	1.0	180	130	110	88	186.0	20.0	7.9
12/01/05	71	61	8.8	7.6	2.2	1.0	185	130	110	88	189.6	19.8	8.0
12/02/05	72	61	8.6	7.6	2.2	1.0	185	130	110	89	190.3	19.8	7.9
12/05/05	71	60	8.6	7.6	2.2	0.75	185	130	110	90	189.7	19.7	8.0
12/06/05	72	60	8.6	7.6	2.4	0.75	180	130	110	90	188.8	20.0	8.0
12/07/05	72	60	8.6	7.6	2.4	1.0	185	130	110	90	187.7	19.7	7.9

Table G-4 Gedge - EDR

Date	Electrode Polarity	Prefilter Inlet PSI	Prefilter Outlet PSI	Feed Temp (deg C)	Concentrate Make-Up GPM	Electrode Feed PSI	Stack Inlet PSI	Stack Outlet PSI	Electrode Flow Top and Bottom	Electrode Flow Center	Stage 1 Volts	Stage 1 Amps	Stage 2 Volts	Stage 2 Amps
09/02/05	-	69	67	15.5	0.6	24	37	7	1	🟩	55	4.3	51	2
09/03/05	+	67	65	15.2	0.6	38	46	4	🟩	0.9	56	4	52	3.3
09/04/05	-	64	62	15.5	0.6	15	48	7	0.8	🟩	55	3.6	52	2.2
09/05/05	+	71	70	16.2	0.6	24	15	2	🟩	0.23	55	1.2	52	3.2
09/06/05	+	64	65	15.7	0.6	34	🟧	🟧	1.5	🟩	55	1.8	52	2.5
09/07/05	-	65	66	17.5	0.6	38	39	8	1.4	0.6	55	1.9	51	3.1
09/08/05	+	68	67	23.2	0.6	38	39	21	1.3	0.6	55	1.9	51	3
09/09/05	+	73	72	15.9	0.6	35	🟧	🟧	1	0.22	55	1.1	52	3
09/12/05	-	65	64	15.2	0.6	35	37	11	0.6	1.4	55	1.7	51	2.6
09/26/05	+	74	69	15.6	0.6	33	34	5	1.3	1.1	56	4.5	53	1.9
09/27/05	-	70	68	15.6	0.6	33	34	7	1.3	1.1	55	4.3	51	2
09/28/05	-	68	66	16	1.4	35	35	5	0.23	1.3	55	4.3	52	1.4
09/29/05	+	68	66	15.4	1.5	37	35	4	1	0.23	56	4.3	53	2.2
09/30/05	+	70	69	17.4	1.4	35	33	5	1	0.21	56	4.4	53	2.2
10/03/05	-	75	73	14	1.2	41	40	8	1.4	0.23	56	4.8	53	1.3
10/04/05	+	73	70	13.4	1.2	43	43	4	0.21	0.8	55	3.7	53	2.8

🟧 Problems with orange valve and scaling
🟨 Reading was taken but recorded in wrong spot
🟩 Reading was not taken, assumed to be zero

Negative

Table G-5 Hill - EDR

Date	Electrode Polarity	Prefilter Inlet PSI	Prefilter Outlet PSI	Feed Temp (deg C)	Concentrate Make-Up GPM	Electrode Feed PSI	Stack Inlet PSI	Stack Outlet PSI	Electrode Flow Top and Bottom	Electrode Flow Center	Stage 1 Volts	Stage 1 Amps	Stage 2 Volts	Stage 2 Amps
10/17/05	+	76	74	16.1	1.4	39	41	1	0	0.8	58	4.4	55	2.1
10/18/05	-	76	78	16.2	1.4	41	40	2	0.22	1.0	58	5.1	54	3.4
10/19/05	-	78	75	14.9	1.4	41	41	7	1.4	0.4	55	5.3	53	2.2
10/20/05	+	71	70	15.2	1.4	31	33	2	0.22	1.2	58	3.4	55	2.2
10/21/05	+	71	70	14.2	1.4	30	41	2	0.22	1.3	56	4.7	53	3.1
10/24/05	+	74	71	14.8	1.3	41	44	2	0.6	1.5	56	4.8	52	1.7
10/25/05	-	74	71	14	1.4	41	41	8	0	0.6	55	5.1	52	2.1
10/26/05	-	72	70	14	1.2	43	44	8	0	0.6	56	5.4	52	2.1
10/28/05	+	73	71	13.7	1.25	36	36.5	7	0	0.8	48	4.2	48	3.3
10/31/05	+	73	71	9.8	1.1	32	35	8	0	0.8	50	2.9	50	2.9
11/01/05	+	72	70	14.4	1.3	37	36	5	0	0.8	49	4.2	50	3.5
11/02/05	-	72	71	16.8	1	39	40	7	0	0.9	49	4.3	52	3.6
11/03/05	-	72	70	14	1.2	41	42	7	1.1	0.2	47	4.5	48	2.1
11/04/05	+	71	70	14.2	1.5	41	40	7	0	0.8	49	3.9	50	3.4
11/07/05	-	74	72	16.6	1.4	37	38	6	1	0.0	48	4.5	49	2.0

Negative

Table G-6 Maynard - EDR

Date	Electrode Polarity	Prefilter Inlet PSI	Prefilter Outlet PSI	Feed Temp (deg C)	Concentrate Make-Up GPM	Electrode Feed PSI	Stack Inlet PSI	Stack Outlet PSI	Electrode Flow Top and Bottom	Electrode Flow Center	Stage 1 Volts	Stage 1 Amps	Stage 2 Volts	Stage 2 Amps
11/08/05	+	72	70	15.2	1.2	40	39	6	0.0	0.85	49	4.0	50	3.0
11/09/05	-	74	71	17.1	1.4	36	38	7	1.2	0	48	4.2	49	1.9
11/10/05	-	72	71	18.0	1.0	37	39	7	1.2	0	48	4.3	49	2.0
11/11/05	+	74	71	15.6	1.6	38	39	5	1.3	0	49	3.9	50	3.6
11/14/05	-	72	71	14.0	1.4	34	36	5	1.2	0	48	4.3	49	2.0
11/15/05	-	74	72	10.2	1.4	39	41	6	1.3	0	48	4.4	49	1.8
11/16/05	+	74	71	13.4	1.5	36	37	3	0.0	0.8	49	3.6	50	3.3
11/17/05	+	74	72	14.0	1.4	36	37	6	0.0	0.8	49	3.5	50	3.4
11/18/05	+	73	70	13.8	1.4	34	37	5	0.0	0.7	49	3.5	50	3.4
11/21/05	+	72	71	13.4	1.4	38	39	5	0.0	0.85	49	3.5	50	3.6
11/22/05	-	72	71	13.6	1.3	37	39	4	1.2	0	48	4.2	49	1.7
11/23/05	-	73	71	14.1	1.4	38	40	5	1.2	0	48	4.3	49	2.1
11/24/05	-	74	71	12.8	1.5	39	40	6	1.2	0	48	4.2	49	2.0
11/25/05	+	75	72	12.7	1.5	39	40	7	0.0	0.8	49	3.4	50	3.8
11/28/05	+	74	72	12.7	1.4	34	35	6	0.0	0.8	49	3.1	50	3.8
11/29/05	+	74	72	13.7	1.5	37	39	10	0.0	0.9	49	3.6	50	3.4
11/30/05	-	72	70	15.1	1.5	40	42	7	1.3	0	48	4.0	49	2.1
12/01/05	+	75	72	13.5	1.6	40	40	5	0.0	0.9	49	3.7	50	3.1
12/02/05	+	74	71	15.4	1.4	41	42	4	0.0	0.95	49	3.9	50	3.2
12/05/05	-	73	71	13.7	1.5	38	40	7	1.2	0	48	4.0	49	1.8
12/16/05	-	73	71	14.1	1.5	33	38	6	1.2	0	48	3.9	49	1.9
12/17/05	+	74	71	13.0	1.5	32	34	3	0.0	0.8	48	5.3	48	6.6

Negative

Figure G-1
RO Prefilter Pressure

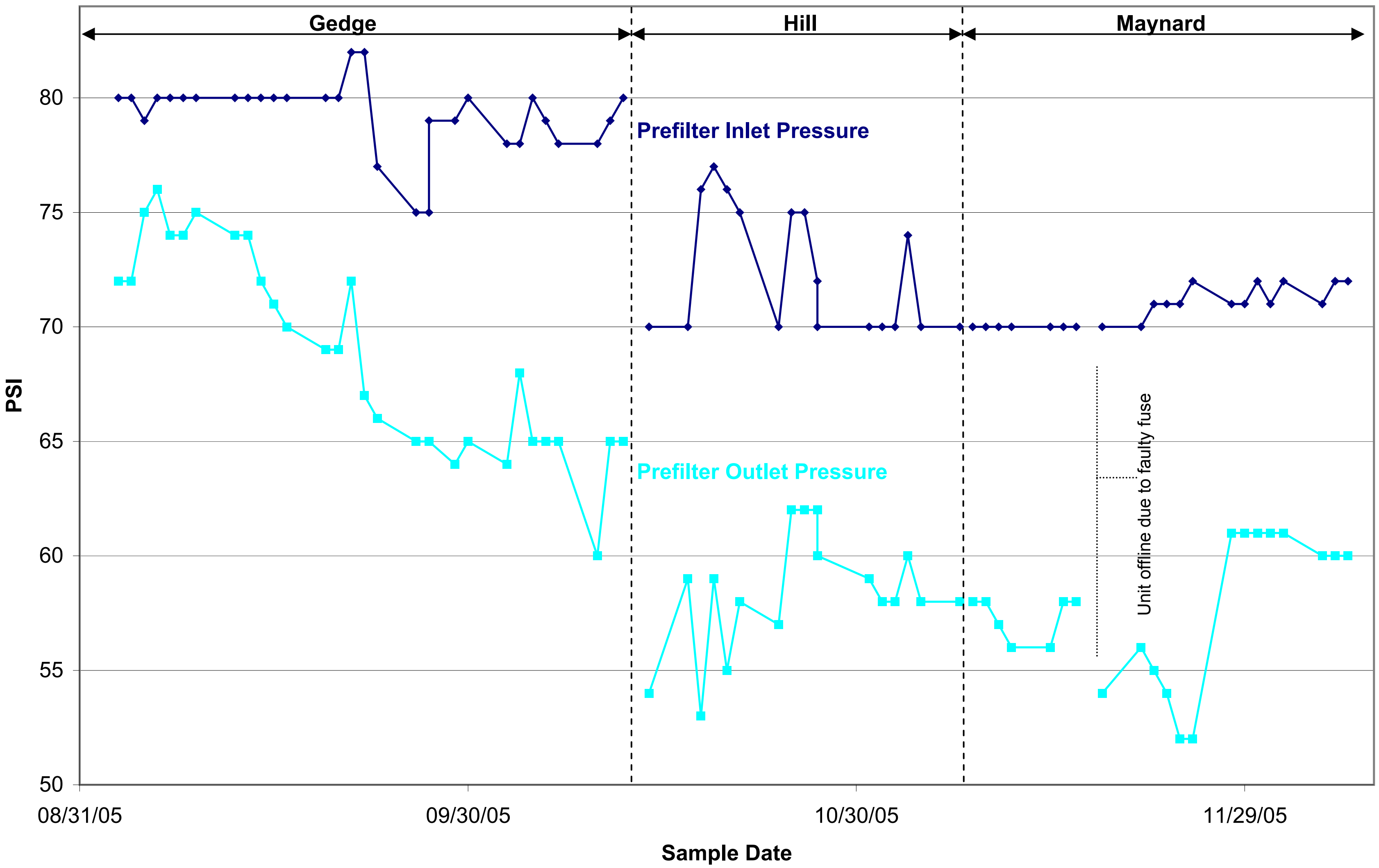


Figure G-2

RO Stage Permeate Flow

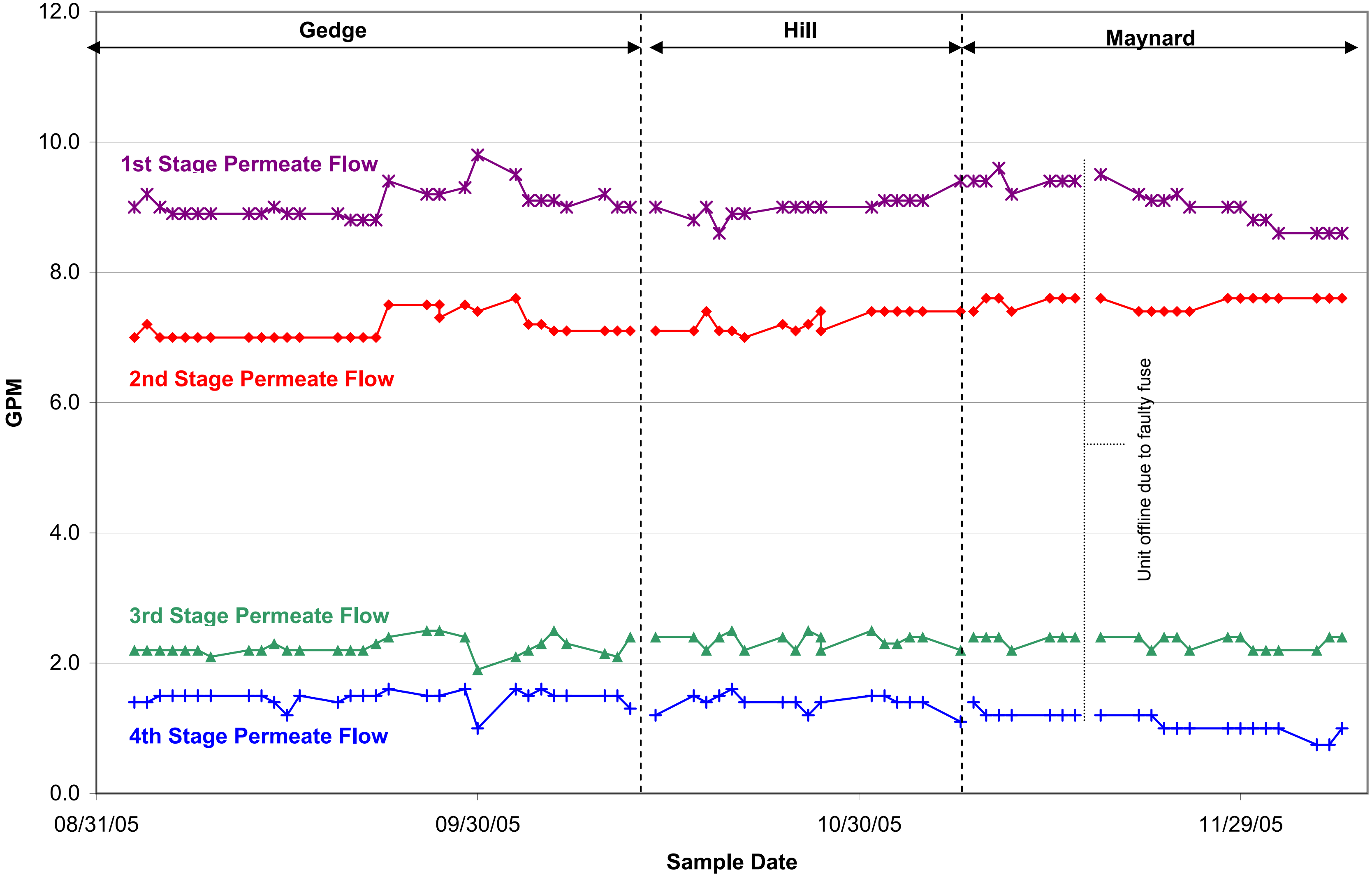


Figure G-3
RO Stage Feed Pressure

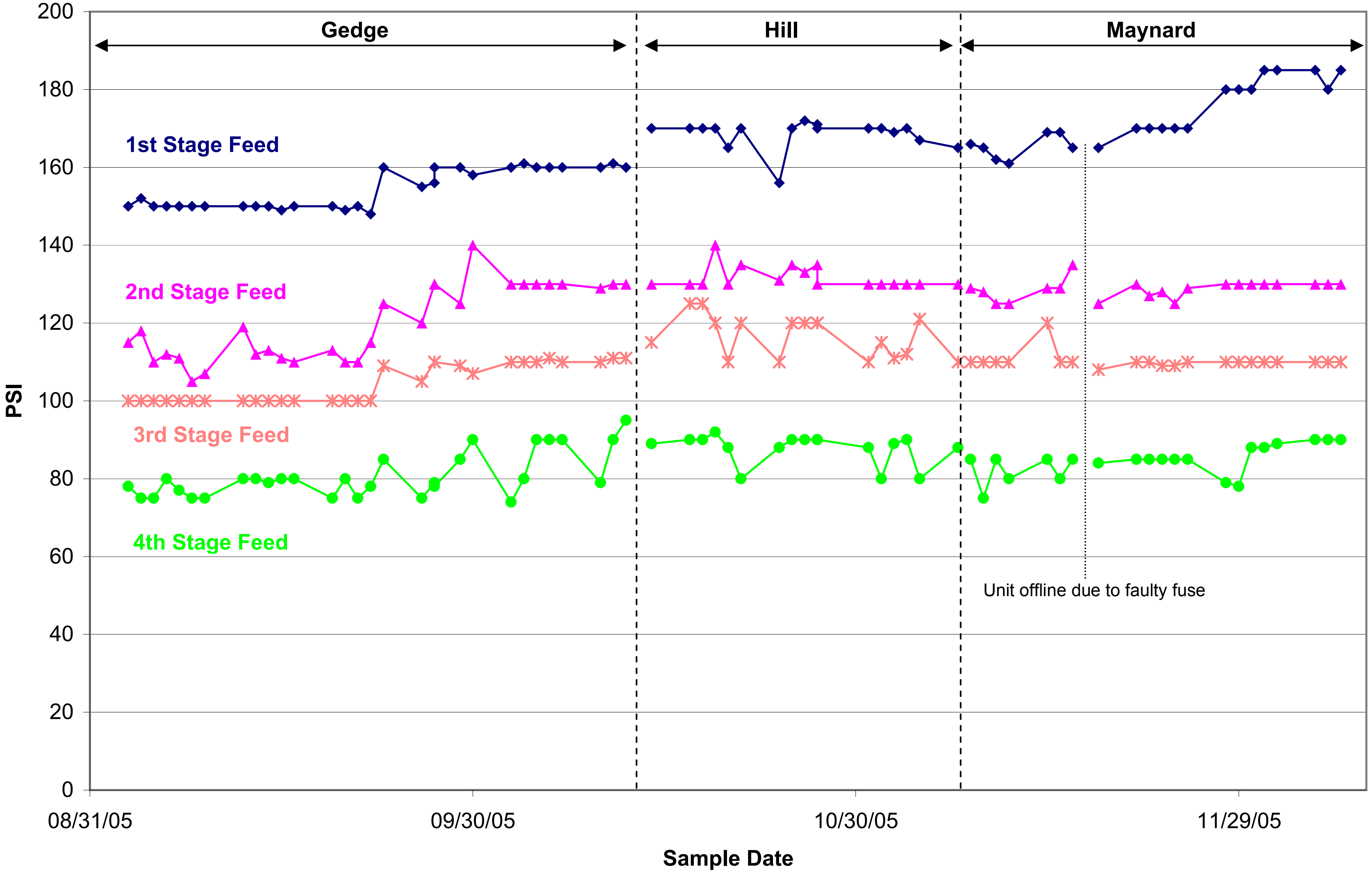


Figure G-4

RO Feed Pressure

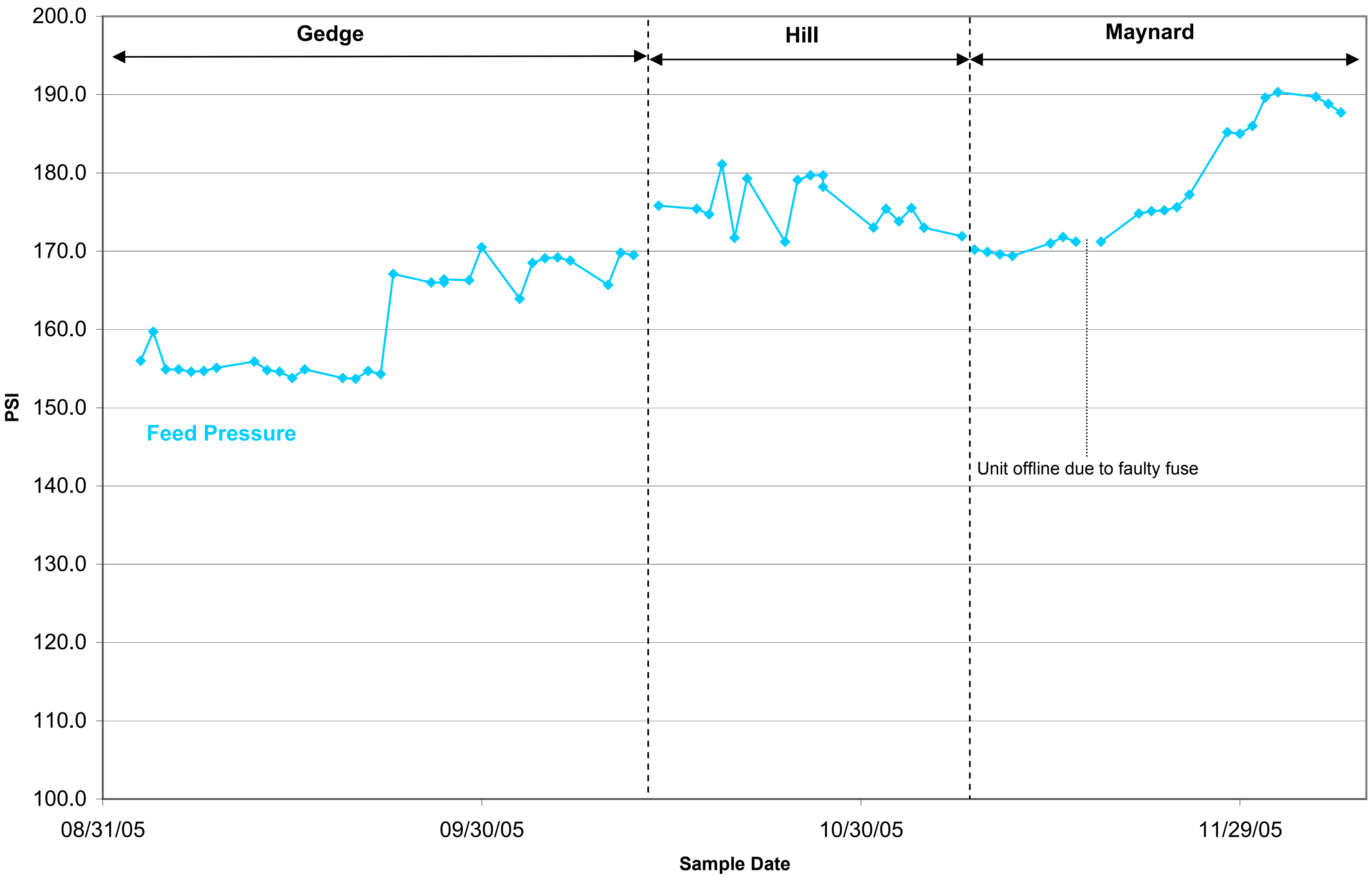


Figure G5

RO Permeate and Concentrate Flow

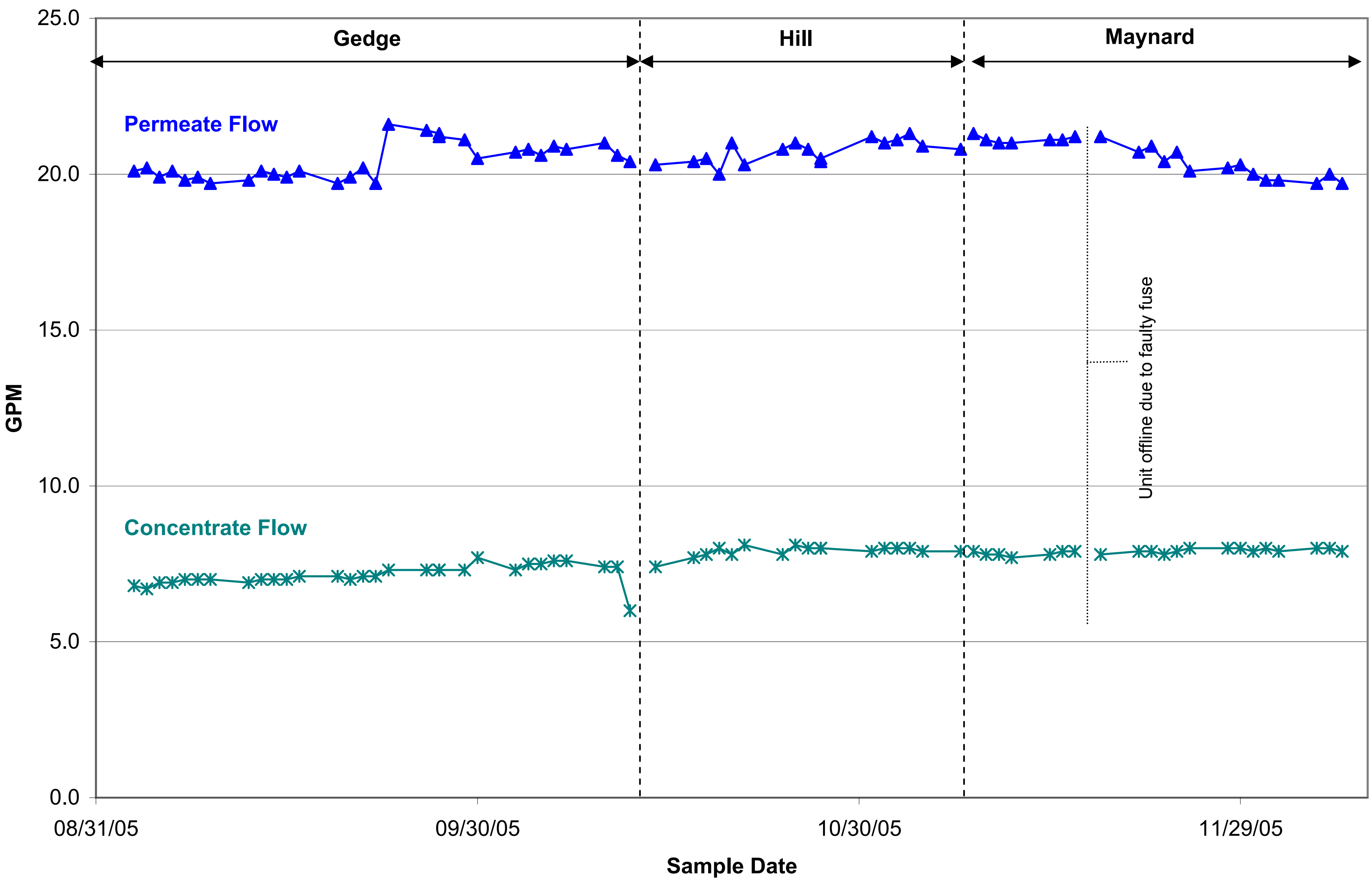


Figure G-6
EDR Prefilter Pressure

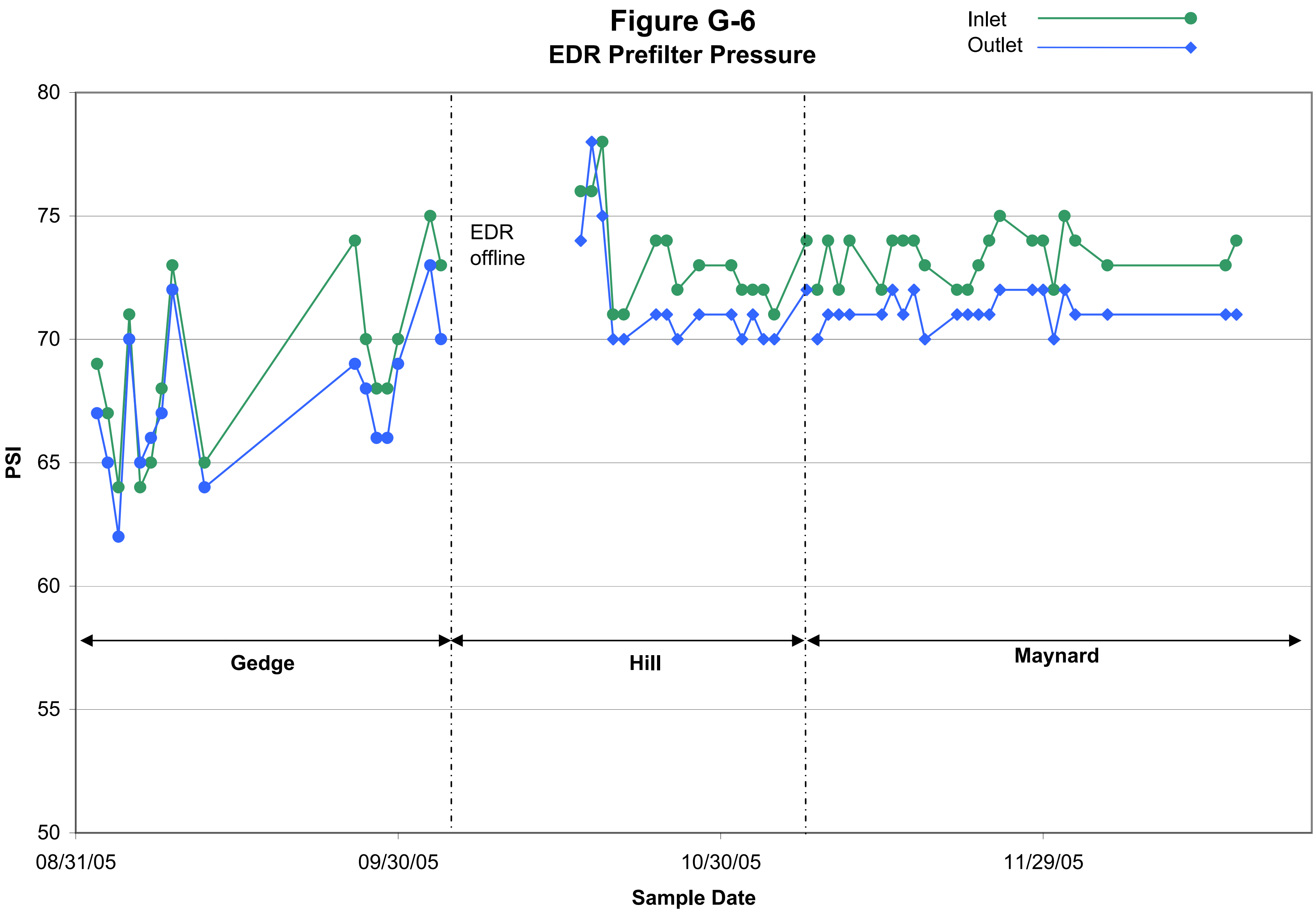


Figure G7
EDR FEEDWATER TEMP

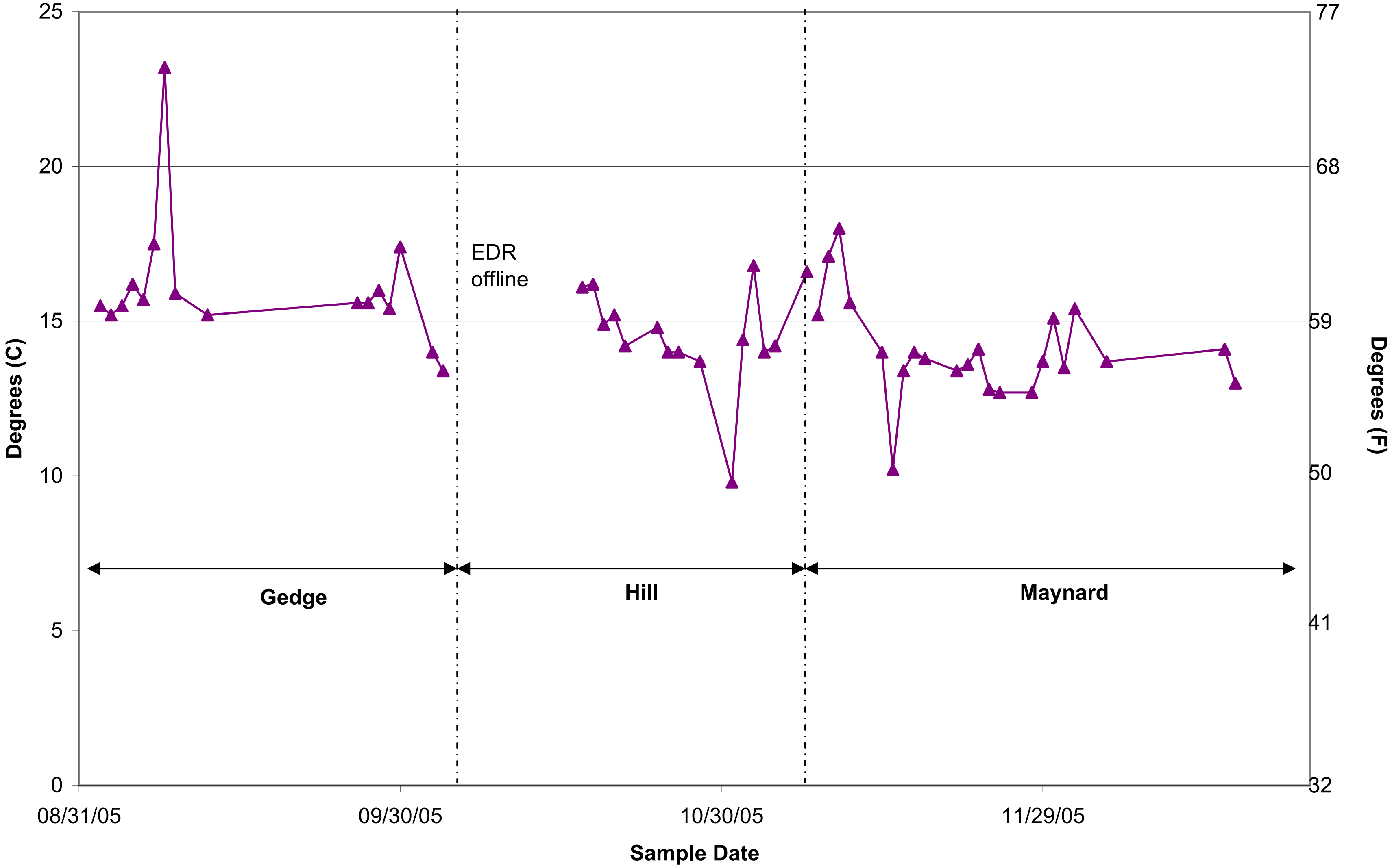


Figure G-8
EDR Concentrate Make-Up

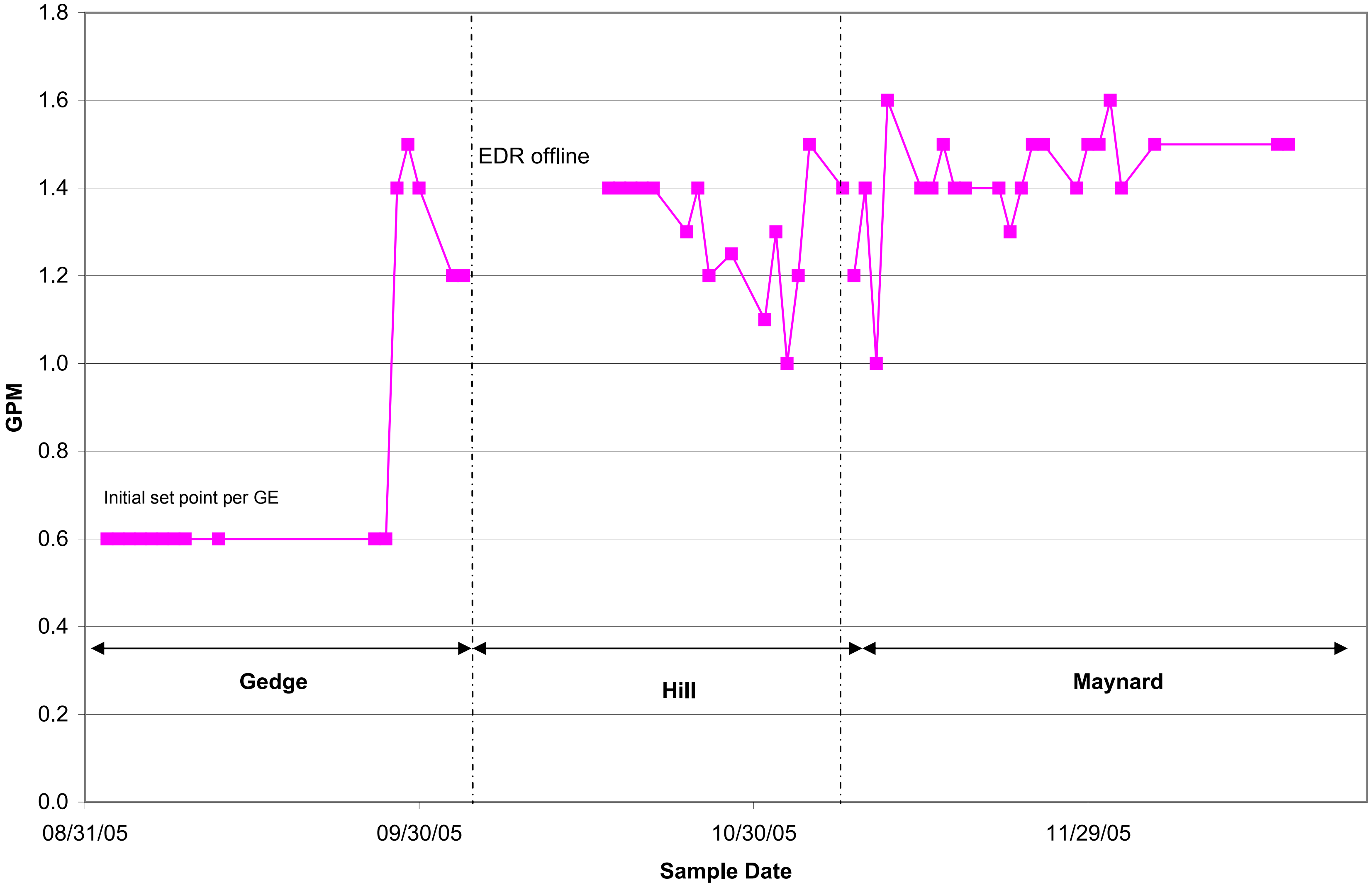


Figure G-9

EDR Electrode Feed Pressure

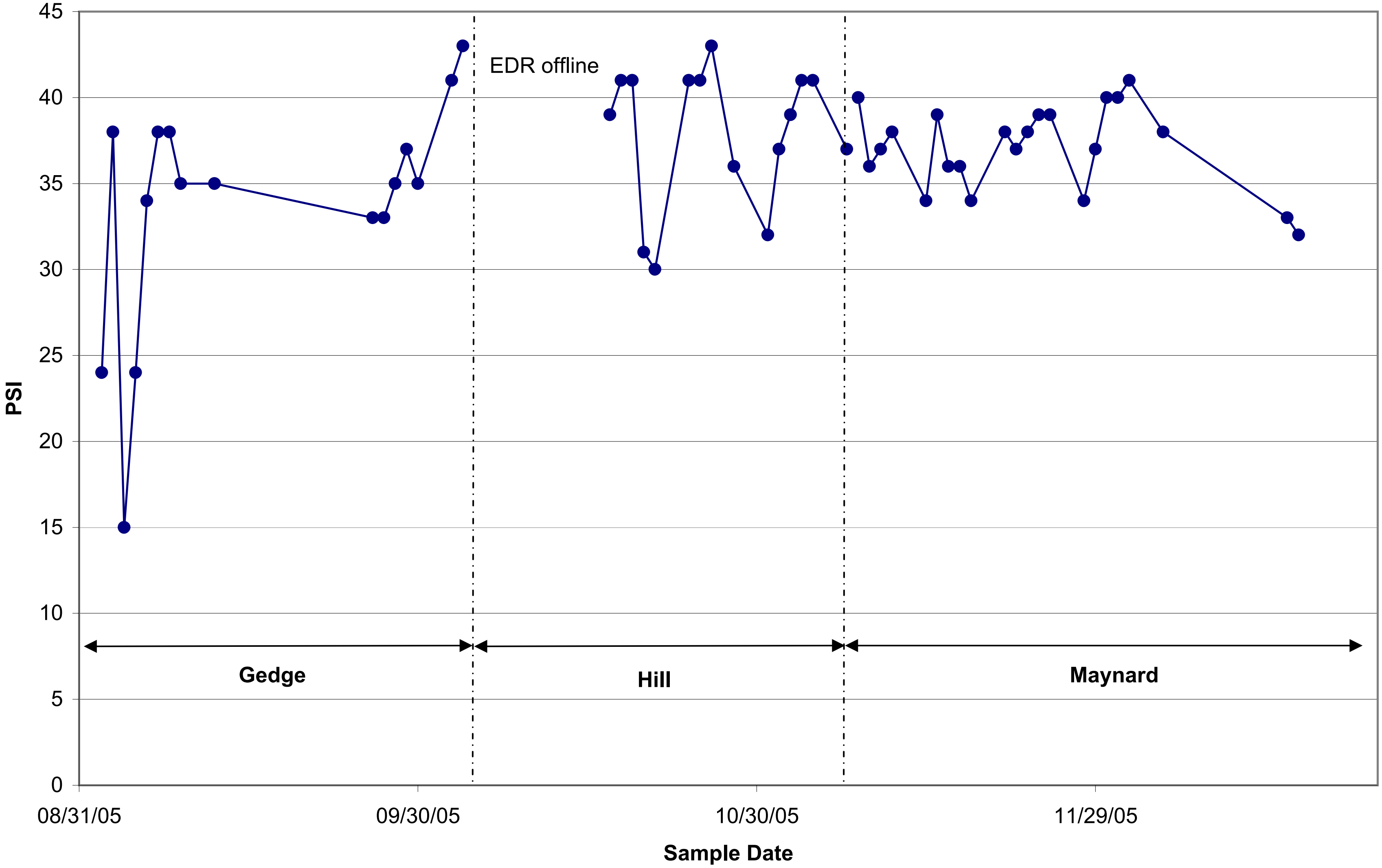


Figure G-10
EDR Stack Pressure

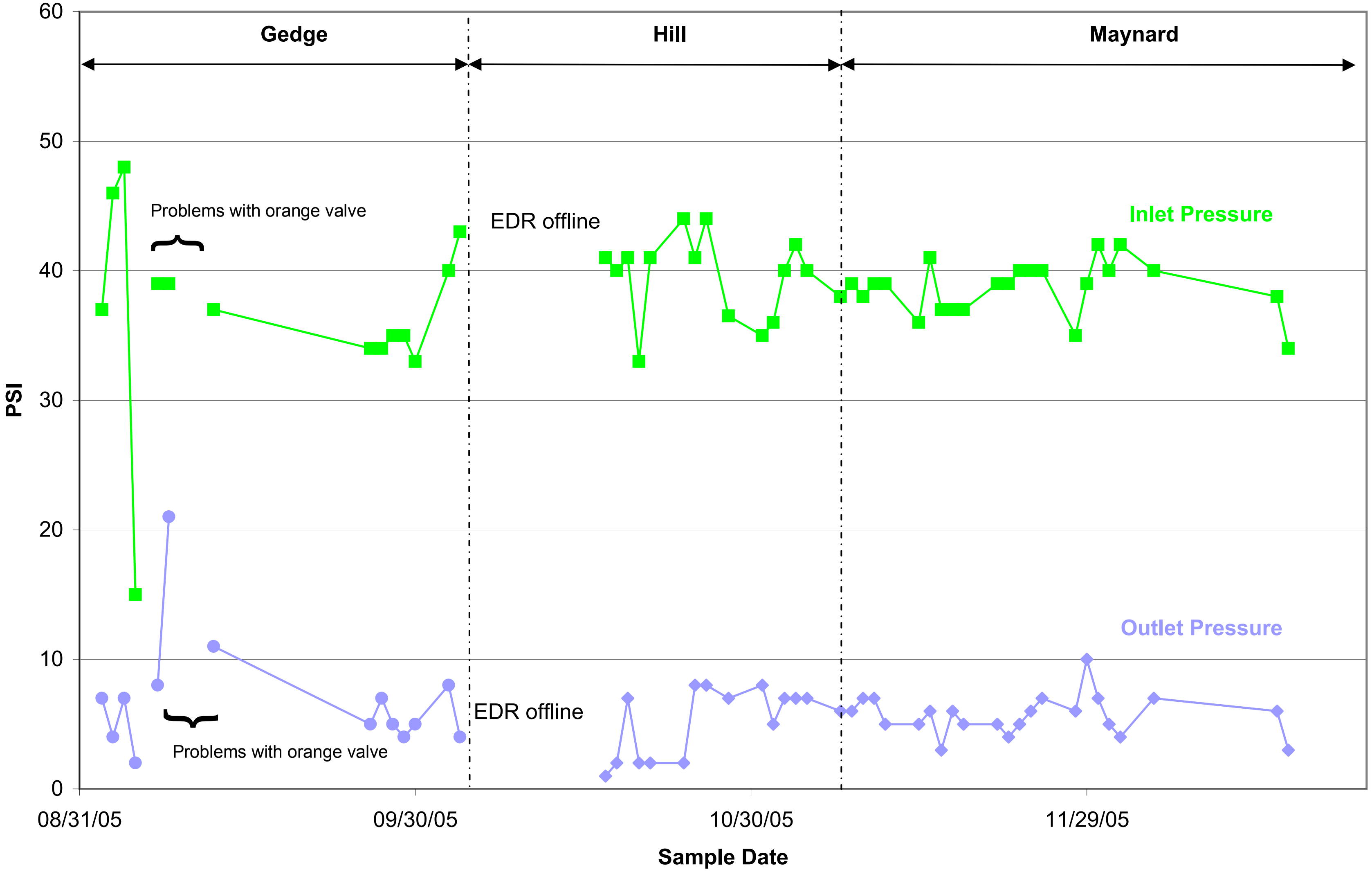


Figure G-11
EDR Electrode Flow

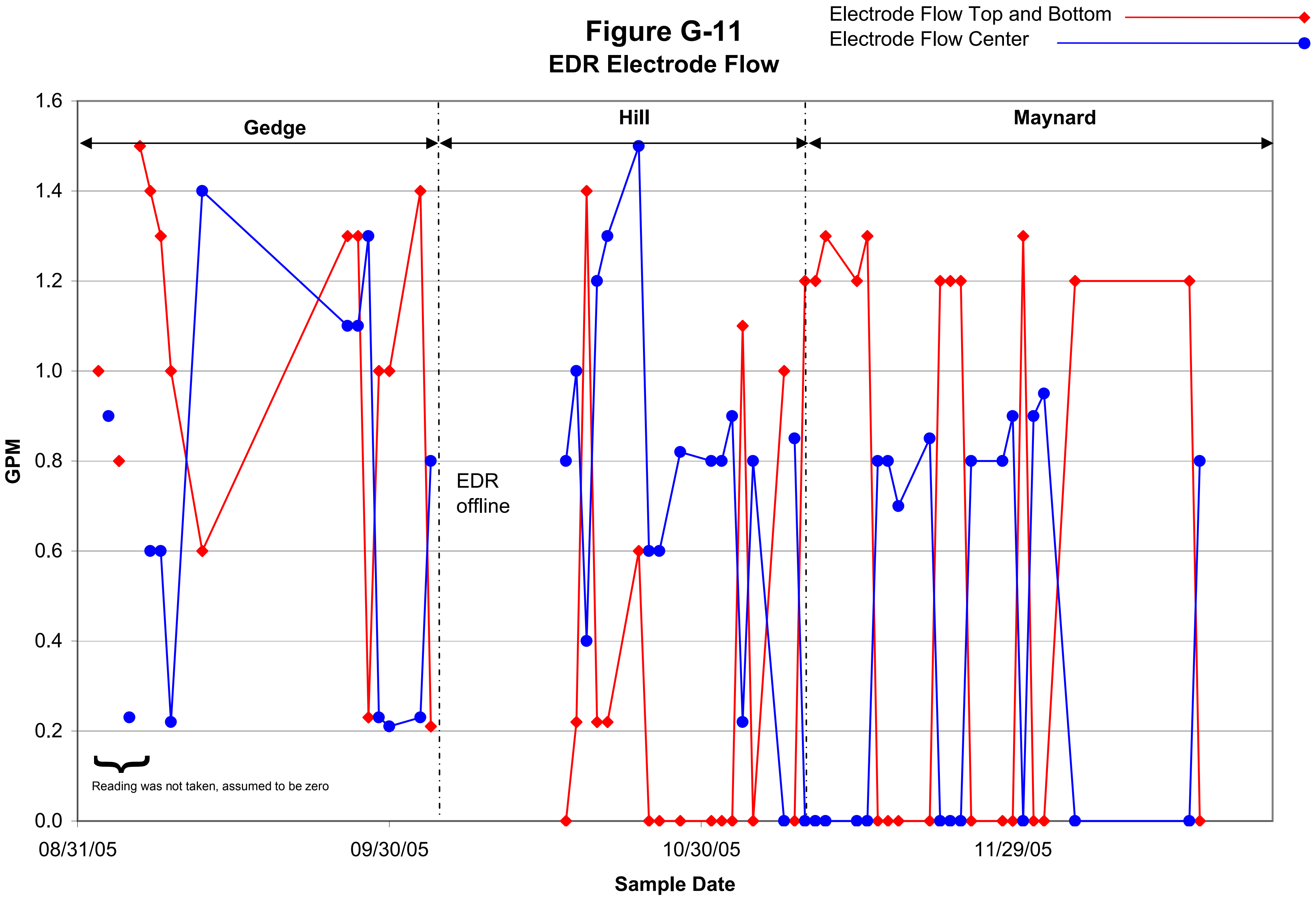
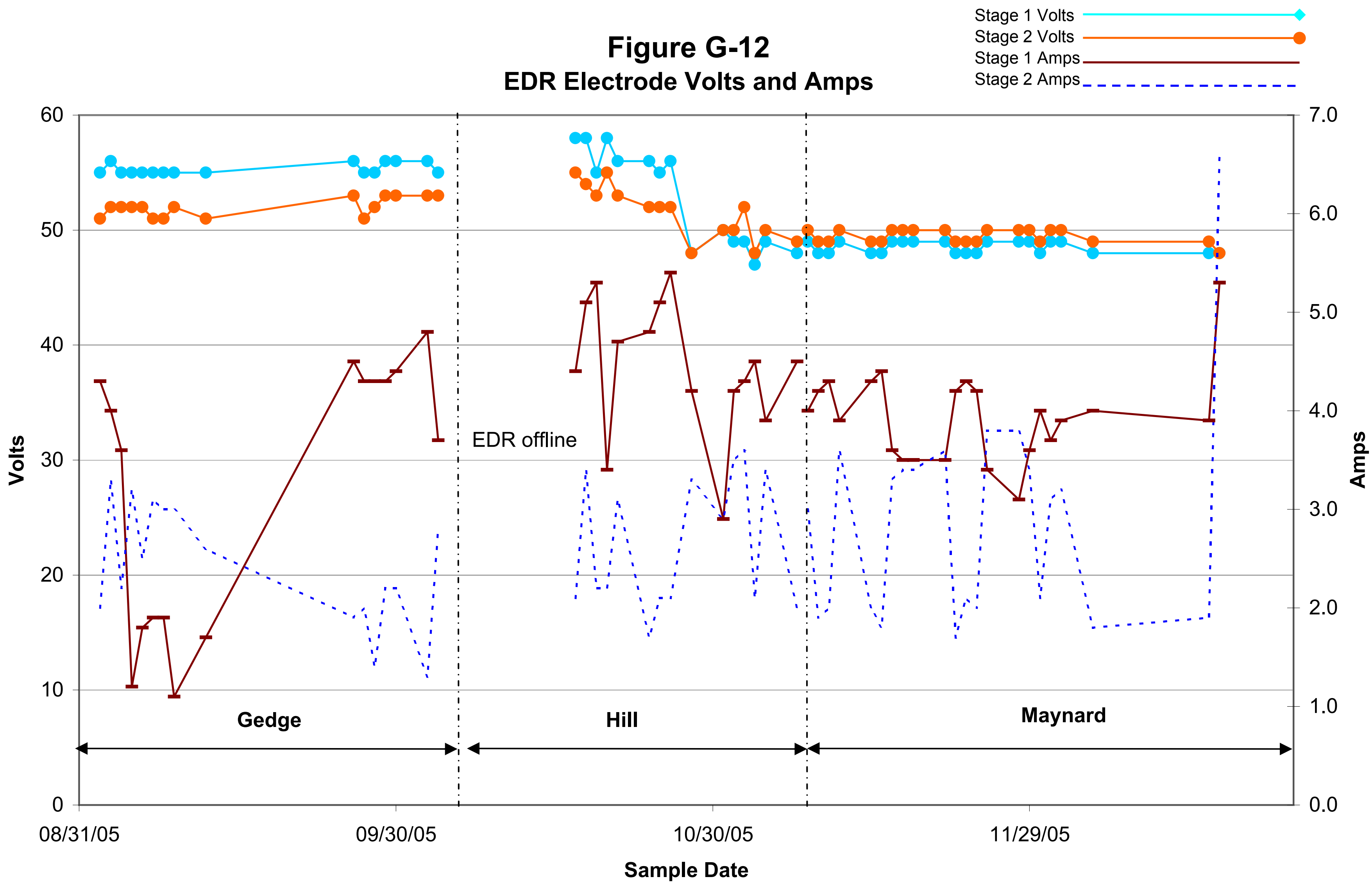


Figure G-12

EDR Electrode Volts and Amps



Appendix H

Laboratory Water Quality Data

Table H-1 Gedge Well TDS Data

Sample Site: Gedge Well					
	Solids, Total Dissolved (TDS)		Solids, Total Dissolved (TDS)		
Sample Date	RO Feed (mg/L)	RO Treated (mg/L)	EDR Feed (mg/L)	EDR Treated (mg/L)	Notes
9/6/2005	880	12	850	280	
9/7/2005	824	24	868	274	
9/8/2005	884	32	846	286	
9/9/2005	874	20	858	308	
9/12/2005	850	36			EDR pilot offline
9/13/2005	830	28			EDR pilot offline
9/14/2005	856	36			EDR pilot offline
9/15/2005	836	16			EDR pilot offline
9/16/2005	846	18			EDR pilot offline
9/19/2005	858	32			EDR pilot offline
9/20/2005	874	24			EDR pilot offline
9/21/2005	866	30			EDR pilot offline
9/22/2005	878	38			EDR pilot offline
9/23/2005	854	32			EDR pilot offline
9/26/2005	880	ND	920	220	
9/27/2005	864	56	868	184	
9/28/2005	844	32	908	188	
9/29/2005	878	34	858	168	
9/30/2005	872	66	910	184	
10/3/2005	746	38	822	174	
10/4/2005	848	40	790	214	
10/5/2005	856	34			EDR pilot offline
10/6/2005	862	40			EDR pilot offline
10/7/2005	846	34			EDR pilot offline
10/10/2005	852	12			EDR pilot offline
10/11/2005	830	8			EDR pilot offline
10/12/2005	792	10			EDR pilot offline

Table H-2 Gedge Well Feed and Treated Water Data

Sample Site: Gedge Well												
RO Feed	**Inorganic**						**Metals**					
Sample Date	Alkalinity Bicarbonate (mg/L)	Alkalinity Carbonate (mg/L)	Alkalinity Hydroxide (mg/L)	Hardness $CaCO_3$ (mg/L)	Sulfate IC (mg/L)	Turbidity (NTU)	Arsenic Total ICP/MS (mg/L)	Calcium Total ICP (mg/L)	Iron Total ICP (mg/L)	Magnesium Total ICP (mg/L)	Silica Reactive (mg/L)	Silica Total ICP (mg/L)
9/9/2005	290	ND	ND	480	139	0.1	0.0048	134	ND	35.4	31.7	34.7
9/16/2005	300	ND	ND	531	145	0.1	0.0049	146	ND	40.6	32.1	37.7
9/23/2005	300	ND	ND	446	143	0.14	0.0047	124	ND	33.2	32.3	32.9
9/30/2005	300	ND	ND	435	142	0.05	0.0025	120	ND	32.6	30.7	30.9
10/7/2005	290	ND	ND	473	138	0.3	0.0052	133	ND	34.2	31.3	33.2
RO Treated	**Inorganic**						**Metals**					
Sample Date	Alkalinity Bicarbonate (mg/L)	Alkalinity Carbonate (mg/L)	Alkalinity Hydroxide (mg/L)	Hardness $CaCO_3$ (mg/L)	Sulfate IC (mg/L)	Turbidity (NTU)	Arsenic Total ICP/MS (mg/L)	Calcium Total ICP (mg/L)	Iron Total ICP (mg/L)	Magnesium Total ICP (mg/L)	Silica Reactive (mg/L)	Silica Total ICP (mg/L)
9/9/2005	2	ND	ND	ND	ND	0.02	ND	0.2	ND	ND	ND	0.3
9/16/2005	1	ND	ND	ND	ND	0.06	ND	0.2	ND	ND	ND	0.3
9/23/2005	1	ND	ND	ND	ND	0.23	ND	0.2	ND	ND	ND	0.1
9/30/2005	ND	ND	ND	1	ND	0.05	0.0022	0.2	ND	ND	0.3	0.3
10/7/2005	ND	ND	ND	0.5	ND	0.07	ND	0.2	ND	ND	0.3	0.3
EDR Feed	**Inorganic**						**Metals**					
Sample Date	Alkalinity Bicarbonate (mg/L)	Alkalinity Carbonate (mg/L)	Alkalinity Hydroxide (mg/L)	Hardness $CaCO_3$ (mg/L)	Sulfate IC (mg/L)	Turbidity (NTU)	Arsenic Total ICP/MS (mg/L)	Calcium Total ICP (mg/L)	Iron Total ICP (mg/L)	Magnesium Total ICP (mg/L)	Silica Reactive (mg/L)	Silica Total ICP (mg/L)
9/9/2005	300	ND	ND	479	140	0.1	0.0028	133	ND	35.7	32.6	34.9
9/30/2005	300	ND	ND	460	140	0.11	0.0058	129	ND	33.7	30.8	32.1
EDR Treated	**Inorganic**						**Metals**					
Sample Date	Alkalinity Bicarbonate (mg/L)	Alkalinity Carbonate (mg/L)	Alkalinity Hydroxide (mg/L)	Hardness $CaCO_3$ (mg/L)	Sulfate IC (mg/L)	Turbidity (NTU)	Arsenic Total ICP/MS (mg/L)	Calcium Total ICP (mg/L)	Iron Total ICP (mg/L)	Magnesium Total ICP (mg/L)	Silica Reactive (mg/L)	Silica Total ICP (mg/L)
9/9/2005	170	ND	ND	106	10	0.06	0.001	27.5	ND	9.1	31.7	36.1
9/30/2005	75	ND	ND	19	2	0.11	ND	4.9	ND	1.7	31.4	31.8

Table H-3 Gedge Well

Sample Site: Gedge Well	
Sample Date:	Organic Carbon, Total (TOC) (mg/L)
10/5/2005	1.5

Table H-4 Hill Well TDS Data

Sample Site:	Hill Well				
	Solids, Total Dissolved (TDS)		Solids, Total Dissolved (TDS)		
Sample Date	RO Feed (mg/L)	RO Treated (mg/L)	EDR Feed (mg/L)	EDR Treated (mg/L)	Notes
10/13/2005	1060	10			
10/14/2005	1020	8			
10/17/2005	1000	8	822	150	
10/18/2005	1000	12	966	272	
10/19/2005	1010	16	988	268	
10/20/2005	1030	28	998	216	
10/21/2005	1010	12	1020	222	
10/24/2005	748	ND	806	162	
10/25/2005	938	ND	962	274	
10/26/2005	1010	10	1030	244	
10/27/2005	1030	ND	1030	262	
10/28/2005	1050	8	1030	258	
10/31/2005	682	8	724	208	
11/1/2005	1000	ND	990	606	
11/2/2005	1000	6	1010	558	
11/3/2005	1020	ND	1000	234	
11/4/2005	832	8	902	238	
11/7/2005	982	12	964	234	Pilot was Relocated

Table H-5 Hill Well Feed and Treated Water Data

Sample Site: Hill Well												
RO Feed	Inorganic						Metals					
Sample Date	Alkalinity Bicarbonate (mg/L)	Alkalinity Carbonate (mg/L)	Alkalinity Hydroxide (mg/L)	Hardness $CaCO_3$ (mg/L)	Sulfate IC (mg/L)	Turbidity (NTU)	Arsenic Total ICP/MS (mg/L)	Calcium Total ICP (mg/L)	Iron Total ICP (mg/L)	Magnesium Total ICP (mg/L)	Silica Reactive (mg/L)	Silica Total ICP (mg/L)
10/14/2005	380	ND	ND	578	165	0.2	0.0062	167	ND	39.2	38.1	41
10/21/2005	370	ND	ND	607	167	0.09	0.006	176	ND	40.8	39.1	44
10/28/2005	380	ND	ND	590	168	0.06	0.0052	169	ND	40.8	39.3	42.4
11/4/2005	330	ND	ND	482	142	0.1	0.00054	139	ND	32.8	32.2	34
RO Treated	Inorganic						Metals					
Sample Date	Alkalinity Bicarbonate (mg/L)	Alkalinity Carbonate (mg/L)	Alkalinity Hydroxide (mg/L)	Hardness $CaCO_3$ (mg/L)	Sulfate IC (mg/L)	Turbidity (NTU)	Arsenic Total ICP/MS (mg/L)	Calcium Total ICP (mg/L)	Iron Total ICP (mg/L)	Magnesium Total ICP (mg/L)	Silica Reactive (mg/L)	Silica Total ICP (mg/L)
10/14/2005	ND	ND	ND	ND	ND	0.34	ND	ND	ND	ND	0.4	0.3
10/21/2005	ND	ND	ND	ND	ND	0.09	ND	ND	ND	ND	0.1	0.1
10/28/2005	ND	ND	ND	ND	ND	0.08	ND	ND	ND	ND	0.2	0.2
11/4/2005	ND	ND	ND	ND	ND	0.05	ND	ND	ND	ND	ND	ND
EDR Feed	Inorganic						Metals					
Sample Date	Alkalinity Bicarbonate (mg/L)	Alkalinity Carbonate (mg/L)	Alkalinity Hydroxide (mg/L)	Hardness $CaCO_3$ (mg/L)	Sulfate IC (mg/L)	Turbidity (NTU)	Arsenic Total ICP/MS (mg/L)	Calcium Total ICP (mg/L)	Iron Total ICP (mg/L)	Magnesium Total ICP (mg/L)	Silica Reactive (mg/L)	Silica Total ICP (mg/L)
10/21/2005	380	ND	ND	614	166	0.08	0.0063	176	ND	42.7	39.1	44.1
10/28/2005	380	ND	ND	586	168	0.12	0.005	168	ND	40.5	38.2	42.2
11/4/2005	340	ND	ND	486	140	0.06	0.0055	140	ND	33.2	32.6	34.4
EDR Treated	Inorganic						Metals					
Sample Date	Alkalinity Bicarbonate (mg/L)	Alkalinity Carbonate (mg/L)	Alkalinity Hydroxide (mg/L)	Hardness $CaCO_3$ (mg/L)	Sulfate IC (mg/L)	Turbidity (NTU)	Arsenic Total ICP/MS (mg/L)	Calcium Total ICP (mg/L)	Iron Total ICP (mg/L)	Magnesium Total ICP (mg/L)	Silica Reactive (mg/L)	Silica Total ICP (mg/L)
10/21/2005	100	ND	ND	39	5	0.06	0.0006	10.4	ND	3.2	38.9	43.4
10/28/2005	150	ND	ND	46	4	0.09	0.0008	12	ND	4	38.4	42.2
11/4/2005	98	ND	ND	47	4	0.09	0.0014	12.5	ND	3.8	33.4	34.6

Table H-6 Hill Well Concentrate

Sample Site:	Hill Well
Sample Date:	Organic Carbon, Total (TOC) (mg/L)
10/27/2005	1.6

Sample Site:	Hill Well	RO Waste
Sample Date:	Solids, Total Dissolved (TDS) (mg/L)	Selenium, Total, ICP/MS (mg/L)
10/21/2005	3380	0.0166
11/4/2005	3260	0.0201

Sample Site:	Hill Well	EDR Waste
Sample Date:	Solids, Total Dissolved (TDS) (mg/L)	Selenium, Total, ICP/MS (mg/L)
10/21/2005	2890	0.0149
11/4/2005	3880	0.0267

Table H-7 **Maynard Well TDS Data**

Sample Site: Maynard Well					
	Solids, Total Dissolved (TDS)		Solids, Total Dissolved (TDS)		
Sample Date	RO Feed (mg/L)	RO Treated (mg/L)	EDR Feed (mg/L)	EDR Treated (mg/L)	Notes
11/8/2005	924	32	1020	228	
11/9/2005	1000	34	1020	298	
11/10/2005	1010	28	994	278	
11/11/2005	1000	30	1020	306	
11/14/2005	960	22	980	250	
11/15/2005	964	12	974	262	
11/16/2005			980	236	RO samples missing
11/17/2005			940	254	RO samples missing
11/18/2005	994	8	878	250	
11/21/2005	964	32	976	286	
11/22/2005	976	28	972	294	
11/23/2005	970	36	980	294	
11/24/2005	938	10	928	278	
11/25/2005	924	12	914	250	
11/28/2005	910	10	956	272	
11/29/2005	944	6	928	390	
11/30/2005	958	8	966	266	
12/1/2005	984	28	990	304	
12/2/2005	980	28	998	290	
12/5/2005	956	10	1010	312	
12/6/2005	966	36	990	302	
12/7/2005	1030	36	984	298	

Table H-8 Maynard Well Feed and Treated Water Data

Sample Site: Maynard Well

RO Feed	Inorganic						Metals					
Sample Date	Alkalinity Bicarbonate (mg/L)	Alkalinity Carbonate (mg/L)	Alkalinity Hydroxide (mg/L)	Hardness $CaCO_3$ (mg/L)	Sulfate IC (mg/L)	Turbidity (NTU)	Arsenic Total ICP/MS (mg/L)	Calcium Total ICP (mg/L)	Iron Total ICP (mg/L)	Magnesium Total ICP (mg/L)	Silica Reactive (mg/L)	Silica Total ICP (mg/L)
11/11/2005	370	ND	ND	496	161	0.06	0.0067	142	ND	34.4	43.5	45.3
11/18/2005	370	ND	ND	506	162	0.05	0.007	144	ND	35.5	44.2	44.3
11/23/2005	360	ND	ND	487	151	0.05	0.0071	139	ND	33.9	45.2	47.9
11/30/2005	360	ND	ND	529	159	0.05	0.0082	150	ND	37.4	44.2	49.2
12/7/2005	370	ND	ND	519	160	0.06	0.0076	148	ND	36.3	46.2	47.7

RO Treated	Inorganic						Metals					
Sample Date	Alkalinity Bicarbonate (mg/L)	Alkalinity Carbonate (mg/L)	Alkalinity Hydroxide (mg/L)	Hardness $CaCO_3$ (mg/L)	Sulfate IC (mg/L)	Turbidity (NTU)	Arsenic Total ICP/MS (mg/L)	Calcium Total ICP (mg/L)	Iron Total ICP (mg/L)	Magnesium Total ICP (mg/L)	Silica Reactive (mg/L)	Silica Total ICP (mg/L)
11/11/2005	1	ND	ND	ND	ND	0.05	ND	0.2	ND	ND	0.4	0.7
11/18/2005	1	ND	ND	ND	ND	0.05	ND	0.2	ND	ND	0.8	0.8
11/23/2005	ND	ND	ND	0.05	ND	0.05	ND	0.2	ND	ND	0.8	0.8
11/30/2005	3	ND	ND	ND	ND	0.04	ND	0.3	ND	ND	0.8	0.8
12/7/2005	2	ND	ND	1	ND	0.05	ND	0.2	ND	ND	0.8	0.8

EDR Feed	Inorganic						Metals					
Sample Date	Alkalinity Bicarbonate (mg/L)	Alkalinity Carbonate (mg/L)	Alkalinity Hydroxide (mg/L)	Hardness $CaCO_3$ (mg/L)	Sulfate IC (mg/L)	Turbidity (NTU)	Arsenic Total ICP/MS (mg/L)	Calcium Total ICP (mg/L)	Iron Total ICP (mg/L)	Magnesium Total ICP (mg/L)	Silica Reactive (mg/L)	Silica Total ICP (mg/L)
11/11/2005	370	ND	ND	503	160	0.08	0.0062	144	ND	34.9	43.3	46.2
11/18/2005	370	ND	ND	516	161	0.04	0.0071	147	ND	36.1	44.8	46.5
11/23/2005	370	ND	ND	491	151	0.16	0.0074	139	ND	34.9	45	49.2
11/30/2005	370	ND	ND	365	161	0.04	0.0085	146	ND	ND	44.7	49.8
12/7/2005	370	ND	ND	523	161	0.06	0.0082	149	ND	36.6	45.7	48.1

EDR Treated	Inorganic						Metals					
Sample Date	Alkalinity Bicarbonate (mg/L)	Alkalinity Carbonate (mg/L)	Alkalinity Hydroxide (mg/L)	Hardness $CaCO_3$ (mg/L)	Sulfate IC (mg/L)	Turbidity (NTU)	Arsenic Total ICP/MS (mg/L)	Calcium Total ICP (mg/L)	Iron Total ICP (mg/L)	Magnesium Total ICP (mg/L)	Silica Reactive (mg/L)	Silica Total ICP (mg/L)
11/11/2005	120	ND	ND	45	5	0.09	0.0012	12	ND	3.7	43.6	44.7
11/18/2005	120	ND	ND	37	3	0.08	0.0013	9.6	ND	3.2	44.1	46.1
11/23/2005	140	ND	ND	44	4	0.05	0.0009	11.3	ND	3.7	43.6	49.5
11/30/2005	150	ND	ND	59.5	5	0.04	0.001	15.6	ND	5	44	49.2
12/7/2005	170	ND	ND	47	5	0.05	0.0012	12.2	ND	4.1	45	47

Table H-9 Maynard Well Concentrate

Sample Site:	Maynard Well
Sample Date:	Organic Carbon, Total (TOC) (mg/L)
11/16/2005	2.3

Sample Site:	Maynard Well	RO Concentrate
Sample Date:	Solids, Total Dissolved (TDS) (mg/L)	Selenium, Total, ICP/MS (mg/L)
11/11/2005	3400	0.014
11/30/2005	3290	0.0187

Sample Site:	Maynard Well	EDR Concentrate
Sample Date:	Solids, Total Dissolved (TDS) (mg/L)	Selenium, Total, ICP/MS (mg/L)
11/11/2005	3950	0.023
11/30/2005	3860	0.025