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Arsenic Removal from Drinking Water by Ion Exchange U.S. EPA Demonstration Project at Fruitland, ID Final Performance Evaluation Report

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Sally Gutierrez, Director
National Risk Management Research Laboratory

ABSTRACT

This report documents the activities performed and the results obtained from this 32-month demonstration study, which evaluated a Kinetico ion exchange (IX) system to remove arsenic and nitrate from source water at the City of Fruitland in Idaho. The 250-gal/min (gpm) IX system consisted of a bank of five sediment filters, two 48-in × 72-in pressure vessels (configured in parallel), one 15-ton saturator, one 685-gal day tank, and ancillary equipment. Each resin vessel contained 50 ft^3 of A300 E strong base anionic exchange resin manufactured by Purolite.

The 32-month demonstration study was divided into three major study periods with Study Period I extending from June 14, 2005, through July 25, 2006; Study Period II from July 25, 2006, through June 18, 2007; and Study Period III from June 18, 2007 to February 11, 2008. Study Period I evaluated performance of the IX system in a co-current regeneration mode. Due to leakage of both arsenic and nitrate after regeneration, attempts were made to switch the regeneration process from co- to counter-current mode in Study Period II. However, a series of mechanical failures was encountered while switching from co- to counter-current regeneration, causing the IX resin to foul. Therefore, Study Period III was devoted to resin cleaning using a caustic/brine mixture before returning to regular but brief system performance evaluation.

Routine system performance evaluation was conducted in Study Period I, when the IX system operated in the co-current regeneration mode. During this period, the IX system operated for a total of 6,836 hr, averaging 17.4 hr/day. The system treated approximately 65,423,000 gal of water with an average daily production of 166,895 gal/day (gpd). The average flowrate was 157 gpm, which was 63% of the 250-gpm design flowrate. This average flowrate yielded an empty bed contact time (EBCT) of 4.8 min and a hydraulic loading rate of 6.2 gpm/ft^2 to each IX resin vessel.

Total arsenic concentrations in raw water ranged from 33.6 to 60.8 µg/L and averaged 42.5 µg/L, which existed primarily as As(V). Nitrate concentrations ranged from 6.9 to 11.5 mg/L (as N) and averaged 10.0 mg/L (as N). The water also contained, on average, 19.4 µg/L of uranium, 39.3 µg/L of vanadium, 59 mg/L of sulfate, 0.32 mg/L of phosphorus (as P), 57 mg/L of silica (as SiO_2), and 387 mg/L of alkalinity (as $CaCO_3$). After treatment, total arsenic and nitrate were reduced to below the respective maximum contaminant levels (MCLs), except when the system was freshly regenerated or experiencing mechanical problems. Near complete removal of uranium, vanadium, and molybdenum by the IX system also was observed.

Sulfate, the most preferred anion by the IX resin, was removed from an average of 59 mg/L in raw water to less than 1 mg/L in the treated water for most sampling events, except when the system was experiencing mechanical problems. Raw water pH values ranged from 6.7 to 7.9. A significant reduction in pH in the treated water was observed immediately after resin regeneration, presumably due to the removal of bicarbonate ions by the freshly regenerated IX resin, as evidenced by the corresponding decrease in total alkalinity.

In addition to routine sampling, six run length and two regeneration (or elution) special studies were performed during Study Periods I and II. The purpose of the run length studies was to delineate arsenic and nitrate breakthrough behavior and determine the resin run length between two consecutive regeneration cycles. Based on the results of these special studies and routine sampling across the treatment train, the resin run length was upwardly adjusted from the initial factory setting of 214,000 gal (or 286 bed volume [BV]) to 335,000 gal (or 448 BV), then downwardly adjusted several times to 316,000 gal (or 422 BV), 275,000 gal (or 368 BV), 260,000 gal (or 348 BV), and finally 220,000 gal (or

294 BV) by the end of evaluation study. Effluent samples collected from the IX vessels indicated arsenic and nitrate leakage during the first 50,000 to 60,000 gal (or 67 to 80 BV) of throughput.

The IX system was regenerated in a downflow, co-current mode during Study Period I using brine at a target salt level of 10 lb/ ft^3 of resin. Triggered automatically by a pre-set throughput in the programmable logic controller (PLC), the two IX vessels were regenerated sequentially, each cycling through the steps of brine draw, slow rinse, and fast rinse before returning to service. A total of 202 regeneration cycles took place during Period I, consuming approximately 271,640 lb of salt. Depending on regeneration settings, average salt usage per regeneration cycle increased from 1,129 lb to as high as 1,736 lb and then decreased to 945 lb, equivalent to a regeneration level of 11.3, 17.4, or 9.5 lb/ft^3. The regeneration settings were adjusted multiple times to reach 9.5 lb/ft^3 regeneration level, which was within 5% of the target value of 10 lb/ft^3. Key settings included brine concentration, brine draw time, and brine draw flowrate. The system production efficiency was 98% considering the amount of treated water used for regeneration.

The purpose of the two regeneration (or elution) studies was to evaluate the effectiveness of the IX resin regeneration process and characterize the residuals produced. Although the majority of arsenic and nitrate on the resin was eluted during the brine draw and slow rinse steps, arsenic concentrations as high as 35 µg/L were still measured towards the end of the fast rinse step. Therefore, it was not surprising to detect over 10 µg/L of arsenic during subsequent service runs. Extending the fast rinse time from 6 to 15 min did not resolve the problem because the leakage was found to continue up to 52,000 gal (or 70 BV) of throughput, or approximately 3 to 4 hr into service runs. The regeneration waste stream discharged to the sewer contained an average of 1.9 mg/L of arsenic and 0.31 g/L of nitrate, equivalent to a mass loading of 47 g for arsenic and 7.9 kg for nitrate per regeneration cycle, based on the wastewater samples collected during nine regeneration events.

Attempts were made in Study Period II to convert the IX system from co- to counter-current regeneration. The conversion, however, was unsuccessful due to various mechanical difficulties. Improper IX resin regeneration for an extended period during Study Period II resulted in resin fouling, which caused deteriorating resin performance. The fouled IX resin was cleaned with a 5% NaOH/10% brine mixture followed by regular co-current regeneration. Although the analytical data of IX resin samples showed some effectiveness, the system performance did not improve after the caustic/brine cleaning. The early leakage of arsenic and nitrate continued to exist after the system was reverted back to the co-current regeneration mode.

The capital investment cost was $286,388, which included $173,195 for equipment, $35,619 for site engineering, and $77,574 for installation. This capital cost was normalized to the system's rated capacity of 250 gpm (360,000 gpd), which resulted in $1,146 per gpm ($0.80 per gpd). Funded separately by the City of Fruitland, the cost associated with the new building, sanitary sewer connection, and other discharge-related infrastructure was not included in the capital cost.

The operation and maintenance (O&M) cost for the IX system included the incremental cost associated with the salt supply, electricity consumption, and labor. Over the first year of system operation, the cost for salt supply was $0.49/1,000 gal of water treated, which could be reduced to $0.35/1,000 gal if a target salt usage rate of 3.16 lb/1,000 gal was reached. The majority of the O&M cost was incurred by salt supply.

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ABBREVIATIONS AND ACRONYMS

Δp	differential pressure
AAL	American Analytical Laboratories
Al	aluminum
AM	adsorptive media
As	arsenic
ASV	anodic stripping voltammetry
AZW	Arizona Water Company
bgs	below ground surface
BV	bed volume(s)
Ca	calcium
C/F	coagulation/filtration
Cl	chlorine
CRF	capital recovery factor
Cu	copper
DO	dissolved oxygen
EBCT	empty bed contact time
EMCT	multi-component chromatography theory
EPA	U.S. Environmental Protection Agency
F	fluoride
Fe	iron
FRP	fiberglass reinforced plastic
gpd	gallons per day
gpm	gallons per minute
hp	horsepower
HCl	hydrochloric acid
ICP-MS	inductively coupled plasma-mass spectrometry
ID	identification
IDEQ	Idaho Department of Environmental Quality
IX	ion exchange
LCR	Lead and Copper Rule
MCL	maximum contaminant level
MDL	method detection limit
MDWCA	Mutual Domestic Water Consumer's Association
Mg	magnesium
Mn	manganese
Mo	molybolenum
mV	millivolts

Na	sodium
NA	not applicable
NaOCl	sodium hypochlorite
NIST	National Institute of Standards and Technology
NRMRL	National Risk Management Research Laboratory
NSF	NSF International
NTU	nephelometric turbidity units
OIP	operator interface panel
O&M	operation and maintenance
ORD	Office of Research and Development
ORP	oxidation-reduction potential
P&ID	piping and instrumentation diagrams
PLC	programmable logic controller
Ppb	part per billion
psi	pounds per square inch
PVC	polyvinyl chloride
QAPP	quality assurance project plan
QA/QC	quality assurance/quality control
RPD	relative percent difference
SBA	strong-base anionic exchange
SDWA	Safe Drinking Water Act
SM	system modification
STMGID	South Truckee Meadows General Improvement District
STS	Severn Trent Services
TBD	to be determined
TDS	total dissolved solids
TOC	total organic carbon
U	uranium
UPS	uninterrupted power supply
UV	ultraviolet
V	vanadium
WRWC	White Rock Water Company

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The authors wish to extend their sincere appreciation to the staff of the City of Fruitland Public Works in Fruitland, Idaho. The Fruitland Public Works staff monitored the treatment system daily and collected samples from the treatment and distribution systems on a regular schedule throughout this reporting period. This performance evaluation would not have been possible without their efforts.

1.0 INTRODUCTION

1.1 Background

The Safe Drinking Water Act (SDWA) mandates that U.S. Environmental Protection Agency (EPA) identify and regulate drinking water contaminants that may have adverse human health effects and that are known or anticipated to occur in public water supply systems. In 1975 under the SDWA, EPA established a maximum contaminant level (MCL) for arsenic at 0.05 mg/L. Amended in 1996, the SDWA required that EPA develop an arsenic research strategy and publish a proposal to revise the arsenic MCL by January 2000. On January 18, 2001, EPA finalized the arsenic MCL at 0.01 mg/L (EPA, 2001). To clarify the implementation of the original rule, EPA revised the rule text on March 25, 2003, to express the MCL as 0.010 mg/L (10 µg/L) (EPA, 2003). The final rule requires all community and non-transient, non-community water systems to comply with the new standard by January 23, 2006.

In October 2001, EPA announced an initiative for additional research and development of cost-effective technologies to help small community water systems (<10,000 customers) meet the new arsenic standard, and to provide technical assistance to operators of small systems in order to reduce compliance costs. As part of this Arsenic Rule Implementation Research Program, EPA's Office of Research and Development (ORD) proposed a project to conduct a series of full-scale, on-site demonstrations of arsenic removal technologies, process modifications, and engineering approaches applicable to small systems. Shortly thereafter, an announcement was published in the *Federal Register* requesting water utilities interested in participating in the first round of this EPA-sponsored demonstration program to provide information on their water systems. In June 2002, EPA selected 17 of 115 candidate sites to host the demonstration studies. The facility at City of Fruitland in Idaho was selected to participate in this demonstration program.

In September 2002, EPA solicited proposals from engineering firms and vendors for cost-effective arsenic-removal treatment technologies for the 17 host sites. EPA received 70 technical proposals for the 17 host sites, with each site receiving one to six proposals. In April 2003, an independent technical panel reviewed the proposals and provided its recommendations to EPA on the technologies that it determined were acceptable for the demonstration at each site. Because of funding limitations and other technical reasons, only 12 of the 17 sites were selected for the demonstration program. Using the information provided by the review panel, EPA, in cooperation with the host sites and the drinking water programs of the respective states, selected one technical proposal for each site. An ion exchange (IX) system proposed by Kinetico was selected for demonstration at the Fruitland, ID, site for the removal of arsenic and nitrate from drinking water supplies.

1.2 Treatment Technologies for Arsenic Removal

The technologies selected for the 12 Round 1 arsenic removal demonstration host sites included nine adsorptive media (AM) systems, one IX system, one coagulation/filtration (C/F) system, and one process modification with iron addition. Table 1-1 summarizes the locations, technologies, vendors, and key source water quality parameters of the 12 demonstration sites. An overview of the technology selection and system design for the 12 demonstration sites and the associated capital cost is provided in two EPA reports (Wang, et al., 2004; Chen, et al., 2004), which are posted on the EPA Web site at http://www.epa.gov/ORD/NRMRL/wswrd/dw/arsenic/index.html.

As of February 2010, all 12 systems were operational and the performance evaluation of all 12 systems was completed.

Table 1-1. Summary of Round 1 Arsenic Removal Demonstration Sites

Demonstration Site	Technology (Media)	Vendor	Design Flowrate (gpm)	Source Water Quality		
				As (µg/L)	Fe (µg/L)	pH
WRWC (Bow), NH	AM (G2)	ADI	70[a]	39	<25	7.7
Rollinsford, NH	AM (E33)	AdEdge	100	36[b]	46	8.2
Queen Anne's County, MD	AM (E33)	STS	300	19[b]	270[c]	7.3
Brown City, MI	AM (E33)	STS	640	14[b]	127[c]	7.3
Climax, MN	C/F (Macrolite)	Kinetico	140	39[b]	546[c]	7.4
Lidgerwood, ND	SM	Kinetico	250	146[b]	1,325[c]	7.2
Desert Sands MDWCA, NM	AM (E33)	STS	320	23[b]	39	7.7
Nambe Pueblo Tribe, NM	AM (E33)	AdEdge	145	33	<25	8.5
AWC (Rimrock), AZ	AM (E33)	AdEdge	90[a]	50	170	7.2
AWC (Valley Vista), AZ	AM (AAFS50)	Kinetico	37	41	<25	7.8
Fruitland, ID	IX (A-300E)	Kinetico	250	44	<25	7.4
STMGID, NV	AM (GFH)	USFilter	350	39	<25	7.4

AM = adsorptive media; C/F = coagulation/filtration; IX = ion exchange; SM = system modification
AWC = Arizona Water Company; MDWCA = Mutual Domestic Water Consumer's Association; STMGID = South Truckee Meadows General Improvement District; WRWC = White Rock Water Company; STS = Severn Trent Services

(a) Design flowrate reduced by 50% due to system reconfiguration from parallel to series operation.
(b) Arsenic existing mostly as As(III).
(c) Iron existing mostly as Fe(II).

1.3 Project Objectives

The objective of the arsenic demonstration program is to conduct full-scale arsenic removal technology demonstration studies on the removal of arsenic from drinking water supplies. The specific objectives are to:

- Evaluate the performance of the arsenic removal technologies for use on small systems
- Determine the required system operation and maintenance (O&M) and operator skill levels
- Characterize process residuals produced by the technologies
- Determine the capital and O&M cost of the technologies.

This report summarizes the performance of the Kinetico IX system at the City of Fruitland, ID, from June 14, 2005, through February 11, 2008. The types of data collected included system operation, water quality (both across the treatment train and in the distribution system), residuals characterization, and capital and O&M cost.

2.0 SUMMARY AND CONCLUSIONS

Based on the information collected during the 32-month demonstration study, the following summary and conclusions were made relating to the overall objectives of the treatment technology demonstration study.

Performance of the IX arsenic/nitrate removal technology for use on small systems:

- A300E IX resin was effective at removing arsenic and nitrate, provided that the system was regenerated properly. The system achieved a useful run length of approximately 220,000 gal (294 bed volumes [BV]) for nitrate, which was shorter than that for arsenic.
- A300E IX resin also was effective at removing uranium, vanadium, and molybdenum.
- After the system was freshly regenerated, elevated arsenic and nitrate concentrations were detected in the treated water up to 50,000 to 60,000 gal (67 to 80 BV) of throughput (or 3 to 4 hr into service runs), indicating incomplete regeneration. Attempts, including converting the IX system from co- to counter-current regeneration, were made to eliminate the early leakage. However, various mechanical difficulties encountered during the system conversion prevented the counter-current mode from being evaluated for its effectiveness. The early leakage continued through the end of the demonstration study.
- Freshly regenerated IX resin removes bicarbonate ions, causing reduction in pH and total alkalinity during the initial 100 BV of service runs.
- Arsenic and nitrate peaking could occur if the system operated beyond exhaustion. To avoid peaking, the IX system must be regenerated in a timely manner.
- Improper resin regeneration in the counter-current mode resulted in resin fouling and deteriorating IX resin performance through the end of the demonstration study. Cleaning the fouled IX resin with a 5% caustic/10% brine mixture was somewhat effective in restoring resin capacity based on measurements such as volumetric and strong base capacity, moisture content, and total organic fouling. However, the IX resin run length did not improve.

Required system O&M and operator skill levels:

- Under normal operating conditions, the skill requirements to operate the system were minimal with a typical daily demand on the operator of 30 min. Other skills needed for performing O&M activities included replacing filter bags periodically, using a hydrometer to check brine concentrations, monitoring salt inventory levels, scheduling salt delivery, and working with the vendor to troubleshoot and perform minor on-site repairs.
- It was important to monitor salt usage during a regeneration cycle to ensure that the IX resin was properly regenerated.

Process residuals produced by the technology:

- Residuals produced by the IX system included spent brine and rinse water. The volume of wastewater produced was dependent upon regeneration frequency and settings.
- Discharging spent brine to the sewer caused problems to the city's sewage lagoons, prompting the city to shorten the daily operating time to 3 hr/day. High salt content in

sewage was thought to have stressed duckweeds in the lagoons. Shorter daily operating time and less frequent system regeneration appeared to alleviate the problems.

Cost of the technology:

- Using the system's rated capacity of 250 gal/min (gpm) (or 360,000 gal/day [gpd]), the capital cost was $1,146/gpm (or $0.80/gpd) of the design capacity.
- Cost of salt supply was the most significant add-on to the previous plant operation. The actual salt supply during the first year of system operation cost $0.49/1,000 gal of water treated, which could be lowered to $0.35/1,000 gal if a salt usage rate of 3.16 lb/1,000 gal was reached.

3.0 MATERIALS AND METHODS

3.1 General Project Approach

Following the pre-demonstration activities summarized in Table 3-1, the performance evaluation of the IX system began on June 14, 2005, and ended on February 11, 2008. Table 3-2 summarizes the types of data collected and/or considered as part of the technology evaluation study. The overall performance of the system was evaluated based on its ability to consistently remove arsenic and nitrate to below their respective MCLs of 10-µg/L and 10-mg/L (as N) through the collection of water samples across the treatment train, as described in a Performance Evaluation Study Plan (Battelle, 2004). The reliability of the system was evaluated by tracking the unscheduled system downtime and frequency and extent of equipment repairs and replacement. The plant operator recorded unscheduled downtime and repair information on a Repair and Maintenance Log Sheet.

Table 3-1. Pre-Demonstration Study Activities and Completion Dates

Activity	Date
Introductory Meeting Held	August 21, 2003
Request for Quotation Issued to Vendor	August 26, 2003
Vendor Quotation Received by Battelle	September 19, 2003
Purchase Order Completed and Signed	October 16, 2003
Letter Report Issued	October 17, 2003
Draft Study Plan Issued	November 26, 2003
Engineering Package Submitted to IDEQ	January 25, 2004
Concrete Pad Poured	February 6, 2004
Building Construction Begun	February 10, 2004
Final Study Plan Issued	February 25, 2004
IX-248-As/N System Shipped	March 3, 2004
Building Construction Completed	March 3, 2004
IX-248-As/N System Arrived	March 8, 2004
Excessive Sediment Production in Well No. 6 Occurred	March 25 to 26, 2004
Well Investigation on Sediment Production Conducted	April 1 to 13, 2004
Replacement Well No. 6-2004 Drilled	May to July 2004
Treatment System Permit Issued	May 10, 2004
System Installation Completed	July 27, 2004
System Shakedown Halted due to Positive Coliform Test Results	July 28, 2004
Well Sanitization Continued due to Positive Coliform Test Results	July 2004 to April 2005
Incorrect IX Resin Replaced with A300E Resin	April 21, 2005
Negative Coliform Test Results Obtained and Submitted to IDEQ	May 4, 2005
New Pump Installed in Well No. 6-2004	May 19, 2005
Request for Discharging Treated Water to Distribution System Approved by IDEQ	June 7, 2005
System Shakedown Completed	June 13, 2005
Performance Evaluation Begun	June 14, 2005

IDEQ = Idaho Department of Environmental Quality

The required system O&M and operator skill levels were evaluated through quantitative data and qualitative considerations, including the need for pre- and/or post-treatment, level of system automation, extent of the preventive maintenance activities, frequency of chemical and/or media handling and

Table 3-2. Evaluation Objectives and Supporting Data Collection Activities

Evaluation Objective	Data Collection
Performance	Ability to consistently meet 10 μg/L of arsenic and 10 mg/L of nitrate (as N) in treated water
Reliability	Unscheduled system downtime Frequency and extent of repairs, including a description of problems, materials and supplies needed, and associated labor and cost
System O&M and Operator Skill Requirements	Pre- and post-treatment requirements Level of automation for system operation and data collection Staffing requirements, including number of operators and laborers Task analysis of preventive maintenance, including number, frequency, and complexity of tasks Chemical handling and inventory requirements General knowledge needed for relevant chemical processes and health and safety practices
Residual Management	Quantity and characteristics of aqueous and solid residuals generated by system operation
System Cost	Capital cost for equipment, site engineering, and installation O&M cost for chemical usage, electricity consumption, and labor

inventory, and general knowledge needed for relevant chemical processes and health and safety practices. The staffing requirements for the system operation were recorded on an Operator Labor Hour Log Sheet.

The cost of the system was evaluated based on the capital cost per gpm (or gpd) of design capacity and the O&M cost per 1,000 gal of water treated. This required tracking the capital cost for equipment, site engineering, and installation, as well as the O&M cost for salt supply, electrical power use, and labor.

The quantity of residuals generated was estimated by monitoring the flowrate and duration of each regeneration step (i.e., brine draw, slow rinse, and fast rinse) and tracking the number of regeneration cycles during the study period. Spent regenerant samples were collected and analyzed for chemical characteristics.

3.2 System O&M and Cost Data Collection

The plant operator performed daily, weekly, and monthly system O&M and data collection according to instructions provided by Kinetico and Battelle. The plant operator recorded system operational data, such as pressure, flowrate, system throughput, hour meter, and regeneration counter readings on a Daily System Operation Log Sheet; checked brine day tank and salt saturator levels; and conducted visual inspections for leaks or faults. If any problems occurred, the plant operator contacted the Battelle Study Lead, who would then determine if Kinetico should be contacted for troubleshooting. The plant operator recorded all relevant information, including problem encountered, course of action taken, materials and supplies used, and associated cost and labor incurred, on the Repair and Maintenance Log Sheet. On a weekly basis, the plant operator measured water quality parameters, including pH, temperature, dissolved oxygen (DO), and oxidation-reduction potential (ORP), and recorded the data on a Weekly Water Quality Parameters Log Sheet. During the study period, the system was regenerated automatically when triggered by a pre-determined throughput setpoint. Occasionally, system regeneration was initiated by the operator for sampling purposes.

The capital cost for the arsenic-removal system consisted of the cost for equipment, site engineering, and system installation. The O&M cost consisted primarily of the cost for salt use, electricity consumption,

and labor. Salt was delivered in bulk quantities by a company, Western Step Saver, Inc. in Boise, ID, on a weekly or as-needed basis to the treatment plant. Salt usage was tracked through monthly invoices. Electricity consumption was obtained from utility bills for the reporting period. Labor hours for routine system O&M, system troubleshooting and repairs, and demonstration-related work, were recorded daily on an Operator Labor Hour Sheet. Routine O&M included activities such as filling field logs and performing system inspections. Demonstration-related work, including activities such as performing field measurements, collecting and shipping samples, and communicating with the Battelle Study Lead, was recorded, but not used for cost analysis.

3.3 Sample Collection Procedures and Schedules

System operation during the performance evluation study underwent three distinct periods as discussed in Section 4.4. The plant operator collected water samples from the treatment plant/distribution system and/or during the IX resin regeneration process either on a regular basis as summarized in Table 3-3 or through special run length and regeneration studies as described in Sectgion 3.5.1. Table 3-3 provides the sampling schedule and analytes measured during each regular sampling event. Figure 3-1 presents a process flow chart, along with the sampling/analysis schedule, for the IX system. Specific sampling requirements for analytical methods, sample volumes, containers, preservation, and holding times are presented in Table 4-1 of the EPA-endorsed Quality Assurance Project Plan (QAPP) (Battelle, 2003).

3.3.1 Source Water. During the initial visit to the site on August 21, 2003, one set of source water samples was collected from Well No. 6 for detailed water quality analyses. Because it had not been in use due to elevated nitrate concentrations, the well was purged for several hours before the samples were taken from a temporary sample tap on a hose that discharged the purged water to the ground. The source water also was speciated onsite for particulate and soluble As, As(III) and As(V), and particulate and soluble iron (Fe), manganese (Mn), and aluminum (Al). Special care was taken to avoid agitation, which might cause unwanted oxidation. After completion of a replacement well, Well No. 6-2004, Battelle arranged source water samples to be taken from the new well by the plant operator on July 13, 2004.

3.3.2 Treatment Plant Water. Routine treatment plant water samples were collected only during Period I extending from June 14, 2005, through July 25, 2006. The plant operator collected water samples across the treatment train weekly on a 4-week cycle (exception for six sampling events that took place biweekly and one sampling event that took place in 3 weeks). For the first week of each 4-week cycle, water samples were collected for arsenic speciation at two locations (i.e., at the wellhead [IN] and at the combined effluent from Vessels A and B [TT]) and analyzed for the analytes listed under the monthly treatment plant analyte list in Table 3-3. For the other three weeks, treatment plant samples were collected at three locations (i.e., IN, after Vessel A [TA], and after Vessel B [TB]) and analyzed for the analytes listed under the weekly treatment plant analyte list in Table 3-3.

3.3.3 Regeneration Wastewater. Similar to treatment plant sampling, routine regeneration wastewater samples were collected only during Study Period I when the IX system was regenerated in a co-current mode. Co-current regeneration introduced brine solution and rinse water downward through each IX resin bed with spent brine/rinse water discharged from the bottom of the vessel to a floor drain. Starting from November 15, 2005, on eight separate occasions, one composite sample from each of the three regeneration steps (i.e., brine draw, slow rinse, and fast rinse) was collected during regeneration of each IX resin vessel. When the IX resin beds were regenerated, a portion of the effluent from each of the three regeneration steps was diverted to a 32-gal plastic container through a garden hose over the duration of each step (Figure 3-2). At the end of the regeneration, the content in the three containers was thoroughly mixed, and a portion of the liquid was transferred to sample bottles for total As, nitrate, sulfate, total dissolved solids (TDS), and pH analyses. Arsenic speciation was not performed on the wastewater samples.

Table 3-3. Sampling and Analysis Schedule at Fruitland, ID

Sample Type	Sampling Locations[a]	No. of Sampling Locations	Frequency	Analytes	Sampling Date
Source Water	IN	1	Three Times	As (total and particulate), As(III), As(V), Fe (total and soluble), Mn (total and soluble), Al (total and soluble), V (total and soluble), Mo (total and soluble), Sb (total and soluble), Na, Ca, Mg, Cl, F, NO_3, S^{2-}, SO_4, SiO_2, PO_4, TOC, alkalinity, turbidity, and pH	Well No. 6: 08/21/03 Well No. 6-2004: 07/13/04, 04/17/07
Treatment Plant Water	IN, TA, and TB	3	Weekly	Onsite: pH, temp., DO, and ORP Offsite: As (total), Fe (total), Mn (total), U (total), V (total), Mo (total), F, NO_3, SO_4, SiO_2, PO_4, P (total), alkalinity, and/or turbidity	06/23/05, 06/29/05, 07/06/05, 07/20/05, 08/03/05, 08/10/05, 08/24/05, 08/31/05, 09/07/05, 09/21/05, 09/28/05, 10/05/05, 10/26/05, 11/02/05, 11/16/05, 11/30/05, 01/04/06, 01/10/06, 01/25/06, 02/01/06, 02/08/06, 02/15/06, 03/01/06, 03/15/06, 03/29/06, 04/05/06, 04/26/06, 05/03/06, 05/09/06, 05/24/06, 05/31/06, 06/07/06, 06/21/06, 06/28/06, 07/06/06
	IN and TT	2	Monthly	Same as those for weekly samples plus following: Offsite: As (soluble), As(III), As(V), Fe (soluble), Mn (soluble), U (soluble), V (soluble), Mo (soluble), Ca, Mg, and TDS	06/15/05, 07/13/05, 08/17/05, 09/14/05, 10/12/05, 11/09/05, 12/14/05, 01/18/06, 02/22/06, 03/22/06, 04/19/06, 05/17/06, 06/14/06, 07/12/06
Distribution Water	One Non-LCR Residence and Two Non-Residential Locations	3	Monthly	pH, alkalinity, As (total), Fe (total), Mn (total), Pb (total), Cu (total), and NO_3	Baseline sampling:[b] 12/08/03, 01/06/04, 02/02/04, 03/02/04 Monthly Sampling: 06/29/05, 08/03/05, 08/24/05, 09/21/05, 10/26/05, 11/30/05, 12/15/05, 01/25/06, 02/22/06, 03/23/06, 04/19/06, 05/24/06, 06/14/06, 07/12/06
Regeneration Wastewater	Drain Pipe off Vessels A and B	6[c]	8 times	As (total), NO_3, SO_4, TDS, and pH	11/15/05, 01/11/06, 02/15/06, 04/04/06, 04/13/06, 05/09/06, 06/07/06, 07/06/06

(a) Abbreviations in parentheses corresponding to sample locations in Figure 3-1: IN = at wellhead, TA = after Vessel A, TB = after Vessel B, and TT = conbined effluent.
(b) Four baseline sampling events performed before system placed online.
(c) Three composite samples from each vessel for each regeneration steps (i.e.,brine draw, slow rinse, and fast rinse).

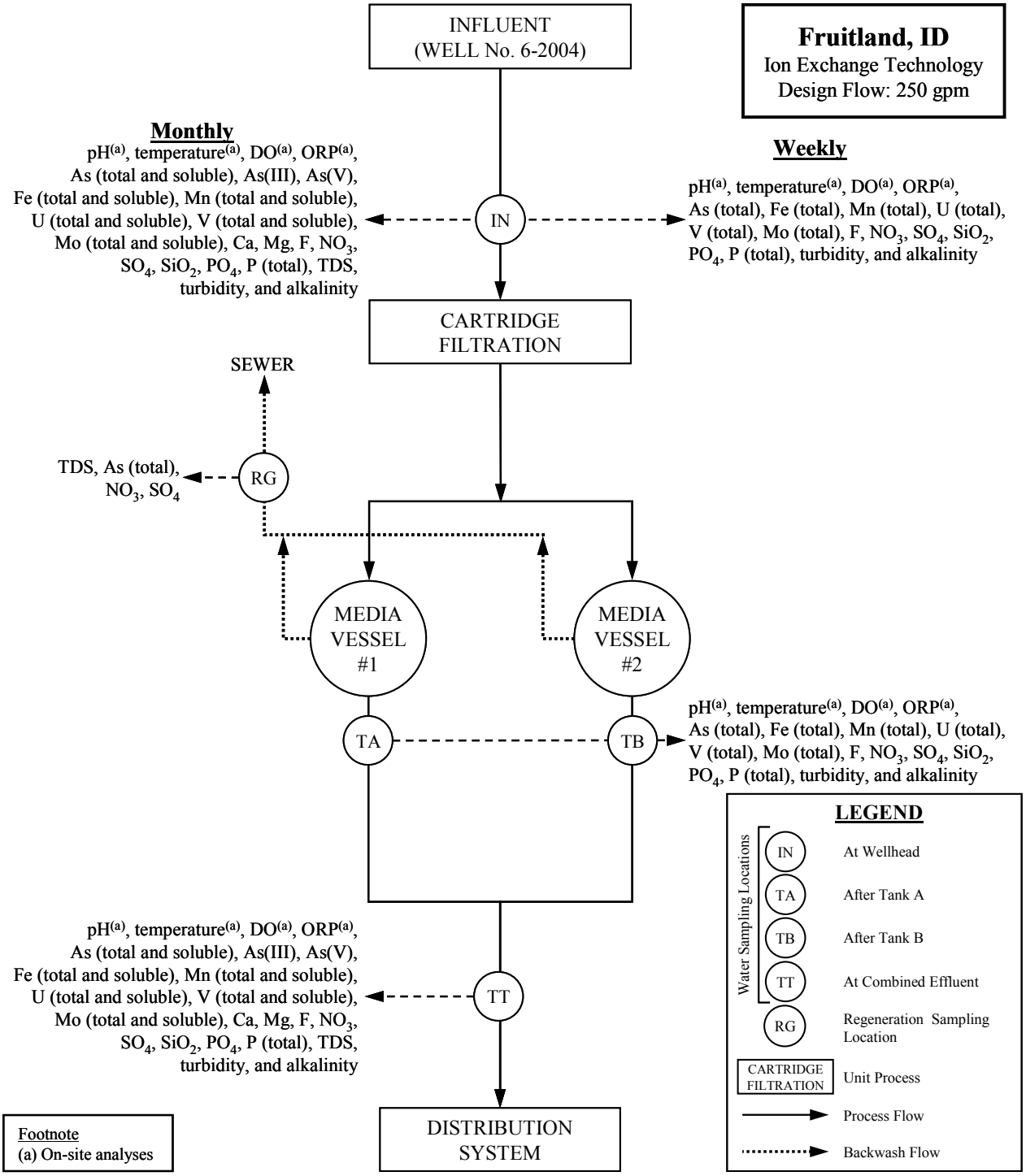


Figure 3-1. Process Flow Diagram and Sampling Locations/Analyses for Fruitland, ID IX System

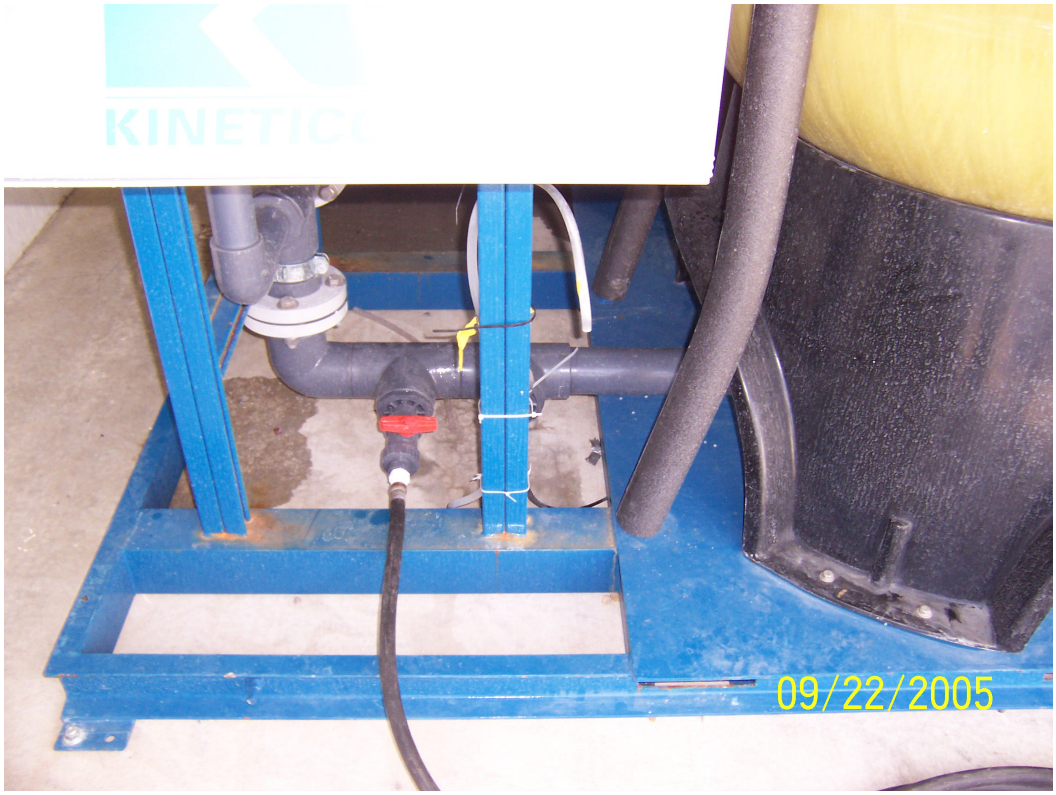


Figure 3-2. A Garden Hose Used for Residual Sampling from IX Resin Vessel

3.3.4 Distribution System Water. Water in the distribution system was sampled at three locations to determine the impact of the IX system on the water chemistry in the distribution system, specifically, the arsenic, nitrate, lead, and copper levels. Since the City of Fruitland had 11 wells to supply the distribution system, sampling locations were selected from a small area of homes that received water primarily from Well No. 6-2004. The sampling locations selected included one residence (the operator's house) and two non-residential locations, even though none of them was part of the city's Lead and Copper Rule (LCR) sampling locations.

The operator collected all of the samples following an instruction sheet developed according to the *Lead and Copper Rule Monitoring and Reporting Guidance for Public Water Systems* (EPA, 2002). First-draw samples were collected from a cold-water faucet that had not been used for at least six hours to ensure that stagnant water was sampled. The sampler recorded the date and time of last water use before sampling and the date and time of sample collection for calculation of the stagnation time. Arsenic speciation was not performed on these samples.

From December 2003 to March 2004 prior to system startup, four monthly samples were collected from the locations within the distribution system to establish the baseline condition. Following system startup in June 2005, distribution system sampling continued on a monthly basis at the same three locations during Study Period I. Analytes for the distribution system sampling are presented in Table 3-3.

3.4 Real-Time Arsenic Monitoring with ArsenicGuard

On May 7, 2007, a real-time total arsenic analyzer, ArsenicGuard, was installed to monitor total arsenic concentrations in IX system effluent at the TT location.

The ArsenicGuard analyzer (Figure 3-3) was developed by TraceDetect, Inc. to measure total inorganic arsenic in drinking and groundwater via Anodic Stripping Voltammetry (ASV) using a gold-coated Nano-Band™ electrode. The normal measurement range is 1 to 25 µg/L. The analyzer also supports dilution up to 50:1, so the measurement range can be extended upwards to 50 to 1,250 µg/L. As claimed by the vendor, the accuracy in the normal range is 1 µg/L or ±20% (whichever is larger), and 50 µg/L or ±20% for the extended range. Because the sensor is only sensitive to arsenite, sample treatment is required prior to actual measurements. Each measurement starts with acidification of a sample to pH ~0.7 with 2M hydrochloric acid (HCl), followed by reduction of all arsenate to arsenite via a reducer not specified by the vendor. The instrument then makes calibrated measurements by first scanning for arsenic in the treated sample, followed by adding a metered quantity of arsenite (the spike) and re-scanning. From these steps, a two-point calibration curve is derived for each sample tested. The result of each measurement is displayed on the front screen of the analyzer.

The ArsenicGuard utilizes electrochemical plating and a stripping technique to measure part-per-billion (ppb) quantities of arsenic. The treated sample is drawn into a measurement cell, which houses a sensor, a reference electrode, and an auxiliary electrode. The voltage of this electrochemical cell is manipulated so that arsenic is first plated on to the tip of the sensor during an accumulation phase, and then stripped off the sensor during a stripping phase. The duration of the accumulation phase is adjusted to ensure a good stripping signal, i.e., high concentrations are measured using a short accumulation time and low concentrations using a longer accumulation time. The sensing action occurs during the stripping phase of the measurement. During this phase, the voltage of the electrochemical cell is ramped from the accumulation potential, past the stripping potential for arsenic. When arsenic is stripped off the sensor, it dissolves back into the test solution. This stripping process releases three electrons per arsenic atom and, therefore, the amount of arsenic accumulated on the tip of the sensor is proportional to the current measured during the stripping operation. This current is recorded for the treated sample as well as for the spiked sample to calculate the arsenic concentration in the original sample stream.

3.5 IX Resin Run Length and Spent IX Resin Regeneration Studies

3.5.1 IX Resin Run Length Studies. Because the routine weekly samples collected from the treatment plant only represented discrete data points from multiple service runs, it was necessary to collect samples from several complete service runs to delineate arsenic and nitrate breakthrough curves and to determine the appropriate run length of the IX system. The results of the studies were used to optimize system performance. Table 3-4 summarizes sampling and analytical schedules of six run length studies, during which effluent samples were collected from either one or both vessels throughout the set service runs. A combined effluent totalizer was used to track the volume of water treated between two consecutive regeneration cycles. The totalizer was automatically reset to "zero" when regeneration of Vessel A was complete and regeneration of Vessel B just began. The reset of the totalizer also signaled the beginning of the service run. The service run ended when the totalizer reached a preset throughput value, which triggered the next regeneration cycle. Additional information for each of the studies is provided below.

Run Length Study 1: Between July 28 and 30, 2005, a vendor technician was onsite to collect samples of the combined effluent from both resin vessels during one service run and perform field measurements for the analytes shown in Table 3-4. Sampling began when Vessel A had completed regeneration and gone into service and when Vessel B had just begun regeneration. Hourly samples were collected until

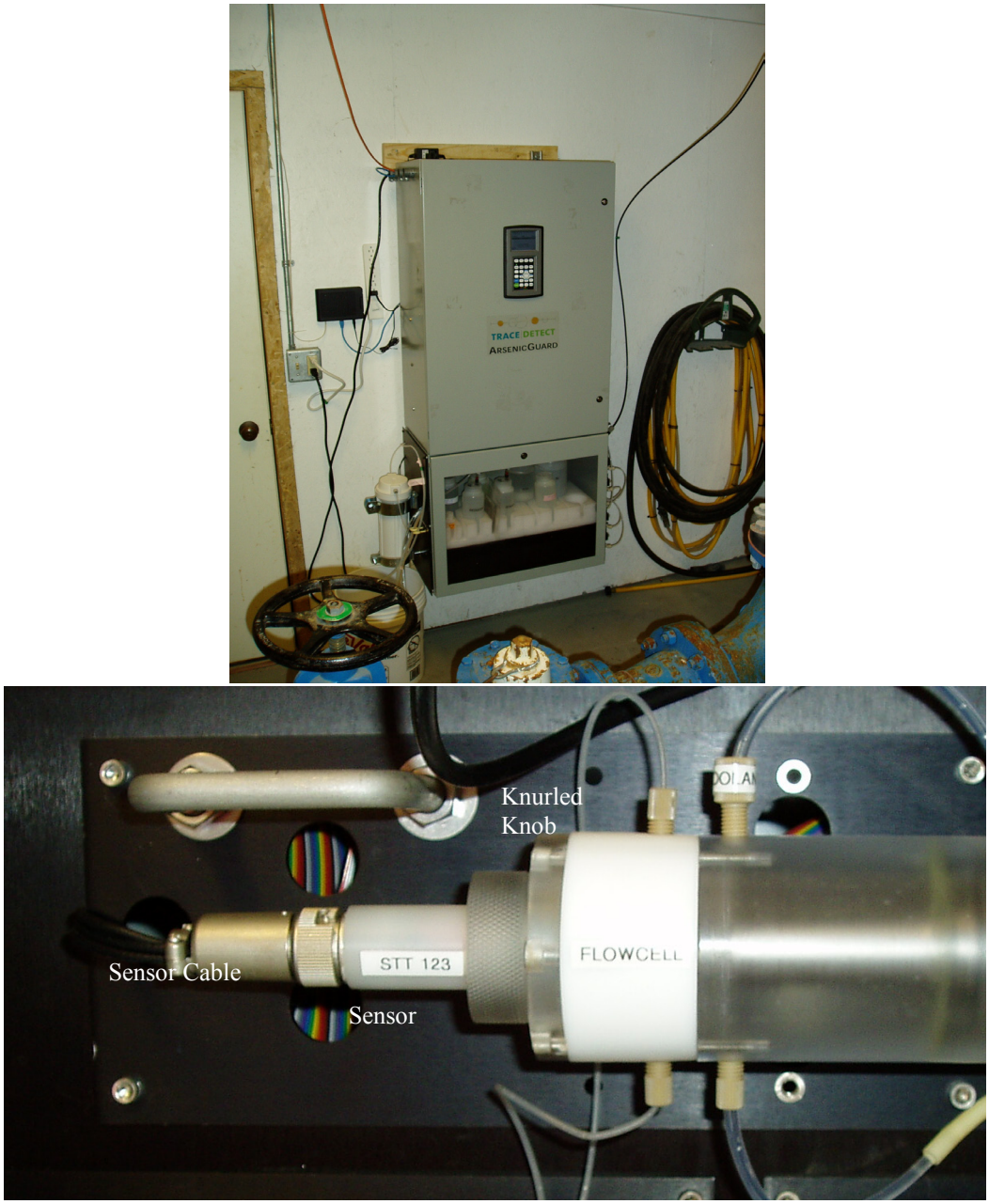


Figure 3-3. Real-Time Arsenic Analyzer – ArsenicGuard

392,000 gal (524 BV) of water was processed. In addition, operational parameters, such as system inlet and outlet pressure, flowrate, and throughput were recorded every hour. Arsenic was analyzed onsite using a Quick™ arsenic test kit (Industrial Test Systems) and a 28°C water bath to maintain the required sample temperature between 24 and 30°C. Nitrate was measured using Hach nitrate test tubes (CAT No. 14037-00). pH was measured using Macerey-Nagel pH 0-14 test strips. Conductivity was taken using a Myron-L, National Institute of Standards and Technology (NIST)-certified meter. Because effluent arsenic and nitrate concentrations reached detectable levels of 2 µg/L and 5 mg/L, respectively, at approximately 400 BV (see Section 4.5.2), the regeneration throughput setpoint was upwardly adjusted from 214,000 gal (or 286 BV) to 335,000 gal (or 448 BV) on July 30, 2005.

Table 3-4. Sampling and Analysis Schedules for Resin Run Length Studies

No.	Date	Run Length Setpoint (gal)	Run Length Setpoint (BV)	Regeneration Mode	Sampling Location	Number of Samples	Analytes	Reason for Study
1	07/28/05–07/30/05	214,000[a]	286	Co-current	IN[b], TT	30	As (total), NO_3, conductivity, pH, and temperature (onsite measurements only)	To determine proper service run length/regeneration frequency after system startup
2	08/16/05–08/17/05	335,000	448	Co-current	IN[b], TA	11	As (total) and NO_3	To further delineate breakthrough behavior after run length had been increased
3	12/07/05–12/08/05	316,000	422	Co-current	IN[b], TA, TB	20	As (total), U (total), V (total), Mo (total), NO_3, SO_4, alkalinity, and pH	To further delineate breakthrough behavior after run length had been slightly decreased
4	04/11/06–04/12/06	316,000	422	Co-current	IN[b], TA, TB	20	As (total) and NO_3	To further delineate breakthrough behavior after brine concentration had been reduced from 8% to 6%
5	08/09/06–08/10/06	316,000	422	Counter-current	IN[b], TA, TB	20	As (total), V (total), NO_3, and pH	To further delineate breakthrough behavior after regeneration had been changed from co- to counter current mode
6	01/17/07–01/18/07	316,000	422	Counter-current	TA, TB	20	As (total) and NO_3	To further delineate breakthrough behavior after brine eductor had been replaced with a brine injection pump per vendor recommendation

(a) Although set at 214,000 gal, system regeneration not taking place until 392,000 gal (524 BV).
(b) Inlet sample collected once at beginning of respective run length studies.

Run Length Study 2: On August 16 and 17, 2005, the plant operator collected a series of samples from Vessel A to help construct arsenic and nitrate breakthrough curves. Sampling at TA began approximately 30 min after regeneration of Vessel A had been completed, and continued by intervals of 1 to 3 hr, except during the night. Flowrates and throughput values were recorded at the time of sampling for calculations of the run length. The samples collected were sent to Battelle for arsenic and nitrate analyses.

Run Length Study 3: Following another adjustment to the throughput setpoint from 335,000 gal (or 448 BV) to 316,000 gal (or 422 BV) on September 19, 2005, Battelle staff and the plant operator collected 10 samples from each IX resin vessel during September 22 through 23, 2005, to further examine arsenic and nitrate breakthrough from the IX system. Sampling from each vessel was repeated on December 7 and 8, 2005, because, for unknown reasons, arsenic and nitrate concentrations in all samples collected on September 22 and 23, 2005, were similar to those in raw water. The first TA and TB samples on December 7, 2005, were collected approximately 30 min after completion of Vessels A and B regeneration. Subsequent samples were taken every 1 to 3 hr thereafter, except during the night. The last sample was collected at 288,000 gal before reaching the 316,000-gal setpoint. The samples collected were sent to Battelle for the analytes listed in Table 3-4.

Run Length Study 4: Following reduction of brine concentrations from 8% to 6% on March 5, 2006, the plant operator collected 10 samples from each IX resin vessel during April 11 through 12, 2006, to examine arsenic and nitrate breakthrough from the IX system. An inlet sample was collected once at the beginning of the study. The first TA and TB samples were collected approximately 20 min after regeneration of the respective vessels. Subsequent samples were taken every 1 to 4 hr thereafter, except during the night. The last sample was collected just before the 316,000-gal setpoint. The samples collected were sent to Battelle for the analytes listed in Table 3-4.

Run Length Study 5: After switching from co-current to counter-current mode on July 25, 2006 (Section 4.4.3.1), the plant operator collected 10 samples from each IX resin vessel during August 9 through 10, 2006, to investigate arsenic and nitrate breakthrough after the system had been regenerated in a counter-current mode. The first TA and TB samples were collected immediately after regeneration of the respective vessels. Subsequent samples were taken every 1 to 4 hr thereafter, except during the night. The last sample was collected just before the 316,000-gal setpoint. The samples collected were sent to Battelle for the analytes listed in Table 3-4.

Run Length Study 6: Another run length study was conducted on January 16 and 17, 2007, after a brine injection pump was installed (to replace the originally installed eductor) and modifications to counter-current regeneration were completed (Section 4.4.3.1). The plant operator collected samples from each IX resin vessel to examine arsenic and nitrate breakthrough following regeneration in a counter-current mode. Similar to Run Length Study 5, the first TA and TB samples were collected immediately after regeneration. Subsequent samples were taken every 1 to 4 hr thereafter (except during the night). The last sample was collected just before the 316,000-gal setpoint. The samples collected were sent to Battelle for the analytes listed in Table 3-4.

3.5.2 Spent IX Resin Regeneration Studies. The regeneration scheme was adjusted several times to improve brine regeneration efficiency and minimize waste production. Two elution studies were performed to evaluate the effectiveness of the IX resin regeneration process and determine the quantity and chemical characteristics of the residuals. Table 3-5 summarizes sampling schedules, analytes measured, and corresponding regeneration settings.

Table 3-5. Sampling and Analysis Schedules for Spent Resin Regeneration Studies

No.	Date	Throughput of Previous Service Run (gal)	Regeneration Steps	Duration (min)	Number of Grab Samples	Number of Composite Samples	Analytes
1	07/30/05	392,000	Brine Draw	32	31	Not collected	specific gravity and conductivity
			Slow Rinse	64	61		
			Fast Rinse	30	28		
2	09/22/05	316,000	Brine Draw	32	8	1	TDS, pH, alkalinity, total As, U, V, and Mo, NO_3, and SO_4
			Slow Rinse	64	6	1	
			Fast Rinse	6	2	1	

Elution Study 1. During a trip to Fruitland in July 2005, a vendor technician changed the brine concentration from 4% to 8% and the brine draw time from 64 to 32 min in an attempt to maintain a target regeneration level of 10 lb NaCl/ft^3 resin. Upon completion of Run Length Study 1 as described above, the technician continued to perform the regeneration study by monitoring the conductivity and specific gravity of regeneration wastewater using a Myron-L NIST-certified meter and a hydrometer every minute. Regenerant and rinse samples were not taken for arsenic and nitrate analyses.

Elution Study 2. To further characterize regeneration residuals, Battelle staff conducted an elution study on both IX resin vessels on September 22, 2005. The test apparatus used was similar to that described in Section 3.3.3 except that a flow-through cell attached to the inner rim of a 32-gal plastic container (Figure 3-4) was used to receive regeneration wastewater continuously during each of the three regeneration steps. Probes/electrodes associated with a Hanna HI 9635 conductivity/TDS meter (Hanna Instruments, Inc., Woonsockett, RI) and a WTW Multi 340i handheld meter (VWR) were placed in the flow-through cell for continuous measurements of conductivity/TDS, pH, and temperature during regeneration. The time elapsed and flow totalizer readings also were recorded every 1 to 2 min once regeneration began. Grab samples were collected every 4 to 6 min by filling up sample bottles with the overflow from the flow-through cell. At the end of the regeneration cycle, the content in each 32-gal container was thoroughly mixed and a composite sample was collected from each container. The samples were shipped to Battelle for the analytes listed in Table 3-5.

3.6 IX Resin Cleaning and Analysis

The IX resin was fouled due to the presence of total organic carbon (TOC) and repeatedly unsuccessful regenerations of the IX resin in the counter-current mode. Core samples were collected from Vessels A and B by Kinetico on March 28, 2007. The samples were sent to Purolite, cleaned in its laboratory with a mixture of 2% NaOH and 10% brine, and analyzed before and after the caustic/brine cleaning. Analytes included moisture content, volumetric capacity, strong base capacity, and total organic fouling. The results are discussed in Section 4.5.5.

The IX resin in both vessels was washed with a 5% caustic/10% brine mixture on June 19, 2007. The caustic/brine mixture was prepared by dispensing 55 gal of a 50% NaOH concentrate to the brine day tank using a drum pump followed by filling the day tank with brine up to 550 gal. The specific gravity of the mixture was 1.045, corresponding to a 6% brine solution. The caustic/brine mixture was drawn downward through the vessels (one at a time) at 48 gpm for about 25 min. By the end of brine draw, a hand valve was closed manually to allow the IX resin to soak in the caustic/brine mixture for 30 min. Slow rinse was then conducted at 38 gpm for about 40 min. Following the slow rinse, fast rinse was conducted at 72 to 74 gpm for about 15 min. Upon completion, the IX vessels were subject to another

round of regular co-current regeneration. Co-current regeneration was used due to the difficulties encountered in the counter-current regeneration mode (Section 4.4.3).

Upon completion of the regeneration with caustic/brine, a core sample was then taken from Vessel B and sent to Purolite for analysis. The same set of analytes above was analyzed for this sample.

3.7 Sampling Logistics

All sampling logistics including arsenic speciation kit preparation, sample cooler preparation, and sample shipping and handling are discussed as follows.

3.7.1 Preparation of Arsenic Speciation Kits. The arsenic field speciation method used an anion exchange resin column to separate the soluble arsenic species, As(V) and As(III) (Edwards et al., 1998). Arsenic speciation kits were prepared in batches at Battelle laboratories according to the procedures detailed in Appendix A of the EPA-endorsed QAPP (Battelle, 2003).

3.7.2 Preparation of Sampling Coolers. For each sampling event, a sample cooler was prepared with the appropriate number and type of sample bottles, disc filters, and/or speciation kits. All sample bottles were new and contained appropriate preservatives. Each sample bottle was taped with a pre-printed, colored-coded, and waterproof label. The sample label consisted of sample identification (ID), date and time of sample collection, collector's name, site location, sample destination, analysis required, and preservative. The sample ID consisted of a two-letter code for a specific water facility, sampling date, a two-letter code for a specific sampling location, and a one-letter code for the specific analysis to be performed. The sampling locations were color-coded for easy identification.

Figure 3-4. Field Setup for Arsenic/Nitrate Regeneration Study

For example, red, yellow, green, and blue were used for IN, TA, TB, and TT sampling locations. Pre-labeled bottles for each sampling location were placed in separate zip-lock bags (each corresponding to a specific sampling location), which were then packed in a sample cooler. When arsenic speciation samples were to be collected, arsenic speciation kits also were included in the cooler.

When appropriate, the sample cooler was packed with bottles for the three distribution system sampling locations. In addition, a packet containing all sampling and shipping-related supplies such as latex gloves, sampling instructions, chain-of-custody forms, prepaid FedEx air bills, and bubble wrap also was placed in the cooler. Except for the operator's signature, the chain-of-custody forms and prepaid FedEx air bills had already been completed with the required information. The sample coolers were shipped via FedEx to the facility approximately 1 week prior to the scheduled sampling date.

3.7.3 Sample Shipping and Handling. After sample collection, samples for off-site analyses were packed carefully in the original coolers with wet ice and shipped to Battelle. Upon receipt, sample custodians verified that all samples indicated on the chain-of-custody forms were included and intact. Sample IDs were checked against the chain-of-custody forms and the samples were logged into the laboratory sample receipt log. Any discrepancies were addressed with the field sample custodian, and the Battelle Study Lead was notified.

Samples for metal analyses were stored at Battelle's inductively coupled plasma-mass spectrometry (ICP-MS) laboratory. Samples for other water quality analyses were packed in coolers and picked up by couriers from American Analytical Laboratories (AAL) in Columbus, OH, or TCCI Laboratories in New Lexington, OH, both of which were under contract with Battelle for this demonstration study. The chain-of-custody forms remained with the samples from the time of preparation through analysis and final disposal. All samples were archived by the appropriate laboratories for the respective duration of the required hold time and disposed of properly thereafter.

3.8 Analytical Procedures

The analytical procedures described in detail in Section 4.0 of the EPA-endorsed QAPP (Battelle, 2003) were followed by Battelle ICP-MS, AAL, and TCCI Laboratories. Laboratory quality assurance/quality control (QA/QC) of all methods followed the prescribed guidelines. Data quality in terms of precision, accuracy, method detection limit (MDL), and completeness met the criteria established in the QAPP, i.e., relative percent difference (RPD) of 20%, percent recovery of 80% to 120%, and completeness of 80%. The QA data associated with each analyte will be presented and evaluated in a QA/QC summary report to be prepared under separate cover and to be shared with the Arsenic Demonstration Project.

Field measurements of pH, temperature, DO, and ORP were conducted by the plant operator using a WTW Multi 340i handheld meter, which was calibrated for pH and DO prior to use following the procedures provided in the user's manual. The ORP probe also was checked for accuracy by measuring the ORP of a standard solution and comparing it to the expected value. The plant operator collected a water sample in a clean, plastic beaker and placed the Multi 340i probe in the beaker until a stable value was obtained.

4.0 RESULTS AND DISCUSSION

4.1 Facility Description

The City of Fruitland is located in southwest Idaho, approximately 50 miles northwest of Boise on Highway I-95. It has multiple production wells (Wells No. 1, 5, 6, 9, 10, 11, 12, 14, 15, 16, and 20) that supply water to approximately 4,000 residents. Well No. 6, originally selected for this demonstration project, is located on South Utah Street between Southwest 4th and 7th Streets. Drilled in 1973 using a rotary drilling method, the well was installed in a 24-in-diameter by 204-ft-deep borehole to a total depth of 199 ft below ground surface (bgs). The well was lined with a 12-in-diameter steel casing extending from 3 ft above ground to 109 ft bgs and a 10-in-diameter steel casing extending from 109 to 199 ft bgs. The well had four screened sections: 44 to 54 ft bgs, 58 to 68 ft bgs, 109 to 119 ft bgs, and 179 to 189 ft bgs. The static water level was 36.4 ft bgs. A submersible pump placed at 105 ft bgs was rated at 250 gpm. A downhole camera survey on October 29, 1998, indicated that 90% of the third screen (109-119 ft bgs) was plugged and that the fourth screened section was completely buried in sediment. Well No. 6 was taken offline since January 2000 due to levels higher than the nitrate MCL in the well water. There was no water treatment in place prior to the installation of the IX system.

Problems with sediment production were encountered with Well No. 6 during the shakedown of the IX system in March 2004. A replacement well, Well No. 6-2004, was installed in June 2004 in a 20-in-diameter by 140-ft-deep borehole to a total depth of 125 ft bgs using a cable tool drilling method at a location approximately 25 ft from the existing well (see more details in Section 4.3). The well was constructed of a 12-in-diameter steel casing with three screened sections: 50 to 70 ft bgs, 95 to 105 ft bgs, and 110 to 120 ft bgs. The submersible pump from the old Well No. 6 was placed into the new well at 105 ft bgs. Well pumping tests indicated that this well could produce about 200 gpm of water while maintaining a similar static water level at 36.3 ft bgs (aggressive pumping was not desired by the city due to its concern over potential subsidence of the ground).

4.1.1 Source Water Quality. Source water samples were collected from the old Well No. 6 on August 21, 2003, and from the replacement well, Well No. 6-2004, on July 13, 2004, and then April 17, 2007, about 22 months into the performance evaluation study to confirm the source water quality. Table 4-1 presents the analytical results of both wells and compares them with the data provided by the city to EPA for the demonstration site selection and with the data independently collected by EPA and the vendor. Figure 4-1 plotted historic nitrate data for Well No. 6 obtained from IDEQ. Tables 4-2 and 4-3 summarize historic data of several heavy metals, fluoride, and radiological analytes for Well No. 6. Based on the data, water quality of Well No. 6-2004 was very similar to that of Well No. 6 and remained rather consistent during the entire study period.

Arsenic Species. Total arsenic concentration in the new well (Well No. 6-2004) ranged from 48.5 to 49.7 µg/L, existing mostly in a soluble form (39.9 µg/L according to July 13, 2004, data). Although total arsenic concentrations in the new well were higher than those in the old well (Well No. 6, which ranged from 32 to 46 µg/L as shown in Tables 4-1 and 4-2), soluble arsenic concentrations were comparable between the two wells (i.e., 39.9 vs. 40.1 µg/L). The higher particulate arsenic concentration observed (i.e., 9.8 vs. 3.4 µg/L) might be caused by insufficient well purging or sample tap flushing. Some particulate arsenic and/or well sediment might be removed by the bag filters (with 20 µm nominal pore size) located upstream of the IX resin vessels. Removal of particulate matter and sediment can help alleviate adverse effects on the resin beds. Similar to the old well, most soluble arsenic existed as As(V) (i.e., $H_2AsO_4^-$ at 39.0 µg/L) with only a small amount existing as As(III) (i.e., H_3AsO_3 at 1.0 µg/L). Because IX resin is effective at removing arsenate, pre-oxidation of the water upstream of the IX process was not required.

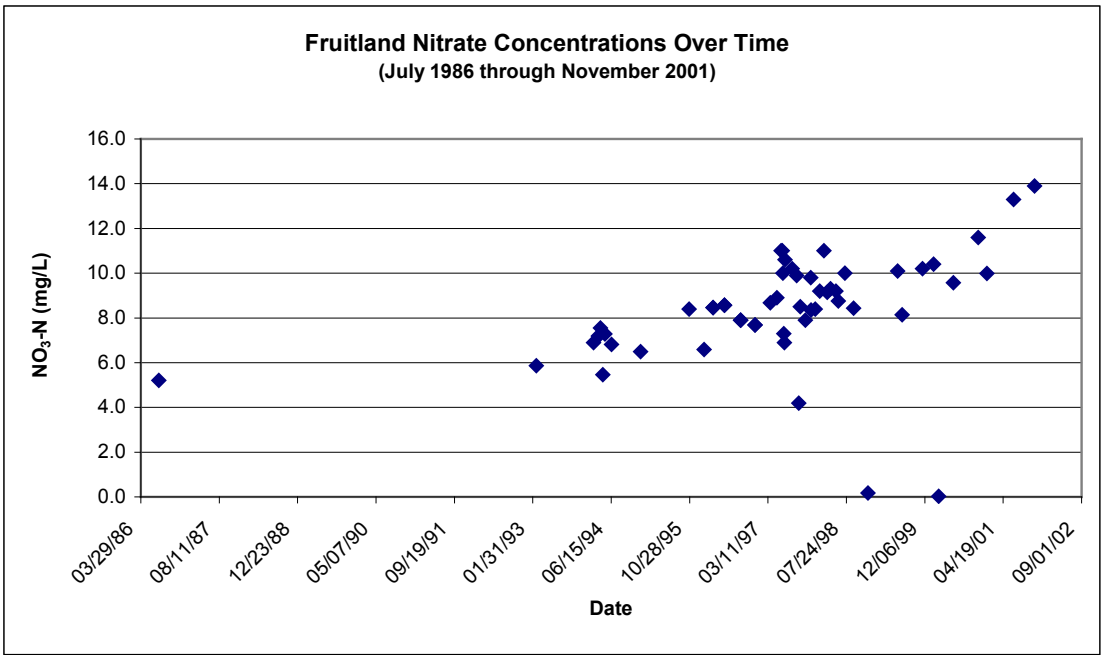
Table 4-1. Source Water Quality Data of Old and Replacement Wells

Parameter	Unit	Facility Data	U.S. EPA Data	Kinetico Data	\Battelle Data		
	Well ID	**No. 6**	**No. 6**	**No. 6**	**No. 6**	**No. 6-2004**	
	Sampling Date	**NA**	**08/28/02**	**NA**	**08/21/03**	**07/13/04**	**04/17/07**
pH	S.U.	7.4	NS	7.6	7.4	7.4	NS
Total Alkalinity (as $CaCO_3$)	Mg/L	357	NS	388	381	379	418
Hardness (as $CaCO_3$)	Mg/L	252	251	271	233	240	269
Chloride	Mg/L	14.0	NS	17.8	16.0	12.0	NS
Fluoride	Mg/L	NS	NS	0.72	1.0	0.6	NS
Nitrate (as N)	Mg/L	5.2–13.9	NS	8.7	NS	14.0	10.8
Sulfate	Mg/L	60.0	57.3	64.0	58.0	53.0	57.0
Silica (as SiO_2)	Mg/L	57.8	54.3	57.8	55.1	57.4	59.1
Orthophosphate (as PO_4)	Mg/L	0.1	NS	0.3 (as P)	<0.1	<0.1	NS
TOC	Mg/L	0.1	NS	NS	<1.0[(a)]	2.2	1.6
As (total)	µg/L	37.0	41.0	44.0	43.5	49.7	48.5
As (soluble)	µg/L	NS	NS	NS	40.1	39.9	NS
As (particulate)	µg/L	NS	NS	NS	3.4	9.8	NS
As (III)	µg/L	8.0	NS	NS	0.8	1.0	NS
As (V)	µg/L	34.0	NS	NS	39.3	39.0	NS
Fe (total)	µg/L	10–190	744	450	<30	268	<25
Fe (soluble)	µg/L	NS	NS	NS	<30	<25	NS
Al (total)	µg/L	NS	120	NS	21	151	NS
Al (soluble)	µg/L	NS	NS	NS	<10	<10	NS
Mn (total)	µg/L	50.0	32.0	50.0	1.6	28.3	12.5
Mn (soluble)	µg/L	NS	NS	NS	0.5	18.0	NS
V (total)	µg/L	NS	NS	NS	36.2	34.0	NS
V (soluble)	µg/L	NS	NS	NS	35.1	33.7	NS
Mo (total)	µg/L	NS	NS	NS	9.7	6.2	NS
Mo (soluble)	µg/L	NS	NS	NS	9.2	6.6	NS
Sb (total)	µg/L	NS	<25	NS	<0.1	<0.1	NS
Sb (soluble)	µg/L	NS	NS	NS	<0.1	<0.1	NS
Na	Mg/L	107	104	118	97	114	NS
Ca	Mg/L	60.5	60.0	66.0	55.0	51.3	NS
Mg	Mg/L	25.4	24.6	26.0	23.1	27.2	NS

(a) Sample collected on October 14, 2003.
NS = Not sampled

Nitrate. Nitrate concentrations in the new well were 14.0 mg/L (as N) on July 13, 2004, and 10.8 mg/L (as N) on April 17, 2007, which were comparable to the levels over the higher end in the old well (Figure 4-1). As shown in the figure, nitrate concentrations in the old well increased from 5.2 mg/L in July 1986 to 13.9 mg/L in November 2001. According to the vendor, the A300E IX resin selected for Fruitland had a similar run length for both arsenate and nitrate, thus maximizing system efficiency.

Sulfate. Sulfate concentrations in the new well were 53.0 mg/L on July 13, 2004, and 57.0 mg/L on April 17, 2007. These concentrations were slightly lower than those (from 57.3 to 64.0 mg/L) in the old well (see Table 4-1). Because sulfate is more preferred by the A300E IX resin than arsenate and nitrate and because of its higher concentrations, sulfate is a strong competing anion for arsenic and nitrate removal.



Source: IDEQ

Figure 4-1. Historic Well No. 6 Nitrate Concentrations

Table 4-2. Historic Well No. 6 Heavy Metals and Fluoride Data

Analyte	10/24/95	07/28/98	03/30/00	06/26/00	11/05/01
	Concentration (mg/L)				
Arsenic	0.046	0.043	0.034	0.032	0.039
Antimony	<0.005	<0.005	NS	NS	<0.005
Barium	0.05	0.06	NS	NS	0.06
Beryllium	<0.0005	<0.0005	NS	NS	<0.0005
Cadmium	<0.0005	<0.0005	NS	NS	<0.0005
Chromium	0.002	0.002	NS	NS	0.002
Mercury	<0.0005	<0.0002	NS	NS	<0.0002
Nickel	<0.02	<0.02	NS	NS	<0.02
Selenium	<0.005	<0.005	NS	NS	<0.005
Sodium	85.8	67.7	NS	NS	110
Thallium	<0.002	<0.002	NS	NS	<0.002
Fluoride	0.68	0.68	NS	NS	0.65

Source: IDEQ
NS = Not sampled

Other Water Quality Parameters. TDS concentration in source water was not measured, but estimated to be 560 mg/L based on 114 mg/L sodium, 51.3 mg/L of calcium, 27.2 mg/L of magnesium, 379 mg/L of bicarbonate, 12.0 mg/L of chloride, 0.6 mg/L of fluoride, 14.0 mg/L of nitrate, 53.0 mg/L of sulfate, and 57.4 mg/L silica after taking into account the loss of CO_2 and H_2O upon evaporation of $Ca(HCO_3)_2$ and $Mg(HCO_3)_2$. This estimated TDS value agreed with the average TDS of 580 mg/L measured during the performance evaluation study (see Table 4-13). Other dissolved ions present included 33.7 µg/L of vanadium and 6.6 µg/L of molybdenum. The uranium concentration measured on December 6, 2000 was

Table 4-3. Historic Well No. 6 Radiological Data

Sampling Date	Radium 226 (pCi/L)	Uranium (µg/L)	Gross Alpha Activity (pCi/L)	Gross Beta Activity (pCi/L)
10/24/95	NS	NS	12.8±4.3	6.3
12/06/95	0.0±0.2	NS	NS	NS
03/04/96	0.0±0.1	NS	NS	NS
06/06/96	0.0±0.2	NS	NS	NS
09/17/96	0.1±0.2	NS	NS	NS
06/08/00	NS	NS	19.7	6.6
09/29/00	NS	NS	23.2	13.9
12/06/00	NS	22.4	21.7	13.4
06/25/01	NS	NS	11.2	14.3
11/05/01	NS	NS	17.5	15.1
03/08/02	<0.2	NS	NS	NS

Source: IDEQ
NS = Not sampled; pCi/L = picoCuries per liter

22.4 µg/L (Table 4-3), lower than its MCL of 30 µg/L. Iron and aluminum were present primarily as particulates; the dissolved species were below the respective detection limits. The pH value of raw water was 7.4. Unlike adsorptive media, IX resins are not sensitive to water pH.

4.1.2 Distribution System and Treated Water Quality. The City of Fruitland has a looped drinking water distribution system with water from multiple production wells entering the distribution system at various locations. During the performance evaluation study, water produced from Wells No. 5, 9, and 10 was pumped into a reservoir, which was then connected to the distribution network. Water from Wells No. 14 and 20 was blended prior to entering the distribution system. The distribution system was constructed of asbestos cement pipe in the area of Well No. 6, but some sections in other areas of the city were constructed of polyvinyl chloride (PVC) pipe. During periods in which production exceeded demand, the excess was stored in one 1,000,000-gal ground level storage tank and one 200,000-gal elevated storage tank. The well pumps were controlled by level sensors in the storage tanks.

Process water from the IX treatment system entered the distribution system via a 6-in-diameter line, from which a branch line delivered water to a small area of homes receiving primarily Well No. 6-2004 water. Service lines to these individual homes were mainly copper, while the lines within these homes were constructed of galvanized iron, copper, and polyethylene. Three sampling locations were selected from this area for the distribution system sampling (Section 3.3.4).

The City of Fruitland sampled water from the distribution system for several analytes. Four monthly samples were collected from six locations for fecal coliform analysis. Samples also were taken for asbestos analysis every three years. Under the EPA LCR, samples were collected from customer taps at 10 locations every three years.

4.2 Treatment Process Description

4.2.1 Ion Exchange Process. IX is a proven technology for removing arsenic and nitrate from drinking water supplies (Clifford, 1999; Ghurye et al., 1999; and Wang et al., 2002). It is a physical/chemical process that removes dissolved arsenate and nitrate ions from water by exchanging them with chloride ions on anionic IX resins. Once its exchange capacity is exhausted, IX resins are

regenerated with a brine solution containing high concentrations of chloride ions to displace the arsenate and nitrate ions. Strong-base anionic (SBA) exchange resins are commonly used for arsenate and nitrate removal. Resin capacity is not sensitive to water pH (in the range of 6.5 to 9.0). An SBA exchange resin tends to have a higher affinity for more highly charged anions, resulting in a general hierarchy of selectivity as follows:

$$SO_4^{2-} > HAsO_4^{2-} > NO_3^- > NO_2^- > Cl^- > H_2AsO_4^-, HCO_3^- >> Si(OH)_4; H_3AsO_4$$

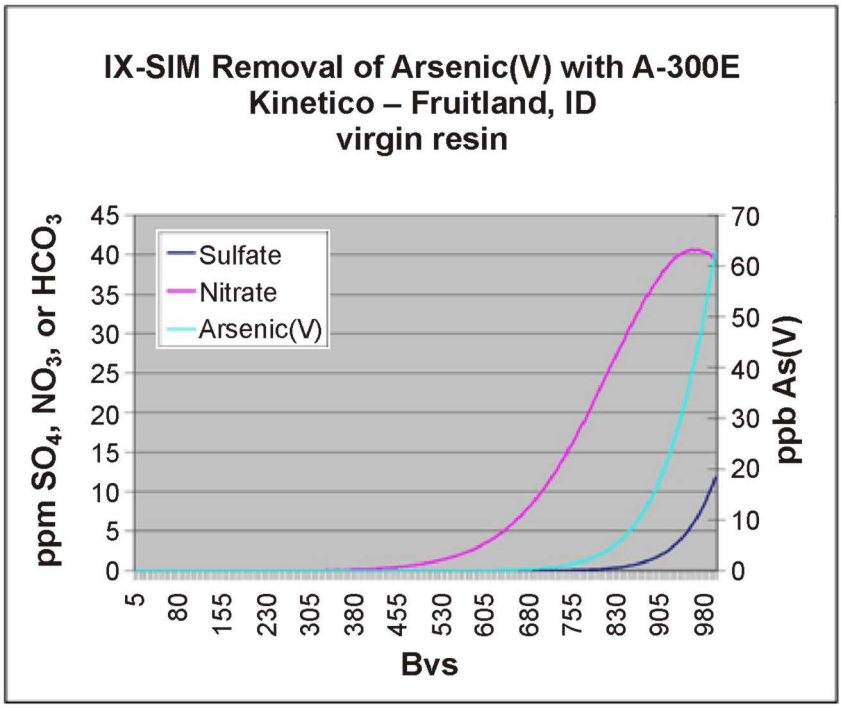
Because sulfate is more preferred over arsenic and nitrate and because its concentrations are at least three orders of magnitude higher than those of arsenic, it is a key competing anion to arsenic and nitrate removal by the IX process. High TDS levels also can significantly reduce arsenic and nitrate removal efficiencies. In general, the IX process is not economically attractive if source water contains >500 mg/L of TDS and >150 mg/L of sulfate. Also, particulates in feed water can potentially foul the SBA IX resin, and must be removed by bag filters upstream of an IX vessel.

The Fruitland IX system used Purolite A300E, a Type II SBA exchange resin in chloride form, to remove arsenic and nitrate from source water. The resin is NSF International (NSF) Standard 61 approved for use in drinking water treatment and its typical physical and chemical properties are presented in Table 4-4. According to Purolite's computerized simulation on the Fruitland water, the A300E resin has a relatively higher capacity for arsenic and nitrate than A520E, a nitrate-selective resin. As shown in Figure 4-2, A300E reaches 10-mg/L nitrate (as N) and 10-µg/L arsenic breakthrough at approximately 700 and 880 BV, respectively (note that this simulation significantly over-predicts the actual resin run length, which was less than 422 BV as discussed in Sections 4.4 and 4.5). Because nitrate breaks through before arsenate, nitrate will determine the resin run length (Ghurye et al., 1999). Using Clifford's equilibrium multi-component chromatography theory (EMCT) model, the run length to the 10-mg/L nitrate (as N) breakthrough was estimated to be about 580 BV when using a type II SBA exchange resin (like A300E) for the Fruitland Well No. 6-2004 water. The estimated run length was further refined to about 450 BV after taking into consideration mass transfer (Clifford, 2006). This run length was close to the 350 to 422 BV actually experienced at the Fruitland, Idaho site.

Table 4-4. Typical Physical and Chemical Properties of Purolite A300E Resin

Property	Values
Polymer Structure	Macroporous styrene-divinylbenzene
Functional Groups	Quaternary ammonium: $R(CH_3)_2(C_2H_4OH)N^+$
Physical Appearance	Clear spherical beads
Ionic Form	Chloride
Mesh Size Range (U.S. Standard Mesh) (Wet)	16 × 50 (+16 mesh <5%; -50 mesh <1%)
Uniformity Coefficient	1.7 maximum
Water Retention (%)	40–45
Swelling (%)	Salt –OH, 10%
pH Limitations	None
Temperature Limitations (°F)	185 (maximum)
Chemical Resistance	Unaffected by dilute acids, alkalis, and most solvents
Whole Clear Beads (%)	92 (minimum)
Shipping Weight (lb/ft^3 or g/L)	44 or 705 g/L
Total Capacity (meq/mL or meq/g)	1.45–1.6 meq/mL minimum volumetric (wet); 3.5–3.7 meq/g minimum weight (dry)

Source: Purolite



Source: Purolite

Figure 4-2. Purolite A-300E Simulation

4.2.2 Treatment Process. The Fruitland IX system utilized the packed-bed IX technology to remove arsenic and nitrate from source water. Figure 4-3 is a process schematic of the system. The process equipment included one bank of five skid-mounted bag filters, two skid-mounted resin vessels, one central control panel, one salt saturator system, one pre-wired brine transfer pump, one brine tank, one air compressor, as well as associated valves, sample ports, pressure gauges, and flow elements/controls. The IX system was fully automated and controlled by a central control panel that consisted of a programmable logic controller (PLC), a touch screen operator-interface-panel (OIP), and a data communication modem. The OIP allowed the operator to monitor system flowrate and volume throughput since last regeneration, change system setpoints as needed, and check the status of alarms. The modem allowed the vendor to remotely dial in for monitoring and troubleshooting purposes. All pneumatic valves were constructed of PVC and all plumbing was Schedule 80 PVC solvent bonded. Table 4-5 summarizes the design specifications of the IX system.

The major process steps and system components are presented as follows:

- **Sediment Filtration.** Prior to entering the IX resin vessels, raw water was filtered through a bag filter assembly to remove well sediment, if any. The bag filter assembly consisted of five parallel FSI X100 polypropylene housing units, each lined with a 20-µm filter bag. Filter bags in the assembly were replaced when pressure gauges on the inlet and outlet of the assembly indicated a head loss of over 6 lb/in^2 (psi). Figure 4-4 presents a photograph of the bag filter assembly.

- **Ion Exchange.** After passing through the bag filters, water flowed downward through two 48 in × 72 in pressure vessels configured in parallel. Mounted on a polyurethane coated, welded steel frame, the pressure vessels were of fiber reinforced plastic (FRP) construction,

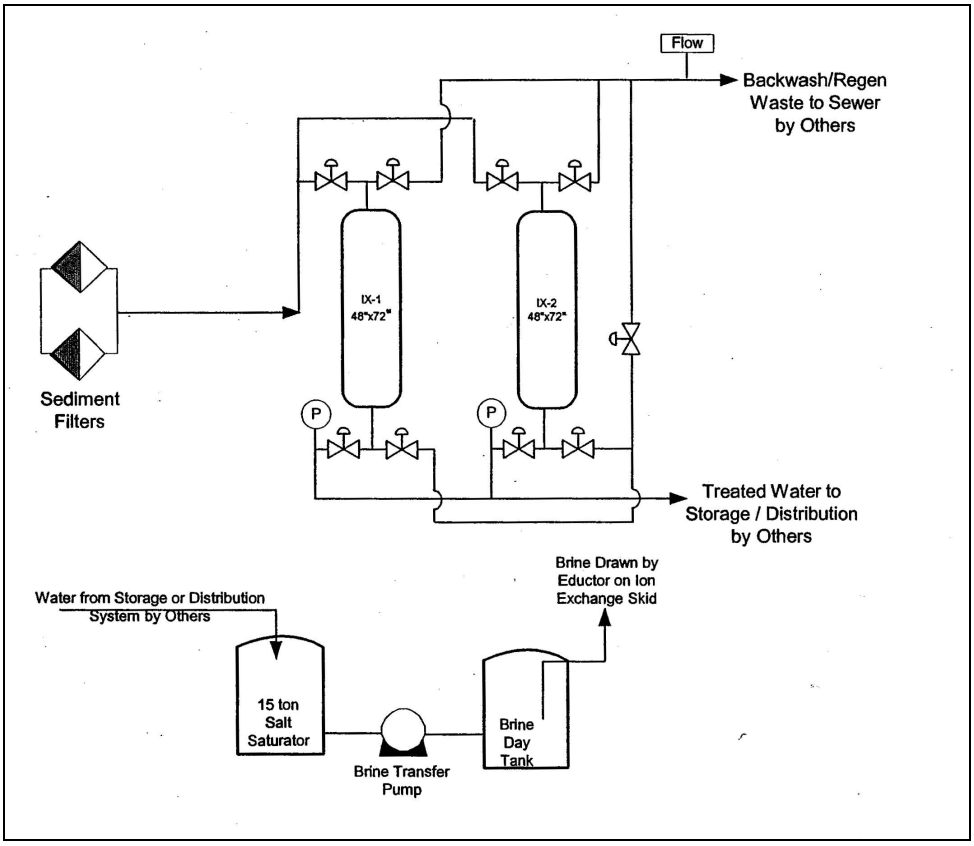


Figure 4-3. Process Schematic of Kinetico's IX-248-As/N Removal System

rated for 150 psi working pressure. Each vessel had a 6-in top and bottom flange and two 4-in side flanges, and was equipped with a diffuser-style upper distributor and a hub and lateral-style lower distributor. Each vessel was filled with 3 ft^3 of flint gravel support media, 50 ft^3 of A300E resin, and 3 ft^3 of polypropylene filler beads on the top (to prevent resin from being washed away in an upflow, counter-current regeneration). The IX system was designed for a flowrate of 250 gpm, yielding a hydraulic loading rate of 10 gpm/ ft^2 and an empty bed contact time (EBCT) of 3 min. Each IX resin vessel was equipped with a 125-gpm flow-limiting device to prevent overrun. However, these devices were removed later because they overly restricted the flow through the IX system.

An insertion-type paddle wheel flow element was installed on the combined effluent line to register flowrate and volume throughput of the IX system since last regeneration. When a pre-determined throughput setpoint was reached, Vessel A was automatically taken out of service for regeneration, whereas Vessel B remained on the line for treatment. The amount of water treated by Vessel B at this time would not be registered on the totalizer during Vessel A regeneration. Once Vessel A regeneration was complete, the totalizer was automatically reset to zero and began to register the amount of water treated by Vessel A. Meanwhile, Vessel B was taken out of service for regeneration. After Vessel B regeneration was complete, the totalizer registered the amount of water treated by both vessels. Figure 4-5 presents a photograph of the IX system at Fruitland. Figure 4-6 provides a close-up view of sampling taps, pressure gauges, and valves.

Table 4-5. Design Specifications of IX System

Parameter	Value	Remarks
Pretreatment-Bag Filter Assembly		
Bag Filter Size (in)	6 × 20	–
Number of Bag Filters	5	–
Configuration	Parallel	–
Nominal Pore Size (μm)	20	–
IX Vessels and Media Beds		
Vessel Size (in)	48 D × 72 H	–
Cross-Sectional Area (ft^2/vessel)	12.6	–
Number of Vessels	2	–
Configuration	Parallel	–
IX Resin Quantity (ft^3/vessel)	50	Total of 100 ft^3 for two vessels
Bed Depth (in)	48	–
Resin Type	Purolite A300E	–
Flint Gravel Support Media (ft^3/vessel)	3	12-in bed depth
Polypropylene Filler Beads (ft^3/vessel)	3	12-in bed depth
Service		
System Design Flowrate (gpm)	250	125 gpm/vessel
Hydraulic Loading (gpm/ft^2)	10	–
EBCT (min)	3.0	Based on design flowrate
Estimated Working Capacity (BV)	400-500	–
Volume Throughput (gal)	299,200-374,000	1 BV = 100 ft^3 = 748 gal
Regeneration		
Regeneration Mode	Co-current	Downflow
Regeneration Level (lb of salt/ft^3 of resin)	10	–
Brine Draw Duration (min)	64	Based on 4% brine
Brine Draw Flowrate (gpm)	23	Based on 4% brine
Slow Rinse Duration (min)	64	–
Slow Rinse Flowrate (gpm)	23	–
Fast Rinse Duration (min)	30	–
Fast Rinse Flowrate (gpm)	75	–
Wastewater Production (gal)	3,500 to 5,250	–
Salt Consumption (lb/regeneration)	500 (per vessel)	1,000 lb (total)
Brine System		
Brine Day Tank Size (in)	61 D × 64 H	Capacity = 685 gal
Brine Day Tank Material	HDPE	–
Brine Transfer Pump Size	½ hp	–
Salt Saturator Size (in)	96 D × 180 H (original) 96 D × 148 H (shortened)	Saturator shortened by 32 in (straight height) to fit to building; corresponding capacity reduced from 15 to 12.3 ton
Salt Saturator Material	Fiberglass	–
Post-Treatment		
None		

D = diameter; H = height.

Figure 4-4. 20-µm Bag Filter Assembly

Figure 4-5. Ion Exchange System at Fruitland, ID

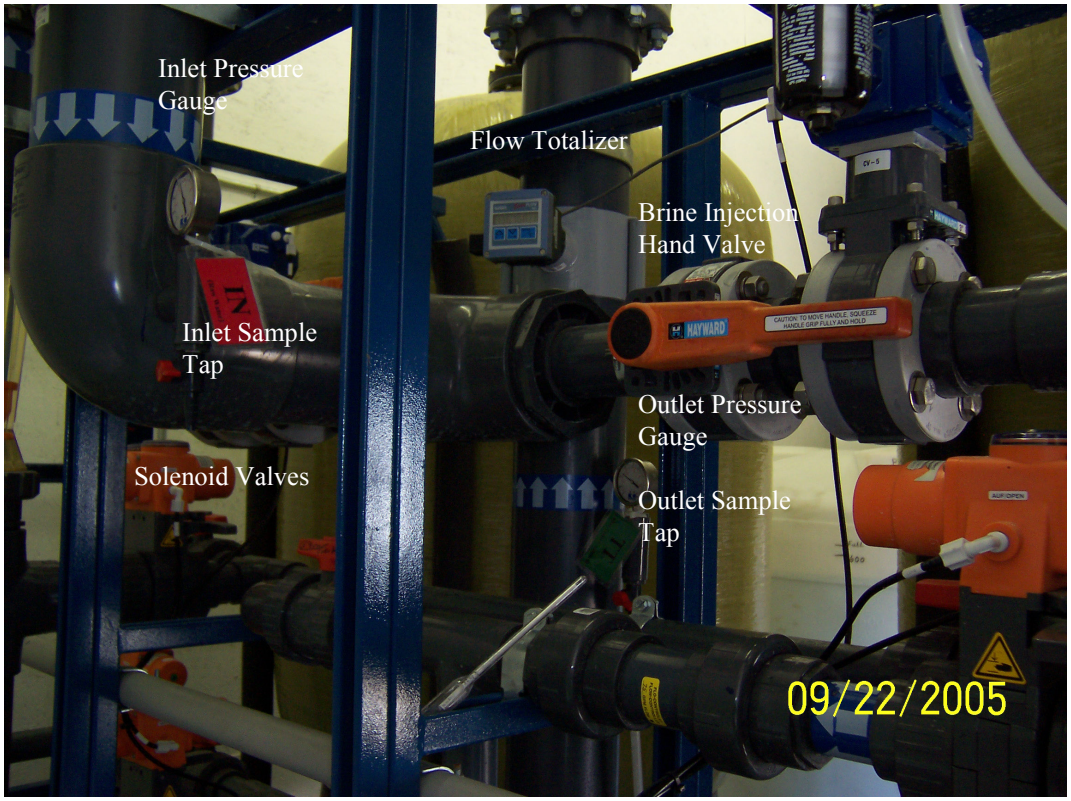


Figure 4-6. Sampling Taps, Pressure Gauges, and Valves

- **Resin Regeneration.** Regeneration can be initiated automatically based on a throughput setpoint or manually by pressing a push-button on the PLC. Once regeneration was initiated, the PLC controlled the sequence of three regeneration steps, i.e., brine draw, slow rinse, and fast rinse. To achieve a regeneration level of 10 lb NaCl/ft^3 of resin, the original design called for 64 min of brine draw at 23 gpm using a 4% brine solution. During the study, the regeneration scheme was adjusted several times to optimize the regeneration efficiency, reduce waste production, and minimize arsenic and nitrate leakage (Section 4.4.2). In doing so, the duration of each regeneration step was reset on the PLC; the brine concentration was adjusted using a hand valve located upstream of the eductor to change the brine draw rate; and a hydrometer was used to measure the specific gravity of the brine solution to confirm its concentration.

  Brine was drawn from a brine day tank (Figure 4-7) into the resin vessels via a Venturi eductor. The brine day tank was equipped with high/low level sensors interlocked with a brine transfer pump to fill the tank with saturated brine (about 23 to 26%) from a 15-ton salt saturator. The salt saturator was sized to hold 30 days of salt supply for daily regeneration and was re-filled by a salt delivery truck on a weekly or as-needed basis (Figure 4-8). Treated water was used to make the brine solution and rinse the beds. Wastewater produced was discharged to a floor drain and a 6-in drain line to a lift station outside of the building. Wastewater was then pumped to a city sewer.

  The system was designed to regenerate in either a co-current or counter-current mode. The vendor decided to use downflow, co-current regeneration, which was thought to be superior to upflow, counter-current regeneration for arsenic and nitrate. Upflow regeneration would

Figure 4-7. Photograph of Brine System

Figure 4-8. Salt Delivery to Fill Salt Saturator

force the contaminants concentrated at the bottom of the IX resin beds back through the entire resin beds, thus leaving more contaminants in the IX resin beds. Clifford et al. (1987, 2003) recommended co-current downflow regeneration for arsenic removal because it was easier to implement. For nitrate removal, co-current "complete" regeneration (i.e., removing over 95% of exchanged nitrate) is recommended only when bypass blending is allowed, which was not the case in Fruitland. Due to the arsenic/nitrate leakage problems detected at Fruitland, the co-current regeneration was converted to upflow counter-current regeneration during the period from July 25, 2006 to May 18, 2007. A series of mechanical problems occurred, however, under the counter-current regeneration mode (Section 4.4.3.2). The system was switched back to downflow, co-current regeneration mode after May 18, 2007.

4.3 System Installation

From the time the system was installed in March 2004 through June 2005, a series of events took place that seriously delayed the startup of the demonstration study. The events included the production of excessive sediment from the old well (Well No. 6), installation of a replacement well, repeated failures of bacterial testing, replacement of the IX resin already loaded in the IX vessels, and replacement of a well pump. These events are discussed in detail in the following sections.

4.3.1 Building Construction. The City of Fruitland constructed an addition to the existing pump house for the IX system. The 17-ft tall addition covered 360 ft^3 of floor space and had a wood frame, steel siding and roofing, and a roll-up door. The total cost was approximately $18,000. The building construction began on February 6, 2004, when the concrete pad was poured. Construction of the wood frame began on February 10, 2004, and the building was completed (with the exception of the electrical and the final siding) on March 3, 2004. Figure 4-9 shows a photograph of the new structure, adjacent to the existing well house.

Figure 4-9. New Addition to Old Well House

4.3.2 Installation of Replacement Well. After the IX system was delivered to the treatment building on March 8, 2004, system installation began immediately. The installation was nearly complete

when excessive accumulation of sediment was noted in the bag filters and the empty IX resin vessels (as much as 3 in) during a hydraulic test on March 25 and 26, 2004. As a result, loading of the IX resin was put off to allow the facility to examine the sand production problem. The city performed an investigation of Well No. 6 from April 1 through 13, 2004, including an initial video surveying, cleaning, bailing, and pumping, and final video surveying. The investigation revealed the presence of two holes in the well casing, with each hole having an associated void in the adjacent sand pack. On April 13, 2004, the city council voted to replace Well No. 6 with a new well on the same lot, located approximately 25 ft from the existing well.

The initial design for Well No. 6-2004 called for a 12-in-diameter steel casing completed to 95 ft bgs, with a screened interval from 50 to 70 ft bgs. Installation of the replacement well commenced on May 5, 2004, after the well location had been approved by IDEQ and a well drilling permit had been issued by the Idaho Department of Water Resources. Well installation continued through May 26, when well development and pump testing indicated that the well was unable to produce an adequate supply of water, presumably caused by the shorter screen interval installed. On May 28, the city council voted to increase well depth to 120 bgs with two additional screened sections extending from 95 to 105 ft bgs and from 110 to 120 ft bgs (see Section 4.1). Modifications to Well No. 6-2004 were completed in July 2004, and water samples were collected for coliform tests. The first water sample tested positive for coliform, requiring another chlorine shock and a second round of coliform sampling. Following the second chlorine shock and a negative coliform test result, the vendor proceeded with the loading of the IX resin in the vessels on July 23, 2004, and the shakedown/startup and operator training activities were scheduled for July 28, 2004.

4.3.3 Permitting. Engineering plans for the system permit application were prepared by Holladay Engineering, a Kinetico subcontractor (also serving as the engineer for the city) located in Payette, Idaho. The plans included general arrangement diagrams, specifications of the IX system, and drawings detailing the connections of the new unit to the existing facility and new building. After incorporating comments from the vendor and Battelle, the plans were submitted on January 25, 2004, by the city to IDEQ for review and approval. Review comments provided by IDEQ on February 25, 2004, were addressed by the city and Holladay Engineering within a week. On May 10, 2004, IDEQ sent an e-mail stating that the submittal for the demonstration was generally acceptable, and that the project was approved to proceed once the new well was installed.

4.3.4 System Installation, Shakedown, and Startup. The IX system was delivered to the site on March 8, 2004. Mechanical Installation, Inc., a subcontractor to Kinetico, performed the off-loading and installation of the system, including connections to the existing entry and distribution piping (Figure 4-10). Because the salt saturator had the same height, i.e., 17 ft, as the building, it had to be shortened before it could be brought into the building. As such, the top section of the fiberglass vessel was cut off and a 32-in long section of the straight shell was removed. After the shortened vessel was brought into the building, the top section was placed back and soldered on March 18, 2004 (Figure 4-11).

Following the installation of the replacement well, the vendor proceeded with the loading of the IX resin in the vessels on July 23, 2004. Battelle staff arrived at Fruitland on July 28, 2004, to provide data and sample collection training to the operator. The vendor engineer also was onsite to install a new touch screen on the control panel. However, the city learned on the same day that the latest sample taken from the system had failed the bacterial test and that the system would require further sanitation. This was complicated by the fact that the IX resin had already been loaded into the vessels and that the resin could not be exposed to any chlorine treatment. The city re-shocked the well with chlorine and bypassed the IX system by pumping water to the ground. Battelle and Kinetico proceeded with the operator training as scheduled and left the site on July 29, 2004.

Figure 4-10. Equipment Offloading

Figure 4-11. Cutting and Soldering a Salt Saturator

Immediately following the completion of operator training, the city began a series of activities involving chlorine shock, pumping, and sampling for Well No. 6-2004. The city administered multiple cycles of chlorine treatment, but samples taken continued to test positively for coliform. The well driller remobilized to the site in December 2004 to redevelop the well, clean the screens, and disinfect the pump and the well. However, intermittent positive coliform results continued after the redevelopment effort. In light of the positive coliform data, IDEQ agreed to a post-chlorination system at Well No. 6-2004 for the period of the demonstration. However, chlorination was not desired by the city due to concerns over taste and odor and resistance from a local beverage bottling facility.

The city continued to chlorine-shock and pump the well from December 2004 through April 2005, but intermittent positive results for coliform persisted during this period. To allow water to enter the distribution system, the city contemplated several pre- and/or post-treatment options, including prechlorination (upstream of the IX system), postchlorination (prior to entering the distribution system), and ultraviolet (UV) treatment. Before any of these treatment options was implemented, the city collected water samples from the outlet of the IX resin vessels in March 2005, and the results were negative for coliform. The vendor, therefore, determined that a specialized sanitization method most likely would not be needed for treating the IX resin and that a brine solution would be sufficient to intoxicate/kill coliform if they were actually present in the IX system.

In April 2005, samples collected at the IX system effluent during a short test run (while the treated water was discharging to the ground) indicated that arsenic breakthrough had already occurred. Examination of relevant information led the vendor to conclude that a nitrate-specific resin, A-520E (also manufactured by Purolite), had been erroneously delivered to the site and loaded into the IX vessels. A vendor technician arrived onsite on April 20, 2005, to remove A-520E resin and load A300E resin into the vessels. After resin replacement and upon IDEQ's request, water samples were collected from the wellhead and the system effluent for a bacterial test, which showed negative coliform results. The sample results were submitted to IDEQ on May 4, 2005.

Meanwhile, it was discovered that the pump in Well No. 6-2004, which had been salvaged from the original well, Well No. 6, was out of order and had to be replaced. The new pump was installed on May 19, 2005, and was disinfected and began pumping to waste on May 20, 2005. Samples collected on May 23 and 24, 2005, indicated the absence of coliform. Holladay Engineering sent a letter to IDEQ on June 1, 2005, reporting the negative coliform results and requesting permission to send the treated water to the distribution system. IDEQ provided an approval in an e-mail dated June 7, 2005. As such, the performance evaluation study officially began on June 14, 2005. After Battelle reviewed the data and sample collection procedures with the operator via telephone, the first set of samples was collected from the IX system on June 15, 2005.

4.4 System Operation

The 32-month demonstration study (from June 14, 2005, through February 11, 2008) can be divided into three study periods. Study Period I, extending from June 14, 2005 through July 25, 2006, focused on treatment system performance evaluation as the system was set in the co-current regeneration mode. The activities carried out in Study Period II, extending from July 25, 2006, through June 18, 2007, involved solving various mechanical problems encountered when efforts were made to convert IX resin regeneration from the co-current to counter-current mode (Section 4.4.3.2). The conversion efforts were made as an attempt to address issues relating to arsenic and nitrate leakage after regeneration. In spite of repeated trials, these efforts were not successful and the system was reverted back to the co-current regeneration mode. Improper IX resin regeneration during this period was thought to have resulted in resin fouling due to the presence of dissolved organic matter in source water (Section 4.4.3.2). Deteriorating resin performance as reflected by shorter system run lengths prompted efforts to clean the

fouled IX resin in Study Period III starting on June 18, 2007 and ending on February 11, 2008. After the fouled IX resin was washed with a caustic/brine solution, the performance evaluation sampling was resumed for a short period. Appendix A chronologically summarizes all operational issues and corrective actions taken during the 32-month demonstration study. Table 4-6 provides an overview of key demonstration study activities throughout the study period.

Table 4-6. Key Demonstration Study Activities and Start/Complete Dates

Demonstration Study Activities	Date
Study Period I. Evaluation of IX System Performance with Co-current Regeneration Mode	06/14/05–07/25/06
• Run Length Study 1	07/28–30/05
• Elution Study 1	07/30/05
• Run Length Study 2	08/16–17/05
• Elution Study 2	09/22/05
• Run Length Study 3	12/07–08/05
• Run Length Study 4	04/11–12/06
Study Period II. Conversion from Co- to Counter-current Regeneration Mode	07/25/06 to 06/18/07
• Run Length Study 5	08/09–10/06
• Run Length Study 6	01/16–17/07
• Meeting with Kinetico and EPA in Columbus, OH	02/07/07
• Installation of ArsenicGuard	05/07/07
Study Period III. Caustic/Brine IX Resin Cleaning Followed with Short Performance Evaluation	06/18/07–02/11/08
• Caustic/Brine IX Resin Cleaning	06/18–21/07
• Performance Evaluation with Co-current Regeneration Mode	06/21/07–01/25/08
• Reduced Daily Run Time[(a)]	09/2007–02/11/08
• Equipment Transfer Letter Signed by City Council	02/11/08

(a) Operating time reduced to 3 hr/day due to concern over high salt content in regeneration waste discharge, which might have caused stress to duckweeds in city's sewage lagoons.

4.4.1 Operational Parameters. Operational data were collected during weekdays from June 14, 2005, through July 25, 2006 (Study Period I), and are attached as Appendix B after tabulation. After July 25, 2006, the demonstration study focused primarily on solving mechanical problems associated with conversion of system regeneration from the co- to counter-current mode and on addressing IX resin fouling issues. Therefore, the treatment system operated only periodically and operational data were recorded only on an as-needed basis.

Table 4-7 summarizes key operational parameters collected during Study Period I. Based on well pump hour meter readings, the IX system operated for a total of 6,836 hr in 392 days, resulting in an average daily operating time of 17.4 hr. Well No. 6-2004 operated longer between June and September, i.e., 22 hr/day (on average), compared to 13 hr/day between December and March. The throughput during the study period was 65,400,000 gal based on wellhead totalizer readings. The average daily demand was 166,895 gpd; the peak daily demand was 255,000 gpd, which occurred on September 14, 2005.

The IX system was equipped with an insertion paddle wheel flow meter/totalizer on the product water discharge line to monitor the combined flow from both IX vessels. During the first week of system operation, flowrates from both IX vessels ranged from 130 to 144 gpm (except for the 73 gpm on June

Table 4-7. Summary of System Operational Data During Study Period I

Parameter	Value
Demonstration Study Period I	June 14, 2005 to July 25, 2006[(a)]
Total Operating Time (hr)	6,836
Total Operating Days (day)	392
Average Daily Operating Time (hr/day)	17.4
Throughput to Distribution (gal)	65,423,000[(b)]
Average Daily Use (gpd)	166,895
Peak Daily Use (gpd)	255,000
Number of Regeneration Cycles	202[(c)]
Service Flowrate (gpm)	126–179[(d)] (average 157)
Empty Bed Contact Time (min)	4.2–5.9 (average 4.8)
Hydraulic Loading to Each Resin Vessel (gpm/ft^2)	5.0–7.1 (average 6.2)
Pressure Loss Across Each Resin Vessel (psi)	4–13[(e)]
Pressure Loss Across Entire System (psi)	8–18[(f)]

(a) System regeneration in co-current mode.
(b) Based on wellhead totalizer readings.
(c) Including 35, 31, 39, 33, and 64 regeneration cycles at initial regeneration setting and four subsequently modified settings, respectively (Section 4.4.2.1).
(d) Excluding lower flowrates during system regeneration and before flow restrictors were removed on July 7, 2005.
(e) Not include data during system regeneration (pressure loss could increase up to 20 psi during regeneration of one vessel).
(f) Not include data during system regeneration (pressure loss could increase up to 26 psi during regeneration of one vessel).

16, 2005, when one IX vessel was regenerating), which was 28% to 35% lower than the 200-gpm well capacity and 42% to 48% lower than the 250-gpm system design flowrate. Meanwhile, the pressure drop (Δp) across the system also was elevated, with values ranging from 20 to 30 psi (excluding the 42 psi on June 16, 2005, when one IX vessel was regenerating). It was determined that the 100-gpm flow restrictors at the outlet side of the IX vessels had overly restricted the flow, causing the unexpectedly low flowrates. The flow restrictors were modified on June 21, 2005, with a wider opening, which resulted in a higher flowrate of 170 gpm and a lower Δp of 6 psi. The flow restrictors were later removed on July 7, 2005, but the removal did not appear to further increase system flowrates. Since then, product water flowrates ranged from 126 to 179 gpm and averaged 157 gpm; system Δp readings ranged from 8 to 18 psi and averaged 11 psi (excluding those recorded during regeneration). Based on this average flowrate, the IX system had been operating at an average hydraulic loading rate of 6.2 gpm/ft^2 (compared to the design value of 10 gpm/ft^2) and an average EBCT of 4.8 min (compared to the design value of 3 min).

As noted above, when one IX vessel was being regenerated, the second IX vessel continued to be in service. Under the circumstances, service flowrates through one IX vessel increased to 109 to 145 gpm, which were significantly higher than those (i.e., 63 to 89.5 gpm/vessel) when both IX vessels were in service. Also, some service flowrates had exceeded the design value of 125 gpm most likely due to the removal of the flow restrictor. This flowrate range represents a hydraulic loading rate of 8.7 to 11.5 gpm/ft^2 and an EBCT of 3.4 to 2.6 min. The pressure drop across the vessel in service also could spike to 21 psi during regeneration.

4.4.2 Regeneration. The system PLC automatically initiated a regeneration cycle based on a throughput setpoint. The duration of each regeneration step, e.g., brine draw, slow rinse, and fast rinse, was controlled by a timer in the PLC. During Study Period I, a total of 202 regeneration cycles took place. The treatment system operated sporadically during Study Periods II and III; therefore, the number

of regeneration cycles that took place was not tracked. Table 4-8 summarizes the regeneration settings set during the entire performance evaluation study.

4.4.2.1 Regeneration Settings. As shown in Table 4-8, during June 14 through July 26, 2005, IX system regeneration was triggered based on a factory throughput setpoint of 214,000 gal. A 4% brine solution was used to regenerate the IX resin at 23 gpm for 64 min to achieve a target regeneration level of 10 lb of salt/ft^3 of resin. Based on the results of arsenic/nitrate breakthrough and resin run length studies (see Section 4.5.2), regeneration settings were modified four times during Study Period I. On July 30, 2005, a Kinetico technician was onsite to change the brine concentration from 4% to 8%, the brine draw time from 64 to 32 min, and the throughput setpoint from 214,000 to 335,000 gal based on field arsenic and nitrate measurements. On September 19, 2005, the operator was given the instructions to reduce the throughput setpoint from 335,000 to 316,000 gal and the fast rinse time from 30 to 6 min based on the results of an arsenic/nitrate run length study conducted on August 16 and 17, 2005 (Run Length Study 2). On December 5, 2005, the brine draw time was reduced again from 32 to 25 min, slow rinse time reduced from 64 to 40 min, and fast rinse time increased from 6 to 15 min. On March 5, 2006, the brine concentration was reduced from 8% to 6%. By this time, the averaged regeneration level achieved was 9.5 lb/ft^3, very close to the design value of 10 lb/ft^3.

Upon completion of Study Period I, the IX system was converted from the co- to counter-current regeneration mode beginning on July 25, 2006, as an attempt to address the arsenic and nitrate leakage issues. On March 14, 2007, the throughput setpoint was further reduced from 316,000 to 275,000 gal due to shorter run lengths experienced during February 1 and 7, 2007 (Appendix A). The attempt to convert to the counter-current regeneration mode was unsuccessful and the regeneration flow direction was reverted back to co-current after caustic/brine resin cleaning on June 21, 2007. On July 7 and October 16, 2007, throughput setpoints were further reduced to 260,000 and 220,000 gal, respectively, based on even shorter run lengths observed for arsenic and nitrate. Rationales of these setting modifications are further discussed in Sections 4.4.3 and 4.5.2.

4.4.2.2 Regeneration Parameters. Regeneration parameters were monitored on 13 occasions during Study Period I (from June 14, 2005, to July 25, 2006). Table 4-9 summarizes the monitoring results. The volume of treated water used for each regeneration step was recorded via a totalizer installed upstream of the Venturi eductor and was used to calculate the average flowrate of each step. Brine usage was recorded from the 685-gal brine day tank with 50-gal graduations. The volume of brine draw (i.e., diluted brine) was calculated using Equation 1:

$$V_{brine,\,d} = (\gamma_{brine,\,s} \times V_{brine,s} + V_{water}) / \gamma_{brine,\,d} \qquad (1)$$

where:

$V_{brine,\,d}$ = volume of diluted brine (gal)
$V_{brine,\,s}$ = volume of saturated brine (gal)
$V_{water,\,s}$ = volume of water used (gal)
$\gamma_{brine,\,s}$ = specific gravity of saturated brine, i.e., 1.160 for 21% brine
$\gamma_{brine,\,d}$ = specific gravity of diluted brine, i.e., 1.061 for 8% brine.

As shown in Table 4-9, 350 to 375 gal, 250 to 325 gal, and 200 to 325 gal of saturated brine was used to regenerate each vessel under Regeneration Settings 2, 3, and 4, respectively. The average brine draw flowrate under Regeneration Setting 2 was 36 gpm, which is approximately 56% higher than the design value of 23 gpm (see Tables 4-5 and 4-8). This higher flowrate resulted in higher salt consumption as discussed in Section 4.4.3. Average brine draw flowrates under Regeneration Settings 3 and 4 were 37 and 43 gpm, respectively, which were even higher than the average brine draw flowrate under Regeneration Setting 2.

Table 4-8. IX System Regeneration Settings at Fruitland, ID

Parameter	Period I					Period II[b]		Period III[b]		
	Initial Setting	**Setting 1**	**Setting 2**	**Setting 3**	**Setting 4**	**Setting 5**	**Setting 6**	**Setting 7**	**Setting 8**	**Setting 9**
Operational Duration	06/14/05–07/30/05	07/30/05–09/19/05	09/19/05–12/05/05	12/05/05–03/05/06	03/05/06–07/25/06	07/25/06–03/14/07	03/14/07–06/18/07	06/18/07–07/07/07	07/07/07–10/16/07	10/16/07–02/11/08
Regeneration Mode (co- or counter)	Co	Co	Co	Co	Co	Counter	Counter	Co	Co	Co
Run Length Setting (gal)	214,000	335,000	316,000	316,000	316,000	316,000	275,000	275,000	260,000	220,000
Run Length Setting (BV)	286	448	422	422	422	422	368	368	348	294
Regeneration Interval (hr)	22	34	32	32	32	32	32	32	32	32
Brine Concentration (%)	4	8	8	8	6	6	6	6	6	6
Brine Draw Time (min)	64[c]	32[c]	32[c]	25[c]	25[c]	25	25	25	25	25
Slow Rinse Time (min)	64	64	64	40	40	40	40	40	40	40
Fast Rinse Time (min)	30	30	6	15	15	15	15	15	15	15
Total Regeneration Time (min)	158	126	102	80	80	80	80	80	80	80
No. of Regeneration Cycles	33	33	39	35	62	-[i]	-[i]	-[i]	-[i]	-[i]
Salt Delivered (lb)	37,260[d]	55,295[e]	67,705[f]	52,855[g]	58,525[h]	-[i]	-[i]	-[i]	-[i]	-[i]
Average Salt Usage (lb/cycle)[a]	1,129	1,675	1,736	1,510	945	-[i]	-[i]	-[i]	-[i]	-[i]
Average Regeneration Level (lb/ft^3)[b]	11.3	16.8	17.4	15.1	9.5	-[i]	-[i]	-[i]	-[i]	-[i]

(a) Calculated by dividing total amounts of salt delivered by number of regeneration cycles, assuming same salt storage levels in saturator at beginning and end of each operational period; theoretical salt usage was 1,000 lb/regeneration.
(b) Calculated based on 100 ft^3 of resin in two vessels; design value was 10 lb/ft^3.
(c) With a constant brine draw flowrate of 23 gpm.
(d) Delivered in 6 shipments with quantities varying from 3,945 to 9,035 lb per shipment.
(e) Delivered in 9 shipments with quantities varying from 3,205 to 8,970 lb per shipment.
(f) Delivered in 11 shipments with quantities varying from 5,955 to 7,240 lb per shipment.
(g) Delivered in 11 shipments with quantities varying from 1,880 to 8,020 lb per shipment.
(h) Delivered in 11 shipments with quantities varying from 1,320 to 8,755 lb per shipment.
(i) Routine operational data not collected after 07/25/06.

Table 4-9. IX System Regeneration Parameters Collected During Study Period I

Date	Regen Setting	Tank Being Regen'd	*Brine Draw*	Brine Used in Day Tank (gal)	Treated Water Used for Brine Draw (gal)	Brine Draw Volume (gal)[c]	Brine Draw Time (min)	Brine Draw Flowrate (gpm)	*Slow Rinse*	Slow Rinse Volume (gal)	Slow Rinse Time (min)	Slow Rinse Flowrate (gpm)	*Fast Rinse*	Fast Rinse Volume (gal)	Fast Rinse Time (min)	Fast Rinse Flowrate (gpm)	*Total Waste Production per Regeneration Cycle*	Total Waste Generated (gal)	Total Waste Produc-tion (BV)	Regen Setpoint (BV)	Water Produc-tion Eff. (%)
09/22/05	Setting 2	A		360	802	1,149	32	36		1,519	64	24		383	6	64		6,100	16	422	96.2
		B		NA	1,340[a]	NA	32	NA		1,542	64	24		359	6	60					
		Total		NA	1,604[b]	2,299[b]	64	36[b]		3,061	128	24		742	12	62					
11/10/05		A		350	800	1,137	32	36		1,900	64	30		300	6	50		6,500	17	422	96
		B		350	800	1,137	32	36		1,600	64	25		400	6	67					
		Total		700	1,600	2,274	64	36		3,500	128	27		700	12	58					
11/15/05		A		375	900	1,258	32	39		1,900	64	30		400	6	67		6,650	18	422	95.7
		B		375	700	1,070	32	34		1,600	64	25		400	6	67					
		Total		750	1,600	2,328	64	37		3,500	128	27		800	12	67					
01/11/06	Setting 3	A		325	600	920	25	37		1,000	40	25		1,110	15	74		6,354	17	422	96
		B		325	700	1,014	25	41		1,200	40	30		1,110	15	74					
		Total		650	1,300	1,934	50	39		2,200	80	28		2,220	30	74					
02/15/06		A		250	650	885	25	35		1,040	40	26		1,110	15	74		6,070	16	422	96.2
		B		250	650	885	25	35		1,040	40	26		1,110	15	74					
		Total		500	1,300	1,770	50	35		2,080	80	26		2,220	30	74					
04/04/06	Setting 4	A		325	900	1,222	25	49		1,400	40	35		1,000	15	67		7,143	19	422	95.5
		B		325	900	1,221	25	49		1,400	40	35		900	15	60					
		Total		650	1,800	2,443	50	49		2,800	80	35		1,900	30	63					
04/13/06		A		225	800	1,016	25	41		1,400	40	35		1,000	15	67		6,918	18	422	95.6
		B		210	800	1,002	25	40		1,500	40	38		1,000	15	67					
		Total		435	1,600	2,018	50	40		2,900	80	36		2,000	30	67					
05/09/06		A		210	900	1,098	25	44		1,440	40	36		1,050	15	70		7,068	19	422	95.5
		B		200	800	990	25	40		1,440	40	36		1,050	15	70					
		Total		410	1,700	2,088	50	42		2,880	80	36		2,100	30	70					
05/31/06		A		210	875	1,075	25	43		1,440	40	36		1,050	15	70		7,117	19	422	95.5
		B		200	875	1,062	25	42		1,440	40	36		1,050	15	70					
		Total		410	1,750	2,137	50	43		2,880	80	36		2,100	30	70					
06/07/06		A		200	875	1,064	25	43		1,440	40	36		1,050	15	70		7,109	19	422	95.5
		B		200	875	1,064	25	43		1,440	40	36		1,050	15	70					
		Total		400	1,750	2,129	50	43		2,880	80	36		2,100	30	70					
06/22/06		A		200	875	1,064	25	43		1,440	40	36		1,050	15	70		7,109	19	422	95.5
		B		200	875	1,064	25	43		1,440	40	36		1,050	15	70					
		Total		400	1,750	2,129	50	43		2,880	80	36		2,100	30	70					
07/06/06		A		200	875	1,065	25	43		1,440	40	36		1,050	15	70		7,112	19	422	95.5
		B		200	875	1,066	25	43		1,440	40	36		1,050	15	70					
		Total		400	1,750	2,132	50	43		2,880	80	36		2,100	30	70					
07/17/06		A		200	875	1,065	25	43		1,440	40	36		1,050	15	70		7,114	19	422	95.5
		B		200	875	1,069	25	43		1,440	40	36		1,050	15	70					
		Total		400	1,750	2,134	50	43		2,880	80	36		2,100	30	70					

(a) Including an unknown amount of water that went into salt saturator.
(b) Assuming TB consumed same amount of brine and water as TA.
(c) Calculated using Equation 1.

Average slow rinse flowrates under Regeneration Settings 2 and 3 were 26 and 27 gpm, respectively, just over the designed value of 23 gpm (see Table 4-5). Slow rinse flowrates under Regeneration Setting 4 averaged 36 gpm, significantly higher than the designed value. Average fast rinse flowrates under Regeneration Settings 2, 3, and 4 were 62, 74, and 69 gpm, respectively, lower than the design value of 75 gpm. Each regeneration cycle produced 6,100 to 7,140 gal of wastewater, equivalent to 16 to 19 BV. At a regeneration setpoint of 316,000 gal (or 422 BV), the water production efficiency was 96%.

4.4.2.3 Salt Usage. The amount of salt used by each regeneration cycle was calculated based on the concentration and volumes of saturated and diluted brine solutions, respectively, according to Equation 2. The results are presented in Table 4-10.

$$W_{salt} = V_{brine} \times \gamma_{brine} \times d_{water} \times C_{salt} \qquad (2)$$

where:

W_{salt} = weight of salt (lb)
V_{brine} = volume of brine (gal)
γ_{brine} = specific gravity of brine
d_{brine} = density of water, e.g., 8.34 (lb/gal)
C_{salt} = percent of salt (%).

The specific gravity of the saturated brine measured with a hydrometer on September 22, 2005, was 1.16, corresponding to 21% of NaCl, which was lower than the ideal salt saturation level of 23 to 25%. Specific gravities of diluted brine solutions measured ranged from 1.061 to 1.062 for Regeneration Settings 2 and 3, and from 1.038 to 1.046 for Regeneration Setting 4, corresponding to 8% and 6% of NaCl, respectively, as expected. Using the ideal salt saturation level for calculations, it yielded amounts of salt usage (by weight) similar to those based on diluted brine solutions, as shown in Table 4-10. Averaged amounts of salt usage under Regeneration Setting 2 were 1,647 and 1,628 lb based on saturated and 8% brine, respectively, which was over 60% higher than the design value of 1,000 lb (derived from 10 lb of salt/ft^3 of IX resin and 100 ft^3 of IX resin in the system). Adjustments made to regeneration settings reduced amounts of salt usage to 1,297 and 1,312 lb (based on saturated and 8% brine, respectively) under Regeneration Setting 3, and then to 986 and 1,098 lb (based on saturated and 6% brine, respectively) under Regeneration Setting 4.

Amounts of salt usage also were estimated based on amounts of salt delivered and the number of regeneration cycles taking place over the respective study periods. In doing so, it was assumed that the same level of salt was maintained in the salt saturator at both the beginning and end of the study periods. As presented in Tables 4-8 and 4-10, average salt usage based the amounts delivered increased from 1,129 lb under the initial regeneration setting to 1,675 and 1,736 lb under Regeneration Settings 1 and 2, respectively, and then decreased to 1,510 and 945 lb under Regeneration Settings 3 and 4, respectively. Divided by 100 ft^3 of IX resin in the system, these amounts corresponded to the regeneration levels of 11.3, 16.8, 17.4, 15.1, and 9.5 lb/ft^3. The salt regeneration level was only 13% higher than the design value of 10 lb/ft^3 during and soon after system startup, but became 67%, 74%, and 51% higher through a number of regeneration setting modifications. Under Regeneration Setting 4, the regeneration level based on the amount salt delivered was within 5% of the target value of 10 lb/ft^3.

Table 4-10. IX System Salt Usage Calculations

Date	Based on Saturated Brine				Based on Diluted Brine				Based on Salt Delivery
	Volume of saturated brine (gal)	Specific gravity[(a)]	Percent of salt (%)	Salt usage (lb)	Volume of diluted brine (gal)	Specific gravity[(b)]	Percent of salt (%)	Salt usage (lb)	Salt usage (lb)
09/22/05	720	1.176	23	1,624	2,299	1.061	8	1,627	1,736
10/25/05	750	1.176	23	1,692	NA	NA	NA	NA	
11/10/05	700	1.176	23	1,579	2,273	1.061	8	1,609	
11/15/05	750	1.176	23	1,692	2,328	1.061	8	1,648	
Average Under Regeneration Setting 2				1,647				1,628	
01/11/06	650	1.176	23	1,466	1,934	1.062	8	1,370	1,510
02/15/06	500	1.176	23	1,128	1,770	1.062	8	1,254	
Average Under Regeneration Setting 3				1,297				1,312	
04/04/06	650	1.176	23	1,466	2,443	1.046	6	1,279	945
04/13/06	425	1.176	23	959	2,018	1.043	6	1,053	
05/09/06	410	1.176	23	925	2,088	1.042	6	1,089	
05/31/06	410	1.176	23	925	2,137	1.042	6	1,114	
06/07/06	400	1.176	23	902	2,129	1.04	6	1,108	
06/22/06	400	1.176	23	902	2,129	1.04	6	1,108	
07/06/06	400	1.176	23	902	2,132	1.039	6	1,108	
07/17/06	400	1.176	23	902	2,134	1.038	5	924	
Average Under Regeneration Setting 4				986				1,098	

(a) Ideal salt saturation level used for calculation.
(b) Measured using a hydrometer.

The higher than expected regeneration levels experienced during most of Study Period I probably were triggered initially by over adjustment of the hand valve located upstream of the Venturi eductor. As noted in Section 4.4.2.2, a higher brine draw flowrate (i.e., 36 gpm vs. the design flowrate of 23 gpm) was observed during September 19 through December 5, 2005 (under Regeneration Setting 2). (Note that this flowrate most likely also was the flowrate experienced during July 30 through September 19, 2005, under Regeneration Setting 1 because of similar amounts of salt usage and the same brine concentration and brine draw time between these two periods.) It was suspected that, when the brine strength in the day tank was changed from 4% to 8% on July 26, 2005, the hand valve might have been overly adjusted, thus resulting in higher brine draw flowrates.

After being notified of the brine draw flowrate issue, the vendor provided instructions to the operator to shorten the brine draw time from 32 to 25 min on the PLC on December 5, 2005. Shortening the brine draw time was done because it was easier to implement (compared to manipulating the hand valve). Reduction of the brine draw time from 32 to 25 min, however, would decrease the salt usage by only 22%; further decrease in the brine draw time was not recommended by the vendor because of the concern of incomplete regeneration. The actual reduction in salt usage (and regeneration level) due to the decrease in brine draw time was 21% based on saturate brine, 20% based on 8% brine, or 13% based on salt delivery (see Table 4-10).

Further adjustment under Regeneration Setting 4 involved a 25% reduction in brine concentration from 8 to 4% in the brine day tank. The actual reduction in salt usage (and regeneration level) was 24% based on saturate brine, 16% based on 8% brine, or 37% based on salt delivery.

Salt usage per 1,000 gal of water treated was calculated to be 5.5, 4.8, and 3.0 lb under Regeneration Settings 2, 3, and 4, respectively, based on the amounts of salt consumed per regeneration cycle (i.e., 1740, 1510, and 945 lb, respectively) and the run length setting of 316,000 gal (Table 4-8). The 5.5 and 4.8 lb/1000 gal usage rates under Settings 2 and 3 were caused by the 56% higher brine draw rate and improper regeneration setting as discussed above. The 3.0 lb salt usage value was slightly lower than the 3.19 lb/1000 gal stated in the vendor's proposal and those reported in the literature (Clifford et al., 1987; 2003). For example, in a nitrate study conducted at Glendale, Arizona, where similar run length to nitrate breakthrough (~400 BV) was obtained from a type II resin, Clifford et al. (1987) reported a salt usage of 3.25 lb/1,000 gal for complete regeneration and 2.36 lb/1,000 gal for partial regeneration. Guter's work on nitrate removal in McFarland, California (1981) produced an even lower salt consumption than experienced in Glendale, Arizona.

4.4.3 System Operational Issues. Major operational issues encountered during Study Periods I, II, and III of the demonstration study are discussed in the following sub-sections.

4.4.3.1 Period I (June 14, 2005 to July 25, 2006)

PLC Problems. A power outage occurred over the weekend of June 18 and 19, 2005, causing several operational issues. First, the product water totalizer read 341,000 gal on June 20, 2005, exceeding the regeneration setpoint of 214,000 gal. An examination of the system revealed that the brine transfer pump had been reset to "off", preventing the scheduled regeneration from taking place. Second, due to the power outage, the PLC regeneration setting was reverted from "co-current" to the factory default of "counter-current." Although the system was designed with flexibilities to support both regeneration modes, the plumbing and valving was configured only for the co-current regeneration. Therefore, it was suspected that the system had not been properly regenerated for about 10 days, as indicated by higher-than-expected arsenic and nitrate concentrations in the treated water on June 23 and 29, 2005 (Section 4.5). To rectify the situation, the PLC setting was changed back to "co-current" on June 29, 2005, after sample collection. In addition, an uninterrupted power supply (UPS) was installed by the vendor on July 26, 2005, to provide a backup power to the PLC.

The system failed to regenerate again on August 3, 2005, due to a broken level sensor in the brine day tank. The product water totalizer read 534,000 gal on that day, far exceeding the setpoint of 335,000 gal. The prolonged service run resulted in higher-than-influent levels of arsenic and nitrate in the treated water, known as "chromatographic effect" (see Section 4.5). The level sensor was repaired by the operator on the same day.

Initial Arsenic and Nitrate Leakage after Regeneration. With co-current regeneration during Study Period I, the IX system performed well (in terms of removing both arsenic and nitrate to below the respective MCLs) except when it was freshly regenerated (Sections 4.5.1.1 and 4.5.2) or was experiencing mechanical problems. Samples collected after the IX system had been freshly regenerated during either weekly sampling or a special study on December 7 and 8, 2005 (i.e., Run Length Study 3 in Table 3-4) contained elevated arsenic and nitrate concentrations until up to 50,000 to 60,000 gal of throughput (or 3 to 4 hr into the service run). The early leakage of arsenic and nitrate was indicative of incomplete regeneration of the IX resin via the downflow, co-current regeneration mode. To curb the problem, a vendor's technician was onsite in March 2006 to (1) remove polyethylene beads from both IX vessels, (2) backwash the vessels, and (3) replace the existing blue eductor with a larger, orange one in March 2006 in the hope of achieving a higher brine draw flowrate. However, the leakage problem

persisted afterwards. A run length study conducted on April 11 and 12, 2006 (i.e., Run Length Study 4 in Table 3-4) again showed significant initial arsenic and nitrate leakage, which prompted the vendor to recommend converting the regeneration from co- to counter-current mode.

4.4.3.2 Study Period II (July 25, 2006, to June 18, 2007)

Mechanical Problems Encountered During Counter-Current Regeneration. The first attempt to change to counter-current regeneration took place on July 25, 2006, when a vendor's technician was onsite to reload the polyethylene beads that were removed for IX vessel backwash in March 2006. Following the modification and an upflow regeneration cycle on August 1, 2006, a run length study was conducted on August 9 and 10, 2006 (i.e., Run Length Study 5 in Table 3-4). The results showed as high as 129 µg/L of arsenic and 17.6 mg/L of nitrate (as N) in the treated water long before the 316,000 gal throughput setting, indicating improper regeneration (Section 4.5.2). As a result, the IX system was shut down on August 18, 2006. On September 5, 2006, the IX system was changed back to co-current regeneration temporarily and the results indicated proper regeneration. At this point, the vendor concluded that the brine eductor had not functioned properly due to "fluctuating pressure" and recommended that the eductor be replaced with a brine injection pump.

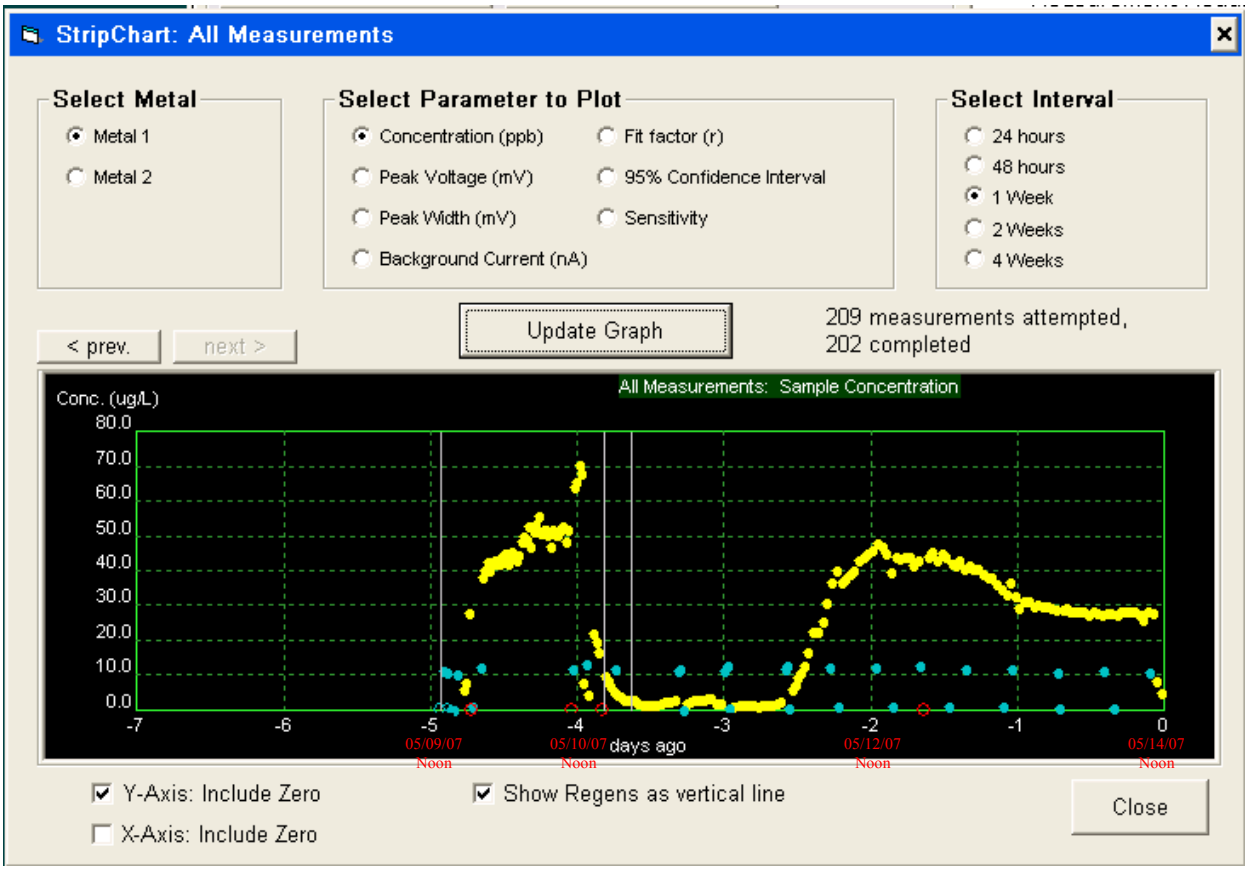
The second attempt took place on October 24, 2006, when a 1.5 horsepower (hp) close-coupled centrifugal pump (Goulds Pumps Model #1BF21512) was installed at the suction side of the eductor. Upon completion of two counter-current regeneration cycles, system operation resumed on December 5, 2006. Battelle conducted another run length study on January 17 to 18, 2007 (i.e., Run Length Study 6 in Table 3-4). The analytical results showed essentially no arsenic or nitrate removal in the treated water during the entire run length study. These results suggested that problems associated with counter-current regeneration persisted even after the brine injection pump had been installed. Samples collected on February 1 and 7, 2007 by the city and analyzed by the city's own laboratory and by a State-certified lab showed nitrate concentration exceeding the 10-mg/L MCL, which prompted the city to shut down the system again on February 13, 2007, and IDEQ to request for a public notice to be issued.

A meeting was held with the vendor and EPA at Battelle on February 21, 2007, to review the system performance issues and formulate a course of action. Consensus was reached among the meeting participants that the performance issues were caused mainly by mechanical failures of the brine injection system. It was suspected that the suction port of the eductor, which was left online, might have restricted the brine flow as brine was pulled (or, in this case, pumped) from the suction chamber to the converging/mixing chamber in the eductor.

The vendor dispatched another technician to Fruitland on February 26, 2007. The technician opened the tops of the vessels and discovered 8 in of freeboard in both vessels. The vendor speculated that the presence of freeboard could have allowed the IX beds to rise and pack around the upper distributor, resulting in excessive pressure drop as observed during regeneration. Additional packing media was shipped to the site and loaded into the IX vessels on March 2, 2007. Meanwhile, the eductor was removed and replaced with a tee and a diaphragm valve on the regeneration water inlet line before the tee for flowrate adjustment. After these modifications, the brine injection pump was able to inject a proper amount of saturated brine (~225 gal per vessel) into the IX system. Samples collected following a regeneration cycle showed 1.5, 1.3, 1.3, 1.1, 4.5, and 7.5 mg/L of nitrate (as N) at 17,000, 40,000, 48,000, 53,000, 207,000, and 248,000 gal of throughput, respectively.

Resin Fouling. From April 12 to May 14, 2007, elevated arsenic and/or nitrate concentrations were detected again in system effluent. For example, 13.8, 11.8, and 13.6 mg/L of nitrate (as N) were detected at 204,000, 28,000, and 149,000 gal of throughput on April 4, April 13, and May 9, 2007. Significantly elevated arsenic concentrations were detected throughout the service run on May 9 and 10, 2007, as

shown on Figure 4-12, a snapshot from the inline arsenic analyzer, ArsenicGuard. Note that the inline data (yellow dots) starting from the night of May 11, 2007, through ~ 10:30 a.m on May 14, 2007 were invalid because the analyzer lost control of arsenic concentrations during this time period. Also note that the analyzer would continue analyzing "samples" even when the IX system was not operating or the analyzer was losing control of arsenic concentrations. Blue dots in the figure reflect the results of 0 and 10.0 µg/L standards, which appear to be well on track.



KEY:

Yellow dots: System Effluent at TT
Blue dots: Check standards (10 or 0 ppb)
Red dots: Failed or aborted measurement
Data plotted as of 11:20 a.m. on 05/14/07, which is 'zero' day on the plot

Figure 4-12. Snapshot from ArsenicGuard on May 9 and 10, 2007

The high arsenic and nitrate concentrations measured during service runs raised the suspicion of IX resin fouling. Source water collected on April 17, 2007 showed 1.6 mg/L of TOC, slightly lower than the 2.2 mg/L of TOC measured three years ago during source water sampling on July 13, 2004 (Table 4-1). The results of other analytes, including total As, Fe, Mn, P, and Ca were comparable to those measured previously (Table 4-1), suggesting that the poor system performance and the suspected IX resin fouling would not have been caused by any changes in water quality.

On May 18, 2007, a conference call was held by Battelle with EPA, Kinetico, and the facility to discuss issues related to IX resin fouling. It was agreed that various mechanical issues associated with the brine

injection system that caused improper resin regeneration for an extended period of time (i.e., since July 2006 after conversion of system regeneration from the co- to counter-current mode) might have resulted in the suspected IX resin fouling. The vendor, therefore, recommended that the IX resin be cleaned with a mixture of 5% NaOH and 10% brine followed by regular co-current regeneration, and that system regeneration be switched back to co-current regeneration due to difficulties encountered in the counter-current regeneration mode.

One additional item discussed during the May 18, 2007, teleconference was the 1.5-hp, close-coupled centrifugal pump installed on October 24, 2006 for brine injection. Due to extensive corrosion, the vendor recommended to order and send a 2-hp replacement pump (G&L model ICS [Investment Cast Stainless 316SS]). Upon arrival, the pump was installed by the operator in mid-June 2007, but had to be returned to the vendor for repair shortly after it was put in use. As such, the plant operator had to switch back to the old pump during IX resin regeneration.

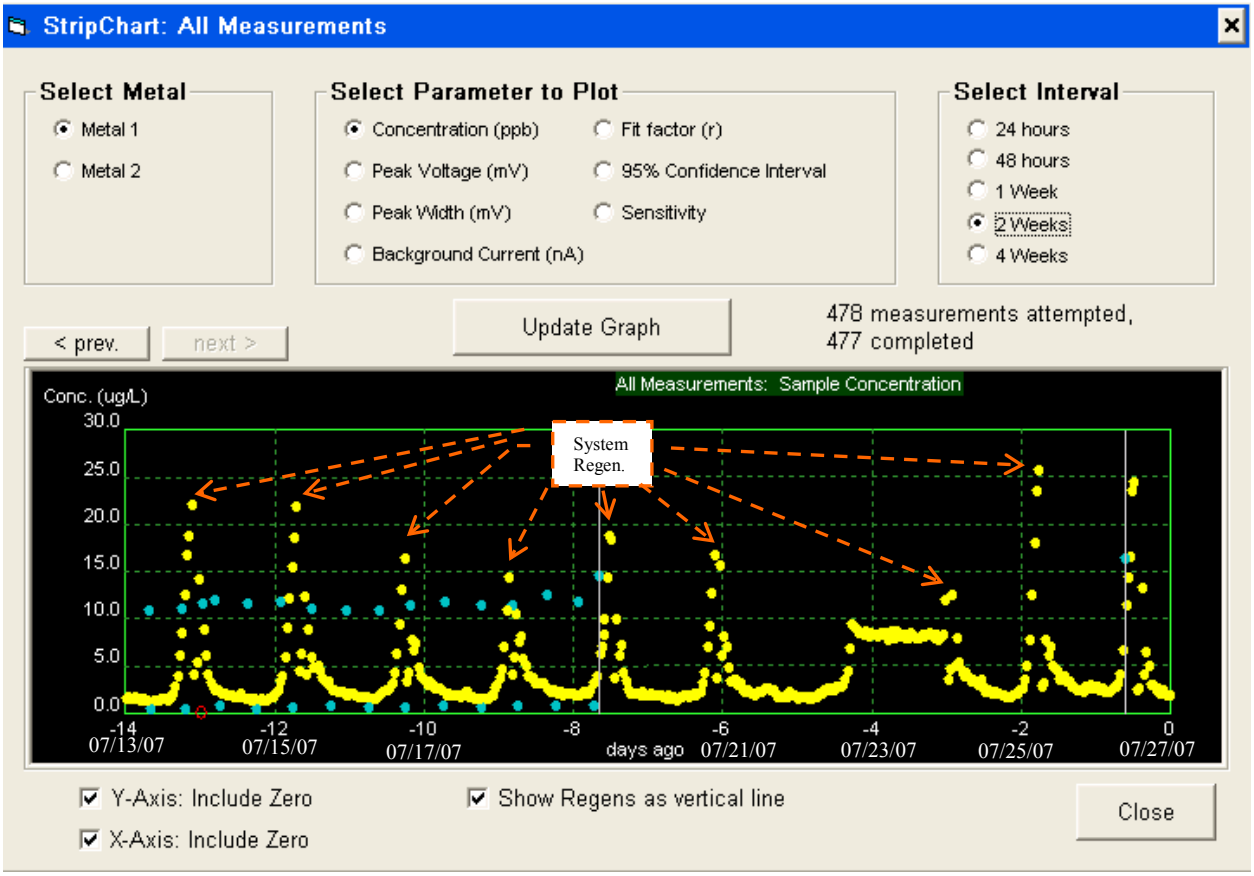
The IX resin fouling issue had been discussed in the February 21, 2007, meeting, during which recommendations were made to pull core samples from each IX resin vessel and send them to Purolite for laboratory cleaning and analysis. The core samples were collected on March 28, 2007, following a regular field regeneration cycle with brine. The results of the resin analysis before and after caustic/brine cleaning are discussed in Section 4.5.5.

4.4.3.3 Study Period III (June 18, 2007 to February 11, 2008)

Initial Arsenic and Nitrate Leakage after Regeneration. The IX resin was cleaned with a caustic/brine mixture on June 19, 2007, and a core sample was taken from Vessel B and shipped to Purolite for analysis. The IX system was then switched back to the co-current regeneration mode. The initial arsenic and nitrate leakages observed during Study Period I continued, as evidenced by the results of field nitrate measurements using nitrate test tubes (CAT No. 14037-00) and inline arsenic measurements using the ArsenicGuard. For example, samples collected daily in July 2007 showed elevated nitrate concentrations both at the beginning and end of service runs, although all were below 10 mg/L (as N). Similarly, arsenic concentrations monitored by the ArsenicGuard were elevated during both the beginning and end of service runs, as shown by a snapshot of the ArsenicGuard display in Figure 4-13.

Ineffective Resin Regeneration Caused by the Newly-installed Brine Injection Pump. Following the resin cleaning on June 19, 2007, system performance continued to be erratic, largely depending on success or failure of regeneration. For example, an automatic regeneration failed on June 26, 2007, with 29.8 µg/L and 12.7 mg/L (as N) of arsenic and nitrate, respectively, measured at 21,000 gal of throughput. A manual regeneration conducted on the following day was successful with 4.8 mg/L (as N) of nitrate measured at 94,000 gal of throughput. Consistently elevated nitrate concentrations were measured again on July 2, 3, and 5, 2007, at 12.7 mg/L (at 145,000 gal), 12.1 mg/L (at 10,000 gal), and 12.9 mg/L (at 160,000 gal), respectively. As a result, the IX system was shut down on July 5, 2007. The vendor suspected that the failed regeneration cycles were caused by the newly installed 2-hp pump and, therefore, asked the plant operator to switch back to the old brine injection pump (see Section 4.4.3.2). The regeneration was manually triggered on July 6, 2007, and it was confirmed that each vessel used approximately 250 gal of brine (SG = 1.043) as intended.

Impact of Spent Brine Discharge on City's Sewage Lagoons. The city experienced problems with its sewage lagoons due to discharge of spent brine and rinse water, which apparently had caused duckweeds in the lagoons to die. Therefore, the use of the IX system was cut back to 3 hr/day starting from September 2007 to reduce any harmful impact on the biological activities in the lagoons. The city plans to completely discontinue the use of the IX system after a new surface water treatment plant is put into service. The IX system would be kept for emergency use only.



KEY:

Yellow dots: System Effluent at TT
Blue dots: Check standards (10 or 0 ppb)
Red dots: Failed or aborted measurement

Figure 4-13. Total Arsenic Concentration in System Effluent – An ArsenicGuard Display Snapshot

Corrosion in IX Treatment Plant. The interior of the IX treatment plant experienced extensive corrosion due to exposure to high salt contents in the plant. This was caused primarily by the presence of the salt saturator and brine day tank and dusty conditions during salt loading in the plant.

4.4.4 Residual Management. Residuals produced by the IX system included spent brine and rinse water, which were discharged to a floor drain. The volume of wastewater produced was determined by the regeneration frequency and the volume of wastewater generated per regeneration cycle. Table 4-11 presents the calculations of wastewater production under different regeneration settings during Study Period I, using the flowrates derived from Table 4-9.

The adjustments to the regeneration settings resulted in significant reductions in wastewater production. For example, increasing the brine concentration from 4% to 8%, decreasing the brine draw time from 64 to 32 min, and increasing the brine draw flowrate reduced the spent brine volume from 2,944 to 2,304 gal per regeneration cycle. The reduction in slow rinse and fast rinse time also decreased the wastewater volume proportionally. Under Regeneration Setting 3, the total wastewater volume per cycle was reduced to 6,230 gal, which was 60% of that under the initial setting. The monthly wastewater production was estimated based on the number of regeneration cycles calculated by dividing the respective run length

Table 4-11. Comparison of Wastewater Production Under Different IX Regeneration Settings

Parameter	Initial Settings	Regeneration Setting 1	Regeneration Setting 2	Regeneration Setting 3	Regeneration Setting 4
Run Length Setting (gal)	214,000	335,000	316,000	316,000	316,000
Brine Draw					
Brine Concentration (%)	4	8	8	8	6
Brine Draw Time (min)	64	32	32	25	25
Brine Draw Flowrate (gpm)[(a)]	23	36[(c)]	36	37	43
Brine Draw Volume (gal)	1,472	1,152	1,152	925	1,075
Slow Rinse					
Slow Rinse Time (min)	64	64	64	40	40
Slow Rinse Flowrate (gpm)[(a)]	23	26	26	27	36
Slow Rinse Volume (gal)	1,472	1,664	1,664	1,080	1,440
Fast Rinse					
Fast Rinse (min)	30	30	6	15	15
Fast Rinse Flowrate (gpm)[(a)]	75	62	62	74	69
Fast Rinse Volume (gal)	2,250	1,860	372	1,110	1,035
Total Waste Production					
Wastewater Produced (gal/tank/cycle)	5,194	4,676	3,188	3,115	3,550
Wastewater Produced (gal/cycle)	10,388	9,352	6,376	6,230	7,100
Average Monthly Production (gal/month)[(b)]	5,076,390	5,076,390	5,076,390	5,076,390	5,076,390
No. of Regeneration Cycles per Month	23	14	15	15	15
Monthly Wastewater Production (gal/month)	238,924	130,928	95,640	93,450	106,500
Water Production Efficiency (%)	95.3	97.4	98.1	98.2	97.9

(a) Flowrates measured under Regeneration Setting 2 used for calculations under Setting 1.
(b) Based on an average daily demand of 166,895 gpd in Table 4-7.
(c) Higher brine draw flowrate caused by over adjustment of a hand valve.

settings by average daily demand of 166,895 gpd. Depending on the settings, water production efficiencies ranged from 95.3% to 98.2%.

4.4.5 System Operation Requirement

4.4.5.1 Required System Operation and Operator Skills. The required system operation and operator skills are further discussed below according to pre- and post-treatment requirements, levels of system automation, operator skill requirements, preventive maintenance activities, and frequency of chemical/media handling and inventory requirements.

Pre- and Post-Treatment Requirements. Pretreatment included filtration with a bank of five bag filters to remove sediment from source water. The bag filters were replaced when Δp readings across the bag filters were greater than 6 psi. The bag filters were replaced eight times during the first 20 months of the demonstration study from June 14, 2005 to February 9, 2007, and it took approximately one hour each time to replace all five filter bags. There was no post-treatment employed, except for the provision of post-chlorination in case of any bacterial outbreak.

System Automation. The IX system was fully automatic and controlled by the PLC in the central control panel. The control panel also contained a touch screen OIP that allowed the operator to monitor system flowrate and throughput since last regeneration. The OIP also allowed the operator to change system setpoints, as needed, and check the status of alarms. Setpoint screens were password-protected so that changes could only be made by authorized personnel. Typical alarms were for no flow, storage tank high/low, and regeneration failure. The IX system was regenerated automatically based on a throughput setpoint, except during the regeneration sampling events when the system was regenerated manually in order to capture spent regenerant and rinse samples. Although the system required minimal operator oversight and intervention, a number of operational issues with automated resin vessel regeneration and associated equipment, as noted in Section 4.4.3 did arise.

Operator Skill Requirements. The O&M of the IX system required minimal additional operator skills beyond those required for small system operators, such as solid work ethic, basic mathematical skills, ability to understand chemical properties, familiarities with electronic and mechanical components, and ability to follow written and verbal instructions. Understanding of and compliance with all occupational and chemical safety rules and regulations also were required. Since all major system operations were automated and controlled by the PLC, the operator was required to understand and learn how to use the PLC and OIP to perform tasks after receiving training from the vendor.

The level of operator certification is determined by the type and class of the public drinking water systems. IDEQ's drinking water rules require that all community and non-transient, non-community public drinking water and distribution systems be classified based on potential health risks. Classifications range from "Class I" (lowest) to "Class IV" (highest) for treatment systems and from "Very Small" to "Class IV" for distribution systems, depending on factors such as system complexity, size, and source water. There are 11 different types and classes of individual drinking water operator classes for which licenses are issued. The City of Fruitland Public Water System is classified as a "Class II" distribution system and the plant operator has a matching "Class II" license. After receiving proper training by the vendor during system startup, the operator understood the PLC, knew how to use the OIP, and worked with the vendor to troubleshoot and perform minor on-site repairs.

4.4.5.2 Preventive Maintenance Activities. Preventive maintenance tasks recommended by the vendor included daily to monthly visual inspection of the piping, valves, vessels, flow meters, and other system components. Routine maintenance also may be required on an as-needed basis for the air compressor motor and the replacement of o-ring seals or gaskets on automated or manual valves and the

brine transfer pump (Kinetico, 2004). During the demonstration study, maintenance activities performed by the operator included replacing filter bags periodically, checking the brine concentration using a hydrometer, adjusting regeneration frequency and setpoints as instructed by the vendor, and conducting troubleshooting activities as described in Section 4.4.3 related to the malfunction of automated regeneration operations.

4.4.5.3 Chemical/Media Handling and Inventory Requirements. Sodium chloride was the only chemical required for IX system operation. The system has fully automated controls with IX resin regeneration triggered by volume throughput. The salt truck delivered salt on a weekly or as-needed basis with or without the operator's presence. The salt saturator was sized to hold 15 tons of salt supply; this capacity, however, was reduced by 18% to 12.3 ton due to shortening of the tank height to fit the building. Assuming that the system regenerated 15 times per month (see Table 4-10) and used 1,000 lb of salt per event (as designed), it would require 15,000 lb or 6.8 tons of salt per month. Therefore, the salt saturator held about seven weeks of salt supply.

4.5 System Performance

The performance of the IX system was evaluated based on analyses of water samples collected across the treatment train, during IX vessel regeneration, and from the distribution system. To help provide additional insight into system performance, samples also were collected during a number of IX resin run length studies and elution studies.

4.5.1 Treatment Plant Sampling. The treatment system performance was evaluated via routine sampling only during Study Period I from June 14, 2005, to July 25, 2006. The treatment plant water was sampled on 52 occasions, including three duplicate sampling events and 14 speciation events. Table 4-12 summarizes arsenic, nitrate, uranium, vanadium, and molybdenum analytical results. Table 4-13 summarizes results of other water quality parameters. Appendix C contains a complete set of analytical results. The results obtained are discussed as follows.

4.5.1.1 Arsenic and Nitrate Removal. Arsenic and nitrate were the two primary contaminants of concern in source water; thus, their removal was the key to assessing the performance of the IX system. Figures 4-14 and 4-15 show total arsenic and nitrate concentrations, respectively, across the treatment train. Each figure consists of two plots: the first one plots total arsenic (or nitrate) concentrations against sampling dates; the second plots the same set of concentration data against system throughput at the time of sample collection. Because the system was regenerated two to three times a week, these weekly treatment plant samples were collected from multiple service runs. Typically, a breakthrough curve is constructed with data from the same service run. To better understand IX system performance with data collected from multiple service runs, the concentration data were plotted against the system throughput (from low to high) when samples were collected. These "reconstructed" breakthrough curves are presented in Figures 4-14b for total arsenic and 4-15b for nitrate. Note that Figures 4-14b and 4-15b do not include the data collected on June 23, June 29, and August 3, 2005, because the IX system operated improperly on those days.

Total arsenic concentrations in raw water ranged from 33.6 to 60.8 µg/L and averaged 42.5 µg/L (Table 4-13). Nitrate concentrations in raw water ranged from 6.9 to 11.5 mg/L (as N) and averaged 10.0 mg/L (as N). After IX treatment, total arsenic concentrations were reduced from to below 10 µg/L in most TA, TB, and TT samples (Figure 4-14b). However, over 10 µg/L of arsenic was measured in 10 samples collected within 28,000 gal into the service runs and one sample collected after 314,000 gal into the service run. Similarly, nitrate concentrations after the IX treatment were reduced to below 10 mg/L (as N) in most TA, TB, and TT samples, except for seven samples collected after 269,000 gal into the service runs (Figure 4-15b). As also shown in Figure 4-15b, somewhat elevated nitrate concentrations (above

Table 4-12. Summary of Arsenic, Nitrate, Uranium, Vanadium, and Molybdenum Data

Parameter	Sampling Location[a]	Unit	Sample Count	Minimum	Maximum	Average	Standard Deviation
As (total)	IN	µg/L	52	33.6	60.8	42.5	6.0
	TA	µg/L	36[b]	<0.1	41.4	-[c]	-[c]
	TB	µg/L	36[b]	0.2	46.3	-[c]	-[c]
	TT	µg/L	14	0.7	3.3	-[c]	-[c]
As (soluble)	IN	µg/L	14	35.1	59.9	40.3	6.2
	TT	µg/L	14	0.7	3.4	-[c]	-[c]
As (particulate)	IN	µg/L	14	0.1	8.9	3.5	3.2
	TT	µg/L	14	<0.1	0.9	-[c]	-[c]
As(III)	IN	µg/L	14	0.4	2.4	1.2	0.6
	TT	µg/L	14	0.4	2.4	-[c]	-[c]
As(V)	IN	µg/L	14	33.7	58.7	39.0	6.2
	TT	µg/L	14	<0.1	2.9	-[c]	-[c]
Nitrate (as N)	IN	mg/L	52	6.9	11.5	10.0	0.9
	TA	mg/L	37	0.4	15.0	4.4	4.3
	TB	mg/L	38	0.3	12.8	3.9	3.3
	TT	mg/L	14	0.4	13.2	3.5	4.5
U (total)	IN	µg/L	52	13.8	24.9	19.4	1.9
	TA	µg/L	38	<0.1	0.3	-[c]	-[c]
	TB	µg/L	38	<0.1	2.5	-[c]	-[c]
	TT	µg/L	14	<0.1	<0.1	-[c]	-[c]
U (soluble)	IN	µg/L	12	15.9	20.4	18.6	1.4
	TT	µg/L	12	<0.1	<0.1	-[c]	-[c]
V (total)	IN	µg/L	52	30.6	53.0	39.3	3.4
	TA	µg/L	38	0.1	16.6	-[c]	-[c]
	TB	µg/L	38	0.2	36.1	-[c]	-[c]
	TT	µg/L	14	<0.1	4.2	-[c]	-[c]
V (soluble)	IN	µg/L	13	36.6	45.2	39.6	2.2
	TT	µg/L	13	<0.1	5.7	-[c]	-[c]
Mo (total)	IN	µg/L	50	11.6	15.9	12.9	0.9
	TA	µg/L	34[d]	<0.1	0.8	-[c]	-[c]
	TB	µg/L	34[d]	<0.1	0.7	-[c]	-[c]
	TT	µg/L	14	<0.1	0.5	-[c]	-[c]
Mo (soluble)	IN	µg/L	13	11.4	14.0	12.7	0.8
	TT	µg/L	13	<0.1	0.4	-[c]	-[c]

(a) See Figure 3-1 for sampling locations.
(b) Excluding data collected on 06/23/05 and 06/29/05, when system was not regenerated properly.
(c) Not meaningful for concentrations related to breakthrough, see Figures 4-14 and 4-15 and Appendix B for results.
(d) Excluding three outliers on 06/23/05, 06/29/05, and 11/30/05.

One-half of detection limit used for nondetect samples for calculations.
Duplicate samples included in calculations.

Table 4-13. Summary of Other Water Quality Parameters

Parameter	Sampling Location[a]	Unit	Sample Count	Minimum	Maximum	Average	Standard Deviation
Alkalinity (as $CaCO_3$)	IN	mg/L	52	365	484	387	18
	TA	mg/L	37	3.0	484	334	146
	TB	mg/L	38	3.0	462	300	179
	TT	mg/L	14	286	484	432	57
Fluoride	IN	mg/L	15	0.3	1.3	0.6	0.2
	TA	mg/L	1	0.7	0.7	0.7	NA
	TB	mg/L	1	0.7	0.7	0.7	NA
	TT	mg/L	14	0.3	0.6	0.5	0.1
Sulfate	IN	mg/L	52	41	91	59	7.9
	TA	mg/L	37	<1	94	6.0	20
	TB	mg/L	38	<1	63	5.7	16
	TT	mg/L	13	<1	<1	<1	0.0
Nitrate (as N)	IN	mg/L	53	6.9	11.5	10.0	0.9
	TA	mg/L	37	0.4	15.0	4.4	4.3
	TB	mg/L	38	0.3	12.8	3.9	3.3
	TT	mg/L	18	0.4	13.2	3.9	4.2
Orthophosphate (as PO_4)	IN	mg/L	28	<0.05	0.56	0.11	0.12
	TA	mg/L	19	<0.05	0.23	0.05	0.06
	TB	mg/L	20	<0.05	0.25	0.05	0.06
	TT	mg/L	8	<0.05	0.85	0.13	0.29
P (total)	IN	mg/L	31	<0.03	0.40	0.32	0.07
	TA	mg/L	22	<0.03	0.28	0.03	0.06
	TB	mg/L	22	<0.03	0.50	0.07	0.13
	TT	mg/L	9	<0.03	0.09	0.02	0.03
Silica (as SiO_2)	IN	mg/L	50	47	63	57	2.8
	TA	mg/L	38	53	62	57	1.8
	TB	mg/L	38	53	63	57	1.9
	TT	mg/L	13[b]	46	62	56	4.4
Turbidity	IN	NTU	52	<0.1	1.4	0.4	0.3
	TA	NTU	37	<0.1	1.5	0.6	0.4
	TB	NTU	38	0.1	1.8	0.6	0.5
	TT	NTU	14	0.1	1.6	0.5	0.6
TDS	IN	mg/L	13	542	610	580	22
	TT	mg/L	12	498	584	547	26
pH	IN	S.U.	49	6.7	7.9	7.6	0.2
	TA	S.U.	34	6.8	7.9	7.5	0.3
	TB	S.U.	35	6.0	7.9	7.3	0.4
	TT	S.U.	14	7.2	7.9	7.5	0.2
Temperature	IN	ºC	49	14.6	15.7	15.1	0.2
	TA	ºC	34	14.6	15.9	15.1	0.3
	TB	ºC	35	14.6	15.7	15.0	0.2
	TT	ºC	14	14.8	15.9	15.1	0.3
Dissolved Oxygen	IN	mg/L	48	1.9	4.3	2.7	0.5
	TA	mg/L	34	1.8	3.4	2.5	0.4
	TB	mg/L	35	1.3	3.5	2.5	0.4
	TT	mg/L	13	1.7	3.6	2.6	0.5
ORP	IN	mV	49	191	314	244	29
	TA	mV	34	180	319	241	29
	TB	mV	34[c]	186	296	239	22
	TT	mV	14	172	288	240	27

Table 4-13. Summary of Other Water Quality Parameters (Continued)

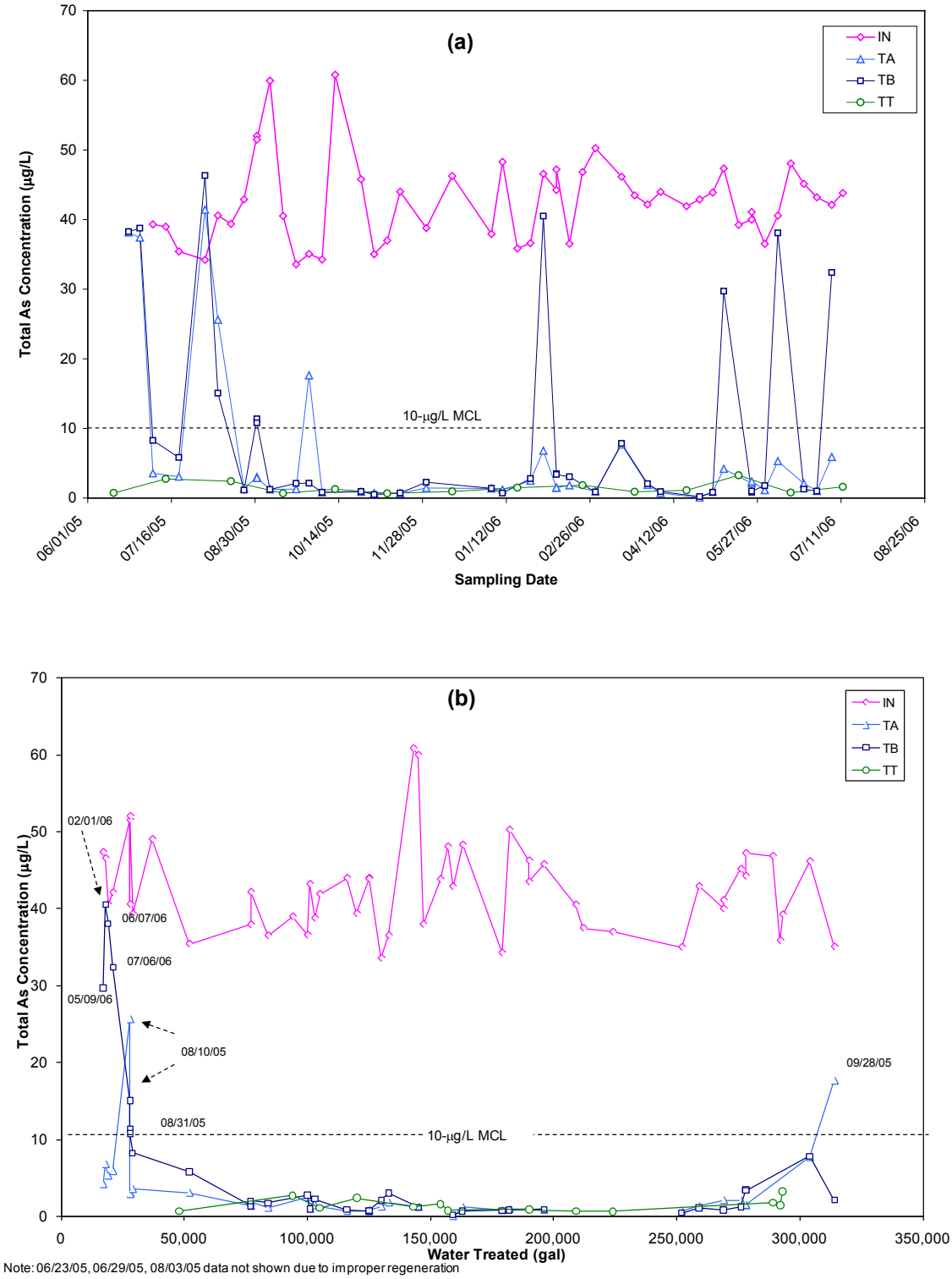
Parameter	Sampling Location[(a)]	Unit	Sample Count	Minimum	Maximum	Average	Standard Deviation
Total Hardness (as $CaCO_3$)	IN	mg/L	15	221	315	249	28
	TA	mg/L	1	243	243	243	NA
	TB	mg/L	1	249	249	249	NA
	TT	mg/L	14	222	350	249	32
Ca Hardness (as $CaCO_3$)	IN	mg/L	16	122	199	146	19
	TA	mg/L	3	114	145	130	15
	TB	mg/L	3	119	146	129	15
	TT	mg/L	13	131	226	150	24
Mg Hardness (as $CaCO_3$)	IN	mg/L	15	86	132	101	13
	TA	mg/L	1	105	105	105	NA
	TB	mg/L	1	105	105	105	NA
	TT	mg/L	14	87	129	100	12
Fe (total)	IN	µg/L	50[(d)]	<25	<25	<25	0.0
	TA	µg/L	38	<25	<25	<25	0.0
	TB	µg/L	38	<25	<25	<25	0.0
	TT	µg/L	14	<25	<25	<25	0.0
Fe (soluble)	IN	µg/L	14	<25	<25	<25	0.0
	TT	µg/L	14	<25	<25	<25	0.0
Mn (total)	IN	µg/L	52	11.8	32.8	22.1	4.7
	TA	µg/L	38	<0.1	33.7	11.9	10.9
	TB	µg/L	38	0.2	28.0	13.9	9.6
	TT	µg/L	14	0.2	26.5	11.4	10.6
Mn (soluble)	IN	µg/L	14	10.0	35.2	21.5	6.7
	TT	µg/L	14	0.2	28.7	11.6	11.2

(a) See Figure 3-1 for sampling locations.
(b) Excluding an outlier on 07/16/06.
(c) Excluding an outlier on 08/10/05.
(d) Excluding two outliers on 06/23/05 and 9/28/05.
NA = not applicable.
One-half of detection limit used for nondetect samples for calculations.
Duplicate samples included in calculations.

~4 mg/L) also were measured within the first 50,000 gal of service run. Both arsenic and nitrate had either leaked from freshly regenerated IX resin beds or broken through from the IX beds upon exhaustion. These results are further discussed below:

Early Arsenic Leakage. On August 10, 2005, TA and TB samples collected at 28,000 gal (or 37 BV) of throughput contained 25.6 and 15.1 µg/L of total arsenic, respectively, exceeding the 10-µg/L MCL. This early arsenic leakage reoccurred on eight additional occasions on August 31, 2005, February 1, 2006, May 9, 2006, June 7, 2006, and July 6, 2006, with concentrations as high as 40.5 µg/L measured at TA at 18,000 gal of throughput. The issues related to early arsenic leakage were discussed in Section 4.4.3.

Arsenic and Nitrate Breakthrough Upon IX Resin Exhaustion. On September 28, 2005, the sample collected at TA contained 17.6 µg/L of total arsenic and 9.7 mg/L of nitrate (as N), which were either exceeding or approaching the respective MCLs. Sampling occurred after 314,000 gal (or 420 BV) of water had been treated, which was close to the regeneration throughput setpoint of 316,000 gal (422 BV). Because the TB sample contained only 2.1 µg/L of arsenic, the combined effluent from both vessels would have contained arsenic just under the MCL.



Note: 06/23/05, 06/29/05, 08/03/05 data not shown due to improper regeneration

Figure 4-14. Total Arsenic Concentrations Measured During Study Period I: (a) Temporal Plot; (b) Composite Breakthrough Curves

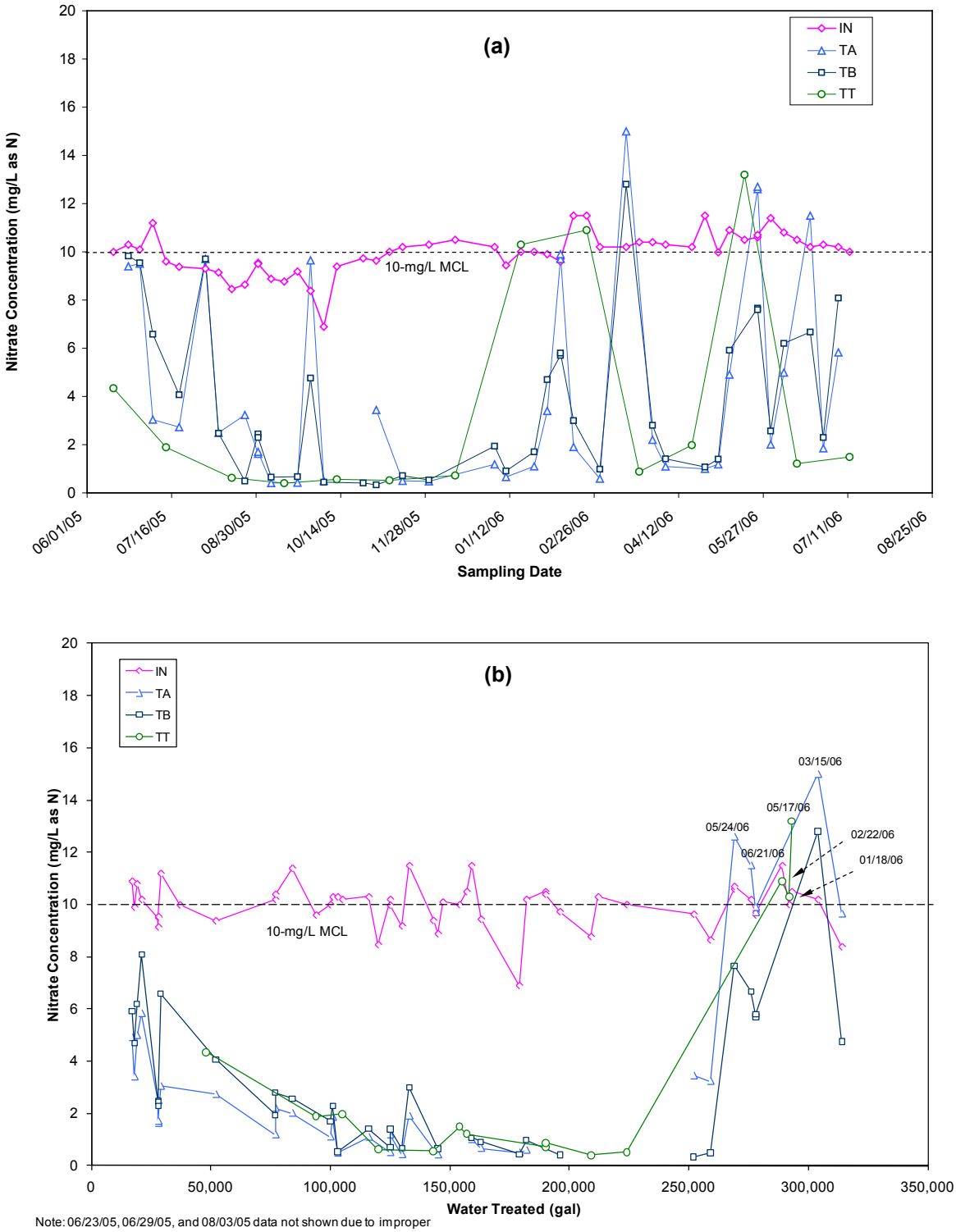


Figure 4-15. Nitrate Concentrations Measured Over the Period I Demonstration Study: (a) Temporal Plot; (b) Composite Breakthrough Curves

Samples collected after 269,000 gal of throughput exceeded the nitrate MCL on a number of occasions (including January 18, February 22, March 15, May 17, May 24, and June 21, 2006), indicating that the regeneration setpoint of 316,000 gal (422 BV) was inadequate for nitrate removal. To ensure proper removal of both arsenic and nitrate, a throughput value of 269,000 gal should have been used to trigger regeneration.

Samples Collected When System Operating Improperly. TA and TB samples collected on June 23 and 29, 2005, after 212,000 gal (or 283 BV) and 147,000 gal (or 197 BV) of water had been treated, respectively, showed almost no arsenic or nitrate removal (data not shown on the "reconstructed" breakthrough curves). It was discovered later that, after a power outage on June 17, 2005, the system PLC was reset automatically to the default "counter-current" regeneration mode. As a result, the system was not properly regenerated during this period. The effluent water quality returned to normal after the problem was corrected on June 29, 2005.

On August 3, 2005, TA and TB samples showed higher-than-raw-water levels of arsenic and nitrate (i.e., 41.4 and 46.3 µg/L vs. 34.2 µg/L for total As and 9.7 and 9.7 mg/L vs. 9.3 mg/L [as N] for nitrate). This occurred because the system had failed to regenerate at the setpoint of 335,000 gal (448 BV) and continued to operate up to 534,000 gal (714 BV) due to a broken brine tank level sensor. The prolonged service run forced previously exchanged arsenic and nitrate to be displaced, presumably, by more preferred anions such as sulfate in raw water, resulting in "chromatographic peaking." According to the selectivity sequence discussed in Section 4.2.1, an SBA resin such as A300E prefers sulfate over $HAsO_4^{2-}$, nitrate, and $H_2AsO_4^-$; HCO_3^- ion is less preferred than $HAsO_4^{2-}$, but has a similar affinity to the resin as $H_2AsO_4^-$.

4.5.1.2 Arsenic Speciation. Figure 4-16 shows the arsenic speciation results of samples collected at the wellhead and combined effluent during Study Period I. As(V) was the predominant species in raw water, ranging from 33.7 to 58.7 µg/L and averaging 39.0 µg/L (Table 4-12). Only trace amounts of particulate As and As(III) existed, with concentrations averaging 3.5 and 1.2 µg/L, respectively. After treatment, As(III) concentrations remained essentially unchanged, averaging 1.2 µg/L. As expected, the IX process did not remove the neutral species of arsenite.

4.5.1.3 Uranium, Vanadium, and Molybdenum Removal. Figure 4-17 presents the reconstructed breakthrough curves of total U, V, and Mo during Study Period I. Total U concentrations ranged from 13.8 to 24.9 µg/L in raw water (Table 4-13), which was removed to less than 1 µg/L in treated water except for July 6, 2005 at 2.5 µg/L (TB). Total V concentrations ranged from 30.6 to 53.0 µg/L and averaged 39.3 µg/L in raw water. After treatment, total V was removed to less than 10 µg/L, except for a few occasions with samples collected at 18,000 and 52,000 gal of throughput. The highest concentration measured was 36.1 µg/L (TB) on July 6, 2005. Total Mo in raw water averaged 12.9 µg/L and was removed to less than 1 µg/L, except for June 23 and 29, 2005, when the IX system was not operating properly.

4.5.1.4 Other Water Quality Parameters. Figures 4-18 and 4-19 present "reconstructed" breakthrough curves for sulfate, pH, and total alkalinity during Study Period I. As shown in Figure 4-18, sulfate concentrations ranged from 41 to 91 mg/L in raw water (Table 4-13), which was removed to less than 1 mg/L after treatment, except for June 23 and 29 and August 3, 2005, when the IX system experienced mechanical problems and for three occasions on February 1, June 28, and July 6, 2006, when sulfate concentrations spiked to 9 to 12 mg/L.

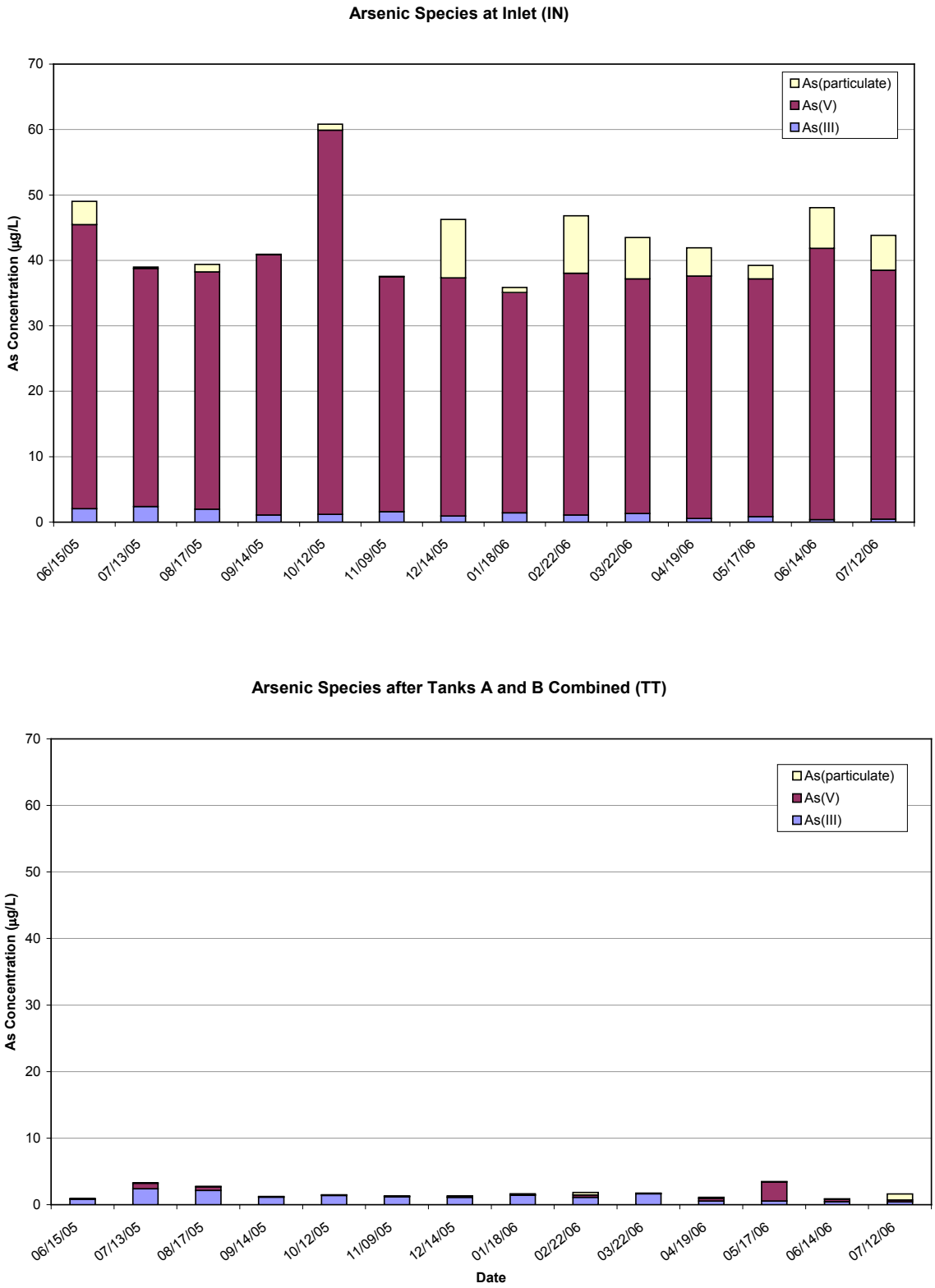
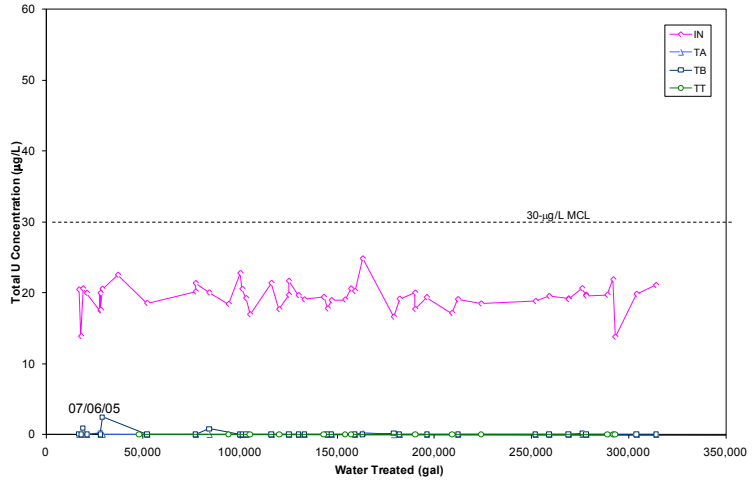
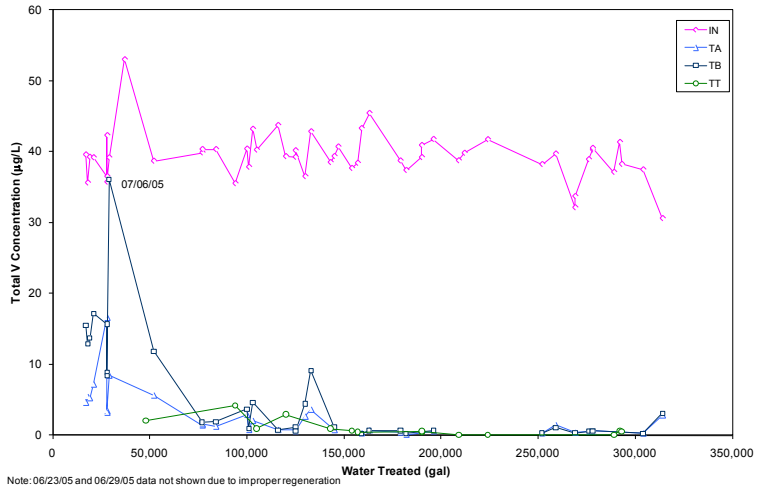
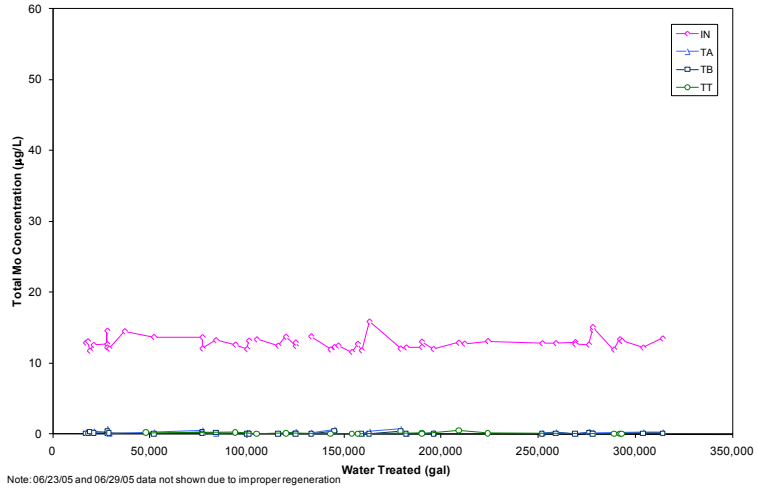


Figure 4-16. Concentrations of Arsenic Species at Wellhead and Combined Effluent





Note: 06/23/05 and 06/29/05 data not shown due to improper regeneration



Note: 06/23/05 and 06/29/05 data not shown due to improper regeneration

Figure 4-17. Composite Breakthrough Curves for Total U, V, and Mo

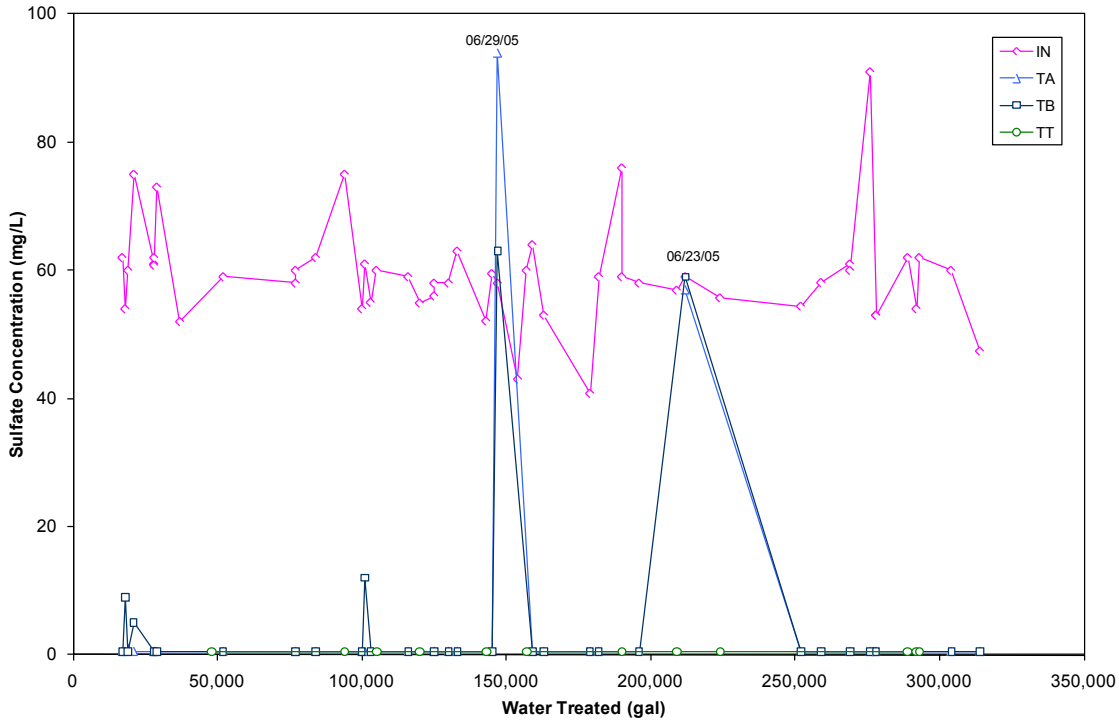
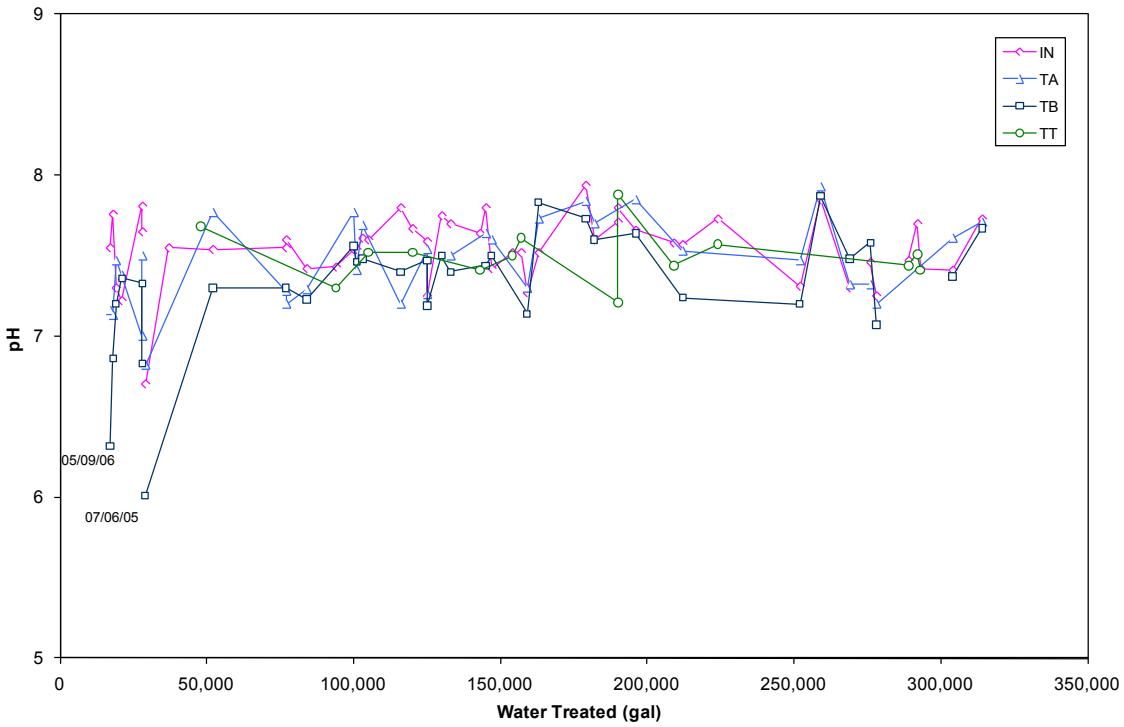


Figure 4-18. Composite Breakthrough Curves for Sulfate

Raw water pH values ranged from 7.2 to 7.9 and averaged 7.6 (except for one outlier of 6.7 on July 6, 2005). Treated water pH values remained in the similar range, but reduction in pH values was observed for a short duration after the system had been freshly regenerated. For example, pH values at IN, TA, and TB locations were 7.8, 7.0, and 7.3, respectively, on August 10, 2005, after 28,000 gal of water was treated; 7.7, 7.5, and 6.8, respectively, on August 31, 2005 after 28,000 gal of water was treated; and 7.8, 7.1, and 6.9, respectively, on February 1, 2006 after 11,000 gal of water was treated. This pH reduction corresponded to the significant reduction in total alkalinity, i.e., from 383 to 3 and 3 mg/L (as $CaCO_3$) on August 10, 2005; from 374 to 158 and 7 mg/L (as $CaCO_3$) on August 31, 2005; and from 393 to 60 and 12 mg/L (as $CaCO_3$) on February 1, 2006.

The reduction in pH and alkalinity immediately after regeneration was attributed to the removal of bicarbonate ions by the IX resin. As well documented in the literature, one disadvantage of the IX process is reduction of pH by the freshly regenerated resin during the initial 100 BV of a service run (Clifford, 1999). Afterwards, rapid breakthrough of bicarbonate ions raises the pH values to those similar to raw water.

4.5.2 Resin Run Length Studies. Four run length studies (1 to 4) were conducted in Study Period I when the IX system was regenerated in the co-current mode. Two run length studies (5 and 6) were conducted in Study Period II after the system was switched to the counter-current mode. Figure 4-20 presents total arsenic and nitrate breakthrough curves from the six run length studies. Total alkalinity, pH, sulfate, and total V also were measured during Run Length Study 3 conducted on December 7 and 8, 2005, and their breakthrough curves are presented in Figure 4-21.



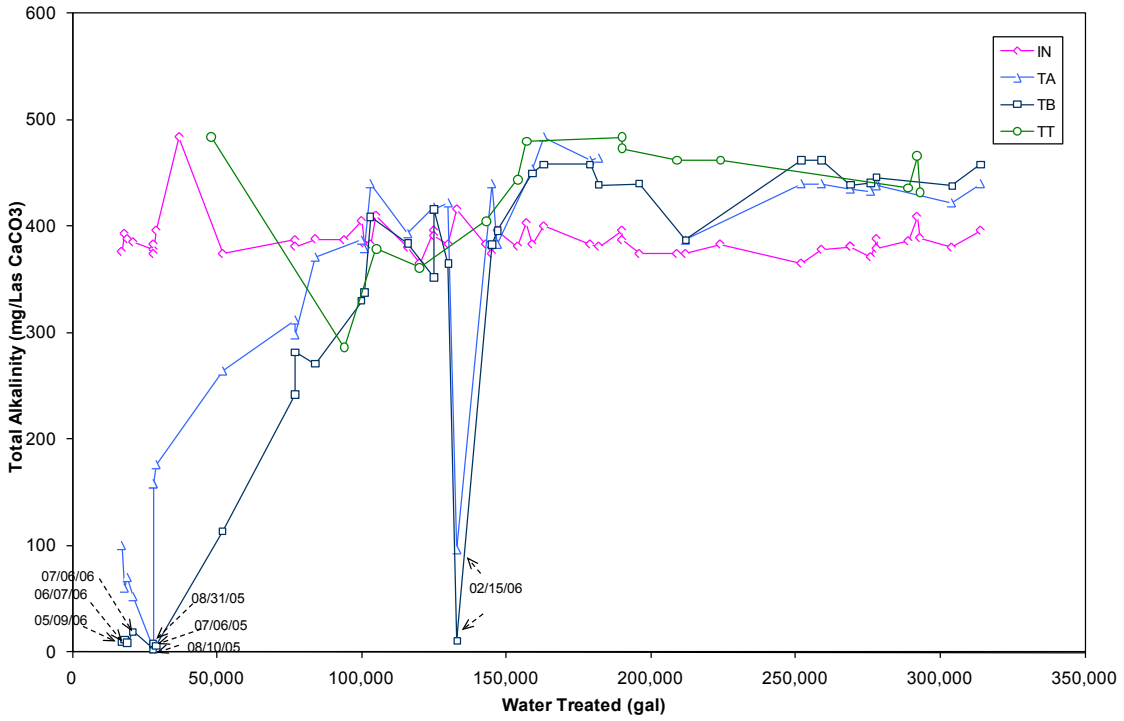


Figure 4-19. Composite Breakthrough Curves for pH and Total Alkalinity

4.5.2.1 Study Period I Run Length Studies

Run Length Study 1 (July 28-30, 2005). Combined effluent samples were collected and analyzed for total arsenic and nitrate using field test kits (Section 3.5.1). Arsenic and nitrate reached the respective detectable concentrations of 2 µg/L and 5 mg/L (as N), respectively, after 303,000 gal (~400 BV) of throughput. Samples collected at 366,000 gal (489 BV) showed arsenic and nitrate breakthrough at 20 µg/L and 10 mg/L (as N), respectively. Subsequent samples were collected from individual vessels to confirm the results. Total arsenic concentrations were measured at >50 µg/L in Vessel A effluent and 10 µg/L in Vessel B effluent. The higher arsenic breakthrough from Vessel A was expected because it had been in service longer than Vessel B. Nitrate concentrations were measured at 10 mg/L for both vessels. As a result of this study, the regeneration setpoint was adjusted from 214,000 gal (286 BV) to 335,000 gal (448 BV) on July 30, 2005 (Table 4-8).

Run Length Study 2 (August 16-17, 2005). The first sample collected from Vessel A at 86,000 gal (115 BV) contained 5 µg/L of total arsenic and 1.5 mg/L of nitrate (as N). Total arsenic concentrations then decreased to as low as 1.2 µg/L at 302,000 gal before rising again to as high as 5.4 µg/L before approaching the 335,000-gal setpoint. Nitrate concentrations decreased to 0.1 mg/L (as N) at 250,000 gal, and then increased steadily to 10 mg/L (as N) at 302,000 gal. Therefore, nitrate reached its MCL earlier than arsenic, which was consistent with the hierarchy of selectivity of an SBA resin (i.e., the divalent arsenate ion is more preferred than nitrate) as discussed in Section 4.2.1. The results of the study prompted the throughput setpoint to be reduced to 316,000 gal (422 BV) on September 19, 2005.

Run Length Study 3 (December 7-8, 2005). In this study, samples were collected from each vessel with more samples taken during the first 60,000 gal (or 80 BV) of throughput. Sampling results clearly indicated initial arsenic and nitrate leakage from both IX resin vessels. Vessel A arsenic and nitrate breakthrough curves were very similar to those of the second run length study. The initial arsenic leakage from Vessel B was as high as 18.7 µg/L at 24,000 gal (or 32 BV). The initial nitrate leakage from either vessel was as high as 4.3 mg/L (as N), which was below the MCL. The nitrate concentration in Vessel A effluent reached 10 mg/L (as N) at 288,000 gal (or 385 BV).

As shown in Figure 4-21, total alkalinity and pH values were significantly reduced to as low as 11 mg/L (as $CaCO_3$) and a standard unit of 6, respectively, immediately after regeneration and then gradually increased to the respective raw water levels at approximately 187,000 gal of throughput. Sulfate concentrations were below the detectable level throughout the service run. Vanadium also showed initial leakage, with more severe leakage observed at Vessel B. Total U and Mo levels were below the MDL of 0.1 µg/L throughout the service run.

Run Length Study 4 (April 11-12, 2006). Significant initial arsenic and nitrate leakage was observed from both IX resin vessels. The first sample was collected from Vessel A at 2,000 gal (3 BV) and contained 43 µg/L of total arsenic and 5.5 mg/L of nitrate (as N). Total arsenic concentrations then decreased to as low as 1.1 µg/L at 216,000 gal before rising again to as high as 7.7 µg/L at the 316,000-gal setpoint. Nitrate concentrations decreased to 0.2 mg/L (as N) at 216,000 gal, and then increased steadily to exceed 10 mg/L (as N) around 279,000 gal. Again, nitrate reached its MCL earlier than arsenic. Vessel B arsenic and nitrate breakthrough curves were similar to those of Vessel A. The first sample collected from Vessel B was at 13,000 gal (17 BV) and contained 30.3 µg/L of total arsenic and 5.9 mg/L of nitrate (as N).

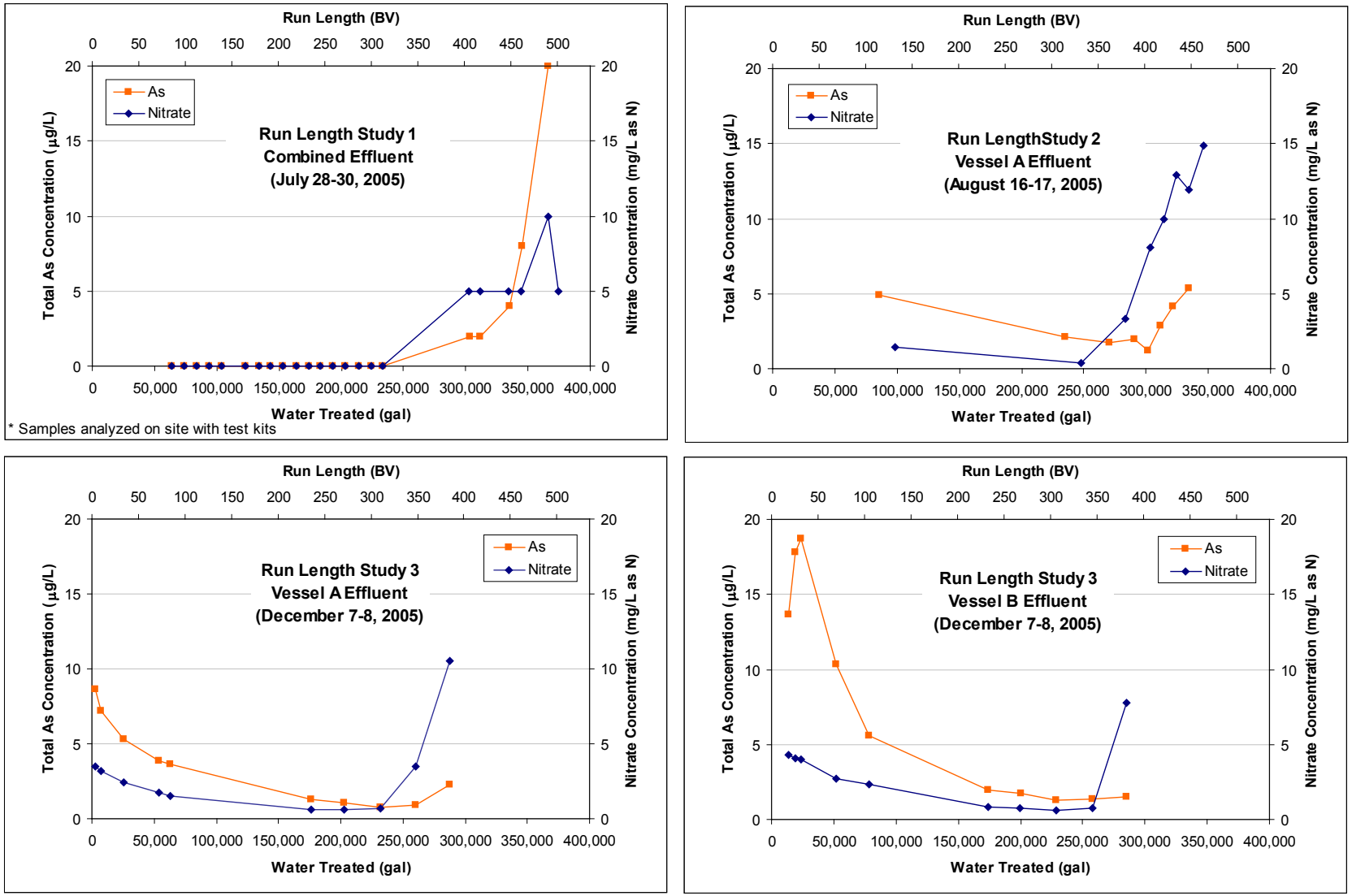
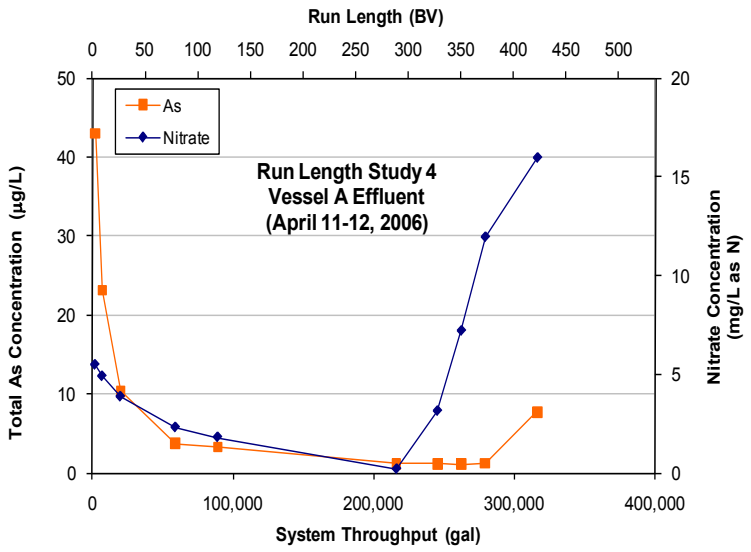
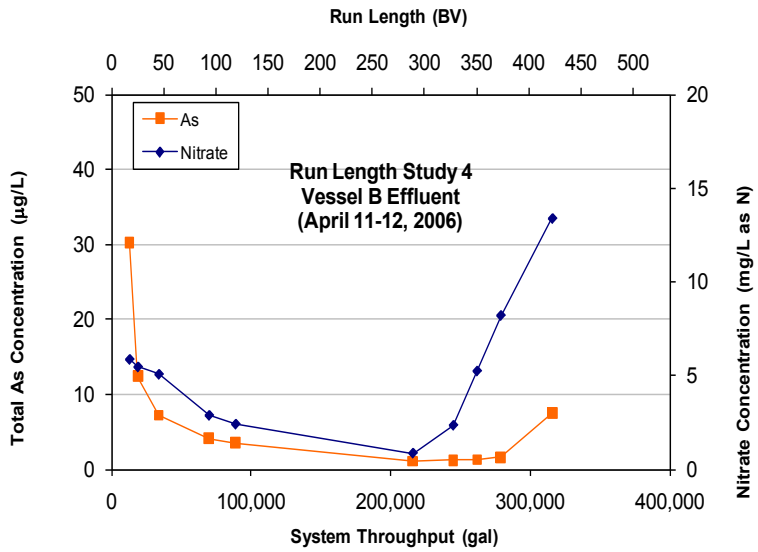
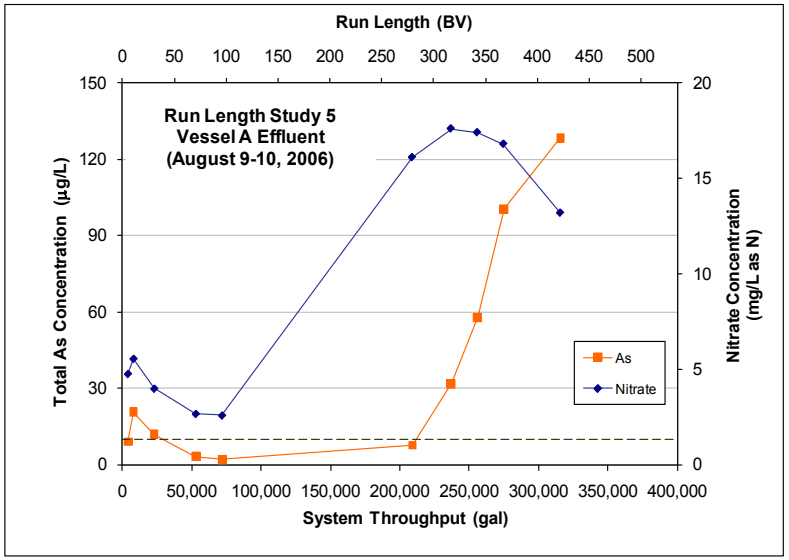


Figure 4-20. Total Arsenic and Nitrate Breakthrough Curves of Run Length Studies







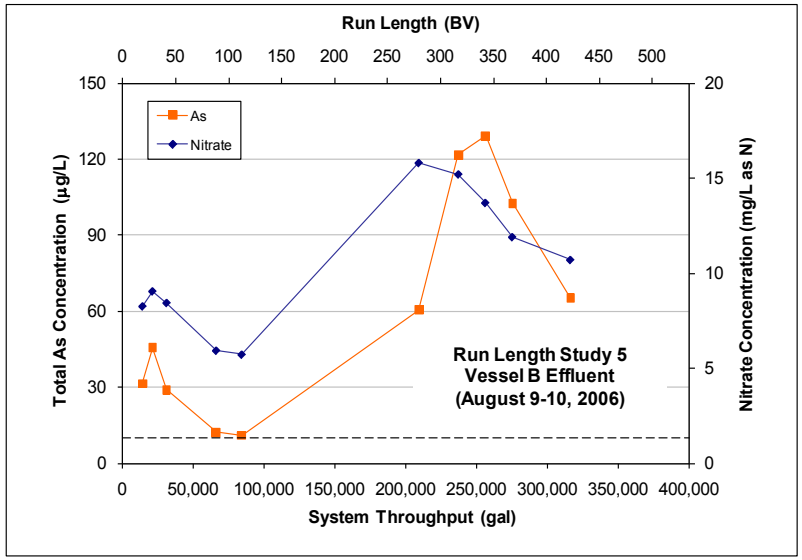


Figure 4-20. Total Arsenic and Nitrate Breakthrough Curves of Run Length Studies (Continued)

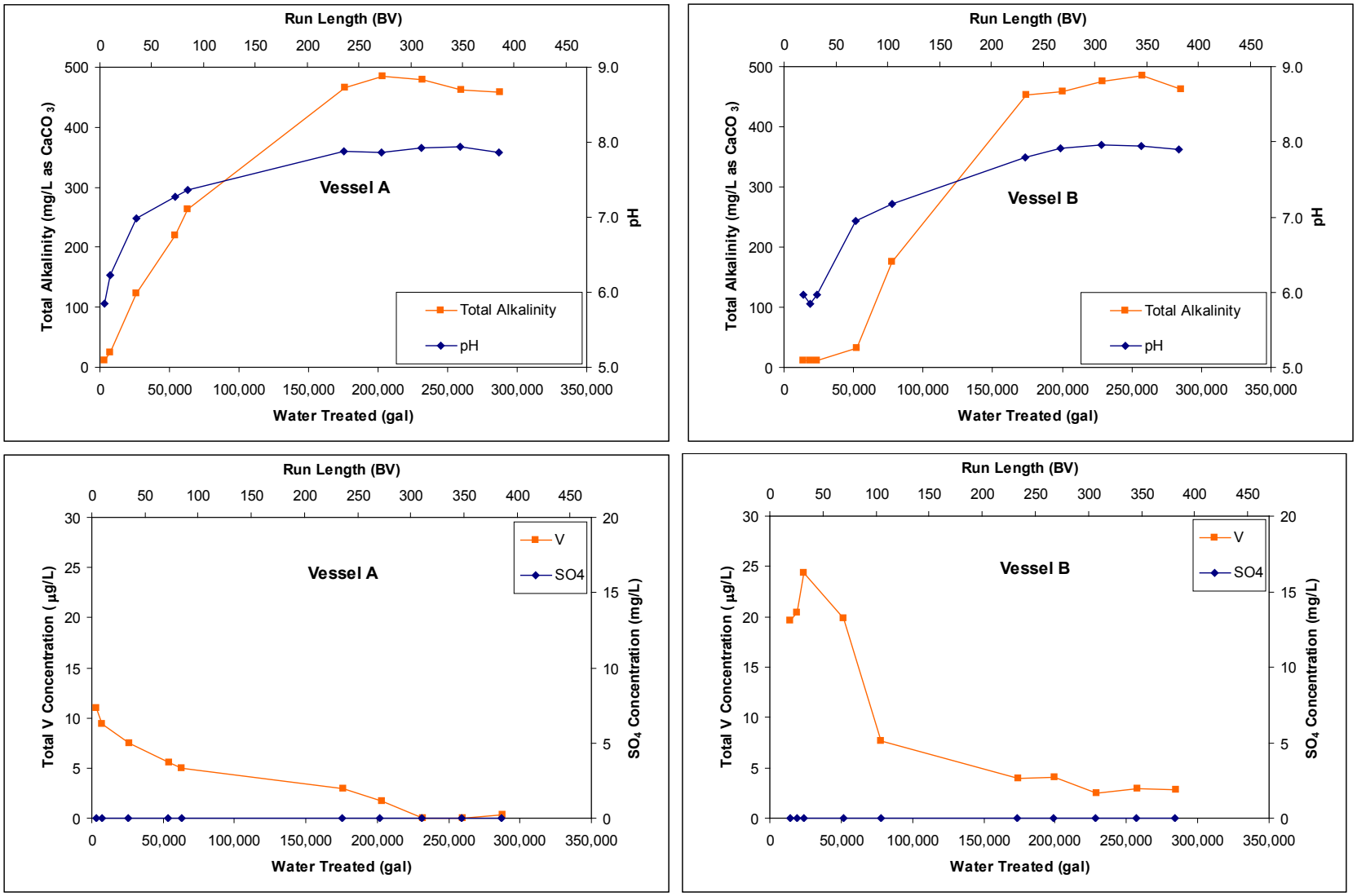


Figure 4-21. Total Alkalinity, pH, Sulfate, and Vanadium Breakthrough Curves of Run Length Study 3 (December 7 to 8, 2005)

4.5.2.2 Period II Run Length Studies

Run Length Study 5 (August 9-10, 2006). This run length study was conducted after the mode of regeneration had switched from co- to counter-current on July 25, 2006 (Table 4-8). For Vessel A, breakthrough of arsenic and nitrate at the respective MCLs occurred at 210,000 and 140,000 gal, respectively. For Vessel B, arsenic concentrations were above the 10 µg/L MCL throughout the entire run length study; nitrate concentrations were above the 10 mg/L (as N) MCL after approximately 133,000 gal of throughput. The highest arsenic and nitrate concentrations measured were 129 µg/L and 17.6 mg/L (as N), respectively. The result of the run length study indicated improper regeneration of the IX resin in counter-current regeneration mode.

Run Length Study 6 (January 16-17, 2007). After the brine injection pump had been installed at the suction side of the eductor, another run length study was conducted on January 17 to 18, 2007. The analytical results showed little or no arsenic/nitrate removal throughout the entire run length study, indicating lack of regeneration due to improper brine draw (Section 4.4.3).

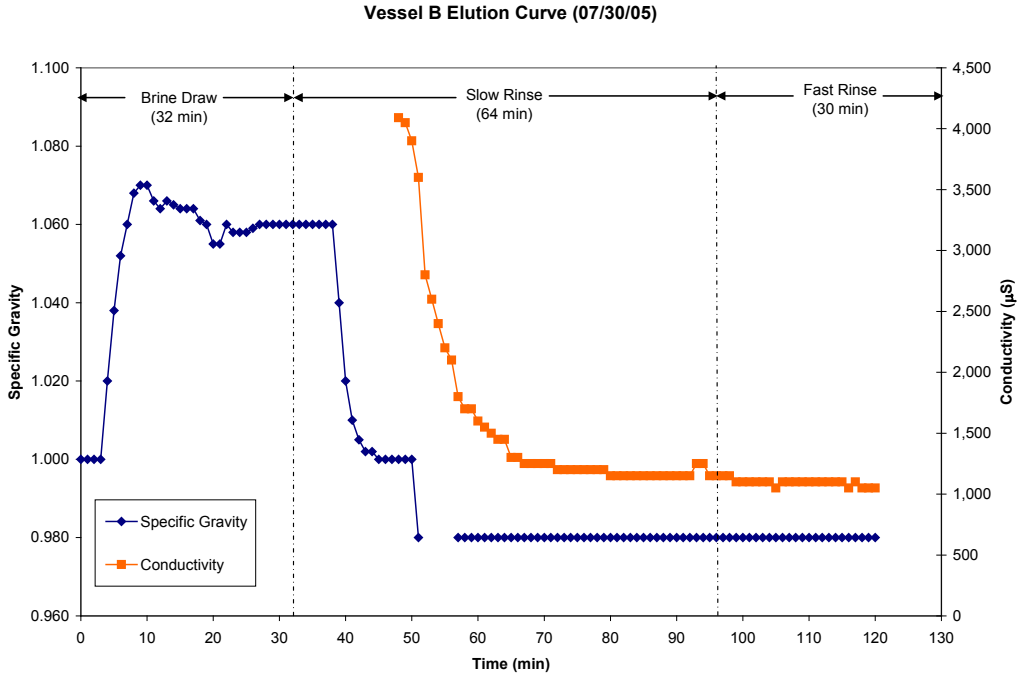
4.5.3 Regeneration Studies

4.5.3.1 Regeneration Study 1 (July 30, 2005). Figure 4-22 presents the specific gravity and conductivity of the wastewater discharged during Vessel B regeneration on July 30, 2005. Specific gravity of the wastewater increased sharply soon after brine draw, leveled off, and then decreased sharply a few minutes into slow rinse. Specific gravity measures percent concentration of salt in a brine solution. It was verified that the brine solution entering Vessel B had a specific gravity of 1.06, corresponding to 8% of salt. Because neither the brine draw flow nor the day tank usage was monitored during this study, the salt consumption could not be verified. Conductivity of the wastewater exceeded the range of the meter during brine draw, dropped sharply during slow rinse, and then leveled off at about 1,200 µS after about 65 min into regeneration. The data suggested that the slow rinse and fast rinse time could be significantly reduced to minimize wastewater production. While the slow rinse time was unchanged, the fast rinse time was reduced from 30 to 6 min on September 19, 2005 (Table 4-8).

4.5.3.2 Regeneration Study 2 (September 22, 2005)

Regeneration Curves. Figures 4-23 and 4-24 present concentrations of total arsenic, nitrate, sulfate, TDS, and pH in/of the wastewater produced during IX system regeneration on September 22, 2005. These regeneration curves were typical of an IX system and similar to those observed previously (Wang, et al., 2002). TDS concentrations reflected salt concentrations in the wastewater. As the 8% brine solution was drawn into an IX vessel, arsenic, nitrate, and sulfate on the exhausted IX resin were displaced by the highly concentrated chloride ions. Peak arsenic (14.9 and 18.9 mg/L) and sulfate (51 and 49 g/L) concentrations were detected about 8 to 12 min into brine draw, slightly earlier than those for nitrate (2.3 and 2.2 g/L [as N]). While nitrate concentrations dropped to below 10 mg/L (as N) towards the end of fast rinse, arsenic concentrations were still around 35 µg/L, thus resulting in elevated concentrations in the treated water after the IX system was returned to service. Extending the fast rinse time to 15 min on December 5, 2005, did not appear to help because the leakage continued up to 52,000 gal (70 BV), or 3 to 4 hr into the service run.

As shown in Figure 4-24, pH values of the wastewater were close to neutral (i.e., 7.5) at the beginning of brine draw, but rose sharply to about 9.0 due to the release of bicarbonate ions from the IX resin. pH value dropped to between 5.5 to 6.0 by the end of fast rinse due to removal of bicarbonates by the freshly regenerated resin. This observation is consistent with the results obtained during the above-mentioned run length studies and regular treatment plant sampling.



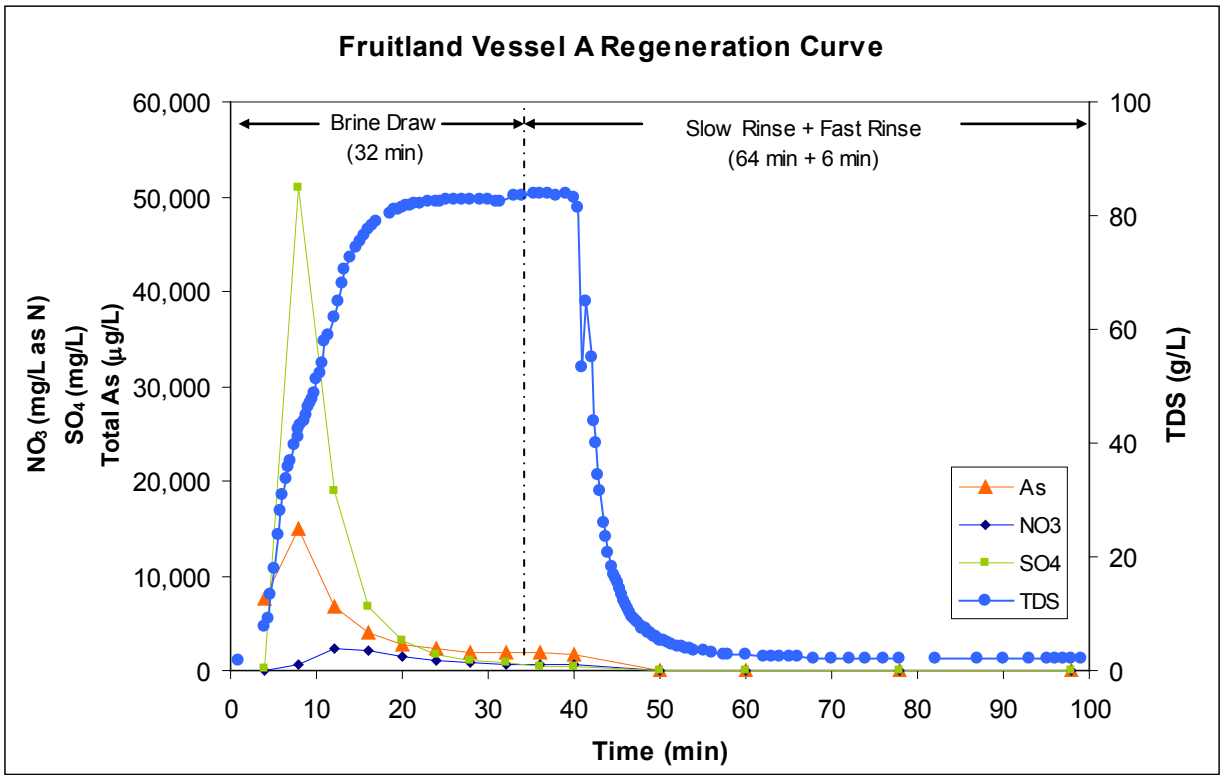
Source: Kinetico

Figure 4-22. Vessel B Regeneration Curve

Regeneration Flowrate. As part of the September 22, 2005 regeneration study, regeneration flowrates were monitored during regeneration and plotted in Figure 4-25. Due to concerns over the accuracy of flowrate readings from a floater-type rotameter installed on the waste discharge line, readings of the totalizer located upstream of the Venturi eductor also were recorded at 1 to 2 min intervals. Because the totalizer did not register the volume of saturated brine drawn by the eductor, the brine draw flowrates shown in Figure 4-25 were lower than the actual values. For Vessel A, flowrates varied from 22 to 29 gpm for brine draw, 22 to 28 gpm for slow rinse, and 56 to 75 gpm for fast rinse, producing 802, 1,519, and 383 gal of wastewater (or 25, 24, and 64 gpm average flowrate for) in the respective steps. Adding the volume of the saturated brine (i.e., 360 gal), the average flowrate for brine draw would be 36 gpm, about 56% higher than the design value of 23 gpm.

For Vessel B, the flowrates were similar to those of Vessel A except for brine draw. A total of 1,340, 1,542, and 359 gal of water was used, corresponding to an average flowrate of 42, 24, and 60 gpm, respectively. The higher brine draw flowrates for Vessel B were caused inadvertently by a chain of events described below. The low-level sensor in the brine day tank was triggered during Vessel B regeneration so that the brine transfer pump was turned on to transfer saturated brine from the salt saturator to refill the day tank. Meanwhile, the level sensor in the salt saturator also reached a low level so that it called for water to make up more saturated brine. The water filling the salt saturator was registered on the same totalizer used for flowrate measurements, causing the seemly higher water usage and flowrates during Vessel B regeneration.

Saturated Brine Usage. As shown in Table 4-9, approximately 360 gal of saturated brine (i.e., 730 lb of salt) was used for Vessel A regeneration on September 22, 2005, equivalent to 14.6 lb of salt/ft^3 of resin.



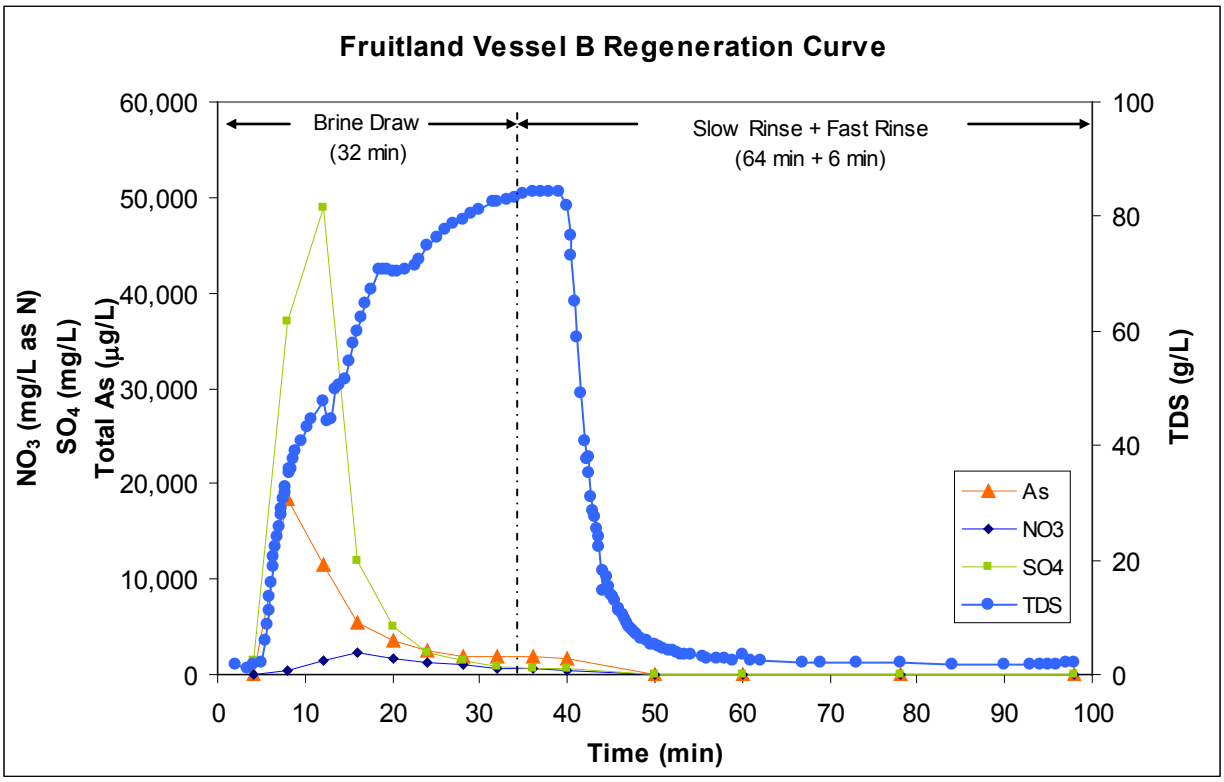


Figure 4-23. Vessels A and B Regeneration Curves of Arsenic, Nitrate, and Sulfate

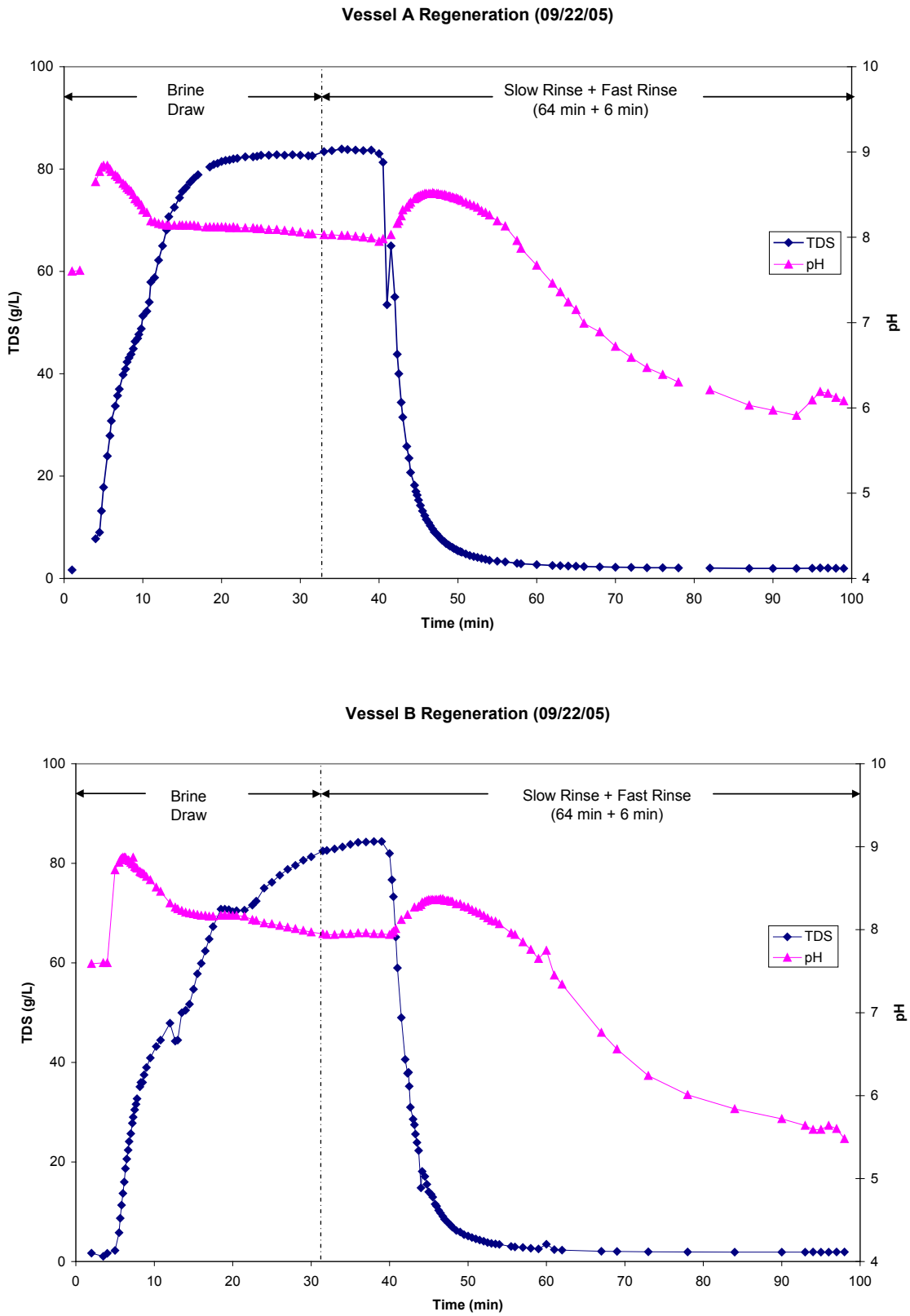


Figure 4-24. Vessels A and B Regeneration Curves of TDS and pH

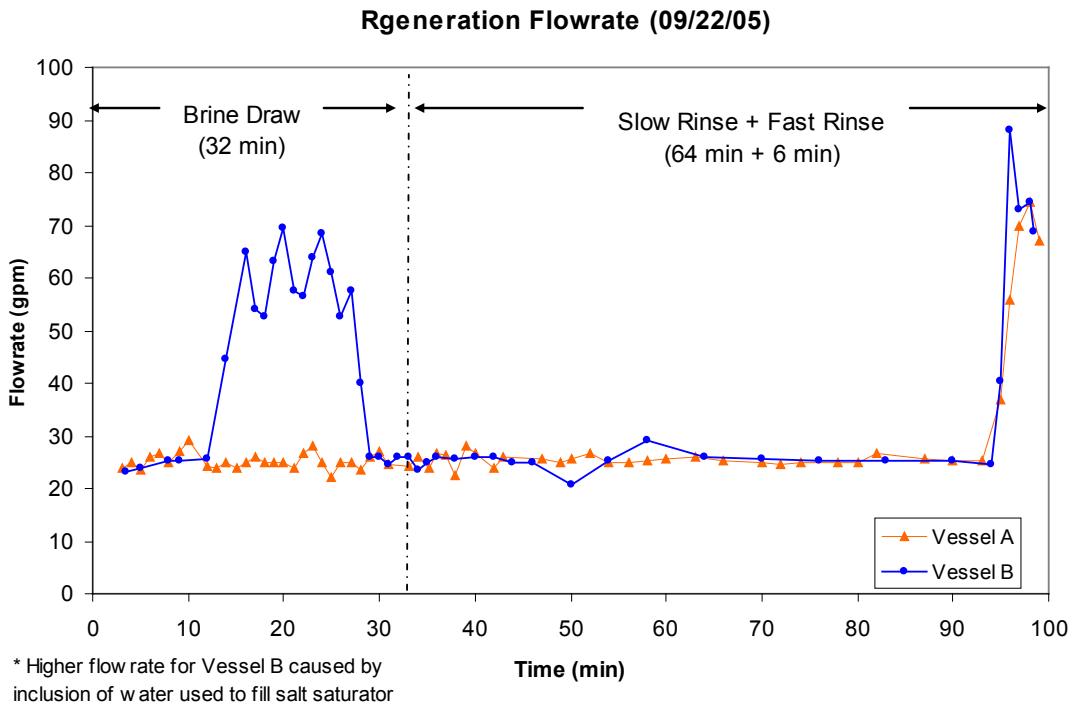


Figure 4-25. Regeneration Flowrates

This regeneration level was 46% higher than the designed value of 10 lb of salt/ft^3 of resin. For a throughput setpoint of 316,000 gal, the salt use is 4.6 lb/1,000 gal of water treated. The brine usage was not recorded for Vessel B because the day tank was refilled automatically in the middle of the brine draw. Although the 600-gal day tank was sized to supply 500 gal of brine for regeneration of both vessels, it had to be refilled in the middle of the brine draw due to the higher usage. To track the brine usage by each vessel, the day tank was refilled manually prior to the regeneration of each vessel and the data are discussed in Section 4.4.2.3. To reduce the salt usage to close to the design level of 10 lb/ft^3, the brine draw time was shortened from 32 to 25 min and the diluted salt concentration was reduced from 8% to 6% (with the brine draw flowrate remaining unchanged). These modifications brought the regeneration level down to 9.5 lb of salt/ft^3 of resin (Table 4-8) as discussed in Section 4.4.2.3.

4.5.4 Regeneration Wastewater Sampling. Composite samples were collected from both IX vessels eight times during each of the three regeneration steps in Study Period I from November 15, 2005, to July 6, 2006. Table 4-14 summarizes the analytical results. As expected, the majority of arsenic, nitrate, and sulfate were eluted during brine draw, and more arsenic, nitrate, and sulfate were eluted during slow rinse than fast rinse. For the eight sampling events, average total arsenic concentrations in the spent brine were 29 times (on average) those in the slow rinse water. Average total arsenic concentrations in the slow rinse water were 10 times (on average) those in the fast rinse water. Total arsenic concentrations in the spent brine (averaged between Vessels A and B) ranged from 3,480 to 9,875 µg/L and averaged 6,272 µg/L. Arsenic concentrations in the slow rinse water ranged from 62 to 773 µg/L and averaged 216 µg/L. Arsenic concentrations in the fast rinse water were 6 to 34 µg/L and averaged 24 µg/L.

Arsenic, nitrate, and sulfate concentrations measured at each regeneration step and the respective volumes of the waste stream were used to calculate the mass of arsenic, nitrate, and sulfate recovered during regeneration. Table 4-15 summarizes the results. Mass of arsenic, nitrate, and sulfate removed from raw

Table 4-14. Regeneration Sampling Results in Study Period I

Sampling Event		Vessel A															Vessel B														
		Brine Draw					Slow Rinse					Fast Rinse					Brine Draw					Slow Rinse					Fast Rinse				
		Total As	Nitrate[a]	Sulfate	TDS	pH	Total As	Nitrate[a]	Sulfate	TDS	pH	Total As	Nitrate[a]	Sulfate	TDS	pH	Total As	Nitrate[a]	Sulfate	TDS	pH	Total As	Nitrate[a]	Sulfate	TDS	pH	Total As	Nitrate[a]	Sulfate	TDS	pH
No.	Date	µg/L	mg/L	mg/L	mg/L	S.U.	µg/L	mg/L	mg/L	mg/L	S.U.	µg/L	mg/L	mg/L	mg/L	S.U.	µg/L	mg/L	mg/L	mg/L	S.U.	µg/L	mg/L	mg/L	mg/L	S.U.	µg/L	mg/L	mg/L	mg/L	S.U.
1	11/15/05	2,602	1,230	4,300	-	-	62	22	26	-	-	33	4.4	4.7	-	-	4,358	1,610	7,500	-	-	61	17	13	-	-	35	3.4	<1	-	-
2	01/11/06	3,531	1,490	9,400	-	-	199	103	143	-	-	29	4.9	8.0	-	-	16,218	772	26,000	-	-	1,346	757	1,100	-	-	24	5.6	6.0	-	-
3	02/15/06	3,930	265	3,000	-	-	92	53	46	-	-	15	4.3	<1	-	-	4,663	394	3,600	-	-	456	195	189	-	-	20	4.0	<1	-	-
4	04/04/06	8,400	176	4,900	-	-	90	77	51.0	-	-	7	4.3	<1	-	-	4,622	317	4,500	-	-	36	30	18	-	-	6	5	<1	-	-
5	04/13/06	6,430	988	12,900	56,800	8.5	204	102	132	8,240	8.0	28	6.9	3.0	880	6.3	4,668	1,070	10,400	57,000	8.4	77	57	50	3,790	7.5	39	6.5	<1	904	6.1
6	05/09/06	1,272	994	1,810	59,600	8.2	92	60	74	5,080	7.9	27	7.2	3.0	980	6.5	12,463	1,040	15,200	51,800	8.5	186	112	142	8,650	8.1	31	8.5	4.0	1,080	6.4
7	06/07/06	4,836	979	10,600	55,500	8.3	201	136	189	10,600	8.2	25	6.6	2.0	802	6.3	10,336	757	16,900	67,800	6.9	23	8	6	968	8.5	23	6.7	<1	770	6.3
8	07/06/06	5,812	891	12,000	48,700	8.5	235	183	2,700	12,300	8.4	23	7.8	4.0	998	6.6	6,212	1,940	30,000	47,600	8.5	102	77	142	4,290	7.7	25	8.4	83	920	6.1
	Average	4,602	877	7,364	55,150	8.4	147	92	420	9,055	8.1	23	5.8	4.1	915	6.4	7,943	988	14,263	56,050	8.1	286	156	207	4,425	7.9	25	6.0	31	919	6.2

Table 4-15. Mass Balance Calculations for Total Arsenic, Nitrate, and Sulfate

Parameter	Unit	09/22/05			11/15/05			01/11/06			02/15/06			04/04/06		
Volume of Water Treated	gal	316,000			314,000			316,000			136,000			96,000		
		Vessel A	Vessel B	Total	Vessel A	Vessel B	Total	Vessel A	Vessel B	Total	Vessel A	Vessel B	Total	Vessel A	Vessel B	Total
		Arsenic Mass Balance														
Concentration in Brine Draw	µg/L	6,014	6,082	6,048[a]	2,602	4,358	3,480[a]	3,531	16,218	9,875[a]	3,930	4,663	4,297[a]	8,400	4,622	6,511[a]
Concentration in Slow Rinse	µg/L	293	271	282[a]	62	61	62[a]	199	1,346	773[a]	92	456	274[a]	90	36	63[a]
Concentration in Fast Rinse	µg/L	35	36	35[a]	33	35	34[a]	29	24	27[a]	15	20	18[a]	7.0	6.0	6.5[a]
Brine Draw Volume	gal	1,149	1,149	2,298	1,258	1,070	2,328	920	1,014	1,934	885	885	1,770	1,222	1,221	2,443
Slow Rinse Volume	gal	1,519	1,542	3,061	1,900	1,600	3,500	1,000	1,200	2,200	1,040	1,040	2,080	1,400	1,400	2,800
Fast Rinse Volume	gal	383	359	742	400	400	800	1,110	1,110	2,220	1,110	1,110	2,220	1,000	900	1,900
Mass Recovered from Brine Draw	mg	26,155	26,450	52,605	12,390	17,650	30,039	12,296	62,245	74,540	13,164	15,620	28,784	38,852	21,361	60,213
Mass Recovered from Slow Rinse	mg	1,685	1,582	3,266	448	370	818	753	6,114	6,867	362	1,795	2,157	477	191	668
Mass Recovered from Fast Rinse	mg	51	49	99	50	53	103	122	101	223	63	84	147	26	20	47
Total Mass Recovered	mg	27,890	28,081	55,971	12,887	18,073	30,960	13,171	68,459	81,630	13,590	17,499	31,088	39,356	21,572	60,927
Average Conc. in wastewater	mg/L	2.4	2.4	2.4	1.0	1.6	1.2	1.1	5.4	3.4	1.2	1.5	1.4	2.9	1.6	2.3
Mass Removed from Raw Water[b]	mg			49,278			48,966			49,397			21,260			15,007
Percent Recovery	**%**			**114**			**63**			**165**			**146**			**406**
		Nitrate Mass Balance														
Conc. In Composite Brine Draw	mg/L	1,020	961	991[a]	1,230	1,610	1,420[a]	1,490	772	1,131[a]	265	394	330[a]	176	317	247[a]
Conc. In Composite Slow Rinse	mg/L	80.4	99.8	90[a]	22	17	19[a]	103	757	430[a]	53	195	124[a]	77	30	54[a]
Conc. In Composite Fast Rinse	mg/L	2.9	3.2	3.1[a]	4.4	3.4	3.9[a]	4.9	5.6	5.3[a]	4.3	4.0	4.2[a]	4.3	5.0	4.7[a]
Brine Draw Volume	gal	1,149	1,149	2,298	1,258	1,070	2,328	920	1,014	1,934	885	885	1,770	1,222	1,221	2,443
Slow Rinse Volume	gal	1,519	1,542	3,061	1,900	1,600	3,500	1,000	1,200	2,200	1,040	1,040	2,080	1,400	1,400	2,800
Fast Rinse Volume	gal	383	359	742	400	400	800	1,110	1,110	2,220	1,110	1,110	2,220	1,000	900	1,900
Mass Recovered from Brine Draw	G	4,436	4,179	8,615	5,857	6,520	12,377	5,188	2,963	8,151	888	1,320	2,207	814	1,465	2,279
Mass Recovered from Slow Rinse	G	462	582	1,045	158	102	260	390	3,438	3,828	209	768	976	408	159	567
Mass Recovered from Fast Rinse	G	4	4	9	7	5	12	21	24	44	18	17	35	16	17	33
Total Mass Recovered	G	4,902	4,766	9,669	6,022	6,627	12,649	5,599	6,425	12,024	1,114	2,104	3,219	1,238	1,641	2,879
Average Conc. in wastewater	g/L	0.4	0.4	0.4	0.4	0.6	0.5	0.5	0.5	0.5	0.1	0.2	0.1	0.1	0.1	0.1
Mass Removed from Raw Water[b]	G			9,772			9,710			5,621			2,419			1,708
Percent Recovery	**%**			**99**			**130**			**214**			**133**			**169**
		Sulfate Mass Balance														
Conc. In Composite Brine Draw	mg/L	9,200	9,100	9,150[a]	4,300	7,500	5,900[a]	9,400	26,000	17,700[a]	3,000	3,600	3,300[a]	4,900	4,500	4,700[a]
Conc. In Composite Slow Rinse	mg/L	318	81	200[a]	26	12.7	19[a]	143	1100	622[a]	46	189	118[a]	51	18	35[a]
Conc. In Composite Fast Rinse	mg/L	3.6	1.1	2.4[a]	4.7	<1	2.6[a]	8	6	4.3[a]	<1	<1	<1[a]	<1	<1	<1[a]
Brine Draw Volume	gal	1,149	1,149	2,298	1,258	1,070	2,328	920	1,014	1,934	885	885	1,770	1,222	1,221	2,443
Slow Rinse Volume	gal	1,519	1,542	3,061	1,900	1,600	3,500	1,000	1,200	2,200	1,040	1,040	2,080	1,400	1,400	2,800
Fast Rinse Volume	gal	383	359	742	400	400	800	1,110	1,110	2,220	1,110	1,110	2,220	1,000	900	1,900
Mass Recovered from Brine Draw	G	40,010	39,576	79,586	20,475	30,375	50,849	32,733	99,788	132,520	10,049	12,059	22,108	22,664	20,797	43,461
Mass Recovered from Slow Rinse	G	1,828	473	2,301	187	77	264	541	4,996	5,537	181	744	925	270	95	366
Mass Recovered from Fast Rinse	G	5	1	7	7	1	8	34	25	59	2	2	4	2	2	4
Total Mass Recovered	G	41,844	40,050	81,894	20,669	30,452	51,121	33,308	104,809	138,117	10,232	12,805	23,037	22,936	20,894	43,830
Average Conc. in wastewater	g/L	3.6	3.5	3.5	1.5	2.6	2.0	2.9	8.3	5.7	0.9	1.1	1.0	1.7	1.6	1.6
Mass Removed from Raw Water[b]	G			69,371			68,932			72,960			31,400			22,165
Percent Recovery	**%**			**118**			**74**			**189**			**73**			**198**

(a) Average of two vessels.
(b) Calculated using average concentrations in raw and treated water.

Table 4-15. Mass Balance Calculations for Total Arsenic, Nitrate, and Sulfate (Continued)

Parameter	Unit	04/13/06			05/09/06			06/07/06			07/06/06		
Volume of Water Treated	gal	316,000			297,000			316,000			309,000		
		Vessel A	Vessel B	Total	Vessel A	Vessel B	Total	Vessel A	Vessel B	Total	Vessel A	Vessel B	Total
		Arsenic Mass Balance											
Concentration in Brine Draw	µg/L	6,430	4,668	5,549[a]	1,272	12,463	6,868[a]	4,836	10,336	7,586[a]	5,812	6,212	6,012[a]
Concentration in Slow Rinse	µg/L	204	77	141[a]	92	186	139[a]	201	23	112[a]	235	102	169[a]
Concentration in Fast Rinse	µg/L	28	39	34[a]	27	31	29[a]	25	23	24[a]	23	25	24[a]
Brine Draw Volume	gal	1,016	1,002	2,018	1,098	990	2,088	1,064	1,064	2,128	1,065	1,066	2,131
Slow Rinse Volume	gal	1,400	1,500	2,900	1,440	1,440	2,880	1,440	1,440	2,880	1,440	1,440	2,880
Fast Rinse Volume	gal	1,000	1,000	2,000	1,050	1,050	2,100	1,050	1,050	2,100	1,050	1,050	2,100
Mass Recovered from Brine Draw	mg	24,727	17,704	42,431	5,286	46,701	51,987	19,476	41,626	61,101	23,428	25,064	48,493
Mass Recovered from Slow Rinse	mg	1,081	437	1,518	501	1,014	1,515	1,096	125	1,221	1,281	556	1,837
Mass Recovered from Fast Rinse	mg	106	148	254	107	123	231	99	91	191	91	99	191
Total Mass Recovered	mg	25,914	18,288	44,202	5,895	47,838	53,733	20,671	41,842	62,513	24,801	25,720	50,520
Average Conc. In wastewater	mg/L	2.0	1.4	1.7	0.4	3.6	2.0	1.5	3.1	2.3	1.8	1.9	1.9
Mass Removed from Raw Water[b]	mg			49,397			46,427			49,397			48,303
Percent Recovery	**%**			**89**			**116**			**127**			**105**
		Nitrate Mass Balance											
Concentration in Brine Draw	mg/L	988	1,070	1029[a]	994	1,040	1017[a]	979	757	868[a]	891	1,940	1416[a]
Concentration in Slow Rinse	mg/L	102	57	80[a]	60	112	86[a]	136	8	72[a]	183	77	130[a]
Concentration in Fast Rinse	mg/L	6.9	6.5	6.7[a]	7.2	8.5	7.9[a]	6.6	6.7	6.7[a]	7.8	8.4	8.1[a]
Brine Draw Volume	gal	1,016	1,002	2,018	1,098	990	2,088	1,064	1,064	2,128	1,065	1,066	2,131
Slow Rinse Volume	gal	1,400	1,500	2,900	1,440	1,440	2,880	1,440	1,440	2,880	1,440	1,440	2,880
Fast Rinse Volume	gal	1000	1000	2,000	1,050	1,050	2,100	1,050	1,050	2,100	1,050	1,050	2,100
Mass Recovered from Brine Draw	g	3,799	4,058	7,857	4,131	3,897	8,028	3,943	3,049	6,991	3,592	7,828	11,419
Mass Recovered from Slow Rinse	g	540	324	864	327	610	937	741	44	785	997	420	1,417
Mass Recovered from Fast Rinse	g	26	25	51	29	34	62	26	27	53	31	33	64
Total Mass Recovered	g	4,366	4,406	8,772	4,487	4,541	9,028	4,710	3,119	7,829	4,620	8,281	12,901
Average Conc. in wastewater	g/L	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.2	0.3	0.3	0.6	0.5
Mass Removed from Raw Water[b]	g			5,621			5,283			5,621			5,497
Percent Recovery	**%**			**156**			**171**			**139**			**235**
		Sulfate Mass Balance											
Conc. in Composite Brine Draw	mg/L	12,900	10,400	11650[a]	1,810	15,200	8505[a]	10,600	16,900	13750[a]	12,000	30,000	21000[a]
Conc. in Composite Slow Rinse	mg/L	132	50	91[a]	74	142	108[a]	189	6	98[a]	2,700	142	1,421[a]
Conc. in Composite Fast Rinse	mg/L	3	<1	1.8[a]	3	4	1.8[a]	2	<1	1.3[a]	4	83	2.3[a]
Brine Draw Volume	gal	1,016	1,002	2,018	1,098	990	2,088	1,064	1,064	2,128	1,065	1,066	2,131
Slow Rinse Volume	gal	1,400	1,500	2,900	1,440	1,440	2,880	1,440	1,440	2,880	1,440	1,440	2,880
Fast Rinse Volume	gal	1,000	1,000	2,000	1,050	1,050	2,100	1,050	1,050	2,100	1,050	1,050	2,100
Mass Recovered from Brine Draw	g	49,608	39,443	89,050	7,522	56,957	64,479	42,689	68,060	110,749	48,372	121,044	169,417
Mass Recovered from Slow Rinse	g	699	284	983	403	774	1,177	1,030	33	1,063	14,716	774	15,490
Mass Recovered from Fast Rinse	g	11	2	13	12	16	28	8	2	10	16	330	346
Total Mass Recovered	g	50,319	39,728	90,047	7,937	57,747	65,684	43,727	68,095	111,822	63,104	122,148	185,252
Average Conc. in wastewater	g/L	3.9	3.0	3.4	0.6	4.4	2.5	3.3	5.1	4.2	4.7	9.1	6.9
Mass Removed from Raw Water[b]	g			72,960			68,573			72,960			71,343
Percent Recovery	**%**			**123**			**96**			**153**			**260**

(a) Average of two vessels.
(b) Calculated using average concentrations in raw and treated water.

water were calculated using volume of water treated before each regeneration, average concentrations in raw water, and average concentrations in treated water. Percent recovery of arsenic, nitrate, and sulfate during regeneration was calculated using Equation 3:

$$\%R = M_{recovered}/M_{\text{removed}} \times 100\% \qquad (3)$$

where:

%R = percent recovery

$M_{recovered}$ *= mass of arsenic, nitrate, or sulfate in regenerant waste (mg or g)*

$M_{removed}$ *= mass of arsenic, nitrate, or sulfate removed from raw water (mg or g)*

Note that in addition to the eight monthly sampling events presented in Table 4-14, a set of composite samples also was collected during the regeneration study on September 22, 2005 and analyzed for total arsenic, nitrate, and sulfate. Mass balance calculations for the sample collected on September 22, 2005 also are presented in Table 4-15.

According to Table 4-15, 47.2 g of arsenic, 7.9 kg of nitrate, and 79.1kg of sulfate (on average) were recovered and discharged to the sewer during a regeneration cycle. Average concentrations of arsenic, nitrate, and sulfate in the waste stream were 1.9 mg/L, 0.31 g/L, and 3.1 g/L, respectively, for the nine regeneration events presented in Table 4-15. Percent recoveries ranged 63% to 165% (averaged 116%, not including an outlier on April 4, 2006) for arsenic, 99% to 235% (averaged 161%) for nitrate, and 73% to 198% for sulfate (averaged 128%, not including an outlier on July 6, 2006). The percent recovery for an IX system was reported to be 85% to 100% in the literature (Clifford, 1999).

4.5.5 Analyses of Fouled IX Resin. The IX resin samples taken especially from Vessel B were visibly fouled with particulate and organic matter when viewed under a microscope. Table 4-16 presents the analytical results provided by Purolite. Fouling resulted in significant losses in volumetric capacity, with 19% and 35% reduction observed for Vessels A and B, respectively (when compared with Purolite's A300E specifications). The reduction in resin capacity also was reflected by lower strong base capacity (24% and 18%, respectively) and lower moisture content.

Table 4-16. IX Resin Analysis Results

Parameter	Purolite A300E Specs	After Normal Brine Cleaning		After Laboratory Caustic/Brine Cleaning		After Field Caustic/Brine cleaning
		Vessel A	Vessel B	Vessel A	Vessel B	Vessel B
Moisture Content (%)	40–45	42	38.3	41.8	40.7	41
Volumetric Capacity (eq/L)	1.4	1.14	0.91	1.2	1.13	1.24
Volumetric Capacity (%)[(a)]	-	81	65	86	81	88
Strong Base Capacity (%)	100	76	82	94	93	84.1
TOC Fouling (mg of C/g of resin)	NA	7.9	12.7	7.2	8.4	4.0

(a) % = actual volumetric capacity/virgin volumetric capacity.
TOC = total organic carbon.

After laboratory cleaning, volumetric and strong base capacities improved significantly (to 86 and 81 % for volumetric capacity and 94% and 93% for strong base capacity). TOC contents also were reduced from 7.9–12.7 to 7.2–8.4 mg of C/g of resin.

Table 4-16 also presents the analytical results of the core sample taken from Vessel B upon completion of field caustic/brine cleaning. As shown in the table, field caustic/brine cleaning achieved somewhat similar results to laboratory cleaning. The TOC content was reduced to 4 mg of C/g of resin, a level viewed by Purolite as moderate fouling (i.e., <5 mg of C/g of resin).

Although the data showed some effectiveness of field cleaning, the IX resin run length for arsenic removal did not improve. The throughput setpoint was scaled back from 275,000 gal before cleaning to 260,000 gal on July 7, 2007, after cleaning. It was reduced further to 220,000 gal on October 16, 2007 after the operator detected 10.3 mg/L of nitrate (as N) in samples collected at 233,000 gal.

4.5.6 Distribution System Water Sampling. Table 4-17 summarizes the results of the distribution system sampling. The stagnation times for the first draw samples ranged from 5.8 to 24 hr, which met the requirements of the EPA LCR sampling protocol (EPA, 2002).

During baseline sampling from December 2003 to March 2004, the old well (Well No. 6) was not in service due to its higher-than-MCL nitrate concentrations; the distribution system was supplied by other wells. Well No. 6-2004 was drilled in May 2004 and put online with the IX treatment system in June 2005. Since then, monthly distribution sampling resumed at the same locations to evaluate impacts of the treatment system, if any, on the distribution water quality. Due to the use of a new well, different water quality could become an issue. For example, average nitrate, alkalinity, and total Mn concentrations were lower in the baseline samples than at inlet to the IX system (see Tables 4-12 and 13). In addition, the average arsenic concentration (65 µg/L) of the baseline samples was higher than that (42.5 µg/L) in the well samples.

Figure 4-26 compares arsenic concentrations measured in distribution system water and in system effluent. Note that results of flushed samples at DS1 and DS2 were plotted because flushed samples should be more representative of the plant effulent. Because no flushed samples were collected at DS3, first draw samples were plotted in Figure 4-26. In general, total arsenic concentrations measured at DS1 and DS3 mirrored those in system effluent, except two apparent outliers measured at DS3 on October 26, 2005, and June 14, 2006. However, more than 50% of the data collected at DS2 had arsenic concentrations significantly higher than those in system effluent, including some having arsenic concentrations close to those in source water. It was suspected that DS2 might have received water from other source wells at the time of sampling. During Study Period I, arsenic levels at DS1 and DS3 were significantly reduced to below MCL when the IX system operated normally. Higher-than-MCL concentrations were measured during the first two sampling events (June 29 and August 3, 2005) when the system experienced operational problems.

No significant changes in pH values were observed in the distribution samples. pH values ranged from 7.3 to 7.7 in the baseline samples and 7.3 to 8.2 after system startup. On four occasions when the plant effluent had a pH value below 7 (i.e., pH 6.0 on July 6, 2005; pH 6.8 on August 31, 2005; pH 6.9 on February 1, 2006; and pH 6.3 on May 9, 2006), distribution samples were not collected. Therefore, there was lack of evidence on whether low water pH produced by the freshly regenerated IX resin would impact the pH in the distribution system. Alkalinity levels ranged from 200 to 304 mg/L and averaged 270 mg/L (as $CaCO_3$) in the baseline samples. After system startup, alkalinity levels ranged from 198 to 467 mg/L (as $CaCO_3$) and averaged 358 mg/L (as $CaCO_3$). The higher values observed were likely caused by the different water quality of the supply wells as discussed above. The freshly regenerated IX system would reduce alkalinity for a short period of time due to exchange of bicarbonates onto the IX resin. Unfortunately, no distribution water samples were taken when the plant effluent contained low alkalinity.

Table 4-17. Summary of Distribution System Sampling Results in Period I Demonstration Study at City of Fruitland

Sampling Event		DS1																	DS2																	DS3									
		409 S Utah																	420 S Utah																	519 S Utah									
		Non-Residence																	Non-residence																	Non-LCR									
		1st Draw									Flushed[a]								1st Draw								Flushed[a]									1st Draw									
		Stagnation Time	pH	Alkalinity	As	Fe	Mn	Pb	Cu	NO_3	pH	Alkalinity	As	Fe	Mn	Pb	Cu	NO_3	Stagnation Time	pH	Alkalinity	As	Fe	Mn	Pb	Cu	NO_3	pH	Alkalinity	As	Fe	Mn	Pb	Cu	NO_3	Stagnation Time	pH	Alkalinity	As	Fe	Mn	Pb	Cu	NO_3
BL1	12/08/03	NA	7.7	264	46.1	<25	1.1	9.5	159	6.9	NS	NS	NS	NS	NS	NS	NS	NS	NA	7.7	252	52.3	<25	0.9	2.3	90.9	5.5	NS	NS	NS	NS	NS	NS	NS	NS	7.5	7.8	246	45.9	<25	<0.1	0.3	86.2	4.6
BL2	01/06/04	NA	7.3	292	55.8	<25	1.0	10.4	148	7.4	7.6	304	58.4	<25	0.2	5.6	101	7.9	NA	7.7	280	59.1	<25	2.7	25.5	330	7.4	7.7	292	58.4	<25	0.1	1.1	75.1	7.8	8.0	7.8	280	58.5	<25	0.6	0.7	178	7.4
BL3	02/02/04	NA	7.4	258	61.0	198	0.5	10.9	44.9	7.9	7.7	242	63.9	<25	0.2	4.1	86.0	7.7	8.0	7.7	248	59.0	53.9	0.6	2.4	299	7.9	7.7	256	56.6	41.0	0.3	0.3	22.0	7.7	7.0	7.7	200	43.9	26.0	0.5	0.8	122	5.7
BL4	03/02/04	10.3	7.6	279	66.2	<25	1.1	6.7	108	8.9	7.6	288	75.4	<25	0.2	2.9	71.2	6.7	12	7.6	283	66.8	<25	6.2	2.8	203	9.9	7.6	288	75.4	<25	0.3	0.7	46.7	6.9	5.8	7.6	288	73.7	<25	0.2	0.2	237	7.9
1	06/29/05	10.8	7.6	383	39.9	<25	13.2	0.8	21.3	NA	7.5	387	40.0	<25	11.5	2.6	10.7	NA	10	7.5	361	37.6	<25	7.8	2.8	330	NA	7.5	396	41.6	<25	9.4	0.4	22.1	NA	9.0	7.5	387	42.6	<25	11.6	0.5	188	NA
2	08/03/05	9.7	7.4	374	44.0	<25	22.4	1.0	22.5	NA	7.4	440	25.3	<25	21.1	2.9	36.9	NA	10	7.6	378	43.5	<25	14.5	0.6	15.6	NA	7.6	396	45.8	<25	15.0	1.2	22.9	NA	9.5	7.5	378	42.9	<25	20.9	0.4	25.5	NA
3	08/24/05	NA	7.5	427	2.7	<25	19.1	0.6	9.7	NA	7.7	458	2.1	<25	19.7	0.4	8.1	NA	10	7.7	422	11.8	<25	11.8	0.3	6.9	NA	7.6	449	9.4	<25	13.2	0.4	7.7	NA	NA	7.7	427	2.0	<25	19.7	0.2	24.4	NA
4	09/21/05	NA	7.6	396	1.1	<25	22.8	0.3	11.5	NA	7.4	392	2.4	<25	25.3	1.2	44.0	NA	10	7.4	396	2.7	<25	12.9	0.7	20.9	NA	7.4	374	3.0	<25	11.0	0.9	44.3	NA	NA	7.4	392	2.7	<25	22.1	0.6	86.3	NA
5	10/26/05	NA	7.7	440	4.0	<25	19.1	1.5	22.0	NA	7.7	431	2.4	<25	17.6	0.8	16.6	NA	13	7.6	462	3.6	<25	11.6	0.6	14.0	NA	7.7	444	3.7	<25	11.4	0.5	8.2	NA	NA	7.7	264	17.7	<25	2.3	0.10	37.6	NA
6	11/30/05	12.5	7.9	431	2.8	<25	17.8	0.5	33.1	NA	7.6	440	4.9	<25	18.5	0.6	31.3	NA	12	7.6	308	16.3	<25	7.2	0.678	119	NA	7.7	308	18.7	<25	6.4	0.3	148	NA	12.3	7.7	427	3.3	<25	15.6	0.05	24.1	NA
7	12/15/05	NA	7.8	462	5.6	<25	23.0	0.5	15.6	<0.05	7.4	330	5.9	<25	17.8	0.7	40.8	1.5	NA	7.4	290	6.4	<25	10.3	0.1	10.6	1.7	7.5	180	6.7	<25	6.4	2.4	143	4.0	NA	7.4	312	4.7	<25	16.9	<0.1	41.2	1.6
8	01/25/06	12.3	7.4	352	8.1	<25	29.8	0.8	15.0	1.4	7.4	370	3.2	<25	10.1	<0.1	38.5	1.3	24	7.3	290	10.3	<25	3.9	1.1	15.4	2.5	7.7	374	30.4	<25	3.2	0.6	126	9.8	12.2	7.5	356	3.8	<25	7.6	<0.1	35.4	1.4
9	02/22/06	10.8	7.8	357	5.0	<25	10.8	0.3	8.0	<0.05	7.8	440	3.6	<25	3.7	0.3	43.5	10.6	11	7.8	283	50.4	<25	0.4	0.2	66.3	6.7	7.9	428	39.9	<25	0.3	<0.1	40.9	7.7	11.8	7.9	440	2.7	<25	1.6	<0.1	43.7	9.3
10	03/23/06	9.5	7.9	435	6.4	<25	29.3	2.9	13.2	12.3	7.7	427	3.6	<25	2.6	2.1	49.4	13.0	10	7.8	423	5.6	<25	0.3	0.4	11.5	11.5	7.7	294	16.6	<25	0.8	1.1	45.6	7.3	10.3	8.2	419	2.9	<25	0.6	0.3	28.9	12.0
11	04/19/06	10.8	7.6	278	2.8	<25	7.9	3.9	51.2	2.8	7.7	406	1.9	<25	1.0	0.8	20.6	1.8	12	7.7	198	30.0	<25	0.2	0.9	50.4	6.0	8.2	260	25.0	<25	0.1	0.3	14.8	5.6	11.0	7.6	366	1.9	<25	0.3	0.4	59.7	2.3
12	05/24/06	9.5	7.6	456	9.0	<25	1.2	5.8	62.3	2.8	7.8	444	3.2	<25	0.5	1.8	42.6	10.6	10	7.8	456	13.9	<25	0.2	1.8	139	8.1	7.8	444	8.2	<25	<0.1	0.6	20.5	8.0	NA	7.8	464	3.5	<25	<0.1	0.8	74.8	5.1
13	06/14/06	9.3	7.6	467	2.8	<25	1.3	5.5	59.2	1.5	7.6	467	1.7	<25	0.3	2.8	52.9	1.2	10	7.6	403	8.2	<25	0.1	0.7	29.9	1.6	7.3	467	11.9	<25	0.3	0.9	220	3.2	9.8	7.6	433	11.4	<25	0.2	2.0	65.1	1.3
14	07/12/06	8.0	7.6	NA	1.4	<25	0.2	<0.1	3.9	<0.05	7.8	440	1.8	<25	0.4	<0.1	10.8	<0.05	11	7.4	360	15.8	<25	0.2	<0.1	11.0	4.3	7.8	NA	21.5	<25	0.3	0.1	124	0.8	NA	7.6	431	1.9	<25	0.3	0.8	89.0	1.6

(a) Stagnation times not applicable for flushed samples.
BL = baseline sampling; NS = not sampled; NA = data not available
Lead action level = 15 µg/L; copper action level = 1.3 mg/L
Unit for analytical parameters is µg/L except for pH and alkalinity (mg/L as $CaCO_3$).

Reduction in lead and copper levels was observed in the first draw samples at DS1 and DS2. For example, before system startup, average lead concentrations in the first draw samples were 9.4, 8.3, and 0.5 µg/L at DS1, DS2, and DS3, respectively. After system startup, the concentrations were reduced to 3.4, 2.4, and 0.5 µg/L, respectively. Similarly, before system startup, average copper concentrations in the first draw samples were 115, 231, and 156 µg/L at DS1, DS2, and DS3, respectively. After system startup, the concentrations were reduced to 45, 98, and 80 µg/L, respectively. Therefore, the lead and copper levels in the distribution system appeared to be lowered by the operation of the IX system.

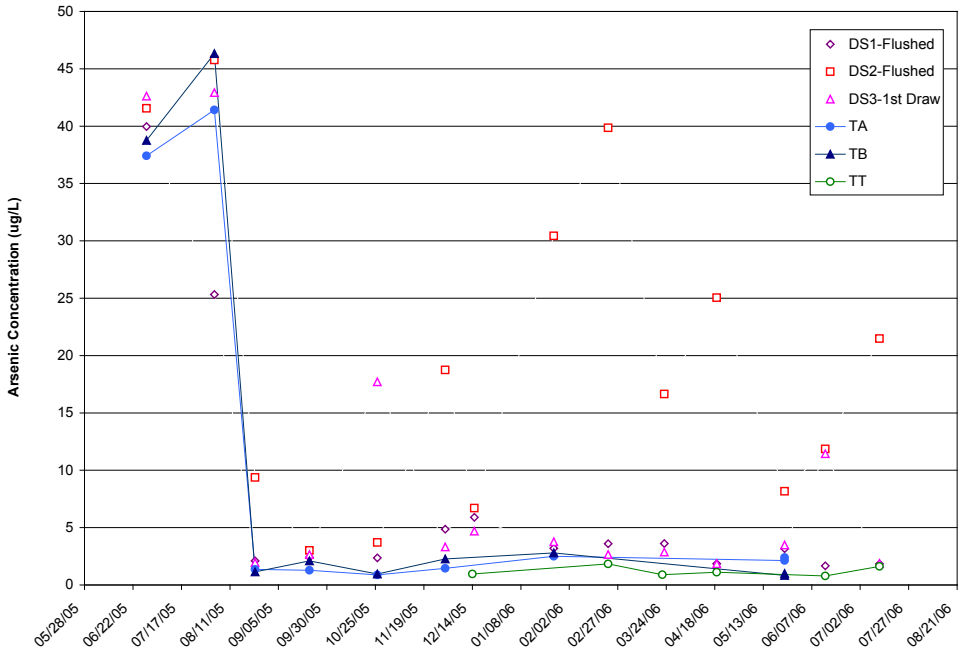


Figure 4-26. Comparsion of Total Arsenic Concentrations in Distribution System Water and Treatment Plant Effluent

4.6 System Cost

The cost of the system was evaluated based on the capital cost per gpm (or gpd) of design capacity and the O&M cost per 1,000 gal of water treated. This required tracking of the capital cost for the treatment equipment, site engineering, and installation and the O&M cost for salt supply, electricity consumption, and labor. The cost associated with the new building, sanitary sewer connection, and other discharge-related infrastructure was not included in the capital cost because it was out of the scope of the demonstration project, and was funded separately by the City of Fruitland.

4.6.1 Capital Cost. The capital investment for the Fruitland IX system was $286,388, which included $173,195 for equipment, $35,619 for site engineering, and $77,574 for installation. Table 4-18 presents breakdowns of the capital cost provided by the vendor. The equipment cost included the cost for the IX resin, filter skid, vessels, brine system, pre-filters, air compressor, instrumentation and controls, engineering subcontractor, labor, and system warranty. The system warranty covered repairs and/or replacement of any equipment or installation workmanship for a period of 12 months after system startup. The equipment cost was 61% of the total capital investment.

Table 4-18. Cost Breakdowns of Capital Investment for Fruitland IX System

Description	Quantity	Cost	% of Capital Investment Cost
Equipment Cost			
IX Resin, Filter Skid, and Vessels	1	$63,673	–
Brine System	1	$35,388	
Pre-treatment Filters	1	$3,540	
Air Compressor	1	$1,295	–
Instrumentation & Controls	1	$11,524	–
Engineering Subcontractor	1	$8,000	–
Labor	–	$32,870	–
Warranty	–	$16,905	–
Equipment Total	–	**$173,195**	**61%**
Engineering Cost			
Labor	–	$35,619	–
Engineering Total	–	**$35,619**	**12%**
Installation Cost			
Labor	–	$11,524	–
Travel	–	$4,095	–
Subcontractor	–	$61,955	–
Installation Total	–	**$77,574**	**27%**
Total Capital Investment	–	**$286,388**	**100%**

The site engineering cost included the cost for preparing a process design report and the required engineering plans, including a general arrangement drawing, piping and instrumentation diagrams (P&IDs), inter-connecting piping layouts, vessel fill details, a schematic of the PLC panel, an electrical on-line diagram, and other associated drawings. After being certified and stamped by an Idaho-registered professional engineer, the plans were submitted to IDEQ for permit review and approval. The engineering cost was 12% of the total capital investment.

The installation cost included the cost for labor and materials for system unloading and anchoring, plumbing, and mechanical and electrical connections (see Section 4.3). The installation cost was 27% of the total capital investment.

The total capital cost of $286,388 was normalized to the system's rated capacity of 250 gpm (360,000 gpd), which resulted in $1,146 per gpm ($0.80 per gpd). The capital cost also was converted to an annualized cost of $27,032/yr using a capital recovery factor of 0.09439 based on a 7% interest rate and a 20-year return. Assuming that the system operated 24 hr/day, 7 day/wk at the design flowrate of 250 gpm to produce 131 million gal of water per year, the unit capital cost would be $0.21/1,000 gal. In fact, the system operated an average of 17.4 hr/day at 157 gpm (see Table 4-7), producing 65.4 million gal of water during the first 13-month demonstration study. At this reduced rate of operation, the unit capital cost increased to $0.47/1,000 gal.

The City of Fruitland constructed an addition to its existing pump house to house the IX system. The 17-ft tall addition covered 360 ft^2 of floor space with a wood frame and steel siding and roofing, and a roll-up door. The total cost for the material and electrical was approximately $18,000.

4.6.2 Operation and Maintenance Cost. The O&M cost included the cost associated with salt supply, electricity consumption, and labor, as summarized in Table 4-19. Morton solar salt was used to prepare brine solution for the resin regeneration. Over the first year of the demonstration study, a total of

253,835 lb of salt was consumed to treat 57,373,000 gal of water. The salt delivery charge totaled $28,109 for the same period, which included fuel surcharges of $50 per delivery starting in October 2005. The average salt use was 4.42 lb/1,000 gal, which corresponded to a salt cost of $0.49/1,000 gal. However, this higher-than-expected salt usage was caused by improper flow control of the brine draw during the initial regenerations as discussed in Section 4.4.2 and Table 4-10. If the target salt usage of 3.16 lb/1,000 gal was achieved, the salt cost would have been reduced to $0.35/1,000 gal.

Incremental electricity consumption associated with the IX system was not available, but was assumed to be minimal. The actual power usage for operating the entire plant was obtained from utility bills and used to estimate the electricity cost at $0.08/1,000 gal of water treated. The routine, non-demonstration related labor activities consumed about 30 min/day, as noted in Section 4.4.4. Based on this time commitment and a labor rate of $21/hr, the labor cost was estimated at $0.05/1,000 gal of water treated. In summary, the total O&M cost was approximately $0.62/1,000 gal based on the actual salt usage and $0.49/1,000 gal based on the target salt usage.

Table 4-19. O&M Cost for Fruitland, ID Treatment System

Cost Category	Value	Assumptions
Annual Volume Processed (1,000 gal)	57,373	From June 14, 2005, through June 14, 2006
Salt Usage		
Salt Unit Price ($/lb)	0.11	Unit price increased progressively from $0.095 to $0.10 and $0.11/lb
Total Salt Usage (lb)	253,835	Quantity delivered
Salt Use (lb/1,000 gal)	4.42	–
Total Salt Cost ($)	28,109	Based on total invoiced amounts, including a $50 monthly fee for fuel surcharge
Unit Salt Use Cost ($/1,000 gal)	0.49	Based on target salt usage of 3.16 lb/1,000 gal; salt cost would be $0.35/1,000 gal
Electricity Consumption		
Power Use ($/1,000 gal)	0.08	Based on utility bills for entire treatment plant
Labor		
Average Weekly Labor Hours (hr/wk)	2.5	30 min/day; 5 day/wk
Total Labor Hours (hr/year)	130	–
Total Labor Cost ($/year)	2,730	Labor rate = $21/hr
Labor Cost ($/1,000 gal)	0.05	–
Total O&M Cost/1,000 gal	**0.62**	–

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APPENDIX A

A SUMMARY OF MAJOR SYSTEM OPERATIONAL PROBLEMS

Fruitland IX System Chronology and Operational Problems

Date	Problem Encountered	Corrective Action
06/14/05	The demonstration study started.	
06/14/05 to 07/07/05	System experienced low flow and elevated pressure loss.	Flow restrictors were modified and subsequently replaced with blank pipe sections on 07/07/05.
06/15/05	Brine transfer pump malfunctioned.	Pump was fixed on the same day by operator.
06/18/05 to 06/29/05	After a power outage, IX system restarted but failed to initiate regeneration because brine transfer pump had been reset to "off"; PLC returned to default "counter-current" regeneration instead of "co-current".	PLC setting was changed back to "co-current" on 06/29/05; an uninterrupted power supply (UPS) was installed on 07/26/05 to provide back-up power.
08/03/05	Regeneration failed to occur after treating 534,000 gal of water due to a broken low level sensor in brine day tank.	Level sensor was fixed on the same day by operator.
09/22/05 to 09/23/05	Brine draw rate and consumption rate were measured higher than setting values.	On 12/05/05, brine draw time was shortened (from 32 to 25 min), slow rinse time was reduced (from 60 to 40min), and fast rinse time was extended (from 6 to 15 min) followed the instruction from Kinetico as a quick-and-easy way to lower salt usage.
August 2005, to the end of demonstration study	Initial As and nitrate leakage during a service run was first noticed in the water samples collected in August 2005. The run length studies conducted on December 7 to 8, 2005 and April 11-12, 2006 also clearly indicated early leakage of arsenic and nitrate (Section 4.5.2). The initial leakage persisted during the demonstration study, and had reached as high as 40.5 µg/L of arsenic on 02/01/06.	A series of efforts made to fix the problem was unsuccessful. Initial As and nitrate leakages were not eliminated through the end of demonstration study. The efforts made included: • Replaced a brine eductor with a large one in March 2006 to obtain a higher brine draw flow rate. • Switched from co-current to counter-current regeneration from 07/25/06 to 06/18/07. • Cleaned the resin with caustic and brine mixture on 06/21/07.
07/25/06	The system was switched to counter-current regeneration mode.	
08/09/06 to 08/11/06	After switched from co-current to counter-current regeneration on July 25, 2006, a run length study was conducted on August 9 to 10, 2006. Arsenic concentration in the effluent of Vessel B was above MCL of 10 µg/L during the entire run length study, with concentrations as high as 129 µg/L of As and 17.6 mg/L of nitrate in the treated water (Figure 4-20).	• The system was shutdown on 08/18/06. • On 09/05/06, system was changed back to co-current regeneration temporarily. The results indicated proper regeneration could be obtained in co-current mode. • Kinetico suspected that incomplete regeneration was due to fluctuating pressure that caused eductor not to work properly; thus, a regeneration pump was installed on 10/24/06 to replace eductor to inject brine into the vessels during regeneration.

Fruitland IX System Chronology and Operational Problems (Continued)

Date	Problem Encountered	Corrective Action
08/18/06 to 12/05/06	The treatment system was taken offline to resolve the problems of significant arsenic and nitrate breakthrough caused by incomplete regeneration.	
09/18/06	OIP screen was broken.	On 10/17/06, broken OIP screen was fixed by Kinetico.
12/05/06	The treatment system was resumed online after being generated twice in counter-current mode.	
01/03/07 to 2/13/07	Higher than MCL levels of As and/or nitrate were detected in system effluent during service runs: • On 01/03/07, samples collected at 107,000 gal of throughput had 44 µg/L of As and 8.7 mg/L of nitrate, similar to raw water quality. • On 01/18/07, samples collected from a service run showed raw water quality. • A run length study was conducted on January 17 to 18, 2007. The analytical results showed little or no arsenic/nitrate removal in the effluent water from both Vessels A and B during the entire run length study (Figure 4-20). • On 02/01/07, samples collected at 232,000 gal showed less than detection limit of As, but 14 mg/L of nitrate. • On 02/07/07, samples collected at 224,000 gal showed less than detection limit of As, but 13 mg/L of nitrate.	• On 02/13/07, system was shutdown. IDEQ requested a Public Notice to be issued. • On 02/21/07, Battelle, EPA, and Kinetico representatives had a meeting in Columbus to discuss the performance issues with the IX system. • 02/26/07-03/07/07: Kinetico's technician made changes to the system based on the decisions of the meeting on February 21, 2007, including: • Taken out the eductor, which was left in the system when switched to the brine injection pump on 10/24/06, and replaced it with a tee. • Loaded additional packing media into the vessels, since the resin bed was found not packed.
02/09/07	Daily operational data collection was discontinued. Since then through the end of demonstration study on February 11, 2008, the operational data was recorded only twice on April 3 and 5, 2007.	
03/14/07	The regeneration throughput setpoint was reduced from 316,000 gal to 275,000 gal.	
03/22/07	System was manually regenerated at counter-current regeneration mode. Regeneration flowrate for each step, however, was low compared to the previous readings.	No response from the vendor about the low regeneration flowrate.
05/07/07	A online real-time arsenic analyzer, ArsenicGuard, was installed by TraceDetect to monitor total arsenic concentration in system effluent.	

Fruitland IX System Chronology and Operational Problems (Continued)

Date	Problem Encountered	Corrective Action
04/12/07 to 05/14/07	High As and nitrate concentrations were detected in system effluent during service runs: • On 04/04/07, sample collected at 204,000 gal throughput showed 13.8 mg/L of nitrate, the system was taken offline immediately. • On 04/13/07, system was back on-line after manual regeneration. Sample collected at 28,000 gal showed 11.8 mg/L of nitrate, system was shutdown immediately. • On 05/09/07, a sample taken at 149,000 gal of water treated had a nitrate concentration of 13.6 mg/L (as N). • From 05/09/07 to 05/14/07, monitoring data by ArsenicGuard showed high arsenic concentrations in system effluent during service runs.	• It was suspected that the poor system performance was due to resin fouling. • On 4/17/07, source water was collected, the result showed TOC, was slightly lower than the historic data, and other analytes were comparable to those measured previously, suggesting that the poor system performance and the suspected resin fouling would not have been caused by any changes in water quality. • On 05/18/07, a conference call was held with EPA, Kinetico, and the facility to discuss various issues with the IX system. - Kinetico concurred that various mechanical issues associated with the brine injection system that caused improper resin regeneration for an extended period of time (i.e., since July 2006 after the system was switched from co- to counter-current regeneration) might have resulted in the suspected resin fouling. - Kinetico proposed to clean the resin with a 5% NaOH and 10% brine mixture followed by regular co-current regeneration. - Kinetico also decided to switch back to co-current regeneration due to difficulties encountered in the counter-current regeneration mode.
06/18/07 to 06/21/07	Kinetico personnel were on-site to perform resin cleaning using caustic and brine mixture. • Resin cleaning was conducted on both vessels on June 19, 2007. • Upon completion on cleaning, a core sample was taken from Vessel B. The resin analysis results on the core sample indicated the field cleaned resin had over 88% of its exchange capacity. The TOC content on the resin was reduced from the original 7.9 to 4 mg carbon per gram resin, which represents going from severe to moderate fouling. • System was switched back to co-current regeneration mode. • The resin run length for arsenic removal after the caustic brine cleaning, however, did not improve.	
06/26/07	The automatic regeneration failed on June 26, 2007. Samples collected at 21,000 gal throughput contained 12.7 µg/L of nitrate (as N) and 29.8 µg/L of arsenic.	• The system was turned off on June 26, 2007. • On June 27, 2007, the plant operator manually triggered regeneration. The regeneration was successful. A sample taken at 94,000 gal throughput contained 4.8 mg/L of nitrate (as N).

Fruitland IX System Chronology and Operational Problems (Continued)

Date	Problem Encountered	Corrective Action
07/02/07 to 07/05/07	Consistently high nitrate concentrations were measured on July 2, 3, and 5, 2007, i.e., 12.7 mg/L (at 145,000 gal), 12.1 mg/L (at 10,000 gal), and 12.9 mg/L (at 160,000 gal), respectively.	• The system was shutdown on July 5, 2007. • Kinetico suspected that the system was not regenerated properly due to the problematic, newly installed brine injection pump. • The plant operator switched back to the old brine injection pump • On July 7, 2007, the regeneration throughput setpoint was reduced from 275,000 to 260,000 gal. - One or two water samples were collected daily to monitor the nitrate concentrations. The nitrate concentrations were higher during the beginning and end of the run, but all below 10 mg/L (as N). - The arsenic concentrations monitored by the ArsenicGuard were below 10 µg/L most of the time, except during the beginning and end of the run, which suggests that the early leakage still exists and that the run length needs to be further shortened.
08/20/07 to 08/27/07	The City turned off the IX system due to a suspicion that the salt might be causing some problems with the biological activities in the lagoons. The IX system was shut down to lower the salt discharge to see if it would change the water quality at the lagoon.	
Early 09/2007	The system was placed back on line in early September and ran about 3 hours a day on average.	
09/01/07 to 10/18/07	Due to a clogged sample pressure regulator, the ArsenicGuard did not work properly. Arsenic data were unavailable for the period.	On October 18, 2007, the ArsenicGuard was repaired by TraceDetect.
10/16/07	The regeneration throughput setpoint was further reduced from 260,000 gal to 220,000 gal, after the operator detected 10.3 mg/L of nitrate in samples collected at 233,000 gal throughput.	
02/11/08	The equipment transfer letter was approved and signed by the City Council.	

APPENDIX B

OPERATIONAL DATA

US EPA Arsenic Demonstration Project at Fruitland, ID – Daily System Operation Log Sheet

		Pump House				Product Water Flow Meter			System Pressures				Regeneration		
	Date	Opt. Hours	Cum. Hours	Master Flow Meter	Treated Volume	Product Water Flowrate	Product Water Flow Totalizer	BV Treated	Combined System Inlet Pressure (IN)	Vessel A Outlet Pressure (TA)	Vessel B Outlet Pressure (TB)	Product Water Pressure (TT)	Regen. Counter	Salt Delivered	Cumulative Salt Delivered
		hr	hr	kgal	Kgal	gpm	kgal	BV	psig	psig	psig	psig		lb	lb
1	06/14/05	NA	NA	80,712	NA	130	111	148	74	65	62	44	NA		
	06/15/05	22.4	22.4	80,866	154	144	37	49	72	64	62	44	NA		
	06/16/05	24.2	46.6	81,067	201	73	NA	In Regen	84	78	In Regen	42	NA	3,945	3,945
	06/17/05	15.5	62.1	81,197	130	142	122	163	73	68	65	46	NA		
2	06/20/05	56.4	118.5	81,666	469	142	341	456	64	62	70	44	NA		
	06/21/05	22.0	140.5	81,838	172	142	100	134	65	62	70	44	NA		
	06/22/05	21.1	161.6	82,031	193	170	58	78	52	52	62	46	NA		
	06/23/05	16.2	177.8	82,195	164	171	212	283	62	58	58	46	NA	3,950	7,895
3	06/27/05	88.1	265.9	83,028	833	167	98	131	63	55	56	45	NA		
	06/28/05	22.0	287.9	83,237	209	155	72	96	62	58	58	50	NA		
	06/29/05	8.4	296.3	83,315	78	156	147	197	64	56	58	48	NA		
	06/30/05	20.6	316.9	83,516	201	160	127	170	62	56	56	46	NA	5,000	12,895
	07/01/05	21.4	338.3	83,704	188	150	77	103	60	54	52	44	NA		
4	07/05/05	93.2	431.5	84,620	916	167	34	45	62	56	54	46	13		
	07/06/05	25.0	456.5	84,851	231	165	24	32	60	54	54	46	14		
	07/07/05	24.0	480.5	85,085	234	122	18	24	70	60	In Regen	40	15	8,860	21,755
	07/08/05	20.4	500.9	85,288	203	164	211	282	60	52	52	44	15		
5	07/11/05	66.0	566.9	85,908	620	163	109	146	60	54	54	46	18		
	07/12/05	23.9	590.8	86,144	236	168	99	132	60	50	50	46	19		
	07/13/05	23.1	613.9	86,386	242	170	94	126	60	48	48	45	20		
	07/14/05	24.3	638.2	86,632	246	170	94	126	60	48	48	44	21	6,470	28,225
	07/15/05	24.0	662.2	86,869	237	168	85	114	60	50	50	48	22		
6	07/18/05	72.0	734.2	87,594	725	164	70	94	60	50	48	42	25		
	07/19/05	23.5	757.7	87,830	236	167	62	83	60	50	48	44	26		
	07/20/05	23.5	781.2	88,067	237	169	52	70	60	50	50	48	27		
	07/21/05	23.7	804.9	88,307	240	167	47	63	60	50	50	48	28		
	07/22/05	23.7	828.6	88,545	238	167	43	57	58	50	50	48	29		

US EPA Arsenic Demonstration Project at Fruitland, ID – Daily System Operation Log Sheet (Continued)

		Pump House				Product Water Flow Meter			System Pressures				Regeneration		
	Date	Opt. Hours hr	Cum. Hours hr	Master Flow Meter kgal	Treated Volume Kgal	Product Water Flowrate gpm	Product Water Flow Totalizer kgal	BV Treated BV	Combined System Inlet Pressure (IN) psig	Vessel A Outlet Pressure (TA) Psig	Vessel B Outlet Pressure (TB) psig	Product Water Pressure (TT) psig	Regen. Counter	Salt Delivered lb	Cumulative Salt Delivered lb
7	07/25/05	69.5	898.1	89,225	680	129	2	3	66	50	In Regen	44	32	9,035	37,260
	07/26/05	23.2	921.3	89,454	229	127	218	291	66	In Regen	48	44	33		
	07/27/05	23.6	944.9	89,678	224	154	197	263	60	50	50	46	33		
	07/28/05	24.0	968.9	89,901	223	160	175	234	58	50	48	42	34	8,970	46,230
	07/29/05	49.9	1018.8	90,139	238	165	168	225	62	52	52	46	35		
8	08/01/05	42.8	1061.6	90,842	703	161	90	120	58	50	50	48	37		
	08/02/05	23.3	1084.9	91,077	235	159	314	420	58	50	50	46	37		
	08/03/05	23.2	1108.1	NM	NA	161	534	714	58	50	50	46	37		
	08/04/05	24.4	1132.5	91,543	466	163	124	166	58	50	50	46	38	3,985	50,215
	08/05/05	21.0	1153.5	91,760	217	155	332	444	58	50	50	46	38		
9	08/08/05	72.0	1225.5	92,387	627	138	232	310	52	50	50	42	40		
	08/09/05	23.8	1249.3	92,631	244	178	115	154	58	50	50	44	41		
	08/10/05	23.9	1273.2	92,882	251	138	4	5	68	50	In Regen	46	42		
	08/11/05	22.0	1295.2	93,111	229	168	223	298	58	50	50	46	42	5,485	55,700
	08/12/05	23.8	1319.0	93,349	238	163	103	138	58	50	50	46	43		
10	08/15/05	69.5	1388.5	93,984	635	109	7	9	62	50	In Regen	46	45		
	08/16/05	23.5	1412.0	94,223	239	175	234	313	60	50	50	46	45		
	08/17/05	24.4	1436.4	94,477	254	173	120	160	58	50	50	46	46		
	08/18/05	21.8	1458.2	94,699	222	133	336	449	70	In Regen	50	46	47	6,010	61,710
	08/19/05	23.7	1481.9	94,939	240	167	215	287	60	60	50	46	47		
11	08/22/05	68.9	1550.8	95,626	687	161	169	226	60	50	50	46	49		
	08/23/05	22.8	1573.6	95,846	220	161	37	49	60	50	50	46	50		
	08/24/05	23.3	1596.9	96,078	232	158	259	346	60	50	50	48	50		
	08/25/05	22.7	1619.6	96,294	216	162	117	156	60	50	50	46	51	3,205	64,915
	08/26/05	23.2	1642.8	96,520	226	158	332	444	58	50	50	48	51		
12	08/29/05	70.5	1713.3	97,179	659	147	258	345	58	50	50	46	53		
	08/30/05	22.7	1736.0	97,411	232	170	128	171	58	50	50	46	54		
	08/31/05	23.3	1759.3	97,652	241	139	5	7	70	50	In Regen	44	55		
	09/01/05	23.0	1782.3	97,893	241	170	237	317	58	50	50	46	55	8,425	73,340
	09/02/05	23.3	1805.6	98,131	238	169	114	152	58	50	50	46	56		
13	09/06/05	87.4	1893.0	99,035	904	170	274	366	58	50	50	48	58		
	09/07/05	23.1	1916.1	99,267	232	161	145	194	59	50	50	48	59		
	09/08/05	22.1	1938.2	99,487	220	130	3	4	68	50	In Regen	48	60	8,025	81,365
	09/09/05	21.5	1959.7	99,696	209	157	265	354	58	50	50	48	60	5,860	87,225

US EPA Arsenic Demonstration Project at Fruitland, ID – Daily System Operation Log Sheet (Continued)

		Pump House				Product Water Flow Meter			System Pressures				Regeneration		
	Date	Opt. Hours hr	Cum. Hours hr	Master Flow Meter kgal	Treated Volume Kgal	Product Water Flowrate gpm	Product Water Flow Totalizer kgal	BV Treated BV	Combined System Inlet Pressure (IN) psig	Vessel A Outlet Pressure (TA) psig	Vessel B Outlet Pressure (TB) psig	Product Water Pressure (TT) psig	Regen. Counter	Salt Delivered lb	Cumulative Salt Delivered lb
14	09/12/05	65.9	2025.6	100,303	607	140	81	108	54	50	50	46	62		
	09/13/05	22.9	2048.5	100,547	244	175	314	420	58	50	50	48	62		
	09/14/05	18.7	2067.2	100,802	255	171	209	279	58	50	50	48	63	5,330	92,555
	09/15/05	27.8	2095.0	101,025	223	168	73	98	58	50	50	48	64		
	09/16/05	21.7	2116.7	101,255	230	165	294	393	58	50	50	48	64		
15	09/19/05	61.9	2178.6	101,904	649	175	216	289	58	50	50	48	66		
	09/20/05	21.8	2200.4	102,129	225	170	106	142	58	50	50	48	67		
	09/21/05	22.2	2222.6	102,356	227	170	130	174	58	50	50	48	68	6,050	98,605
	09/22/05	16.8	2239.4	102,534	178	170	300	401	58	50	50	48	68		
	09/23/05	22.3	2261.7	102,760	226	164	187	250	58	50	50	48	69		
16	09/26/05	73.9	2335.6	103,511	751	170	264	353	58	50	50	48	71		
	09/27/05	24.3	2359.9	103,757	246	170	172	230	58	50	50	48	72		
	09/28/05	14.3	2374.2	103,906	149	170	314	420	58	50	50	48	72		
	09/29/05	11.9	2386.1	104,018	112	170	94	126	58	50	50	48	73	7,240	105,845
	09/30/05	16.5	2402.6	104,193	175	174	261	349	58	49	49	46	73		
17	10/03/05	51.4	2454.0	104,753	560	167	127	170	58	50	50	48	75		
	10/04/05	20.9	2474.9	104,943	190	125	NA	In Regen	68	In Regen	50	48	76		
	10/05/05	18.8	2493.7	105,133	190	165	179	239	58	50	50	48	76	6,510	112,355
	10/06/05	24.1	2517.8	105,367	234	165	74	99	58	50	50	48	77		
	10/07/05	20.6	2538.4	105,566	199	147	262	350	58	50	50	48	77		
18	10/11/05	69.7	2608.1	106,296	730	167	302	404	58	50	50	48	79		
	10/12/05	17.1	2625.2	106,475	179	173	143	191	58	50	50	48	80	6,020	118,375
	10/13/05	14.0	2639.2	106,624	149	173	286	382	59	50	50	48	80		
	10/14/05	5.3	2644.5	106,678	54	179	11	15	58	48	48	48	80		
19	10/17/05	39.3	2683.8	107,094	416	170	80	107	58	50	50	48	82		
	10/18/05	16.2	2700.0	107,264	170	169	244	326	59	50	50	48	82	6,040	124,415
	10/19/05	14.8	2714.8	107,415	151	170	59	79	59	50	50	48	83		
	10/20/05	17.7	2732.5	107,630	215	170	239	320	59	50	50	48	83		
	10/21/05	4.0	2736.5	107,640	10	170	280	374	59	50	50	50	83		
20	10/24/05	38.7	2775.2	108,050	410	145	108	144	68	50	In Regen	44	85	5,965	130,380
	10/25/05	18.4	2793.6	108,243	193	170	192	257	58	50	50	46	85		
	10/26/05	21.3	2814.9	108,463	220	164	196	262	59	50	50	46	86		
	10/27/05	18.9	2833.8	108,661	198	173	58	78	60	50	50	46	87		
	10/28/05	18.2	2852.0	108,846	185	168	235	314	59	50	50	44	87		

US EPA Arsenic Demonstration Project at Fruitland, ID – Daily System Operation Log Sheet (Continued)

		Pump House				Product Water Flow Meter			System Pressures				Regeneration		
	Date	Opt. Hours hr	Cum. Hours hr	Master Flow Meter kgal	Treated Volume Kgal	Product Water Flowrate gpm	Product Water Flow Totalizer kgal	BV Treated BV	Combined System Inlet Pressure (IN) psig	Vessel A Outlet Pressure (TA) psig	Vessel B Outlet Pressure (TB) psig	Product Water Pressure (TT) psig	Regen. Counter	Salt Delivered lb	Cumulative Salt Delivered lb
21	10/31/05	58.1	2910.1	109,445	599	165	148	198	58	50	50	44	89		
	11/01/05	22.2	2932.3	109,669	224	168	33	44	58	50	50	44	90		
	11/02/05	22.0	2954.3	109,898	229	165	252	337	58	50	50	46	90	6,000	136,380
	11/03/05	20.4	2974.7	110,102	204	166	118	158	58	50	50	46	91		
	11/04/05	22.0	2996.7	110,323	221	138	NA	In Regen	68	In Regen	50	46	92		
22	11/07/05	54.7	3051.4	110,881	558	168	203	271	67	50	50	49	93		
	11/08/05	18.8	3070.2	111,069	188	161	54	72	59	50	50	49	94		
	11/09/05	17.7	3087.9	111,248	179	161	224	299	59	50	50	49	94	5,955	142,335
	11/10/05	7.8	3095.7	111,342	94	171	314	420	59	50	50	44	94		
	11/11/05	20.5	3116.2	111,537	195	170	178	238	58	50	50	46	95		
23	11/14/05	37.5	3153.7	111,916	379	160	212	283	49	50	50	49	96		
	11/15/05	10.5	3164.2	112,024	108	161	314	420	49	50	50	44	96		
	11/16/05	15.0	3179.2	112,169	145	160	125	167	49	50	50	46	97	5,975	148,310
	11/17/05	18.5	3197.7	112,350	181	163	302	404	58	50	50	48	97		
	11/18/05	15.7	3213.4	112,509	159	169	168	225	58	50	50	44	98		
24	11/21/05	42.7	3256.1	112,935	426	160	199	266	58	50	50	49	99		
	11/22/05	12.0	3268.1	113,102	167	160	30	40	58	50	50	49	100		
	11/23/05	21.8	3289.9	113,270	168	160	190	254	58	50	50	49	100	6,005	154,315
25	11/28/05	62.1	3352.0	113,890	620	170	135	180	58	50	50	49	102		
	11/29/05	17.3	3369.3	114,062	172	159	299	400	58	50	50	49	102		
	11/30/05	18.5	3387.8	114,241	179	158	103	138	58	50	50	49	103	5,965	160,280
	12/01/05	15.0	3402.8	114,388	147	159	283	378	58	50	50	49	103		
26	12/05/05	64.1	3466.9	115,021	633	158	233	311	58	50	50	48	105		
	12/06/05	13.6	3480.5	115,151	130	168	32	43	58	50	50	49	106		
	12/07/05	13.8	3494.3	115,287	136	167	102	136	58	50	50	48	107		
	12/08/05	23.3	3517.6	115,512	225	151	193	258	59	50	50	49	107	5,975	166,255
	12/09/05	22.9	3540.5	115,735	223	151	83	111	59	50	50	49	108		
27	12/12/05	26.2	3566.7	115,989	254	128	NA	In Regen	59	In Regen	50	49	109		
	12/13/05	9.1	3575.8	116,078	89	158	85	114	59	50	50	49	109		
	12/14/05	11.1	3586.9	116,188	110	160	190	254	59	50	50	49	109		
	12/15/05	23.8	3610.7	116,418	230	150	86	115	59	50	50	49	110		
	12/16/05	24.7	3635.4	116,658	240	152	294	393	59	50	50	49	110		

US EPA Arsenic Demonstration Project at Fruitland, ID – Daily System Operation Log Sheet (Continued)

		Pump House				Product Water Flow Meter			System Pressures				Regeneration		
	Date	Opt. Hours hr	Cum. Hours hr	Master Flow Meter kgal	Treated Volume Kgal	Product Water Flowrate gpm	Product Water Flow Totalizer kgal	BV Treated BV	Combined System Inlet Pressure (IN) psig	Vessel A Outlet Pressure (TA) psig	Vessel B Outlet Pressure (TB) psig	Product Water Pressure (TT) psig	Regen. Counter	Salt Delivered lb	Cumulative Salt Delivered lb
28	12/19/05	24.2	3659.6	116,892	234	153	211	282	59	50	50	49	111		
	12/20/05	5.4	3665.0	116,945	53	153	262	350	59	50	50	49	111		
	12/21/05	14.9	3679.9	117,085	140	160	71	95	59	50	50	49	112	5,800	178,190
	12/22/05	13.7	3693.6	117,216	131	157	196	262	59	50	50	49	112		
29	12/27/05	65.3	3758.9	117,842	626	150	144	193	59	50	50	49	114		
	12/28/05	13.0	3771.9	117,968	126	156	264	353	59	50	50	48	114		
	12/29/05	7.4	3779.3	118,037	69	155	13	17	59	50	50	48	115	3,685	181,875
	12/30/05	15.3	3794.6	118,185	148	155	155	207	59	50	50	49	115		
30	01/03/06	48.9	3843.5	118,655	470	155	280	374	59	50	50	49	116		
	01/04/06	13.7	3857.2	118,783	128	158	77	103	59	50	50	49	117		
	01/05/06	16.7	3873.9	118,937	154	150	120	160	59	50	50	49	118		
	01/06/06	13.5	3887.4	119,067	130	153	120	160	59	50	50	49	118	5,435	187,310
31	01/09/06	45.7	3933.1	119,501	434	126	8	11	68	50	0	49	120		
	01/10/06	17.0	3950.1	119,663	162	151	163	218	58	50	50	49	120		
	01/11/06	12.1	3962.2	119,778	115	153	273	365	58	50	50	49	120		
	01/12/06	24.2	3986.4	120,003	225	155	170	227	58	50	50	49	121	3,590	190,900
32	01/17/06	37.0	4023.4	120,351	348	149	176	235	59	50	50	49	122		
	01/18/06	12.1	4035.5	120,473	122	149	292	390	59	50	50	49	123		
	01/19/06	8.7	4044.2	120,544	71	151	32	43	59	50	50	49	123	3,170	194,070
	01/20/06	23.8	4068.0	120,768	224	150	248	332	59	50	50	49	123		
33	01/23/06	11.4	4079.4	120,873	105	154	27	36	59	50	50	49	124		
	01/24/06	24.2	4103.6	121,100	227	149	244	326	59	50	50	49	124		
	01/25/06	20.8	4124.4	121,290	190	149	100	134	59	50	50	49	125		
	01/26/06	11.8	4136.2	121,355	65	140	198	265	59	50	50	49	125		
	01/27/06	23.4	4159.6	121,607	252	144	154	206	59	50	50	49	126		
34	01/30/06	73.3	4232.9	122,264	657	143	127	170	59	50	50	49	128		
	01/31/06	10.7	4243.6	122,360	96	144	218	291	59	50	50	49	128		
	02/01/06	14.1	4257.7	122,480	120	146	11	15	59	50	50	49	129	4,385	198,455
	02/02/06	14.1	4271.8	122,612	132	146	132	176	59	50	50	49	129		
	02/03/06	10.9	4282.7	122,709	97	148	224	299	59	50	50	49	129		

US EPA Arsenic Demonstration Project at Fruitland, ID – Daily System Operation and Operation Labor Log Sheet (Continued)

		Pump House				Product Water Flow Meter			System Pressures				Regeneration		
	Date	Opt. Hours	Cum. Hours	Master Flow Meter	Treated Volume	Product Water Flowrate	Product Water Flow Totalizer	BV Treated	Combined System Inlet Pressure (IN)	Vessel A Outlet Pressure (TA)	Vessel B Outlet Pressure (TB)	Product Water Pressure (TT)	Regen. Counter	Salt Delivered	Cumulative Salt Delivered
		hr	hr	kgal	Kgal	gpm	kgal	BV	psig	psig	psig	psig		lb	lb
35	02/06/06	70.0	4352.7	123,325	616	144	159	213	59	50	50	49	131		
	02/08/06	14.3	4367.0	123,451	126	144	278	372	59	50	50	49	131		
	02/09/06	8.3	4375.3	123,523	72	144	29	39	59	50	50	49	132		
	02/10/06	0.1	4375.4	123,524	1	144	30	40	59	50	50	49	132		
36	02/13/06	18.8	4394.2	123,688	164	140	186	249	59	50	50	49	132	4,780	203,235
	02/14/06	10.5	4404.7	123,780	92	139	272	364	59	50	50	49	132		
	02/15/06	9.0	4413.7	123,870	90	158	133	178	59	50	50	49	133		
	02/16/06	17.4	4431.1	124,032	162	153	133	178	59	50	50	49	134		
	02/17/06	12.0	4443.1	124,145	113	153	248	332	59	50	50	49	134		
37	02/21/06	27.5	4470.6	124,415	270	155	179	239	59	50	50	49	135		
	02/22/06	11.9	4482.5	124,530	115	158	289	386	59	50	50	49	135	8,020	211,255
	02/23/06	23.9	4506.4	124,763	233	158	185	247	59	50	50	49	136		
	02/24/06	13.2	4519.6	124,894	131	158	309	413	59	50	50	49	136		
38	02/27/06	21.6	4541.2	125,106	212	156	201	269	59	50	50	49	137		
	02/28/06	9.0	4550.2	125,191	85	156	282	377	59	50	50	49	137		
	03/01/06	23.7	4573.9	125,426	235	156	182	243	59	50	50	49	138		
	03/02/06	6.2	4580.1	125,481	55	154	239	320	59	50	50	49	138	1,880	213,135
	03/03/06	8.8	4588.9	125,572	91	154	314	420	59	50	50	49	138		
39	03/06/06	41.6	4630.5	125,977	405	160	57	76	59	50	50	49	140		
	03/07/06	11.5	4642.0	126,087	110	160	161	215	59	50	50	49	140		
	03/09/06	29.2	4671.2	126,380	293	164	225	301	59	50	50	49	141		
	03/10/06	15.0	4686.2	126,533	153	165	43	57	59	50	50	49	142		
40	03/13/06	39.1	4725.3	126,914	381	164	81	108	59	50	50	49	143		
	03/14/06	12.4	4737.7	127,039	125	160	157	210	59	50	50	49	143		
	03/15/06	11.0	4748.7	127,149	110	166	304	406	59	50	50	49	143		
	03/16/06	11.9	4760.6	127,262	113	154	87	116	59	50	50	49	144	5,760	218,895
	03/17/06	7.6	4768.2	127,337	75	156	158	211	59	50	50	49	144		
41	03/20/06	27.7	4795.9	127,603	266	156	87	116	59	50	50	49	145		
	03/21/06	5.9	4801.8	127,662	59	158	144	193	59	50	50	49	145		
	03/22/06	10.0	4811.8	127,761	99	156	190	254	59	50	50	49	145		
	03/23/06	6.9	4818.7	127,828	67	150	302	404	59	50	50	49	145		
	03/24/06	24.0	4842.7	128,059	231	160	198	265	59	50	50	49	146		

US EPA Arsenic Demonstration Project at Fruitland, ID – Daily System Operation and Operation Labor Log Sheet (Continued)

		Pump House				Product Water Flow Meter			System Pressures				Regeneration		
	Date	Opt. Hours hr	Cum. Hours hr	Master Flow Meter kgal	Treated Volume kgal	Product Water Flowrate gpm	Product Water Flow Totalizer kgal	BV Treated BV	Combined System Inlet Pressure (IN) psig	Vessel A Outlet Pressure (TA) psig	Vessel B Outlet Pressure (TB) psig	Product Water Pressure (TT) psig	Regen. Counter	Salt Delivered lb	Cumulative Salt Delivered lb
42	03/27/06	32.6	4875.3	128,377	318	156	176	235	59	49	50	50	147		
	03/28/06	12.5	4887.8	128,500	123	156	294	393	59	49	50	50	147		
	03/29/06	11.1	4898.9	128,605	105	156	77	103	59	49	50	50	148		
	03/30/06	13.4	4912.3	128,734	129	156	200	267	59	49	50	50	148	5,920	224,815
	03/31/06	8.0	4920.3	128,817	83	157	279	373	59	49	50	50	148		
43	04/03/06	6.3	4926.6	128,885	68	160	19	25	59	50	50	49	149		
	04/04/06	8.7	4935.3	128,961	76	160	92	123	59	50	50	49	149		
	04/05/06	14.4	4949.7	129,101	140	160	116	155	59	50	50	49	150		
	04/06/06	14.0	4963.7	129,249	148	158	267	357	59	50	50	49	150		
	04/07/06	5.9	4969.6	129,297	48	0	313	418	48	0	50	50	150		
44	04/10/06	0.0	4969.6	129,297	0	0	314	420	48	50	50	0	150		
	04/11/06	0.0	4969.6	129,297	0	160	316	422	59	50	50	49	150		
	04/12/06	25.1	4994.7	129,538	241	150	215	287	59	50	50	49	151		
	04/13/06	10.5	5005.2	129,639	101	151	316	422	59	50	50	49	151	3,920	228,735
	04/14/06	17.9	5023.1	129,810	171	151	151	202	59	50	50	49	151		
45	04/17/06	41.8	5064.9	130,211	401	158	208	278	59	50	50	49	153		
	04/18/06	13.0	5077.9	130,334	123	119	2	2	71	50	In Regen	49	154		
	04/19/06	11.5	5089.4	130,440	106	159	105	140	59	50	50	49	154		
	04/20/06	13.3	5102.7	130,570	130	154	225	301	59	50	50	49	154		
	04/21/06	5.1	5107.8	130,619	49	0	272	364	49	50	50	49	154		
46	04/24/06	6.4	5114.2	130,679	60	152	11	15	59	50	50	49	155		
	04/25/06	8.1	5122.3	130,754	75	152	83	111	59	50	50	49	155		
	04/26/06	8.0	5130.3	130,834	80	152	159	213	59	50	50	49	155		
	04/27/06	15.8	5146.1	130,985	151	0	302	404	46	50	50	46	155	6,200	234,935
	04/28/06	16.2	5162.3	131,340	355	0	126	168	46	50	50	46	156		
47	05/01/06	28.9	5191.2	131,418	78	164	78	104	59	50	50	49	157		
	05/02/06	23.9	5215.1	131,649	231	154	297	397	59	50	50	49	157	1,320	236,255
	05/03/06	16.2	5231.3	131,803	154	155	125	167	59	50	50	49	158		
	05/04/06	24.0	5255.3	132,090	287	154	14	19	59	50	50	49	159		
	05/05/06	15.5	5270.8	132,177	87	150	155	207	59	50	50	49	159		

US EPA Arsenic Demonstration Project at Fruitland, ID – Daily System Operation and Operation Labor Log Sheet (Continued)

		Pump House				Product Water Flow Meter			System Pressures				Regeneration		
	Date	Opt. Hours hr	Cum. Hours hr	Master Flow Meter kgal	Treated Volume kgal	Product Water Flowrate gpm	Product Water Flow Totalizer kgal	BV Treated BV	Combined System Inlet Pressure (IN) psig	Vessel A Outlet Pressure (TA) psig	Vessel B Outlet Pressure (TB) psig	Product Water Pressure (TT) psig	Regen. Counter	Salt Delivered lb	Cumulative Salt Delivered lb
48	05/08/06	45.3	5316.1	132,598	421	153	231	309	59	50	50	48	160		
	05/09/06	7.2	5323.3	132,666	68	155	297	397	59	50	50	48	160		
	05/12/06	56.1	5379.4	133,189	523	153	158	211	59	50	50	48	162		
49	05/15/06	45.9	5425.3	133,619	430	152	244	326	59	50	50	49	163		
	05/16/06	20.0	5445.3	133,809	190	153	103	138	59	50	50	49	164	6,900	243,155
	05/17/06	21.3	5466.6	134,010	201	152	293	392	59	50	50	49	164		
	05/18/06	23.0	5489.6	134,217	207	153	164	219	59	50	50	46	165		
	05/19/06	23.0	5512.6	134,428	211	152	39	52	59	50	50	46	154		
50	05/22/06	32.7	5545.3	134,717	289	146	312	417	59	50	50	49	166		
	05/23/06	17.0	5562.3	134,868	151	144	130	174	59	50	50	49	167		
	05/24/06	16.5	5578.8	135,018	150	144	269	360	59	50	50	49	167		
	05/25/06	22.9	5601.7	135,225	207	148	168	225	59	50	50	49	168	4,520	247,675
51	05/30/06	52.7	5654.4	135,684	459	144	257	344	59	50	50	49	169		
	05/31/06	18.4	5672.8	135,844	160	142	84	112	59	50	50	49	170		
	06/01/06	20.0	5692.8	136,030	186	141	150	201	59	50	50	49	171		
	06/02/06	17.3	5710.1	136,192	162	160	302	404	59	50	50	49	171		
52	06/05/06	44.9	5755.0	136,610	418	165	173	231	59	50	50	49	173		
	06/06/06	19.5	5774.5	136,793	183	153	228	305	59	50	50	49	173		
	06/07/06	8.4	5782.9	136,872	79	158	302	404	59	50	50	49	173		
	06/08/06	20.9	5803.8	137,062	190	149	174	233	59	50	50	49	174	5,660	253,335
53	06/12/06	80.8	5884.6	137,767	705	140	183	245	59	50	50	49	176		
	06/13/06	22.4	5907.0	137,958	191	142	39	52	59	50	50	49	177		
	06/14/06	15.0	5922.0	138,085	127	142	157	210	59	50	50	49	177		
	06/15/06	19.6	5941.6	138,251	166	140	312	417	59	50	50	49	177		
54	06/19/06	82.1	6023.7	138,908	657	140	276	369	59	50	50	49	179		
	06/20/06	15.0	6038.7	139,044	136	146	80	107	59	50	50	49	180		
	06/21/06	22.0	6060.7	139,248	204	143	180	241	59	50	50	49	180		
	06/22/06	21.8	6082.5	139,445	197	150	132	176	59	50	50	49	181	4,840	258,175

US EPA Arsenic Demonstration Project at Fruitland, ID – Daily System Operation and Operation Labor Log Sheet (Continued)

		Pump House				Product Water Flow Meter			System Pressures				Regeneration		
	Date	Opt. Hours hr	Cum. Hours hr	Master Flow Meter kgal	Treated Volume kgal	Product Water Flowrate gpm	Product Water Flow Totalizer kgal	BV Treated BV	Combined System Inlet Pressure (IN) psig	Vessel A Outlet Pressure (TA) psig	Vessel B Outlet Pressure (TB) psig	Product Water Pressure (TT) psig	Regen. Counter	Salt Delivered lb	Cumulative Salt Delivered lb
55	06/26/06	84.0	6166.5	140,174	729	160	25	33	59	50	50	49	184		
	06/27/06	22.7	6189.2	140,393	219	160	233	311	59	50	50	49	184		
	06/28/06	21.7	6210.9	140,597	204	150	101	135	59	50	50	49	185		
	06/29/06	23.7	6234.6	140,824	227	150	315	421	59	50	50	49	185		
	06/30/06	22.9	6257.5	141,038	214	153	190	254	59	50	50	49	186		
56	07/03/06	66.5	6324.0	141,637	599	148	102	136	59	50	50	49	188		
	07/05/06	47.9	6371.9	142,060	423	148	175	234	59	50	50	49	189		
	07/06/06	14.4	6386.3	142,189	129	164	299	400	59	50	50	49	189		
	07/07/06	26.2	6412.5	142,399	210	140	184	246	59	50	50	49	190	8,755	266,930
57	07/10/06	71.2	6483.7	142,999	600	140	98	131	59	50	50	49	192		
	07/11/06	23.6	6507.3	143,195	196	130	279	373	59	50	50	49	192		
	07/12/06	24.1	6531.4	143,406	211	142	154	206	59	50	50	49	193		
	07/13/06	24.3	6555.7	143,623	217	149	34	45	59	50	50	49	194		
	07/14/06	23.6	6579.3	143,839	216	154	236	316	59	50	50	49	194	4,730	271,660
58	07/24/06	-	-	145,921	2,082	144	45	60	58	46	46	48	201		
	07/25/06	-	6835.7	146,135	214	151	127	170	58	45	45	44	202		
	07/26/06	23.2	6858.9	146,357	222	160	144	193	52	44	44	42	203		
	07/27/06	24.6	6883.5	146,543	186	148	49	66	54	49	49	48	206		
59	08/07/06	185.9	7069.4	148,224	1,681	157	38	51	58	49	49	46	209		
	08/08/06	25.4	7094.8	148,425	201	158	230	307	58	49	49	46	209		
	08/09/06	2.9	7097.7	148,508	83	158	314	420	58	49	49	46	209		
	08/10/06	26.9	7124.6	148,759	251	151	230	307	58	49	49	46	210		
60	08/14/06	74.9	7199.5	149,399	640	117	200	267	59	46	46	48	212		
61	12/12/06	203.3	7402.8	151,430	7,591	159	87	116	60	50	50	50	227		
	12/13/06	1.1	7403.9	151,447	17	156	105	140	60	50	50	50	227		
62	12/18/06	48.6	7452.5	151,920	473	160	9	12	60	50	50	50	229		
	12/19/06	17.1	7469.6	152,099	179	160	180	241	60	50	50	50	229		
	12/20/06	13.2	7482.8	152,280	181	159	303	405	60	50	50	50	229		
	12/21/06	11.8	7494.6	152,344	64	159	89	119	60	50	50	50	230		

US EPA Arsenic Demonstration Project at Fruitland, ID – Daily System Operation and Operation Labor Log Sheet (Continued)

		Pump House				Product Water Flow Meter			System Pressures				Regeneration		
	Date	Opt. Hours hr	Cum. Hours hr	Master Flow Meter kgal	Treated Volume kgal	Product Water Flowrate gpm	Product Water Flow Totalizer kgal	BV Treated BV	Combined System Inlet Pressure (IN) psig	Vessel A Outlet Pressure (TA) psig	Vessel B Outlet Pressure (TB) psig	Product Water Pressure (TT) psig	Regen. Counter	Salt Delivered lb	Cumulative Salt Delivered lb
63	12/26/06	44.4	7539.0	152,786	442	165	172	230	60	50	50	49	231		
	12/27/06	20.0	7559.0	152,984	198	161	49	66	60	50	50	49	232		
	12/28/06	18.0	7577.0	153,167	183	160	222	297	60	50	50	49	232		
64	01/02/07	121.0	7698.0	154,324	1,157	NA	26	35	60	50	50	49	236		
	01/03/07	8.8	7706.8	154,409	85	NA	107	143	60	50	50	49	236		
	01/04/07	19.5	7726.3	154,594	185	NA	285	381	60	50	50	49	236		
65	01/08/07	9.0	7735.3	154,691	97	163	58	78	60	50	50	49	237		
	01/09/07	2.9	7738.2	154,719	28	160	86	115	60	50	50	50	237		
	01/10/07	4.6	7742.8	154,766	47	166	130	174	60	50	50	50	237		
66	01/16/07	17.2	7760.0	154,938	172	161	296	396	59	50	50	49	237		
67	01/25/07	80.2	7840.2	NA	NA	158	76	102	59	50	50	49	240		
68	01/29/07	21.5	7861.7	155,938	NA	158	281	376	59	50	50	49	240		
	01/30/07	12.6	7874.3	156,063	125	NA	79	106	50	NA	NA	49	241		
69	02/01/07	15.8	7890.1	156,223	160	161	232	310	59	50	50	49	241		
	02/02/07	19.3	7909.4	156,403	180	161	78	104	59	50	50	49	242		
70	02/05/07	17.4	7926.8	156,587	184	158	254	340	59	50	50	49	242		
	02/06/07	16.6	7943.4	156,748	161	158	83	111	59	50	50	49	243		
	02/07/07	15.1	7958.5	156,896	148	158	224	299	59	50	50	49	243		
	02/08/07	5.5	7964.0	156,946	50	158	272	364	59	50	50	49	243		
71	02/09/07	8.0	7972	157025	79	160	22	29	59	50	50	49	244		
72	04/03/07	164.9	8136.9	158593	1568	158	146000	-	60	50	50	49	252		
73	04/05/07	0.0	8136.9	158593	0	158	146000	-	60	50	50	49	252		

System regenerates every 316,000 gallons.
NM = Not measured
NA = Not available

APPENDIX C

ANALYTICAL DATA

Analytical Results from Long-Term Sampling at Fruitland, ID

Sampling Date		6/15/2005		6/23/2005[c,d]			6/29/2005[d]			7/6/2005			7/13/2005		7/20/2005			8/3/2005[e]		
Sampling Location / Parameter	Unit	IN	TT	IN	TA	TB	IN	TA	TB	IN	TA	TB	IN	TT	IN	TA	TB	IN	TA	TB
Water Treated	Kgal	-	37	-	212		-	147		-	29		-	94	-	52		-	534	
Bed Volume	BV	-	49	-	283		-	197		-	39		-	126	-	70		-	714[f]	
Alkalinity	mg/L[a]	484 -	484 -	374 -	387 -	387 -	396 -	383 -	396 -	396 -	176 -	6 -	387 -	286 -	374 -	264 -	114 -	378 -	383 -	378 -
Fluoride	mg/L	0.5	0.5	-	-	-	0.7	0.7	0.7	-	-	-	0.5	0.5	-	-	-	-	-	-
Sulfate	mg/L	52 -	<1 -	59 -	57 -	59 -	58 -	94 -	63 -	73 -	<1 -	<1 -	75 -	<1 -	59 -	<1 -	<1 -	61 -	55 -	53 -
Nitrate (as N)	mg/L	10.0 -	4.3 -	10.3 -	9.4 -	9.8 -	10.1 -	9.5 -	9.5 -	11.2 -	3.0 -	6.6 -	9.6 -	1.9 -	9.4 -	2.7 -	4.1 -	9.3 -	9.7 -	9.7 -
Orthophosphate	mg/L[b]	<0.05 -	<0.05 -	<0.05 -	<0.05 -	<0.05 -	0.2 -	0.2 -	0.3 -	0.1 -	<0.05 -	<0.05 -	<0.05 -	<0.05 -	<0.05 -	<0.05 -	<0.05 -	0.1 -	0.2 -	0.2 -
Total P (as PO_4)	mg/L[b]	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Silica (as SiO2)	mg/L	57.8 -	57.2 -	57.7 -	57.3 -	58.0 -	59.3 -	58.6 -	57.5 -	58.6 -	58.4 -	59.0 -	46.6 -	48.1 -	55.8 -	56.6 -	55.5 -	56.2 -	56.1 -	55.5 -
Turbidity	NTU	0.1 -	<0.1 -	1.4 -	0.1 -	0.4 -	0.7 -	0.7 -	0.5 -	0.2 -	0.2 -	0.6 -	0.2 -	<0.1 -	0.1 -	<0.1 -	<0.1 -	<0.1 -	<0.1 -	<0.1 -
TDS	mg/L	568	542	-	-	-	-	-	-	-	-	-	578	558	-	-	-	-	-	-
pH	S.U.	7.6	7.7	7.6	7.5	7.2	7.4	7.6	7.5	6.7	6.8	6.0	7.4	7.3	7.5	7.8	7.3	7.7	7.5	7.4
Temperature	^{0}C	15.2	15.1	15.0	15.2	15.3	14.9	14.9	14.8	15.2	15.8	15.1	15.2	15.2	15.4	15.3	15.3	15.4	15.1	14.8
DO	mg/L	2.6	3.0	4.0	3.4	3.5	2.4	2.4	2.1	3.6	2.2	3.3	2.1	1.9	1.9	2.2	2.5	3.1	1.8	2.5
ORP	mV	212	172	192	204	199	225	191	225	209	180	260	206	217	191	209	198	199	227	186
Total Hardness	mg/L	303	252	-	-	-	-	-	-	-	-	-	242	242	-	-	-	-	-	-
Ca Hardness	mg/L	180	150	-	-	-	-	-	-	-	-	-	143	145	-	-	-	-	-	-
Mg Hardness	mg/L	123	101	-	-	-	-	-	-	-	-	-	98.8	97.0	-	-	-	-	-	-
As (total)	µg/L	49.0 -	0.7 -	37.5 -	38.2 -	38.3 -	38.0 -	37.4 -	38.8 -	39.3 -	3.6 -	8.3 -	39.0 -	2.8 -	35.4 -	3.1 -	5.8 -	34.2 -	41.4 -	46.3 -
As (soluble)	µg/L	45.5	0.9	-	-	-	-	-	-	-	-	-	38.8	3.2	-	-	-	-	-	-
As (particulate)	µg/L	3.5	<0.1	-	-	-	-	-	-	-	-	-	0.2	<0.1	-	-	-	-	-	-
As (III)	µg/L	2.1	0.8	-	-	-	-	-	-	-	-	-	2.4	2.4	-	-	-	-	-	-
As (V)	µg/L	43.4	<0.1	-	-	-	-	-	-	-	-	-	36.4	0.8	-	-	-	-	-	-
Total Fe	µg/L	<25 -	<25 -	211 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -
Soluble Fe	µg/L	<25	<25	-	-	-	-	-	-	-	-	-	<25	<25	-	-	-	-	-	-
Total Mn	µg/L	11.8 -	9.9 -	15.4 -	13.9 -	14.3 -	15.7 -	14.5 -	15.1 -	19.4 -	20.3 -	20.9 -	18.4 -	19.8 -	25.4 -	20.8 -	23.3 -	23.3 -	23.1 -	24.7 -
Soluble Mn	µg/L	10.0	10.4	-	-	-	-	-	-	-	-	-	20.2	20.2	-	-	-	-	-	-
Total U	µg/L	22.6 -	<0.1 -	19.1 -	<0.1 -	<0.1 -	19.0 -	<0.1 -	<0.1 -	20.6 -	<0.1 -	2.5 -	18.4 -	<0.1 -	18.6 -	<0.1 -	<0.1 -	16.6 -	<0.1 -	<0.1 -
Soluble U	µg/L	19.5	<0.1	-	-	-	-	-	-	-	-	-	18.8	<0.1	-	-	-	-	-	-
Total V	µg/L	53.0 -	2.1 -	39.8 -	0.9 -	1.1 -	40.7 -	5.0 -	4.5 -	39.2 -	8.4 -	36.1 -	35.5 -	4.2 -	38.7 -	5.6 -	11.9 -	35.4 -	1.1 -	2.1 -
Soluble V	µg/L	45.2	2.1	-	-	-	-	-	-	-	-	-	36.6	5.7	-	-	-	-	-	-
Mo (total)	µg/L	14.5 -	0.2 -	12.8 -	8.2 -	10.7 -	12.5 -	13.0 -	13.3 -	12.1 -	<0.1 -	0.2 -	12.6 -	0.3 -	13.7 -	0.3 -	<0.1 -	12.2 -	0.3 -	0.7 -
Mo (soluble)	µg/L	14.0	0.2	-	-	-	-	-	-	-	-	-	12.0	0.2	-	-	-	-	-	-

(a) As $CaCO_3$. (b) As PO_4.
(c) Nitrate, turbidity, and orthophosphate analyzed outside of holding time. (d) Vessels were not properly regenerated due to wrong settings caused by power outage on 6/17/05. The problem was fixed on 6/29/05 after sampling.
(d) Kinetico technician was on site 7/26/05 - 7/30/05 conducting an arsenic and nitrate breakthrough study and regeneration elution study. They changed the system regeneration setpoint from 214,000 gal to 335,000 gal of water treated. The brine draw time was reduced from 64 to 32 min.
(e) Regeneration didn't start until 199,000 gallons past the setpoint at 355,000 gallons due to a problem with level sensor in the brine day tank.

Analytical Results from Long-Term Sampling at Fruitland, ID (Continued)

Sampling Date		8/10/2005			8/17/2005		8/24/2005			8/31/2005			9/7/2005			9/14/2005		9/21/2005		
Sampling Location Parameter	Unit	IN	TA	TB	IN	TT	IN	TA	TB	IN	TA	TB	IN	TA	TB	IN	TT	IN	TA	TB
Water Treated	Kgal	-	28		-	120	-	259		-	28		-	145		-	209	-	130	
Bed Volume	BV	-	37		-	160	-	346		-	37		-	194		-	279	-	174	
Alkalinity	mg/L[(a)]	383 -	3 -	3 -	365 -	361 -	378 -	440 -	462 -	374 378	158 158	7 8	374 -	440 -	383 -	374 -	462 -	383 -	422 -	365 -
Fluoride	mg/L	-	-	-	0.5	0.5	-	-	-	-	-	-	-	-	-	0.5	0.5	-	-	-
Sulfate	mg/L	61 -	<1 -	<1 -	55 -	<1 -	58 -	<1 -	<1 -	62 61	<1 <1	<1 <1	60 -	<1 -	<1 -	57 -	<1 -	58 -	<1 -	<1 -
Nitrate (as N)	mg/L	9.1 -	2.5 -	2.5 -	8.5 -	0.6 -	8.6 -	3.2 -	0.5 -	9.5 9.5	1.6 1.7	2.4 2.3	8.9 -	0.4 -	0.7 -	8.8 -	0.4 -	9.2 -	0.4 -	0.7 -
Orthophosphate	mg/L[(b)]	0.1 -	0.1 -	<0.05 -	0.1 -	<0.05 -	0.2 -	<0.05 -	<0.05 -	0.2 0.2	<0.05 <0.05	<0.05 <0.05	0.3 -	<0.05 -	<0.05 -	0.3 -	<0.05 -	0.1 -	<0.05 -	<0.05 -
Total P (as PO_4)	mg/L[(b)]	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Silica (as SiO2)	mg/L	58.7 -	58.4 -	58.6 -	48.3 -	45.9 -	63.4 -	61.6 -	63.2 -	58.7 57.1	57.6 57.3	58.3 57.7	57.5 -	57.0 -	57.1 -	58.7 -	54.0 -	55.7 -	55.3 -	55.8 -
Turbidity	NTU	<0.1 -	<0.1 -	<0.1 -	0.1 -	<0.1 -	0.1 -	0.1 -	0.1 -	0.2 0.3	0.3 0.2	0.1 0.4	0.2 -	0.3 -	0.3 -	0.1 -	0.1 -	0.2 -	0.5 -	0.1 -
TDS	mg/L	-	-	-	598	552	-	-	-	-	-	-	-	-	-	574	542	-	-	-
pH	S.U.	7.8	7.0	7.3	7.7	7.5	7.9	7.9	7.9	7.7	7.5	6.8	7.8	7.6	7.4	7.6	7.4	7.8	NA[(c)]	7.5
Temperature	^{0}C	15.4	15.0	14.8	15.3	15.2	15.1	14.7	14.9	14.9	15.0	14.7	15.1	14.8	14.8	15.1	14.8	15.1	NA[(c)]	14.8
DO	mg/L	3.0	2.2	3.1	-	-	2.4	2.6	2.6	3.7	2.1	2.8	3.8	2.9	2.4	2.7	2.6	3.0	NA[(c)]	2.3
ORP	mV	216	297	3.0	240	244	242	235	244	265	207	246	247	260	252	241	240	276	NA[(c)]	253
Total Hardness	mg/L	-	-	-	247	249	-	-	-	-	-	-	-	-	-	247	247	-	-	-
Ca Hardness	mg/L	-	-	-	145	145	-	-	-	-	-	-	-	-	-	150	148	-	-	-
Mg Hardness	mg/L	-	-	-	102	104	-	-	-	-	-	-	-	-	-	97.7	98.9	-	-	-
As (total)	µg/L	40.6 -	25.6 -	15.1 -	39.4 -	2.4 -	42.9 -	1.4 -	1.1 -	52.0 51.5	3.0 2.9	11.4 10.8	60.0 -	1.3 -	1.2 -	40.5 -	0.7 -	33.6 -	1.3 -	2.1 -
As (soluble)	µg/L	-	-	-	38.2	2.7	-	-	-	-	-	-	-	-	-	40.9	0.7	-	-	-
As (particulate)	µg/L	-	-	-	1.1	<0.1	-	-	-	-	-	-	-	-	-	<0.1	<0.1	-	-	-
As (III)	µg/L	-	-	-	2.0	2.1	-	-	-	-	-	-	-	-	-	1.1	1.1	-	-	-
As (V)	µg/L	-	-	-	36.3	0.5	-	-	-	-	-	-	-	-	-	39.8	<0.1	-	-	-
Total Fe	µg/L	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 <25	<25 <25	<25 <25	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -
Soluble Fe	µg/L	-	-	-	<25	<25	-	-	-	-	-	-	-	-	-	<25	<25	-	-	-
Total Mn	µg/L	30.0 -	25.8 -	26.4 -	28.0 -	26.4 -	26.5 -	25.5 -	24.6 -	25.2 25.1	25.7 25.2	25.5 25.7	26.4 -	26.2 -	28.0 -	30.8 -	26.5 -	27.4 -	24.4 -	24.2 -
Soluble Mn	µg/L	-	-	-	29.0	27.2	-	-	-	-	-	-	-	-	-	30.4	28.7	-	-	-
Total U	µg/L	20.0 -	0.3 -	0.2 -	17.7 -	<0.1 -	19.5 -	<0.1 -	<0.1 -	17.6 17.5	<0.1 <0.1	<0.1 -	17.8 -	<0.1 -	<0.1 -	17.2 -	<0.1 -	19.7 -	<0.1 -	<0.1 -
Soluble U	µg/L	-	-	-	17.9	<0.1	-	-	-	-	-	-	-	-	-	16.2	<0.1	-	-	-
Total V	µg/L	42.3 -	16.6 -	15.7 -	39.3 -	3.0 -	39.7 -	1.4 -	1.1 -	35.7 36.5	3.4 3.2	8.9 8.4	39.4 -	0.8 -	1.1 -	38.7 -	<0.1 -	36.5 -	2.6 -	4.4 -
Soluble V	µg/L	-	-	-	40.0	3.4	-	-	-	-	-	-	-	-	-	38.4	<0.1	-	-	-
Mo (total)	µg/L	14.6 -	0.2 -	0.1 -	13.7 -	0.1 -	12.8 -	0.3 -	0.1 -	12.2 12.7	0.8 0.7	0.5 0.5	12.3 -	0.7 -	0.5 -	12.9 -	0.5 -	- -	- -	- -
Mo (soluble)	µg/L	-	-	-	13.2	0.1	-	-	-	-	-	-	-	-	-	12.4	0.4	-	-	-

(a) As $CaCO_3$.
(b) As PO_4.
(c) Operator did not record water quality measurement.

Analytical Results from Long Term Sampling at Fruitland, ID (Continued)

Sampling Date		9/28/2005			10/5/2005			10/12/2005		10/26/2005			11/2/2005			11/9/2005	
Sampling Location Parameter	Unit	IN	TA	TB	IN	TA	TB	IN	TT	IN	TA	TB	IN	TA	TB	IN	TT
Water Treated	Kgal	-	314		-	179		-	143	-	196		-	252		-	224
Bed Volume	BV	-	420		-	239		-	191	-	262		-	337		-	299
Alkalinity	mg/L[(a)]	396 -	440 -	458 -	383 -	462 -	458 -	383 -	405 -	374 -	NA[(c)] -	440 -	365 -	440 -	462 -	383 -	462 -
Fluoride	mg/L	-	-	-	-	-	-	0.5	0.5	-	-	-	-	-	-	0.5	0.5
Sulfate	mg/L	47 -	<1 -	<1 -	41 -	<1 -	<1 -	52 -	<1 -	58 -	NA[(c)] -	<1 -	54 -	<1 -	<1 -	55.7 -	<1 -
Nitrate (as N)	mg/L	8.4 -	9.7 -	4.8 -	6.9 -	0.5 -	0.4 -	9.4 -	0.6 -	9.7 -	NA[(c)] -	0.4 -	9.6 -	3.4 -	0.3 -	10.0 -	0.5 -
Orthophosphate	mg/L[(b)]	<0.05 -	<0.05 -	<0.05 -	<0.05 -	<0.05 -	<0.05 -	0.6 -	0.9 -	0.1 -	NA[(c)] -	<0.05 -	<0.05 -	<0.05 -	<0.05 -	<0.05 -	<0.05 -
Total P (as PO_4)	mg/L[(b)]	- -	- -	- -	- -	- -	- -	0.4 -	<0.03 -	0.4 -	<0.03 -	<0.03 -	0.3 -	<0.03 -	<0.03 -	0.4 -	<0.03 -
Silica (as SiO2)	mg/L	56.1 -	57.4 -	58.0 -	53.8 -	53.8 -	54.5 -	56.7 -	57.2 -	NA[(c)] -	57.0 -	58.5 -	57.1 -	58.3 -	57.3 -	56.2 -	56.1 -
Turbidity	NTU	1.0 -	0.2 -	0.1 -	<0.1 -	0.5 -	0.1 -	0.2 -	<0.1 -	<0.1 -	NA[(c)] -	<0.1 -	<0.1 -	0.2 -	<0.1 -	<0.1 -	<0.1 -
TDS	mg/L	-	-	-	-	-	-	566	524	-	-	-	-	-	-	566	498
pH	S.U.	7.7	7.7	7.7	7.9	7.8	7.7	7.6	7.4	7.7	7.9	7.6	7.3	7.5	7.2	7.7	7.6
Temperature	^{0}C	15.0	15.0	15.0	14.6	14.6	14.6	14.9	15.0	14.8	14.8	14.8	14.8	14.8	14.8	14.7	14.8
DO	mg/L	4.3	2.5	2.7	2.3	2.4	2.8	3.2	2.9	1.9	3.1	2.2	2.1	2.9	2.4	2.6	1.7
ORP	mV	248	214	219	249	242	216	242	260	252	251	237	248	260	220	257	259
Total Hardness	mg/L	-	-	-	-	-	-	232	241	-	-	-	-	-	-	257	251
Ca Hardness	mg/L	-	-	-	-	-	-	134	142	-	-	-	-	-	-	157	155
Mg Hardness	mg/L	-	-	-	-	-	-	97.1	99.2	-	-	-	-	-	-	99.2	96.5
As (total)	µg/L	35.1 -	17.6 -	2.1 -	34.3 -	0.8 -	0.8 -	60.8 -	1.3 -	45.8 -	0.9 -	1.0 -	35.0 -	0.7 -	0.5 -	37.0 -	0.7 -
As (soluble)	µg/L	-	-	-	-	-	-	59.9	1.2	-	-	-	-	-	-	37.5	0.7
As (particulate)	µg/L	-	-	-	-	-	-	0.9	<0.1	-	-	-	-	-	-	<0.1	<0.1
As (III)	µg/L	-	-	-	-	-	-	1.2	1.4	-	-	-	-	-	-	1.6	1.2
As (V)	µg/L	-	-	-	-	-	-	58.7	<0.1	-	-	-	-	-	-	35.9	<0.1
Total Fe	µg/L	102 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -
Soluble Fe	µg/L	-	-	-	-	-	-	<25	<25	-	-	-	-	-	-	<25	<25
Total Mn	µg/L	25.5 -	33.7 -	15.6 -	24.8 -	23.4 -	23.1 -	23.2 -	23.0 -	22.9 -	22.2 -	22.9 -	24.9 -	23.3 -	23.1 -	21.8 -	23.0 -
Soluble Mn	µg/L	-	-	-	-	-	-	21.8	24.0	-	-	-	-	-	-	21.7	23.1
Total U	µg/L	21.1 -	<0.1 -	<0.1 -	16.6 -	0.0 -	0.2 -	19.4 -	<0.1 -	19.4 -	<0.1 -	<0.1 -	18.8 -	<0.1 -	<0.1 -	18.5 -	<0.1 -
Soluble U	µg/L	-	-	-	-	-	-	19.7	<0.1	-	-	-	-	-	-	18.3	<0.1
Total V	µg/L	30.6 -	2.8 -	3.1 -	38.7 -	0.4 -	0.7 -	38.5 -	0.9 -	41.8 -	0.6 -	0.7 -	38.2 -	0.3 -	0.3 -	41.7 -	<0.1 -
Soluble V	µg/L	-	-	-	-	-	-	40.0	0.9	-	-	-	-	-	-	40.7	<0.1
Mo (total)	µg/L	13.5 -	0.3 -	0.1 -	12.1 -	0.8 -	0.4 -	12.0 -	<0.1 -	12.0 -	0.1 -	<0.1 -	12.8 -	0.1 -	<0.1 -	13.1 -	0.1 -
Mo (soluble)	µg/L	-	-	-	-	-	-	13.3	<0.1	-	-	-	-	-	-	13.0	<0.1

(a) As $CaCO_3$.
(b) As PO_4.
(c) Sampling error

Analytical Results from Long Term Sampling at Fruitland, ID (Continued)

Sampling Date		11/16/2005			11/30/2005			12/14/2005	
Sampling Location									
Parameter	Unit	IN	TA	TB	IN	TA	TB	IN	TT
Water Treated	Kgal	-	125		-	103		-	190
Bed Volume	BV	-	167		-	138		-	254
Alkalinity	mg/L[(a)]	396 -	418 -	352 -	383 -	440 -	409 -	396 -	484 -
Fluoride	mg/L	-	-	-	-	-	-	0.5	0.5
Sulfate	mg/L	56 -	<1 -	<1 -	55 -	<1 -	<1 -	76 -	<1 -
Nitrate (as N)	mg/L	10.2 -	0.5 -	0.7 -	10.3 -	0.5 -	0.5 -	10.5 -	0.7 -
Orthophosphate	mg/L[(b)]	0.1 -	<0.05 -	<0.05 -	0.1 -	<0.05 -	<0.05 -	0.1 -	<0.05 -
Total P (as PO_4)	mg/L[(b)]	0.3 -	<0.03 -	<0.03 -	0.3 -	<0.03 -	<0.03 -	- -	- -
Silica (as SiO2)	mg/L	56.1 -	56 -	55.9 -	57.0 -	57.5 -	57.6 -	56.8 -	56.6 -
Turbidity	NTU	<0.1 -	<0.1 -	0.2 -	<0.1 -	0.2 -	0.1 -	0.8 -	1.6 -
TDS	mg/L	-	-	-	-	-	-	-	-
pH	S.U.	7.6	7.5	7.5	7.6	7.7	7.5	7.7	7.2
Temperature	^{0}C	15.2	14.8	14.8	15.4	15.9	15.4	15.1	14.9
DO	mg/L	2.2	2.1	2.8	3.3	2.5	2.4	2.3	2.5
ORP	mV	252	248	250	249	213	221	248	224
Total Hardness	mg/L	-	-	-	-	-	-	227	229
Ca Hardness	mg/L	-	-	-	-	-	-	141	140
Mg Hardness	mg/L	-	-	-	-	-	-	86.2	89.3
As (total)	µg/L	44.0 -	0.7 -	0.7 -	38.8 -	1.5 -	2.3 -	46.3 -	1.0 -
As (soluble)	µg/L	-	-	-	-	-	-	37.3	0.8
As (particulate)	µg/L	-	-	-	-	-	-	8.9	0.2
As (III)	µg/L	-	-	-	-	-	-	0.9	1.1
As (V)	µg/L	-	-	-	-	-	-	36.4	<0.1
Total Fe	µg/L	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -
Soluble Fe	µg/L	-	-	-	-	-	-	<25	<25
Total Mn	µg/L	19.9 -	20.3 -	21.2 -	21.9 -	21.4 -	22.1 -	15.0 -	14.6 -
Soluble Mn	µg/L	-	-	-	-	-	-	14.8	14.1
Total U	µg/L	19.7 -	<0.1 -	<0.1 -	19.2 -	<0.1 -	<0.1 -	20.0 -	<0.1 -
Soluble U	µg/L	-	-	-	-	-	-	19.1	<0.1
Total V	µg/L	39.2 -	0.7 -	1.2 -	43.2 -	2.0 -	4.6 -	39.2 -	0.5 -
Soluble V	µg/L	-	-	-	-	-	-	40.4	0.3
Mo (total)	µg/L	12.5 -	0.4 -	0.2 -	12.6 -	20.1 -	20.1 -	12.3 -	0.2 -
Mo (soluble)	µg/L	-	-	-	-	-	-	11.8	0.1

(a) As $CaCO_3$.
(b) As PO_4.

Analytical Results from Long Term Sampling at Fruitland, ID (Continued)

Sampling Date		1/4/2006			1/10/2006			1/18/2006		1/25/2006			2/1/2006		
Sampling Location Parameter	Unit	IN	TA	TB	IN	TA	TB	IN	TT	IN	TA	TB	IN	TA	TB
Water Treated	Kgal	-	77		-	163		-	292	-	100		-	18	
Bed Volume	BV	-	103		-	218		-	390	-	134		-	24	
Alkalinity	mg/L[(a)]	387 -	312 -	242 -	400 -	484 -	458 -	409 -	466 -	405 -	387 -	330 -	393 -	60 -	12 -
Fluoride	mg/L	-	-	-	-	-	-	0.5	0.5	-	-	-	-	-	-
Sulfate	mg/L	58 -	<1 -	<1 -	53 -	<1 -	<1 -	54 -	<1 -	54 -	<1 -	<1 -	54 -	<1 -	9 -
Nitrate (as N)	mg/L	10.2 -	1.2 -	1.9 -	9.4 -	0.7 -	0.9 -	10 -	10.3 -	10 -	1.1 -	1.7 -	9.9 -	3.4 -	4.7 -
Orthophosphate	mg/L[(b)]	0.1 -	<0.05 -	<0.05 -	<0.05 -	<0.05 -	<0.05 -	<0.06 -	<0.06 -	0.1 -	<0.05 -	<0.05 -	- -	- -	- -
Total P (as PO_4)	mg/L[(b)]	0.3 -	<0.03 -	<0.03 -	0.3 -	0.3 -	<0.03 -	0.2 -	<0.03 -	0.3 -	<0.03 -	<0.03 -	0.3 -	<0.03 -	0.5 -
Silica (as SiO_2)	mg/L	57.6 -	58.3 -	57.4 -	58.6 -	58.8 -	58.9 -	58.6 -	58.8 -	57.7	56.7	57.9	58.7 -	58.3 -	58.1 -
Turbidity	NTU	0.5 -	0.7 -	0.7 -	0.5 -	0.8 -	0.6 -	0.7 -	1.3 -	0.6 -	1.1 -	1.3 -	0.2 -	0.4 -	0.8 -
TOC	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TDS	mg/L	-	-	-	-	-	-	542	572	-	-	-	-	-	-
pH	S.U.	7.6	7.3	7.3	7.5	7.7	7.8	7.7	7.5	7.5	7.8	7.6	7.8	7.1	6.9
Temperature	^{0}C	15.3	14.9	15.0	14.9	14.9	14.9	15.5	15.9	15.2	15.2	15.1	15.4	15.2	15.4
DO	mg/L	2.4	2.9	2.1	2.3	2.4	2.2	2.25	2.4	2.3	2.4	2.5	2.4	2.4	2.3
ORP	mV	220	223	223	261	222	244	268	260	279	222	214	227	238	255
Total Hardness	mg/L	-	-	-	-	-	-	221	241	-	-	-	-	-	-
Ca Hardness	mg/L	- -	- -	- -	- -	- -	- -	129 -	146 -	-	-	-	- -	- -	- -
Mg Hardness	mg/L	-	-	-	-	-	-	91.7	94.9	-	-	-	-	-	-
As (total)	µg/L	37.9 -	1.4 -	1.4 -	48.3 -	1.2 -	0.7 -	35.9 -	1.5 -	36.6 -	2.5 -	2.8 -	46.6 -	6.8 -	40.5 -
As (soluble)	µg/L	-	-	-	-	-	-	35.1	1.4	-	-	-	-	-	-
As (particulate)	µg/L	-	-	-	-	-	-	0.8	0.1	-	-	-	-	-	-
As (III)	µg/L	-	-	-	-	-	-	1.4	1.4	-	-	-	-	-	-
As (V)	µg/L	-	-	-	-	-	-	33.7	<0.1	-	-	-	-	-	-
Total Fe	µg/L	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -
Soluble Fe	µg/L	-	-	-	-	-	-	<25	<25	-	-	-	-	-	-
Total Mn	µg/L	22.6 -	13.9 -	19.0 -	30.1 -	15.1 -	21.4 -	21.3 -	10.4 -	19.5 -	8.0 -	17.1 -	19.6 -	4.8 -	16.5 -
Soluble Mn	µg/L	-	-	-	-	-	-	21.8	10.3	-	-	-	-	-	-
Total U	µg/L	20.2 -	<0.1 -	<0.1 -	24.9 -	0.3 -	<0.1 -	21.9 -	<0.1 -	22.8 -	<0.1 -	<0.1 -	13.9 -	<0.1 -	<0.1 -
Soluble U	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total V	µg/L	39.9 -	1.4 -	1.9 -	45.4 -	0.7 -	0.7 -	41.3 -	0.7 -	40.4 -	2.9 -	3.7 -	35.6 -	5.4 -	12.9 -
Soluble V	µg/L	-	-	-	-	-	-	41.3	1.0	-	-	-	-	-	-
Mo (total)	µg/L	13.7 -	0.6 -	0.3 -	15.9 -	0.4 -	<0.1 -	13.4 -	<0.1 -	12.0 -	0.2 -	<0.1 -	13.1 -	0.3 -	0.1 -
Mo (soluble)	µg/L	-	-	-	-	-	-	13.8	<0.1	-	-	-	-	-	-

(a) As $CaCO_3$. (b) As PO_4.

Analytical Results from Long Term Sampling at Fruitland, ID (Continued)

Sampling Date		2/8/2006			2/15/2006			2/22/2006		3/1/2006			3/15/2006		
Sampling Location Parameter	Unit	IN	TA	TB	IN	TA	TB	IN	TT	IN	TA	TB	IN	TA	TB
Water Treated	Kgal	-	278		-	133		-	289	-	182		-	304	
Bed Volume	BV	-	372		-	178		-	386	-	243		-	406	
Alkalinity	mg/L[(a)]	388 379	442 438	446 446	416 -	96 -	11 -	386 -	436 -	381 -	464 -	439 -	380 -	422 -	438 -
Fluoride	mg/L	-	-	-	-	-	-	0.5	0.5	-	-	-	-	-	-
Sulfate	mg/L	53 53	<1 <1	<1 <1	63 -	<1 -	<1 -	62 -	<1 -	59 -	<1 -	<1 -	60 -	<1 -	<1 -
Nitrate (as N)	mg/L	9.6 9.7	9.7 9.9	5.7 5.8	11.5 -	1.9 -	3 -	11.5 -	10.9 -	10.2 -	0.6 -	1.0 -	10.2 -	15 -	12.8 -
Orthophosphate	mg/L[(b)]	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Total P (as PO_4)	mg/L[(b)]	0.3 0.3	<0.03 <0.03	<0.03 <0.03	0.4 -	0.1 -	<0.03 -	0.3 -	<0.03 -	0.4 -	<0.03 -	<0.03 -	0.3 -	0.1 -	0.1 -
Silica (as SiO_2)	mg/L	56.5 57.1	57.1 57.1	57.2 57.3	61.6 -	59.3 -	60.3 -	58.5 -	59.4 -	55.2 -	55.5 -	53.9 -	52.3 -	53.4 -	53.0 -
Turbidity	NTU	0.7 0.6	1.1 1.3	1.1 1.1	0.8 -	1.5 -	1.4 -	0.3 -	1.2 -	1.4 -	0.9 -	1.5 -	0.7 -	1 -	1 -
TOC	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TDS	mg/L	-	-	-	-	-	-	582[(c)]	520[(c)]	-	-	-	-	-	-
pH	S.U.	7.3	7.2	7.1	7.7	7.5	7.4	7.5	7.4	7.6	7.7	7.6	7.4	7.6	7.4
Temperature	^{0}C	15.2	15.2	15.2	14.9	14.9	14.9	14.9	14.9	15.4	15.7	15.7	14.9	14.8	14.9
DO	mg/L	2.5	2.4	2.3	2.39	2.14	2.26	2.1	2.3	2.8	2.5	2.6	2.5	2.3	1.3
ORP	mV	235	239	245	252	260	244	248	244	254	254	223	247	241	246
Total Hardness	mg/L	-	-	-	-	-	-	226	222	-	-	-	-	-	-
Ca Hardness	mg/L	- -	- -	- -	- -	- -	- -	133 -	131 -	- -	- -	- -	- -	- -	- -
Mg Hardness	mg/L	-	-	-	-	-	-	93.0	91.3	-	-	-	-	-	-
As (total)	µg/L	44.2 47.2	1.5 1.5	3.5 3.4	36.5 -	1.8 -	3.1 -	46.8 -	1.8 -	50.2 -	1.0 -	0.9 -	46.2 -	7.7 -	7.8 -
As (soluble)	µg/L	-	-	-	-	-	-	38.0	1.5	-	-	-	-	-	-
As (particulate)	µg/L	-	-	-	-	-	-	8.8	0.4	-	-	-	-	-	-
As (III)	µg/L	-	-	-	-	-	-	1.1	1.1	-	-	-	-	-	-
As (V)	µg/L	-	-	-	-	-	-	36.9	0.3	-	-	-	-	-	-
Total Fe	µg/L	<25 <25	<25 <25	<25 <25	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -
Soluble Fe	µg/L	-	-	-	-	-	-	<25	<25	-	-	-	-	-	-
Total Mn	µg/L	19.1 18.7	1.1 1.1	5.6 5.7	22.0 -	4.6 -	11.4 -	19.7 -	3.1 -	21.3 -	4.0 -	7.1 -	19.3 -	1.0 -	2.2 -
Soluble Mn	µg/L	-	-	-	-	-	-	18.3	3.0	-	-	-	-	-	-
Total U	µg/L	19.7 19.6	<0.1 <0.1	<0.1 <0.1	19.1 -	<0.1 -	<0.1 -	19.7 -	<0.1 -	19.2 -	<0.1 -	<0.1 -	19.9 -	<0.1 -	<0.1 -
Soluble U	µg/L	-	-	-	-	-	-	19.2	<0.1	-	-	-	-	-	-
Total V	µg/L	40.3 40.5	0.6 0.6	0.5 0.6	42.8 -	3.6 -	9.1 -	37.1 -	<0.1 -	37.4 -	0.1 -	0.3 -	37.5 -	0.3 -	0.2 -
Soluble V	µg/L	-	-	-	-	-	-	37.2	<0.1	-	-	-	-	-	-
Mo (total)	µg/L	14.7 15.1	0.2 0.2	<0.1 <0.1	13.8 -	0.2 -	<0.1 -	11.9 -	<0.1 -	12.2 -	<0.1 -	<0.1 -	12.2 -	0.3 -	0.1 -
Mo (soluble)	µg/L	-	-	-	-	-	-	11.8	<0.1	-	-	-	-	-	-

(a) As $CaCO_3$.
(b) As PO_4.
(c) Sample reanalyzed outside of hold time.

Analytical Results from Long Term Sampling at Fruitland, ID (Continued)

Sampling Date		3/22/2006		3/29/2006			4/5/2006			4/19/2006		4/26/2006		
Sampling Location Parameter	Unit	IN	TT	IN	TA	TB	IN	TA	TB	IN	TT	IN	TA	TB
Water Treated	Kgal	-	190	-	77		-	116		-	105	-	159	
Bed Volume	BV	-	254	-	103		-	155		-	140	-	213	
Alkalinity	mg/L[(a)]	387 -	473 -	381 -	298 -	282 -	380 -	393 -	384 -	410 -	379 -	383 -	454 -	450 -
Fluoride	mg/L	0.6	0.6	-	-	-	-	-	-	1.3	0.3	-	-	-
Sulfate	mg/L	59 -	<1 -	60 -	<1 -	<1 -	59 -	<1 -	<1 -	60 -	<1 -	64 -	<1 -	<1 -
Nitrate (as N)	mg/L	10.4 -	0.9 -	10.4 -	2.2 -	2.8 -	10.3 -	1.1 -	1.4 -	10.2 -	2.0 -	11.5 -	1 -	1.1 -
Orthophosphate	mg/L[(b)]	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Total P (as PO_4)	mg/L[(b)]	0.3 -	<0.01 -	0.4 -	<0.01 -	<0.01 -	0.3 -	<0.01 -	<0.01 -	0.4 -	<0.01 -	0.4 -	<0.01 -	<0.01 -
Silica (as SiO_2)	mg/L	56.9 -	57.0 -	56.9 -	57.1 -	56.4 -	57.4 -	57.4 -	57.0 -	56.0 -	55.6 -	56.8 -	57.4 -	57.6 -
Turbidity	NTU	0.3 -	1.3 -	0.6 -	1.2 -	0.7 -	0.4 -	1.3 -	1.3 -	0.2 -	0.4 -	0.5 -	0.5 -	0.7 -
TOC	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-
TDS	mg/L	610	584	-	-	-	-	-	-	-	-	-	-	-
pH	S.U.	7.8	7.9	7.6	7.2	7.3	7.8	7.2	7.4	7.6	7.5	7.3	7.3	7.1
Temperature	^{0}C	15.7	15.1	15.4	15.2	15.0	15.2	15.2	15.1	14.8	14.9	14.9	14.9	15.0
DO	mg/L	2.9	2.2	2.7	2.3	2.4	2.7	2.3	2.4	2.6	2.8	2.3	2.4	2.2
ORP	mV	225	234	239	271	238	235	271	240	210	253	224	241	271
Total Hardness	mg/L	235	227	244	243	249	-	-	-	274	270	-	-	-
Ca Hardness	mg/L	145 -	140 -	- -	- -	- -	- -	- -	- -	142 -	141 -	- -	- -	- -
Mg Hardness	mg/L	90.1	87.0	105	105	105	-	-	-	132	129	-	-	-
As (total)	µg/L	43.5 -	0.9 -	42.2 -	1.9 -	2.1 -	44.0 -	0.7 -	0.9 -	41.9 -	1.1 -	42.9 -	<0.1 -	0.2 -
As (soluble)	µg/L	37.2	0.9	-	-	-	-	-	-	37.6	0.9	-	-	-
As (particulate)	µg/L	6.3	<0.1	-	-	-	-	-	-	4.3	0.2	-	-	-
As (III)	µg/L	1.3	1.6	-	-	-	-	-	-	0.6	0.6	-	-	-
As (V)	µg/L	35.9	<0.1	-	-	-	-	-	-	37.1	0.4	-	-	-
Total Fe	µg/L	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -
Soluble Fe	µg/L	<25	<25	-	-	-	-	-	-	<25	<25	-	-	-
Total Mn	µg/L	15.1 -	0.5 -	17.2 -	0.9 -	0.7 -	15.7 -	0.4 -	0.6 -	19.5 -	0.3 -	18.0 -	0.6 -	0.9 -
Soluble Mn	µg/L	14.7	0.5	-	-	-	-	-	-	18.4	0.3	-	-	-
Total U	µg/L	17.7 -	<0.1 -	21.4 -	<0.1 -	<0.1 -	21.4 -	<0.1 -	<0.1 -	17.0 -	<0.1 -	20.3 -	<0.1 -	<0.1 -
Soluble U	µg/L	18.1	<0.1	-	-	-	-	-	-	15.9	<0.1	-	-	-
Total V	µg/L	40.9 -	0.6 -	40.3 -	1.6 -	1.8 -	43.7 -	0.8 -	0.7 -	40.3 -	1.0 -	43.3 -	0.3 -	0.2 -
Soluble V	µg/L	39.4	0.7	-	-	-	-	-	-	40.1	0.9	-	-	-
Mo (total)	µg/L	13.1 -	<0.1 -	12.1 -	0.2 -	0.1 -	12.5 -	<0.1 -	<0.1 -	13.4 -	<0.1 -	11.8 -	<0.1 -	<0.1 -
Mo (soluble)	µg/L	13.0	0.2	-	-	-	-	-	-	13.2	<0.1	-	-	-

(a) As $CaCO_3$. (b) As PO_4.

Analytical Results from Long Term Sampling at Fruitland, ID (Continued)

Sampling Date		5/3/2006			5/9/2006			5/17/2006		5/24/2006			5/31/2006		
Sampling Location Parameter	Unit	IN	TA	TB	IN	TA	TB	IN	TT	IN	TA	TB	IN	TA	TB
Water Treated	Kgal	-	125		-	17		-	293	-	269		-	84	
Bed Volume	BV	-	167		-	23		-	392	-	360		-	112	
Alkalinity	mg/L[(a)]	391 -	416 -	416 -	376 -	100 -	10 -	389 -	432 -	381 381	435 444	439 448	388 -	371 -	271 -
Fluoride	mg/L	-	-	-	-	-	-	0.5	0.5	-	-	-	-	-	-
Sulfate	mg/L	58 -	<1 -	<1 -	62	<1	<1	62 -	<1 -	61 60	<1 <1	<1 <1	62 -	<1 -	<1 -
Nitrate (as N)	mg/L	10.0 -	1.2 -	1.4 -	10.9	4.9	5.9	10.5 -	13.2 -	10.6 10.7	12.6 12.7	7.7 7.6	11.4 -	2.0 -	2.6 -
Orthophosphate	mg/L[(b)]	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Total P (as PO_4)	mg/L[(b)]	0.3 -	<0.01 -	<0.01 -	0.4	<0.01	0.2	0.4 -	0.1 -	- -	- -	- -	0.3 -	<0.01 -	<0.01 -
Silica (as SiO_2)	mg/L	59.4 -	59.8 -	58.2 -	60.4 -	59 -	59.9 -	58.6 -	59 -	57.2 57.9	57.9 56.5	57.8 57.2	54.7 -	54.9 -	56.5 -
Turbidity	NTU	0.5 -	0.7 -	0.4 -	0.4 -	0.2 -	0.3 -	0.3 -	0.4 -	0.3 0.3	0.7 0.7	0.5 0.6	0.5 -	0.7 -	0.9 -
TOC	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TDS	mg/L	-	-	-	-	-	-	600	582	-	-	-	-	-	-
pH	S.U.	7.3	7.3	7.2	7.6	7.2	6.3	7.4	7.4	7.3	7.3	7.5	7.4	7.3	7.2
Temperature	^{0}C	14.9	14.9	14.9	15.1	15.2	15.2	15.2	15.0	15.0	15.0	15.0	15.0	14.9	15.2
DO	mg/L	2.3	2.4	2.3	3.2	3.3	3.4	3.3	3.0	3.0	3.1	3.1	2.3	2.8	2.8
ORP	mV	212	236	241	307	296	262	314	288	311	319	296	219	239	244
Total Hardness	mg/L	-	-	-	-	-	-	315	350	-	-	-	-	-	-
Ca Hardness	mg/L	- -	- -	- -	- -	- -	- -	199 -	226 -	132 122	114 131	119 122	- -	- -	- -
Mg Hardness	mg/L	-	-	-	-	-	-	115	124	-	-	-	-	-	-
As (total)	µg/L	43.9 -	0.9 -	0.8 -	47.4 -	4.2 -	29.7 -	39.2 -	3.3 -	40.0 41.1	2.1 2.4	0.8 1.0	36.5 -	1.1 -	1.8 -
As (soluble)	µg/L	-	-	-	-	-	-	37.2	3.4	-	-	-	-	-	-
As (particulate)	µg/L	-	-	-	-	-	-	2.1	<0.1	-	-	-	-	-	-
As (III)	µg/L	-	-	-	-	-	-	0.8	0.5	-	-	-	-	-	-
As (V)	µg/L	-	-	-	-	-	-	36.3	2.9	-	-	-	-	-	-
Total Fe	µg/L	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -
Soluble Fe	µg/L	-	-	-	-	-	-	<25	<25	-	-	-	-	-	-
Total Mn	µg/L	21.9 -	0.5 -	0.8 -	19.0 -	0.8 -	4.3 -	23.5 -	0.4 -	19.3 19.3	<0.1 0.3	0.2 0.2	22.3 -	<0.1 -	1.8 -
Soluble Mn	µg/L	-	-	-	-	-	-	24.6	0.3	-	-	-	-	-	-
Total U	µg/L	21.7 -	<0.1 -	<0.1 -	20.5 -	<0.1 -	0.1 -	13.8 -	<0.1 -	19.2 19.1	<0.1 <0.1	<0.1 <0.1	20.1 -	<0.1 -	0.9 -
Soluble U	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total V	µg/L	40.2 -	0.6 -	0.6 -	39.6 -	4.6 -	15.5 -	38.2 -	0.6 -	32.1 33.7	0.4 0.4	0.3 0.3	40.3 -	1.2 -	1.9 -
Soluble V	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mo (total)	µg/L	12.9 -	0.1 -	<0.1 -	12.9 -	0.3 -	0.1 -	13.1 -	<0.1 -	13.0 12.7	<0.1 <0.1	<0.1 <0.1	13.3 -	<0.1 -	0.2 -
Mo (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-

(a) As $CaCO_3$. (b) As PO_4.

Analytical Results from Long Term Sampling at Fruitland, ID (Continued)

Sampling Date		6/7/2006			6/14/2006		6/21/2006			6/28/2006			7/6/2006		
Sampling Location Parameter	Unit	IN	TA	TB	IN	TT	IN	TA	TB	IN	TA	TB	IN	TA	TB
Water Treated	Kgal	-	19		-	157	-	276		-	101		-	21	
Bed Volume	BV	-	25		-	210	-	369		-	135		-	28	
Alkalinity	mg/L[(a)]	388 -	70 -	9 -	403 -	480 -	371 -	433 -	441 -	383 -	379 -	338 -	385 -	52 -	19 -
Fluoride	mg/L	-	-	-	0.6	0.6	-	-	-	-	-	-	-	-	-
Sulfate	mg/L	60 -	1 -	<1 -	60 -	<1 -	91 -	<1 -	<1 -	61 -	<1 -	12 -	75 -	<1 -	5 -
Nitrate (as N)	mg/L	10.8	5.0	6.2	10.5 -	1.2 -	10.2 -	11.5 -	6.7 -	10.3 -	1.9 -	2.3 -	10.2 -	5.8 -	8.1 -
Orthophosphate	mg/L[(b)]	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Total P (as PO_4)	mg/L[(b)]	- -	- -	- -	0.4 -	<0.01 -	0.4 -	<0.03 -	<0.01 -	0.3 -	<0.01 -	<0.01 -	0.3 -	<0.01 -	0.4 -
Silica (as SiO_2)	mg/L	59.1 -	58.1 -	58.3 -	62.0 -	61.5 -	55.6 -	54.4 -	54.8 -	59.9 -	61.6 -	60 -	57.3 -	57.0 -	55.0 -
Turbidity	NTU	0.3 -	0.6 -	0.4 -	0.7 -	0.4 -	0.8 -	0.9 -	0.9 -	0.6 -	1.1 -	1.8 -	0.4 -	0.8 -	0.8 -
TOC	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TDS	mg/L	-	-	-	604	534	-	-	-	-	-	-	-	-	-
pH	S.U.	7.3	7.5	7.2	7.5	7.6	7.5	7.3	7.6	7.5	7.4	7.5	7.2	7.4	7.4
Temperature	^{0}C	14.9	14.9	14.9	15.0	15.2	14.9	14.9	15.0	15.1	15.4	15.1	15.0	15.0	15.0
DO	mg/L	2.3	2.5	2.4	2.9	3.6	2.2	2.4	2.5	2.3	2.5	2.6	2.3	2.3	2.4
ORP	mV	240	248	250	244	228	281	256	256	264	240	244	302	234	261
Total Hardness	mg/L	-	-	-	233	228	-	-	-	-	-	-	-	-	-
Ca Hardness	mg/L	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Mg Hardness	mg/L	-	-	-	92.9	91.0				-	-	-	-	-	-
As (total)	µg/L	40.6 -	5.3 -	38.1 -	48.1 -	0.8 -	45.1 -	2.1 -	1.3 -	43.2 -	1.0 -	1.0 -	42.1 -	5.9 -	32.4 -
As (soluble)	µg/L	-	-	-	41.8	0.8	-	-	-	-	-	-	-	-	-
As (particulate)	µg/L	-	-	-	6.2	<0.1	-	-	-	-	-	-	-	-	-
As (III)	µg/L	-	-	-	0.4	0.4	-	-	-	-	-	-	-	-	-
As (V)	µg/L	-	-	-	41.4	0.4	-	-	-	-	-	-	-	-	-
Total Fe	µg/L	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -
Soluble Fe	µg/L	-	-	-	<25	<25	-	-	-	-	-	-	-	-	-
Total Mn	µg/L	20.2 -	2.1 -	10.2 -	18.8 -	0.2 -	30.6 -	1.8 -	7.0 -	28.4 -	0.6 -	8.6 -	27.1 -	1.5 -	5.0 -
Soluble Mn	µg/L	-	-	-	19.4	0.2	-	-	-	-	-	-	-	-	-
Total U	µg/L	20.6 -	<0.1 -	0.9 -	20.6 -	<0.1 -	20.6 -	<0.1 -	0.2 -	20.6 -	<0.1 -	<0.1 -	20.0 -	<0.1 -	<0.1 -
Soluble U	µg/L	-	-	-	20.4	<0.1	-	-	-	-	-	-	-	-	-
Total V	µg/L	39.2 -	5.2 -	13.7 -	38.4 -	0.4 -	38.9 -	0.5 -	0.6 -	37.8 -	0.8 -	1.0 -	39.2 -	7.2 -	17.2 -
Soluble V	µg/L	-	-	-	38.0	0.5	-	-	-	-	-	-	-	-	-
Mo (total)	µg/L	11.8 -	0.2 -	0.4 -	12.7 -	<0.1 -	12.6 -	0.3 -	0.2 -	13.2 -	0.2 -	<0.1 -	12.6 -	0.4 -	0.2 -
Mo (soluble)	µg/L	-	-	-	12.7	<0.1	-	-	-	-	-	-	-	-	-

(a) As $CaCO_3$. (b) As PO_4.

Analytical Results from Long Term Sampling at Fruitland, ID (Continued)

Sampling Date		7/12/2006	
Sampling Location Parameter	Unit	IN	TT
Water Treated	Kgal	-	154
Bed Volume	BV	-	206
Alkalinity	mg/L[(a)]	381 -	444 -
Fluoride	mg/L	0.3	0.6
Sulfate	mg/L	43 -	- -
Nitrate (as N)	mg/L	10 -	1.5 -
Orthophosphate	mg/L[(b)]	- -	- -
Total P (as PO_4)	mg/L[(b)]	0.3 -	<0.01 -
Silica (as SiO_2)	mg/L	55.6 -	553 -
Turbidity	NTU	0.1 -	0.3 -
TOC	mg/L	-	-
TDS	mg/L	602	560
pH	S.U.	7.5	7.5
Temperature	^{0}C	15.2	15.1
DO	mg/L	2.8	3.2
ORP	mV	210	233
Total Hardness	mg/L	239	231
Ca Hardness	mg/L	140 -	139 -
Mg Hardness	mg/L	99.0	91.3
As (total)	µg/L	43.8 -	1.6 -
As (soluble)	µg/L	38.5	0.7
As (particulate)	µg/L	5.3	0.9
As (III)	µg/L	0.5	0.4
As (V)	µg/L	38.0	0.3
Total Fe	µg/L	<25 -	<25 -
Soluble Fe	µg/L	<25	<25
Total Mn	µg/L	32.8 -	1.2 -
Soluble Mn	µg/L	35.2	0.2
Total U	µg/L	19.1 -	<0.1 -
Soluble U	µg/L	19.8	<0.1
Total V	µg/L	37.7 -	0.7 -
Soluble V	µg/L	37.8	0.6
Mo (total)	µg/L	11.6 -	<0.1 -
Mo (soluble)	µg/L	11.4	<0.1

(a) As $CaCO_3$. (b) As PO_4.